AQA A-LEVEL CHEMISTRY · 7405

CHEMISTRY



EXAM QUESTION PACK

3.1.2 AMOUNT OF SUBSTANCE

SCORE	PERCENTAGE
/2203	%

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Q1.

This question is about sodium fluoride (NaF).

Some toothpastes contain sodium fluoride.
The concentration of sodium fluoride can be expressed in parts per million (ppm).
1 ppm represents a concentration of 1 mg in every 1 kg of toothpaste.

(a) A 1.00 g sample of toothpaste was found to contain 2.88×10^{-5} mol of sodium fluoride.

Calculate the concentration of sodium fluoride, in ppm, for the sample of toothpaste.
Give your answer to 3 significant figures.

Concentration of sodium fluoride _____ ppm

(4)

(b) Sodium fluoride is toxic in high concentrations.
Major health problems can occur if concentrations of sodium fluoride are greater than 3.19×10^{-2} g per kilogram of body mass.

Deduce the maximum mass of sodium fluoride, in mg, that a 75.0 kg person could swallow without reaching the toxic concentration.

Mass of sodium fluoride _____ mg

(1)

(c) The concentration of sodium fluoride in a prescription toothpaste is 2800 ppm.

Use your answer to Question (b) to deduce the mass of toothpaste, in kg, that a 75.0 kg person could swallow without reaching the toxic concentration.

Mass of toothpaste _____ kg

(1)

(d) Identify the diagram in the figure below that shows the correct relative sizes of the ions in sodium fluoride.
Justify your answer.

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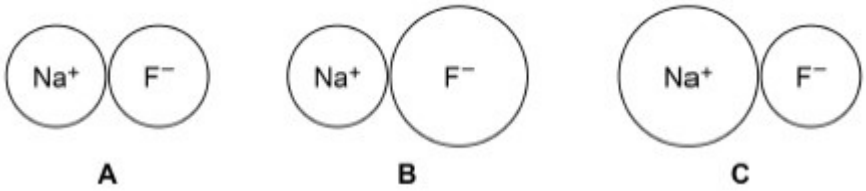


Diagram _____

Justification _____

_____

_____

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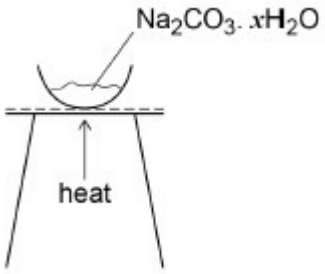
(3)

(Total 9 marks)

Q2.

A student heated a solid sample of $Na_2CO_3.\ xH_2O$ for 1 minute to remove water and determine a value for x

The diagram shows the apparatus used. The table shows the results recorded.



Mass of empty evaporating basin	24.35 g
Mass of evaporating basin and solid before heating	25.47 g
Mass of evaporating basin and solid after heating for 1 minute	24.92 g

(a) Use the data in the table to calculate a value for x in the formula $Na_2CO_3.\ xH_2O$ Give your answer to 2 decimal places.

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Value for x _____

(5)

(b) The correct value for x is 10.
Suggest a reason for the difference between the experimental value for x and the correct value.

(If you were unable to calculate an experimental value for x assume it was 8.05. This is **not** the correct experimental value.)

_____

_____

_____

(1)

(c) Suggest how the procedure could be improved, using the same apparatus, to give a more accurate value for x
Justify your answer.

Suggestion _____

_____

_____

_____

Justification _____

_____

_____

_____

(2)

(Total 8 marks)

Q3.

Separate unlabelled solid samples of three anhydrous sodium compounds are provided for a student to identify.
These compounds are known to be sodium carbonate, sodium fluoride and sodium chloride but it is not known which sample is which.

Outline a logical sequence of test-tube reactions that the student could carry out to identify each of these compounds.
Include the observations the student would expect to make.
Give equations, including **state symbols**, for any reactions that would take place.

_____

_____

_____

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_____

_____

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_____

(Total 6 marks)

Q4.

Chlorine is used to decrease the numbers of microorganisms in water.

When chlorine is added to water, there is a redox reaction, as shown by the equation

$$Cl_2 + H_2O \rightleftharpoons HClO + HCl$$

(a) Deduce the oxidation state of chlorine in HClO and the oxidation state of chlorine in HCl

Oxidation state of chlorine in HClO _____

Oxidation state of chlorine in HCl _____

(1)

(b) Give two half-equations to show the oxidation and reduction processes that occur in this redox reaction.

Oxidation half-equation _____

Reduction half-equation _____

(2)

(c) Chlorine is reacted with cold, aqueous sodium hydroxide in the manufacture of bleach.

Give an equation for this reaction between chlorine and sodium hydroxide.

_____

(1)

(d) The concentration of ClO^- ions in bleach solution can be found by reaction with iodide ions.

The overall equation for this reaction is shown.

$$ClO^- + 2I^- + 2H^+ \rightarrow I_2 + Cl^- + H_2O$$

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A sample of bleach solution was found to contain ClO^- ions with a concentration of 0.0109 mol dm^{-3}

Potassium iodide is added to a 20.0 cm^3 portion of this bleach solution.

Calculate the mass, in mg, of potassium iodide needed to react with all of the ClO^- ions in the sample of bleach.
Give your answer to the appropriate number of significant figures.
Give **one** observation during this reaction.

Mass of potassium iodide _____ mg

Observation _____

_____

_____

_____

(4)

(e) Potassium chlorate(VII), $KClO_4$, is used in fireworks. When potassium chlorate(VII) decomposes, it produces potassium chloride and oxygen.

Give an equation for the decomposition of potassium chlorate(VII).
Use the data in the table to calculate the enthalpy change for this reaction.

Substance	$\Delta_f H$ **/ kJ mol^{-1}**
$KClO_4(s)$	– 434
KCl(s)	– 436

Equation _____

Enthalpy change _____ kJ mol^{-1}

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(2)
(Total 10 marks)

Q5.

A 30 cm^3 sample of nitrogen was reacted with a 60 cm^3 sample of fluorine according to the equation

$$\frac{1}{2}N_2(g) + \frac{3}{2}F_2(g) \rightarrow NF_3(g)$$

What is the volume of the gas mixture after the reaction, at constant temperature and pressure?

A 20 cm^3 ⬭

B 30 cm^3 ⬭

C 40 cm^3 ⬭

D 50 cm^3 ⬭

(Total 1 mark)

Q6.

A student devised an experiment to find the concentration of sulfuric acid in a sample of battery acid.

- A measuring cylinder was used to transfer 10 cm^3 of battery acid to a volumetric flask.
- Distilled water was added to the volumetric flask until the volume reached 250 cm^3
- A 25.0 cm^3 sample of diluted acid was transferred from the volumetric flask to a conical flask using a pipette.
- A few drops of methyl orange indicator were added to the acid in the conical flask before titrating the acid with sodium hydroxide.
- The titration was repeated five times but concordant results were **not** obtained. (Note: Methyl orange is red in acid and yellow in alkali.)

Which suggestion would improve the chances of obtaining concordant titres?

A Invert the volumetric flask several times after adding the distilled water. ⬭

B Wash the pipette with distilled water between each titration. ⬭

C Add extra drops of indicator to the sample when nearing the end point in each titration. ⬭

D Use a more concentrated solution of sodium hydroxide in the burette. ⬭

(Total 1 mark)

Q7.

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A student devised an experiment to find the concentration of sulfuric acid in a sample of battery acid.

- A measuring cylinder was used to transfer 10 cm^3 of battery acid to a volumetric flask.
- Distilled water was added to the volumetric flask until the volume reached 250 cm^3
- A 25.0 cm^3 sample of diluted acid was transferred from the volumetric flask to a conical flask using a pipette.
- A few drops of methyl orange indicator were added to the acid in the conical flask before titrating the acid with sodium hydroxide.
- The titration was repeated five times but concordant results were **not** obtained.
(Note: Methyl orange is red in acid and yellow in alkali.)

Which suggestion about rinsing the conical flask between each titration would improve the accuracy of the titrations?

A Rinsing with acid. ⬭

B Rinsing with alkali. ⬭

C Rinsing with water. ⬭

D No rinsing with any liquid. ⬭

(Total 1 mark)

Q8.

A student devised an experiment to find the concentration of sulfuric acid in a sample of battery acid.

- A measuring cylinder was used to transfer 10 cm^3 of battery acid to a volumetric flask.
- Distilled water was added to the volumetric flask until the volume reached 250 cm^3
- A 25.0 cm^3 sample of diluted acid was transferred from the volumetric flask to a conical flask using a pipette.
- A few drops of methyl orange indicator were added to the acid in the conical flask before titrating the acid with sodium hydroxide.
- The titration was repeated five times but concordant results were **not** obtained.
(Note: Methyl orange is red in acid and yellow in alkali.)

Which suggestion would reduce the overall measurement uncertainty in the titration?

A Use less concentrated alkali in the burette. ⬭

B Use phenolphthalein indicator instead of methyl orange. ⬭

C Use smaller samples of the diluted acid in each titration. ⬭

D Begin each titration with the burette filled to the 0.00 cm^3 mark. ⬭

(Total 1 mark)

Q9.

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A student devised an experiment to find the concentration of sulfuric acid in a sample of battery acid.

- A measuring cylinder was used to transfer 10 cm^3 of battery acid to a volumetric flask.
- Distilled water was added to the volumetric flask until the volume reached 250 cm^3
- A 25.0 cm^3 sample of diluted acid was transferred from the volumetric flask to a conical flask using a pipette.
- A few drops of methyl orange indicator were added to the acid in the conical flask before titrating the acid with sodium hydroxide.
- The titration was repeated five times but concordant results were **not** obtained. (Note: Methyl orange is red in acid and yellow in alkali.)

Which of these is important in ensuring that the student's experiment is safe?

A Do the titration in a fume cupboard. ⬭

B Wear gloves when measuring out the battery acid. ⬭

C Wash hands before doing the titration. ⬭

D Carry the burette horizontally when collecting the apparatus. ⬭

(Total 1 mark)

Q10.

A student devised an experiment to find the concentration of sulfuric acid in a sample of battery acid.

- A measuring cylinder was used to transfer 10 cm^3 of battery acid to a volumetric flask.
- Distilled water was added to the volumetric flask until the volume reached 250 cm^3
- A 25.0 cm^3 sample of diluted acid was transferred from the volumetric flask to a conical flask using a pipette.
- A few drops of methyl orange indicator were added to the acid in the conical flask before titrating the acid with sodium hydroxide.
- The titration was repeated five times but concordant results were **not** obtained. (Note: Methyl orange is red in acid and yellow in alkali.)

Which colour change is observed at the end point in each titration?

A Yellow to red ⬭

B Red to orange ⬭

C Yellow to orange ⬭

D Red to yellow ⬭

(Total 1 mark)

Q11.

Citric acid, $C_3H_5O(COOH)_3$, occurs naturally in many fruits and can also be synthesised in the laboratory for use as a food flavouring. A student analysed a sample of citric acid to

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determine its percentage purity.

The student dissolved 784 mg of impure citric acid in water to prepare 250 cm^3 of solution in a volumetric flask.

The student titrated 25.0 cm^3 samples of this solution with 0.0500 mol dm^{-3} sodium hydroxide solution using phenolphthalein as the indicator.

$$C_3H_5O(COOH)_3(aq) + 3NaOH(aq) \rightarrow C_3H_5O(COO)_3Na_3(aq) + 3H_2O(l)$$

(a) The student rinsed the burette before filling it with the sodium hydroxide solution.

State why the student should use sodium hydroxide solution rather than water for the final rinse of the burette.

_____

_____

_____

(1)

(b) The student carried out several titrations. The results are shown in the table.

Complete the table to show the titre in each titration.

Titration	**Rough**	**1**	**2**	**3**
Final reading / cm^3	25.2	23.95	47.65	24.10
Start reading / cm^3	0.0	0.05	23.95	0.10
Titre / cm^3				

(1)

(c) Calculate the mean titre using the concordant results.

Give your answer to the appropriate number of significant figures.

Mean titre _____ cm^3

(2)

(d) The total uncertainty when using the burette is ±0.15 cm^3. This is the combination of uncertainties in the start reading, final reading and the determination of the end point.

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Use your answer to part (c) to calculate the percentage uncertainty for the use of the burette in this experiment.

Percentage uncertainty _____ %

(1)

(e) Use your answer to part (c) to find the mass, in mg, of citric acid dissolved in 250 cm^3 of the solution.

The relative molecular mass (M_r) of citric acid is 192.0

mass _____ mg

(3)

(f) Calculate the percentage purity of this sample of citric acid.

Percentage purity _____ %

(1)

(Total 9 marks)

Q12.

Ethanol can be made from glucose by fermentation.

$$C_6H_{12}O_6 \rightarrow 2C_2H_5OH + 2CO_2$$

In an experiment, 268 g of ethanol (M_r = 46.0) were made from 1.44 kg of glucose (M_r = 180.0).

What is the percentage yield?

A 18.6% ⬭

B 36.4% ⬭

C 51.1% ⬭

D 72.8% ⬭

(Total 1 mark)

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Q13.

This question is about s-block metals.

(a) Give the full electron configuration for the calcium ion, Ca^{2+}

_____

(1)

(b) Explain why the second ionisation energy of calcium is lower than the second ionisation energy of potassium.

_____

_____

_____

_____

_____

(2)

(c) Identify the s-block metal that has the highest first ionisation energy.

_____

(1)

(d) Give the formula of the hydroxide of the element in Group 2, from Mg to Ba, that is least soluble in water.

_____

(1)

(e) A student added 6 cm^3 of 0.25 mol dm^{-3} barium chloride solution to 8 cm^3 of 0.15 mol dm^{-3} sodium sulfate solution.
The student filtered off the precipitate and collected the filtrate.

Give an ionic equation for the formation of the precipitate.
Show by calculation which reagent is in excess.
Calculate the total volume of the other reagent which should be used by the student so that the filtrate contains only one solute.

Ionic equation _____

Reagent in excess _____

Total volume of other reagent _____

_____

_____

_____

_____

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(3)

(f) A sample of strontium has a relative atomic mass of 87.7 and consists of three isotopes, ^{86}Sr, ^{87}Sr and ^{88}Sr
In this sample, the ratio of abundances of the isotopes ^{86}Sr :^{87}Sr is 1:1

State why the isotopes of strontium have identical chemical properties.
Calculate the percentage abundance of the ^{88}Sr isotope in this sample.

Why isotopes of strontium have identical chemical properties

_____

_____

_____

Percentage abundance of ^{88}Sr _____ %

(4)

(g) A time of flight (TOF) mass spectrum was obtained for a sample of barium that contains the isotopes ^{136}Ba, ^{137}Ba and ^{138}Ba

The sample of barium was ionised by electron impact.

Identify the ion with the longest time of flight.

_____

(1)

(h) A $^{137}Ba^{+}$ ion travels through the flight tube of a TOF mass spectrometer with a kinetic energy of 3.65×10^{-16} J
This ion takes 2.71×10^{-5} s to reach the detector.

$KE = \frac{1}{2} mv^2$ where m = mass (kg) and v = speed (m s^{-1})

The Avogadro constant, $L = 6.022 \times 10^{23}$ mol^{-1}

Calculate the length of the flight tube in metres.

Give your answer to the appropriate number of significant figures.

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Length of flight tube _____ m

(5)

(Total 18 marks)

Q14.

A student added 627 mg of hydrated sodium carbonate ($Na_2CO_3.xH_2O$) to 200 cm^3 of 0.250 mol dm^{-3} hydrochloric acid in a beaker and stirred the mixture.
After the reaction was complete, the resulting solution was transferred to a volumetric flask, made up to 250 cm^3 with deionised water and mixed thoroughly.
Several 25.0 cm^3 portions of the resulting solution were titrated with 0.150 mol dm^{-3} aqueous sodium hydroxide. The mean titre was 26.60 cm^3 of aqueous sodium hydroxide.

Calculate the value of x in $Na_2CO_3.xH_2O$
Show your working.
Give your answer as an integer.

Value of x _____

(Total 7 marks)

Q15.

Compounds **A** and **B** react together to form an equilibrium mixture containing compounds **C** and **D** according to the equation

$$2\mathbf{A} + \mathbf{B} \rightleftharpoons 3\mathbf{C} + \mathbf{D}$$

(a) A beaker contained 40 cm^3 of a 0.16 mol dm^{-3} aqueous solution of A.
9.5×10^{-3} mol of **B** and 2.8×10^{-2} mol of **C** were added to the beaker and the mixture was left to reach equilibrium.
The equilibrium mixture formed contained 3.9×10^{-3} mol of **A**.

Calculate the amounts, in moles, of **B**, **C** and **D** in the equilibrium mixture.

Amount of **B** _____ mol

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Amount of **C** _____ mol

Amount of **D** _____ mol

(5)

(b) Give the expression for the equilibrium constant (K_c) for this equilibrium **and** its units.

K_c

Units _____

(2)

(c) A different equilibrium mixture of these four compounds, at a different temperature, contained 0.21 mol of **B**, 1.05 mol of **C** and 0.076 mol of **D** in a total volume of 5.00×10^2 cm^3 of solution.
At this temperature the numerical value of K_c was 116

Calculate the concentration of **A**, in mol dm^{-3}, in this equilibrium mixture.
Give your answer to the appropriate number of significant figures.

Concentration of **A** _____ mol dm^{-3}

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(3)

(d) Justify the statement that adding more water to the equilibrium mixture in part (c) will lower the amount of **A** in the mixture.

_____

_____

_____

_____

_____

_____

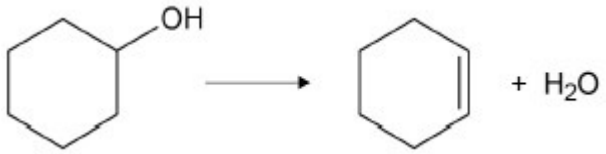
_____

(3)

(Total 13 marks)

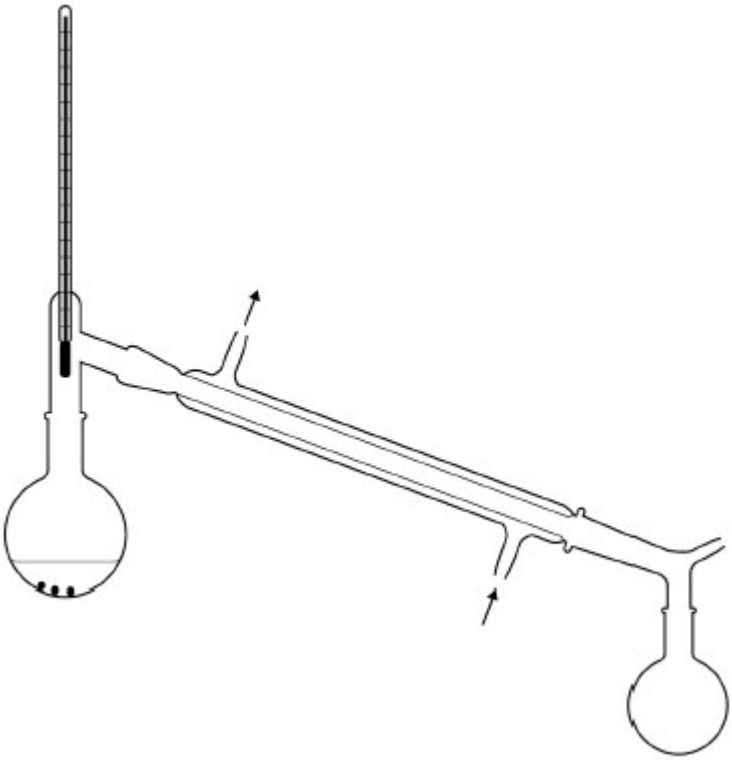
Q16.

Cyclohexene (boiling point = 83 °C) can be prepared by the dehydration of cyclohexanol (boiling point = 161 °C) using concentrated phosphoric acid.



A student prepared cyclohexene by placing 10 cm^3 of cyclohexanol (density = 0.96 g cm^{-3}) into a round-bottomed flask.
3 cm^3 of concentrated phosphoric acid were then carefully added to the flask.
The student added a few anti-bumping granules and set up the apparatus shown in the diagram.

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- The student heated the mixture and collected the liquid that distilled at temperatures below 100 °C
- The distillate was poured into a separating funnel and washed by shaking with sodium carbonate solution.
- Periodically, the separating funnel was inverted and the tap opened.
- The aqueous layer was discarded and the final organic product was dried using anhydrous calcium chloride.
- After the product was dried, the drying agent was removed by filtration under reduced pressure.

(a) The student collected 5.97 g of cyclohexene in the experiment.

Calculate the percentage yield of cyclohexene.

Percentage yield _____ %

(3)

(b) Describe a test-tube reaction, on the product, to show that the cyclohexanol had been dehydrated.

State what you would observe. _____

_____

_____

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_____

(2)

(c) Suggest why sodium carbonate solution was used to wash the distillate.

_____

_____

_____

(1)

(d) Explain why it is important to open the tap of the separating funnel periodically.

_____

_____

_____

(1)

(e) Give a property of anhydrous calcium chloride, other than its ability to absorb water, that makes it suitable as a drying agent in this preparation.

_____

_____

_____

(1)

(f) Describe the apparatus used to remove the drying agent by filtration under reduced pressure. Your description of the apparatus can be either a labelled diagram or a description in words.

(2)

(g) A sample of cyclohexene has been contaminated with cyclohexanol. The cyclohexene can be separated from the cyclohexanol by column chromatography. Silica gel is used as the stationary phase and hexane as the mobile phase.

Explain why cyclohexene has a shorter retention time than cyclohexanol.

_____

_____

_____

_____

_____

_____

(2)

(h) Explain how an infrared spectrum would confirm that the cyclohexene obtained from the chromatography column did not contain any cyclohexanol.

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_____

_____

_____

(1)

(Total 13 marks)

Q17.

Some 1.0 mol dm^{-3} solutions were mixed using equal volumes of each solution.

Which pair of solutions would give the greatest mass of solid?

A $Ba(OH)_2$ and $MgCl_2$ ⬭

B $Ba(OH)_2$ and $MgSO_4$ ⬭

C $Ba(OH)_2$ and NaCl ⬭

D $Ba(OH)_2$ and Na_2SO_4 ⬭

(Total 1 mark)

Q18.

Copper can be produced from rock that contains $CuFeS_2$

(a) Balance the equations for the two stages in this process.

.....$CuFeS_2$ + ...O_2 + ...SiO_2 ⟶ .....Cu_2S + ...Cu_2O + ...SO_2 + ...$FeSiO_3$

.....Cu_2S + ...Cu_2O ⟶ .....Cu + ...SO_2

(2)

(b) Suggest two reasons why the sulfur dioxide by-product of this process is removed from the exhaust gases.

Reason 1 _____

_____

_____

Reason 2 _____

_____

_____

(2)

(c) A passenger jet contains 4050 kg of copper wiring.

A rock sample contains 1.25% $CuFeS_2$ by mass.

Calculate the mass, in tonnes, of rock needed to produce enough copper wire for a passenger jet. (1 tonne = 1000 kg)

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Mass of rock _____ tonnes

(4)

(d) Copper can also be produced by the reaction of carbon with copper(II) oxide according to the equation

$$2CuO + C \longrightarrow 2Cu + CO_2$$

Calculate the percentage atom economy for the production of copper by this process.

Give your answer to the appropriate number of significant figures.

Percentage atom economy _____

(2)

(Total 10 marks)

Q19.

When an acidified solution of sodium nitrite ($NaNO_2$) is added to aqueous potassium iodide, iodine and nitrogen monoxide (NO) are formed.

(a) Give the oxidation state of nitrogen in the following species.

NO_2^- _____

NO _____

(2)

(b) Write a half-equation for the conversion of NO_2^- in an acidic solution into NO

_____

(1)

(c) Write a half-equation for the conversion of I^- into I_2

_____

(1)

(d) Write an overall ionic equation for the reaction of NO_2^- in an acidic solution with I^-

_____

(1)

(e) State the role of NO_2^- in the reaction with I^-

_____

(1)

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(f) In aqueous solution, nitrite ions react with acidified chlorate(V) ions according to the equation

$$2ClO_3^- + 5NO_2^- + 2H^+ \longrightarrow Cl_2 + 5NO_3^- + H_2O$$

25.0 cm^3 sample of an aqueous solution of sodium nitrite required 27.40 cm^3 of a 0.0200 mol dm^{-3} solution of potassium chlorate(V) for complete reaction.

Calculate the concentration, in g dm^{-3}, of sodium nitrite in the sample.

Concentration of sodium nitrite _____ g dm^{-3}

(4)

(Total 10 marks)

Q20.

A 4.85 g sample of anhydrous sodium sulfate is dissolved in water and the solution made up to 250 cm^3 in a volumetric flask.

What is the concentration in mol dm^{-3} of sodium sulfate in the solution?

A 0.0341 ⬭

B 0.137 ⬭

C 0.163 ⬭

D 0.273 ⬭

(Total 1 mark)

Q21.

25.0 cm^3 samples of NaOH solution were taken by pipette from a beaker. These were then titrated with an aqueous solution of ethanoic acid. The concentration of ethanoic acid calculated from the experimental results was found to be lower than the actual value.

Which of these could explain the difference?

A Rinsing the pipette with distilled water before filling with NaOH ⬭

B Rinsing the burette with distilled water before filling with ethanoic acid ⬭

C Rinsing the walls of the conical flask with distilled water during the titration ⬭

D Rinsing the beaker with distilled water before filling with NaOH ⬭

(Total 1 mark)

Q22.

A 20.0 cm^3 sample of a 0.400 mol dm^{-3} aqueous solution of a metal bromide (MBr_n) reacts

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exactly with 160 cm^3 of 0.100 mol dm^{-3} aqueous silver nitrate.

What is the formula of the metal bromide?

A MBr ⬭

B MBr_2 ⬭

C MBr_3 ⬭

D MBr_4 ⬭

(Total 1 mark)

Q23.

Ethanedioic acid ($H_2C_2O_4$) is a diprotic acid. Beekeepers use a solution of this acid as a pesticide.

A student carried out a titration with sodium hydroxide solution to determine the mass of the acid in the solution. The student repeated the titration until concordant titres were obtained.

$$H_2C_2O_4(aq) + 2NaOH(aq) \longrightarrow Na_2C_2O_4(aq) + 2H_2O(l)$$

(a) The student found that 25.0 cm^3 of the ethanedioic acid solution reacted completely with 25.30 cm^3 of 0.500 mol dm^{-3} sodium hydroxide solution.

Calculate the mass, in mg, of the acid in 25.0 cm^3 of this solution.

Mass of acid = _____ mg

(4)

(b) The student used a wash bottle containing deionised water when approaching the end-point to rinse the inside of the conical flask.

Explain why this improved the accuracy of the titration.

_____

_____

_____

(1)

(c) Give the meaning of the term concordant titres.

_____

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_____

_____

(1)

(Total 6 marks)

Q24.

2-Methylpropan-1-ol can be prepared by reacting 1-bromo-2-methylpropane with dilute aqueous sodium hydroxide.

(a) Name and outline the mechanism for this reaction.

Name of mechanism _____

Mechanism

(3)

(b) When 2.0 cm^3 of 1-bromo-2-methylpropane (M_r = 136.9) were reacted with an excess of sodium hydroxide, 895 mg of 2-methylpropan-1-ol (Mr = 74.0) were obtained.

The density of 1-bromo-2-methylpropane is 1.26 g cm^{-3}

Calculate the percentage yield for this reaction.

Percentage yield _____

(3)

(c) When 1-bromo-2-methylpropane reacts with hot, concentrated ethanolic potassium hydroxide rather than dilute aqueous sodium hydroxide, a different product is formed.

Name this organic product and name the mechanism for this reaction.

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Name of organic product _____

Name of mechanism _____

(2)

(Total 8 marks)

Q25.

What is the burette reading for this transparent liquid?



A 24.10 cm^3 ○

B 24.30 cm^3 ○

C 25.70 cm^3 ○

D 25.90 cm^3 ○

(Total 1 mark)

Q26.

A volumetric flask was used to prepare 250 cm^3 of a solution.

The solute was added from a plastic weighing container.

	Mass / g
Weighing container with solute	10.13
Weighing container after solute added to volumetric flask	4.48

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Each reading from the balance has an uncertainty of ±0.005 g

What is the percentage uncertainty in the mass of the solute used?

A 0.09% ○

B 0.11% ○

C 0.18% ○

D 0.22% ○

(Total 1 mark)

Q27.

A sample of 2.0 mol dm^{-3} acid has a volume of 100 cm^3
What volume of water, in cm^3, should be added to this acid to dilute the sample to a concentration of 1.5 mol dm^{-3}?

A 25 ○

B 33.3 ○

C 50 ○

D 66.7 ○

(Total 1 mark)

Q28.

This question is about compounds containing ethanedioate ions.

(a) A white solid is a mixture of sodium ethanedioate ($Na_2C_2O_4$), ethanedioic acid dihydrate ($H_2C_2O_4.2H_2O$) and an inert solid. A volumetric flask contained 1.90 g of this solid mixture in 250 cm^3 of aqueous solution.

Two different titrations were carried out using this solution.

In the first titration 25.0 cm^3 of the solution were added to an excess of sulfuric acid in a conical flask. The flask and contents were heated to 60 °C and then titrated with a 0.0200 mol dm^{-3} solution of potassium manganate(VII). When 26.50 cm^3 of potassium manganate(VII) had been added the solution changed colour.

The equation for this reaction is

$$2MnO_4^- + 5C_2O_4^{2-} + 16H^+ \rightarrow 2Mn^{2+} + 8H_2O + 10CO_2$$

In the second titration 25.0 cm^3 of the solution were titrated with a 0.100 mol dm^{-3} solution of sodium hydroxide using phenolphthalein as an indicator. The indicator changed colour after the addition of 10.45 cm^3 of sodium hydroxide solution.

The equation for this reaction is

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$$H_2C_2O_4 + 2OH^- \rightarrow C_2O_4^{2-} + 2H_2O$$

Calculate the percentage by mass of sodium ethanedioate in the white solid.

Give your answer to the appropriate number of significant figures.

Show your working.

Percentage by mass of sodium ethanedioate _____ %

(8)

(b) Ethanedioate ions react with aqueous iron(III) ions in a ligand substitution reaction.

Write an equation for this reaction.

Suggest why the value of the enthalpy change for this reaction is close to zero.

_____

_____

_____

_____

(2)

(c) Draw the displayed formula of the iron complex produced in the reaction in part (b)

Indicate the value of the O—Fe—O bond angle.

State the type of isomerism shown by the iron complex.

Bond angle _____

Type of isomerism _____

(3)

(d) Ethanedioate ions are poisonous because they react with iron ions in the body.
Ethanedioate ions are present in foods such as broccoli and spinach.

Suggest one reason why people who eat these foods do not suffer from poisoning.

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_____

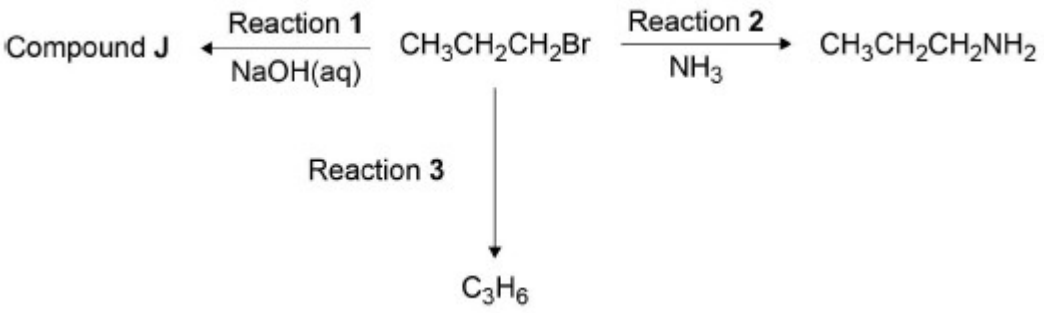
_____

(1)

(Total 14 marks)

Q29.

The diagram shows some compounds made from a halogenoalkane.



(a) Draw the displayed formula of compound **J**.

(1)

(b) Name the mechanism for Reaction **2** and give an essential condition used to ensure that $CH_3CH_2CH_2NH_2$ is the major product.

Name of mechanism _____

Condition _____

(2)

(c) Calculate the mass, in grams, of $CH_3CH_2CH_2NH_2$ produced from 25.2 g of $CH_3CH_2CH_2Br$ in Reaction **2** assuming a 75.0% yield.

Give your answer to the appropriate number of significant figures.

Mass _____ g

(3)

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(d) When Reaction **2** is carried out under different conditions, a compound with molecular formula $C_9H_{21}N$ is produced.

Draw the skeletal formula of the compound.

Identify the functional group in the compound including its classification.

Skeletal formula

Functional group including classification _____

(2)

(e) Identify the reagent and conditions used in Reaction **3**.

_____

(1)

(f) Name and outline a mechanism for Reaction 3.

Name of mechanism _____

Mechanism

(4)

(Total 13 marks)

Q30.

What is the mass, in mg, of carbon formed when 3.0×10^{-3} mol of propene undergoes incomplete combustion?

$$2C_3H_6 + 3O_2 \rightarrow 6C + 6H_2O$$

A 9.0×10^{-3} ⬭

B 3.6×10^{-2} ⬭

C 1.08×10^{2} ⬭

D 2.16×10^{2} ⬭

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(Total 1 mark)

Q31.

The equation for the reaction between zinc and hydrochloric acid is

$$Zn + 2HCl \rightarrow ZnCl_2 + H_2$$

What is the minimum mass, in mg, of zinc (A_r = 65.4) needed to react with 50.0 cm^3 of 1.68 mol dm^{-3} hydrochloric acid?

A 2.75 ⬭

B 5.49 ⬭

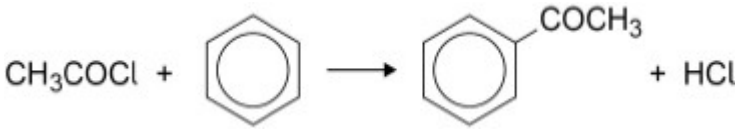
C 2.75×10^3 ⬭

D 5.49×10^3 ⬭

(Total 1 mark)

Q32.

Phenylethanone can be prepared by the reaction between ethanoyl chloride and benzene.



In a preparation, with an excess of benzene, the mass of ethanoyl chloride (M_r = 78.5) used was 5.7×10^{-2} kg.

The percentage yield of phenylethanone was 62%.

What mass, in grams, of phenylethanone was produced?

A 35 g ⬭

B 54 g ⬭

C 87 g ⬭

D 102 g ⬭

(Total 1 mark)

Q33.

A sample of strontium ore is known to contain strontium oxide, strontium carbonate and some inert impurities. To determine the mass of strontium carbonate present, a student weighed a sample of the solid ore and then heated it in a crucible for 5 minutes. The sample was allowed to cool and then reweighed. This heating, cooling and reweighing was carried out three times.

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The results are set out in the table.

Mass of crucible / g	9.85
Mass of crucible and ore sample / g	16.11
Mass of crucible and sample after first heating / g	14.66
Mass of crucible and sample after second heating / g	14.58
Mass of crucible and sample after third heating / g	14.58

(a) When strontium carbonate is heated it decomposes according to the following equation.

$$SrCO_3 \longrightarrow SrO + CO_2$$

Give a reason why the mass of the solid sample changed during the experiment.

_____

_____

_____

(1)

(b) Use the data in the table to calculate the mass of strontium carbonate in the original ore sample. Give your answer to an appropriate precision.

Mass of strontium carbonate = ___ g

(5)

(c) Each balance reading has an uncertainty of ±5.00 mg.

Calculate the percentage error in the initial mass of ore used.

Percentage error = _____ %

(1)

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(d) The mass of inert impurities in the sample was 347 mg.

Deduce the mass of SrO in the sample and justify any assumption made in calculating your answer.
(If you have been unable to answer part **(b)**, assume the mass of strontium carbonate was 4.85 g. This is **not** the correct answer.)

Mass of SrO = _____

_____

_____

(2)

(e) Strontium metal can be extracted by heating strontium oxide with aluminium metal.

In this reaction, strontium vapour and solid aluminium oxide are formed.

Write an equation for the reaction and state the role of the aluminium in the process.
Explain why strontium forms a vapour but aluminium oxide is formed as a solid.

Equation

_____

Role of aluminium _____

_____

Explanation _____

_____

_____

_____

_____

_____

_____

(5)

(Total 14 marks)

Q34.

A measuring cylinder has an uncertainty of ±5 cm^3.

What is the minimum volume of liquid that can be measured if the percentage error in the volume is to be less than 0.20%?

A 0.025 dm^3 ⬭

B 0.25 dm^3 ⬭

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C 2.5 dm^3 ○

D 25 dm^3 ○

(Total 1 mark)

Q35.

What is the volume of 0.200 mol dm^{-3} $Ba(OH)_2$ (aq) required to neutralise exactly 30.0 cm^3 of 0.100 mol dm^{-3} HCl(aq)?

A 150.0 cm^3 ○

B 75.0 cm^3 ○

C 15.0 cm^3 ○

D 7.50 cm^3 ○

(Total 1 mark)

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Q1.

(a) M_r NaF = 42(.0)

Incorrect M_r loses M1 & M4

1

Mass NaF in 1 g = $2.88 \times 10^{-5} \times 42.0$ (= 1.210 (1.2096) $\times 10^{-3}$ g)

1

Mass NaF in 1 kg = 1.210 (1.2096) g

M3 = M2 × 1000 (g)

Units, if given, must match answer

1

(Mass in mg = 1210 (1209.6) mg)

Concentration of NaF = <u>1210</u> (ppm)

Allow 1.21 × 10^3 ppm

1

(b) Toxic mass = $3.19 \times 10^{-2} \times 75 \times 1000$
= 2390 mg

Allow 2393

1

(c) Mass of toothpaste needed = $\frac{2390}{2800}$
= 0.854 kg

Mark consequential to (b)

(b) ÷ 2800 (to at least 2 sig fig)

Allow 0.85 - 0.86 kg

1

(d) B

If not B, allow M2 only

If blank, read on.

1

Both Na^+ and F^- same electron arrangement ($1s^2 2s^2 2p^6$) or isoelectronic

Electronegativity, molecules or IMF = CE, M1 only

1

Sodium (ion) has more protons <u>so attracts (outer) electrons closer</u> / Sodium (ion) has more protons <u>so stronger attractions for (outer) electrons</u>

Ignore shielding, higher charge density, atomic radius

If reference to fluorine rather than fluoride, then penalise 1 mark only

1

[9]

Q2.

(a) **M1**: Mass Na_2CO_3 = 0.57g AND Mass H_2O = 0.55g

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If incorrect masses other than AE, lose M1 & M3

1

M2: Mol Na_2CO_3 $= \frac{0.57}{106}$ AND Mol H_2O = $\frac{0.55}{18}$

M2 = process

1

M3: = 0.0054 : 0.0306

M3 = these values only (at least 2sf)

1

M4: ÷ by smallest = 1 : 5.682

M4 = process mark

1

M5: Value of × = 5.68 (2dp)

Allow 5.67 – 5.74

1

OR

M1: Mass Na_2CO_3 = 0.57g AND Mass $Na_2CO_3.xH_2O$ = 1.12g

1

M2: Moles anhydrous Na_2CO_3 = $\frac{0.57}{106}$ = 5.377×10^{-3}

1

M3: Mr of hydrated Na_2CO_3 = $1.12/5.377 \times 10^{-3}$

= 208.3

1

M4: Mr of × H_2O = 102.3

1

M5: Value of × = 5.68 (2dp)

Allow 5.67 – 5.74

1

(b) Failure to drive off all the water
OR
Failure to heat for long enough
OR
Not heated to constant mass

Allow evaporate instead of drive off
Ignore incomplete reaction

1

(c) Heat to constant mass / heat for longer / use a smaller mass

1

You can be sure all / more of the water has been driven off

Ignore incomplete reaction
M2 dependent on M1

1

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[8]

Q3.

Marks awarded for this answer will be determined by the quality of written communication as well as the standard of the scientific response. Examiners should apply a 'best-fit' approach to the marking. **Additional tests limits to lower mark within a level.** This would include, for example, adding silver nitrate to the already identified sodium carbonate. Use of hydrochloric acid with silver nitrate also limits to lower mark within a level as this would not be a logical sequence/method that would work.	
Level 3 5-6 marks	All stages are covered and each stage is generally correct and virtually complete. Answer is communicated coherently and shows a logical progression from Stage 1 to Stages 2 and 3 to identify all three compounds in a logical sequence with results and equations for all compounds stated. **Covers 2 tests with matching observations, conclusions and equations**
Level 2 3-4 marks	All stages are covered but stage(s) may be incomplete or may contain inaccuracies OR two stages are covered and are generally correct and virtually complete. Answer is communicated mainly coherently and shows a logical progression from Stage 1 to Stages 2 and 3. **Covers 2 compounds** Isolated tests on named compounds – max LEVEL 2
Level 1 1-2 marks	Two stages are covered but stage(s) may be incomplete or may contain inaccuracies OR only one stage is covered but is generally correct and virtually complete. Answer includes isolated statements but these are not presented in a logical order.

Indicative Chemistry Content

Stage 1 Suggested tests
1a Add named acid to all 3
1b Add water / <u>make into</u> a solution
1c Add $AgNO_3$
Ignore addition of NH_3 / Ignore additional test for CO_2 produced

Stage 2 Expected observations - conclusions
2a Na_2CO_3 will fizz with acid
2b NaCl gives white ppt with $AgNO_3$
2c NaF shows no (visible) change / no ppt
Additional incorrect observations loses point

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Stage 3 Equations – state symbols must match method
3a $Na_2CO_3 + 2HNO_3 \rightarrow 2NaNO_3 + CO_2 + H_2O$ … or ionic
3b $AgNO_3 + NaCl \rightarrow AgCl + NaNO_3$
… or ionic
3c correct state symbols

[6]

Q4.

(a) Two correct Cl ox states: HClO = +1 HCl = -1

1

(b) Oxidation:
$Cl_2 + 2H_2O \rightarrow 2HClO + 2H^+ + 2e^-$
Accept - $2e^-$ on the other side
Allow $Cl_2 + 2H_2O \rightarrow 2ClO^- + 2e^-$

1

Reduction:
$Cl_2 + 2H^+ + 2e^- \rightarrow 2HCl$
Allow $Cl_2 + 2e^- \rightarrow 2Cl^-$
If both equations correct but incorrect order, allow 1
Ignore state symbols

1

(c) $2NaOH + Cl_2 \rightarrow NaCl + NaClO + H_2O$
Allow
$2OH^- + Cl_2 \rightarrow Cl^- + ClO^- + H_2O$
Allow NaOCl
Ignore state symbols

1

(d) mol ClO^- = conc × vol = 0.0109 × 0.02
= $\underline{0.000218 / 2.18 \times 10^{-4}}$ mol

1

mol KI = 0.000218 × 2 = 0.000436 mol
M2 = M1 x2
If incorrect ratio, M2 & M3 = 0

1

mass KI = Mr ×mol = 166.0 × 0.000436
= 0.072376 g
= 72.4 (mg)
M3 = M1 × 2 × 166.0 × 1000
Must be to <u>3 sig figs</u>

1

<u>black solid/ppt</u> appears/forms (in a colourless solution)
or (colourless solution) turns brown (solution)
Not purple. Not red. Not brown ppt/solid
Ignore grey.

1

(e) $KClO_4 \rightarrow KCl + 2O_2$

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Ignore state symbols

Allow multiples

1

ΔH = – 436 – – 434 = – 2 kJ mol^{-1}

Must be negative

Mark independently

Allow consequential for multiples

1

[10]

Q5.

D

[1]

Q6.

A

[1]

Q7.

C

[1]

Q8.

A

[1]

Q9.

B

[1]

Q10.

B

[1]

Q11.

(a) use of water would <u>dilute</u> the NaOH OR
use of water would change the <u>concentration</u> of NaOH OR
to ensure the <u>concentration</u> of the NaOH is not changed OR

Ignore reference to weakening the solution, watering down the solution, contaminate

Allow

it would gives a titre value that is larger

it would decrease the pH of the NaOH

(any additional qualifying reason given must be correct)

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1

(b) Rough = 25.2, 1= 23.90, 2 = 23.70, 3 = 24.00.

Need all four (with rough to 1dp and the other three to 2dp)

1

(c) **M1** use of titrations 1 & 3 only

***M1** is for choosing correct titres*

1

M2 23.95 (cm^3)

***M2** is for calculating the mean to 2dp for their chosen titres*

24.0 cm^3 = 1 mark (wrong number of decimal places)

24 cm^3 = 1 mark (only if it is clear that titration 2 is not included)

23.86 cm^3 = 1 mark (used all three titrations)

23.9 cm^3 = 0 marks (used all three titrations and wrong number of decimal places)

If error(s) made in 2.2, allow ECF from 2.2, where they choose concordant titres and find the mean (can score M1 and M2)

1

(d) $\left(\frac{0.15}{23.95} \times 100\right) = 0.63\%$

(0.6263%)

Allow any correct value with at least 2 significant figures based on their answer to 2.3. Rounding must be correct.

1

(e) **M1** moles NaOH = $\frac{23.95}{1000} \times 0.0500$ (=0.001198)

1

M2 moles acid in flask = $\frac{M1}{3} \times 10$ (= 0.003992)

1

M3 mass acid (= 0.003992 x 192.0 = 0.766 g) = 766 (mg)

Correct answer to at least 2sf = 3 marks (allow 760-770 mg)

Correct value in grams (lose M3) = 2 marks (allow 0.76-0.77 g)

Allow ECF at each stage (including those based on value from 2.3)

Incorrect answers that are a factor of 10 too small lose M2 (76-77 mg = 2 marks, 0.076-0.077 g = 1 mark)

*(if use 25 cm^3 for volume of NaOH, then max 2 marks (**M2** and **M3** for 800 mg)*

1

(f) $\left(\frac{\text{Answer to Q (e)}}{784} \times 100\right) = 97.7$ or 97.8%

Allow any correct value to at least 2 significant figures based on their answer to Q(e)

(values may be over 100% if 2.5 is incorrect)

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1

[9]

Q12.

B

[1]

Q13.

(a) $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ (4s^0)$

1

(b) **M1** In $Ca^{(+)}$ (outer) electron(s) is further from nucleus

Or $Ca^{(+)}$ loses electron from a higher (energy) orbital

Or $Ca^{(+)}$ loses electron from a 4(s) orbital or 4th energy level or 4th energy shell and $K^{(+)}$ loses electron from a 3(p) orbital or 3rd energy level or 3rd energy shell

Must be comparative

Allow converse arguments

1

M2 More shielding (in Ca^{+})

1

(c) Be /Beryllium

1

(d) $Mg(OH)_2$

1

(e) $Ba^{2+} + SO_4^{2-} \rightarrow BaSO_4$

Ignore state symbols

1

n $BaCl_2$ $(6/1000 \times 0.25) = 1.5 \times 10^{-3}$ and n Na_2SO_4 $= (8/1000 \times 0.15) = 1.2 \times 10^{-3}$

and $BaCl_2$ /barium chloride in excess

Working required or 3×10^{-4} of $BaCl_2$

1

10 cm^3 (of 0.15 mol dm^{-3} sodium sulfate)

or $0.01dm^3$

1

(f) **M1** Same electronic configuration / same number of electrons (in outer shell) / all have 37 electrons (1)

Ignore protons and neutrons unless incorrect numbers

Not just electrons determine chemical properties

1

M2 $\frac{86x + 87x + 88(100-2x)}{100} = 87.7$

$= 87.7$

Alternative M2:

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$$\frac{86 + 87 + 88y}{1 + 1 + y} = 87.7$$

1

M3 x = 10% (or × = 0.1)

M3 y = 8

1

M4 (% abundance of 88 isotope is 100 – 2x10) = 80(.0)%

M4 % of 88 isotope is 100 – 10y = 80(.0) %

Allow other alternative methods

1

(g) $^{138}Ba^{+}$

1

(h) **M1** $\text{mass} = \frac{137 \times 10^{-3}}{6.022 \times 10^{23}}$ = 2.275 × 10^{-25} (kg)

Calculation of m in kg

If not converted to kg, max 4

If not divided by L lose M1 and M5, max 3

1

M2 $v^2 = \frac{2KE}{m} = \frac{2 \times 3.65 \times 10^{-16}}{2.275 \times 10^{-25}}$ = 3.2088 × 10^{9}

For re-arrangement

1

M3 $v = \sqrt{2KE/m}$ (v = 5.6646 × 10^{4})

For expression with square root

1

M4 v = d/t or d = vt or with numbers

1

M5 d = (5.6646 × 10^{4} × 2.71 × 10^{-5}) = 1.53 - 1.54 (m)

M5 must be to 3sf

If not converted to kg, answer = 0.0485-0.0486 (3sf). This scores 4 marks

1

Alternative method

M1 $m = \frac{137 \times 10^{-3}}{6.022 \times 10^{23}}$ = 2.275 × 10^{-25}

M1 Calculation of m in kg

1

M2 v = d/t

M2, M3 and M4 are for algebraic expressions or correct expressions with numbers

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1

M3 $d^2 = \frac{KE \times 2t^2}{m}$

1

M4 $d = \sqrt{\frac{KE \times 2t^2}{m}}$ $(= \sqrt{(3.65 \times 10^{-16} \times 2 \times (2.71 \times 10^{-5})^2 / 2.275 \times 10^{-25})})$

1

M5 d = 1.53 – 1.54 (m)

M5 must be to 3sf

1

[18]

Q14.

M1 HCl added = 0.050 mol and
NaOH used in titration = 3.99×10^{-3} mol

1

M2 So moles that would be needed to neutralise total excess HCl = 3.99×10^{-3} **× 10** = 3.99×10^{-2} mol

Alternative: divide moles HCl by 10 = 0.005 and 0.005 - 3.99 × 10^{-3} = 0.00101

1

M3 Therefore the moles of HCl reacted with the $Na_2CO_3.xH_2O$ = 0.050 - 3.99×10^{-2} = 0.0101 mol

Alternative: 0.00101 × 10 to produce 0.0101

1

M4 So moles $Na_2CO_3.xH_2O$ reacted with the HCl = 0.0101 / **2** = 5.05 x 10^{-3} mol

1

M5 Conversion of mg to g = 0.627 (g) or 627×10^{-3} (g)

1

M6 xH_2O = 0.627/5.05×10^{-3} -106.0 = 18 (.16)

Alternative: mass Na2CO3 that reacted with the HCl 5.05 × 10^{-3} x106.0 = 0.5353 g and mass H_2O = 0.627- 0.5353 = 0.0917 g

1

M7 so *x* = **1**

Alternative: 0.0917 /18.0 = 5.094 × 10^{-3} so ratio Na_2CO_3 to H_2O = 1:1.009 ie 1:1 so × = 1

1

[7]

Q15.

(a) Initial amount of A = 6.4×10^{-3}

If M1 wrong can score max 3

M1

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Equ A = $6.4 \times 10^{-3} - 2x \therefore x = 1.25 \times 10^{-3}$

If incorrect x can score max 3

M2

B = $9.5 \times 10^{-3} - x = 8.25 \times 10^{-3}$

Allow 2 or more sig figs

M3

C = $2.8 \times 10^{-2} + 3x = 0.0318$

M4

D = $x = 1.25 \times 10^{-3}$

M5

(b) $K_c = \dfrac{[C]^3[D]}{[A]^2[B]}$

Penalise ( ) but mark on in (b) & (c)

1

Units = mol dm^{-3}

If K_c wrong no mark for units

1

(c) M1 for correct rearrangement $[A]^2 = \dfrac{[C]^3[D]}{K_c[B]}$ or $[A] = \sqrt{\dfrac{[C]^3[D]}{K_c[B]}}$

If K_c wrong in (b) can score 1 for dividing by correct volume

M1

M2 for division of mol of B, C and D by correct volume

If K_c correct but incorrect rearrangement can score 1 for dividing by correct volume

M2

$$[A]^2 = \frac{[1.05/0.5]^3[0.076/0.5]}{116 \times [0.21/0.5]}$$

M3 for final answer: [A] = 0.17 (must be 2 sfs)

M3

(d) (All) conc fall: (ignore dilution)

OR K_c = mole ratio × 1/V

1

Equm moves to side with more moles

If vol increases, mole ratio must increase

1

To oppose the decrease in conc

To keep K_c constant

If only conc of A falls CE=0

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If pressure falls CE=0

1

[13]

Q16.

(a) **M1** Moles of cyclohexanol = (10 × 0.96)/100.0 = 0.096

Correct answer scores all 3 marks

1

M2 Max mass of cyclohexene = 0.096 × 82.0 = 7.87(2)

= M1 × 82.0 (process mark)

1

M3 % yield = (5.97 / 7.87) × 100 = 76% (Allow range 75.8 – 76)

= (5.97 / M2) × 100 (process mark)

1

Alternative method

M1 Moles of cyclohexanol = (10 × 0.96)/100.0 = 0.096

M2 Moles of cyclohexene = 5.97/82.0 = 0.0728

M3 % yield = 0.0728 / 0.096 × 100 = 76% (allow range 75.8 – 76)

= (M2 / M1) × 100

Allow 1/3 for 62(.2)%

(b) Add bromine (water)

If M1 not correct then only allow M2 if reagent involves bromine (water)

1

Would turn (from orange to) colourless / decolourise

Do not allow incorrect starting colour, but allow brown/red/yellow

Not discolour.

Ignore clear

1

(c) Na_2CO_3 would neutralise/react with/remove (phosphoric) acid/H_3PO_4/H^+

1

(d) avoid pressure build-up / release pressure / release CO_2/air/gas / prevent stopper blowing out

Ignore explosion

Do not allow an incorrect named gas

Allow idea that build-up of gas/CO_2 would lead to increased pressure/stated effect of increased pressure

1

(e) Does not dissolve in/react with the cyclohexene

Allow remains a solid/is inert in cyclohexene

Allow organic product/organic compound formed/ organic

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layer/distillate instead of cyclohexene

Do not allow if answer implies cyclohexanol

Do not allow if answer says does not react with products

Ignore references to filtration

Do not allow insoluble/unreactive unless qualified by implied reference to cyclohexene

1

(f) If diagram drawn:

M1 diagram of basic set up to include flask or tube with side-arm/Buchner flask, flat-bottomed funnel/Buchner funnel, filter paper

M2 apparatus should work, flow through, air-tight connection between flask and funnel, arrow/label/description (to vacuum pump)

Do not allow "standard" Y-shaped funnel

1

If description given:

M1 Buchner funnel/flat-bottomed funnel containing filter paper

M2 Buchner flask/side-arm flask connected to vacuum pump

Do not allow just "funnel"

Penalise M2 if described apparatus would not actually work.

1

(g) Cyclohexene is less polar than cyclohexanol / cyclohexanol is more polar than cyclohexene

It = cyclohexene

Allow cyclohexene is non-polar and cyclohexanol is polar

1

Cyclohexene has a greater affinity/attraction for the mobile phase/hexane / cyclohexanol has a greater affinity/attraction for the stationary phase/silica

Allow cyclohexanol held in the stationary phase for longer

Allow cyclohexene is more soluble in the mobile phase/hexane or converse for cyclohexanol

Allow references to hydrogen bonds between cylcohexanol and silica

1

(h) Would be no peak at 3230 – 3550 cm^{-1} due to O—H((alcohol))

OR

There would be no additional peaks in the fingerprint region compared to a pure sample / fingerprint region exactly matches cyclohexene

Need wavenumber and bond for mark

1

[13]

Q17.

B

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[1]

Q18.

(a) $4CuFeS_2 + 9\frac{1}{2}O_2 + 4SiO_2 \rightarrow Cu_2S + Cu_2O + 7SO_2 + 4FeSiO_3$

Allow multiples

1

$Cu_2S + 2Cu_2O \rightarrow 6Cu + SO_2$

1

(b) ANY TWO
- Prevents acid rain (which damages buidlings / ecology)
- Toxic OR causes breathing problems
- Reduces waste product OR makes use of the waste OR improves atom economy OR Reduces need for sulfur mining OR used to produce sulfuric acid OR any named products

2

(c) M1, M2, M3 are process marks

M1 Mol Cu = $\frac{450 \times 1000}{63.5}$ (= 63780)

1

M2 Mass $CuFeS_2$ = (63780) × 183.5 (= 1.17×10^7g)

1

M3 Mass ore = (1.17 × 107) × $\frac{100}{1.25}$

1

M4 Mass ore = 936 tonnes (Allow 936 –937)

1

Alternative method
M1 % of Cu in $CuFeS_2$ = (63.5/183.5) × 100 = 34.6%
M2 % of Cu in the rock = (34.6/100) × 1.25 = 0.4325%
M3 mass of rock = 4050 × 100/0.4325 = 936416kg
M4 mass of rock in tonnes = 936 tonnes

Notes
M1 A_r Cu must be used
M2 M_r $CuFeS_2$ to have been used
M3 Grossing up for the mass of rock
M4 Final answer correct in tonnes

(d) % atom economy = $\frac{(2 \times 63.5)}{171} \times 100$

1

= 74.3% must be 3sf

1

[10]

Q19.

(a) NO_2^- +3 or III or 3 or 3+

1

NO +2 or II or 2 or 2+

1

(b) $NO_2^- + e^- + 2H^+ \rightarrow NO + H_2O$ (OR double)

1

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(c) $2I^- \longrightarrow I_2 + 2e^-$ (OR half)

1

(d) $2NO_{2-} + 2I^- + 4H^+ \longrightarrow I_2 + 2NO + 2H_2O$

1

(e) Oxidising agent

Allow to accept / gain electrons

Allow Oxidant

Do not allow accept / gain pairs of electrons

Do not allow Oxidise

1

(f) Mol ClO_3^- = $0.02 \times \frac{27.4}{1000} = 5.48 \times 10^{-4}$

1

Mol NO_2^- = $\frac{5}{2}$ $(0.02 \times \frac{27.4}{1000}) = 1.37 \times 10^{-3}$)

1

$[NO_2^-]$ = mol NO_2^- /$(\frac{25}{1000})$

$[NaNO_2] = 0.0548$ moldm^{-3}

1

Conc $NaNO_2 = (0.0548) \times 69.0 = 3.78$ gdm^{-3}

1

Minimum 2 sf

[10]

Q20.

B

[1]

Q21.

B

[1]

Q22.

B

[1]

Q23.

(a) **M1** Amount NaOH = $0.02530 \times 0.500 = 0.01265$ mol

567-590 = 4 marks

0.567-0.590 = 3 marks

1

M2 Amount acid = 0.006325 mol (i.e. **M1** ÷ 2)

Allow ECF at each stage

1

M3 $M_r = 90(.0)$

***M3** can be scored from use of value of 90(.0) within working*

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1

M4 mass acid = 569 (mg) (allow 567 to 576) (i.e. **M2** × **M3** in mg)

__M4__ should be to at least 2sf. Any individual marks for __M1/2/3__ should be to at least 2sf (or 90 for __M3__)

1

1134-1180 = 3 marks (due to not dividing moles of NaOH by 2)

1.134-1.180 = 2 marks (due to not dividing moles of NaOH by 2 and not converting to mg)

(b) Idea that it ensures all ethanedioic acid / acid / sodium hydroxide / alkali / reactants are in the mixture / solution / reaction or the idea that some of the ethanedioic acid / acid / sodium hydroxide / alkali / reactants would be on the sides of the flask

the idea that it is the transfer of all the acid/alkali alone is not enough

1

(c) Titres that are within 0.1 cm^3 of each other

Units are needed

Allow 0.05-0.15 cm^3

Do not allow idea of identical results

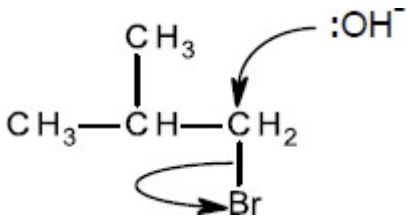
Allow answers that refer to titres that are within the uncertainty of the burette/apparatus of each other

1

[6]

Q24.

(a) **M1** nucleophilic substitution



Penalise __M3__ for formal charge on C and/or Br of C-Br or incorrect partial charges on C-Br

Max 1 out of 2 for __M2__ & __M3__ for incorrect reactant or product (ignore poorly drawn bond from C to OH group in product if shown)

For SN^2

penalise __M2__ for any additional arrow(s) on NaOH

penalise __M3__ for any additional arrow(s) to/from the Br to/from anything else

1

M2 curly arrow from lone pair on O of OH^- to C of C-Br

1

M3 curly arrow from C-Br bond to the Br

1

If SN^1 mechanism given (loss of Br first followed by attack by

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OH^-) then:

M2 *curly arrow from C-Br bond to the Br*

M3 *curly arrow from lone pair on O of OH^- to positive C atom of correct carbocation*

*penalise **M2** for any additional arrow(s) to/from the Br to/from anything else*

*penalise **M3** for any additional arrow(s) on NaOH*

*If curly arrows represent an attempt at an elimination mechanism, cannot score **M2** or **M3***

(b) **M1** Amount 1-bromo-2-methylpropane
(= (2 × 1.26) / 136.9 = 2.52/136.9) = 0.0184 mol

Correct answer scores 3 marks; answer to at least 2sf and any individual marks for M1/2 should be at least 2sf; answers that are a factor of 10^x out score 2;

1

M2 mass of 2-methylpropan-1-ol expected
(= 0.0184 × 74.0) = 1.36 g

Allow ECF through the question

1

M3 % yield = 100 × (0.895/1.36) = 65.7% (65-67%)

1

Alternative method:

M2 *amount of 2-methylpropan-1-ol produced*

= 0.895/74.0 = 0.0121 mol

M3 *% yield = 100 × (0.0121/0.0184) = 65.7% (65-67%)*

Allow 2 marks for 82.7-83% (comes from starting with 2 g not 2.52 g), with answers that are a factor of 10^x out from this scoring 1

(c) **M1** methylpropene

M1 *Do not allow any names with numbers for the position of the double bond. Allow 2-methylpropene but no other answer*

Ignore any drawn mechanism

1

M2 elimination

M2 *allow base (or basic) elimination but no other answer*

1

[8]

Q25.

B

[1]

Q26.

C

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[1]

Q27.

B

[1]

Q28.

(a) Moles MnO_4^- $\frac{26.50 \times 0.02}{1000}$ = 5.30×10^{-4}

1

Moles in $25cm^3$ sample / pipette $C_2O_4^{2-}$ (from acid and salt)
= 5.30×10^{-4} **× 5/2 = (1.325×10^{-3})**

1

Moles NaOH = $\frac{10.45 \times 0.1}{1000}$ (= 1.045×10^{-3})

1

So moles $C_2O_4^{2-}$ from acid in $25cm^3$ sample / pipette
= 1.045×10^{-3} **÷ 2** = 5.225×10^{-4}

1

Hence moles $C_2O_4^{2-}$ in sodium ethanedioate in 25 cm^3

= $1.325 \times 10^{-3} - 5.225 \times 10^{-4}$ (= 8.025×10^{-4})

1

So moles $C_2O_4^{2-}$ in sodium ethanedioate in original sample
= 8.025×10^{-4} **× 10** **(= 8.025×10^{-3})**

1

Mass $Na_2C_2O_4$ = 8.025×10^{-3} **× 134(.0) = 1.075(35) g**
So % sodium ethanedioate in original sample

1

$\frac{1.075(35)}{1.90} \times 100$ = 56.6 % to 3 sig fig

1

The first CE is penalised by 2 marks; further errors are penalised by one mark each

M2 = M1 × 5/2

M4 = M3 ÷ 2

M5 = M2 – M4 (do not allow if negative and do not allow = M4-M2)

If no subtraction, max = 5 (M1, M2, M3, M4 and M6)

If incorrect subtraction, max = 6 (M1, M2, M3, M4, M6 and M7)

M6 = M5 × 10

(M6 can be scored by multiplying M2 and M4 by 10 before subtraction (giving $1.325 \times 10^{-2} - 5.225 \times 10^{-3} = 8.025 \times 10^{-3}$)

M7 = M6 × 134

M8 = (M7/1.90) × 100 Allow 56.5 – 56.8%

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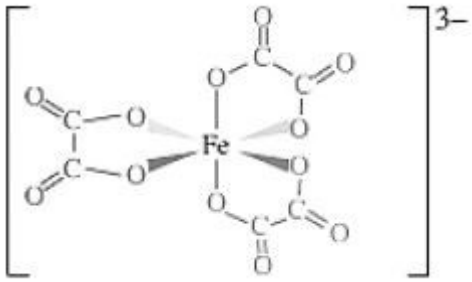
(b) $[Fe(H_2O)_6]^{3+} + 3C_2O_4^{2-} \longrightarrow [Fe(C_2O_4)_3]^{3-} + 6H_2O$

1

There are 6 Fe–O bonds broken and then made / same number and type of bond being broken and made.

1

(c)



Ignore all charges even if wrong
Ignore absence of square brackets
Candidates do not need to show 3D shape

1

90° or 180°

1

optical

1

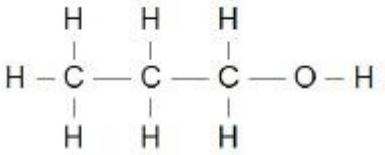
(d) The ethanedioic acid is only present in small quantities/low concentration in these foods.

1

[14]

Q29.

(a)



Must be displayed

1

(b) Nucleophilic substitution

1

Excess NH_3

Ignore aqueous, alcoholic, conc, dil, temp, heat, pressure

1

(c) Amount of $CH_3CH_2CH_2Br$ 25.2/122.9 (=0.205) (mol)

M1

Amount of $CH_3CH_2CH_2NH_2$ M1 × 0.75 (= 0.154) (mol)

M2

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Mass $CH_3CH_2CH_2NH_2$ M2 × 59.0 = 9.07g Must be 3sf

M3

If either Mr incorrect or used incorrectly then only award 1 mark for 75% yield calculation

(ignore rounding to 123 for $CH_3CH_2CH_2Br$)

OR

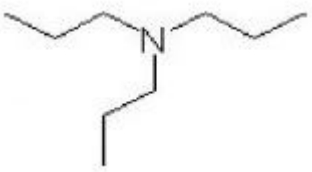
Max mass amine = M1 × 59.0 (= 12.1) (g)

Actual mass = M2 × 0.75 = 9.07g Must be 3sf

Allow 9.09 but if 9.08 check for AE

18.9 scores 1 for 75%

(d)



Must be skeletal

Ignore lone pair

1

tertiary amine or 3° amine (only award if a tertiary amine shown)

1

(e) NaOH/ ethanol or KOH / ethanol (both required)

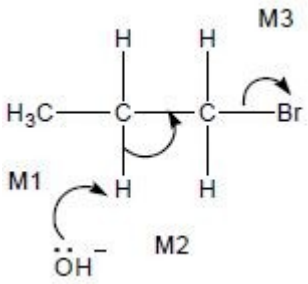
***NOT** aqueous*

Ignore heat, temp, conc., dil,

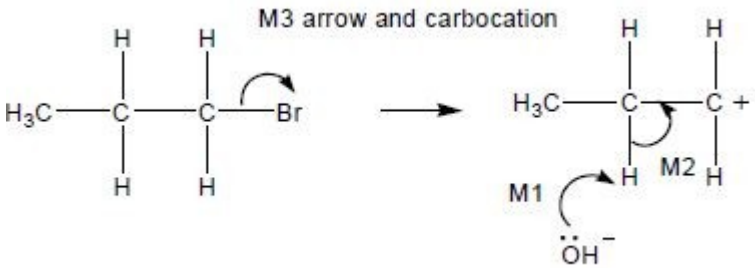
Accept alcoholic for ethanol

1

(f) (Basic) Elimination



Also credit E1 mechanism



1

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M1 arrow from lone pair on O of hydroxide to correct H (or to space mid way between hydroxide O and H)

M2 arrow from C-H bond to C-C bond following attack by OH^- on the correct H

M3 arrow from C-Br bond to Br

If nucleophilic substitution shown then allow M3 only in mechanism

If wrong haloalkane used then Max 2 for mechanism

M3 curly arrow for loss of Br^- & structure of carbocation

M1 arrow from lone pair on O of hydroxide to H (or to space mid way between hydroxide O and H) (same as E2)

M2 arrow from C-H bond to C-C bond (same as E2)

3

[13]

Q30.

C

[1]

Q31.

C

[1]

Q32.

B

[1]

Q33.

(a) CO_2 gas escapes or is lost

1

(b) Mass CO_2 = 16.11 − 14.58 = 1.53 g

1

M_r CO_2 = 44.0

Mol CO_2 = 1.53 / 44.0 = 3.48×10^{-2}

1

Mol $SrCO_3$ = 3.48×10^{-2}

1

Mass $SrCO_3$ = mol × M_r = $3.48 \times 10^{-2} \times 147.6$

Mass $SrCO_3$ = 5.13 (g)

1 mark for the answer and 1 for 3 sf precision

Allow 5.14 g (as a result of rounding)

2

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(c) Percentage error = $^{0.01}/_{6.26} \times 100$

= 0.160 (%)

1

(d) Original Mass SrO = 6.26 − 0.347 − 5.13

= 0.783 g (or 783 mg)

OR 6.26 − 0.347 − 4.85 = 1.063 g

Allow 0.773 g or 773 mg (from rounding error in part ***(b)***

1

Justification: All $SrCO_3$ reacted because heated to constant mass.

1

(e) $3SrO + 2Al \longrightarrow Al_2O_3 + 3Sr$

1

Al acts as a <u>reducing agent</u>

1

Sr is collected as a vapour because

1

Al_2O_3 is an <u>ionic</u> lattice and so has <u>strong ionic attractions</u>

1

Than Sr which is a <u>metallic</u> structure with (relatively) <u>weaker bonding</u>

1

[14]

Q34.

C

[1]

Q35.

D

[1]

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Q1.

(a) Almost all students were able to give the correct Mr for sodium fluoride but many became confused by the different units involved in this question. Students should be advised that they should explain their working for each step in a calculation. When only numbers were provided in an answer, it was not clear what students were calculating in each step.

(b) A good number of students (39.9%) were able to determine the maximum mass of sodium fluoride that a 75.0 kg person could swallow without reaching a toxic concentration, although a few struggled with the conversion to mg.

(c) Many students completed this calculation with the figures upside-down and so were unable to score. A surprisingly high proportion of students (16%) made no attempt whatsoever at this question.

(d) Many students were unable to identify the correct relative sizes – many stated that both ions were the same size because they had the same number of electrons, without considering the impact of the protons. Other students did not appreciate that both ions were isoelectronic.

Q2.

(a) Most students that were successful in this question completed it using the first method. A good number, however, were unable to determine the mass of water lost during the reaction whilst many also got the masses the wrong way around. A number of students did not quote their answer to two decimal places as asked for in the question.

(b) This was answered reasonably well (46.3% of students gained the mark) but a common misconception was the idea that there would have been heat loss during the process. Additionally, some students just listed reasons why an answer may not be correct in a practical without considering the specific context of this procedure.

(c) This question was also completed well with many students (40.1%) scoring both marks and explaining how the experiment could be improved. A few students attempted to refer to changing the apparatus which was prohibited by the question.

Q3.

Students found this challenging and did not always express their ideas clearly. Many approached this question as if they already knew which compound was which. A good number did not appreciate that the compounds were solids and so they should make them into solutions. The best students realised that acid should be added first to identify the sodium carbonate and that this solid can then be discarded from further tests. A large number of students realised that silver nitrate would be the best reagent that could be used to determine which solid was sodium chloride and which was sodium fluoride. Additional use of ammonia solution was not necessary in this case. Equations were well written, although did not often include state symbols as required. A high number of students felt that concentrated sulfuric could be used to determine which solid was which despite the fact that all three solids would give very similar observations. The question discriminated particularly well.

Q4.

(a) This was answered well – nearly all students (83.8%) were able to state two correct oxidation states.

(b) Very few students were able give the first half-equation for the oxidation of chlorine whereas the second half-equation was more regularly correct.

(c) Only some students (23.1%) were able to recall this equation from the specification.

(d) Some students successfully calculated the mass of potassium iodide. However, many did not appreciate that this reaction was not 1:1 and so used the incorrect reacting ratio in their calculations. Many students stated incorrectly that the iodine formed would be observed as purple fumes or as a purple solution. This question discriminated particularly well.

(e) Most students were able both to write the correct equation and calculate the enthalpy change. Only 8.4% of students were unable to score at least one mark.

Q5.

The most common answer (C) was incorrect. Most students believed that the total volume of gas in the mixture at the end of the reaction was 40 cm^3, and did not realise that there would have been 10 cm^3 of unreacted gas. Only 16% of students were successful here.

Q6.

Only a minority of students (38.3%) answered this question correctly; many felt that washing the pipette with water between each titration helped to improve concordancy.

Q7.

The majority of students (64.5%) appreciated that the conical flask should be rinsed with water between titrations.

Q8.

Only 30.5% of students gained this mark, thus most students did not appreciate that a higher burette reading would lead to a lower uncertainty so less concentrated alkali should be used. Instead, the majority of students felt that the most appropriate way to reduce uncertainty was to fill the burette to the 0.00 cm^3 mark.

Q9.

The majority of students (76%) were able to suggest the most appropriate safety precaution.

Q10.

The majority of students felt that the end point when using methyl orange would be red to yellow rather than red to orange. Just under a third of students gave the correct answer.

Q11.

(a) Only a minority of students (42.3%) could explain why the final rinse of a burette in a titration should be done with the solution going into the burette rather than with water. This showed the importance of students understanding *why* they are doing

what they are doing in a practical procedure rather than just following instructions.

(b) Very few students (only 15%) could give the volumes in each titration to the appropriate precision, for example writing 23.9 instead of 23.90 cm^3.

(c) The calculation of the uncertainty in the use of the burette in the titration was answered well, but a significant number of students did double the uncertainty perhaps because they did not appreciate the origins of the ±0.15 cm^3 uncertainty.

(d) Many students could identify the concordant titres to use to find the mean, although many did not, but few students quoted the mean to the appropriate precision.

(e) This calculation was done well, but some students used the wrong volume of alkali, using the volume of the acid instead. The conversion of g to mg was done well. This question discriminated particularly well.

(f) Nearly half of students could find the percentage purity based on their answer to question (e). Worryingly, just over 20% of students made no attempt at all at this question.

Q12.

A good number of students (37.2%) could work out the percentage yield, but the many incorrect answers suggest that many students do not understand how to calculate percentage yield.

Q13.

(a) The electron configuration was well known (88.9% correct).

(b) Only the best students gained both marks here (19%); many students focused on whether the electron was being removed from a full or partially full orbital instead of considering why the attraction between the nucleus and the electron might be different.

(c) Less than half of the students (39.5%) could give the correct answer here; lithium was a common error.

(d) The majority of students (76.3%) answered this correctly, although there were quite a number who gave the incorrect formula.

(e) The ionic equation was generally correct and many students could also calculate that barium chloride was in excess. Just under a third of students managed to score all three marks.

(f) Most students could state why isotopes have the same chemical properties. In the calculation, many students gave an algebraic equation with two unknowns and could not proceed any further. The students who gave a correct algebraic expression with one unknown could work through the calculation and generally gained full marks. Some students answered the question by trial and error and this was also given full credit. Pleasingly, 43.7% of students gained all four marks available.

(g) Most students deduced that the mass number of the ion would be 138 but less than 30% of students could give the correct formula for the ion including its charge.

(h) Some students answered this part very well (with 36.6% scoring full marks), but most students scored partial marks or no marks; common errors included failure to

use the Avogadro constant, not converting mass to kg, and incorrect rearrangement of expressions.

Q14.

This challenging question discriminated very well, with 16.6% of students scoring all of the marks and 20% scoring zero marks; 5.7% did not attempt this question. Many students calculated the amount, in moles, of hydrochloric acid added and the amount of sodium hydroxide used in the titration. Many did not then multiply the amount of sodium hydroxide by 10 to calculate the total amount, in moles, of hydrochloric acid remaining and fewer students still were able to calculate the original amount of sodium carbonate. Many students could convert mg to g. Only the best students could continue to the end and calculate that $x = 1$.

Q15.

(a) Many students gained high marks in this question – over 70% scored 4 or 5. Others often failed to use the mole ratio from the equation when deducing the amounts, in moles, of reagents at equilibrium.

(b) The expression and its units were given correctly by over 82% of students.

(c) In this question, many students were able to re-arrange the expression for K_c but significant numbers failed to divide the amounts in moles that they were given by the correct volume in dm^3. Some failed to gain a mark by giving the answer as the amount, in moles, of A rather than its concentration. Since the least precise data in the question were given to two significant figures, the final answer for concentration should have been given to two significant figures, so some students failed to gain the final mark because the answer was given to the wrong number of significant figures.

(d) This question was poorly answered and showed that students were unfamiliar with the idea of the equilibrium moving to the side with a larger amount, in moles, to oppose the fall in concentrations of all reagents when more water was added to the equilibrium mixture. Credit was given to those few students who adopted a mathematical approach. 65.8% of students failed to score here.

Q16.

(a) Most students coped with the need to convert volume to mass and gave 9.6 g of cyclohexanol at the start, but too many then assumed that this meant the maximum possible yield of cyclohexene would be 9.6 g and so divided 5.97 by this. 47.5% of students completed the calculation successfully.

(b) Most students (70.2%) were able to suggest the use of bromine water, with only very few getting the colour change the wrong way round. The most common wrong answer was the suggestion of a test for the absence of alcohol rather than a positive test for the presence of an alkene.

(c) This was not answered as well as expected (42% correct), with many vague references to ‘removing impurities’ or ‘separating the layers’.

(d) The key to questions like this about understanding the method of a practical is to relate the answer to the position of the process in the overall method. The reference to periodic opening of the tap preceded the actual separation of the layers in the method, yet many answers referred to opening the tap to run off one of the layers. It was interesting that more students (57.4% correct) were able to suggest that this

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was to release pressure of CO_2 (due to reaction with acid) than were able to suggest, in part (c), that the carbonate had been added in order to react with acid.

(e) The low success rate in this question (28.2% correct) is explained by a lack of specificity in students' answers; the mark required a reference to a lack of reactivity with, or solubility in, **cyclohexene**.

(f) Most students chose to draw a diagram rather than write a description; the former is the recommended approach. However, clear, simple cross-sectional line diagrams of a Buchner funnel and filter paper on top of a Buchner flask (with side-arm attached to a vacuum pump) were seldom seen. Tubes were often shown as sealed, bungs and side-arms were missing and the side-arm was often drawn on the funnel rather than the flask. Only 28.7% of students gained both marks; 37.1% failed to score.

(g) This part gave numerous examples of repeating the question, with many answers seen along the lines of "the retention time is shorter because the retention time is shorter". Some students also inverted the question and tried to describe why cyclohexene had a longer retention time, while others thought incorrectly that cyclohexene is polar due to the C=C bond. An inversion of reasoning that was often seen was the incorrect idea that cyclohexanol has hydrogen bonding, which is why it is polar. 34.9% of students scored zero here.

(h) Too many students failed to remember the need always to mention both the wavenumber range **and** the bond responsible in questions of this type. Most correctly stated that a peak in the range 3230−3550 would not be visible, but many then failed to state that this peak relates to the O−H bond in an alcohol. As a result, only 43.7% of students gained the mark.

Q17.

D was the commonest incorrect response, presumably from a failure to recognise that $Mg(OH)_2$ is sparingly soluble as well as $BaSO_4$. 46.8% of students were successful.

Q18.

(a) The first equation proved very challenging, but the second one was answered better, with only 20.8% of students gaining both marks.

(b) The reasons for removal of sulfur dioxide were quite well known despite the unfamiliar context; 86.3% of students picked up at least one mark on this question.

(c) This question was very poorly answered and very few students scored full marks. The unfamiliarity of the context and the changes of units that were required led to 53.3% of students failing to score any marks at all.

(d) This question proved much easier than the previous one. A much more familiar calculation meant that over half of students scored at least one mark here.

Q19.

(a) Students showed admirable ability to calculate the oxidation states and 71.8% of them gained both marks.

(b) This question was well answered with 44.6% of students gaining the mark.

(c) 62.4% of students gained the mark for this familiar half-equation.

(d) This question discriminated better than the previous two part-questions; surprisingly, 8.5% of students did not even attempt it.

(e) 56.3% of students were successful in gaining this mark.

(f) Despite the challenging mole ratio, this question was answered really well. The familiar context of the question requiring manipulation of concentrations and volumes proved to be more accessible. The final answer required unfamiliar units and failure to grasp that aspect often limited students to three marks.

Q20.

38.1% of students were successful. The most popular answer was C which shows that an incorrect formula ($NaSO_4$) must have been used by these students.

Q21.

42.3% of students selected the correct answer. Most of the other students chose C – rinsing the walls of the conical flask with water. This is a common misconception and is clearly not well understood.

Q22.

A pleasing 66% of students could perform this relatively tricky calculation.

Q23.

(a) Most students made good progress with the calculation to find the mass (in mg) of ethanedioic acid dissolved.

(b) This question highlighted the need for students to understand the practical procedures they carry out. Only a minority could explain that the walls of the conical flask are washed down to ensure all the reactants are washed into the reaction mixture.

(c) The meaning of the term concordant titres was reasonably well known, but only a minority of students knew that titres should be within 0.1 cm^3 of each other.

Q24.

(a) This straightforward nucleophilic substitution mechanism was well known and well drawn in general.

(b) This yield calculation proved to be challenging, with the combined use of the volume and density of the starting material proving to be beyond many students.

(c) Most students knew that an elimination reaction took place, but few could give the correct name for the product, methylpropene.

Q25.

Most students (77%) read the burette correctly, but a significant number read the scale upside- down to get 25.70 cm^3 rather than 24.30 cm^3.

Q26.

Students struggled with this question (30.2% correct). Many did not appreciate that there are two uncertainties as two readings of the balance are taken to find a change in mass. Many did not realise that the uncertainty is with the mass of the solute itself.

Q27.

Nearly half of the students (44.8%) could do this, but many could not work out how much water to add to a solution to dilute it by a specific factor.

Q28.

This was a challenging question with students finding most parts of it difficult.

(a) Only the best students got to the end of the calculation. Many students scored the first four marks, and some of these then realised that they needed to multiply by ten because of the dilution used. Very few students appreciated that the amount in moles of ethanedioic acid had to be taken away from the total amount in moles of ethanedioate ions to find the amount in moles of sodium ethanedioate. Those students who did, usually went on to get the right answer.

(b) Students often failed to give a balanced equation; charges on the complex ions were often incorrect, and many did not give water as one of the products. Many students understood that the same number of bonds were broken and formed, but few could also state that they were the same type of bonds. Some stated that the bond enthalpies were similar, but could not explain why.

(c) Many students struggled to draw the displayed formula; those who got close often omitted the carbon atoms from the ligand. Most students knew the bond angle, but some incorrectly gave 120° or 109.5°. The most common incorrect type of isomerism given was stereoisomerism or cis/trans.

(d) Common answers that did not score here included references to ethanedioate ions being indigestible, or being so firmly chelated to iron ions already that they were not free to be absorbed.

Q29.

(a) Although most students identified compound **J** as propan-1-ol, a surprising number failed to show the O−H bond as is necessary in a displayed formula.

(b) Most students could name the mechanism, but the condition proved more difficult.

(c) This calculation was done well and 56% of students scored full marks. The main errors were in working out or using the correct M_r values.

(d) Only 30% of students scored both marks here. Others drew a primary amine or a non-skeletal structure.

(e) Both the reagent (which must be a complete compound) and a condition were needed to score the mark; several omitted the condition.

(f) This was a high scoring question for many. For others, the main errors were missing the negative sign or the lone pair on the hydroxide ion, or showing attack on the wrong hydrogen atom.

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Q1.

Which reaction has the largest atom economy for the production of hydrogen?

A $C + H_2O \longrightarrow CO + H_2$ ⬭

B $Zn + 2HCl \longrightarrow ZnCl_2 + H_2$ ⬭

C $CH_4 + H_2O \longrightarrow CO + 3H_2$ ⬭

D $CO + H_2O \longrightarrow CO_2 + H_2$ ⬭

(Total 1 mark)

Q2.

After reaction of some zinc metal with excess sulfuric acid, a student collected 40.8 g of $ZnSO_4.7H_2O$ crystals. The yield of crystals was 70.0%.

What was the original mass of zinc used?

A 9.28 g ⬭

B 13.3 g ⬭

C 23.6 g ⬭

D 58.3 g ⬭

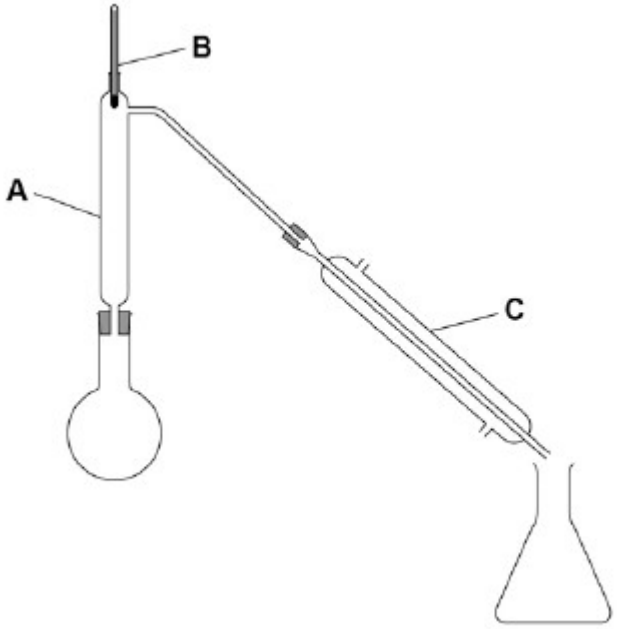
(Total 1 mark)

Q3.

A group of students wanted to produce a biofuel to power the central heating system in their school. They collected scraps of fruits and vegetables from the kitchens and fermented them with yeast, in the absence of air, in order to produce ethanol.
The aqueous mixture was filtered to remove the remaining solids.

The students then set up the apparatus shown in the diagram below and placed the aqueous mixture in the round bottomed flask.

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(a) Describe how the students would use this apparatus to collect a sample of ethanol. Include in your answer the functions of the parts of the apparatus labelled **A**, **B** and **C**.

(6)

(b) The students collected a 20 cm^3 sample of liquid and weighed it. The mass of the sample was 16 g.

The density of ethanol is 0.79 g cm^{-3} and that of water 1.00 g cm^{-3}.

Use these data to calculate the mass of ethanol in the sample collected.
You should assume that the volume of the sample is equal to the sum of the

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volumes of water and ethanol.

Mass of ethanol = _____ g

(2)

(Total 8 marks)

Q4.

The equation for the hydrogenation of ethyne is

$$C_2H_2 + 2H_2 \longrightarrow C_2H_6$$

The experimental yield is 65.0%.

What is the mass in grams of ethane that can be produced from 16.20 g of hydrogen?

A 42.53 g ⬭

B 78.98 g ⬭

C 121.5 g ⬭

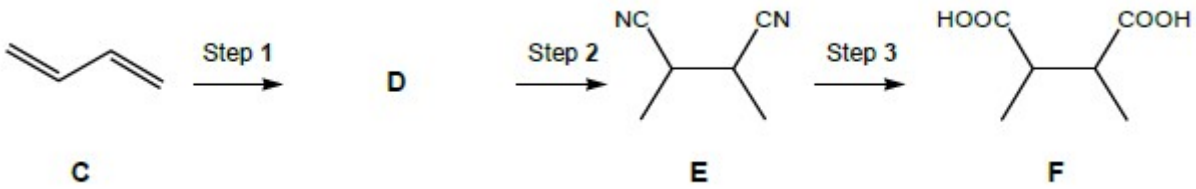
D 527.7 g ⬭

(Total 1 mark)

Q5.

Chemists design synthetic routes to convert one organic compound into another.

Buta-1,3-diene, **C**, is converted into compound **F** as shown in the diagram below.



(a) State the IUPAC name of compound **F**.

_____

(1)

(b) Deduce the structure of compound **D**.

For each of the conversions in steps **1** and **2**, suggest a reagent for the conversion and name the mechanism.

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Suggest the type of reaction occurring in step **3**.

Structure of **D**

Step **1** _____

_____

_____

_____

_____

Step **2** _____

_____

_____

_____

_____

Type of reaction in Step **3** _____

_____

(6)

(c) Compound **F** can also be made from compound **G**.



F **G**

State a reagent (or combination of reagents) that can be used in a test-tube reaction to distinguish between F and G.

Describe what you would observe when the reagent is added to each compound and the test tube is shaken.

Reagent(s) _____

_____

Observation with **F** _____

_____

_____

Observation with **G** _____

_____

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_____

(3)

(d) Compounds **F** and **G** react to form a polymer.

Draw the repeating unit of the polymer.

(2)

(e) In an experiment, 0.930 kg of purified **F** were obtained from 1.11 dm^3 of **G** (density 1.04 g cm^{-3}).

Calculate the percentage yield.

Give your answer to the appropriate number of significant figures.

Percentage yield _____ %

(4)

(f) One reason for a yield of less than 100% in part **(e)** is that **G** reacts to form a number of other compounds.

The other compounds are all liquids at room temperature.

Name the technique that should be used to separate and collect each of these other compounds from the reaction mixture.

Include in your answer a description of the apparatus.

Your description of the apparatus can be either a description in words or a labelled sketch.

Name of technique _____

Apparatus

(4)

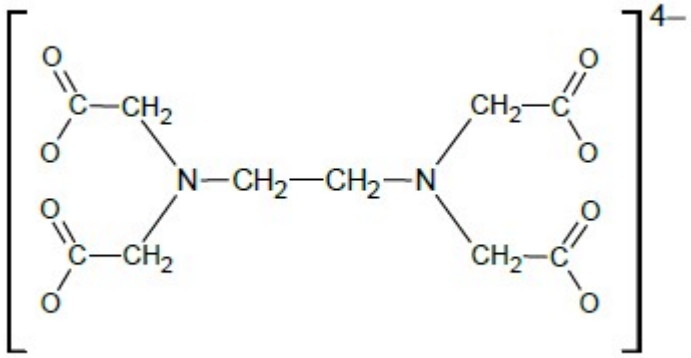
(Total 20 marks)

Q6.

EDTA is a useful laboratory chemical and is found in a wide variety of commercial

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products including detergents. It is very soluble in water and is often used in its ionic form $EDTA^{4-}$ as shown in the diagram below.



(a) $EDTA^{4-}$ can act as a multidentate ligand.

Explain the meanings of the terms **multidentate** and **ligand** with reference to the reaction of $EDTA^{4-}$ with $[Cu(H_2O)_6^{2+}](aq)$ ions to form a complex ion.

Draw on the diagram above a separate circle around each atom that bonds to the Cu^{2+} ion in this complex ion.

Multidentate _____

_____

Ligand _____

_____

(3)

(b) Copper(II) compounds may be used as fungicides in vineyards. When used in this way, copper(II) ions can enter the water supply and cause problems because they are toxic in high concentrations.

The water supply near a vineyard can be tested for copper(II) ions by forming a blue aqueous complex with $EDTA^{4-}$ ions. The concentration of this complex can be determined using a colorimeter.

Outline the practical steps that you would follow, using colorimetry, to determine the concentration of this complex in a sample of water.

_____

_____

_____

_____

_____

_____

(3)

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(c) The concentration of copper(II) ions, in the sample of water, determined by colorimetry was 7.56×10^{-5} mol dm^{-3}.

This result was checked by titrating a sample of the water with a solution containing $EDTA^{4-}(aq)$ ions.

The $EDTA^{4-}(aq)$ used in the titration had a concentration of 1.00×10^{-3} mol dm^{-3}.

Write an equation for the reaction between $[Cu(H_2O)_6]^{2+}$ and $EDTA^{4-}$ ions.

Calculate the volume of the $EDTA^{4-}$ solution needed to react with a 25.0 cm^3 sample of the water.

Justify whether this titration will give an accurate value for the concentration of copper(II) ions. If necessary, suggest a practical step that would improve the accuracy.

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

(5)

(Total 11 marks)

Q7.

Iodine reacts slowly with propanone in the presence of an acid catalyst according to the equation

$$CH_3COCH_3 + I_2 \longrightarrow CH_3COCH_2I + HI$$

The rate of this reaction can be followed by preparing mixtures in which only the initial concentration of propanone is varied. At suitable time intervals, a small sample of the mixture is removed and titrated with sodium thiosulfate solution. This allows determination of the concentration of iodine remaining at that time.The rate of this reaction can be followed by preparing mixtures in which only the initial concentration of propanone is varied. At suitable time intervals, a small sample of the mixture is removed and titrated with sodium thiosulfate solution. This allows determination of the concentration of iodine remaining at that time.

Five mixtures, **A**, **B**, **C**, **D** and **E**, are prepared as shown in **Table 1**.

Table 1

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Mixture	A	B	C	D	E
Volume of 0.0200 mol dm^{-3} $I_2(aq)$/cm^3	40.0	40.0	40.0	40.0	40.0
Volume of 0.100 mol dm^{-3} $H_2SO_4(aq)$/cm^3	25.0	25.0	25.0	25.0	25.0
Volume of 1.00 mol dm^{-3} $CH_3COCH_3(aq)$/cm^3	25.0	20.0	15.0	10.0	6.5
Volume of distilled water/cm^3	0.0	5.0	10.0	15.0	18.5

(a) Calculate the initial concentration, in mol dm^{-3}, of the propanone in mixture **A**.

Concentration = _____ mol dm^{-3}

(2)

(b) State and explain why different volumes of water are added to mixtures **B**, **C**, **D** and **E**.

_____

_____

_____

_____

(2)

(c) Calculate the volume of 0.0100 mol dm^{-3} sodium thiosulfate solution required to react with all of the iodine in a 10.0 cm^3 sample of mixture **E**, before the iodine reacts with propanone.

The equation for the reaction in the titration is

$$2Na_2S_2O_3(aq) + I_2(aq) \longrightarrow Na_2S_4O_6(aq) + 2NaI(aq)$$

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Volume = _____ cm^3

(4)

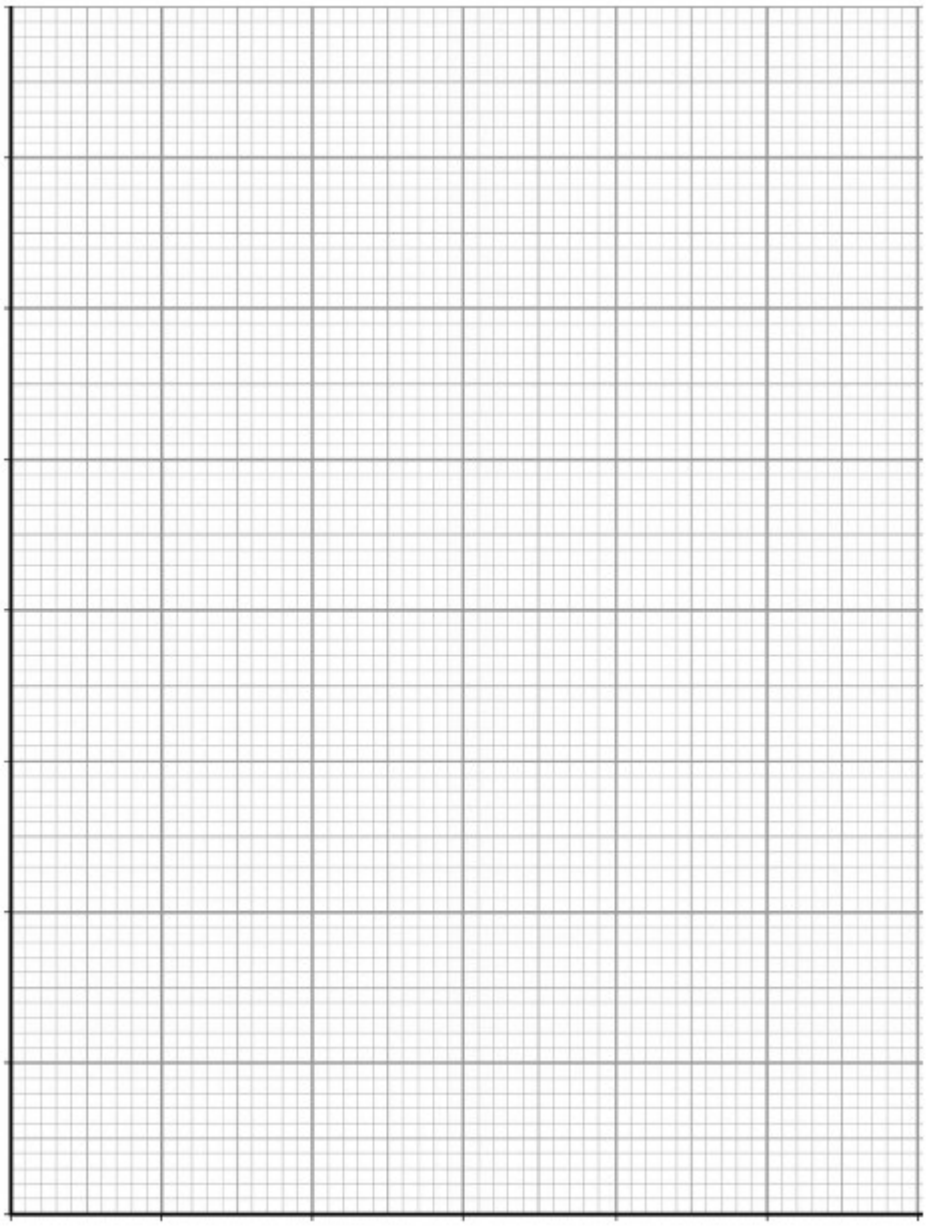
(d) The results for mixture **E** are shown in **Table 2**.
V is the volume of 0.0100 mol dm^{-3} sodium thiosulfate solution needed, at different times, **t**, to react with the iodine in a 10.0 cm^3 sample of **E**.

Table 2

t/min	5	10	20	30
V/cm^3	17.5	17.2	16.6	16.0

Use these data and your answer to part **(c)** to plot a graph of **V** (y-axis) against **t** (x-axis) for mixture **E**.
Draw a best-fit straight line through your points and calculate the gradient of this line.

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gradient = _____ $cm^3\ min^{-1}$

(5)

(e) The gradients for similar graphs produced by mixtures **A**, **B**, **C** and **D** are shown in **Table 3**.
Each gradient is a measure of the rate of the reaction between iodine and propanone.

Table 3

Mixture	**A**	**B**	**C**	**D**
Gradient / $cm^3\ min^{-1}$	−0.24	−0.20	−0.15	−0.10

Use information from **Table 1** and **Table 3** to deduce the order with respect to propanone. Explain your answer.

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_____

_____

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_____

_____

_____

(2)

(f) Each sample taken from the reaction mixtures is immediately added to an excess of sodium hydrogencarbonate solution before being titrated with sodium thiosulfate solution.

Suggest the purpose of this addition.
Explain your answer.

_____

_____

_____

_____

_____

_____

(2)

(Total 17 marks)

Q8.

This question is about the elements in Group 2 and their compounds.

(a) Use the Periodic Table to deduce the full electron configuration of calcium.

_____

(1)

(b) Write an ionic equation, with state symbols, to show the reaction of calcium with an excess of water.

_____

(1)

(c) State the role of water in the reaction with calcium.

_____

(1)

(d) Write an equation to show the process that occurs when the first ionisation energy of calcium is measured.

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_____

(1)

(e) State and explain the trend in the first ionisation energies of the elements in Group 2 from magnesium to barium.

Trend _____

Explanation _____

_____

_____

_____

_____

_____

(3)

(Total 7 marks)

Q9.

(a) Write an equation, including state symbols, for the reaction with enthalpy change equal to the standard enthalpy of formation for $CF_4(g)$.

_____

(1)

(b) Explain why CF_4 has a bond angle of 109.5°.

_____

_____

_____

_____

_____

(2)

(c) **Table 1** gives some values of standard enthalpies of formation ($\Delta_f H^\ominus$).

Table 1

Substance	$F_2(g)$	$CF_4(g)$	$HF(g)$
$\Delta_f H^\ominus$ / kJ mol^{-1}	0	−680	−269

The enthalpy change for the following reaction is −2889 kJ mol^{-1}.

$$C_2H_6(g) + 7F_2(g) \longrightarrow 2CF_4(g) + 6HF(g)$$

Use this value and the standard enthalpies of formation in **Table 1** to calculate the

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standard enthalpy of formation of $C_2H_6(g)$.

Standard enthalpy of formation of $C_2H_6(g)$ = _____ kJ mol^{-1}

(3)

(d) Methane reacts violently with fluorine according to the following equation.

$$CH_4(g) + 4F_2(g) \longrightarrow CF_4(g) + 4HF(g) \quad \Delta H = -1904 \text{ kJ mol}^{-1}$$

Some mean bond enthalpies are given in **Table 2**.

Table 2

Bond	C−H	C−F	H−F
Mean bond enthalpy / kJ mol^{-1}	412	484	562

A student suggested that one reason for the high reactivity of fluorine is a weak F−F bond.

Is the student correct? Justify your answer with a calculation using these data.

_____

_____

(4)

(Total 10 marks)

Q10.

This question is about reactions of calcium compounds.

(a) A pure solid is thought to be calcium hydroxide. The solid can be identified from its relative formula mass.

The relative formula mass can be determined experimentally by reacting a measured mass of the pure solid with an excess of hydrochloric acid. The equation for this reaction is

$$Ca(OH)_2 + 2HCl \longrightarrow CaCl_2 + 2H_2O$$

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The unreacted acid can then be determined by titration with a standard sodium hydroxide solution.

You are provided with 50.0 cm^3 of 0.200 mol dm^{-3} hydrochloric acid.
Outline, giving brief practical details, how you would conduct an experiment to calculate accurately the relative formula mass of the solid using this method.

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

(8)

(b) A 3.56 g sample of calcium chloride was dissolved in water and reacted with an excess of sulfuric acid to form a precipitate of calcium sulfate.

The percentage yield of calcium sulfate was 83.4%.

Calculate the mass of calcium sulfate formed.
Give your answer to an appropriate number of significant figures.

Mass of calcium sulfate formed = _____ g

(3)

(Total 11 marks)

Q11.

Which of these pieces of apparatus has the lowest percentage uncertainty in the measurement shown?

A Volume of 25 cm^3 measured with a burette with an uncertainty of ±0.1 cm^3. ⬭

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B Volume of 25 cm^3 measured with a measuring cylinder with an uncertainty of ±0.5 cm^3. ⬭

C Mass of 0.150 g measured with a balance with an uncertainty of ±0.001 g. ⬭

D Temperature change of 23.2 °C measured with a thermometer with an uncertainty of ±0.1 °C. ⬭

(Total 1 mark)

Q12.

Compound **J**, known as leaf alcohol, has the structural formula $CH_3CH_2CH{=}CHCH_2CH_2OH$ and is produced in small quantities by many green plants. The *E* isomer of **J** is responsible for the smell of freshly cut grass.

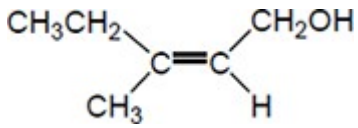
(a) Give the structure of the *E* isomer of **J**.

(1)

(b) Give the **skeletal formula** of the organic product formed when **J** is dehydrated using concentrated sulfuric acid.

(1)

(c) Another structural isomer of **J** is shown below.



Explain how the Cahn-Ingold-Prelog (CIP) priority rules can be used to deduce the full IUPAC name of this compound.

_____

_____

_____

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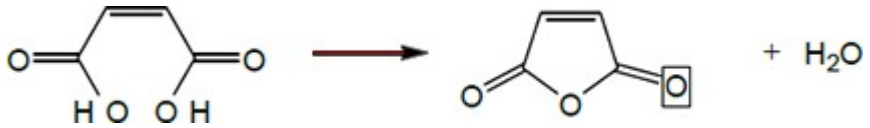
_____

_____

_____

(6)

(d) The effect of gentle heat on maleic acid is shown below.



A student predicted that the yield of this reaction would be greater than 80%.

In an experiment, 10.0 g of maleic acid were heated and 6.53 g of organic product were obtained.

Is the student correct? Justify your answer with a calculation using these data.

_____

_____

_____

(2)

(Total 10 marks)

Q13.

What is the total volume of gas remaining after 20 cm^3 ethane are burned completely in 100 cm^3 oxygen? All volumes are measured at the same pressure and the same temperature, which is above 100 °C.

$$C_2H_6 + 3\tfrac{1}{2}O_2 \longrightarrow 2CO_2 + 3H_2O$$

A 40 cm^3 ⬭

B 100 cm^3 ⬭

C 120 cm^3 ⬭

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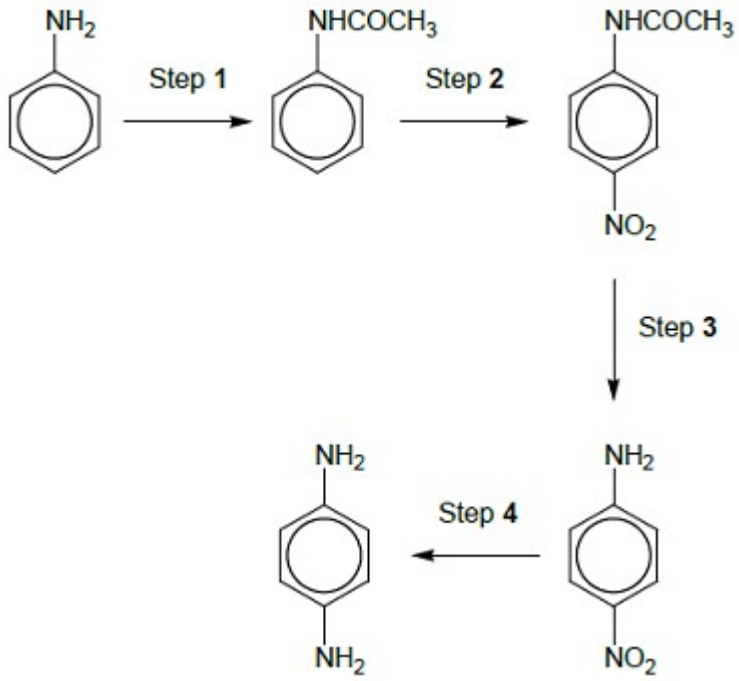
D 130 cm^3 ⬭

(Total 1 mark)

Q14.

1,4-diaminobenzene is an important intermediate in the production of polymers such as Kevlar and also of polyurethanes, used in making foam seating.

A possible synthesis of 1,4-diaminobenzene from phenylamine is shown in the following figure.



(a) A suitable reagent for step **1** is CH_3COCl

Name and draw a mechanism for the reaction in step **1**.

Name of mechanism _____

Mechanism

(5)

(b) The product of step **1** was purified by recrystallisation as follows.

The crude product was dissolved in **the minimum quantity of hot water** and the hot solution was filtered through a hot filter funnel into a conical flask. This filtration removed any insoluble impurities. The flask was **left to cool to room temperature**.

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The crystals formed were filtered off using a Buchner funnel and a clean cork was used **to compress the crystals in the funnel. A little cold water was then poured through the crystals.**
After a few minutes, the crystals were removed from the funnel and weighed.
A small sample was then used to find the melting point.

Give reasons for each of the following practical steps.

The minimum quantity of hot water was used

_____

_____

_____

The flask was cooled to room temperature before the crystals were filtered off

_____

_____

_____

The crystals were compressed in the funnel

_____

_____

_____

A little cold water was poured through the crystals

_____

_____

_____

(4)

(c) The melting point of the sample in part (b) was found to be slightly lower than a data-book value.

Suggest the most likely impurity to have caused this low value and an improvement to the method so that a more accurate value for the melting point would be obtained.

_____

_____

_____

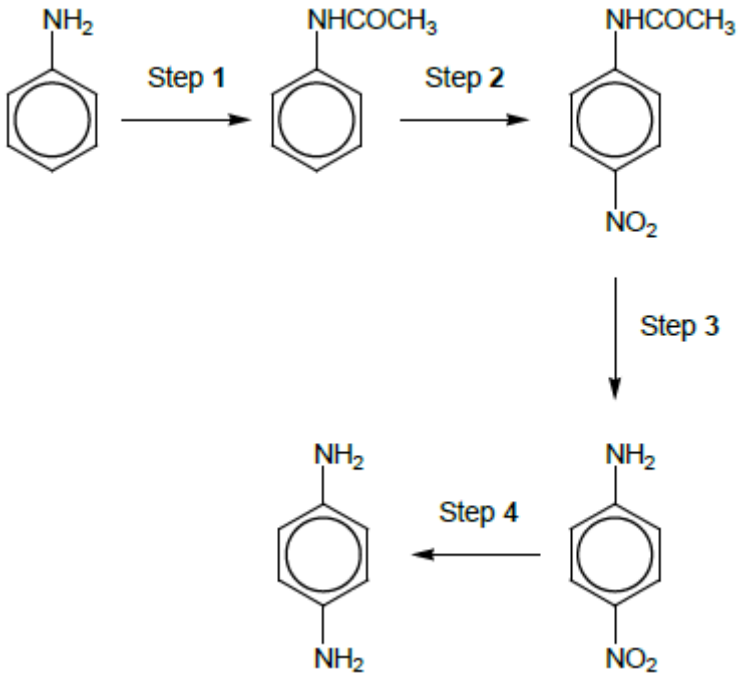
_____

_____

(2)

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The figure above is repeated here to help you answer the following questions.



(d) In an experiment starting with 5.05 g of phenylamine, 4.82 g of purified product were obtained in step **1**.

Calculate the percentage yield in this reaction.
Give your answer to the appropriate number of significant figures.

Percentage yield = _____%

(3)

(e) A reagent for step **2** is a mixture of concentrated nitric acid and concentrated sulfuric acid, which react together to form a reactive intermediate.

Write an equation for the reaction of this intermediate in step **2**.

_____

(1)

(f) Name a mechanism for the reaction in step **2**.

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_____

(1)

(g) Suggest the type of reaction occurring in step **3**.

_____

(1)

(h) Identify the reagents used in step **4**.

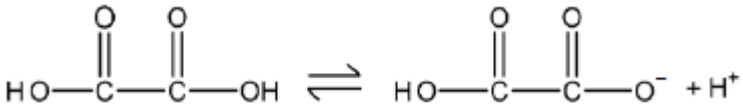
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(1)

(Total 18 marks)

Q15.

Ethanedioic acid is a weak acid.
Ethanedioic acid acts, initially, as a monoprotic acid.



(a) Use the concept of electronegativity to justify why the acid strengths of ethanedioic acid and ethanoic acid are different.

_____

_____

_____

_____

_____

_____

_____

_____

(6)

(b) A buffer solution is made by adding 6.00×10^{-2} mol of sodium hydroxide to a solution containing 1.00×10^{-1} mol of ethanedioic acid ($H_2C_2O_4$).
Assume that the sodium hydroxide reacts as shown in the following equation and that in this buffer solution, the ethanedioic acid behaves as a monoprotic acid.

$$H_2C_2O_4(aq) + OH^-(aq) \longrightarrow HC_2O_4^-(aq) + H_2O(l)$$

The dissociation constant K_a for ethanedioic acid is 5.89×10^{-2} mol dm^{-3}.

Calculate a value for the pH of the buffer solution.
Give your answer to the appropriate number of significant figures.

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pH = _____

(5)

(c) In a titration, the end point was reached when 25.0 cm^3 of an acidified solution containing ethanedioic acid reacted with 20.20 cm^3 of 2.00 $\times 10^{-2}$ mol dm^{-3} potassium manganate(VII) solution.

Deduce an equation for the reaction that occurs and use it to calculate the original concentration of the ethanedioic acid solution.

Equation _____

Calculation

Original concentration = _____ mol dm^{-3}

(4)

(Total 15 marks)

Q16.

An ester is hydrolysed as shown by the following equation.

$$RCOOR' + H_2O \longrightarrow RCOOH + R'OH$$

What is the percentage yield of RCOOH when 0.50 g of RCOOH (M_r = 100) is obtained from 1.0 g of RCOOR' (M_r = 150)?

A 33% ⬭

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B 50% ⬭

C 67% ⬭

D 75% ⬭

(Total 1 mark)

Q17.

A saturated aqueous solution of magnesium hydroxide contains 1.17×10^{-3} g of $Mg(OH)_2$ in 100 cm^3 of solution. In this solution, the magnesium hydroxide is fully dissociated into ions.

What is the concentration of $Mg^{2+}(aq)$ ions in this solution?

A 2.82×10^{-2} mol dm^{-3} ⬭

B 2.01×10^{-3} mol dm^{-3} ⬭

C 2.82×10^{-3} mol dm^{-3} ⬭

D 2.01×10^{-4} mol dm^{-3} ⬭

(Total 1 mark)

Q18.

Magnesium reacts with hydrochloric acid according to the following equation.

$$Mg + 2HCl \longrightarrow MgCl_2 + H_2$$

A student calculated the minimum volume of 2.56 mol dm^{-3} hydrochloric acid required to react with an excess of magnesium to form 5.46 g of magnesium chloride (M_r = 95.3).

Which of the following uses the correct standard form and the appropriate number of significant figures to give the correct result of the calculation?

A 4.476×10^{-2} dm^3 ⬭

B 4.48×10^{-2} dm^3 ⬭

C 4.50×10^{-2} dm^3 ⬭

D 44.8×10^{-3} dm^3 ⬭

(Total 1 mark)

Q19.

The following equation represents the oxidation of vanadium(IV) ions by manganate(VII) ions in acid solution.

$$5V^{4+} + MnO_4^- + 8H^+ \longrightarrow 5V^{5+} + Mn^{2+} + 4H_2O$$

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What volume of 0.020 mol dm^{-3} $KMnO_4$ solution is required to oxidise completely a solution containing 0.010 mol of vanadium(IV) ions?

A 10 cm^3 ⬭

B 25 cm^3 ⬭

C 50 cm^3 ⬭

D 100 cm^3 ⬭

(Total 1 mark)

Q20.

Two reactions occurred when the impure quicklime was added to the acid. Calcium oxide reacted according to this equation

$$CaO(s) + 2HCl(aq) \longrightarrow CaCl_2(aq) + H_2O(l)$$

Some carbon dioxide was evolved by the reaction of any remaining calcium carbonate that had not decomposed in the kiln.

$$CaCO_3(s) + 2HCl(aq) \longrightarrow CaCl_2(aq) + H_2O(l) + CO_2(g)$$

The carbon dioxide was collected and its volume was found to be 18.3 dm^3 at a temperature of 25 ºC and pressure of 100 kPa. The gas constant R = 8.31 J K^{-1} mol^{-1}

(a) Calculate the amount, in moles, of carbon dioxide that was given off when the impure quicklime reacted with the hydrochloric acid. Show your working.

_____

_____

_____

_____

_____

(2)

(b) Calculate the amount, in moles, of hydrochloric acid used up by the reaction with calcium carbonate. Show your working.

_____

_____

(1)

(c) Use your Periodic Table to calculate the relative formula mass of $CaCO_3$
Give your answer to one decimal place.

_____

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_____

(1)

(d) Use your answers to part **(a)** and part **(c)** to calculate the mass of calcium carbonate in the sample of quicklime.

_____

_____

(1)

(Total 5 marks)

Q21.

Sodium bromate(V) is a primary standard. This means that its solution can be used to check the concentration of other solutions.

(a) The half-equations for the reaction between bromate(V) ions and thiosulfate ions in the presence of acid are

$$2S_2O_3^{2-} \longrightarrow S_4O_6^{2-} + 2e^-$$

$$BrO_3^- + 6H^+ + 6e^- \longrightarrow Br^- + 3H_2O$$

Use these half-equations to deduce an overall equation for this reaction.

_____

_____

(1)

(b) A laboratory technician decided to use a 5.00×10^{-3} mol dm^{-3} solution of sodium bromate(V) to check the concentration of a sodium thiosulfate solution that was labelled as 1.00×10^{-3} mol dm^{-3}. The sodium bromate(V) solution was placed in the burette and 25.0 cm^3 of the sodium thiosulfate solution was pipetted into a conical flask.

Use the concentration of the sodium thiosulfate solution to calculate the expected titre value in this experiment.
Show your working.

_____

_____

_____

_____

_____

(2)

(c) Consider the titre value that you have calculated in part **(b)**.

Suggest one change to the experimental procedure in part **(b)** that would enable you to calculate a more accurate value for the concentration of the sodium thiosulfate

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solution.

_____

_____

_____

(1)

(Total 4 marks)

Q22.

This question is about a white solid, $MHCO_3$, that dissolves in water and reacts with hydrochloric acid to give a salt.

$$MHCO_3 + HCl \longrightarrow MCl + H_2O + CO_2$$

A student was asked to design an experiment to determine a value for the M_r of $MHCO_3$. The student dissolved 1464 mg of $MHCO_3$ in water and made the solution up to 250 cm^3. 25.0 cm^3 samples of the solution were titrated with 0.102 mol dm^{-3} hydrochloric acid. The results are shown in the table.

	Rough	**1**	**2**	**3**
Initial burette reading / cm^3	0.00	10.00	19.50	29.25
Final burette reading / cm^3	10.00	19.50	29.25	38.90
Titre / cm^3	10.00	9.50	9.75	9.65

(a) Calculate the mean titre and use this to determine the amount, in moles, of HCl that reacted with 25.0 cm^3 of the $MHCO_3$ solution.

_____

_____

_____

_____

_____

(3)

(b) Calculate the amount, in moles, of $MHCO_3$ in 250 cm^3 of the solution.
Then calculate the experimental value for the M_r of $MHCO_3$.
Give your answer to the appropriate number of significant figures.

_____

_____

_____

_____

(3)

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(c) The student identified use of the burette as the largest source of uncertainty in the experiment.

Using the same apparatus, suggest how the procedure could be improved to reduce the percentage uncertainty in using the burette.

Justify your suggested improvement.

Suggestion _____

_____

Justification _____

_____

_____

(2)

(d) Another student is required to make up 250 cm^3 of an aqueous solution that contains a known mass of $MHCO_3$. The student is provided with a sample bottle containing the $MHCO_3$.

Describe the method, including apparatus and practical details, that the student should use to prepare the solution.

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

(6)

(Total 14 marks)

Q23.

A student was given a powder made from a mixture of anhydrous barium chloride and anhydrous magnesium chloride. The student dissolved 1.056 g of the powder in water in a conical flask and added an excess of sulfuric acid.

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A white precipitate formed and was filtered off, washed and dried.
The mass of this solid was 0.764 g.

Identify the white precipitate and calculate the percentage, by mass, of magnesium chloride in the powder.

(Total 4 marks)

Q24.

Refer to the unbalanced equation below when answering this question.

$$K_2Cr_2O7 + 3H_2C_2O_4 + \_H_2SO_4 \longrightarrow Cr_2(SO_4)_3 + \_H_2O + 6CO_2 + K_2SO_4$$

In the balanced equation the mole ratio for sulfuric acid to water is

A 1 : 4 ⬭

B 1 : 2 ⬭

C 4 : 7 ⬭

D 4 : 9 ⬭

(Total 1 mark)

Q25.

In a molecule of a hydrocarbon, the fraction by mass of carbon is $\frac{9}{11}$

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What is the empirical formula of the hydrocarbon?

A CH ⬭

B CH_3 ⬭

C C_3H_8 ⬭

D C_5H_{12} ⬭

(Total 1 mark)

Q26.

30 cm^3 of xenon are mixed with 20 cm^3 of fluorine. The gases react according to the following equation. Assume that the temperature and pressure remain constant.

$$Xe(g) + F_2(g) \rightarrow XeF_2(g)$$

What is the final volume of gas after the reaction is complete?

A 50 cm^3 ⬭

B 40 cm^3 ⬭

C 30 cm^3 ⬭

D 20 cm^3 ⬭

(Total 1 mark)

Q27.

Which of the following solutions would react exactly with a solution containing 0.0500 mol sulfuric acid?

A 50.0 cm^3 of 1.00 mol dm^{-3} KOH ⬭

B 100.0 cm^3 of 2.00 mol dm^{-3} KOH ⬭

C 100.0 cm^3 of 2.00 mol dm^{-3} $Ba(OH)_2$ ⬭

D 50.0 cm^3 of 1.00 mol dm^{-3} $Ba(OH)_2$ ⬭

(Total 1 mark)

Q28.

In a car airbag, sodium azide (NaN_3) decomposes to form sodium metal and nitrogen gas.

$$2NaN_3(s) \longrightarrow 2Na(s) + 3N_2(g)$$

The sodium metal then reacts with potassium nitrate to produce more nitrogen gas.

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$$10Na(s) + 2KNO_3(s) \longrightarrow N_2(g) + 5Na_2O(s) + K_2O(s)$$

If 2.00 mol of sodium azide react in this way, how many molecules of N_2 will be formed?
(The Avogadro constant L = 6.022×10^{23} mol^{-1})

A 2.41×10^{24} ⬭

B 1.93×10^{24} ⬭

C 1.81×10^{24} ⬭

D 9.63×10^{23} ⬭

(Total 1 mark)

Q29.

Propene can be made by the dehydration of propan-2-ol.

What is the percentage yield when 30 g of propene (M_r = 42.0) are formed from 50 g of propan-2-ol (M_r = 60.0)?

A 60% ⬭

B 67% ⬭

C 81% ⬭

D 86% ⬭

(Total 1 mark)

Q30.

Compounds containing $Cu2^+$, OH^- and CO_3^{2-} ions are sometimes described as basic copper carbonates.

(a) Solid $Cu_2(OH)_2CO_3$ is added to an excess of dilute hydrochloric acid.
A solution of copper(II) chloride is formed, together with two other products.

(i) Write an equation for the reaction.

_____

(2)

(ii) Suggest **one** observation that could be made during the reaction.

_____

_____

(1)

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(b) A 5.000 g sample of a different basic copper carbonate contains 0.348 g of carbon, 0.029 g of hydrogen and 1.858 g of oxygen.

(i) State what is meant by the term empirical formula.

_____

_____

(1)

(ii) Calculate the empirical formula of this basic copper carbonate.
Show your working.

_____

_____

_____

_____

_____

_____

_____

_____

(3)

(Total 7 marks)

Q31.

Phosphoric(V) acid (H_3PO_4) is an important chemical. It can be made by two methods. The first method is a two-step process.

(a) In the first step of the first method, phosphorus is burned in air at 500 ºC to produce gaseous phosphorus(V) oxide.

$$P_4(s) + 5O_2(g) \longrightarrow P_4O_{10}(g)$$

220 g of phosphorus were reacted with an excess of air.

Calculate the volume, in m^3, of gaseous phosphorus(V) oxide produced at a pressure of 101 kPa and a temperature of 500 ºC.
The gas constant R = 8.31 J K^{-1} mol^{-1}
Give your answer to 3 significant figures.

_____

_____

_____

_____

_____

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(4)

(b) In the second step of the first method, phosphorus(V) oxide reacts with water to form phosphoric(V) acid.

$$P_4O_{10}(s) + 6H_2O(l) \longrightarrow 4H_3PO_4(aq)$$

Calculate the mass of phosphorus(V) oxide required to produce 3.00 m^3 of 5.00 mol dm^{-3} phosphoric(V) acid solution.

(3)

(c) In the second method to produce phosphoric(V) acid, 3.50 kg of $Ca_3(PO_4)_2$ are added to an excess of aqueous sulfuric acid.

$$Ca_3(PO_4)_2(s) + 3H_2SO_4(aq) \longrightarrow 2H_3PO_4(aq) + 3CaSO_4(s)$$

1.09 kg of phosphoric(V) acid are produced.

Calculate the percentage yield of phosphoric(V) acid.

(4)

(d) Explain whether the first method or the second method of production of phosphoric acid has the higher atom economy.
You are not required to do a calculation.

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_____

(1)

(Total 12 marks)

Q32.

Some airbags in cars contain sodium azide (NaN_3).

(a) Sodium azide is made by reacting dinitrogen monoxide gas with sodium amide ($NaNH_2$) as shown by the equation.

$$2NaNH_2 + N_2O \longrightarrow NaN_3 + NaOH + NH_3$$

Calculate the mass of sodium amide needed to obtain 550 g of sodium azide, assuming there is a 95.0% yield of sodium azide.
Give your answer to 3 significant figures.

_____

_____

_____

_____

_____

_____

_____

_____

(5)

(b) If a car is involved in a serious collision, the sodium azide decomposes to form sodium and nitrogen as shown in the equation.

$$2NaN_3(s) \longrightarrow 2Na(s) + 3N_2(g)$$

The nitrogen produced then inflates the airbag to a volume of 7.50×10^{-2} m^3 at a pressure of 150 kPa and temperature of 35 °C.

Calculate the minimum mass of sodium azide that must decompose.
(The gas constant R = 8.31 J K^{-1} mol^{-1})

_____

_____

_____

_____

_____

_____

_____

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_____

_____

_____

(6)

(c) Sodium azide is toxic. It can be destroyed by reaction with an acidified solution of nitrous acid (HNO_2) as shown in the equation.

$$2NaN_3 + 2HNO_2 + 2HCl \longrightarrow 3N_2 + 2NO + 2NaCl + 2H_2O$$

(i) A 500 cm^3 volume of the nitrous acid solution was used to destroy completely 150 g of the sodium azide.

Calculate the concentration, in mol dm^{-3}, of the nitrous acid used.

_____

_____

_____

_____

_____

_____

(3)

(ii) Nitrous acid decomposes on heating.

Balance the following equation for this reaction.

$$.....HNO_2 \longrightarrow .....HNO_3 + ...NO + ...H_2O$$

(1)

(d) Sodium azide has a high melting point.

Predict the type of bonding in a crystal of sodium azide.
Suggest why its melting point is high.

Type of bonding _____

Reason for high melting point _____

_____

_____

_____

_____

(3)

(e) The azide ion has the formula N_3^-

(i) The azide ion can be represented as $N \equiv N - N^-$

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One of these bonds is a co−ordinate bond.

On the following diagram, draw an arrowhead on one of the bonds to represent the direction of donation of the lone pair in the co−ordinate bond.



(1)

(ii) Give the formula of a molecule that has the same number of electrons as the azide ion.

_____

(1)

(iii) Which is the correct formula of magnesium azide?

Tick (✓) **one** box.

Mg_3N ☐

MgN ☐

MgN_6 ☐

Mg_3N_2 ☐

(1)

(Total 21 marks)

Q33.

Zinc is similar to Group 2 metals and forms compounds containing Zn^{2+} ions.

Write an equation for the thermal decomposition of zinc carbonate to zinc oxide.

Calculate the percentage atom economy for the formation of zinc oxide from zinc carbonate in this reaction.

Equation _____

_____

Percentage atom economy _____

_____

_____

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(Total 3 marks)

Q34.

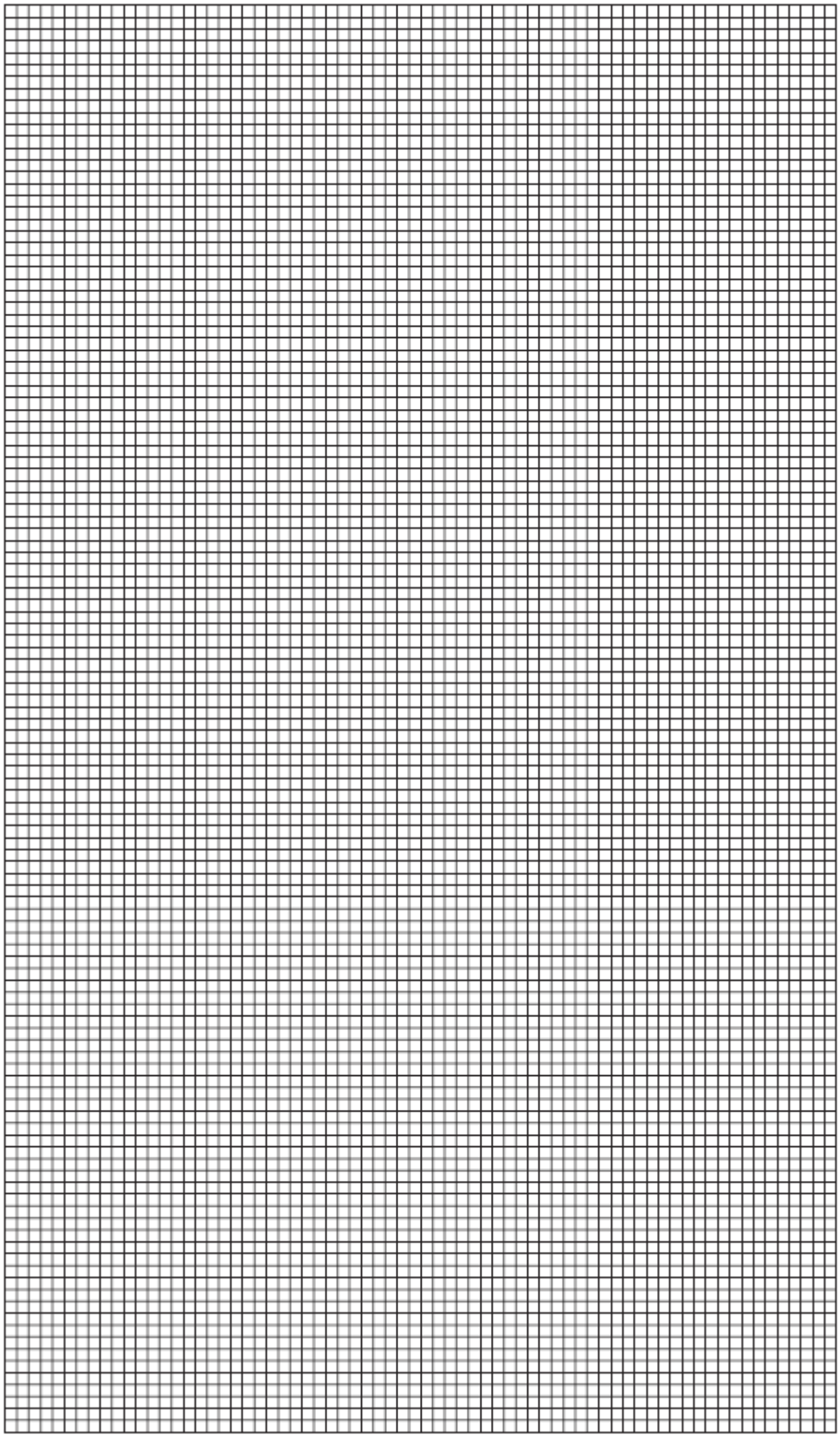
Calamine lotion can contain a mixture of zinc carbonate and zinc oxide in suspension in water. A manufacturer of calamine lotion claims that a sample contains 15.00 g of zinc carbonate and 5.00 g of zinc oxide made up to 100 cm^3 with distilled water.

(a) A chemist wanted to check the manufacturer's claim. The chemist took a 20.0 cm^3 sample of the calamine lotion and added it to an excess of sulfuric acid.
The volume of carbon dioxide evolved was measured over time. The chemist's results are shown in the table.

Time / s	0	15	30	45	60	75	90	105	120	135
Volume / cm^3	0	135	270	380	470	530	560	570	570	570

(i) Plot a graph of the results in the table on the grid. The volume should be on the *y*-axis. Draw a best-fit curve through **all** the points.

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(3)

(ii) Estimate the time taken for the reaction to be completed.

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_____

(1)

(b) (i) The volume of carbon dioxide in part (a) was measured at 293 K and at a pressure of 100 kPa.

Use information from your graph to calculate the maximum amount, in moles, of carbon dioxide evolved from the zinc carbonate in this 20.0 cm^3 sample.

The gas constant, R = 8.31 $J\ K^{-1}\ mol^{-1}$

Show your working.

_____

_____

_____

_____

_____

_____

(3)

(ii) Use your answer to part (i) to calculate the mass of zinc carbonate in the 20.0 cm^3 sample of calamine lotion.

(If you were unable to complete part (i), you may assume that the amount of carbon dioxide evolved was 0.0225 mol. This is **not** the correct answer.)

_____

_____

_____

_____

_____

(2)

(iii) Calculate the difference between your answer to part (ii) and the manufacturer's claim that there are 15.00 g of zinc carbonate in 100 cm^3 of the calamine lotion.

Express this difference as a percentage of the manufacturer's claim.

(If you were unable to complete part (ii), you may assume that the mass of zinc carbonate in the 20 cm^3 sample of calamine lotion was 2.87 g. This is **not** the correct answer.)

Difference _____

Percentage _____

_____

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(2)

(c) Draw a diagram of a suitable apparatus needed to perform the experiment outlined in part (a). Include in your diagram a method for collecting and measuring the carbon dioxide. The apparatus should be airtight.

(2)

(Total 13 marks)

Q35.

(a) Suggest **one** reason why sugars are often added to antacid tablets.

_____

_____

_____

(1)

(b) In one titration, a student added significantly more phenolphthalein than instructed. The volume of sodium hydroxide solution in this titration was greater than the average value of the concordant titres.

State a property of the indicator that would explain this result.

_____

_____

_____

(1)

(c) Some other types of antacid tablets contain carbonate ions.

Suggest why this may be a disadvantage when used as a medicine to relieve indigestion.

_____

_____

_____

(1)

(Total 3 marks)

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Q1.

C

[1]

Q2.

B

[1]

Q3.

(a) This question is marked using levels of response. Refer to the Mark Scheme Instructions for Examiners for guidance on how to mark this question.

Level 3
All stages are covered and the explanation of each stage is generally correct and virtually complete.

Answer communicates the whole process coherently and shows a logical progression through the distillation apparatus. The first two points in stage 1 are in the correct order and all other steps are in a logical order for carrying out the practical.

5-6 marks

Level 2
All stages are covered but the explanation of each stage may be incomplete or may contain inaccuracies.

Answer is mainly coherent and shows a progression through the distillation apparatus.

Some steps in each stage may be out of order and incomplete but the first two points in stage 1 are in the correct order.

3-4 marks

Level 1
Most points are covered but the explanation of each stage may be incomplete or may contain inaccuracies.

Answer includes some isolated statements, but these are not presented in a logical order or show confused reasoning. The first two points in stage 1 are present but not necessarily in the correct order.

1-2 marks

Level 0
Insufficient correct chemistry to warrant a mark.

Omission of heating of the apparatus.

0 marks

Indicative content:

Stage 1

- *Turn on the water.*

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- *Heat the flask, with a Bunsen burner.*
- *This causes water and ethanol vapours to be produced.*

Stage 2

- *Vapours pass up the fractionating column A.*
- *Water and ethanol are separated in column A.*
- *Water condenses back into the flask in column A.*

Stage 3

- *Observe the thermometer at B to keep the temperature at or below the boiling point of ethanol.*

  Only ethanol vapour (with a little water) passes into the condenser.
- *Use the condenser at part C to cool the vapours and condense the ethanol back into a liquid.*

(b) Volume of sample = volume of ethanol + volume of water

Let m = mass of ethanol

20 = m / 0.79 + (16–m) / 1.00

1.266m − m = 20 − 16

1

0.266m = 4 so m = 15 (g)

1

[8]

Q4.

B

[1]

Q5.

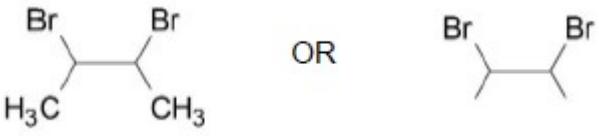
(a) 2,3-dimethylbutane(-1,4-)dioic acid

Penalise other numbers.

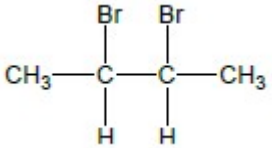
Ignore hyphens, commas, spaces.

1

(b)



Allow displayed formula



1

Step 1:

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HBr

1

Electrophilic addition

1

Step 2:

KCN

Not HCN, not KCN with acid.

1

Nucleophilic substitution

1

Step 3:

Hydrolysis

1

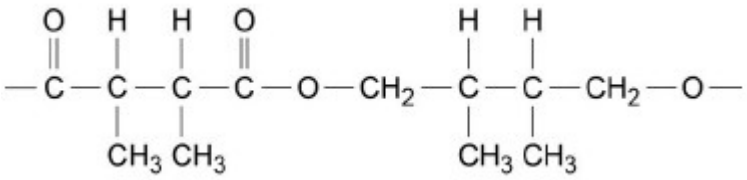
(c)

	Mark
Reagent	1
Observation with **F**	1
Observation with **G**	1

$K_2Cr_2O_7$ & H_2SO_4 (allow acidified)	**Mg**	**Na_2CO_3 or $NaHCO_3$**
F: no visible change	**F:** effervescence	**F:** effervescence
G: orange to green	**G:** no visible change	**G:** no visible change

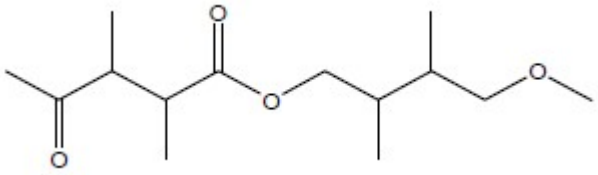
Named alcohol and conc. sulfuric acid	**Named carboxylic acid and conc. sulfuric acid**
F: pleasant smell	**F:** no visible change
G: no visible change	**G:** pleasant smell

(d)



OR

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Two ester groups.

1

One unit only.
Must have trailing bonds.
Ignore n and brackets.

1

(e) Mass of **G** = (1.11 × 10^3) cm^3 × 1.04 g cm^{-3} = 1154 g

65.1 scores 4 marks.

1

Amount of **G** $\frac{1154}{Mr = 118}$ = 9.78 mols

1

Amount of **F** (actual) = $\frac{930}{Mr = 146}$ =

6.37 mol

OR

Expected mass of **F** = 9.78 × (M_r =)

146 = 1428 g

1

% yield = $\frac{6.37}{9.78}$ × 100 = 65.1(%)

OR

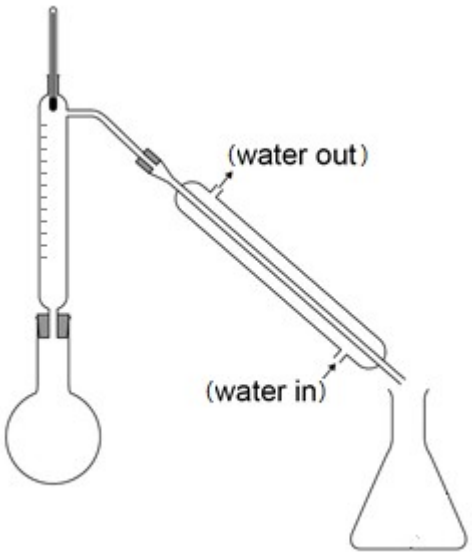
% yield = $\frac{930}{1428}$ × 100 = 65.1(%)

M4 answer must be to 3 significant figures.

1

(f) Fractional distillation

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A rough labelled sketch illustrating these points scores the marks.

1

Apparatus for fractional distillation must clearly work with fractionating column.

1

Fractionating column and thermometer.

1

Condenser / water jacket.

Ignore heat source.

1

[20]

Q6.

(a) Multidentate − EDTA can form many / six dative bonds with central cation.

1

Ligand − lone pair (on N or O of EDTA) can form dative bond with copper(II) ions.

1

6 circles drawn on $EDTA^{4-}$ structure − 2 × N and 4 × −O

1

(b) Calibrate a colorimeter / produce a calibration curve.

1

By testing the colorimeter with solutions of copper-EDTA complex of known concentration.

1

Add excess EDTA salt to the sample.

1

(c) $[Cu(H_2O)_6]^{2+} + EDTA^{4-} \longrightarrow [Cu(EDTA)]^{2-} + 6H_2O$

1

Amount of copper(II) = $(25.0 \times 7.56 \times 10^{-5}) / 1000 = 1.89 \times 10^{-6}$ mol

1

Volume of $EDTA^{4-} = (1.89 \times 10^{-6} / 0.001) \times 1000 = 1.89\ cm^3$

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1

This is too small to be accurate.

1

Dilute the $EDTA^{4-}$ solution / use larger volume of river water.

1

[11]

Q7.

(a) Amount of propanone = (25.0 × 1) / 1000 = 0.025 mol

1

Concentration in mixture **A** = 0.025 / (90.0/1000) = 0.278 mol dm^{-3}

1

(b) To make volumes constant for all mixtures.

1

So that volume of propanone is proportional to concentration.

1

(c) Amount of iodine in mixture **E** = (40.0 × 0.02) / 1000 = 8.0×10^{-4} mol

1

Amount of iodine in sample = $8.0 \times 10^{-4} \times (10 / 90) = 8.89 \times 10^{-5}$ mol

As 10 cm^3 sample taken from total volume of 90 cm^3

1

Amount of thio required = $2 \times 8.89 \times 10^{-5} = 1.78 \times 10^{-4}$ mol

1

Volume of thio = $(1.78 \times 10^{-4} / 0.01) \times 1000 = 17.8$ cm^3

1

(d) Scale

Graph must cover at least half the grid and axes must be plotted in correct orientation but ignore labeling.

1

Points

Must be correctly plotted to within ± half a small square.

1

Best-fit straight line

Must be the best-fit line possible if point(s) are plotted incorrectly.
Penalise doubled or kinked lines.

1

Gradient = y / x

1

= −0.060

Allow −0.059 to −0.061
Ignore any units given.

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1

(e) Gradients / rates are proportional to volumes / concentrations of propanone **or** B to D show that gradient / rate halves when vol / concentration halves.

1

So first order with regard to propanone.

1

(f) To stop / quench the reaction at that time.

Ignore $NaHCO_3$ reacts with the HI produced.

1

By removing the acid catalyst for the reaction (by neutralisation).

1

[17]

Q8.

(a) $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2$

Allow correct numbers that are not superscripted

1

(b) $Ca(s) + 2H_2O(l) \longrightarrow Ca^{2+}(aq) + 2OH^-(aq) + H_2(g)$

State symbols essential

1

(c) Oxidising agent

1

(d) $Ca(g) \longrightarrow Ca^+(g) + e^-$

State symbols essential

Allow 'e' without the negative sign

1

(e) Decrease

If answer to 'trend' is not 'decrease', then chemical error = 0 / 3

1

Ions get bigger / more (energy) shells

Allow atoms instead of ions

1

Weaker attraction of ion to lost electron

1

[7]

Q9.

(a) $C(s) + 2F_2(g) \longrightarrow CF_4(g)$

State symbols essential

1

(b) Around carbon there are 4 bonding pairs of electrons (and no lone pairs)

1

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Therefore, these repel equally and spread as far apart as possible

1

(c) $\Delta H = \Sigma\ \Delta_f H$ products $- \Sigma\ \Delta_f H$ reactants or a correct cycle

1

Hence = $(2 \times -680) + (6 \times -269) - (x) = -2889$

1

$x = 2889 - 1360 - 1614 = -85$ (kJ mol^{-1})

1

Score 1 mark only for +85 (kJ mol^{-1})

(d) Bonds broken = 4(C–H) + 4(F–F) = 4 × 412 + 4 × F–F

Bonds formed = 4(C–F) + 4(H–F) = 4 × 484 + 4 × 562

Both required

1

$-1904 = [4 \times 412 + 4(F–F)] - [4 \times 484 + 4 \times 562]$

$4(F–F) = -1904 - 4 \times 412 + [4 \times 484 + 4 \times 562] = 632$

1

F–F = 632 / 4 = 158 (kJ mol^{-1})

1

The student is correct because the F–F bond energy is much less than the C–H or other covalent bonds, therefore the F–F bond is weak / easily broken

Relevant comment comparing to other bonds

(Low activation energy needed to break the F–F bond)

1

[10]

Q10.

(a) Stage 1: appreciation that the acid must be in excess and calculation of amount of solid that permits this

Statement that there must be an excess of acid

1

Moles of acid = $50.0 \times 0.200 / 1000 = 1.00 \times 10^{-2}$ mol

1

2 mol of acid react with 1 mol of calcium hydroxide therefore moles of solid weighed out must be less than half the moles of acid = $0.5 \times 1.00 \times 10^{-2} = 5.00 \times 10^{-3}$ mol

1

Mass of solid must be $^{-3} \times 74.1 =$

1

Stage 2: Experimental method

Measure out 50 cm^3 of acid using a pipette and add the weighed amount of solid in a conical flask

1

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Titrate against 0.100 (or 0.200) mol dm^{-3} NaOH added from a burette and record the volume (v) when an added indicator changes colour

1

Stage 3: How to calculate M_r from the experimental data

Moles of calcium hydroxide = 5.00×10^{-3} – (v/2 × conc NaOH) / 1000 = z mol

1

M_r = mass of solid / *z*

1

Extended response

Maximum of 7 marks for answers which do not show a sustained line of reasoning which is coherent, relevant, substantiated and logically structured.

(b) Moles of calcium chloride = $3.56 / 111.1 = 3.204 \times 10^{-2}$

1

Moles of calcium sulfate = $3.204 \times 10^{-2} \times 83.4 / 100 = 2.672 \times 10^{-2}$

1

Mass of calcium sulfate = $2.672 \times 10^{-2} \times 136.2 = 3.6398 = 3.64$ (g)

Answer must be to 3 significant figures

1

[11]

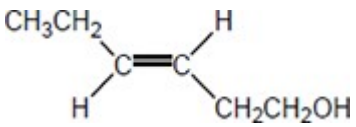
Q11.

A

[1]

Q12.

(a)



1

(b)



1

(c) **Stage 1**: consider the groups joined to right hand carbon of the C=C bond

Extended response

Maximum of 5 marks for answers which do not show a sustained line of reasoning which is coherent, relevant, substantiated and logically structured.

Consider the atomic number of the atoms attached

M1 can be scored in stage 1 or stage 2

1

C has a higher atomic number than H, so CH_2OH takes priority

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1

Stage 2: consider the groups joined to LH carbon of the C=C bond

Both groups contain C atoms, so consider atoms one bond further away

1

C, (H and H) from ethyl group has higher atomic number than H, (H and H) from methyl group, so ethyl takes priority

1

Stage 3: conclusion

The highest priority groups, ethyl and CH_2OH are on same side of the C=C bond so the isomer is Z

Allow M5 for correct ECF conclusion using either or both wrong priorities deduced in stages 1 and 2

1

The rest of the IUPAC name is 3-methylpent-2-en-1-ol

1

(d) Moles of maleic acid = 10.0 / 116.0 = 8.62×10^{-2}

AND mass of organic product expected = $(8.62 \times 10^{-2}) \times 98.0 = 8.45$ g

Or moles of organic product formed = 6.53 / 98.0 = 6.66×10^{-2}

1

% yield = 100 × 6.53 / 8.45

OR = $100 \times (6.66 \times 10^{-2}) / (8.62 \times 10^{-2})$

= 77.294 = 77.3%

AND statement that the student was NOT correct

1

[10]

Q13.

D

[1]

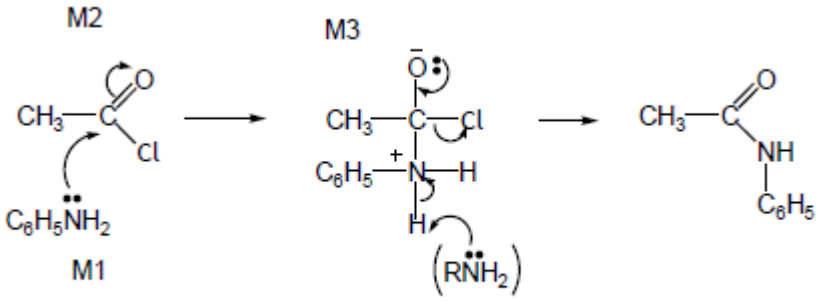
Q14.

(a) (nucleophilic) addition-elimination

Not electrophilic addition-elimination

1

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M4 for 3 arrows and lp

Allow C_6H_5 or benzene ring

Allow attack by :$NH_2C_6H_5$

M2 not allowed independent of M1, but allow M1 for correct attack on C+

M3 for correct structure <u>with charges</u> but lone pair on O is part of M4

M4 (for three arrows and lone pair) can be shown in more than one structure

4

(b) **The minimum quantity of hot water was used:**

To ensure the hot solution would be saturated / crystals would form on cooling

1

The flask was left to cool before crystals were filtered off:

Yield lower if warm / solubility higher if warm

1

The crystals were compressed in the funnel:

Air passes through the sample not just round it

Allow better drying but not water squeezed out

1

A little cold water was poured through the crystals:

To wash away soluble impurities

1

(c) Water

Do not allow unreacted reagents

1

Press the sample of crystals between filter papers

Allow give the sample time to dry in air

1

(d) M_r product = 135.0

1

Expected mass = $5.05 \times \frac{135.0}{93.0}$ = 7.33 g

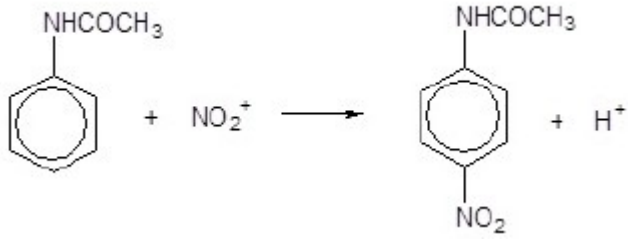
1

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Percentage yield = $\frac{4.82}{7.33} \times 100 = 65.75 = 65.8(\%)$

Answer must be given to this precision

(e)



OR

$C_6H_5NHCOCH_3 + NO_2^+ \rightarrow C_6H_4(NHCOCH_3)NO_2 + H^+$

1

(f) Electrophilic substitution

1

(g) Hydrolysis

1

(h) Sn / HCl

Ignore acid concentration; allow Fe / HCl

1

[18]

Q15.

(a) This question is marked using levels of response. Refer to the Mark Scheme Instructions for Examiners for guidance on how to mark this question.

All stages are covered and the explanation of each stage is generally correct and virtually complete.

Answer is communicated coherently and shows a logical progression from stage 1 and stage 2 to stage 3. Steps in stage 3 must be complete, ordered and include a comparison.

Level 3
5 – 6 marks

All stages are covered but the explanation of each stage may be incomplete or may contain inaccuracies OR two stages are covered and the explanations are generally correct and virtually complete.

Answer is mainly coherent and shows a progression from stage 1 and stage 2 to stage 3.

Level 2
3 – 4 marks

Two stages are covered but the explanation of each stage may be incomplete or may contain inaccuracies, OR only one stage is covered but the explanation is generally correct and virtually complete.

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Answer includes some isolated statements, but these are not presented in a logical order or show confused reasoning.

Level 1
1 – 2 marks

Insufficient correct Chemistry to warrant a mark.

Level 0
0 marks

Indicative Chemistry content

Stage 1: difference in structure of the two acids
- The acids are of the form RCOOH
- but in ethanoic acid R = CH_3
- whilst in ethanedioic acid R = COOH

Stage 2: the inductive effect
- The unionised COOH group contains two very electronegative oxygen atoms
- therefore has a negative inductive (electron withdrawing)effect
- The CH_3 group has a positive inductive (electron pushing) effect

Stage 3: how the polarity of OH affects acid strength
- The O–H bond in the ethanedioic acid is more polarised / H becomes more δ^+
- More dissociation into H^+ ions
- Ethanedioic acid is stronger than ethanoic acid

6

(b) Moles of NaOH = Moles of $HOOCCOO^-$ formed = 6.00×10^{-2}

Extended response

1

Moles of HOOCCOOH remaining = $1.00 \times 10^{-1} - 6.00 \times 10^{-2}$

$= 4.00 \times 10^{-2}$

1

$K_a = [H^+][A^-] / [HA]$

$[H^+] = K_a \times [HA] / [A^-]$

1

$[H^+] = 5.89 \times 10^{-2} \times (4.00 \times 10^{-2} / V) / (6.00 \times 10^{-2} / V) = 3.927 \times 10^{-2}$

1

$pH = -\log_{10}(3.927 \times 10^{-2}) = 1.406 = 1.41$

Answer must be given to this precision

1

(c) $5H_2C_2O_4 + 6H^+ + 2MnO_4^- \longrightarrow 2Mn^{2+} + 10CO_2 + 8H_2O$

OR $5C_2O_4^{2-} + 16H^+ + 2MnO_4^- \longrightarrow 2Mn^{2+} + 10CO_2 + 8H_2O$

1

Moles of $KMnO_4 = 20.2 \times 2.00 \times 10^{-2} / 1000 = 4.04 \times 10^{-4}$

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1

Moles of $H_2C_2O_4$ = 5 / 2 × 4.04 × 10^{-4} = 1.01 × 10^{-3}

1

Concentration = moles / volume (in dm^3)

= 1.01 × 10^{-3} × 1000 / 25 = 4.04 × 10^{-2} (mol dm^{-3})

If 1:1 ratio or incorrect ratio used, M2 and M4 can be scored

1

[15]

Q16.

D

[1]

Q17.

D

[1]

Q18.

B

[1]

Q19.

D

[1]

Q20.

(a) n = pV/RT **M1**

Do not accept pV=nRT as the sole working.
Allow correct substitution of numbers.

1

0.739 **M2**

Answer must be to a minimum of 2 s.f.
*Correct answer without working scores **M2** only.*

1

(b) (a) × 2

Answer will often be 1.48 (or 1.5 or 1.478)
Answer must be to a minimum of 2 s.f.

1

(c) 100.1

Answer must be to 1 d.p.

1

(d) (a) × (c)

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Answer will often be 74.0

Answer must be to a minimum of 2 s.f.

1

[5]

Q21.

(a) $6S_2O_3^{2-} + BrO_3^- + 6H^+ \rightarrow 3S_4O_6^{2-} + Br^- + 3H_2O$

Check the formulae and charges carefully and penalise any transcription errors.

Allow multiples and fractions.

Ignore state symbols.

1

(b) Mol of thio = $25.0 \times 0.00100 / 1000 = 2.50 \times 10^{-5}$

and

Mol of bromate(V) = $(1/6) \times 2.5 \times 10^{-5} = 4.17 \times 10^{-6}$

If equation in Q5a is wrong, mark consequentially.

1

Vol of bromate(V) = $(4.17 \times 10^{-6} / 0.005) \times 1000 = 0.83$ cm^3

Lose this mark if (correct) unit of volume not given.

Do not penalise precision.

1

(c) Use a more dilute solution of sodium bromate

Allow 'use a bigger volume of sodium thiosulfate solution'.

1

[4]

Q22.

(a) Selects correct titres

If 3 or more titres used them MAX 1 for conseq M3

1

$$\text{mean titre} = \frac{9.75 + 9.65}{2}$$

= 9.7(0) cm^3

Calculates mean

1

mol HCL = $0.102 \times 9.70/1000 = 9.89 \times 10^{-4}$

(allow 9.9 × 10-4 for M3 but check not via 4 titres in which case only 1 mark)

Calculates mol (working or result gains credit)

9.92×10^{-4} scores 1 if all 4 titres used

9.83×10^{-4} scores 1 if titres 1,2, and 3 used

1

(b) mol $MHCO_3$ = ANS 3.1×10 ($= 9.89 \times 10^{-3}$)

Use ecf if wrong mean calculated above

1

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$$Mr = \frac{1464/1000}{M1}$$

1

Mr = 148 (3sf)

Allow ecf following wrong mass conversion

1

(c) Suggestion: Use a larger mass of solid OR use a more concentrated solution of $MHCO_3$ OR less concentrated / more dilute solution of HCl OR more $MHCO_3$

1

Cannot score justification mark unless suggestion correct, but suggestion could be after justification

Justification: So a larger titre/reading will be needed OR larger volume of HCl

Assume reference to the solution means the $MHCO_3$

1

(d) This question is marked using levels of response.

Level 3
Must use volumetric flask to access level 3
Answer is communicated coherently and shows a logical progression from stage 1 to stage 2 then stage 3.

All stages are covered and the description of each stage is complete

6 marks

All stages are covered but up to 2 omissions/errors from different stages. If 2 omissions/errors from same stage only level 2 possible

5 marks

Level 2
Answer is mainly coherent and shows progression from stage 1 to stage 3

All stages are covered but 3 omissions/errors

4 marks

All stages are attempted

3 marks

Level 1
Answer includes isolated statements but these are not presented in a logical order or show confused reasoning.

2 stages attempted

2 marks

1 stage attempted

1 mark

Level 0
Insufficient correct chemistry to gain a mark.

0 marks

Indicative Chemistry content

Stage 1*: transfers known mass of solid*

a) Weigh the sample bottle containing the solid on a (2 dp) balance

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b) Transfer to beaker and reweigh sample bottle*

c) Record the difference in mass

Or

d) Place beaker on balance and tare*

e) Transfer solid into beaker

f) Record mass

Or

g) Known mass provided

*h) Transfers (known) mass into beaker**

i) Wash all remaining solid from sample bottle into beaker

Allow use of weighing boat

**Allow other suitable glassware including volumetric flask*

***Stage 2**: Dissolves in water*

a) Add distilled / deionised water

b) Stir (with a glass rod) or swirl

c) Until all solid has dissolved

***Stage 3**: Transfer, washing and agitation*

a) Transfer to volumetric / graduated flask. Allow if a clear description/diagram given eg long necked flask with 250 cm^3 mark

b) With washings

c) Make up to 250 cm^3 / mark with water

d) Shakes/inverts/mixes

6

[14]

Q23.

Identifies precipitate as being $BaSO_4$

1

Moles of Barium sulfate = mass/Mr
(= 0.764 / 233.4)
= 0.003273 moles

Allow conseq if Mr $BaSO_4$ or $BaCl_2$ incorrect

1

Mass of Barium chloride = 208.3 × 0.003273 = 0.6818 g

1

Percentage of Magnesium chloride $= \frac{1.056 - 0.6818}{1.056} \times 100$

Do NOT penalise incorrect precision here

Allow range 33.7-35.5% (rounding errors penalised elsewhere in paper)

1

[4]

Q24.

C

[1]

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Q25.

C

[1]

Q26.

C

[1]

Q27.

D

[1]

Q28.

B

[1]

Q29.

D

[1]

Q30.

(a) (i) $H_2O + CO_2$ (as products in any equation)

Allow $H_2O + H_2CO_3$

1

$Cu_2(OH)_2CO_3 + 4HCl \rightarrow 2CuCl_2 + 3H_2O + CO_2$

Allow multiples

Ignore states

1

(ii) Bubbles or fizzing or effervescence
Or solid disappears
Or blue(-green) solution

Do not allow dissolves

Ignore CO_2 gas or gas evolved

1

(b) (i) Simplest (whole-number) ratio of atoms of each element in a compound

Allow atoms of Cu, H & O in this compound

1

(ii) Mass of copper = 2.765
Dividing masses by A_r

1

Cu	C	H	O
$\frac{2.765}{63.5} (= 0.0435)$	$\frac{0.348}{12.0} (= 0.029)$	$\frac{0.029}{1.0} (= 0.029)$	$\frac{1.858}{16.0} (= 0.116)$

1

Correct whole number ratio of integers
or

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Cu:C:H:O
3:2:2:8
or
Correct empirical formula $Cu_3C_2H_2O_8$

Any order

Ignore $Cu_3(OH)_2(CO_3)_2$

1

[7]

Q31.

(a) Correct conversion of temperature and pressure (773 and 101×10^3)

Correct answer with or without working scores 4 marks

1

No moles P = (220 / 4 × 31.0) = 1.77

Max 2 (M1 and M3) if 31.0 used

(=0.451 m^3 or if 220/31 rounded to 2 sf ie 7.1 then 0.452)

1

V = nRT/P (correct rearrangement **or** insert of values V = $1.77 \times 8.31 \times 773/101 \times 10^3 = 0.1128\ m^3$)

Max 2 (M1 and M3) if 284 (P_4O_{10}) used then 0.0493

1

V = 0.113 (m^3)

Must be 3 sig figs

1

(b) No moles H_3PO_4 = 3×10^3 (dm^3) × 5 = 15,000 (mols)

Correct answer with or without working scores 3 marks

If M1 incorrect then can only score M2

1

No moles phosphorus(V) oxide = $\frac{15000}{4}$ (= 3,750 mols)

$M2 = \frac{M1}{4}$ (process)

If M2 incorrect can only score M1

1

1.1×10^6 or1.07×10^6 or 1.065×10^6 (g)
or 1,100 or 1,070 or 1065 kg
or 1.1 or 1.07 or 1.065 tonne

= ($3.75 \times 10^3 \times 284.0$)

Min 2 sig fig

1

(c) No moles $Ca_3(PO_4)_2$ (= 3.50kg =) $\frac{3500\ g}{310(.3)}$ = 11.28

Correct answer with or without working scores 4 marks

If M1 incorrect can only score M2 and M3

1

Theoretical No. moles H_3PO_4 = 11.28 × 2 = 22.56

If M2 incorrect can only score M1 and M3

1

Theoretical mass H_3PO_4 = 22.56 × 98(.0) = 2211

If M3 incorrect can only score M1and M2

1

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or Actual No. moles H_3PO_4 produced = $\frac{1090}{98}$ = 11.12

$\underline{49 - 49(.312)\ (\%)}$

$$(\%\ \text{yield (moles)} = (\frac{11/.12}{22.56} \times 100)$$

$$\text{or } (\%\ \text{yield (mass)} = (\frac{1090}{2211} \times 100)$$

1

(d) Method 1 / (a) & (b) because only one product / no other products formed / atom economy = 100% (even though two steps)

Allow calculations

Do not allow if P_2O_5 is formed

Allow converse explanation

1

[12]

Q32.

(a) M1 $550 \times \frac{100}{95}$ = 579 g would be 100% mass

Allow alternative methods.

There are 4 process marks:

1

M2 So $\frac{579}{65}$ = 8.91 moles NaN_3

or

M1 $\frac{550}{65}$ = 8.46 moles NaN_3 (this is 95%)

M2 So 100% would be $8.46 \times \frac{100}{95}$ = 8.91 moles NaN_3

1: mass ÷ 65

2: mass or moles × 100 / 95 or × 1.05

3: moles NaN_3 × 2

4: moles $NaNH_2$ × 39

1

Then M3 Moles $NaNH_2$ = 8.91 $\underline{\times 2}$ = (17.8(2) moles)

1

M4 mass $NaNH_2$ = 17.8(2) $\underline{\times 39}$

1

M5 $\underline{693}$ or $\underline{694}$ or $\underline{695}$ (g)

If 693, 694 or 695 seen to 3 sig figs award 5 marks

1

(b) M1 308 K and 150 000 Pa

1

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M2 $n = \frac{PV}{RT}$ or $\frac{150\ 000 \times 7.5 \times 10^{-2}}{8.31 \times 308}$

1

M3 = 4.4(0) or 4.395 moles N_2

Allow only this answer but allow to more than 3 sig figs

1

M4 Moles NaN_3 = 4.395 × $\frac{2}{3}$ (= 2.93)

M4 is for M3 × $\frac{2}{3}$

1

M5 Mass NaN_3 = (2.93) × 65

M5 is for moles M4 × 65

1

M6 = 191 g

Allow 190 to 191 g allow answers to 2 sig figs or more

1

(c) (i) 150 / 65 = 2.31 moles NaN_3 or 2.31 moles nitrous acid

1

Conc = 2.31 × $\frac{1000}{500}$

M2 is for M1 × 1000 / 500

1

4.6(1) or 4.6(2) (mol dm^{-3})

Only this answer

1

(ii) $3HNO_2 \longrightarrow HNO_3 + 2NO + H_2O$

Can allow multiples

1

(d) Ionic

If not ionic then CE = 0 / 3

1

Oppositely charged ions / Na^+ and N_3^- ions

Penalise incorrect ions here but can allow M3

1

Strong attraction between (oppositely charged) ions / lots of energy needed to overcome (strong) attractions (between ions)

M3 dependent on M2

1

(e) (i) $N \equiv N \longrightarrow N^-$

Only

1

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(ii) CO_2 / N_2O / BeF_2 / HN_3

Allow other correct molecules

1

(iii) MgN_6

Only

1

[21]

Q33.

$ZnCO_3 \rightarrow ZnO + CO_2$

Ignore state symbols.

If equation incorrect, allow one mark only for correct atom economy method.

1

Percentage atom economy =

Mark consequentially for incorrect formula mass(es)

1

$\frac{81.4}{125.4} \times 100 = 64.9$

Accept answer to at least 2 significant figures

1

[3]

Q34.

(a) (i) Uses sensible scales.

*Lose this mark if the **plotted points** do not cover half of the paper.*

Lose this mark if the graph plot goes off the squared paper

Lose this mark if volume is plotted on the x-axis

1

All points plotted correctly

Allow ± one small square.

1

Smooth curve from 0 seconds to at least 135 seconds − the line must pass through or close to all points (± one small square).

Make some allowance for the difficulties of drawing a curve but do not allow very thick or doubled lines.

1

(ii) Any value in the range 91 to 105 s

Allow a range of times within this but not if 90 quoted.

1

(b) (i) Using pV = nRT

This mark can be gained in a correctly substituted equation.

1

$100\,000 \times 570 \times 10^{-6} = n \times 8.31 \times 293$

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Correct answer with no working scores one mark only.

1

n = 0.0234 mol

Do not penalise precision of answer but must have a minimum of 2 significant figures.

1

(ii) Mol of $ZnCO_3$ = 0.0234

Mark consequentially on Q6

M1
1

Mass of $ZnCO_3$ = M1 × 125.4 = 2.9(3) or 2.9(4) g

If 0.0225 used then mass = 2.8(2) g

M2
1

(iii) Difference = (15.00 / 5) − Ans to b

If 2.87 g used then percentage is 4.3

M1
1

Percentage = (M1 / 3.00) × 100

Ignore precision beyond 2 significant figures in the final answer

If 2.82 g used from (ii) then percentage = 6.0

M2
1

(c) A reaction vessel which is clearly airtight round the bung

1

Gas collection over water or in a syringe

Collection vessel must be graduated by label or markings

Ignore any numbered volume markings.

1

[13]

Q35.

(a) (To make chewing the tablets) more palatable

Tastes better / sweet taste / mask the taste of the $Mg(OH)_2$

Do not allow 'to aid digestion'.

1

(b) The indicator is acidic

1

(c) They produce CO_2 gas that may produce 'wind' / a bloated feeling.

1

[3]

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Q20.

There was some confusion over unit conversions but the main error related to an incorrect application of the reacting ratio; consequential marking was allowed here.

Q21.

Half-equation manipulation was well done in **(a)** and the mole calculation in **(b)** elicited many good answers. Answers to **(c)** were sometimes poorly expressed or incomplete.

Q22.

Only the most able students answered this question correctly. It was noted that many students selected incorrect titres in (a) limiting them to 1 mark out of 3. Consequential marking allowed students to score full marks for (b) but (c) was answered poorly showing a lack of practical experience. Question (d) was marked using a levels of response mark scheme that tested students' ability to give a logical description of a common practical technique. Many students were able to access at least 3 marks but few scored the full 6. It was not uncommon to see some students describe the titration technique itself and in so doing fail to address the question asked.

Q23.

This question was very poorly answered with few getting to the correct overall answer. The unstructured nature of this calculation proved too difficult for most especially following the requirement to identify correctly $BaSO_4$ as the precipitate formed. Only the very best students scored well here.

Q26.

This question was also not answered correctly by most; this idea has not been tested often in the previous specification so students may not have had much prior experience of the type of question.

Q29.

Students generally did well but many gave answers that demonstrated a lack of understanding about how to calculate percentage yield by dividing the mass of the product by the mass of the starting material.

Q30.

In part (a)(i) most students were able to deduce that CO_2 and H_2O were the missing products but not all were able to balance the equation. Multiples were common and accepted. Most students deduced correctly that bubbles would be observed in (a)(ii). A statement such as 'CO_2 gas is formed' is not an observation. The definition of the term empirical formula is still not well known. One or more key words, usually atoms of each element, were frequently omitted. The empirical formula calculation in part (b)(ii) was answered well with many students scoring full marks. For those who did not score full marks there was a good attempt at the question with marks one and two being accessed by the majority of students, although a number simplified the ratio by rounding 1.5 up to 2, rather than doubling the entire ratio to obtain the simplest whole number ratio.

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Q31.

The calculation in part (a) was answered well with many students scoring full marks. Common mistakes included using a *Mr* of 31 for P_4 or that of phosphorus(V) oxide or misreading the question and starting with 200g of phosphorus. The correct answer to the calculation in part (b) was seen regularly. The most common errors were incorrectly calculating the amount in moles of phosphoric acid since they failed to convert the volume of solution from m_3 into dm_3 or failed to use the factor of 4 from the equation. Part (c) discriminated well. Alternative methods based upon mass or moles were seen and these were all given full credit. The most common error was incorrectly calculating the amount in moles of phosphoric acid since many students failed to convert the given mass in kg into grams. A number of students failed to use the factor of 2 from the equation or misread the question and calculated the percentage yield of sulfuric acid. Part (d) was well answered although there were some students who incorrectly based their answer on moles of product formed and others who thought that a one step process was more economical.

Q32.

The correct answer to the calculation in part (a) was seen regularly, but there were some students who made an attempt at it, gained two or three marks, and then could not complete the calculation. The most common errors were either to ignore the factor of 2 from the equation or multiply by 78 rather than 39. The calculation in part (b) was attempted by almost all students resulting in the full range of marks. The first three marks were regularly seen in students' answers but often this was followed by a failure to multiply by the correct factor from the equation. It was disappointing to note that there were still some students who could not rearrange the ideal gas equation correctly. In part (c)(i) many students did not score full marks since they could not convert volume into dm3 and therefore could not give the concentration in mol dm^{-3} as asked for in the question. Many students could not balance the equation in part (c)(ii). Part (d) was well answered although there were some students who thought the azide ion was N^{3-} rather than N^{3-}. The arrow in part (e)(i) was rarely in the right place and it was disappointing to note how many did not use an arrowhead on one of the bonds shown as specified in the question. Part (e)(ii) was not well answered with many students suggesting species that were not molecules; Ti was a common incorrect answer. The whole range of answers was seen in part (e)(iii) but many students were able to identify the correct formula.

Q33.

This question was well done with a few of the weaker students having problems with correct formulae.

Q34.

Part (a)(i) produced the usual crop of poor scales and poor lines of best fit that were curiously accepted by some centres. Additionally, a failure to plot the point at 0,0 should be penalised. Part (a)(ii) was a very easy question and there were many good answers to parts (b)(i) and (ii). Weaker students still have problems with correct substitution and rearrangement of the equation. Part (b)(iii) was a more challenging question and many Centres failed to give credit for a (correct) alternative method. Part (c) again highlighted the need for students to get better training in the drawing of diagrams. This is a communication skill and correct chemical apparatus should be seen – poor bungs and cross-sections were very common and centres were often too lenient in their marking.

Q35.

Parts (a) and (b) were well answered. In (c) some centres were very lenient in the marking – the production of CO_2 gas in itself is not worthy of the mark. It is interesting to note that a

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vast range of students were aware of and used the term ‘bloating’ in relation to this question.

Q1.

A green solution, **X**, is thought to contain $[Fe(H_2O)_6]^{2+}$ ions.

(a) The presence of these ions can be confirmed by reacting separate samples of solution **X** with aqueous ammonia and with aqueous sodium carbonate.

Write equations for each of these reactions and describe what you would observe.

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_____

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(4)

(b) A 50.0 cm^3 sample of solution **X** was added to 50 cm^3 of dilute sulfuric acid and made up to 250 cm^3 of solution in a volumetric flask.

A 25.0 cm^3 sample of this solution from the volumetric flask was titrated with a 0.0205 mol dm^{-3} solution of $KMnO_4$
At the end point of the reaction, the volume of $KMnO_4$ solution added was 18.70 cm^3.

(i) State the colour change that occurs at the end point of this titration and give a reason for the colour change.

_____

_____

_____

_____

(2)

(ii) Write an equation for the reaction between iron(II) ions and manganate(VII) ions.

Use this equation and the information given to calculate the concentration of iron(II) ions in the original solution **X**.

_____

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(5)

(Total 11 marks)

Q2.

N-phenylethanamide is used as an inhibitor in hydrogen peroxide decomposition and also in the production of dyes.

N-phenylethanamide can be produced in a laboratory by the reaction between phenylammonium sulfate and an excess of ethanoic anhydride:

(a) A student carried out this preparation using 1.15 g of phenylammonium sulfate (M_r = 284.1) and excess ethanoic anhydride.

$$(C_6H_5NH_3)_2SO_4 + 2(CH_3CO)_2O \rightarrow 2C_6H_5NHCOCH_3 + 2CH_3COOH + H_2SO_4$$

(i) Calculate the maximum theoretical yield of N−phenylethanamide that could be produced in the reaction. Record your answer to an appropriate precision.

Show your working.

(3)

(ii) In the preparation, the student produced 0.89 g of N−phenylethanamide.

Calculate the percentage yield for the reaction.

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_____

_____

_____

_____

(1)

(b) The student purified the crude solid product, N−phenylethanamide, by recrystallisation.

(i) Outline the method that the student should use for this recrystallisation.

_____

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_____

_____

_____

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_____

_____

_____

(4)

(ii) Outline how you would carry out a simple laboratory process to show that the recrystallised product is a pure sample of N−phenylethanamide.

_____

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_____

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(3)

(iii) Assume that the reaction goes to completion.

Suggest **two** practical reasons why the percentage yield for this reaction may **not** be 100%.

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1. _____

_____

2. _____

_____

(2)

(c) The reaction to form N−phenylethanamide would happen much more quickly if the student used ethanoyl chloride instead of ethanoic anhydride.

Explain why the student might prefer to use ethanoic anhydride, even though it has a slower rate of reaction.

_____

_____

_____

(2)

(Total 15 marks)

Q3.

In a titration experiment, a good technique is essential for an accurate result to be obtained.

(a) Suggest a reason for removing the funnel after it has been used for filling the burette.

_____

_____

(1)

(b) Suggest **one** other source of error in using the burette to carry out a titration.

_____

_____

(1)

(c) During the titration, the inside of the conical flask is rinsed with distilled water.

Suggest why rinsing improves the accuracy of the titre.

_____

_____

(1)

(d) Explain why adding this extra water does **not** change the volume of EDTA solution that is required in the titration.

_____

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_____

(1)

(Total 4 marks)

Q4.

The maximum errors for the pipette and the burette are shown below. These errors take into account multiple measurements.

Pipette ± 0.05 cm^3
Burette ± 0.15 cm^3

Estimate the maximum percentage error in using each of these pieces of apparatus.

Use an average titre 24.25 cm^3 to calculate the percentage error in using the burette.

Show your working.

Pipette _____

_____

Burette _____

_____

(Total 2 marks)

Q5.

(a) Calcium phosphate reacts with aqueous nitric acid to produce phosphoric acid and calcium nitrate as shown in the equation.

$$Ca_3(PO_4)_2 + 6HNO_3 \longrightarrow 2H_3PO_4 + 3Ca(NO_3)_2$$

(i) A 7.26 g sample of calcium phosphate reacted completely when added to an excess of aqueous nitric acid to form 38.0 cm^3 of solution.

Calculate the concentration, in mol dm^{-3}, of phosphoric acid in this solution. Give your answer to 3 significant figures.

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(5)

(ii) Calculate the percentage atom economy for the formation of calcium nitrate in this reaction.
Give your answer to 1 decimal place.

_____

_____

_____

(2)

(b) Write an equation to show the reaction between calcium hydroxide and phosphoric acid to produce calcium phosphate and water.

_____

(1)

(c) Calcium dihydrogenphosphate can be represented by the formula $Ca(H_2PO_4)_x$ where x is an integer.
A 9.76 g sample of calcium dihydrogenphosphate contains 0.17 g of hydrogen, 2.59 g of phosphorus and 5.33 g of oxygen.

Calculate the empirical formula and hence the value of x.
Show your working.

_____

_____

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_____

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_____

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_____

(4)

(Total 12 marks)

Q6.

Sodium hydroxide is often sold as a concentrated solution containing 12.0 mol dm^{-3} of sodium hydroxide.

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Calculate the volume of water that should be added to 10.0 cm^3 of a 12.0 mol dm^{-3} solution of sodium hydroxide to make a 0.250 mol dm^{-3} solution. Show your working.

_____

_____

_____

_____

(Total 2 marks)

Q7.

Sodium phosphate and ammonia are formed when ammonium phosphate is heated with sodium hydroxide solution in a conical flask. There is **one** other product in this reaction.

(a) Complete and balance the equation for the reaction of ammonium phosphate with sodium hydroxide.

$(NH_4)_3PO_4$ + ... NaOH $\longrightarrow$ Na_3PO_4 + ... NH_3 + ...

(2)

(b) Ammonia is an alkaline gas. Describe how you would use a named indicator to show that ammonia gas is released from the flask in this reaction. State the colour change that you would observe.

_____

_____

_____

_____

(2)

(Total 4 marks)

Q8.

The alcohol 2-methylpropan-2-ol, $(CH_3)_3COH$, reacts to form esters that are used as flavourings by the food industry. The alcohol can be oxidised to produce carbon dioxide and water.

A student carried out an experiment on a pure sample of 2-methylpropan-2-ol to determine its enthalpy of combustion. A sample of the alcohol was placed into a spirit burner and positioned under a beaker containing 50 cm^3 of water. The spirit burner was ignited and allowed to burn for several minutes before it was extinguished.

The results for the experiment are shown in **Table 1**.

Table 1

Initial temperature of the water / °C	18.1
Final temperature of the water / °C	45.4

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Initial mass of spirit burner and alcohol / g	208.80
Final mass of spirit burner and alcohol / g	208.58

(a) Use the results from **Table 1** to calculate a value for the heat energy released from the combustion of this sample of 2-methylpropan-2-ol.
The specific heat capacity of water is 4.18 J K^{-1} g^{-1}.
Show your working.

(2)

(b) Calculate the amount, in moles, of 2-methylpropan-2-ol burned in the experiment.
Hence calculate a value, in kJ mol^{-1}, for the enthalpy of combustion of 2-methylpropan-2-ol.
Show your working.

(If you were unable to calculate an answer to part (a), you should assume that the heat energy released was 5580 J. This is **not** the correct value.)

(3)

(c) An equation for the combustion of 2-methylpropan-2-ol is

$$(CH_3)_3COH(l) + 6O_2(g) \longrightarrow 4CO_2(g) + 5H_2O(l)$$

Table 2 contains some standard enthalpy of formation data.

Table 2

	$(CH_3)_3COH(l)$	$O_2(g)$	$CO_2(g)$	$H_2O(l)$
$\Delta H_f^{\ominus}$ **/ kJ mol^{-1}**	–360	0	–393	–286

Use the data from **Table 2** to calculate a value for the standard enthalpy of combustion of 2-methylpropan-2-ol. Show your working.

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(3)

(d) An accurate value for the enthalpy of combustion of 2-methylpropan-2-ol in which water is formed as a gas is –2422 kJ mol^{-1}.

Use this value and your answer from part (b) to calculate the overall percentage error in the student's experimental value for the enthalpy of combustion of 2-methylpropan-2-ol.

_____

_____

_____

(1)

(e) Suggest **one** improvement that would reduce errors due to heat loss in the student's experiment.

_____

_____

_____

(1)

(f) Suggest **one** other source of error in the student's experiment. Do **not** include heat loss, apparatus error or student error.

_____

_____

_____

(1)

(Total 11 marks)

Q9.

A student carried out an experiment to find the mass of $FeSO_4.7H_2O$ in an impure sample, **X**.

The student recorded the mass of **X**. This sample was dissolved in water and made up to 250 cm^3 of solution.

The student found that, after an excess of acid had been added, 25.0 cm^3 of this solution

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reacted with 21.3 cm^3 of a 0.0150 mol dm^{-3} solution of $K_2Cr_2O_7$

(a) Use this information to calculate a value for the mass of $FeSO_4.7H_2O$ in the sample of **X**.

(5)

(b) The student found that the calculated mass of $FeSO_4.7H_2O$ was greater than the actual mass of the sample that had been weighed out. The student realised that this could be due to the nature of the impurity.

Suggest **one** property of an impurity that would cause the calculated mass of $FeSO_4.7H_2O$ in **X** to be greater than the actual mass of **X**.
Explain your answer.

(2)

(Total 7 marks)

Q10.

Zinc forms many different salts including zinc sulfate, zinc chloride and zinc fluoride.

(a) People who have a zinc deficiency can take hydrated zinc sulfate ($ZnSO_4.xH_2O$) as a dietary supplement.

A student heated 4.38 g of hydrated zinc sulfate and obtained 2.46 g of anhydrous zinc sulfate.

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Use these data to calculate the value of the integer x in $ZnSO_4.xH_2O$
Show your working.

(3)

(b) Zinc chloride can be prepared in the laboratory by the reaction between zinc oxide and hydrochloric acid.
The equation for the reaction is

$$ZnO + 2HCl \longrightarrow ZnCl_2 + H_2O$$

A 0.0830 mol sample of pure zinc oxide was added to 100 cm^3 of 1.20 mol dm^{-3} hydrochloric acid.

Calculate the maximum mass of anhydrous zinc chloride that could be obtained from the products of this reaction.

(4)

(c) Zinc chloride can also be prepared in the laboratory by the reaction between zinc and hydrogen chloride gas.

$$Zn + 2HCl \longrightarrow ZnCl_2 + H_2$$

An impure sample of zinc powder with a mass of 5.68 g was reacted with hydrogen chloride gas until the reaction was complete. The zinc chloride produced had a mass of 10.7 g.

Calculate the percentage purity of the zinc metal.
Give your answer to 3 significant figures.

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(4)

(d) Predict the type of crystal structure in solid zinc fluoride and explain why its melting point is high.

(3)

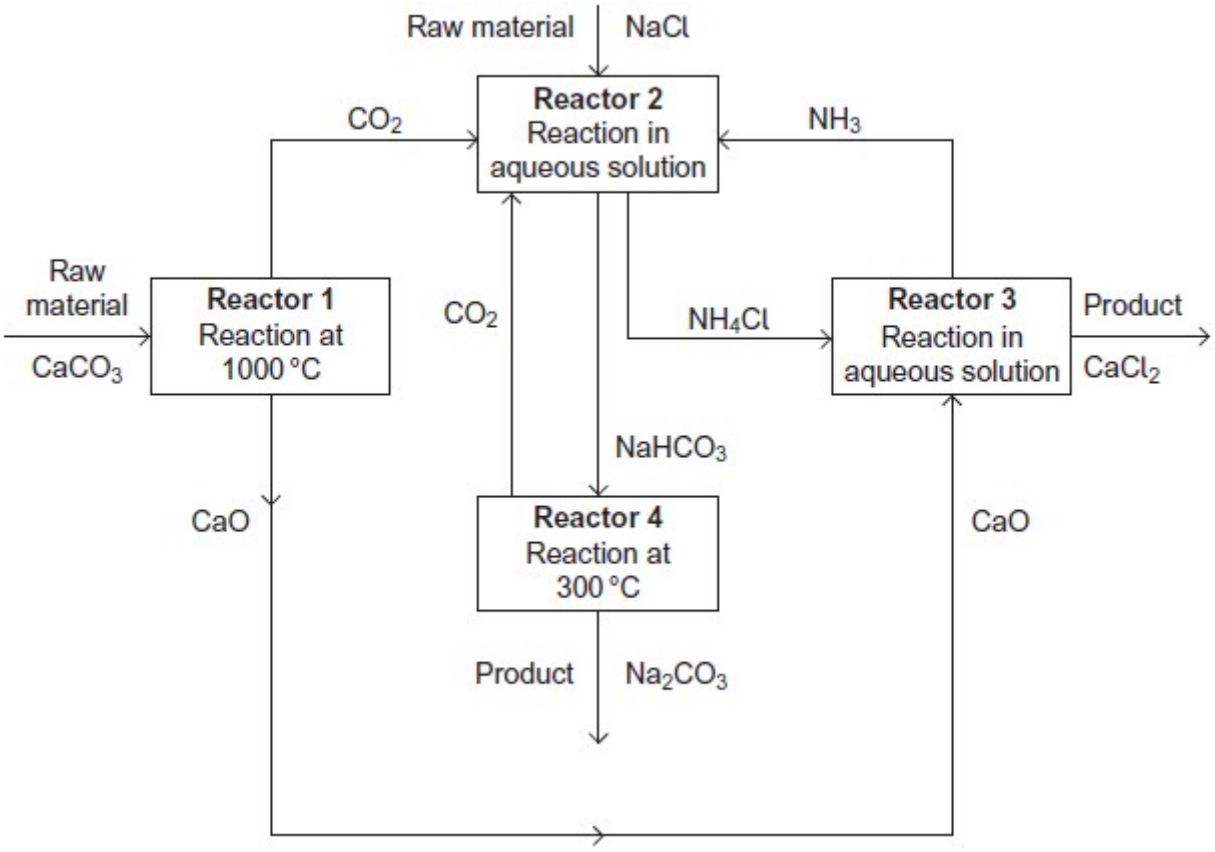
(Total 14 marks)

Q11.

Sodium carbonate is manufactured by the Solvay Process.

The separate stages involved in this process are shown in this diagram.

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(a) In **Reactor 1**, calcium carbonate is decomposed into calcium oxide and carbon dioxide. Despite no significant leakage of carbon dioxide from this decomposition, this part of the process results in an increase in carbon dioxide in the atmosphere.

State why this increase in carbon dioxide occurs.

_____

_____

(1)

(b) In **Reactor 2**, sodium chloride solution, carbon dioxide and ammonia react to form sodium hydrogencarbonate and ammonium chloride.

Write an equation for this reaction.

_____

(1)

(c) Use information from the diagram to deduce an equation for the reaction taking place in **Reactor 3**.

_____

_____

(1)

(d) An equation for the overall reaction in the Solvay Process is

$$2NaCl(aq) + CaCO_3(s) \longrightarrow Na_2CO_3(s) + CaCl_2(aq)$$

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(i) Calculate the percentage atom economy of this reaction to produce sodium carbonate. Show your working.

_____

_____

_____

(2)

(ii) State what could be done to improve the percentage atom economy of the Solvay Process.

_____

_____

(1)

(e) Use information from the diagram to suggest why ammonia is **not** regarded as a raw material in the Solvay Process.

_____

_____

(1)

(Total 7 marks)

Q12.

This question explores some reactions and some uses of cobalt compounds.

(a) Ethanal is oxidised to ethanoic acid by oxygen. The equation for this reaction is

$$2CH_3CHO + O_2 \longrightarrow 2CH_3COOH$$

This redox reaction is slow at room temperature but speeds up in the presence of cobalt compounds.

Explain why a cobalt compound is able to act as a catalyst for this process.

Illustrate your explanation with **two** equations to suggest how, in the presence of water and hydrogen ions, Co^{3+} and then Co^{2+} ions could be involved in catalysing this reaction.

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_____

(4)

(b) In aqueous solution, the $[Co(H_2O)_6]^{2+}$ ion reacts with an excess of ethane-1,2-diamine to form the complex ion **Y**.

(i) Write an equation for this reaction.

Explain, in terms of the chelate effect, why the complex ion **Y** is formed in preference to the $[Co(H_2O)_6]^{2+}$ complex ion.

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_____

_____

_____

_____

_____

_____

(3)

(ii) Draw a diagram that shows the shape of the complex ion **Y** and shows the type of bond between the ethane-1,2-diamine molecules and the cobalt.

(3)

(c) Compound **Z** is a complex that contains only cobalt, nitrogen, hydrogen and chlorine.

A solid sample of **Z** was prepared by reaction of 50 cm^3 of 0.203 mol dm^{-3} aqueous cobalt(II) chloride with ammonia and an oxidising agent followed by hydrochloric acid.

When this sample of **Z** was reacted with an excess of silver nitrate, 4.22 g of silver chloride were obtained.

Use this information to calculate the mole ratio of chloride ions to cobalt ions in **Z**.

Give the formula of the complex cobalt compound **Z** that you would expect to be formed in the preparation described above.

Suggest **one** reason why the mole ratio of chloride ions to cobalt ions that you have

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calculated is different from the expected value.

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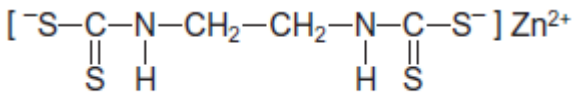
_____

(5)

(Total 15 marks)

Q13.

(a) Because of the toxic nature of the copper(II) ion, a wide range of alternative anti-fungal drugs has been developed for use in agriculture. One example is Zineb.



Zineb

(i) The negative ion in Zineb could act as a bidentate ligand.

On the structure above, draw a ring around each of **two** atoms that could provide the lone pairs of electrons when this ion acts as a bidentate ligand.

(1)

(ii) Calculate the M_r of Zineb. Give your answer to the appropriate precision.

_____

_____

_____

_____

(1)

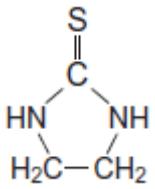
(iii) Name the functional group formed at each end of the negative ion when all the sulfur atoms in the structure of Zineb are replaced by oxygen atoms.

_____

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(1)

(b) Zineb has been investigated for harmful effects. Generally, Zineb has been found to be safe to use in agriculture. It is only slightly soluble in water and is sprayed onto plants. A breakdown product of Zineb is ethylene thiourea (ETU), which is very soluble in water. The structure of ETU is shown below.



Determine the percentage, by mass, of sulfur in ETU (M_r = 102.1).

_____

_____

_____

(1)

(c) Chromatography is a technique used to show the presence of a small amount of ETU in Zineb.

Outline how this technique is used to separate and identify ETU from a sample of Zineb powder.

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(4)

(Total 8 marks)

Q14.

Ammonia is used to make nitric acid (HNO_3) by the Ostwald Process.
Three reactions occur in this process.

Reaction **1** $4NH_3(g) + 5O_2(g) \longrightarrow 4NO(g) + 6H_2O(g)$

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Reaction **2** $2NO(g) + O_2(g) \longrightarrow 2NO_2(g)$

Reaction **3** $3NO_2(g) + H_2O(l) \longrightarrow 2HNO_3(aq) + NO(g)$

(a) In one production run, the gases formed in Reaction **1** occupied a total volume of 4.31 m^3 at 25 °C and 100 kPa.

Calculate the amount, in moles, of NO produced.
Give your answer to 3 significant figures.
(The gas constant R = 8.31 J K^{-1} mol^{-1})

(4)

(b) In another production run, 3.00 kg of ammonia gas were used in Reaction **1** and all of the NO gas produced was used to make NO_2 gas in Reaction **2**.

(i) Calculate the amount, in moles, of ammonia in 3.00 kg.

(2)

(ii) Calculate the mass of NO_2 formed from 3.00 kg of ammonia in Reaction **2** assuming an 80.0% yield.
Give your answer in kilograms.
(If you have been unable to calculate an answer for part (b)(i), you may assume a value of 163 mol. This is **not** the correct answer.)

(3)

(c) Consider Reaction **3** in this process.

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$$3NO_2(g) + H_2O(l) \longrightarrow 2HNO_3(aq) + NO(g)$$

Calculate the concentration of nitric acid produced when 0.543 mol of NO_2 is reacted with water and the solution is made up to 250 cm^3.

_____

_____

_____

_____

_____

(2)

(d) Suggest why a leak of NO_2 gas from the Ostwald Process will cause atmospheric pollution.

_____

_____

(1)

(e) Give **one** reason why excess air is used in the Ostwald Process.

_____

_____

(1)

(f) Ammonia reacts with nitric acid as shown in this equation.

$$NH_3 + HNO_3 \longrightarrow NH_4NO_3$$

Deduce the type of reaction occurring.

_____

(1)

(Total 14 marks)

Q15.

(a) Boron trichloride (BCl_3) can be prepared as shown by the following equation.

$$B_2O_3(s) + 3C(s) + 3Cl_2(g) \longrightarrow 2BCl_3(g) + 3CO(g)$$

A sample of boron oxide (B_2O_3) was reacted completely with carbon and chlorine. The two gases produced occupied a total volume of 5000 cm^3 at a pressure of 100 kPa and a temperature of 298 K.

Calculate the mass of boron oxide that reacted.
Give your answer to 3 significant figures.

(The gas constant R = 8.31 J K^{-1} mol^{-1})

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(5)

(b) Boron trichloride can also be prepared from its elements.

Write an equation for this reaction.
Explain why boron trichloride has a trigonal planar shape with equal bond angles.

(3)

(c) (i) Boron trichloride is easily hydrolysed to form two different acids as shown in the following equation.

$$BCl_3(g) + 3H_2O(l) \longrightarrow H_3BO_3(aq) + 3HCl(aq)$$

Calculate the concentration, in mol dm^{-3}, of hydrochloric acid produced when 43.2 g of boron trichloride are added to water to form 500 cm^3 of solution.
Give your answer to 3 significant figures.

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(4)

(ii) Boric acid (H_3BO_3) can react with sodium hydroxide to form sodium borate and water.
Write an equation for this reaction.

_____

(1)

(d) Boron trichloride can be reduced by using hydrogen to form pure boron.

$$BCl_3(g) + 1\frac{1}{2} H_2(g) \longrightarrow B(s) + 3HCl(g)$$

Calculate the percentage atom economy for the formation of boron in this reaction.

Apart from changing the reaction conditions, suggest **one** way a company producing pure boron could increase its profits from this reaction.

_____

_____

_____

_____

_____

(3)

(e) A different compound of boron and chlorine has a relative molecular mass of 163.6 and contains 13.2% of boron by mass.

Calculate the molecular formula of this compound.
Show your working.

_____

_____

_____

_____

_____

_____

_____

(4)

(Total 20 marks)

Q16.

A student calculated that a value for the enthalpy change of neutralisation

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is –51.2 kJ mol^{-1}.

The design of a possible hand-warmer using hydrochloric acid and sodium hydroxide was discussed. It was proposed that 500 cm^3 of hydrochloric acid should be used in a flexible, sealed plastic container with a breakable tube of solid sodium hydroxide also in the container. On breaking the tube, the sodium hydroxide would be released, react with the acid and produce heat.
A 40 °C temperature rise was thought to be suitable.

(a) Calculate the heat energy, in J, required to raise the temperature of the reaction mixture by 40 °C. Assume that the reaction mixture has a density of 1.00 g cm^{-3} and a specific heat capacity of 4.18 J K^{-1} g^{-1}.
Assume that all of the heat energy given out is used to heat the reaction mixture.

_____

_____

_____

_____

(2)

(b) Use your answer from part (a) and the value for the enthalpy change of neutralisation of –51.2 kJ mol^{-1} to calculate the minimum amount, in moles, and hence the minimum mass of sodium hydroxide required in the breakable tube.
(If you could not complete the calculation in part (a) assume that the heat energy required was 77 400 J. This is **not** the correct answer).

Show your working.

Moles of NaOH _____

_____

Mass of NaOH _____

_____

(3)

(c) Use the amount, in moles, of sodium hydroxide from part (b) to calculate the minimum concentration, in mol dm^{-3}, of hydrochloric acid required in the 500 cm^3 of solution used in the sealed container.

_____

_____

_____

(1)

(d) Suggest **one** possible risk to a person who uses a hand-warmer containing sodium hydroxide and hydrochloric acid.

_____

_____

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(1)

(e) A commercial hand-warmer uses powdered iron sealed in a plastic container.
A valve allows air to enter the container, and oxygen in the air reacts slowly with the iron to form solid iron(III) oxide. The heat released warms the container.

(i) Write an equation for this reaction between iron and oxygen to form iron(III) oxide.

_____

(1)

(ii) One version of an iron-oxygen hand-warmer advertises that it is designed to stay warm for up to four hours.
Other than by increasing the amount of iron in the container, state **one** change to the iron in the hand-warmer that would increase this time.
Explain why this change to the iron might **not** be an advantage.

Change to the iron _____

_____

Explanation _____

_____

_____

(3)

(f) Another type of hand-warmer uses sodium thiosulfate. Sodium thiosulfate is very soluble in water at 80 °C but is much less soluble at room temperature.
When a hot, concentrated solution of sodium thiosulfate is cooled it does not immediately crystallise. The sodium thiosulfate stays dissolved as a stable 'super-saturated' solution until crystallisation is triggered.
Heat energy is then released when the sodium thiosulfate crystallises.

(i) This type of hand-warmer is re-usable.
Suggest **one** environmental advantage that a sodium thiosulfate hand-warmer has over the other two types.

_____

(1)

(ii) Describe the **two** steps that you would take to make the sodium thiosulfate hand-warmer ready for re-use.

Step 1 _____

_____

Step 2 _____

_____

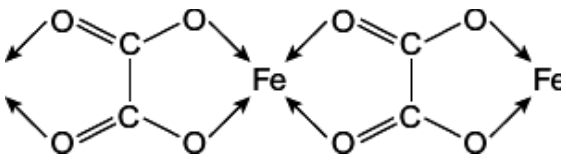
(2)

(Total 14 marks)

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Q17.

Solid iron(II) ethanedioate dihydrate ($FeC_2O_4.2H_2O$) has a polymeric structure.
Two repeating units in the polymer chain are shown.



Each iron ion is also bonded to two water molecules. These are **not** shown in the diagram.

(a) Name the type of bond that is represented by the arrows.

_____

(1)

(b) In terms of electrons explain how the water molecules, **not** shown in the diagram, form bonds to the iron.

_____

_____

_____

_____

(2)

(c) Predict the value of the bond angle between the two bonds to iron that are formed by these two water molecules.

_____

(1)

(d) Iron(II) ethanedioate dihydrate can be analysed by titration using potassium manganate(VII) in acidic solution. In this reaction, manganate(VII) ions oxidise iron(II) ions and ethanedioate ions.

A 1.381 g sample of impure $FeC_2O_4.2H_2O$ was dissolved in an excess of dilute sulfuric acid and made up to 250 cm^3 of solution.
25.0 cm^3 of this solution decolourised 22.35 cm^3 of a 0.0193 mol dm^{-3} solution of potassium manganate(VII).

(i) Use the half-equations given below to calculate the reacting ratio of moles of manganate(VII) ions to moles of iron(II) ethanedioate.

$$MnO_4^- + 8H^+ + 5e^- \longrightarrow Mn^{2+} + 4H_2O$$

$$Fe^{2+} \longrightarrow Fe^{3+} + e^-$$

$$C_2O_4^{2-} \longrightarrow 2CO_2 + 2e^-$$

_____

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_____

_____

(1)

(ii) Calculate the percentage by mass of $FeC_2O_4.2H_2O$ in the original sample.

(If you have been unable to answer part (d)(i) you may assume that three moles of manganate(VII) ions react with seven moles of iron(II) ethanedioate. This is **not** the correct ratio.)

_____

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_____

(5)

(Total 10 marks)

Q18.

A student was given a task to determine the percentage purity of a sample of salicylic acid. The method used by the student to prepare a solution of salicylic acid is described below.

- 0.500 g of an impure sample of salicylic acid was placed in a weighing bottle.
- The contents were tipped into a beaker and 100 cm^3 of distilled water were added.
- Salicylic acid does not dissolve well in cold water so the beaker and its contents were heated gently until all the solid had dissolved.
- The solution was poured into a 250 cm^3 graduated flask and made up to the mark with distilled water.

(a) Give **two** additional instructions that would improve this method for making up the salicylic acid solution.

_____

_____

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_____

_____

_____

(2)

(b) The pH of this solution was measured and a value of 2.50 was obtained.
Calculate the concentration of salicylic acid in this solution.
Assume that salicylic acid is the only acid in this solution. The K_a for salicylic acid is 1.07×10^{-3} mol dm^{-3}. You may represent salicylic acid as HA.
Show your working.

_____

_____

_____

_____

_____

(3)

(c) Use your answer to part (b) to calculate the mass of salicylic acid (M_r = 138.0) present in the original sample.
(If you were unable to complete the calculation in part (b), assume that the concentration of salicylic acid is 8.50×10^{-3} mol dm^{-3}. This is **not** the correct answer.)

_____

_____

_____

(2)

(d) Use your answer to part (c) to calculate the percentage purity of the salicylic acid used to make the solution.
(If you were unable to complete the calculation in part (c), assume that the mass of salicylic acid is 0.347 g. This is **not** the correct answer.)

_____

_____

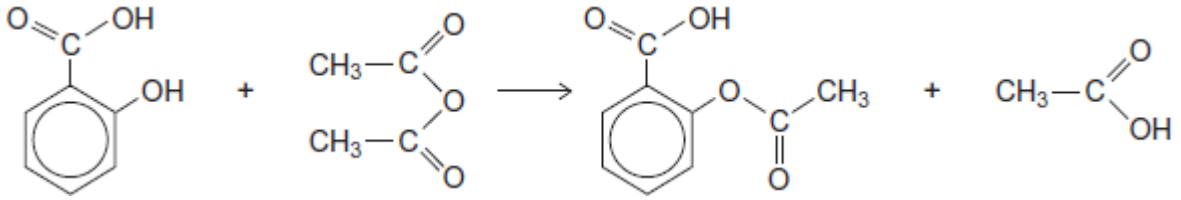
(1)

(Total 8 marks)

Q19.

Aspirin can be made by reacting salicylic acid with ethanoic anhydride as outlined below.

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(a) In an experiment, after purification by recrystallisation, 1.76 g of aspirin (M_r = 180.0) were produced from 2.00 g of salicylic acid.
Calculate the percentage yield for this experiment.

(2)

(b) Suggest **one** practical reason why the yield of purified aspirin is less than 100%.

(1)

(Total 3 marks)

Q20.

The metal lead reacts with warm dilute nitric acid to produce lead(II) nitrate, nitrogen monoxide and water according to the following equation.

$$3Pb(s) + 8HNO_3(aq) \longrightarrow 3Pb(NO_3)_2(aq) + 2NO(g) + 4H_2O(l)$$

(a) In an experiment, an 8.14 g sample of lead reacted completely with a 2.00 mol dm^{-3} solution of nitric acid.

Calculate the volume, in dm^3, of nitric acid required for complete reaction.
Give your answer to 3 significant figures

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(3)

(b) In a second experiment, the nitrogen monoxide gas produced in the reaction occupied 638 cm^3 at 101 kPa and 298 K.
Calculate the amount, in moles, of NO gas produced.
(The gas constant R = 8.31 $J\ K^{-1}\ mol^{-1}$)

_____

_____

_____

_____

_____

(3)

(c) When lead(II) nitrate is heated it decomposes to form lead(II) oxide, nitrogen dioxide and oxygen.

(i) Balance the following equation that shows this thermal decomposition.

.....$Pb(NO_3)_2(s)$ ⟶ ..... $PbO(s)$ + ...$NO_2(g)$ + ...$O_2(g)$

(1)

(ii) Suggest **one** reason why the yield of nitrogen dioxide formed during this reaction is often less than expected.

_____

_____

(1)

(iii) Suggest **one** reason why it is difficult to obtain a pure sample of nitrogen dioxide from this reaction.

_____

_____

(1)

(Total 9 marks)

Q21.

Norgessaltpeter was the first nitrogen fertiliser to be manufactured in Norway. It has the formula $Ca(NO_3)_2$

(a) Norgessaltpeter can be made by the reaction of calcium carbonate with dilute nitric acid as shown by the following equation.

$$CaCO_3(s) + 2HNO_3(aq) \longrightarrow Ca(NO_3)_2(aq) + CO_2(g) + H_2O(l)$$

In an experiment, an excess of powdered calcium carbonate was added to 36.2 cm^3 of 0.586 mol dm^{-3} nitric acid.

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(i) Calculate the amount, in moles, of HNO_3 in 36.2 cm^3 of 0.586 mol dm^{-3} nitric acid. Give your answer to 3 significant figures.

_____

_____

(1)

(ii) Calculate the amount, in moles, of $CaCO_3$ that reacted with the nitric acid. Give your answer to 3 significant figures.

_____

_____

(1)

(iii) Calculate the minimum mass of powdered $CaCO_3$ that should be added to react with all of the nitric acid.

Give your answer to 3 significant figures.

_____

_____

_____

(2)

(iv) State the type of reaction that occurs when calcium carbonate reacts with nitric acid.

_____

(1)

(b) Norgessaltpeter decomposes on heating as shown by the following equation.

$$2Ca(NO_3)_2(s) \longrightarrow 2CaO(s) + 4NO_2(g) + O_2(g)$$

A sample of Norgessaltpeter was decomposed completely.

The gases produced occupied a volume of 3.50×10^{-3} m^3 at a pressure of 100 kPa and a temperature of 31 °C.
(The gas constant R = 8.31 J K^{-1} mol^{-1})

(i) Calculate the total amount, in moles, of gases produced.

_____

_____

_____

_____

(3)

(ii) Hence calculate the amount, in moles, of oxygen produced.

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_____

_____

(1)

(c) Hydrated calcium nitrate can be represented by the formula $Ca(NO_3)_2.xH_2O$ where x is an integer.

A 6.04 g sample of $Ca(NO_3)_2.xH_2O$ contains 1.84 g of water of crystallisation.

Use this information to calculate a value for x.
Show your working.

_____

_____

_____

_____

_____

_____

(3)

(Total 12 marks)

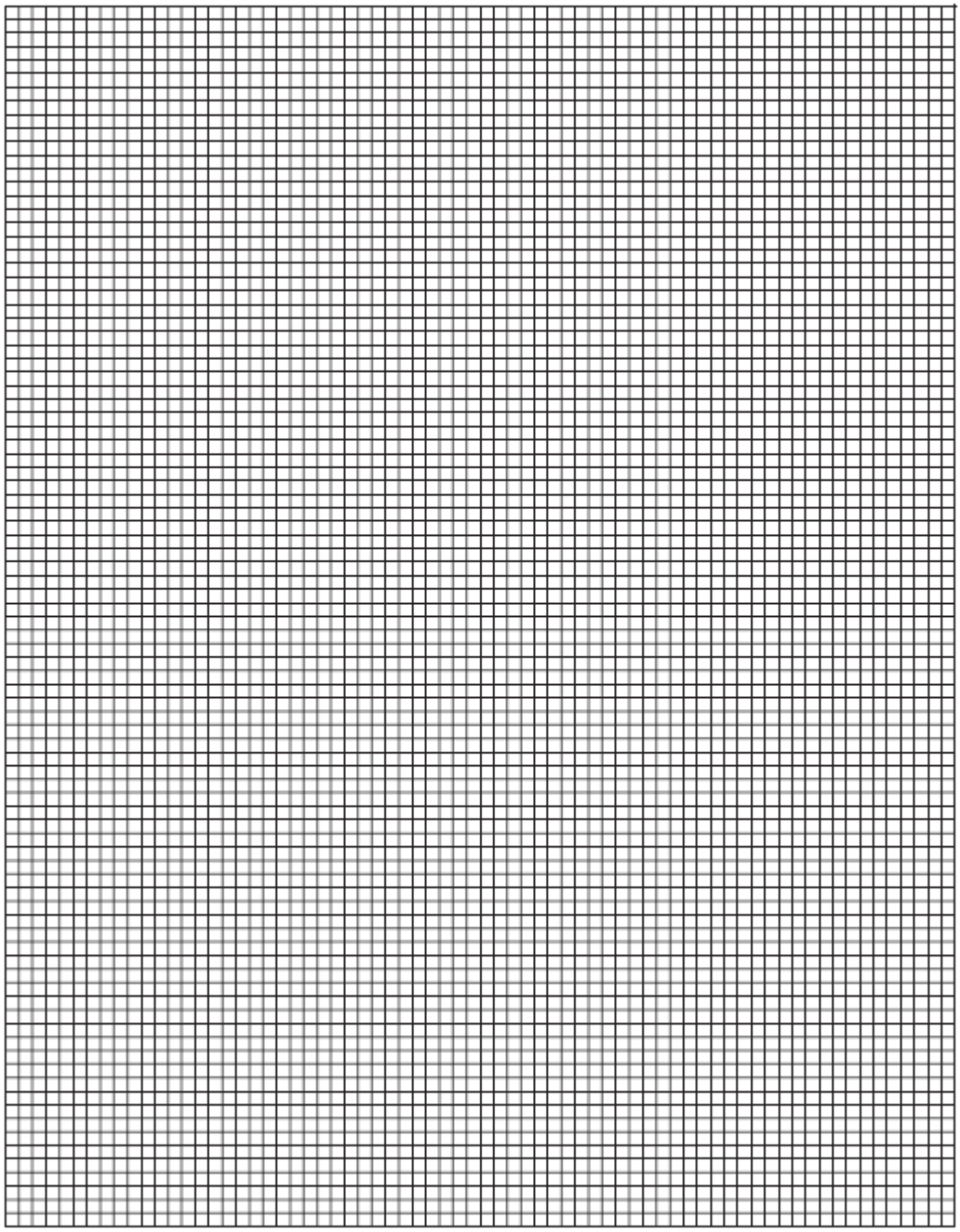
Q22.

(a) A student investigated the acid content of a different crater-lake solution. The student used a 50.0 cm^3 burette to measure out different volumes of this crater-lake solution. Each volume of crater-lake solution was titrated with a 0.100 mol dm^{-3} sodium hydroxide solution. Each titration was repeated. The results are shown below.

Volume of crater-lake solution / cm^3		10.0	20.0	30.0	40.0	50.0
Volume of sodium hydroxide solution / cm^3	Experiment 1	5.85	17.00	20.00	26.50	32.45
	Experiment 2	6.15	13.00	19.90	26.50	32.55
Average titre / cm^3		6.00	15.00	19.95	26.50	32.50

(i) On the graph paper below, plot a graph of average titre (y-axis) against volume of crater-lake solution. Both axes must start at zero.

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(3)

(ii) Draw a line of best fit on the graph.

(1)

(iii) Use the graph to determine the titre that the student would have obtained using a 25.0 cm^3 sample of crater-lake solution.

_____

(1)

(iv) Excluding any anomalous points, which average titre value would you expect to be the least accurate value? Give **one** reason for your choice.

Least accurate average titre _____

Reason _____

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_____

(2)

(b) Another 100 cm^3 sample of crater-lake solution was reacted with an excess of powdered limestone. The gas produced was collected in a gas syringe. The equation for the reaction between the sulfuric(IV) acid in the crater-lake solution and the calcium carbonate in the powdered limestone is shown below.

$$H_2SO_3 + CaCO_3 \longrightarrow CaSO_3 + H_2O + CO_2$$

The volume of gas collected from the reaction of the sulfuric(IV) acid in 100 cm^3 of crater-lake solution with an excess of powdered limestone was 81.0 cm^3 at 298 K and 1.00×10^5 Pa.

(i) State the ideal gas equation.

_____

(1)

(ii) Use the ideal gas equation to calculate the amount, in moles, of carbon dioxide formed.
Show your working.
(The gas constant R = 8.31 J K^{-1} mol^{-1})

_____

_____

_____

_____

(3)

(iii) Use the equation for the reaction and your answer from part (b)(ii) to calculate the minimum mass of calcium carbonate needed to neutralise the sulfuric(IV) acid in 1.00 dm^3 of crater-lake solution.
Show your working.

(If you could not complete the calculation in part (b)(ii) assume that the amount of carbon dioxide is 1.25×10^{-2} mol. This is **not** the correct value.)

_____

_____

_____

_____

(3)

(iv) The percentage by mass of calcium carbonate in the powdered limestone was 95.0%.
Calculate the minimum mass of this powdered limestone needed to neutralise the sulfuric(IV) acid in 1.00 dm^3 of this crater-lake solution.

_____

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_____

(2)

(v) Give **one** reason, other than cost, why limestone rather than solid sodium hydroxide is often used to neutralise acidity in lakes.

_____

_____

(1)

(Total 17 marks)

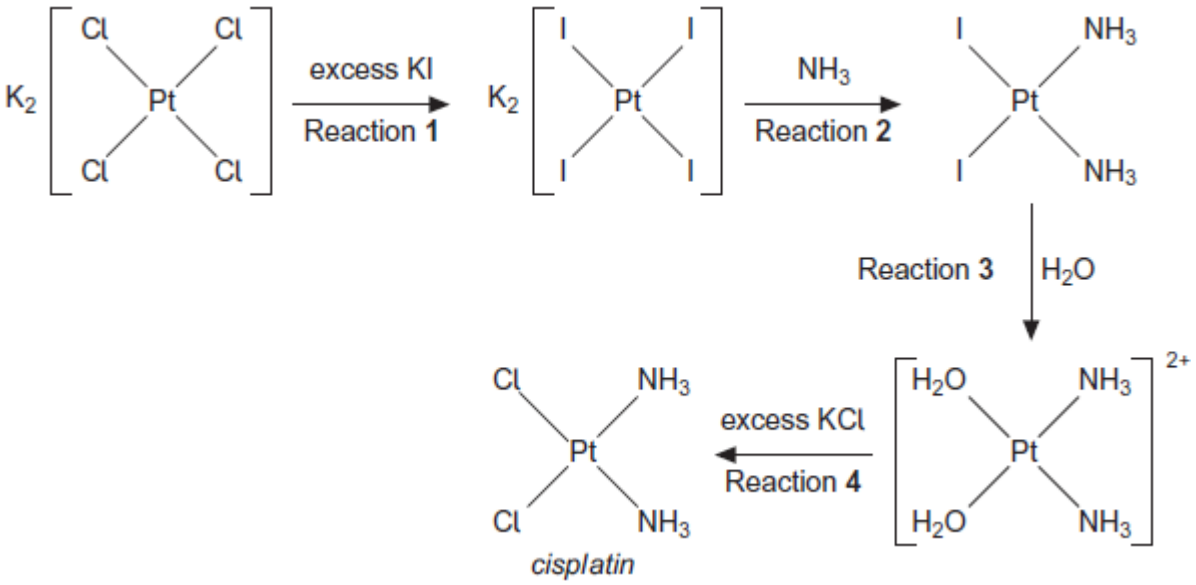
Q23.

Complexes containing transition elements have a wide variety of uses including acting as dyestuffs like *Prussian Blue*.

Cisplatin is a platinum-based chemotherapy drug used to treat various types of cancers. It was the first member of a class of anti-cancer drugs that react with DNA in tumour cells.

Cisplatin is prepared from K_2PtCl_4 according to the following scheme.

All the reactions shown are reversible.



(a) Name the type of reaction occurring in all four steps of the scheme.

_____

(1)

(b) Explain why an excess of potassium iodide is used in Reaction **1**.

_____

_____

_____

(2)

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(c) (i) Write an equation for Reaction **1**.

_____

_____

(1)

(ii) Calculate the percentage atom economy for the formation of K_2PtI_4 in Reaction **1**.
Show your working.

_____

_____

_____

_____

(2)

(d) In Reaction **3**, silver nitrate solution is added to improve the yield of product.

(i) Write the **simplest ionic** equation for the reaction of iodide ions with silver nitrate.

_____

(1)

(ii) Suggest why addition of silver nitrate improves the yield of product from Reaction **3**.

_____

_____

(1)

(e) Suggest two reasons, other than poor practical technique, why the overall yield of *cisplatin* in this synthesis may be low.

Reason 1 _____

_____

Reason 2 _____

_____

(2)

(f) The *cisplatin* formed in Reaction **4** is impure. Outline how the impure solid is purified by recrystallisation.

_____

_____

_____

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_____

_____

(3)

(g) Platinum compounds are highly toxic.

(i) State why *cisplatin* is used in cancer treatment despite its toxicity.

_____

_____

(1)

(ii) Suggest a suitable precaution that should be taken by medical staff when using *cisplatin*.

_____

(1)

(Total 15 marks)

Q24.

(a) Some metal ions are toxic to humans. A substance that can be used to treat such poisoning contains the ion $EDTA^{4-}$.
$EDTA^{4-}$ forms very stable complexes with metal ions. These complexes are **not** toxic.

(i) Write an equation for the reaction of $EDTA^{4-}$ with aqueous copper(II) ions, $[Cu(H_2O)_6]^{2+}$.

_____

(1)

(ii) A solution containing $EDTA^{4-}$ can also be used in a titration to determine the concentration of metal ions in solution.
A river was polluted with copper(II) ions. When a 25.0 cm^3 sample of the river water was titrated with a 0.0150 mol dm^{-3} solution of $EDTA^{4-}$, 6.45 cm^3 were required for complete reaction.
Calculate the concentration, in mol dm^{-3}, of copper(II) ions in the river water.
Show your working.

_____

_____

_____

_____

(2)

(b) The determination of the concentration of copper(II) ions in a single sample of river water gives an unreliable value for the copper(II) ion pollution in the river.
Give one reason why this value is unreliable.

_____

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_____

(1)

(c) Silver complexes can be used to identify a particular organic functional group. Give **one** example of a silver complex that can be used in this way and state the organic functional group it identifies.

Silver complex _____

Organic functional group _____

(2)

(Total 6 marks)

Q25.

Steel rods are cleaned before they are painted. The rods are cleaned by passing them through a bath of dilute sulfuric acid. This process produces large quantities of iron(II) sulfate.

(a) Write an equation for the reaction between iron and dilute sulfuric acid.

_____

(1)

(b) State **one** chemical hazard in this process and suggest an appropriate safety precaution for this hazard.

Hazard _____

Precaution _____

(2)

(Total 3 marks)

Q26.

(a) An unknown metal carbonate reacts with hydrochloric acid according to the following equation.

$$M_2CO_3(aq) + 2HCl(aq) \rightarrow 2MCl(aq) + CO_2(g) + H_2O(l)$$

A 3.44 g sample of M_2CO_3 was dissolved in distilled water to make 250 cm^3 of solution. A 25.0 cm^3 portion of this solution required 33.2 cm^3 of 0.150 mol dm^{-3} hydrochloric acid for complete reaction.

(i) Calculate the amount, in moles, of HCl in 33.2 cm^3 of 0.150 mol dm^{-3} hydrochloric acid. Give your answer to 3 significant figures.

_____

_____

(1)

(ii) Calculate the amount, in moles, of M_2CO_3 that reacted with this amount of HCl. Give your answer to 3 significant figures.

_____

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_____

(1)

(iii) Calculate the amount, in moles, of M_2CO_3 in the 3.44 g sample. Give your answer to 3 significant figures.

_____

_____

(1)

(iv) Calculate the relative formula mass, M_r, of M_2CO_3 Give your answer to 1 decimal place.

_____

_____

(1)

(v) Hence determine the relative atomic mass, A_r, of the metal M and deduce its identity.

A_r of M _____

Identity of M _____

(2)

(b) In another experiment, 0.658 mol of CO_2 was produced. This gas occupied a volume of 0.0220 m^3 at a pressure of 100 kPa.
Calculate the temperature of this CO_2 and state the units.
(The gas constant R = 8.31 J K^{-1} mol^{-1})

_____

_____

_____

_____

_____

_____

_____

(3)

(c) Suggest **one** possible danger when a metal carbonate is reacted with an acid in a sealed flask.

_____

_____

(1)

(d) In a different experiment, 6.27 g of magnesium carbonate were added to an excess of sulfuric acid. The following reaction occurred.

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$$MgCO_3 + H_2SO_4 \rightarrow MgSO_4 + CO_2 + H_2O$$

(i) Calculate the amount, in moles, of $MgCO_3$ in 6.27 g of magnesium carbonate.

_____

_____

(2)

(ii) Calculate the mass of $MgSO_4$ produced in this reaction assuming a 95% yield.

_____

_____

_____

_____

(3)

(Total 15 marks)

Q27.

Hydrogen peroxide is used as an oxidising agent in the preparation of transition metal complexes.

(a) Consider the following reaction scheme. All the complexes are in aqueous solution.

$$[Co(H_2O)_6]^{2+} \xrightarrow{\text{Reaction 1}} \text{cobalt(II) complex} \xrightarrow[H_2O_2]{\text{Reaction 2}} [Co(NH_3)_6]^{3+}$$

(i) Identify a reagent for Reaction **1** and describe the colour change that occurs.

_____

_____

_____

_____

(3)

(ii) State the colour of the final solution formed in Reaction **2**.

_____

(1)

(b) Consider the following reaction scheme. All the complexes are in aqueous solution.

$$[Cr(H_2O)_6]^{3+} \xrightarrow[\text{Excess NaOH(aq)}]{\text{Reaction 3}} \text{chromium(III) complex} \xrightarrow[H_2O_2]{\text{Reaction 4}} CrO_4^{2-}$$

(i) For Reaction **3**, state the colour of the initial and of the final solution and write an equation for the reaction.

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_____

_____

_____

_____

(4)

(ii) Write a half-equation for the reduction of hydrogen peroxide to hydroxide ions.

Deduce an overall equation for Reaction **4** and state the colour of the final solution.

_____

_____

_____

_____

_____

_____

(4)

(c) The concentration of a hydrogen peroxide solution can be determined by titration with acidified potassium manganate(VII) solution. In this reaction the hydrogen peroxide is oxidised to oxygen gas.

A 5.00 cm^3 sample of the hydrogen peroxide solution was added to a volumetric flask and made up to 250 cm^3 of aqueous solution. A 25.0 cm^3 sample of this diluted solution was acidified and reacted completely with 24.35 cm^3 of 0.0187 mol dm^{-3} potassium manganate(VII) solution.

Write an equation for the reaction between acidified potassium manganate(VII) solution and hydrogen peroxide.
Use this equation and the results given to calculate a value for the concentration, in mol dm^{-3}, of the original hydrogen peroxide solution.
(If you have been unable to write an equation for this reaction you may assume that 3 mol of $KMnO_4$ react with 7mol of H_2O_2. This is **not** the correct reacting ratio.)

_____

_____

_____

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_____

(5)

(Total 17 marks)

Q28.

In this question give all your answers to three significant figures.

Magnesium nitrate decomposes on heating to form magnesium oxide, nitrogen dioxide and oxygen as shown in the following equation.

$$2Mg(NO_3)_2(s) \rightarrow 2MgO(s) + 4NO_2(g) + O_2(g)$$

(a) Thermal decomposition of a sample of magnesium nitrate produced 0.741 g of magnesium oxide.

(i) Calculate the amount, in moles, of MgO in 0.741 g of magnesium oxide.

_____

_____

(2)

(ii) Calculate the total amount, in moles, of gas produced from this sample of magnesium nitrate.

_____

_____

(1)

(b) In another experiment, a different sample of magnesium nitrate decomposed to produce 0.402 mol of gas. Calculate the volume, in dm^3, that this gas would occupy at 333 K and 1.00×10^5 Pa.
(The gas constant $R = 8.31$ J K^{-1} mol^{-1})

_____

_____

_____

_____

(3)

(c) A 0.0152 mol sample of magnesium oxide, produced from the decomposition of magnesium nitrate, was reacted with hydrochloric acid.

$$MgO + 2HCl \rightarrow MgCl_2 + H_2O$$

(i) Calculate the amount, in moles, of HCl needed to react completely with the 0.0152 mol sample of magnesium oxide.

_____

(1)

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(ii) This 0.0152 mol sample of magnesium oxide required 32.4 cm^3 of hydrochloric acid for complete reaction. Use this information and your answer to part (c) (i) to calculate the concentration, in mol dm^{-3}, of the hydrochloric acid.

_____

_____

_____

(1)

(Total 8 marks)

Q29.

(a) The manufacturer of vinegar buys concentrated ethanoic acid as a 15.0 mol dm^{-3} solution. In case of an accidental spillage of this ethanoic acid the manufacturer always has sodium carbonate readily available to neutralise the acid. The equation for this reaction is shown below.

$$2CH_3COOH + Na_2CO_3 \longrightarrow 2CH_3COONa + H_2O + CO_2$$

(i) Calculate the amount, in moles, of ethanoic acid in 10.0 cm^3 of a 15.0 mol dm^{-3} solution.

_____

(1)

(ii) Use your answer from part (i) to calculate the amount, in moles, of sodium carbonate needed to react completely with this amount of ethanoic acid.

_____

(1)

(iii) Use data from the Periodic Table to calculate the relative formula mass of sodium carbonate. Give your answer to the appropriate precision.

_____

(1)

(iv) Use your answers from parts (ii) and (iii) to determine the minimum mass of sodium carbonate needed to react completely with 10.0 cm^3 of the 15.0 mol dm^{-3} solution of ethanoic acid.

_____

(1)

(b) State **one** hazard when using concentrated ethanoic acid and **one** safety precaution you would take to minimise this hazard.

Hazard _____

Precaution _____

_____

(1)

(Total 5 marks)

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Q30.

(a) Sodium hydrogencarbonate ($NaHCO_3$) can also be used to neutralise ethanoic acid spillages. The equation for this reaction is shown below.

$$CH_3COOH + NaHCO_3 \longrightarrow CH_3COONa + H_2O + CO_2$$

State the ideal gas equation.

_____

(1)

(b) There are several methods by which ethanoic acid is synthesised on an industrial scale. One method is the oxidation of butane in the presence of metal ion catalysts. Balance the equation given below which summarises this reaction.

$$.....C_4H_{10} + ...O_2 \longrightarrow .....CH_3COOH + ...H_2O$$

(1)

(c) A second method by which ethanoic acid is synthesised involves the oxidative fermentation of ethanol in the presence of bacteria. The equation representing this reaction is given below.

$$C_2H_5OH + O_2 \longrightarrow CH_3COOH + H_2O$$

In a small scale experiment using this second method it was found that 23.0 g of ethanol produced only 4.54 g of ethanoic acid. Calculate the percentage yield for this experiment.

_____

_____

_____

(2)

(Total 4 marks)

Q31.

In an experiment to determine the concentration of a solution of sodium hydroxide, 25.0 cm^3 of 0.100 mol dm^{-3} hydrochloric acid were transferred to a conical flask. An indicator was added to the flask. The solution of sodium hydroxide was then added to the flask from a burette.

(a) State a suitable amount of indicator solution that should be added to the flask.

_____

_____

(1)

(b) State why it is important to fill the space below the tap in the burette with alkali before beginning the titration.

_____

_____

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(1)
(Total 2 marks)

Q32.

The electrons transferred in redox reactions can be used by electrochemical cells to provide energy.

Some electrode half-equations and their standard electrode potentials are shown in the table below.

Half-equation	$E^{\ominus}$/V
$Cr_2O_7^{2-}(aq) + 14H^+(aq) + 6e^- \rightarrow 2Cr^{3+}(aq) + 7H_2O(l)$	+1.33
$Fe^{3+}(aq) + e^- \rightarrow Fe^{2+}(aq)$	+0.77
$2H^+(aq) + 2e^- \rightarrow H_2(g)$	0.00
$Fe^{2+}(aq) + 2e^- \rightarrow Fe(s)$	–0.44
$Li^+(aq) + e^- \rightarrow Li(s)$	–3.04

(a) Describe a standard hydrogen electrode.

_____

_____

_____

_____

_____

_____

_____

(4)

(b) A conventional representation of a lithium cell is given below.
This cell has an e.m.f. of +2.91 V

$$Li(s) \mid Li^+(aq) \parallel Li^+(aq) \mid MnO_2(s) , LiMnO_2(s) \mid Pt(s)$$

Write a half-equation for the reaction that occurs at the positive electrode of this cell.

Calculate the standard electrode potential of this positive electrode.

_____

_____

_____

_____

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(2)

(c) Suggest what reactions occur, if any, when hydrogen gas is bubbled into a solution containing a mixture of iron(II) and iron(III) ions. Explain your answer.

(2)

(d) A solution of iron(II) sulfate was prepared by dissolving 10.00 g of $FeSO_4.7H_2O$ (M_r = 277.9) in water and making up to 250 cm^3 of solution. The solution was left to stand, exposed to air, and some of the iron(II) ions became oxidised to iron(III) ions. A 25.0 cm^3 sample of the partially oxidised solution required 23.70 cm^3 of 0.0100 mol dm^{-3} potassium dichromate(VI) solution for complete reaction in the presence of an excess of dilute sulfuric acid.

Calculate the percentage of iron(II) ions that had been oxidised by the air.

(6)

(Total 14 marks)

Q33.

(a) When a solution containing iron(II) ions is treated with a slight excess of a solution containing ethanedioate ions a bright yellow precipitate of hydrated iron(II) ethanedioate, $FeC_2O_4.2H_2O$, is formed. The precipitate is filtered off, washed with

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propanone and then allowed to dry. A typical yield of the solid is 95%.

(i) Propanone boils at 56 °C and is miscible with water in all proportions. Suggest **two** reasons why washing with propanone is an effective method for producing a pure, dry precipitate.

Reason 1 _____

_____

Reason 2 _____

_____

(2)

(ii) By suggesting a simple test tube reaction, state how the filtrate could be tested to show that all of the iron(II) ions have been removed from the solution. State what you would observe.

Test _____

Observation _____

(2)

(iii) Suggest **one** reason why the typical yield of iron(II) ethanedioate is less than 100%.

_____

_____

(1)

(iv) Calculate the mass of hydrated iron(II) ethanedioate, $FeC_2O_4.2H_2O$ that can be formed from 50.0 cm^3 of a 0.50 mol dm^{-3} solution of iron(II) sulfate when the yield of the reaction is 95%. Show your working.

_____

_____

_____

_____

_____

(3)

(v) The identity of the precipitate can be confirmed by dissolving it in sulfuric acid and titrating the mixture with potassium manganate(VII).

Deduce the number of moles of iron(II) ethanedioate that would react with one mole of potassium manganate(VII) in acidic solution.

_____

_____

(1)

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(b) Ethanedioate ions can be used to remove calcium ions from blood plasma. A precipitate of calcium ethanedioate is formed. Write an ionic equation for the reaction of ethanedioate ions with calcium ions.

_____

_____

(1)

(c) Ethanedioic acid is used to clean marble, a form of calcium carbonate. Suggest **one** reason why the reaction between ethanedioic acid and marble stops after a short time.

_____

_____

(1)

(d) Tea leaves contain ethanedioic acid. Suggest **one** reason why tea drinkers do **not** suffer from ethanedioic acid poisoning.

_____

(1)

(e) Ethanedioic acid is produced by the oxidation of carbon monoxide in a multi-step process. The equation which summarises the reactions taking place is shown below.

$$4CO + 4NaOH + O_2 + 4HCl \rightarrow 2H_2C_2O_4 + 4NaCl + 2H_2O$$

Calculate the percentage atom economy for the formation of ethanedioic acid in this reaction. Show your working.

_____

_____

_____

(2)

(Total 14 marks)

Q34.

Hydrogen peroxide is sold commercially as an aqueous solution containing approximately 60 g dm^{-3} of hydrogen peroxide.

(a) Use data from the Periodic Table to calculate the M_r of hydrogen peroxide. Give your answer to the appropriate precision.

_____

_____

(1)

(b) Calculate the concentration, in mol dm^{-3}, of a solution containing 60.0 g dm^{-3} of hydrogen peroxide.

_____

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_____

(1)

(c) The concentration of hydrogen peroxide in a hair bleach is 0.050 mol dm^{-3}. Use your answer from (b) to calculate the dilution factor needed to make the commercial hydrogen peroxide solution suitable for use in this hair bleach. Show your working.

_____

_____

(2)

(Total 4 marks)

Q35.

Ammonium sulfate reacts with sodium hydroxide to form ammonia, sodium sulfate and water as shown in the equation below.

$$(NH_4)_2SO_4(s) + 2NaOH(aq) \rightarrow 2NH_3(g) + Na_2SO_4(aq) + 2H_2O(l)$$

(a) A 3.14 g sample of ammonium sulfate reacted completely with 39.30 cm^3 of a sodium hydroxide solution.

(i) Calculate the amount, in moles, of $(NH_4)_2SO_4$ in 3.14 g of ammonium sulfate.

_____

_____

_____

(2)

(ii) Hence calculate the amount, in moles, of sodium hydroxide which reacted.

_____

(1)

(iii) Calculate the concentration, in mol dm^{-3}, of the sodium hydroxide solution used.

_____

_____

(1)

(b) Calculate the percentage atom economy for the production of ammonia in the reaction between ammonium sulfate and sodium hydroxide.

_____

_____

_____

(2)

(c) Ammonia is manufactured by the Haber Process.

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$N_2 + 3H_2 \rightleftharpoons 2NH_3$

Calculate the percentage atom economy for the production of ammonia in this process.

_____

_____

(1)

(d) A sample of ammonia gas occupied a volume of 1.53×10^{-2} m^3 at 37 °C and a pressure of 100 kPa.
(The gas constant R = 8.31 J K^{-1} mol^{-1})

Calculate the amount, in moles, of ammonia in this sample.

_____

_____

_____

(3)

(e) Glauber's salt is a form of hydrated sodium sulfate that contains 44.1% by mass of sodium sulfate. Hydrated sodium sulfate can be represented by the formula $Na_2SO_4.xH_2O$ where x is an integer. Calculate the value of x.

_____

_____

_____

_____

(3)

(Total 13 marks)

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Q1.

(a) $[Fe(H_2O)_6]^{2+} + 2NH_3 \rightarrow Fe(H_2O)_4(OH)_2 + 2NH_4^+$

Allow equation with OH^- provided equation showing formation of OH^- from NH_3 given

1

Green precipitate

1

$[Fe(H_2O)_6]^{2+} + CO_3^{2-} \rightarrow FeCO_3 + 6H_2O$

1

Green precipitate

effervescence incorrect so loses M4

1

(b) (i) Colourless / (pale) green changes to pink / purple (solution)

Do not allow pale pink to purple

1

Just after the end−point MnO_4^- is in excess / present

1

(ii) $MnO_4^- + 8H^+ + 5Fe^{2+} \rightarrow Mn^{2+} + 4H_2O + 5Fe^{3+}$

1

Moles $KMnO_4 = 18.7 \times 0.0205 / 1000 = (3.8335 \times 10^{-4})$

Process mark

1

Moles $Fe^{2+} = 5 \times 3.8335 \times 10^{-4} = 1.91675 \times 10^{-3}$

Mark for M2 × 5

1

Moles Fe^{2+} in 250 $cm^3 = 10 \times 1.91675 \times 10^{-3} = 0.0191675$ moles in 50 cm^3

Process mark for moles of iron in titration (M3) × 10

1

Original conc $Fe^{2+} = 0.0191675 \times 1000 / 50 = 0.383$ $\underline{\text{mol dm}^{-3}}$

Answer for moles of iron (M4) × 1000 / 50

Answer must be to at least 2 sig. figs. (0.38)

1

[11]

Q2.

(a) (i) M_r N−phenylethanamide = 135.0

1

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Theoretical yield = 135.0 × 2 (1.15 / 284.1) = 1.09 g

1

Answer recorded to 3 significant figures.

1

(ii) $\frac{0.89}{\text{Ans to (a)}} \times 100$

= 81.4 %

Mark consequentially to (a)
Allow 81 to 82

1

(b) (i) Dissolve the product in the **minimum** volume of water / solvent (in a boiling tube / beaker)

If dissolving is not mentioned, CE = 0 / 4

1

Hot water / solvent

Steps must be in a logical order to score all 4 marks

1

Allow the solution to cool and allow crystals to form.

1

Filter off the pure product under reduced pressure / using a Buchner funnel and side arm flask

Ignore source of vacuum for filtration (electric pump, water pump, etc.)

1

(ii) Measure the melting point

1

Use of melting point apparatus or oil bath

1

Sharp melting point / melting point matches data source value

1

(iii) Any **two** from:
Product left in the beaker or glassware
Sample was still wet
Sample lost during recrystallisation.

Do not allow "sample lost" without clarification.

2 Max

(c) An identified hazard of ethanoyl chloride

E.g. "Violent reaction", "harmful", "reacts violently with water"
Do not allow "toxic", "irritant" (unless linked with HCl gas).

1

HCl gas / fumes released / HCl not released when ethanoic anhydride used

1

[15]

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Q3.

(a) As a droplet from the funnel could enter the burette / affect volume / readings / titre

1

(b) Air bubble in jet or wtte

Do not allow misreading burette or overshooting end point.

1

(c) Ensures **all** reagents are able to react / mix / come into contact

Accept no reagent is left unreacted on sides of flask

Do not allow any reference to 'removal' of the solution unless it is clear that it is added to the flask.

1

(d) The added water does not affect the mols / amount of reagents / reactants / solution Z

Do not allow mols of solution or mols in the flask.

Allow water does not react with the reagents / water is not one of the reactants

Do not allow 'water is not involved'

1

[4]

Q4.

Pipette = 0.05 × 100 / **25.0** = 0.2%

Ignore precision

1

Burette = 0.15 × 100 / 24.25 cm^3

Must show working

Allow one mark for two correct answers with no working

1

[2]

Q5.

(a) (i) M1 - M_r calcium phosphate = 310(.3)

If M_r wrong, lose M1 and M5.

1

M2 - Moles calcium phosphate = $\frac{7.26}{M1}$ (= 0.0234)

0.0234 moles can score M1 and M2.

If M_r incorrect, can score M2 for $\frac{7.26}{M1}$.

Allow M2 and / or M3 to 2 significant figures here but will lose M5 if answer not 1.23.

1

M3 - Moles phosphoric acid = 2 × 0.0234 = 0.0468

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Allow student's M2 × 2. If not multiplied by 2 then lose M3 and M5.

1

M4 - Vol phosphoric acid = 0.038(0) dm^3

If not 0.038(0) dm^3 then lose M4 and M5.

1

Conc phosphoric acid = $\frac{0.0468}{0.038(0)}$

M5 = 1.23 (mol dm^{-3})

This answer only – unless arithmetic or transcription error that has been penalised by 1 mark.

Allow no units but incorrect units loses M5.

1

(ii) $\frac{492.3}{688.3} \times 100$ **OR** $\frac{492}{688} \times 100$

1 mark for both M_r correctly placed.

= 71.5%

2

(b) $3Ca(OH)_2 + 2H_3PO_4 \longrightarrow Ca_3(PO_4)_2 + 6H_2O$

Allow multiples.

1

(c)

Ca	H	P	O
$\frac{1.67}{40.1}$	$\frac{0.17}{1}$	$\frac{2.59}{31}$	$\frac{5.33}{16}$
= 0.042	0.17	0.084	0.333
1	4	2	8

If x = 2 with no working, allow M4 only.

Ca = 1.67 g (M1).

1

Mark for dividing by correct A_r in Ca and P (M2).
If M1 incorrect can only score M2.

1

Correct ratio (M3).

1

$CaH_4P_2O_8$ **OR** $Ca(H_2PO_4)_2$ **OR** x = 2

Value of x or correct formula (M4).

1

Alternative

Ca H_2PO_4

Ca = 1.67 g (M1).

$\frac{1.67}{40.1}$ $\frac{8.09}{97.0}$

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Mark for dividing by correct A_r / M_r in Ca and H_2PO_4 (M2).
If M1 incorrect can only score M2.

$= \frac{0.042}{1} \quad \frac{0.083}{2}$

Correct ratio (M3).

$CaH_4P_2O_8$ **OR** $Ca(H_2PO_4)_2$ **OR** x = 2

Value of x or correct formula (M4).

[12]

Q6.

Total volume = (10 × 12) / 0.25 = 480 (cm^3) **M1**

Allow any correct method.

1

Therefore add 470 (cm^3) **M2**

*For **M2**, allow **M1** – 10, even if **M1** is incorrect.*

Correct answer without working scores 1 mark only.

1

[2]

Q7.

(a) Other product in equation is water

If product incorrect, CE = 0 / 2

1

$(NH_4)_3PO_4 + \mathbf{3}NaOH \rightarrow Na_3PO_4 + \mathbf{3}NH_3 + \mathbf{3}H_2O$

Allow multiples, including fractions.

Ignore state symbols.

1

(b) Named indicator paper placed in gas / add named indicator to gas / collect gas and add named indicator

If indicator not named, CE = 0 / 2

Lose this mark if the indicator is added to the reaction mixture. Can still score the second mark.

1

Correct full colour change

If universal indicator is used, allow 'green to blue / purple' or 'yellow to blue / purple'.

If litmus is used, allow 'purple to blue' or 'red to blue'.

Allow one mark overall for 'add universal indicator' and 'turns purple / blue'.

Allow one mark overall for 'add litmus' and 'turns blue'.

1

[4]

Q8.

(a) ($Q = mc\Delta T$)

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= 50 × 4.18 × 27.3

If incorrect (eg mass = 0.22 or 50.22 g) ***CE = 0 / 2***

1

= **5706 J** (accept 5700 and 5710)

Accept 5.7 kJ with correct unit. Ignore sign.

1

(b) M_r of 2-methylpropan-2-ol = 74(.0)

For incorrect M_r, lose M1 but mark on.

1

Moles = mass / M_r

= 0.22 / 74(.0)

= **0.00297 moles**

1

ΔH = –5706 / (0.002970 × 1000)

= **–1921 (kJ mol^{-1})**

If 0.22 is used in part (a), answer = –8.45 kJ mol^{-1} scores 3

(Allow –1920, –1919)

If uses the value given (5580 J), answer = –1879 kJ mol^{-1} scores 3

Answer without working scores M3 only.

Do not penalise precision.

Lack of negative sign loses M3

1

(c) ΔH = ΣΔH products – ΣΔH reactants
OR a correct cycle

Correct answer with no working scores 1 mark only.

1

ΔH = −(−360) + (4 × −393) + (5 × −286)

M2 also implies M1 scored.

1

ΔH = **–2642** (kJ mol^{-1}) This answer only.

Allow 1 mark out of 3 for correct value with incorrect sign.

1

(d) (–2422 – part (b)) × 100 / –2422

Ignore negative sign.

Expect answers in region of 20.7

If error carried forward, 0.22 allow 99.7

If 5580 J used earlier, then allow 22.4

1

(e) Reduce the distance between the flame and the beaker / put a sleeve around the flame to protect from drafts / add a lid / use a copper calorimeter rather than a pyrex beaker / use a food calorimeter

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Any reference to insulating material around the beaker must be on top.

Accept calibrate the equipment using an alcohol of known enthalpy of combustion.

1

(f) Incomplete combustion

1

[11]

Q9.

(a) moles of $Cr_2O_7^{2-}$ per titration = 21.3 × 0.0150 / 1000 = $\underline{3.195 \times 10^{-4}}$

1

($Cr_2O_7^{2-} + 14H^+ + 6Fe^{2+} \rightarrow 2Cr^{3+} + 7H_2O + 6Fe^{3+}$) $Cr_2O_7^{2-}$:Fe^{2+} = 1:6

If 1:6 ratio incorrect cannot score M2 or M3

1

moles of Fe^{2+} = 6 × 3.195 × 10^{-4} = 1.917 × 10^{-3}

Process mark for M1 × 6 (also score M2)

1

original moles in 250 cm^3 = 1.917 × 10^{-3} × 10 = 1.917 × 10^{-2}

Process mark for M3 × 10

1

mass of $FeSO_4.7H_2O$ = 1.917 × 10^{-2} × 277.9 = 5.33 (g)

Mark for answer to M4 × 277.9

(allow 5.30 to 5.40)

*Answer **must** be to at least 3 sig figs*

Note that an answer of 0.888 scores M1, M4 and M5 (ratio 1:1 used)

1

(b) (Impurity is a) reducing agent / reacts with dichromate / impurity is a version of $FeSO_4$ with fewer than 7 waters (not fully hydrated)

Allow a reducing agent or compound that that converts Fe^{3+} into Fe^{2+}

1

Such that for a given mass, the impurity would react with more dichromate than a similar mass of $FeSO_4.7H_2O$

OR for equal masses of the impurity and $FeSO_4.7H_2O$, the impurity would react with more dichromate.

Must compare mass of impurity with mass of $FeSO_4.7H_2O$

1

[7]

Q10.

(a)

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Method 1	Method 2
Mass of H_2O = 4.38−2.46	Percentage of H_2O = 44%
(= 1.92 g)	

If there is an AE in M1 then can score M2 and M3
If M_r incorrect can only score M1

1

$ZnSO_4$		H_2O		ZnSO4		H2O	
2.46		1.92		56		44	
161.5		18		161.5		18	

1

(0.0152		0.107)		(0.347		2.444)	
(1	:	7)		(1	:	7)	

x = 7 x = 7

If x = 7 with working then award 3 marks.
Allow alternative methods.
If M1 incorrect due to AE, M3 must be an integer.

1

(b) Moles HCl = 0.12(0)

1

mol $ZnCl_2$ = 0.06(0) ***OR*** 0.12 / 2

1

If M2 incorrect then CE and cannot score M2, M3 and M4.

mass $ZnCl_2$ = 0.06 × 136.4
Allow 65.4 + (2 × 35.5) for 136.4

1

= 8.18(4) (g) ***OR*** 8.2 (g)
Must be to 2 significant figures or more.
Ignore units.

1

(c) Moles $ZnCl_2 = \frac{10.7}{136.4}$ (= 0.0784)

1

OR moles Zn = 0.0784

Mass Zn reacting = 0.0784 × 65.4 = (5.13 g)
M2 is for their M1 × 65.4

1

$$\%\,\text{purity of Zn} = \frac{5.13}{5.68} \times 100$$

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M3 is M2 × 100 / 5.68 provided M2 is < 5.68

1

= 90.2% ***OR*** 90.3%

Allow alternative methods.

M1 = Moles $ZnCl_2$ = 10.7 (= 0.0784)
136.4

M2 = Theoretical moles Zn = 5.68 (= 0.0869)
65.4

M3 = M1 × 100 / M2 = (0.0784 × 100 / 0.0869)

*M4 = 90.2% **OR** 90.3%*

1

(d) Ionic

If not ionic CE = 0/3

1

Strong (electrostatic) attraction (between ions)

1

between oppositely charged ions / + and − ions / F^- and Zn^{2+} ions

If IMF, molecules, metallic bonding implied CE = 0/3

1

[14]

Q11.

(a) (CO_2 from) burning (fossil) fuels

1

(b) $NaCl + CO_2 + NH_3 + H_2O \rightarrow NaHCO_3 + NH_4Cl$

Allow multiples, including fractions.

Ignore state symbols.

1

(c) $CaO + 2NH_4Cl \rightarrow CaCl_2 + 2NH_3 + H_2O$

Allow multiples, including fractions.

Allow ionic equations.

Do not allow equations involving NH_4OH or NH_4^+ on the right hand side.

Ignore state symbols.

1

(d) (i) = (106) × 100 / (117 + 100(.1))

Do not penalise precision but must be to minimum of two significant figures.

1

= 48.8

This answer without working scores 1 mark only.

1

(ii) The percentage atom economy cannot be improved

OR

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Sell the by-product / $CaCl_2$ (solution)

Do not accept answers which refer to improving the efficiency of the process.

1

(e) It is used up but then regenerated later in the cycle / No overall consumption of NH_3

Allow 'can act as a catalyst'.

1

[7]

Q12.

(a) Cobalt has variable oxidation states

Allow exists as Co(II) and Co(III)

1

(It can act as an intermediate that) lowers the activation energy

Allow (alternative route with) lower E_a

1

$CH_3CHO + 2Co^{3+} + H_2O \rightarrow CH_3COOH + 2Co^{2+} + 2H^+$

Allow multiples; allow molecular formulae

Allow equations with H_3O+

1

$\frac{1}{2}O_2 + 2Co^{2+} + 2H^+ \rightarrow 2Co^{3+} + H_2O$

1

(b) (i) $[Co(H_2O)_6]^{2+} + 3H_2NCH_2CH_2NH_2 \rightarrow [Co(H_2NCH_2CH_2NH_2)_3]^{2+} + 6H_2O$

Do not allow en in equation, allow $C_2H_8N_2$

1

The number of particles increases / changes from 4 to 7

Can score M2 and M3 even if equation incorrect or missing provided number of particles increases

1

So the entropy change is positive / disorder increases / entropy increases

1

(ii) Minimum for **M1** is 3 bidentate ligands bonded to Co

Ignore all charges for M1 and M3 but penalise charges on any ligand in M2

1

Ligands need not have any atoms shown but diagram must show 6 bonds from ligands to Co, 2 from each ligand

Minimum for **M2** is one ligand identified as H_2N-----NH_2

Allow linkage as −C−C− or just a line.

1

Minimum for **M3** is one bidentate ligand showing two arrows from

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separate nitrogens to cobalt

1

(c) Moles of cobalt = (50 × 0.203) / 1000 = <u>0.01015</u> mol

Allow 0.0101 to 0.0102

1

Moles of AgCl = 4.22/143.4 = 0.0294

Allow 0.029

*If not AgCl (eg $AgCl_2$ or $AgNO_3$), lose this mark and can only score **M1, M4** and **M5***

1

Ratio = Cl^- to Co = 2.9 : 1

*Do not allow 3 : 1 if this is the only answer but if 2.9:1 seen somewhere in answer credit this as **M3***

1

$[Co(NH_3)_6]Cl_3$ (square brackets not essential)

1

Difference due to incomplete oxidation in the preparation

Allow incomplete reaction.

Allow formation $[Co(NH_3)_5Cl]Cl_2$ etc.

Some chloride ions act as ligands / replace NH_3 in complex.

Do not allow 'impure sample' or reference to practical deficiencies

1

[15]

Q13.

(a) (i) Two rings only around nitrogen or sulfur

Lose this mark if more than 2 atoms are ringed.

Do not allow two atoms at the same end of the ion.

1

(ii) 275.8

Accept this answer only. Do not allow 276

1

(iii) Carboxylate / COO^-

Allow salt of carboxylic acid or just carboxylic acid.

1

(b) (32.1 / 102.1) = 31.4%

Do not penalise precision but do not allow 1 significant figure.

1

(c) Zineb is mixed with a <u>solvent / water</u>

Max=2 if M1 missed

1

Use of column / paper / TLC

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Lose M1 and M2 for GLC

1

Appropriate collection of the ETU fraction
OR Appropriate method of detecting ETU

Allow ETU is an early fraction in a column or collecting a range of samples over time, lowest retention time / travels furthest on paper or TLC (allow 1 mark for having the longest retention time in GLC).

1

Method of identification of ETU (by <u>comparison</u> with standard using chromatography)

If method completely inappropriate, only M1 is accessible

1

[8]

Q14.

(a) P = 100 000 Pa and T = 298 K

Wrong conversion of V or incorrect conversion of P / T lose M1 + M3

1

$$n = \frac{PV}{RT} \text{ or } \frac{100\,000 \times 4.31}{8.31 \times 298}$$

If not rearranged correctly then cannot score M2 and M3

1

n(total) = 174(.044)

1

n (NO) = <u>69.6</u>

Allow student's M3 × 4 / 10 but must be to 3 significant figures

1

(b) (i) $\frac{3000}{17}$

Allow answer to 2 significant figures or more

1

176.5

Allow 176 − 177
But if answer = 0.176 − 0.18 (from 3 / 17) then allow 1 mark

1

(ii) 176.47 × 46 = 8117.62

M1 is for the answer to (b)(i) × 46. But lose this mark if 46 ÷ 2 at any stage
However if 92 ÷ 2 allow M1

1

$$8117.62 \times \frac{80}{100} \ (= 6494\ \text{g})$$

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M2 is for M1 × 80 / 100

1

$$\frac{6494}{1000} = 6.5$$

M3 is for the answer to M2 ÷ 1000 to min 2 significant figures (kg)

OR

If 163 mol used:
163 × 46 = 7498 (1)

$$7498 \times \frac{80}{100} = 5998.4\,\text{g}\,(1)$$

6.00 kg (1)

1

(c) $0.543 \times \frac{2}{3} (= 0.362)$

if not $\times \frac{2}{3}$ CE = 0/2

1

$$0.362 \times \frac{1000}{250} = 1.45\,(\text{mol dm}^{-3})$$

Allow 1.447 − 1.5 (mol dm^{-3}) for 2 marks

1

(d) NO_2 contributes to acid rain / is an acid gas / forms HNO_3 / NO_2 is toxic / photochemical smog

Ignore references to water, breathing problems and ozone layer.
Not greenhouse gas

1

(e) Ensure the ammonia is used up / ensure complete reaction or combustion

OR

Maximise the yield of nitric acid or products

1

(f) Neutralisation

Allow acid vs alkali or acid base reaction

1

[14]

Q15.

(a) P = 100 000 (Pa) and V = 5.00 x 10^{-3} (m^3)

M1 is for correctly converting P and V in any expression or list Allow 100 (kPa) and 5 (dm^3) for M1.

1

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$$n = \frac{PV}{RT} = \frac{100\ 000 \times 5.00 \times 10^{-3}}{8.31 \times 298}$$

M2 is correct rearrangement of PV = nRT

1

= 0.202 moles (of gas produced)

This would score M1 and M2.

Therefore $\frac{0.202}{5}$ = 0.0404 moles B_2O_3

M3 is for their answer divided by 5

1

Mass of B_2O_3 = 0.0404 x 69.6

M4 is for their answer to M3 x 69.6

1

= 2.81 (g)

M5 is for their answer to 3 sig figures.

2.81 (g) gets 5 marks.

1

(b) $B + 1.5\ Cl_2 \rightarrow BCl_3$

Accept multiples.

1

3 bonds

1

Pairs repel equally/ by the same amount

Do not allow any lone pairs if a diagram is shown.

1

(c) (i) 43.2/117.3 (= 0.368 moles BCl_3)

1

0.368 x 3 (= 1.105 moles HCl)

Allow their BCl_3 moles x 3

1

Conc HCl = $\frac{1.105 \times 1000}{500}$

Allow moles of HCl × 1000 / 500

1

= 2.20 to 2.22 mol dm^{-3}

Allow 2.2

Allow 2 significant figures or more

1

(ii) $H_3BO_3 + 3NaOH \rightarrow Na_3BO_3 + 3H_2O$

Allow alternative balanced equations to form acid salts.

Allow $H_3BO_3 + NaOH \rightarrow NaBO_2 + 2H_2O$

1

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(d) $\frac{10.8}{120.3}(\times 100)$

Mark is for both M_r values correctly as numerator and denominator.

1

8.98(%)

Allow 9(%).

1

Sell the HCl

1

(e) Alternative method

Cl = 86.8%

Cl = 142 g

1

$\frac{\text{B}}{\frac{13.2}{10.8}}$ $\frac{\text{Cl}}{\frac{86.8}{35.5}}$

$\frac{B}{\frac{21.6}{10.8}}$ $\frac{Cl}{\frac{142}{35.5}}$

1

1.22 *2.45 or ratio 1:2 or BCl_2*

2:4 ratio

1

BCl_2 has M_r of 81.8 so
81.8 x 2 = 163.6
Formula = B_2Cl_4

B_2Cl_4

Allow 4 marks for correct answer with working shown.

Do not allow $(BCl_2)_2$

1

[20]

Q16.

(a) q = 500 × 4.18 × 40

Do not penalise precision.

1

= 83600 J

Accept this answer only.

Ignore conversion to 83.6 kJ if 83600 J shown.

Unit not required but penalise if wrong unit given.

Ignore the sign of the heat change.

An answer of 83.6 with no working scores one mark only.

An answer of 83600 with no working scores both marks.

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1

(b) Moles (= 83.6 / 51.2) = 1.63

Using 77400 alternative gives 1.51 mol

Allow (a) in kJ / 51.2

Do not penalise precision.

1

Mass = 1.63 × 40(.0) = 65.2 (g)

Allow 65.3 (g)

Using 77400 alternative gives 60.4 to 60.5

Allow consequential answer on M1.

1 mark for M_r (shown, not implied) and 1 for calculation.

Do not penalise precision.

2

(c) Molarity = 1.63 / 0.500 = 3.26 mol dm–3

Allow (b) M1 × 2

Using 1.51 gives 3.02

1

(d) Container splitting and releasing irritant / corrosive chemicals

Must have reference to both aspects; splitting or leaking (can be implied such as contact with body / hands) ***and*** *hazardous chemicals.*

Allow 'burns skin / hands' as covering both points

Ignore any reference to 'harmful'.

Do not allow 'toxic'.

1

(e) (i) $4Fe + 3O_2 \rightarrow 2Fe_2O_3$

Allow fractions / multiples in equation.

Ignore state symbols.

1

(ii) Iron powder particle size could be increased / surface area lessened

Decrease in particle size, chemical error = 0 / 3

Change in oxygen, chemical error = 0 / 3

1

Not all the iron reacts / less reaction / not all energy released / slower release of energy / lower rate of reaction

Mark points M2 and M3 independently.

1

Correct consequence of M2

An appropriate consequence, for example

- *too slow to warm the pouch effectively*
- *lower temperature reached*
- *waste of materials*

1

(f) (i) Conserves resources / fewer disposal problems / less use of landfill / fewer waste products

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Must give a specific point.

Do not allow 'does not need to be thrown away' without qualification.

Do not accept 'no waste'.

1

(ii) Heat to / or above 80 °C (to allow thiosulfate to redissolve)

Accept 'heat in boiling water'.

If steps are transposed, max 1 mark.

1

Allow to cool before using again

Reference to crystallisation here loses this mark.

1

[14]

Q17.

(a) Co-ordinate / dative / dative covalent / dative co-ordinate

Do not allow covalent alone

1

(b) (lone) pair of electrons on <u>oxygen/O</u>

If co-ordination to O^{2-}, CE=0

1

forms co-ordinate bond with <u>Fe</u> / donates electron pair to <u>Fe</u>

'Pair of electrons on O donated to Fe□ scores M1 and M2

1

(c) 180° / 180 / 90

Allow any angle between 85 and 95

Do not allow 120 or any other incorrect angle

Ignore units eg °C

1

(d) (i) 3 : 5 / 5 FeC_2O_4 reacts with 3 MnO_4^-

Can be equation showing correct ratio

1

(ii) **M1** Moles of MnO_4^- per titration = 22.35 × 0.0193/1000 = <u>4.31×10^{-4}</u>

Method marks for each of the next steps (no arithmetic error allowed for M2):

Allow <u>4.3×10^{-4}</u> (2 sig figs)

Allow other ratios as follows:

eg from given ratio of 7/3

1

M2 moles of FeC_2O_4= ratio from (d)(i) used correctly × 4.31×10^{-4}

M2 *= 7/3 × 4.31×10^{-4} = 1.006×10^{-3}*

1

M3 moles of FeC_2O_4 in 250 cm^3 = M2 ans × 10

M3 *= $1.006 \times 10^{-3} \times 10 = 1.006 \times 10^{-2}$*

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1

M4 Mass of $FeC_2O_4.2H_2O$ = M3 ans × 179.8

M4 *= 1.006 × 10^{-2} × 179.8 = 1.81 g*

1

M5 % of $FeC_2O_4.2H_2O$ = (M4 ans/1.381) × 100

M5 *= 1.81 × 100/1.381 = 131 % (130 to 132)*

1

(OR for M4 max moles of $FeC_2O_4.2H_2O$ = 1.381/179.8 (= 7.68 × 10^{-3})
for M5 % of $FeC_2O_4.2H_2O$ = (M3 ans/above M4ans) × 100)
eg using correct ratio 5/3:
Moles of FeC_2O_4 = 5/3 × 4.31 × 10^{-4} = 7.19 × 10^{-4}
Moles of FeC_2O_4 in 250 cm^3 = 7.19 × 10^{-4} × 10 = 7.19 × 10^{-3}
Mass of $FeC_2O_4.2H_2O$ = 7.19 × 10^{-3} × 179.8 = 1.29 g
% of $FeC_2O_4.2H_2O$ = 1.29 × 100/1.381 = 93.4 (allow 92.4 to 94.4)
Note correct answer (92.4 to 94.4) scores 5 marks

Allow consequentially on candidate's ratio
eg ***M2*** *= 5/2 × 4.31 × 10^{-4} = 1.078 × 10^{-3}*
M3 *= 1.0078 × 10^{-3} × 10 = 1.078 × 10^{-2}*
M4 *= 1.078 × 10^{-2} × 179.8 = 1.94 g*
M5 *= 1.94 × 100/1.381 = 140 % (139 to 141)*
Other ratios give the following final % values
1:1 gives 56.1% (55.6 to 56.6)
5:1 gives 281% (278 to 284)
5:4 gives 70.2% (69.2 to 71.2)

[10]

Q18.

(a) Any **two** from:

Weigh by difference or rinse weighing bottle and add to beaker

Rinse beaker and add washings to graduated flask

Invert flask several times to ensure uniform solution

Use a funnel to transfer to the flask and rinse the funnel

Use a stirrer to prepare the solution and rinse the stirrer

If more than two answers apply the list rule.

Max 2

(b) $K_a = [H^+]^2 / [HA]$

Allow any correct expression relating K_a, $[H^+]$ and [HA]

1

$[HA] = (10^{-2.50})^2 / 1.07 \times 10^{-3}$

M2 also scores M1

1

$= 9.35 \times 10^{-3}$ (mol dm^{-3})

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Do not allow 9.4 (answer is 9.346).

Correct answer only scores 1 mark.

Do not penalise precision but must be to at least two significant figures.

1

(c) (b) × 138.0 / 4

1

= 0.322

Using 8.50 × 10^{-3} gives 0.293

Correct answer scores M1 and M2.

Do not penalise precision but must be to at least two significant figures.

1

(d) (c) × 100 / 0.500 = 64.5%

Using 0.293 from (c) gives 58.7%

Using 0.347 gives 69.4%

Do not penalise precision.

1

[8]

Q19.

(a) Theoretical mass produced = 180 × 2 / 138 = 2.61 g

Using 1.76 × 100 / 2 is a chemical error (CE), scores 0 / 2

1

Percentage yield = 1.76 × 100 / 2.61 = 67.5%

Correct answer scores M1 and M2.

Accept 67.4%

Do not penalise precision but answers must be to at least two significant figures.

1

(b) Crystals lost when filtering or washing / some aspirin stays in solution / other reactions occurring

Ignore references to impurities.

1

[3]

Q20.

(a) Mol Pb = 8.14 / 207(.2) (= 0.0393 mol)

M1 and M2 are process marks

1

Mol HNO_3 = 0.0393 × 8 / 3 = 0.105 mol

Allow mark for M1 × 8/3 or M1 × 2.67

1

Vol HNO_3 = 0.105 / 2 = 0.0524 (dm^3)

Accept range 0.0520 to 0.0530

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No consequential marking for M3

Answer to 3 sig figs required

1

(b) 101000 (Pa) and 638×10^{-6} (m^3)

1

$n = pV/RT \quad (= \frac{101000 \times 638 \times 10^{-6}}{8.31 \times 298})$

Can score M2 with incorrect conversion of p and V

If T incorrect lose M1 and M3

1

0.026(0) (mol)

If answer correct then award 3 marks

Allow answers to 2 sig figs or more

26.02 = 1

If transcription error lose M3 only

1

(c) (i) $2Pb(NO_3)_2(s) \rightarrow 2\ PbO(s) + 4NO_2(g) + (1)O_2(g)$

Allow multiples

Allow fractions

1

(ii) Decomposition not complete / side reactions / by-products / some (NO_2) escapes / not all reacts / impure $Pb(NO_3)_2$

Ignore reversible / not heated enough / slow

1

(iii) Hard to separate O_2 from NO_2 / hard to separate the 2 gases

Allow mixture of gases

Not 'all products are gases'

1

[9]

Q21.

(a) (i) 0.0212

Need 3 sig figs

Allow correct answer to 3 sig figs eg 2.12 x 10^{-2}

1

(ii) 0.0106

Mark is for (a)(i) divided by 2 leading to correct answer 2 sig figs

1

(iii) M_r = 100.1

1.06 g

Allow 100.1 as 'string'

Need 3 sig figs or more

Consequential on (a)(ii) x 100(.1)

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2

(iv) Neutralisation or acid / base reaction

Allow acid / alkali reaction

Apply list principle

1

(b) (i) T = 304(K) and P = 100 000 (Pa)

Only T and P correctly converted

1

$$\frac{100\,000 \times 3.50 \times 10^{-3}}{8.31 \times 304} \text{ OR } n = \frac{PV}{RT}$$

1

0.139 (mol)

Allow <u>0.138 – 0.139</u>

1

(ii) 0.0276 – 0.0278(mol)

Allow answer to (b)(i) divided by 5 leading to a correct answer

Allow 0.028

1

(c) 4.20 g $Ca(NO_3)_2$

1

$Ca(NO_3)_2$ H_2O

$$\frac{4.20}{164(.1)} \qquad \frac{1.84}{18}$$

Mark is for dividing by the correct Mr values

M2 and M3 dependent on correct M1

0.0256 0.102

M2 can be awarded here instead

1 : 3.98

x = 4

If $Ca(NO_3)_2.4H_2O$ seen with working then award 3 marks

Credit alternative method which gives x = 4

1

[12]

Q22.

(a) (i) Volume of crater-lake solution on x-axis

Do not penalise missing axes labels.

If axes unlabelled use data to decide.

Lose this mark if axes mis-labelled.

1

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Sensible scales

*Lose this mark if **plotted points** do not cover at least half the paper or plot goes off the squared paper.*

1

All points plotted correctly +/– one square

1

(ii) Draws appropriate line of best fit, omitting point at 20 cm^3 / 15 cm^3

Lose this mark if the line deviated towards the anomalous result.

Lose this mark if the candidate's line is doubled or kinked.

Candidate does not have to extrapolate to the origin.

1

(iii) 16.5 cm^3 +/– 0.5 cm^3

Accept this answer only.

Do not mark consequentially on candidate's graph.

1

(iv) Value corresponding to 10 cm^3 crater-lake solution / 6.00 cm^3

Must have correct identity for explanation mark.

Accept results aren't concordant.

1

Greatest % error from use of burette

Accept difficult to be accurate with small volumes (owtte).

1

(b) (i) $pV = nRT$

Accept any correct rearrangement.

Ignore case.

1

(ii) $V = 81.0 \times 10^{-6}$ or 8.1×10^{-5}

1

$n = (1 \times 10^5 \times 81.0 \times 10^{-6}) / (8.31 \times 298)$

Mark consequentially on candidate's volume.

1

$n = 3.27 \times 10^{-3}$ (mol)

Correct answer without working scores one mark only.

Allow consequential mark using incorrect conversion.

Incorrect units lose this mark.

1

(iii) M_r $CaCO_3$ = 100.1 (M1)

Accept 100 (can score this mark in calculation for M2 and M3).

1

Moles $CaCO_3 = (3.27 \times 10^{-3} \times 10) = 3.27 \times 10^{-2}$ (M2)

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Do not penalise lack of units.
Allow b(ii) × 10
Allow 1.25 × 10^{-3} × 10

1

Mass $CaCO_3$ = M1 × M2 (= 3.27 g)
Correct mass without working scores one mark only.
Allow 1.25 × 10^{-2} × 10 × 100.1= 12.5 g

1

(iv) (3.27 / 95) × 100
Accept (b(iii) / 95) × 100.
Do not penalise precision.

1

3.44 g
Do not penalise lack of units.
Using 12.5 g gives 13.2 g
Correct answer without working scores 2 marks.

1

(v) Abundant / readily available
Accept not caustic or alkaline.

Non-corrosive
Accept insoluble so safe to add in excess (owtte).

1

[17]

Q23.

(a) (ligand) substitution
Allow 'ligand exchange'.

1

(b) To displace the equilibrium to the right
To ensure reaction goes to completion.

1

To improve the yield
Allow 'to replace all chlorines'.

1

(c) (i) $K_2PtCl_4 + 4KI \rightarrow K_2PtI_4 + 4KCl$
Allow correct ionic equations $PtCl_4^{2-} + 4I^- \rightarrow PtI_4^{2-} + 4Cl^-$
Allow multiples and fractions.

1

(ii) = (780.9) ×100 / (415.3 + 664)
Working must be clearly shown.
Allow one mark for correct relationship even if M_r values are incorrect eg using values from ionic equation.

1

= 72.4

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Allow 72%

1

(d) (i) $Ag^+ + I^- \rightarrow AgI$

Ignore state symbols even if incorrect.

This equation only.

1

(ii) Stops the reverse reaction / equilibrium displaced to the right

1

(e) Number of steps in the process

Allow 'equilibrium may lie on the reactant side' / side reactions / isomer formation.

1

Losses at each stage of the synthesis

Equilibrium losses or practical losses or yield not 100% for each step.

1

(f) Minimum amount of hot solvent

Accept 'small' for minimum.

Accept water.

1

Cool / crystallise

1

Filter

1

(g) (i) Small amounts are more likely to kill cancer cells rather than the patient

1

(ii) Wear gloves / wash hands after use

Ignore masks.

Apply the list principle if more than one answer.

1

[15]

Q24.

(a) (i) $EDTA^{4-} + [Cu(H_2O)_6]^{2+} \rightarrow [Cu(EDTA)]^{2-} + 6H_2O$

1

(ii) (Mol EDTA = (6.45/1000) ×0.015 =)9.68×10^{-5} mol Cu(II)

1

Conc. Cu(II) = ((9.68×10^{-5}) / 0.025 =) 0.00387 mol dm^{-3}

Correct answer without working gains M2 only.

1

(b) Samples may not be consistent throughout the river
OR
Concentration may vary over time

Ignore comments on technique.

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1

(c) $[Ag(NH_3)_2]^+$

Accept name eg diamminesilver(I) ion.

1

aldehyde

Allow CHO.

1

[6]

Q25.

(a) $Fe + H_2SO_4 \rightarrow FeSO_4 + H_2$

Accept multiples.

Ignore state symbols, even if incorrect.

1

(b) Hazard acid corrosive **or**
hydrogen flammable / explosive

Accept 'iron(II) sulfate / sulfuric acid an irritant'.

1

Precaution gloves or eye protection **or**
avoid naked flames / spark

Allow 'if reagent contacts skin wash off immediately' or answers to that effect instead of gloves.

Do not allow 'wipe up spillages'.

Ignore 'lab coat' or 'use of fume cupboard' or 'do not ingest chemicals'.

1

[3]

Q26.

(a) (i) $\underline{4.98 \times 10^{-3}}$

1

Only

(ii) 2.49×10^{-3}

Allow answer to (a)(i) ÷ 2

Allow answers to 2 or more significant figures

1

(iii) 2.49×10^{-2}

Allow (a)(ii) × 10

Allow answers to 2 or more significant figures

1

(iv) 138.2

3.44 divided by the candidate.s answer to (a)(iii)

138.2 or 138.1 (i.e. to 1 d.p.)

1

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(v) (138 – 60) ÷ 2 = 39.1

Allow 39 – 39.1

Allow ((a)(iv) – 60) ÷ 2

1

K/potassium

Allow consequential on candidate's answer to (a)(iv) and (a)(v) if a group 1 metal

Ignore + sign

1

(b) PV = n RT or rearranged

If incorrectly rearranged CE = 0

1

$$T = \frac{0.022 \times 100000}{0.658 \times 8.31}$$

Correct M2 also scores M1

1

402(.3) K (or 129 °C)

allow 402-403K

or 129-130 °C

do not penalise °K

M3 must include units for mark

1

(c) Pressure build up from gas/may explode/stopper fly out/glass shatters/breaks

Penalise incorrect gas

1

(d) (i) M_r = 84.3

If 84 used, max 1

1

$\frac{6.27}{84.3}$ = 0.074(4)

CE if not 84 or 84.3

Allow answers to 2 or more significant figures

M2 = 0.074-0.075

1

(ii) M1 M_r $MgSO_4$ = 120(.4)

allow 120.3 and 120.1

CE if wrong Mr

1

M2 Expected mass $MgSO_4$ = 0.074(4) × 120(.4) = 8.96 g

Allow 8.8 – 9.0 or candidate's answer to (d)(i) × 120(.4)

1

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M3 95% yield = $\frac{8.96 \times 95}{100}$ = 8.51 g

Allow 8.3 – 8.6

M3 dependent on M2

Alternative method

M2 0.074(4) × 95/100 = 0.0707

M3 0.0707 × 120(.4) = 8.51 g

Allow (d)(i) × 95/100

Allow 8.3 – 8.6

M3 dependent on M2

1

[15]

Q27.

(a) (i) Ammonia

If reagent is missing or incorrect cannot score M3

1

Starts as a pink (solution)

1

Changes to a yellow/straw (solution)

Allow pale brown

Do not allow reference to a precipitate

1

(ii) (dark) brown

Do not allow pale/straw/yellow-brown (i.e. these and other shades except for dark brown)

1

(b) (i) Ruby/red-blue/purple/violet/green

Do not allow red or blue

If ppt mentioned contradiction/CE =0

1

Green

If ppt mentioned contradiction/CE =0

1

$[Cr(H_2O)_6]^{3+} + 6OH^- \rightarrow [Cr(OH)_6]^{3-} + 6H_2O$

1

Formula of product

Can score this mark in (b) (ii)

1

(ii) $H_2O_2 + 2e^- \rightarrow 2OH^-$

1

$2[Cr(OH)_6]^{3-} + 3H_2O_2 \rightarrow 2CrO_4^{2-} + 8H_2O + 2OH^-$

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Allow 1 mark out of 2 for a balanced half-equation such as $Cr(III) \rightarrow Cr(VI) + 3e^-$

or $Cr^{3+} + 4H_2O \rightarrow CrO_4^{2-} + 8H^+ + 3e^-$ *etc*

also for $2Cr(III) + 3H_2O_2 \rightarrow 2CrO_4^{2-}$ *(unbalanced)*

2

Yellow

Do not allow orange

1

(c) $2MnO_4^- + 6H^+ + 5H_2O_2 \rightarrow 2Mn^{2+} + 8H_2O + 5O_2$

if no equation and uses given ratio can score M2, M3, M4 & M5

1

Moles MnO_4^- = (24.35/1000) × 0.0187 = $\underline{4.55 \times 10^{-4}}$

Note value must be quoted to at least 3 sig. figs.

M2 is for 4.55×10^{-4}

1

Moles H_2O_2 = (4.55×10^{-4}) $\underline{\times 5/2}$ = 1.138×10^{-3}

M3 is for × 5/2 (or 7/3)

Mark consequential on molar ratio from candidate's equation

1

Moles H_2O_2 in 5 cm^3 original

M4 is for × 10

1

= (1.138×10^{-3}) $\underline{\times 10}$ = 0.01138

Original $[H_2O_2]$ = 0.01138 $\underline{\times (1000/5)}$ = 2.28 mol dm^{-3}

(allow 2.25-2.30)

M5 is for consequentially correct answer from (answer to mark 4) × (1000/5)

Note an answer of between 2.25 and 2.30 is worth 4 marks)

If candidate uses given ratio 3/7 max 4 marks:

M1*: Moles of* MnO_4^- = $\underline{4.55 \times 10^{-4}}$

M2*: Moles* $H_2O_2 = (4.55 \times 10^{-4}) \underline{\times 7/3} = 1.0617 \times 10^{-3}$

M3*: Moles* H_2O_2 *in 5* cm^3 *original*

$= (1.0617 \times 10^{-3}) \times 10 = 0.01062$

M4: Original $[H_2O_2] = 0.01062 \times (1000/5) = 2.12$ *mol* dm^{-3}

(allow 2.10 to 2.15)

1

[17]

Q28.

(a) (i) M_r MgO = 40.3

If used 40 then penalise this mark but allow consequential M2 (0.0185)

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1

0.741/40.3 = 0.0184

0.018 with no M_r shown = 0
Penalise if not 3 sig figs in this clip only

1

(ii) 0.0184 × 5/2 = 0.0460

Allow 0.0459 to 0.0463
Allow their (a)(i) × 5/2 ie allow process mark of × 5/2 but insist on a correct answer being written down
Ignore sig figs

1

(b) pV = nRT

1

$$(V = \frac{0.402 \times 8.31 \times 333)}{100\,000})$$

If rearranged incorrectly then lose M1
If this expression correct then candidate has scored first mark

0.0111

1

Ignore units

11.1 (dm^3)

3 marks for 11.1 (dm^3)
However if 11.1 m^3 or cm^3 allow 2 (ie penalise wrong units in final answer)
Ignore sig figs- but must be 2 sig figs or greater

1

(c) (i) 0.0152 × 2 = 0.0304

Allow 0.03

1

(ii) 0.938 mol dm^{-3}

Allow range 0.92 – 0.94
Minimum 2 sig figs
Allow consequential marking from (c)(i)
Ignore units even if wrong

1

[8]

Q29.

(a) (i) 0.150

Accept 0.15

1

(ii) 0.0750

Accept 0.75
Accept consequential answer from (i)

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1

(iii) 106.0

Must have M_r to 1 d.p. to score mark.
Only penalise once in paper
Do not penalise correct answer in g.
Ignore wrong units.

1

(iv) 7.95

Accept consequential answer from (ii) and (iii).

1

(b) Hazard: (acid) corrosive
Precaution: eye protection / gloves

Both hazard and appropriate precaution needed for 1 mark.
Do not accept 'toxic' as hazard.
Accept 'irritant vapour' and 'fume cupboard'.
Do not accept 'ingest'.

1

[5]

Q30.

(a) pV = nRT

Do not penalise incorrect use of capitals / lower case letters.
Accept correct rearrangement of equation.

1

(b) $\mathbf{2}C_4H_{10} + \mathbf{5}O_2 \rightarrow \mathbf{4}CH_3COOH + \mathbf{2}H_2O$

Accept any correct combination of multiples, including fractions.

1

(c) 23.0 g ethanol produces 30.0 g ethanoic acid

1

15.1% (4.54 ×100 / 30)

Do not penalise precision.
15.1% scores 2 marks.
Accept consequential answer on wrong mass of ethanoic acid for second mark only.

1

[4]

Q31.

(a) 2-6 drops / 0.1-0.3 cm^3

Accept 'a few drops'

1

(b) Incorrect volume recorded / space will fill during titration / produces larger titre value

Do not accept 'to give an accurate result' without further qualification

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Do not accept references to contamination

1

[2]

Q32.

(a) Hydrogen/H_2 gas/bubbles

1

1.0 mol dm^{-3} HCl/H^+

1

At 298K and 100kPa

Allow 1 bar instead of 100 kPa
Do not allow 1 atm

1

Pt (electrode)

1

(b) $Li^+ + MnO_2 + e^- \rightarrow LiMnO_2$

Ignore state symbols

1

–0.13(V)

1

(c) Fe^{3+} ions reduced to Fe^{2+}

Can score from equation/scheme

1

Because $E(Fe^{3+}/Fe^{2+}) > E(H^+/H_2)$/$E$(hydrogen)

Allow emf/E_{cell} +ve/0.77V
Allow Fe^{3+} better oxidising agent than H^+
Allow H_2 better reducing agent than Fe^{2+}
Only award this explanation mark if previous mark given

1

(d) Moles $Cr_2O_7^{2-}$ =$\underline{23.7 \times 0.01/1000}$ = 2.37×10^{-4}

1

1 mol $Cr_2O_7^{2-}$ reacts with 6 mol Fe^{2+} so moles Fe^{2+} in 25 cm^3 = $6 \times 2.37 \times 10^{-4} = 1.422 \times 10^{-3}$

1

M1 × 6

Moles Fe^{2+} in 250 cm^3 = 1.422×10^{-2}

M2 × 10 or M4/10

1

Original moles Fe^{2+} = $\underline{10.00/277.9}$ = 0.0360

Independent mark

1

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Moles Fe^{2+} oxidised = 0.0360 – 0.0142 = 0.0218

M4 – M3

1

% oxidised = (0.0218 × 100)/0.0360 = 60.5%

(M5 × 100)/M4
Allow 60 to 61
Note Max 3 if mol ratio for M2 wrong
eg 1:5 gives 67.1%
1:1 gives 93.4%
Note also, 39.5% (39-40) scores M1, M2, M3 and M4 (4 marks)

1

[14]

Q33.

(a) (i) Propanone evaporates (or similar)

1

Removes water (from the precipitate)

Accept 'removes impurities / excess reagents'.
Accept 'salt insoluble in propanone'.

1

(ii) Add NaOH / NH_3 / Na_2CO_3

1

No green ppt

Accept 'no visible change'.
Must have correct reagent to score this mark.

1

(iii) Some salt dissolves (in propanone) **or** some lost in filtration **or** some Fe^{2+} gets oxidised (to Fe^{3+} in air)

Do not accept 'reaction reversible' or 'incomplete reaction' or similar.

1

(iv) Moles $Fe^{2+} = 2.50 \times 10^{-2}$

Accept 2.5×10^{-2}

1

M_r of salt = 179.8

Allow 180
Allow if 179.8 or 180 appears in a calculation.

1

Mass of salt = $179.8 \times 2.5 \times 10^{-2} \times 0.95 = 4.27$ (g)

Correct answer with no working scores this mark only.
Allow range 4.2 to 4.3 (g)

1

(v) 1.67 mol or correct ratio of $5FeC_2O_4 : 3MnO_4^-$

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1

(b) $Ca^{2+} + C_2O_4^{2-} \rightarrow CaC_2O_4$

Accept multiples.

1

(c) (Insoluble) calcium ethanedioate coats surface

Allow 'calcium ethanedioate is insoluble'.

Do not allow answers based on ethanedioic acid being a weak acid.

Do not accept 'acid used up' or 'reaction very fast'.

1

(d) Small amount of tea used **or** concentration of the acid in tea is low

Accept 'high temperature decomposes the acid'.

Accept 'calcium ions in milk form a precipitate with the acid'.

Do not accept 'do not drink tea often' or similar.

1

(e) Mass of acid = 180.0 and mass of reagents = 450.0

Accept 180 and 450.

1

(180 / 450 ×100 =) 40.0%

Do not penalise precision.

Correct answer without working scores this mark only.

1

[14]

Q34.

(a) 34.0

Penalise precision once

1

(b) 1.76 mol dm^{-3}

1

(c) answer to (b) divided by 0.05

35(.3) on correct figures

1

Shows working

Correct answer only scores this mark

Lose this mark if any units are given for the factor

1

[4]

Q35.

(a) (i) M_r = 132.1

1

132

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0.0238

Allow 0.024
Allow 0.0237
Penalise less than 2 sig fig once in (a)

1

(ii) 0.0476

1

0.0474-0.0476
Allow (a) (i) × 2

(iii) 1.21

Allow consequential from (a) (ii)
ie allow (a) (ii) × 1000/39.30
Ignore units even if wrong

1

(b) $\frac{34 \times 100}{212.1}$

Allow mass or Mr of desired product times one hundred divided by total mass or Mr of reactants/products
If 34/212.1 seen correctly award M1

1

= 16.0(3)%

Allow 16%
16 scores 2 marks

1

(c) 100(%)

Ignore all working

1

(d) PV = nRT or n = $\frac{PV}{RT}$

If rearranged incorrectly lose M1 and M3

1

n = $\frac{100000 \times 1.53 \times 10^{-2}}{8.31 \times 310}$

M2 for mark for converting P and T into correct units in any expression

1

= 0.59(4)

Allow 0.593
M3 consequential on transcription error only not on incorrect P and T

1

(e) (Na_2SO_4) H_2O
(44.1%) 55.9%

M1 is for 55.9

1

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44.1/142.1 55.9/18
0.310 3.11
= 1 = 10

Alternative method gives180 for water part = 2 marks

1

x = 10

X = 10 = 3 marks
10.02 = 2 marks

1

[13]

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Q1.

Most students gave correct observations in part (a) but their attempts at equations were less successful and often unbalanced. Very few correct answers to part (b)(i) were seen. The most usual response was to suggest, without any explanation, that the colour change was from purple to colourless. Part (b)(ii) produced a whole range of responses. Good students were able to score all 5 marks in impressive style but others lost marks. The most common mistake was an incorrect equation and the use of an incorrect molar ratio for moles of iron(II) to manganate(VII). Many students were also unable to calculate the concentration of iron(II) ions in the original solution from the number of moles of iron(II) ions in the 250 cm^3 flask. A factor of 1000/50 was required but factors such as 1000/250 or 250/25 were common mistakes.

Q2.

The skill of chemical communication is one which is being assessed here. Parts (a)(i) and (ii) were frequently well done with, occasionally the usual difficulty with what is expected for precision – this cannot be ignored by centres. Many good answers were seen for part (b)(i) but only the best students got full marks with parts of the detail missing. There appeared, for some centres, to be an obsession with washing, even ‘washing solutions’! Part (b)(ii) was well answered by many, especially where they had carried out the procedure but M3 was occasionally lost through a lack of clarity regarding the required ‘match’ with data values. Part (b)(iii) was well answered but part (c) was marked too generously; again a lack of clarity was often evident and centres were frequently too generous, misapplying the Marking Guidelines e.g. HCl is not toxic.

Q3.

All sections of this question were answered relatively poorly. A number of students did not have any awareness of the practical skills necessary to carry out a titration, or of the possible errors which would have a large impact on their results and how these could arise and should be minimised. It was common for all of the students in a centre to give similar, incorrect, responses to questions, especially part (b) where students frequently described operator errors instead of errors associated with the burette itself. It is very important that students are taught all of the background theory and essential skills of the practical techniques they meet throughout the specification as a secure knowledge and understanding of how to carry out these practicals is essential.

Q4.

This question was generally well answered, although some unusual calculations and methods were seen.

Q5.

The number of correct answers to the unstructured calculation in part (a)(i) was pleasing. However, many students lost marks because they did not use the stoichiometry in the equation to answer the question. Over half of students scored both marks in part (a)(ii) but attempts by the rest were varied. Some could not calculate the M_r correctly, some forgot to multiply by 100 and a few obviously did not know what was meant by the term atom economy. The equation in part (b) was found to be difficult by many students; the biggest error involved an incorrect formula of calcium hydroxide and consequently an incorrect equation. The empirical formula calculation was well done by many students but some

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scored zero because they did not involve calcium in their working.

Q6.

The higher-scoring students were able to complete in this Question easily but a few markers did not realise that if M1 had been lost then M2 could still be accessed if the incorrect volume had 10 cm^3 subtracted.

Q7.

In this Question, the equation was difficult but often completed well. In the test for ammonia, the requirement for a **complete** indicator colour change and for the student to make it clear that the test was not being done on the solution were areas of lenient marking.

Q8.

(a) This part was mostly well answered, with the exception of those who chose to use the wrong mass.

(b) In this part, failure to give the negative sign was the most common error where students did not score full marks.

(c) This part was usually done very well.

(d) In contrast, this part was very poorly answered, almost always because –2642 was used from (c) rather than their answer to (b).

(e) Many vague answers were seen in response to this part. Simply adding insulation was insufficient and use of a polystyrene cup was wrong in this situation.

(f) The idea of incomplete combustion seemed to be poorly understood in this part, with quite a few students stating that 'not all the alcohol had burned'. Comments about heat loss etc were disqualified by the question.

Q9.

Many good answers were seen to part (a) in which full marks were scored. However, most students used an incorrect ratio for the amount, in moles, of iron(II) that reacts with one mole of dichromate ions. For these students, the maximum they could score was three out of a possible five marks. In part (b), many students suggested, correctly, that the impurity was likely to be a reducing agent but very few went on to explain that the impurity must react with more moles of dichromate than would the same mass of $FeSO_4.7H_2O$.

Q10.

Some students found no difficulty with the three numerical parts of this question. However, this question proved challenging for many students who often gave a jumble of figures with little explanation of where they came from.

Part (a) was the most well answered of the calculations although a small number could not score the first mark. In part (b), most students scored the mark for the number of moles of HCl. However, many students then used 0.083 in their answer and did not realise that the HCl was the limiting reagent. Many added the moles of HCl to the moles of pure zinc oxide whilst others multiplied the moles of HCl by 2 rather than dividing.

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Answers to part (c) used various methods with many scoring the first two marks of the alternative method shown in the mark scheme. It should be noted that if an answer requires 3 significant figures, then the calculation should use at least 3 significant figures throughout. If less than this is used and then the answer is given as 3 'significant' figures, this will have introduced error and the final answer will not be within the margin of tolerance allowed. The bonding in part (d) was answered well by the majority of students.

Q11.

The need to burn fossil fuels to generate energy was not well appreciated in this part (a). The equations in part (b) and (c) proved surprisingly elusive. Most students gave good answers to this part (d)(ii), but had little concept of what constitutes a raw material. Most simply mentioned that ammonia was made in Reactor 3, and were usually, but wrongly, awarded a mark for this incomplete answer.

Q12.

This stretch and challenge question proved testing for many students, particularly parts (a) and (c). The most frequent mark for part (a) was one out of four for stating that cobalt has variable oxidation states. Attempts at the two equations were poor. Equations should be balanced andshould not be half-equations with electrons. Despite the parallel with similar catalysed systems in the specification, students did not appreciate that the Co^{3+} ions would be the oxidising agents, reacting with ethanal and that Co^{2+} ions would be oxidised by oxygen back to Co^{3+}. In part (b)(i), weaker students did not know that the chelate effect is explained by entropy changes and they often, incorrectly, attempted to explain the effect in terms of the stability of a complex ion with bidentate ligands. Part (b)(ii) was answered well by most students. Part (c) proved to be very discriminating with only the very best students scoring more than three out of five marks. The most difficult marks to achieve were the formula of **Z**, $[Co(NH_3)_6]Cl_3$ and an explanation for the difference between the expected and the given ratio of cobalt ions to chloride ions in the complex. Many students lost marks because they did not use a correct formula for silver chloride–incorrectly using $AgCl_2$ or $AgNO_3$. Another common error was to ignore the precision of the data given in the question and to give the calculated molar ratio to only 1 significant figure whereas 3 significant figures were required, consistent with the data given.

Q13.

(a) In part (i), most students were able to identify two appropriate atoms in the structure, but the ionic nature of Zineb resulted in many students failing to calculate its M*r* correctly in part (ii).In part (iii) proved to be demanding too, ester being the most common error.

(b) The simple calculation in this part proved straightforward for most students.

(c) This part highlighted the difficulties students face when applying theoretical ideas. Many students ignored the specific references to Zineb and ETU and wrote at length about the theory of chromatography. It was not uncommon to see long answers that did not specify the type of chromatography to be used, or make any mention of Zineb or ETU. Students were similarly reluctant to use the information in the questions to predict the outcomes for this particular separation. Such non-specific answers received few marks. A significant number of students chose gas chromatography, and even then could not make any use of the information at hand.

Q14.

Students are generally confident using the ideal gas equation although some felt the need

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to convert volume into different units as well. Many students scored three of the possible four marks in part (a) by failing to realise that the question asked about nitrogen oxide only. Some students who realised this still did not quote their answer to the required precision. In part (b), students were more likely to score marks in (b)(i) but a few did not convert to grams in order to calculate the amount in moles. Students found part (b)(ii) difficult with the most common error being the failure to understand the mole ratios in the equation. The calculation in part (c) was not well done by many students since they did not use the balanced equation given and hence did not use the correct mole ratio in their calculation. In part (d), many students referred to nitrogen dioxide as a greenhouse gas and some students failed to score a mark since they gave a list of correct and incorrect answers and were penalised for this. Most students were able to give a correct answer to part (e), although many incorrect answers stated that excess air was needed simply to give a good supply of oxygen. Most students were able to give the correct answer to part (f) although a small, but significant, number quoted exothermic or oxidation.

Q15.

The unstructured calculation in part (a) was attempted by all but a few students. Most students managed to score two marks. The most common errors were the incorrect conversion of pressure and volume into the appropriate units and a failure to divide the total moles of gas by five. The equation in part (b) was often incorrect with many examples of B_2 and atomic chlorine given. The students who knew that there were three bonding pairs of electrons often did not realise that the repulsions of the bonding pairs were equal. The calculation in part (c)(i) was reasonably well answered. Many students scored the first two marks but then incorrectly multiplied by 500/1000. Very few produced the expected equation in part (c)(ii) although the alternative equations were often seen. Many examples of the incorrect formulae '$NaBO_3$' and 'NaB' in unbalanced equations were also seen. Part (d) was well answered by the majority of students. A wide variety of methods were seen that could score full marks in part (e). The first three marks were usually obtained but the final mark proved elusive. Many students suggested that the molecular formula was $2BCl_2$ rather than the correct answer, B_2Cl_4.

Q16.

Section B proved more demanding. In part (a), the calculation had similar faults to Question 5 but some students failed to read that the answer was to be in Joules - an answer in kJ was penalized unless there was a clear correct answer in the working. Part (b) and part (c) were well done though the alternative answer to part (a) was frequently used in these. In part (d), only a few students failed to highlight the need for the bag to split or the chemicals to come into contact with skin / hands. Part (e)(i) indicated that a considerable number of students found difficulties with the equation; common errors were the wrong formula for iron (III) oxide, the inclusion of ions on the reagent side of the equation and using Fe2 for the metal. Part (e)(ii) contained many good partial answers but there was a significant failure to focus finally on why longer times might not be an advantage. In part (f)(i), the main errors were to re-state the question about being reusable or to indicate that there would be no waste following use of these handwarmers. There were some vague answers to part (f)(ii) which referred to 'heating' the bag or 'keeping it in a warm place' and, for some, the contents were removed before further treatment. Nevertheless, sensible answers were frequently seen.

Q17.

This question was answered well by most students. In part (b), a mark was lost by those students who failed to mention that the electron pair donated to the iron(II) ion by water was donated by oxygen. Part (d)(i) was the most demanding part of the question but it was pleasing to find that 37% of students gave the correct reacting ratio of 3:5 for

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MnO_4^-:FeC_2O_4. Many students tried unsuccessfully to write a balanced equation. The best students did not attempt an equation. They realised that the reduction of manganate(VII) ions is a 5–electron change reaction. The oxidation of FeC_2O_4 is a 3–electron change reaction. Therefore, the reacting ratio is 3:5. Answers to part (d)(ii) were awarded method marks and most students scored at least 4 out of the 5 marks available. Some students lost a mark for an incorrect relative formula mass of $FeC_2O_4.2H_2O$ and some for an incorrect method of calculating the percentage. Some students who used their own incorrect ratio obtained in part (d)(i) and those who used the alternative 3:7 ratio given in the question obtained an apparent mass of iron(II) ethanedioate that was greater than the original mass. A common error was for students to calculate a percentage with the mass of the impure compound as the numerator rather than the denominator.

Although question 6(d)(ii) could still be answered and all students were able to access all of the available marks, we recognise that the alternative ratio given was unhelpful and caused confusion for some students. We apologise for this and accept that it would have been better to have provided a different ratio. During marking of this question, senior examiners identified any student who used the 3:7 ratio. These students' scripts were then reviewed by experienced senior examiners and special consideration was given to any student who had clearly been disadvantaged by using the given ratio.

Q18.

(a) Many incomplete answers were given credit in this part. When the components of a two-part answer are linked by the underlined word '<u>and</u>' **both** components are needed to earn the mark.

(b) A pleasing majority of students were able to complete the calculation in this part. Occasionally, a centre was unduly harsh in penalising minor rounding in the intermediate steps.

Q19.

(a) Students continue to struggle with calculations of a yield in a chemical reaction. Only the better students completed in this part successfully.

(b) In this part, most students were able to suggest one reason for the yield not being quantitative.

Q20.

Many students found the unstructured calculation in part (a) difficult. Weaker students divided the mass by 3 × 207.2 and many did not use the 8/3 ratio. Some students obtained the correct volume of nitric acid but then failed to give their answer to the required precision. The calculation in part (b) was generally well answered by the more able students but many weaker students found the conversion of volume into the correct units difficult. The balancing of the equation in part (c)(i) was generally well done although many students attempted to correct their work by writing one number over another leading to unclear answers. It is better to cross out and rewrite numbers. There were many correct answers to part (c)(ii) although answers to part (c)(iii) showed that many students did not realise that it is hard to separate gases. A few students thought that oxygen would be difficult to separate from PbO.

Q21.

Parts (a)(i), (ii) and (iii) were generally well done although many answers were not given to the precision required in the question. Part (a)(iv) was found to be difficult and

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generated answers such as ‘displacement’ and ‘condensation’. The calculation in part (b)(i) was done well by many candidates but a significant number could not rearrange the equation correctly or convert the given pressure and temperature into the correct units. In part (b)(ii) there was a tendency to divide by 2 or 7. The empirical formula calculation in part (e) differentiated well with weaker candidates usually scoring only one of the available marks.

Q22.

(a) Virtually all candidates scored at least two marks for the graph in this part (i). The usual error was a poor scale, and most centres correctly penalised this. In this part (ii), drawing a straight line of best-fit was more demanding. Some candidates ignored the hint about anomalous points, while a surprising number did not realise that the origin is an extra point in this graph. Some centres were generous when marking best-fit lines.

In this part (iv) proved surprisingly demanding. Even A grade candidates failed to remember that the smallest volume will usually have the greatest error in measurement.

(b) Only the higher-scoring candidates obtained full marks in part (ii). The volume conversion was the usual mistake, although weaker candidates could not rearrange the ideal gas equation correctly. Similarly in part (iii) many candidates failed to scale up by a factor of ten. A number of centres were too harsh here, penalising this error by two marks.

In this part (iv) a majority of candidates could not correctly apply a factor to account for a 95% yield. This was an area where some teachers were very generous, ignoring a palpably incorrect method and crediting an answer which looked similar to the correct answer because the candidate had rounded the final figure.

This part (v) saw a number of vague answers, such as ‘Limestone won’t harm the environment’ or incorrect answers such as ‘Sodium hydroxide is toxic’, wrongly being awarded a mark.

Q23.

(a) While most candidates scored the mark in part (a) only the best candidates scored both marks in part (b). Many candidates could not clearly explain the changes in an equilibrium reaction.

(b) While most candidates scored the mark in part (a) only the best candidates scored both marks in part (b). Many candidates could not clearly explain the changes in an equilibrium reaction.

(c) The equation in part (i) proved quite demanding but most candidates had a good appreciation of atom economy in part (ii), though mathematical slips were quite common.

(d) (i) Most candidates scored the mark for the ionic equation in this part, the presence of spectator ions was the usual error.

(ii) Answers to this part were disappointing. Most candidates explained what happened in the reaction, rather than addressing the improvement. Many answers that had little relevance to the question were incorrectly awarded a mark.

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(e) Many candidates had little awareness of the practical consequences of a multi-stage process in this part. There was a tendency for candidates to repeat themselves and for the centre, incorrectly, to award two marks.

(f) A surprising number could not give a satisfactory description of recrystallisation in this part. Far too many candidates described completely different techniques. Centres need to exercise some common sense in this type of question. For example, a candidate cannot be awarded a mark for filtration or recrystallisation if a solution was not prepared or if the candidate melted the mixture.

(g) (i) In this part many candidates described how cisplatin works rather than addressing the balance of factors when using a toxic drug.

(ii) The safety factor in this part was well known.

Q24.

(a) While most candidates were able to write a correct equation in part (i), many struggled with the mole calculation in part (ii). The usual error was in scaling for the final volume.

(b) Some candidates continue to have difficulty with questions such as this part, once again being unable to see beyond the possibility of an error in the analysis itself.

(c) Many centres were too generous in the first part of this part, awarding a mark for Tollens' reagent or silver nitrate in ammonia.

Q25.

In this Question the equation for the reaction between an acid and a metal produced the usual errors, with water or Fe_2SO_4 commonly given as products. A surprisingly large number of candidates wrote an otherwise correct equation but gave iron as Fe^{2+}. The question about reaction hazards was well answered but too many candidates identified a hazardous substance without stating the type of hazard.

Q26.

The calculations in part (a) discriminated very well. Parts (a)(i) and (a)(ii) were generally well done although some candidates confused three decimal places and three significant figures or gave their answers to only one or two significant figures. Parts (a)(iii) and (a)(iv) proved more difficult. Many candidates did not read the rubric of the question and did not give their answer to one decimal place. Answers to part (a)(v) were varied. Even those candidates who reached the correct M_r could not always calculate the A_r of the metal. Common errors included failing to divide by 2 so the answer given was Se with an A_r of 78.2. The calculation in part (b) was extremely well done. Very few candidates could not rearrange the equation. The errors seen were incorrect conversion of the pressure unit or needlessly converting the volume unit. In part (c), most candidates answered this well with less able candidates suggesting that toxic or flammable gases were produced. The calculation in part (d)(i) was generally well done although many candidates used the Ar of magnesium as 24 rather than 24.3 and rounded their answer to 0.070. Part (d)(ii) discriminated well although it defeated many candidates.

Q27.

This question also proved to be discriminating. In questions similar to part (a), candidates may need to be reminded that when the question asks for a description of the colour change, the colours of the initial and final solutions are required. Part (b)(ii) proved to be

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very demanding. Only 3% of candidates scored all four marks. Most candidates did not recognise that the equation should start with the $[Cr(H_2O)_6]^{3-}$ ion and even when they did, they could not usually write a balanced equation for the reaction with hydrogen peroxide. Most candidates made a reasonable attempt at part (c) and the average score for this question was about half marks. However, only about 7% of candidates scored full marks. The most difficult mark to gain was for the reaction equation. The second most difficult mark was the final one awarded for a correct conversion of moles of hydrogen peroxide in 5 cm^3 of the original solution into a concentration.

Q28.

Part (a)(i) was done well but the 5/2 ratio in part (a)(ii) proved very difficult for many candidates. The calculation in part (b) was attempted well but the conversion into cubic decimetres proved challenging for a large number of candidates. Part (c)(i) was answered well but part (c)(ii) was less well answered.

Q29.

(a) Virtually all candidates scored the mark in part (i), and most candidates could make the ratio adjustment in part (ii). Some markers incorrectly penalised the precision of the answer in part (iii) when the candidate had already made this mistake in Question 4.

(b) In this part, a large number of candidates did not appreciate that a concentrated acid is likely to be corrosive. They defaulted to 'harmful', as a general hazard for a chemical substance. Others answered without stating a hazard – 'it would get in your eyes', for example. Neither of these answers was worth a mark.

Q30.

(a) In this part, the vast majority of candidates correctly stated the ideal gas equation.

(b) In this part, many candidates wrote a correct equation which included fractional numbers of moles. This version of a multiple of the expected answer is acceptable and should have been rewarded with a mark.

(c) This part was poorly answered. Most candidates simply calculated the ratio of the numbers given in the stem and converted to a percentage. This was not worth a mark. Yield calculations must start with the appropriate M_r values to earn any credit.

Q31.

This section tested the understanding of the skills and techniques acquired during the AS course. It again proved very challenging and full marks for this section were very rare.

(a) This part was answered well. The usual mistake was to misread the question and suggest a suitable titre volume. A few candidates had no concept of volume, thinking one drop equals one cm^3.

(b) In contrast, this part was poorly answered. Most candidates did not see the significance of a burette measuring a volume difference, and talked about the accuracy of a single volume reading being affected.

Q32.

This was the most difficult question in the paper. In part (a) most candidates knew that a

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standard hydrogen electrode uses hydrogen gas and a platinum electrode but only a minority went on to state the correct and necessary conditions of concentration, temperature and pressure for operation of the electrode. In part (b) most candidates gave a correct value for the electrode potential of the positive electrode but very few candidates were able to use the cell representation to deduce a half-equation for the electrode reaction. Answers to part (c) were also disappointing. Despite the given electrode potentials and half-equations, most candidates could not predict and explain the redox reaction between hydrogen and iron(III) ions. Part (d) also proved to be a difficult question. Candidates were usually able to score three marks out of six for a correct calculation of the number of moles of dichromate(VI) ions, a calculation of the original number of moles of iron(II) sulfate and for recognising the involvement of a factor of ten. Only the very best candidates realised that the number of moles of iron ions was six times the number of moles of dichromate(VI) ions and that a subtraction was required to calculate the percentage of iron(II) ions that had been oxidised by air before the titration.

Q33.

In part (a)(i), credit cannot be given to candidates who repeat the information from the question stem, rather than apply this information.

A surprising number could not give a satisfactory test in part (a)(ii). Centres are reminded that if the candidate chooses an incorrect test reagent the mark for the observation cannot be awarded. Centres are also reminded that ‘OH-‘or ‘hydroxide’ is not acceptable as a test reagent, but a correct observation can score the second mark. When required to identify a test reagent, a candidate must give the full name or formula.

Candidates tended to overlook the practical process in search of an answer to part (a)(iii), ‘incomplete reaction’ being a popular choice.

As at AS, the yield calculation in part (a)(iv) proved to be beyond a large number of candidates. Many did not attempt the question.

Only a handful of candidates could deduce the mole ratio in part (a)(v).

Many candidates continue to struggle with questions such as part (c), once again unable to see beyond the observations in a familiar practical activity. Similarly, the application of logic to everyday chemistry in part (d) defeated many candidates.

The above notes are intended for that small minority of centres experiencing difficulty in meeting the marking criteria. They must not be allowed to unduly detract from the very healthy overall picture. Given the pressures on centres to deliver the teaching programme, this was a very positive first session. Centres are again warmly commended for the trouble taken to assemble a sample which proved to be easy to moderate. Their efforts continue to be much appreciated by the moderator team.

Q34.

In part (a) some candidates were still not giving M_r values to one decimal place. Part (b) and (c) saw many correct answers but some candidates got into mathematical difficulties after a promising start – one error was the appearance of units in the dilution factor.

Q35.

Parts (a)(i) and (ii) were generally answered well although a disappointing number of candidates were unable to calculate the M_r for the given formula correctly in part (a)(i). Candidates should be able to give their answers to three significant figures when this degree of precision is given in the data in the question. Some candidates used only one

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significant figure or truncated their answers. Part (a) (iii) proved more challenging with many candidates missing out the factor of 1000. Several errors were made in part (b) including using an incorrect total for the M_r of the reactants, using 17 instead of 34 for ammonia, and failing to multiply by 100. Candidates would find it beneficial to learn the definition of atom economy and write it at the start of their answer. A surprising number of candidates failed to answer part (c) correctly. Some attempted a calculation, which was not needed, and failed to achieve the correct answer. In part (d) the equation PV= *n*RT was well known but some candidates were unable to rearrange this to calculate *n* or were unable to convert temperature and pressure into the correct units. The empirical formula calculation in part (e) was tackled well by a large number of candidates. Weaker candidates found difficulty getting started and some only calculated the water percentage. Some candidates then divided 55.9 by 18 and gave the answer as 3.

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Q1.

(a) State and explain the trend in electronegativities across Period 3 from sodium to sulfur.

(4)

(b) Explain why the oxides of the Period 3 elements sodium and phosphorus have different melting points. In your answer you should discuss the structure of and bonding in these oxides, and the link between electronegativity and the type of bonding.

(6)

(c) A chemical company has a waste tank of volume 25 000 dm^3. The tank is full of phosphoric acid (H_3PO_4) solution formed by adding some unwanted phosphorus(V) oxide to water in the tank.

A 25.0 cm^3 sample of this solution required 21.2 cm^3 of 0.500 mol dm^{-3} sodium hydroxide solution for complete reaction.

Calculate the mass, in kg, of phosphorus(V) oxide that must have been added to the water in the waste tank.

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_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

(5)

(Total 15 marks)

Q2.

Under suitable conditions magnesium will react with dilute nitric acid according to the following equation.

$$Mg(s) + 2HNO_3(aq) \rightarrow Mg(NO_3)_2(aq) + H_2(g)$$

A 0.0732 g sample of magnesium was added to 36.4 cm^3 of 0.265 mol dm^{-3} nitric acid. The acid was in excess.

(a) (i) Calculate the amount, in moles, of magnesium in the 0.0732 g sample.

_____

_____

(1)

(ii) Hence calculate the amount, in moles, of nitric acid needed to react completely with this sample of magnesium.

_____

_____

(1)

(iii) Calculate the amount, in moles, of nitric acid originally added to this sample of magnesium.

_____

_____

(1)

(iv) Hence calculate the amount, in moles, of nitric acid that remains unreacted.

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_____

_____

(1)

(b) In a second experiment, 0.512 mol of hydrogen gas was produced when another sample of magnesium reacted with dilute nitric acid. Calculate the volume that this gas would occupy at 298 K and 96 kPa. Include units in your final answer.
(The gas constant R = 8.31 J K^{-1} mol^{-1})

_____

_____

_____

_____

_____

(3)

(c) Concentrated nitric acid reacts with magnesium to form an oxide of nitrogen which contains 30.4% by mass of nitrogen.

Calculate the empirical formula of this oxide of nitrogen. Show your working.

_____

_____

_____

_____

_____

(3)

(Total 10 marks)

Q3.

In the past 150 years, three different processes have been used to extract bromine from potassium bromide. These processes are illustrated below.

Extraction Process **1**

$2KBr + MnO_2 + 2H_2SO_4 \rightarrow MnSO_4 + K_2SO_4 + 2H_2O + Br_2$

Extraction Process **2**

The reaction of solid potassium bromide with concentrated sulfuric acid.

Extraction Process **3**

The reaction of aqueous potassium bromide with chlorine gas.

(a) Write a half-equation for the conversion of MnO_2 in acid solution into Mn^{2+} ions and water. In terms of electrons, state what is meant by the term *oxidising agent* and

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identify the oxidising agent in the overall reaction.

(3)

(b) Write an equation for Extraction Process **2** and an equation for Extraction Process **3**.
Calculate the percentage atom economy for the extraction of bromine from potassium bromide by Extraction Process **3**. Suggest why Extraction Process **3** is the method in large-scale use today.

(5)

(c) Bromine has been used for more than 70 years to treat the water in swimming pools.
The following equilibrium is established when bromine is added to water.

$$Br_2 + H_2O \rightleftharpoons HBrO + HBr$$

Give the oxidation state of bromine in HBr and in HBrO

Deduce what will happen to this equilibrium as the HBrO reacts with micro-organisms in the swimming pool water. Explain your answer.

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_____

_____

_____

_____

_____

(4)

(Total 12 marks)

Q4.

Some antacid tablets contain sodium hydrogencarbonate, sucrose and citric acid.

(a) Analysis of a pure sample of citric acid showed that it contained 37.50% of carbon and 4.17% of hydrogen by mass, the remainder being oxygen. Use these data to show that the empirical formula of the acid is $C_6H_8O_7$.

_____

_____

_____

_____

(3)

(b) When the antacid tablet is added to water, sodium hydrogencarbonate and citric acid react together to form a gas. Identify this gas.

_____

(1)

(c) A weighed portion of this antacid was added to water. The gas formed was collected and its volume measured.

(i) Draw a diagram to show how this experiment could have been carried out to collect and measure the volume of the gas.

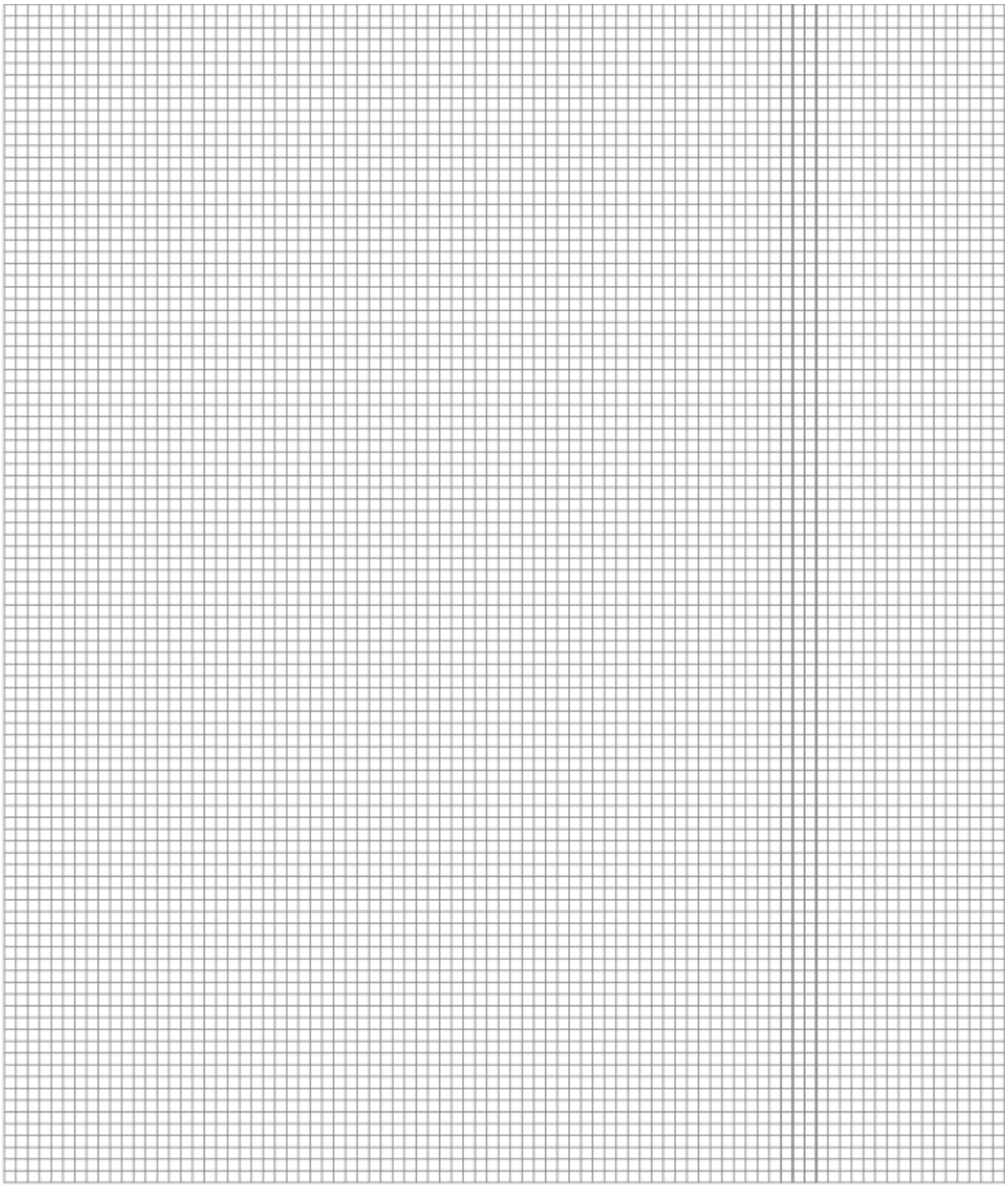
(ii) The experiment was repeated with further weighed portions of the same antacid.

The results are shown below.

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Experiment	1	2	3	4	5
Mass of antacid / g	2.60	1.17	0.88	2.31	1.80
Volume of gas collected / cm^3	168	86	57	149	116

1 On the graph paper below, plot a graph of mass of antacid (x-axis) against volume of gas collected.



(3)

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2 Draw a line of best fit on the graph, ignoring any anomalous points.

(1)

3 Use the graph to determine the volume of gas which would have been collected using 2.00 g of antacid.

Volume of gas collected _____

(1)

(d) Suggest **one** reason why the presence of sodium hydrogencarbonate in the stomach may cause a person to suffer some extra discomfort for a short time.

_____

(1)

(e) Explain why the value for the M_r of citric acid does not need to be an exact value to deduce the molecular formula of citric acid from its empirical formula.

_____

_____

(2)

(f) Apart from misreading the gas volume, suggest **two** reasons why the volumes of gas collected may be lower than the volumes of gas produced.

Reason 1 _____

_____

Reason 2 _____

_____

(2)

(g) Explain why it is important to record the temperature and pressure when measuring the volume of a gas.

_____

_____

(1)

(h) Suggest why, in an analysis of an antacid, it is important to test samples from more than one bottle of the antacid.

_____

_____

(1)

(i) In the industrial production of sodium hydrogencarbonate, ammonia and carbon dioxide are bubbled through a saturated solution of sodium chloride. The equation for this reaction, and some solubility data, are shown below.

$$NaCl(aq) + NH_3(aq) + CO_2(g) + H_2O(l) \rightarrow NaHCO_3(s) + NH_4Cl(aq)$$

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Compound	Solubility in water at 20 °C / g dm^{-3}
sodium chloride	360
sodium hydrogencarbonate	96
ammonium chloride	370

(i) Suggest **one** reason why sodium hydrogencarbonate precipitates from the reaction mixture at this temperature.

_____

(1)

(ii) Explain how this reaction could be used to remove carbon dioxide from the gases formed when fossil fuels are burned.

_____

_____

(1)

(j) The thermal decomposition of sodium hydrogencarbonate produces sodium carbonate. The other products are water and carbon dioxide. Write an equation for this thermal decomposition.

_____

(1)

(k) Sodium carbonate is produced on an industrial scale by a multi-step process. The equation which summarises the reactions taking place is shown below.

$$CaCO_3 + 2NaCl \rightarrow CaCl_2 + Na_2CO_3$$

Calculate the percentage atom economy for the production of sodium carbonate by this reaction.

_____

(1)

(Total 20 marks)

Q5.

Magnesium carbonate, $MgCO_3$, can occur as the anhydrous compound, or as hydrates with 2, 3 or 5 molecules of water of crystallisation. All types of magnesium carbonate can be decomposed to form magnesium oxide, an important starting material for many processes. This decomposition reaction can be used to identify the type of magnesium carbonate present in a mineral.

A chemist was asked to identify the type of magnesium carbonate present in a mineral imported from France. The chemist weighed a clean dry crucible, and transferred 0.25 g of the magnesium carbonate mineral to the crucible. The crucible was then heated for a few minutes. The crucible was then allowed to cool, and the crucible and its contents were reweighed. This process was repeated until the crucible and its contents had reached constant mass. The mass of the crucible and its contents was then recorded.

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The experiment was repeated using different masses of the magnesium carbonate mineral.

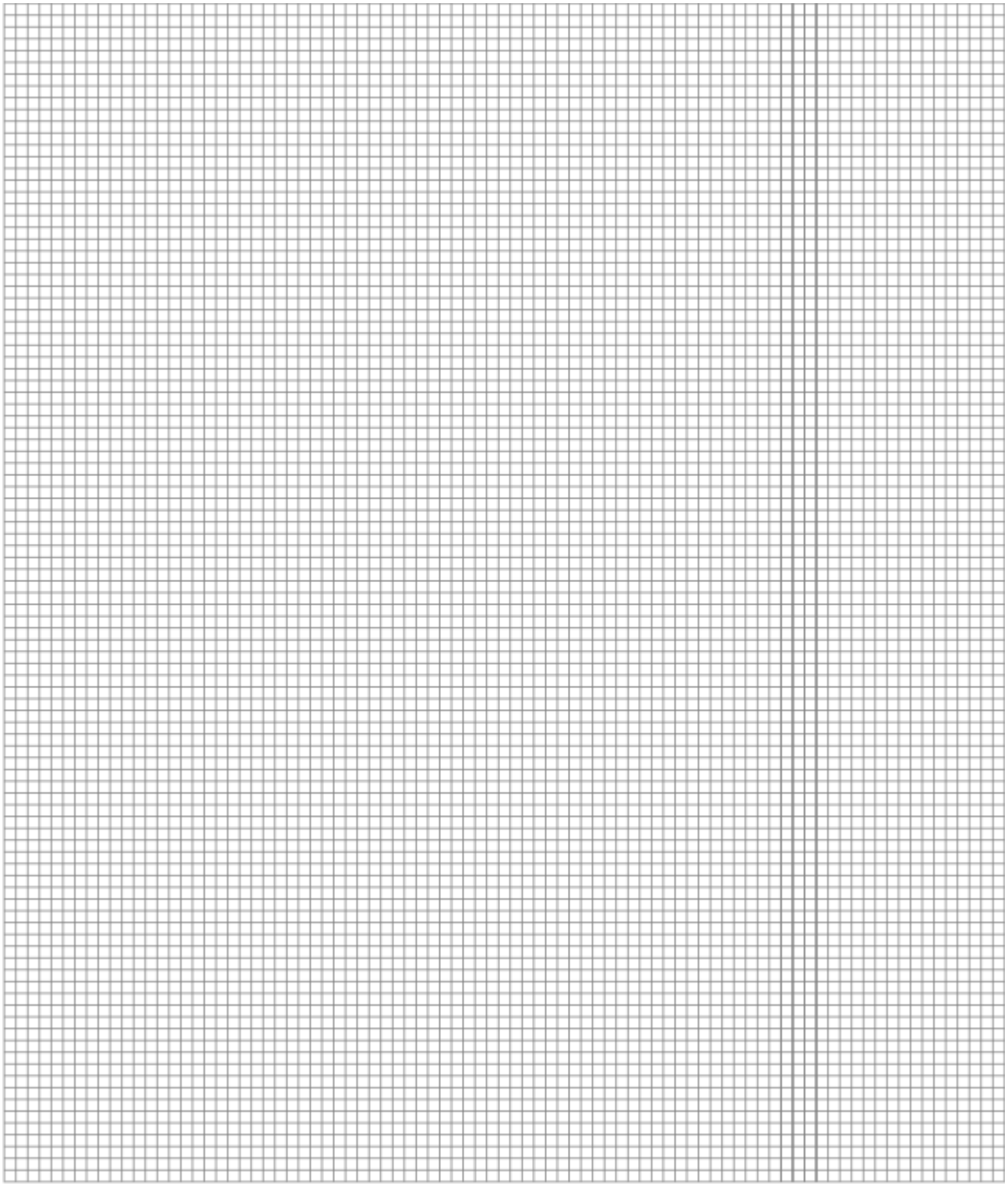
For each experiment the chemist recorded the original mass of the mineral and the mass of magnesium oxide left after heating to constant mass. The chemist's results are shown in the table below.

Experiment	1	2	3	4	5	6
Mass of mineral / g	1.60	1.17	0.74	1.31	1.80	1.34
Mass of magnesium oxide / g	0.54	0.39	0.24	0.44	0.61	0.49

(a) Plot a graph of the mass of the mineral (x-axis) against the mass of magnesium oxide on the grid below.

Draw a straight line of best fit on your graph.

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(4)

(b) Use the graph to determine the mass of the mineral which would have formed 0.50 g of magnesium oxide.

Mass of the mineral _____

(1)

(c) Calculate the amount, in moles, of MgO present in 0.50 g of magnesium oxide.

_____

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_____

(1)

(d) Use your answers from part (b) and from part (c) to calculate the M_r of the magnesium carbonate present in the mineral.

_____

_____

_____

(1)

(e) Use your answer from part (d) to confirm that this mineral is $MgCO_3.2H_2O$

(If you could not complete the calculation in part (d), you should assume that the experimental M_r value is 122.0 This is not the correct answer.)

_____

_____

_____

(1)

(f) Explain why it was **not** necessary to use a more precise balance in this experiment.

_____

_____

(1)

(g) Consider your graph and comment on the results obtained by the chemist. Identify any anomalous results.

Comment _____

_____

Anomalous results _____

_____

(2)

(h) Explain why it was necessary for the chemist to heat the crucible and its contents to constant mass.

_____

(1)

(i) Suggest **one** reason in each case why

(i) small amounts of the mineral, such as 0.10 g, should **not** be used in this experiment.

_____

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_____

(1)

(ii) large amounts of the mineral, such as 50 g, should **not** be used in this experiment.

_____

_____

(1)

(j) Analysis of a different hydrated magnesium carbonate showed that it contained 39.05% by mass of water. Determine the formula of this hydrated magnesium carbonate.

_____

_____

_____

_____

(2)

(k) Magnesium oxide is produced by the thermal decomposition of magnesium carbonate and by the thermal decomposition of magnesium hydroxide. The equations for the reactions taking place are shown below.

Reaction 1 $MgCO_3 \rightarrow MgO + CO_2$
Reaction 2 $Mg(OH)_2 \rightarrow MgO + H_2O$

Show that Reaction 2 has the greater atom economy for the production of magnesium oxide.

_____

_____

(2)

(l) Apart from cost, suggest **one** advantage of using magnesium hydroxide rather than magnesium carbonate to reduce acidity in the stomach.

_____

_____

(1)

(Total 19 marks)

Q6.

Titanium(IV) oxide (TiO_2, M_r = 79.9) is used as a white pigment in some paints. The pigment can be made as shown in the following equation.

$$TiCl_4(l) + 2H_2O(l) \rightarrow TiO_2(s) + 4HCl(aq)$$

(a) (i) Calculate the percentage atom economy for the formation of TiO_2

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_____

_____

_____

(2)

(ii) In view of the low atom economy of this reaction, suggest how a company can maximise its profits without changing the reaction conditions or the production costs.

_____

_____

(1)

(b) In an experiment 165 g of $TiCl_4$ were added to an excess of water.

(i) Calculate the amount, in moles, of $TiCl_4$ in 165 g.

_____

_____

_____

(2)

(ii) Calculate the maximum amount, in moles, of TiO_2 which can be formed in this experiment.

_____

_____

(1)

(iii) Calculate the maximum mass of TiO_2 formed in this experiment.

_____

_____

(1)

(iv) In this experiment only 63.0 g of TiO_2 were produced. Calculate the percentage yield of TiO_2

_____

_____

_____

(1)

(Total 8 marks)

Q7.

A metal carbonate MCO_3 reacts with hydrochloric acid as shown in the following equation.

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$$MCO_3 + 2HCl \rightarrow MCl_2 + H_2O + CO_2$$

A 0.548 g sample of MCO_3 reacted completely with 30.7 cm^3 of 0.424 mol dm^{-3} hydrochloric acid.

(a) (i) Calculate the amount, in moles, of HCl which reacted with 0.548 g MCO_3

_____

_____

(1)

(ii) Calculate the amount, in moles, of MCO_3 in 0.548 g.

_____

_____

(1)

(iii) Calculate the relative formula mass of MCO_3

_____

_____

(1)

(b) Use your answer from part (a)(iii) to deduce the relative atomic mass of metal M and suggest its identity.
(If you have been unable to calculate a value for the relative formula mass of MCO_3 you should assume it to be 147.6 but this is not the correct answer.)

Relative atomic mass _____

_____

_____

Identity of M _____

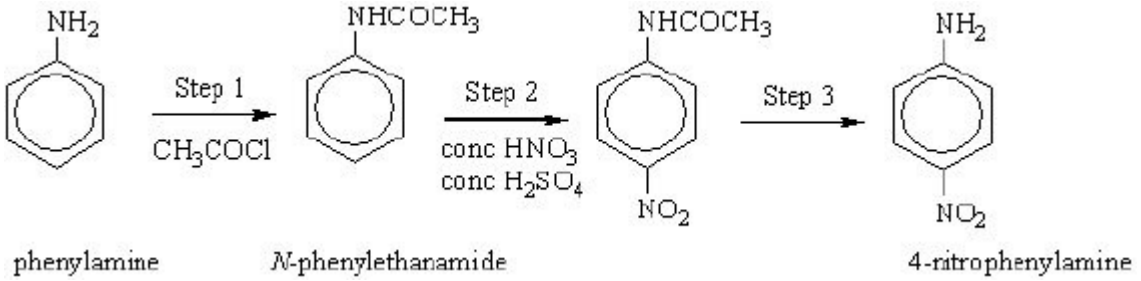
(2)

(Total 5 marks)

Q8.

Synthetic dyes can be manufactured starting from compounds such as 4-nitrophenylamine.

A synthesis of 4-nitrophenylamine starting from phenylamine is shown below.



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(a) An equation for formation of *N*-phenylethanamide in Step 1 of the synthesis is shown below.

$$2C_6H_5NH_2 + CH_3COCl \rightarrow \underset{N\text{-phenylethanamide}}{C_6H_5NHCOCH_3} + C_6H_5NH_3Cl$$

(i) Calculate the % atom economy for the production of *N*-phenylethanamide (M_r = 135.0).

_____

_____

_____

_____

_____

_____

(3)

(ii) In a process where 10.0 kg of phenylamine are used, the yield of *N*-phenylethanamide obtained is 5.38 kg.

Calculate the percentage yield of *N*-phenylethanamide.

_____

_____

_____

_____

(2)

(iii) Comment on your answers to parts (i) and (ii) with reference to the commercial viability of the process.

_____

_____

_____

_____

(2)

(b) Name and outline a mechanism for the reaction in Step 1.

_____

_____

_____

_____

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(5)

(c) The mechanism of Step 2 involves attack by an electrophile. Write an equation showing the formation of the electrophile. Outline a mechanism for the reaction of this electrophile with benzene.

(4)

(Total 16 marks)

Q9.

Iron from the Blast Furnace contains carbon. In the steel-making process, oxygen is blown through molten impure iron. At stages during this process samples of iron are taken and analysed to determine the remaining carbon content. One method of analysis involves a redox titration.

At one stage a 1.27g sample of this impure iron was reacted with an excess of dilute sulphuric acid. All of the iron in the sample was converted into iron(II) sulfate, and hydrogen was evolved. The solution formed was made up to 250 cm^3. A 25.0 cm^3 sample of this solution reacted completely with exactly 19.6 cm^3 of a 0.0220 mol dm^{-1} solution of potassium manganate(VII).

(a) Write an equation for the reaction between iron and dilute sulphuric acid.

(1)

(b) Write an equation for the reaction of iron(II) ions with manganate(VII) ions in acid solution.

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_____

_____

(1)

(c) Assuming that carbon is the only impurity, calculate the percentage by mass of carbon in the 1.27g sample.

_____

_____

_____

_____

_____

(5)

(d) How would you ensure the reliability of the result obtained in this experiment?

_____

(1)

(e) Suggest one way in which the reliability of this analysis could be improved.

_____

(1)

(Total 9 marks)

Q10.

Nitroglycerine, $C_3H_5N_3O_9$, is an explosive which, on detonation, decomposes rapidly to form a large number of gaseous molecules. The equation for this decomposition is given below.

$$4C_3H_5N_3O_9(l) \rightarrow 12CO_2(g) + 10H_2O(g) + 6N_2(g) + O_2(g)$$

(a) A sample of nitroglycerine was detonated and produced 0.350 g of oxygen gas.

(i) State what is meant by the term *one mole* of molecules.

_____

(ii) Calculate the number of moles of oxygen gas produced in this reaction, and hence deduce the total number of moles of gas formed.

Moles of oxygen gas _____

Total moles of gas _____

_____

_____

(iii) Calculate the number of moles, and the mass, of nitroglycerine detonated.

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Moles of nitroglycerine _____

_____

Mass of nitroglycerine _____

_____

_____

(7)

(b) A second sample of nitroglycerine was placed in a strong sealed container and detonated. The volume of this container was 1.00×10^{-3} m^3. The resulting decomposition produced a total of 0.873 mol of gaseous products at a temperature of 1100 K.

State the ideal gas equation and use it to calculate the pressure in the container after detonation.

(The gas constant R = 8.31 J $K^{-1}mol^{-1}$)

Ideal gas equation _____

Pressure _____

_____

_____

_____

(4)

(Total 11 marks)

Q11.

The reaction of bromine with ethane is similar to that of chlorine with ethane. Three steps in the bromination of ethane are shown below.

Step **1** $Br_2 \longrightarrow 2Br^{\bullet}$

Step **2** $Br^{\bullet} + CH_3CH_3 \longrightarrow CH_3CH_2^{\bullet} + HBr$

Step **3** $CH_3CH_2^{\bullet} + Br_2 \longrightarrow CH_3CH_2Br + Br^{\bullet}$

(a) (i) Name this type of mechanism.

_____

(ii) Suggest an essential condition for this reaction.

_____

(iii) Steps **2** and **3** are of the same type. Name this type of step.

_____

(iv) In this mechanism, another type of step occurs in which free-radicals combine. Name this type of step. Write an equation to illustrate this step.

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Type of step _____

*Equation*_____

(5)

(b) Further substitution in the reaction of bromine with ethane produces a mixture of liquid organic compounds.

(i) Name a technique which could be used to separate the different compounds in this mixture.

_____

(ii) Write an equation for the reaction between bromine and ethane which produces hexabromoethane, C_2Br_6, by this substitution reaction.

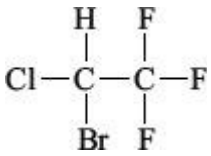
_____

(2)

(c) The compound 1,2-dibromo-1,1,2,2-tetrafluoroethane is used in some fire extinguishers. Draw the structure of this compound.

(1)

(d) Halothane is used as an anaesthetic and has the following structure.



(i) Give the systematic name of *halothane*.

_____

(ii) Calculate the M_r of halothane.

_____

(iii) Calculate the percentage by mass of fluorine in halothane.

_____

(3)

(Total 11 marks)

Q12.

A 0.263 g sample of impure iron, containing an unreactive impurity, was reacted with an excess of hydrochloric acid. All of the iron in the sample reacted, evolving hydrogen gas and forming a solution of iron(II) chloride. The volume of hydrogen evolved was 102 cm^3,

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measured at 298 K and 110 kPa.

The percentage, by mass, of iron in the sample can be determined using either the volume of hydrogen produced or by titrating the solution of iron(II) chloride formed against a standard solution of potassium dichromate(VI).

(a) (i) Write an equation for the reaction between iron and hydrochloric acid.

_____

(ii) Calculate the number of moles of hydrogen produced in the reaction.

_____

_____

_____

_____

(iii) Use your answers to parts (a)(i) and (ii) to determine the number of moles of iron and the mass of iron in the original sample. (If you have been unable to complete part (a)(ii) you should assume the answer to be 4.25×10^{-3} mol. This is not the correct answer.)

Moles of iron _____

Mass of iron _____

(iv) Calculate the percentage of iron in the original sample.

_____

_____

(7)

(b) (i) Write half-equations for the oxidation of Fe^{2+} and for the reduction of $Cr_2O_7^{2-}$ in acidic solution, and use these to construct an overall equation for the reaction between these two ions.

Half-equation for the oxidation of Fe^{2+}

_____

Half-equation for the reduction of $Cr_2O_7^{2-}$

_____

Overall equation

_____

(ii) The number of moles of iron in the sample was determined in part (a)(iii). Use this answer to calculate the volume of a 0.0200 mol dm^{-3} solution of potassium dichromate(VI) which would react exactly with the solution of iron(II) chloride formed in the reaction.

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(If you have been unable to complete part (a)(iii) you should assume the answer to be 3.63×10^{-3} mol. This is not the correct answer.)

_____

_____

_____

_____

_____

(iii) Explain why an incorrect value for the number of moles of iron(II) chloride formed would have been obtained if the original solution had been titrated with potassium manganate(VII).

_____

_____

(7)

(Total 14 marks)

Q13.

The removal of silicon dioxide with limestone in the Blast Furnace can be represented by the following equation.

$$CaCO_3(s) + SiO_2(s) \rightarrow CaSiO_3(l) + CO_2(g)$$

The minimum mass of calcium carbonate needed to remove 1.00 tonne (1000 kg) of silicon dioxide is

A 0.46 tonne

B 0.60 tonne

C 1.67 tonne

D 2.18 tonne

(Total 1 mark)

Q14.

The removal of silicon dioxide with limestone in the Blast Furnace can be represented by the following equation.

$$CaCO_3(s) + SiO_2(s) \rightarrow CaSiO_3(l) + CO_2(g)$$

The volume of carbon dioxide, measured at 298 K and 1.01×10^5 Pa, formed in this reaction during the removal of 1.00 tonne (1000 kg) of silicon dioxide is

A 24.5 dm^3

B 408 dm^3

C 24.5 m^3

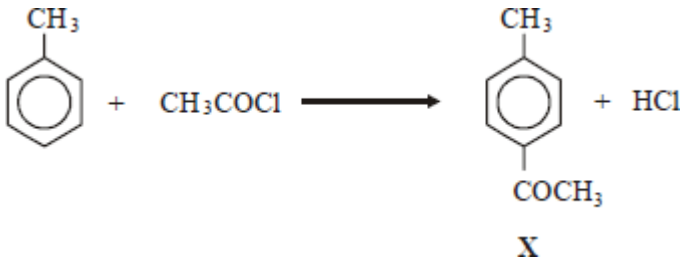
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D 408 m^3

(Total 1 mark)

Q15.

Ethanoyl chloride reacts with methylbenzene forming compound **X** according to the equation below.



X

If the experimental yield is 40.0%, the mass in grams of **X** (M_r = 134.0) formed from 18.4 g of methylbenzene (M_r = 92.0) is

A 26.8

B 16.1

C 10.7

D 7.4

(Total 1 mark)

Q16.

(a) Complete the following table.

	Relative mass	Relative charge
Neutron		
Electron		

(2)

(b) An atom has twice as many protons as, and four more neutrons than, an atom of ^{9}Be. Deduce the symbol, including the mass number, of this atom.

_____

(2)

(c) Draw the shape of a molecule of $BeCl_2$ and the shape of a molecule of Cl_2O. Show any lone pairs of electrons on the central atom. Name the shape of each molecule.

$BeCl_2$ *Cl_2O*

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Name of shape _____ *Name of shape* _____

(4)

(d) The equation for the reaction between magnesium hydroxide and hydrochloric acid is shown below.

$$Mg(OH)_2(s) + 2HCl(aq) \rightarrow MgCl_2(aq) + 2H_2O(l)$$

Calculate the volume, in cm^3, of 1.00 mol dm^{-3} hydrochloric acid required to react completely with 1.00 g of magnesium hydroxide.

_____

_____

_____

_____

_____

_____

(4)

(Total 12 marks)

Q17.

Potassium nitrate, KNO_3, decomposes on strong heating, forming oxygen and solid **Y** as the only products.

(a) A 1.00 g sample of KNO_3 (M_r = 101.1) was heated strongly until fully decomposed into **Y**.

(i) Calculate the number of moles of KNO_3 in the 1.00 g sample.

_____

_____

(ii) At 298 K and 100 kPa, the oxygen gas produced in this decomposition occupied a volume of 1.22×10^{-4} m^3.

State the ideal gas equation and use it to calculate the number of moles of oxygen produced in this decomposition.
(The gas constant R = 8.31 J K^{-1} mol^{-1})

Ideal gas equation _____

Moles of oxygen _____

_____

_____

_____

_____

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(5)

(b) Compound **Y** contains 45.9% of potassium and 16.5% of nitrogen by mass, the remainder being oxygen.

(i) State what is meant by the term *empirical formula*.

_____

_____

(ii) Use the data above to calculate the empirical formula of **Y**.

_____

_____

_____

(4)

(c) Deduce an equation for the decomposition of KNO_3 into **Y** and oxygen.

_____

(1)

(Total 10 marks)

Q18.

(a) Lead(II) nitrate may be produced by the reaction between nitric acid and lead(II) oxide as shown by the equation below.

$PbO + 2HNO_3 \rightarrow Pb(NO_3)_2 + H_2O$

An excess of lead(II) oxide was allowed to react with 175 cm^3 of 1.50 mol dm^{-3} nitric acid. Calculate the maximum mass of lead(II) nitrate which could be obtained from this reaction.

_____

_____

_____

_____

_____

(4)

(b) An equation representing the thermal decomposition of lead(II) nitrate is shown below.

$2Pb(NO_3)_2(s) \rightarrow 2PbO(s) + 4NO_2(g) + O_2(g)$

A sample of lead(II) nitrate was heated until the decomposition was complete. At a temperature of 500 K and a pressure of 100 kPa, the total volume of the gaseous mixture produced was found to be 1.50×10^{-4} m^3.

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(i) State the ideal gas equation and use it to calculate the total number of moles of gas produced in this decomposition.
(The gas constant R = 8.31 J K^{-1} mol^{-1})

Ideal gas equation _____

Total number of moles of gas _____

_____

_____

_____

(ii) Deduce the number of moles, and the mass, of NO_2 present in this gaseous mixture. (If you have been unable to calculate the total number of moles of gas in part (b)(i), you should assume this to be 2.23 × 10^{-3} mol. This is not the correct answer.)

Number of moles of NO_2 _____

_____

Mass of NO_2 _____

_____

(7)

(Total 11 marks)

Q19.

(a) Name and outline a mechanism for the reaction between propanoyl chloride, CH_3CH_2COCl, and methylamine, CH_3NH_2
Draw the structure of the organic product.

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

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(6)

(b) Benzene reacts with propanoyl chloride in the presence of aluminium chloride. Write equations to show the role of aluminium chloride as a catalyst in this reaction. Outline a mechanism for this reaction of benzene.

(5)

(c) Write an equation for the reaction of propanoyl chloride with water. An excess of water is added to 1.48 g of propanoyl chloride. Aqueous sodium hydroxide is then added from a burette to the resulting solution.
Calculate the volume of 0.42 mol dm^{-3} aqueous sodium hydroxide needed to react exactly with the mixture formed.

(5)

(Total 16 marks)

Q20.

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25.0 cm^3 of ethanedioic acid required 22.5 cm^3 of 0.100 mol dm^{-3} potassium hydroxide solution for complete neutralisation.

The concentration of ethanedioic acid is

A 0.0225 mol dm^{-3}

B 0.0450 mol dm^{-3}

C 0.0560 mol dm^{-3}

D 0.0900 mol dm^{-3}

(Total 1 mark)

Q21.

Silver oxide, Ag_2O, can be reduced by passing hydrogen gas over the heated oxide. The maximum mass of silver that could be obtained from 2.32 g of silver oxide is

A 2.02 g

B 2.06 g

C 2.12 g

D 2.16 g

(Total 1 mark)

Q22.

In a reaction which gave a 27.0% yield, 5.00 g of methylbenzene were converted into the explosive 2,4,6-trinitromethylbenzene (TNT) (M_r = 227.0). The mass of TNT formed was

A 1.35 g

B 3.33 g

C 3.65 g

D 12.34 g

(Total 1 mark)

Q23.

(a) Ammonium sulphate reacts with aqueous sodium hydroxide as shown by the equation below.

$$(NH_4)_2SO_4 + 2NaOH \rightarrow 2NH_3 + Na_2SO_4 + 2H_2O$$

A sample of ammonium sulphate was heated with 100 cm^3 of 0.500 mol dm^{-3} aqueous sodium hydroxide. To ensure that all the ammonium sulphate reacted, an excess of sodium hydroxide was used.
Heating was continued until all of the ammonia had been driven off as a gas.
The unreacted sodium hydroxide remaining in the solution required 27.3 cm^3 of 0.600 mol dm^{-3} hydrochloric acid for neutralisation.

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(i) Calculate the original number of moles of NaOH in 100 cm^3 of 0.500 mol dm^{-3} aqueous sodium hydroxide.

_____

_____

(ii) Calculate the number of moles of HCl in 27.3 cm^3 of 0.600 mol dm^{-3} hydrochloric acid.

_____

_____

(iii) Deduce the number of moles of the unreacted NaOH neutralised by the hydrochloric acid.

_____

(iv) Use your answers from parts (a) (i) and (a) (iii) to calculate the number of moles of NaOH which reacted with the ammonium sulphate.

_____

_____

(v) Use your answer in part (a) (iv) to calculate the number of moles and the mass of ammonium sulphate in the sample.
(If you have been unable to obtain an answer to part (a) (iv), you may assume that the number of moles of NaOH which reacted with ammonium sulphate equals 2.78×10^{-2} mol. This is not the correct answer.)

Moles of ammonium sulphate _____

_____

Mass of ammonium sulphate _____

_____

(7)

(b) A 0.143g gaseous sample of ammonia occupied a volume of 2.86×10^{-4} m^3 at a temperature ***T*** and a pressure of 100 kPa.

State the ideal gas equation, calculate the number of moles of ammonia present and deduce the value of the temperature ***T***.

(The gas constant R = 8.31 J K^{-1} mol^{-1})

Ideal gas equation _____

Moles of ammonia _____

_____

Value of ***T*** _____

_____

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_____

_____

_____

(4)

(Total 11 marks)

Q24.

A 0.0720 g sample of reducing agent **R** was dissolved in water and acidified with an excess of dilute H_2SO_4. The resulting solution was found to react with exactly 18.0 cm^3 of a 0.0200 mol dm^{-3} solution of $KMnO_4$.

In this reaction, 5 mol of **R** react with 3 mol of $KMnO_4$. The M_r of **R** is

A 120

B 167

C 240

D 333

(Total 1 mark)

Q25.

The percentage by mass of carbon is 83.3% in

A propane.

B butane.

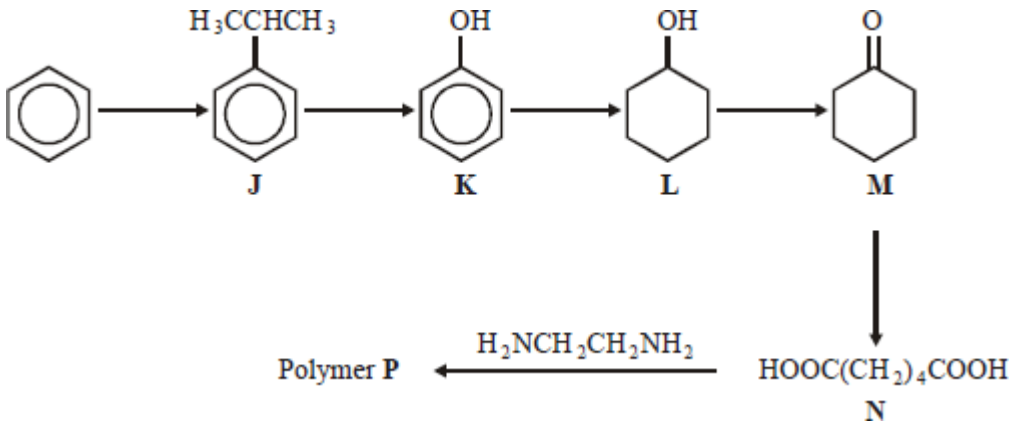
C pentane.

D hexane.

(Total 1 mark)

Q26.

This question is about the following reaction scheme which shows the preparation of polymer **P**.



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If 1.0 kg of benzene gave 0.98 kg of **J**, the percentage yield of **J** was

A 64

B 66

C 68

D 70

(Total 1 mark)

Q27.

(a) Sodium carbonate forms a number of hydrates of general formula $Na_2CO_3.xH_2O$

A 3.01 g sample of one of these hydrates was dissolved in water and the solution made up to 250 cm^3.
In a titration, a 25.0 cm^3 portion of this solution required 24.3 cm^3 of 0.200 mol^{-1} dm^{-3} hydrochloric acid for complete reaction.

The equation for this reaction is shown below.

$Na_2CO_3 + 2HCl \rightarrow 2NaCl + H_2O + CO_2$

(i) Calculate the number of moles of HCl in 24.3 cm^3 of 0.200 mol dm^{-3} hydrochloric acid.

_____

(ii) Deduce the number of moles of Na_2CO_3 in 25.0 cm^3 of the Na_2CO_3 solution.

_____

(iii) Hence deduce the number of moles of Na_2CO_3 in the original 250 cm^3 of solution.

_____

(iv) Calculate the M_r of the hydrated sodium carbonate.

_____

_____

(5)

(b) In an experiment, the M_r of a different hydrated sodium carbonate was found to be 250.
Use this value to calculate the number of molecules of water of crystallisation, *x*, in this hydrated sodium carbonate, $Na_2CO_3.xH_2O$

_____

_____

_____

_____

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(3)

(c) A gas cylinder, of volume 5.00×10^{-3} m^3, contains 325 g of argon gas.

(i) Give the ideal gas equation.

_____

(ii) Use the ideal gas equation to calculate the pressure of the argon gas in the cylinder at a temperature of 298 K.
(The gas constant R = 8.31 J K^{-1} mol^{-1})

_____

_____

_____

_____

(4)

(Total 12 marks)

Q28.

A particular sample of iron ore contains 85% by mass of Fe_2O_3 (M_r= 159.6) and no other iron compound. The maximum mass of iron that could be extracted from 1.0 tonne of this ore is

A 0.59 tonne

B 0.66 tonne

C 0.75 tonne

C 0.85 tonne

(Total 1 mark)

Q29.

(a) The equation for the reaction between magnesium carbonate and hydrochloric acid is given below.

$$MgCO_3 + 2HCl \rightarrow MgCl_2 + H_2O + CO_2$$

When 75.0 cm^3 of 0.500 mol dm^{-3} hydrochloric acid were added to 1.25 g of impure $MgCO_3$ some acid was left unreacted. This unreacted acid required 21.6 cm^3 of a 0.500 mol dm^{-3} solution of sodium hydroxide for complete reaction.

(i) Calculate the number of moles of HCl in 75.0 cm^3 of 0.500 mol dm^{-3} hydrochloric acid.

_____

(ii) Calculate the number of moles of NaOH used to neutralise the unreacted HCl.

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_____

_____

(iii) Show that the number of moles of HCl which reacted with the $MgCO_3$ in the sample was 0.0267

_____

(iv) Calculate the number of moles and the mass of $MgCO_3$ in the sample, and hence deduce the percentage by mass of $MgCO_3$ in the sample.

Moles of $MgCO_3$ _____

_____

Mass of $MgCO_3$ _____

_____

Percentage of $MgCO_3$ _____

_____

_____

(8)

(b) A compound contains 36.5% of sodium and 25.5% of sulphur by mass, the rest being oxygen.

(i) Use this information to show that the empirical formula of the compound is Na_2SO_3

_____

_____

_____

_____

_____

_____

(ii) When Na_2SO_3 is treated with an excess of hydrochloric acid, aqueous sodium chloride is formed and sulphur dioxide gas is evolved. Write an equation to represent this reaction.

_____

_____

(4)

(Total 12 marks)

Q30.

(a) A sample of ethanol vapour, C_2H_5OH (M_r = 46.0), was maintained at a pressure of

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100 kPa and at a temperature of 366K.

(i) State the ideal gas equation.

_____

(ii) Use the ideal gas equation to calculate the volume, in cm^3, that 1.36 g of ethanol vapour would occupy under these conditions.
(The gas constant R = 8.31 J K^{-1} mol^{-1})

_____

_____

_____

_____

_____

_____

_____

(5)

(b) Magnesium nitride reacts with water to form magnesium hydroxide and ammonia.

(i) Balance the equation, given below, for the reaction between magnesium nitride and water.

$$Mg_3N_2 + H_2O \rightarrow Mg(OH)_2 + NH_3$$

(ii) Calculate the number of moles, and hence the number of molecules, of NH_3 in 0.263 g of ammonia gas.
(The Avogadro constant L = 6.02 × 10^{23} mol^{-1})

_____

_____

_____

_____

_____

(4)

(c) Sodium carbonate is manufactured in a two-stage process as shown by the equations below.

$$NaCl + NH_3 + CO_2 + H_2O \rightarrow NaHCO_3 + NH_4Cl$$

$$2NaHCO_3 \rightarrow Na_2CO_3 + H_2O + CO_2$$

Calculate the maximum mass of sodium carbonate which could be obtained from 800 g of sodium chloride.

_____

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_____

_____

_____

_____

(4)

(Total 13 marks)

Q31.

Butan-1-ol was converted into butyl propanoate by reaction with an excess of propanoic acid. In the reaction, 6.0 g of the alcohol gave 7.4 g of the ester. The percentage yield of ester was

A 57

B 70

C 75

D 81

(Total 1 mark)

Q32.

(a) Calculate the concentration, in mol dm^{-3}, of the solution formed when 19.6 g of hydrogen chloride, HCl, are dissolved in water and the volume made up to 250 cm^3.

_____

_____

_____

(3)

(b) The carbonate of metal **M** has the formula M_2CO_3. The equation for the reaction of this carbonate with hydrochloric acid is given below.

$M_2CO_3 + 2HCl \rightarrow 2MCl + CO_2 + H_2O$

A sample of M_2CO_3, of mass 0.394 g, required the addition of 21.7 cm^3 of a 0.263 mol dm^{-3} solution of hydrochloric acid for complete reaction.

(i) Calculate the number of moles of hydrochloric acid used.

_____

_____

(ii) Calculate the number of moles of M_2CO_3 in 0.394 g.

_____

_____

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(iii) Calculate the relative molecular mass of M_2CO_3

_____

_____

(iv) Deduce the relative atomic mass of **M** and hence suggest its identity.

*Relative atomic mass of **M*** _____

_____

*Identity of **M*** _____

(6)

(Total 9 marks)

Q33.

The percentage of copper in a copper(II) salt can be determined by using a thiosulphate titration. 0.305 g of a copper(II) salt was dissolved in water and added to an excess of potassium iodide solution, liberating iodine according to the following equation:

$$2Cu^{2+}(aq) + 4I^-(aq) \rightarrow 2CuI(s) + I_2(aq)$$

The iodine liberated required 24.5 cm^3 of a 0.100 mol dm^{-3} solution of sodium thiosulphate:

$$2S_2O_3^{2-}(aq) + I_2(aq) \rightarrow 2I^-(aq) + S_4O_6^{2-}(aq)$$

The percentage of copper, by mass, in the copper(II) salt is

A 64.2

B 51.0

C 48.4

D 25.5

(Total 1 mark)

Q34.

(a) The mass of one mole of $_1H$ atoms is 1.0078 g and that of one $_1H$ atom is 1.6734×10^{-24} g.
Use these data to calculate a value for the Avogadro constant accurate to five significant figures. Show your working.

_____

_____

_____

(2)

(b) How does the number of atoms in one mole of argon compare with the number of molecules in one mole of ammonia?

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_____

(1)

(c) A sample of ammonia gas occupied a volume of 0.0352 m^3 at 298 K and 98.0 kPa. Calculate the number of moles of ammonia in the sample.
(The gas constant R = 8.31 J K^{-1} mol^{-1})

_____

_____

_____

_____

(3)

(d) A solution containing 0.732 mol of ammonia was made up to 250 cm^3 in a volumetric flask by adding water. Calculate the concentration of ammonia in this final solution and state the appropriate units.

_____

_____

_____

(2)

(e) A different solution of ammonia was reacted with sulphuric acid as shown in the equation below.

$$2NH_3(aq) + H_2SO_4(aq) \rightarrow (NH_4)_2SO_4(aq)$$

In a titration, 25.0 cm^3 of a 1.24 mol dm^{-3} solution of sulphuric acid required 30.8 cm^3 of this ammonia solution for complete reaction.

(i) Calculate the concentration of ammonia in this solution.

_____

_____

_____

_____

(ii) Calculate the mass of ammonium sulphate in the solution at the end of this titration.

_____

_____

_____

_____

(6)

(f) The reaction of magnesium nitride, Mg_3N_2, with water produces ammonia and

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magnesium hydroxide. Write an equation for this reaction.

_____

(2)

(Total 16 marks)

Q35.

On heating, magnesium reacts vigorously with element **X** to produce compound **Y**. An aqueous solution of **Y**, when treated with aqueous silver nitrate, gives a white precipitate that is readily soluble in dilute aqueous ammonia. What is the minimum mass of **X** that is needed to react completely with 4.05 g of magnesium?

A 11.83 g

B 5.92 g

C 5.33 g

D 2.67 g

(Total 1 mark)

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Q1.

(a) Electronegativity increases

1

Proton number increases (increase in nuclear charge)

1

Same number of electron shells/levels

Or same radius or Shielding of outer electrons remains the same

1

Attraction of bond pair to nucleus increases

Allow 'electrons in bond' instead of 'bond pair'

1

(b) Big difference in electronegativity leads to ionic bonding, smaller covalent

Lose a mark if formula incorrect

1

Sodium oxide ionic lattice

1

Strong forces of attraction between ions

1

P_4O_{10} covalent molecular

Must have covalent and molecular (or molecules)

1

Weak (intermolecular) forces between molecules

Or weak vdW, or weak dipole–dipole between molecules

1

melting point Na_2O greater than for P_4O_{10}

Or argument relating mpt to strength of forces

1

(c) Moles NaOH = 0.0212 × 0.5 = 0.0106

M1 moles of NaOH correct

1

Moles of H_3PO_4 = 1/3 moles of NaOH (= 0.00353)

M2 is for 1/3

1

Moles of P in 25000 l = $0.00353 \times 10^6 = 3.53 \times 10^3$

M3 is for factor of 1,000,000

1

Moles of $P_4O_{10} = 3.53 \times 10^3/4$

M4 is for factor of 1/4 (or 1/2 if P_2O_5)

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1

Mass of P_4O_{10} = 3.53 × 10^3/4 × 284 = 0.251 × 10^6 g
= 251 kg

(Or if P_2O_5 3.53 × 10^3/2 × 142)
M5 is for multiplying moles by M_r with correct units
allow conseq on incorrect M4
(allow 250-252)

1

[15]

Q2.

(a) (i) 0.00301/ 3.01 × 10^{-3};

Penalise < 3sf in (a)(i);

Allow 3.01 × 10^{-3} – 3.05 × 10^{-3}.
(for candidates who have used Mg as 24)

1

(ii) 0.00602

Allow correct answer a(i) × 2.

1

(iii) 0.00965/ 9.65 × 10^{-3};

Allow 0.009646/ 0.0096-0.0097.

1

(iv) 0.00363 moles;

Allow range 0.0035 to 0.0037.
Allow (a)(iii) – 2 (a)(ii) (must be positive).

1

(b) PV = nRT;

Allow all capitals/ lower case.

1

$$V = \frac{0.512 \times 8.31 \times 298}{96000};$$

M2 Mark is for <u>all numbers correct</u>.
If units in answer are in dm^3 allow this expression with 96 in denominator.

1

0.0132 m^3/ 13.2 dm^3;

M3 <u>Must have correct units</u>/
allow 13200 cm^3.

Allow min 2 sig figs in answer.

1

(c) O = 69.6 (%);

1

$$\frac{30.4}{14} \quad \frac{69.6}{16} \qquad 2.17 : 4.35$$

Use of 7/8 CE then M1 only.

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1

(1 : 2) $\underline{NO_2}$

Mark for formula not ratio.
If NO_2 and no working shown then allow 1 mark.
If 69.6% + NO_2 only = 2.
Need to see evidence of M2 working.
Allow M2 conseq on the wrong M1 (ie max 1).

1

[10]

Q3.

(a) **M1** $MnO_2 + 4H^+ + 2e^- \rightarrow Mn^{2+} + 2H_2O$

1

OR multiples

M2 An oxidising agent is an <u>electron acceptor</u> OR
<u>receives / accepts / gains electrons</u>

Ignore state symbols
M2 NOT an "electron pair acceptor"

1

M3 MnO_2 is the oxidising agent

Ignore "takes electrons" or "takes away electrons"

1

(b) **M1** Formation of SO_2 and Br_2 (could be in an equation)

1

M2 Balanced equation
Several possible equations
2KBr + **3**$H_2SO_4 \rightarrow$ **2**$KHSO_4$ + Br_2 + SO_2 + **2**H_2O
OR
2KBr + $2H_2SO_4 \rightarrow K_2SO_4 + Br_2 + SO_2$ + **2**H_2O

1

M3 **2**KBr + $Cl_2 \rightarrow$ **2**KCl + Br_2

M2 Could be ionic equation with or without K^+
***2**Br^- + **6**H^+ + **3**$SO_4^{2-} \rightarrow Br_2$ + **2**HSO_4^- + SO_2 + **2**H_2O*
*(**3**H_2SO_4)*
***2**Br^- + **4**H^+ + $SO_4^{2-} \rightarrow Br_2 + SO_2$ + **2**H_2O*
*(**2**HBr + H_2SO_4)*
Accept HBr and H_2SO_4 in these equations as shown or mixed variants that balance.
Ignore equations for KBr reacting to produce HBr
M3 Could be ionic equation with or without K^+
***2**Br^- + $Cl_2 \rightarrow$ **2**Cl^- + Br_2*

1

M4 % atom economy of bromine

$$= \frac{Br_2}{2KBr + Cl_2} \times 100 = \frac{(2 \times 79.9)}{238 + 71} \times 100 = \frac{159.8}{309} \times 100$$

= **51.7%** OR **52%**

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M4 Ignore greater number of significant figures

1

M5 One from:

- High atom economy
- Less waste products
- Cl_2 is available on a large-scale
- No SO_2 produced
- Does not use concentrated H_2SO_4
- (Aqueous) KBr or bromide (ion) in seawater.
- Process 3 is simple(st) or easiest to carry out

M5 Ignore reference to cost
Ignore reference to yield

1

(c) **M1** HBr **–1**

1

M2 HBrO **(+)1**

1

M3 Equilibrium will shift <u>to the right</u>
OR
<u>L to R</u>
OR
Favours forward reaction
OR
Produces more HBrO

1

M4 **<u>Consequential on correct M3</u>**
OR
to <u>oppose the loss</u> of HBrO
OR
<u>replaces</u> (or implied) the HBrO (that has been used up)

1

[12]

Q4.

(a) percentage of oxygen is 58.33

1

correct calculation of ratios (C 3.125, H 4.17, O 3.645)

1

clearly relates ratios to formula eg
simplifies ratios (C 1, H 1.29, O 1.17) or for H then 3.125 × 8 / 6 = 4.17% etc

1

Notes
** correct percentage of oxygen can be stated or shown clearly in a calculation*

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** to score final mark must **clearly** show how ratios relate to $C_6H_8O_7$*
** allow full credit to candidate who correctly finds*
percentage of oxygen
calculates M_r
shows percentage of H is 8 divided by M_r

(b) carbon dioxide / CO_2

1

(c) (i) suitable reaction vessel
eg sealed flask or test-tube with side arm or
eg tube in bung

1

suitable collection method
eg gas syringe / over water in measuring
eg cylinder

1

Notes
** collection vessel must allow measurement of gas*
** if apparatus would leak lose second mark*
** ignore heating*
** can draw tubing as single line*
** accept 2D or 3D diagrams*
** do not need labels, and ignore mis-labelling*

(ii) (1) mass on x-axis

1

Notes
** If axes unlabelled use data to decide that mass is on the x-axis*

sensible scales

1

Notes
** lose this mark if the **plotted points** do not cover at least half of the paper*
** lose this mark if the graph plot goes off the squared paper*

plots points correctly ± one square

1

(2) draws appropriate straight line of best fit, omitting point at 1.17g / 86 cm^3

Notes
** lose this mark if the line deviates towards the point at 1.17g / 86 cm^3*
** candidates does not have to extrapolate the line to the origin to score this mark*
** when checking for best fit, candidate's line **must** go through the origin ± one square. Extend candidate's line if necessary*

1

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(3) 129 ± 1 cm^3

Notes
* *accept this answer* ***only***

1

(d) CO_2 / gas formed distends stomach / produces wind / increases pressure in stomach

1

(e) molecular formula has to be a simple multiple of the empirical formula

1

so approximate M_r value will distinguish between the options or equivalent wording

1

(f) gas escapes before bung inserted any 2 × 1 for

syringe sticks

carbon dioxide soluble in water

Notes
* *do* ***not*** *accept 'operator error' / 'inaccurate equipment' / 'equipment leaks'*

2

(g) volume depends on pressure and temperature

Notes
* *do* ***not*** *accept 'to get a more accurate result' or equivalent wording without qualification*

1

(h) Tablets could vary between samples or equivalent wording

Notes
* *do* ***not*** *accept 'to get a more accurate / reliable result' or 'to make a fair test' without qualification*

1

(i) (i) $NaHCO_3$ **least** soluble

1

(ii) exhaust gases passed into mixture of NaCl and NH_3

1

(j) $2NaHCO_3 \rightarrow Na_2CO_3 + CO_2 + H_2O$

Notes
* *accept multiples*

1

(k) 106.0 divided by 217.1 × 100 = 48.8%

Notes
* *ignore precision of answer*

1

[22]

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Q5.

(a) Mass of mineral on x-axis;

If axes unlabelled use data to decide if mass of mineral is on the x-axis.

1

Sensible continuous scales;

*Lose this mark if the **plotted points** do not cover at least 9 squares by 7.*
Lose this mark if the graph plot goes off the squared paper.
The graph does not have to start at the origin.

1

Plots points correctly ± one square;

Award this mark if the line is close to your line.

1

Draws a best fit straight line

Award this mark if best fit line is consistent with candidate's plotted points.
Lose this mark if line is kinked or doubled.

1

(b) 1.48 or 1.49 or 1.50 or 1.5 (g);

*Accept these answers **only***
Ignore precision of answer.
Allow range 1.48 – 1.5

1

(c) 0.0124 (mol);

Accept 0.012, 0.0125.
Allow answer without working.

1

(d) (1.49 / 0.0124) = 119.4 – 125.0;

Must divide answer to part (b) by answer to part (c) to score first mark.
Allow consequential answer from part (b).
Allow answer without working.
Ignore precision of answer.

1

(e) Answer to part (e) close to 120.3;

Allow consequential answer from part (d).
Allow correct calculation of x

1

(f) $\underline{x}$ must be a whole number;

1

(g) Good / straight line so results good / reliable;

Allow consequential answers from candidate's graph
Do not allow 'so results are accurate'.

1

Anomaly at 1.34 g;

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Allow anomaly clearly indicated on the graph.

1

(h) Ensure reaction / decomposition goes to completion;

Do not allow 'to make fair test' or 'improve reliability'
Accept to 'remove all carbon dioxide and water'.

1

(i) (i) Percentage errors too high / errors in weighing too high;

Do not allow 'to make fair test' or 'improve reliability'
Do not allow 'errors' on its own.

1

(ii) Incomplete decomposition or words to that effect;

Do not allow 'to make fair test' or 'improve reliability'
Do not allow 'takes too long' or 'wastes chemicals'
Do not allow 'not all of the water removed'.

1

(j) 39.05 / 18 = 2.170 and 60.95 / 84.3 = 0.723;

Allow M_r of $MgCO_3.H_2O$ = 138.3

1

$MgCO_3.3H_2O$;

54 / 138.3 + 39.05%
$MgCO_3.3H_2O$ without working scores 1 mark.

1

(k) Atom economy for Reaction 1 is (40.3 / 84.3) x 100 = 47.8%

Maximum 1 mark if no working.
Ignore precision of answers.

1

Atom economy for Reaction 2 is (40.3 / 58.3) x 100 = 69.1%

1

(l) No gas produced in stomach / won't cause wind;

Do not allow 'gas produced' on its own.

1

[19]

Q6.

(a) (i) $\frac{79.9}{225.9} \times 100$;

Whole expression
Ignore >3 sig figs

1

= 35.37(%) allow 35.0 – 35.4%;

Allow 35%
Allow 2 marks if correct %

1

(ii) Sell the HCl or sell the other product or sell the acid (formed in the reaction);

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Need a financial gain

1

(b) (i) $\frac{165}{189.9}$ = 0.869;

One mark for M_r = 189.9

allow 0.86 – 0.87;;

Ignore units

2

(ii) 0.869

Accept same value as in (i)

1

(iii) 0.869 × 79.9 = 69.4;

Allow 68.7 – 70;

Accept answer to (ii) × 79.9

1

(iv) $\frac{63}{69.4}$ × 100;

Accept 63 × 100 /answer to (iii)

= 90.75%;

If > 100% lose this mark

Accept 90.6 to 92%

1

[8]

Q7.

(a) (i) 0.013;

1

(ii) 0.0065;

Answer to (i) ÷ 2

1

(iii) $\frac{0.548}{0.0065}$ = 84.3;

Allow 0.548 ÷ answer to (ii)
Allow 84.1 – 84.4

1

(b) 84.3 – 60 = 24.3;

1 mark for -60

1

Mg;

If 147.6 used the answer is 87.6 (1)
And this is Sr (1)

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Allow consequential metal from their calculated A
Answer has got to be a metal to score M2

1

[5]

Q8.

Mark Range	The marking scheme for this part of the question includes an overall assessment for the Quality of Written Communication (QWC). There are no discrete marks for the assessment of QWC but the candidates' QWC in this answer will be one of the criteria used to assign a level and award the marks for this part of the question **Descriptor** an answer will be expected to meet most of the criteria in the level descriptor
4-5	– claims supported by an appropriate range of evidence – good use of information or ideas about chemistry, going beyond those given in the question – argument well structured with minimal repetition or irrelevant points – accurate and clear expression of ideas with only minor errors of grammar, punctuation and spelling
2-3	– claims partially supported by evidence – good use of information or ideas about chemistry given in the question but limited beyond this – the argument shows some attempt at structure – the ideas are expressed with reasonable clarity but with a few errors of grammar, punctuation and spelling
0-1	– valid points but not clearly linked to an argument structure – limited use of information or ideas about chemistry – unstructured – errors in spelling, punctuation and grammar or lack of fluency

(a) (i) M_r of $C_6H_5NH_2$ = 93 M_r of CH_3COCl = 78.5
total M_r of reagents = 264.5

1

$$\% \text{ atom economy} = \frac{M_r \text{ of wanted product}}{\text{total } M_r \text{ of all reagents}} \times 100 \text{ QWC}$$

1

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$$= \frac{135}{264.5} \times 100 = 51.0\ \%$$

1

(ii) expected yield = $\frac{10}{93} \times 0.5 \times 135 = 7.26$ kg

1

$$\%\ \text{yield} = \frac{5.38}{7.26} \times 100 = 74.1\ \%$$

1

(iii) Although yield appears satisfactory (74%) % atom economy is only 51% QWC

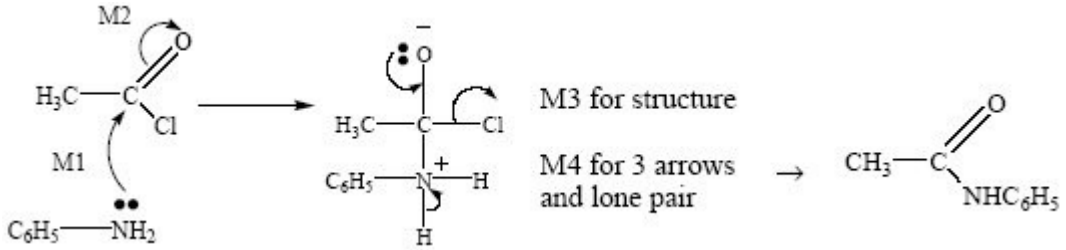
1

nearly half of the material produced is waste and must be disposed of QWC

1

(b) (nucleophilic) addition-elimination

1

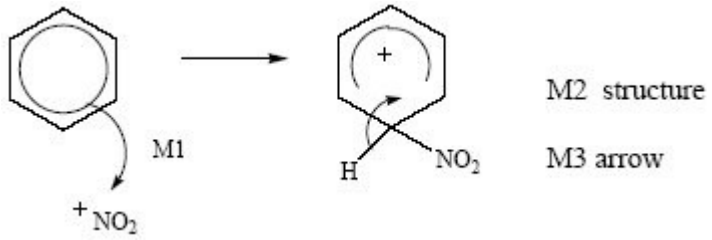


QWC (2)

4

(c) $HNO_3 + 2H_2SO_4 \rightarrow NO_2^+ + H_3O^+ + 2HSO_4^-$

1



3

[16]

Q9.

(a) $Fe + H_2SO_4 \rightarrow FeSO_4 + H_2$

1

(b) $MnO_4^- + 8H^+ + 5Fe^{2+} \rightarrow Mn^{2+} + 4H_2O + 5Fe^{3+}$

1

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(c) Moles MnO_4^- in 19.6 cm^3
= $19.6 \times 0.022 \times 10^{-3} = 4.312 \times 10^{-4}$

1

Moles Fe^{2+} in 25 cm^3
= $5 \times 4.312 \times 10^{-4} = 2.156 \times 10^{-3}$

1

Moles Fe^{2+} in 250 cm^3
= $10 \times 2.156 \times 10^{-3} = 2.156 \times 10^{-2}$

1

Mass Fe^{2+} = moles × A_r
$A_r = 2.156 \times 10^{-2} \times 55.8 = 1.203$ g

1

Percentage by mass of carbon
= (1.270 – 1.203) × 100/1.270
= 5.28%

1

(d) Repeat the titration and take an average of the concordant results

1

(e) Analyse several samples from different parts of the molten iron

1

[9]

Q10.

(a) (i) Avogadro's number/constant of molecules/particles/species / 6×10^{23}
[Not 'atoms']

1

Or same number of particles as (there are atoms)
[Not molecules]

in 12.(00)g of ^{12}C

1

(ii) *Moles* $O_2 = \frac{0.350}{32}$ *(= 1.09 × 10⁻² mol)*

1

= 29 (× 1.09×10^{-2})
[Accept answers via 4 separate mole calculations]

1

= 0.316 – 0.317 mol [answer to 3 + sf]
[Mark conseq on errors in M1/M2] (1)

1

(iii) Moles of nitroglycerine = $4 \times 1.09 \times 10^{-2}$ (= 0.0438 mol)
[Mark conseq on their moles of O_2]

1

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M_r of nitroglycerine = 227 or number string

1

Moles of nitroglycerine = 227 × 0.0438 = 9.90 – 9.93(g)

[answer to 3+ sf]

[If string OK but final answer wrong then allow M6 but AE for M7]

[Mark conseq on error in M_r] *[Penalise wrong units]*

[Penalise sig. fig. errors once only in whole question]

(b) pV = nRT **or** pV = $\frac{m}{V}RT$ **or** p = $\frac{n}{V}RT$

1

p = $\frac{n}{V}RT$ = $\frac{0.873 \times 8.31 \times 1100}{1.00 \times 10^{-3}}$

1

= 7980093 **or** 7980 **or** 7.98

[ignore s.f.]

1

units = Pa **or** kPa **or** MPa (as appropriate)

[If error in conversion from Pa, treat as a contradiction of the units mark]

[If transfer error, mark conseq but penalise M2]

[If data from outside of above used, penalise M2 and M3]

[If pV expression incorrectly rearranged, penalise M2 and M3]

[if T = 1373 K used, penalise M2]

1

[11]

Q11.

(a) (i) (free–)radical substitution

(both words required for the mark)

1

(ii) uv light OR sunlight OR high temperature OR 150 °C to 500 °C

1

(iii) Propagation

(ignore "chain", "first", "second" in front of the word propagation)

1

(iv) Termination

1

$\bullet CH_2CH_3 + Br\bullet \longrightarrow CH_3CH_2Br$
OR $2\bullet CH_2CH_3 \longrightarrow C_4H_{10}$

(penalise if radical dot is obviously on CH_3, but not otherwise)

(penalise $C_2H_5\bullet$)

(credit $2Br\bullet \longrightarrow Br_2$)

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(ignore "chain" in front of the word termination)

1

(b) (i) Fractional distillation OR fractionation

(credit gas–liquid chromatography, GLC)

1

(ii) $CH_3CH_3 + 6Br_2 \longrightarrow C_2Br_6 + 6HBr$

(credit C_2H_6 for ethane)

1

(c) Correct structure for CF_2BrCF_2Br drawn out

(penalise "Fl" for fluorine)

1

(d) (i) 2–bromo–2–chloro–1,1,1–trifluoroethane
OR 1–bromo–1–chloro–2,2,2–trifluoroethane

(insist on all numbers, but do not penalise failure to use alphabet)

(accept "flourine" and "cloro" in this instance)

1

(ii) 197.4 only

(ignore units)

1

(iii) (57/197.4 × 100) = 28.9% OR 28.88%

(credit the correct answer independently in part (d)(iii), even if (d)(ii) is blank or incorrectly calculated, but mark consequential on part (d)(ii), if part (d)(ii) is incorrectly calculated, accepting answers to 3sf or 4sf only)

(penalise 29% if it appears alone, but not if it follows a correct answer)

(do not insist on the % sign being given)

(the percentage sign is not essential here, but penalise the use of units e.g. grams)

1

[11]

Q12.

(a) (i) $Fe + 2HCl \rightarrow FeCl_2 + H_2$

(allow ionic formulae)

or $Fe + 2H^+ \rightarrow Fe^{2+} + H_2$

1

(ii) $PV = nRT$ $n = PV/RT$

(allow either formula but penalise contradiction)

1

$$n = \frac{110000 \times 102 \times 10^{-6}}{8.31 \times 298}$$

1

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= 4.53×10^{-3} (mol)

(answer must have at least 3 sig. figs. Ignore units)

1

(iii) Moles of iron = $4.5(3) \times 10^{-3}$ mol

(allow conseq on (a)(ii))

(or = $4.2(5) \times 10^{-3}$ if candidate uses given moles of hydrogen)

1

Mass of iron = $4.53 \times 10^{-3} \times 55.8 = 0.253$ g
(mark is for method mass = moles × A_r)
(Mass of iron can be 56)

1

(iv) 0.253 × 100/0.263 = 96.1 % (mark is for answer to 2 sig. figs.)

(allow conseq on mass of iron. E.g. = 90% from $4.2(5) \times 10^{-3}$ moles of H_2 and Fe)

(Do not allow answers greater than or equal to 100%)

1

(b) (i) $Fe^{2+} \rightarrow Fe^{3+} + e^-$

(ignore state symbols)

1

$Cr_2O_7^{2-} + 14H^+ + 6e^- \rightarrow 2Cr^{3+} + 7H_2O$

1

$Cr_2O_7^{2-} + 14H^+ + 6Fe^{2+} \rightarrow 2Cr^{3+} + 7H_2O + 6Fe^{3+}$

1

(ii) Moles of dichromate = moles $Fe^{2+}/6$
= $4.53 \times 10^{-3}/6 = 7.55 \times 10^{-4}$

(Allow conseq, mark is for method (a)(iii)/6)

1

Volume of dichromate = moles/concentration
(= $(7.55 \times 10^{-4} \times 1000)/0.0200$)

(mark is for this method)

1

V = 37.75 (cm^3)

(allow 37.7 to 37.8, allow no units but penalise wrong units)

(allow conseq on moles of dichromate)

(if value of 3.63×10^{-3} used answer is 30.2 to 30.3, otherwise ans = moles $Fe^{2+}/0.00012$)

(if mole ratio wrong and candidate does not divide by 6, max score is ONE for volume method)

1

(iii) ($KMnO_4$) will also oxidise (or react with) Cl^- (or chloride or HCl)

1

[14]

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Q13.

C

[1]

Q14.

D

[1]

Q15.

C

[1]

Q16.

(penalty for sig fig error =1 mark per question)

(a) neutron: relative mass = 1 relative charge = 0

(not 'neutral')

1

electron: relative mass = 1/1800 → 0/negligible *or*

5.56 × 10–4 → 0 relative charge = –1

1

(b) $^{17}O/O^{17}$ mass number (*Do not accept 17.0*)

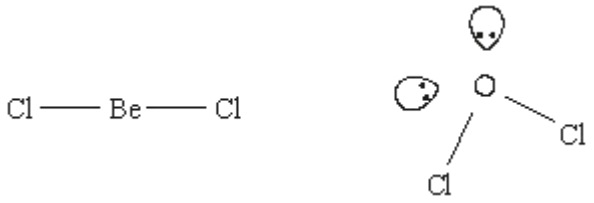
1

oxygen symbol 'O'

(if 'oxygen' + — 'mass number = 17'(1))
(if 'oxygen'+ — 'mass number = 17'(0))
(if at N^0 given but ≠ 8, treat as 'con' for M2)
(if lp on Be, diagram = 0)
(ignore bond angles)
(not dot and cross diagrams)

1

(c)



2

QoL Linear **(1)** bent / V-shaped / angular **(1)**

(mark name and shape independently)
(accept (distorted) tetrahedral)
(if balls instead of symbols, lose M1 – can award M2)
(penalise missing 'Cl' once only)
(not 'non-linear')

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2

(d) M_r ($Mg(NO_3)_2$ = 58(.3) *(if At N⁰ used, lose M1 and M2)*

1

moles $Mg(OH)_2$ = 0.0172 (conseq on wrong M2) (answer to 3+ s.f.)

1

moles HCl = 2 × 0.0172 = 0.0344 *or* 0.0343 (mol) *(process mark)*

1

vol HCl = $\frac{0.0343 \times 1000}{1}$ = 34.3 – 34.5 (cm^3) *(unless wrong unit)*

*(if candidate **used** 0.017 or 0.0171 lose M2)*

(just answer with no working, if in range = (4).
if, say, 34 then =(2))

(if not 2:1 ratio, lose M3 and M4)

(if work on HCl, CE = 0/4)

1

[12]

Q17.

(penalty for sig fig error =1mark per question)

(a) (i) moles KNO_3 = 1.00/101.1 = 9.89×10^{-3} (mol)

1

(ii) pV = nRT or n = pV/RT

1

moles O2 = n = $\frac{pV}{RT}$ = **(1)** $\frac{100000 \times 1.22 \times 10^{-4}}{8.31 \times 298}$ **(1)**

2

= 4.93×10^{-3} (mol)

1

(mark answer first – check back if wrong)

(transcription error lose M3, mark M4 conseq on error)

(if 'untraceable' figures used M3=M4=0)

(if wrong temp conversion – lose M3 – conseq M4)

(if n = RT/pV CE, lose M3 and M4)

(b) (i) simplest/lowest ratio of atoms of each / element/s in a compound / substance / species / entity / molecule

1

(ii)

K	N	O	
$\frac{45.9}{39.1}$	$\frac{16.5}{14}$	$\frac{37.6}{16}$	(1)
1.17	1.18	2.35	(1)

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1 1 2 KNO^2 (1)

(M3 tied to M2), (M3 can be transferred from equation if ratio correct but EF not given) (if calc inverted, lose M2 and M3), (if used At N[1] / wrong No for Ar then CE, lose M2 and M3) (if % of O missing, award M2 only)

3

(c) $2KNO_3 \rightarrow 2KNO_2 + O_2$ or fractions/multiples

(accept $2KNO_3 \rightarrow K_2N_2O_4 + O_2$)

(do NOT accept 'Y' in equation)

1

[10]

Q18.

(a) moles $HNO_3 = 175 \times 10^{-3} \times 1.5 = (0.2625$ mol);

1

moles $Pb(NO_3)_2 = ½ \times 0.2625 = (0.131$ mol);

1

M_r $Pb(NO_3)_2 = 331(.2)$;

1

mass $Pb(NO_3)_2 = 331.2 \times 0.131 = 43.5$ g;

(accept 43.2 - 43.8)

(M1 & M2 are process marks. If error in M1, or in M2, do not mark M4 consequentially, i.e. do not award M4)
(if atomic numbers used in M3, do not award M4)

1

(b) (i) pV = nRT;

1

$$n = \frac{pV}{RT} = \frac{100000 \times 1.5 \times 10^{-4}}{8.31 \times 500};$$

1

= 3.61×10^{-3};

(If pressure not converted to Pa, max 2)

(If n = $\frac{RT}{pV}$ used = CE; M2 = M3 = 0)

1

(ii) moles $NO_2 = 4/5 \times 3.61 \times 10^{-3}$;

[mark is for use of 4/5]

1

$= 2.89 \times 10^{-3}$ *OR* 1.78×10^{-3};

1

M_r NO_2 = 46;

1

massNO_2 = $46 \times 2.89 \times l0^{-3} = 0.1.33$(g)

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OR 0.0821 (g);

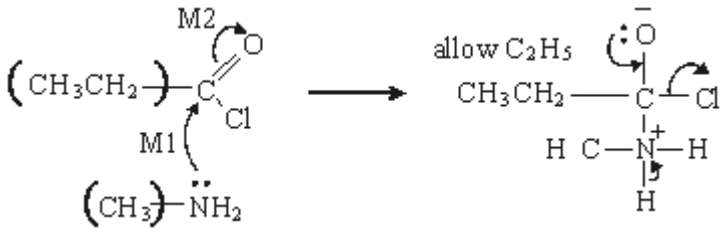
(if atomic numbers used, M3 = M4 = 0)

1

[11]

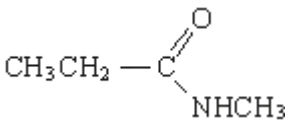
Q19.

(a) (nucleophilic) addition-elimination;



(M3 for structure)
(M4 for 3 arrows and lone pair)
(M2 not allowed independent of M1, but allow M1 for correct attack
on C+ if M2 show as independent first.)
(+on C of C=O loses M2 but ignore δ+ if correct)
(Cl^- removing Ft loses M4)

1



(If MS lost above for wrong C chain, do not penalise same error again here)

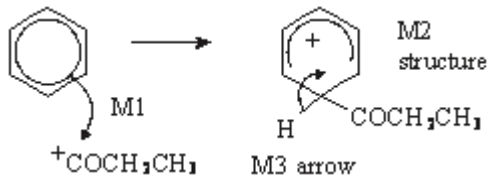
5

(b) $CH_3CH_2COCl + AlCl_3 \rightarrow [CH_3CH_2CO]^+ + AlCl_4^-$;

(penalise wrong alkyl group once at first error)

(position of + on electrophile can be on O or C or outside [ ])
(penalise wrong curly arrow in the equation or lone pair on $AlCl_3$)

1

 *(M1 arrow from within hexagon to C or to + on C)*	*(horseshoe must not extend beyond C2 to C6 but can be smaller)* *(+ not too close to C1)* *(penalise M2 if CH_3 chain wrong again but allow M1 and M3)* *(M3 arrow into hexagon unless Kekule)* *(allow M3 arrow independent*

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(don't penalise position of + on C of RCO+)	*of M2 structure)*

3

$AlCl_4^- + H^+ \rightarrow AlCl_3 + HCl$;

(or can be gained in mechanism);

1

(c) M1 $CH_3CH_2COCl + H_2O \rightarrow CH_3CH_2COOH + HCl$ 1
(penalise wrong alkyl group once at first error)

1

M2 M_r of CH_3CH_2COCl = 92.5 1
(if Mr wrong, penalise M2 only)

1

M3 moles of CH_3CH_2COCl = 1.48/92.5 = 0.016 1

1

M4 moles NaOH = 2 × 0.016 = 0.032 1
(allow for × 2 conseq to wrong no of moles)

1

M5 volume of NaOH = 0.032/0.42 = 0.0762 dm^3 or 76.2 cm^3 1
(with correct units)
(if ×2 missed in M4 lose M5 also)

1

[16]

Q20.

B

[1]

Q21.

D

[1]

Q22.

B

[1]

Q23.

(a) (i) $100 \times 10^{-3} \times 0.500 = 5.00 \times 10^{-2}$ (mol)
accept $5 \times 10^{-2} / 0.05$

1

(ii) $27.3 \times 10^{-3} \times 0.600 = 1.64 \times 10^{-2} / 1.638 \times 10^{-2}$ (mol) <u>only</u>

1

(iii) 1.64×10^{-2} (mol)
Mark conseq on (ii)

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1

(iv) $5.00 \times 10^{-2} - 1.64 \times 10^{-2} = 3.36 \times 10^{-2}$ (mol)

Mark conseq on (i) & (iii)

1

(v) $3.36 \times 10^{-2} \times ½ = 1.68 \times 10^{-2}$ (mol)

If 2.78×10^{-2} used 1.39×10^{-2}

Mark conseq on (iv)

1

$1.68 \times 10^{-2} \times 132(.1)$ **or** $1.39 \times 10^{-2} \times 132(.1)$

Mark for M_r

1

= 2.22 g **or** 1.83 g

1

(b) pV = nRT

1

$n = \frac{0.143}{17}$ = 8.4(1) × 10^{-3} (mol)

1

$T = \frac{pV}{nR} = \frac{100000 \times 2.86 \times 10^{-4}}{8.31 \times 8.4 \times 10^{-3}}$ (1)

1

= 408.5 – 410.5 (K)

Mark conseq on moles

***Note** Sig. fig. penalty - apply once if single sf given, unless calc works exactly*

1

[11]

Q24.

A

[1]

Q25.

C

[1]

Q26.

A

[1]

Q27.

(a) (i) 4.86×10^{-3}

1

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(ii) 2.43×10^{-3}

(mark conseq on (a)(i))

1

(iii) 2.43×10^{-2}

(mark conseq on (a)(ii))

1

(iv) $3.01/2.43 \times 10^{-2}$

(mark conseq on (a)(iii))

1

124

(Do not allow 124 without evidence of appropriate calculation in (a)(iii))

1

(b) $M_r(Na_2CO_3) = 106$
M_r (xH_2O) = 250 –106 = 144 *(mark conseq on M1)*
x = 8 *(mark conseq on M2)*

(Penalise sf errors once only)

3

(c) (i) PV = nRT

1

(ii) Moles A_r = 325/39.9 = 8.15

(accept M_r = 40)

1

P = nRT/V = (8.15 × 8.31 × 298)/5.00 × 10^{-3}
= 4.03×10^6 Pa or = 4.03×10^3 kPa

Range = 4.02×10^6 Pa to 4.04×10^6 Pa

(If equation incorrectly rearranged, M3 & M4 = 0 If n =325, lose M2)

(Allow M1 if gas law in (ii) if not given in (i))

2

[12]

Q28.

A

[1]

Q29.

(a) (i) $75.0 \times 10^{-3} \times 0.500 = 0.0375$ (mol) **(1)**

accept 0.037 or 0.038

(ii) $21.6 \times 10^{-3} \times 0.500 = 0.0108$ (mol) **(1)**

accept 0.011

If both (i) and (ii) answers wrong, allow ONE process mark for both correct processes

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(iii) 0.0375 - 0.0108 = 0.0267 (mol) **(1)**

Not conseq – must use figures shown

(iv) *Moles of $MgCO_3$* = 0.0267/2 = 0.01335 (mol) **(1)**

allow 0.0134 - 0.0133

Mass of $MgCO_3$ = 0.01335 × 84.3 **(1)**

allow 84

mark conseq on moles $MgCO_3$

= 1.125g **(1)**

accept 1.13g

mark conseq

Percentage $MgCO_3$ = 1.125/1.25 × 100 **(1)**

mark conseq (check for inversion)

= 90% **(1)**

mark conseq

range = 89.5 - 90.5%

If % expression inverted, lose M4 and M5

8

(b) (i) % oxygen = 38.0 **(1)**

Na = 36.5/23 S = 25.5/32(.1) O = 38.0/16 **(1)**

= 1.587 = 0.794 = 2.375

= 2:1:3 **(1)**

If no % of oxygen Max 1 (allow M2 only)
If % for Na and S transposed, or atomic numbers used, M1 only available

(ii) $Na_2SO_3 + 2HCl \rightarrow 2NaCl + H_2O + SO_2$ **(1)**

allow multiples

allow $SO_3^{2-} + 2H^+ \rightarrow H_2O + SO_2$

4

[12]

Q30.

(a) (i) pV = nRT **(1)**

(ii) Moles ethanol = n = 1.36/46 (=0.0296 mol) **(1)**

$V = nRT/p = \frac{0.0296 \times 8.31 \times 366}{100000}$ **(1)**

if V = p/nRT lose M3 and M4

= 8.996×10^{-4} (m^3) **(1)**

= 899 (900) cm^3 **(1)** *range = 895 – 905*

*If final answer = 0.899 award (2 + M1); if = 0.899 dm^3 **or** if =*

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912 award (3 + M1)

***Note:** If 1.36 **or** 46 or 46/1.36 used as number of moles (**n**) then M2 and M4 not available*

***Note:** If pressure = 100 then, unless answer = 0.899 **dm**^{3}, deduct M3 and mark consequentially*

5

(b) (i) $Mg_3N_2 + \mathbf{6}H_2O \rightarrow \mathbf{3}Mg(OH)_2 + \mathbf{2}NH_3$ **(1)**

(ii) Moles $NH_3 = \frac{0.263}{17}$ (=0.0155 mol) **(1)**

Number of molecules of $NH_3 = 0.0155 \times 6.02 \times 10^{23}$ **(1)**

[mark conseq] = 9.31×10^{21} **(1)**
[range 9.2×10^{21} to 9.4×10^{21}]

*Conseq (**min** 2 sig fig)*

4

(c) Moles NaCl = 800/58.5 (= 13.68) **(1)**

Moles of $NaHCO_3$ = 13.68 **(1)**

Moles of $Na2CO_3$ = 13.68/2 = 6.84 **(1)**

Mass of Na_2CO_3 = 6.84 × 106 = 725 g **(1)** **[**range = 724 – 727]

[1450 g (range 1448 – 1454) is worth 3 marks]

Accept valid calculation method, e.g. reacting masses or calculations via the mass of sodium present. Also, candidates may deduce a direct 2:1 ratio for $NaCl:Na_2CO_3$

4

[13]

Q31.

B

[1]

Q32.

(a) Moles HCl = $\frac{\text{mass}}{M_r} = \frac{19.6}{36.5}$ **(1)** (= 0.537)

Concentration = $\frac{0.537}{0.25}$ **(1)**

= 2.15 (mol dm^{-3}) **(1)**

Conseq on $\frac{mass}{M_r}$ correct
min 2 d.p. 2.14 to 2.15
Ignore wrong units
A.E. lose one mark

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3

(b) (i) $\frac{21.7}{1000} \times 0.263$ = 5.7**(1)** × 10^{-3} (mol) **(1)**

5.7 to 5.71 × 10^{-3}

(ii) $\frac{5.71 \times 10^{-3}}{2}$ = 2.85 × 10^{-3} (mol) **(1)**

Conseq

(iii) $\frac{0.394}{2.85 \times 10^{-3}}$ = 138 **(1)**

Conseq

(iv) *Relative atomic mass of **M***: 138 - 60 = 78 **(1)**

$\frac{78}{2}$ **= 39 (1)**

***Identify of M*: Potassium or K or K^+ (1)**

Conseq

If 78 = M_r then M = selenium

6

[9]

Q33.

B

[1]

Q34.

(a) L = $\frac{1.0078}{1.6734 \times 10^{-24}}$ **(1)** or $\frac{\text{mass of 1 mol}}{\text{mass of 1 atom}}$

must show working

= 6.0225 × 10^{23} **(1)**

Ignore wrong units

NB answer only scores 1

2

(b) equal **(1)**

Or same or 1:1

1

(c) PV = nRT (or n = $\frac{PV}{RT}$) **(1)**

= $\frac{98000 \times 0.0352}{8.31 \times 298}$ **(1)**

= 1.39 **(1)**

Allow 1.390 to 1.395

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ignore units even if incorrect
answer = 1.4 loses last mark

3

(d) $0.732 \times \frac{1000}{250}$ = 2.93 **(1)** mol.dm^{-3} **(1)**
OR M, mol/dm^3, mol.l^{-1}
allow 2.928 to 2.93
Note unit mark tied to current answer but allow unit mark if answer = 2.9 or 3

2

(e) (i) moles H_2SO_4 = $\frac{25}{1000}$ × 1.24 = 0.0310 **(1)**
If use $m_1v_1 = m_2v_2$ scores 3 if answer is correct otherwise zero

moles NH_3 in 30.8 cm^3 = 0.0310 × 2 = 0.0620 **(1)**
Mark is for ×2
CE if × 2 not used

moles of NH_3 in 1 dm^3 = 0.620 × $\frac{1000}{30.8}$ = 2.01 **(1)** (mol dm^{-3})
Allow 2.010 to 2.015
No units OK, wrong units lose last mark

(ii) moles $(NH_4)_2SO4$ = moles H_2SO_4 = 0.310 **(1)**
Allow consequential wrong moles in part (i) if clear H_2SO_4=$(NH_4)SO_4$
Wrong formula for $(NH_4)_2SO_4$ CE=0

M_r $(NH_4)_2SO_4$ = 132.1 **(1)**
Allow (132)

mass = moles × M_r = 0.0310 × 132.1 = 4.10 **(1)**
if moles of $(NH_4)_2SO_4$ not clear CE
(g) wrong unit loses mark
Allow 4.09 – 4.1 – 4.11

6

(f) $Mg_3N_2 + 6H_2O \rightarrow 3Mg(OH)_2 + 2NH_3$
Formulae (1)
Balanced equation (1)

2

[16]

Q35.

A

[1]

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Q1.

The first part of this question tested synoptic understanding of periodicity. The question discriminated well with good candidates gaining full marks. Weaker candidates often confused electronegativity with ionisation energy. Part (b) also produced a wide spread of marks. Many candidates did not include in their explanations, reasons for the strong forces between ions in sodium oxide and why the forces between molecules in phosphorus(V) oxide are relatively weak. Common errors amongst weak candidates were to mistake sodium oxide for an oxide of sulfur or to refer to the existence of molecules in sodium oxide. Part (c) demanded an appreciation that three moles of sodium hydroxide react with one mole of phosphoric acid and that one mole of phosphorus(V) oxide gives four moles of phosphoric acid. This, together with the dilution factor of one million, resulted in a wide but even spread of marks for the question with only 15% of candidates gaining all six marks.

Q2.

This was generally well done and candidates appear to be able to do simple numerical questions. There was confusion over the number of decimal places in the answers with some candidates simply writing all the digits from their calculator. In general, answers should be to the same number of significant figures as given in the question. The major problem with part (b) was the conversion of pressure into the correct units and the subsequent effect on the units of the answer. Part (c) was done well by the majority of candidates. It should however be stressed that the answer to an empirical formula calculation is a formula and not simply the ratio of the elements.

Q3.

This question aimed to test areas of the Specification in the context of the historical methods used for the extraction of bromine and a real application of the chemistry of bromine in its use in swimming pools in France and the USA. Part (a) proved quite demanding although almost 75% of candidates gained some credit. Part (b) discriminated well with the full range of marks seen and more than half of the candidates were able to gain at least 2 marks. Candidates who could balance the equation had no difficulty with this part of the question. Part (c) was often well answered with 80% of the candidates gaining at least 2 marks.

Q4.

In part (a) most candidates easily scored the first two marks, but converting the ratios to an empirical formula was more demanding. Some centres virtually awarded this mark by default, even when the candidate’s explanation for the third mark was simply wrong.

In part (c)(i) the candidate was required to draw simple apparatus. Many candidates drew a practical set-up that would not work. The common problems were that the gas could not escape from the preparation vessel or that the collection vessel was not graduated and could therefore not record volume. A number of candidates assembled apparatus that was unsafe and should not have been awarded any marks at all. Marking of this question was often very generous indeed.

In part (c)(ii) the candidate was required to draw a simple graph. This generated the usual problems with marks being wrongly awarded for plotted points which did not cover half the paper and for graphs containing incorrectly plotted points. If the candidate’s graph

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included the origin, then the candidate's line had to pass through the origin to score the line of best fit mark.

When candidates wrote 'because a gas is produced' as an answer to part (d) they were often credited with a mark. In general, candidates do not receive a mark for basically rewording part of a question rubric. The Marking Guidelines were quite clear that the effect on the human body was needed in a correct answer

Part (e) was, perhaps, the most demanding question of all. Full marks were rarely seen because the great majority of candidates struggled to express themselves clearly. Marking of this question was often very generous indeed. Candidates were often given a mark for any chemical reference to empirical or molecular formula. In this question two distinct ideas were required for the full award. Candidates needed to link molecular formula to empirical formula as a multiple and then say that a small error in the molecular formula mass would still allow a good judgement of which multiplier should have been used.

Marking was often very generous in part (f). When candidates are asked to suggest reasons why an experiment might not deliver the expected result the candidate is expected to suggest something more imaginative than misread the apparatus' or 'the apparatus was faulty'. The Marking Guidelines were quite clear that a reference to when the apparatus was assembled was needed for a gas leak to be worth a mark. The idea of the gas remaining in the flask was not sufficient unless the possibility of the gas dissolving was specifically mentioned.

In part (g) a statement of the Gas Law was often given a mark. 'PV = nRT' is not a sufficient answer since it does not show that the candidate understands what the equation means in regard to the volume of the gas.

In part (i)(i) centres were too generous in the interpretation of the key words in an answer. "Less soluble" and "not very soluble" were not acceptable alternatives to "least soluble".

Centres are asked to check candidates' equations carefully. Some candidates had an incorrect equation for part (j) but were still given a mark.

Q5.

In part (a) the candidate was required to draw a graph. This generated the usual problems of plotted points which did not cover half the paper and graphs containing incorrectly plotted points. If the candidate's graph included the origin, then the candidate's line had to pass through the origin to score the line of best fit mark.

A surprising number of candidates used a non-linear scale for the *x*-axis, and some lost a mark for drawing a doubled line of best fit.

To score the mark in part (d) the candidate had to provide a definite link between the answer to part (c) and the M_r of $MgCO_3.2H_2O$. A large number of candidates simply stated the M_r value and left it to the marker to draw the appropriate conclusion, thereby losing the mark.

Candidates' answers to part (e) usually missed the point. Very few realised the significance of the number of molecules of water of crystallisation being a whole number.

In part (f) many candidates lost a mark because they did not comment on the quality of their line of best fit. Answers such as 'the graph shows a positive correlation' need to be expanded to be worth a mark. Most candidates were able to identify the anomalous result.

In part (g) many candidates lost a mark by referring to a loss of water from the sample,

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rather than appreciating that the decomposition went further.

A number of candidates still struggled to express themselves in part (h)(i). Many stated that ‘small amounts were hard to weigh’ or ‘couldn’t be weighed’, rather than focussing on the significance of the percentage errors in obtaining the mass of small amounts. In part (h)(ii) ‘the experiment takes too long’ or ‘the experiment is too expensive’ were popular choices which were not worth a mark.

Candidates found several valid approaches to answering part (i) and many scored full marks.

If candidates understood the meaning of atom economy, they tended to score full marks on this part. It was surprising however to see how many could not calculate two simple M_r values.

part (l) proved to be the most difficult question of all. There was a wide range of ingenious answers but hardly any candidates made reference to the pressure from a gas produced in the stomach causing discomfort.

Q6.

In part (a), atom economy, being a relatively new type of calculation, posed a few problems with candidates unsure of which relative formula masses to use. Some candidates inverted the formula and a few incorrectly copied the 79.9 as 79 into their working. Most candidates realised that the HCl needed to be sold although incorrect answers referred to recycling or just using the HCl. Most candidates could calculate the number of moles in part (b) (i) but then some could not use the equation to answer part (b) (ii) and even more could not use the correct molecular mass formula in part (b) (iii). Part (b) (iv) was more demanding with many candidates not using their answer to part (b) (iii) or realising that a yield of over 100% was impossible.

Q7.

Most candidates correctly calculated the number of moles in part (a) (i) but errors were made in part (a) (ii) by candidates who failed to divide by 2 or sometimes multiplied by 2. There were quite a few errors involving powers of ten and in part (a) (iii) not all candidates used the value 0.548 in their calculation. Part (b) was generally done well although some candidates tried to identify their metal using the atomic number and not the relative atomic mass. A small number gave fluorine as their answer not realising that it was not a metal.

Q10.

Part (a)(i) was often poorly answered. Answers in terms of M_r and mass were quite common, as were statements such as the *number of atoms/particles in lg of substance.* Candidates, who correctly defined a mole in terms of the Avogadro constant, often spoiled their answer by misquoting its value or by referring to there being the Avogadro number of atoms, rather than molecules, in a mole of molecules. Some good answers linking the mole to the number of atoms of carbon in 12.00 g of ^{12}C, were seen.

-

In part a(ii), the majority of candidates, when attempting to calculate the number of moles of oxygen formed in the reaction, divided the mass by 16 rather than by 32. Also, in part (a)(iii), a surprising number of candidates used 908, rather than 227, as the M_T for nitroglycerine. Similarly, there were many errors in determining the total number of moles of gas formed; the most common error being 28, rather than 29. As the remaining marks were awarded consequentially, many candidates still achieved a reasonable mark for this

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calculation. In part (b), the Gas law expression was well known and the question was well answered. However, a significant number of candidates, having correctly calculated the pressure and quoted its units as Pa., thereby earning all 4 marks, chose to convert their answer into larger pressure units. Errors in this conversion were quite common and so the final mark was lost.

Q11.

This was a high scoring question with many scores of eight or more marks. In part (a) candidates were penalised if the radical dot was shown to be on the CH_3 group, rather than as given in the question. In part (b) many equations gave hydrogen as the product rather than hydrogen bromide, suggesting that candidates had difficulty applying the information to a novel situation. Parts (c) and (d) (i) were frequently correct, although the failure to number all of the substituents on the two carbon atoms of halothane was penalised. In part (d) (ii), many candidates had problems using the data to calculate a correct relative molecular mass and the answer of 197.4 was the only response accepted. In part (d) (iii), consequential credit was awarded, with correct answers to either 3 or 4 significant figures being accepted.

Q12.

This question discriminated effectively between candidates of differing abilities. Very able candidates scored well in all parts of the question except in parts (b) (ii) and (b)(iii). In part (a) a surprising number of candidates attempted to write an equation with the Fe^{2+} ion as a reactant instead of Fe. Answers to part (a)(ii) were usually correct. In part (a)(iii), many candidates incorrectly calculated the number of moles of iron by halving the number of moles of hydrogen. The method for calculating the mass of iron was usually correct but, although it was allowed, it was disappointing to note that candidates were using an^4$_r$ value of 56 for iron instead of the value of 55.8, given on the Periodic Table. Answers to part (a)(iv) usually used the correct method. Answers to part (b) (i) were almost always correct but the equations involving dichromate(VI) ions were only given correctly by the best candidates. Very few correct answers to part (b)(ii) were seen. The usual error was a failure to recognise that six moles of iron(II) ions react with one mole of dichromate(VI) ions. In part (b)(iii) most candidates did not recognise that chloride ions would be oxidised by manganate(VII) ions.

Q16.

On the whole, this question was well answered. The relative masses and charges of neutrons and electrons were generally well known but errors were not uncommon. Some candidates reversed the contents of the *mass* and *charge* columns, suggesting that they had rote learned a table with a different layout of columns.

Part (b) was quite well done but errors such as ^{17}Be, ^{13}O, $^{17.0}O$ and ^{16}O were not uncommon.

While many candidates correctly deduced the shapes of the molecules in part (c), the presence of a lone pair of electrons on the Be atom, or one/three lone pairs of electrons on the O atom, was quite common. The shape of the $BeCl_2$ molecule was well known but there was considerable confusion regarding the shape of the Cl_2O molecule. Many candidates gave *tetrahedral* as the shape of this molecule. While the distribution of electron pairs around the oxygen atom might be described as *tetrahedral*, this is not the shape produced by the atoms in the molecule. Many candidates described the shape in appropriately by using the terms *bent*, *V-shaped* and *angular*. The use of *tetrahedral* was accepted in this examination but this may not be the case in future examinations. A significant number of candidates used the term *bent linear* when describing the shape of Cl_2O molecules; this was treated as a contradiction and so earned no credit. A significant

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number of candidates attempted to show the shapes of these molecules using dot-and-cross diagrams; these were not accepted.

The calculation in part (d) was correctly performed by many candidates, but errors such as the use of incorrect *M*r values or the use of an incorrect mole ratio were quite common. A small but significant number of candidates assumed the use of a known mass of HCl and ignore the 1.00 g of $Mg(OH)_2$ stipulated in the question; such answered earned no credit.

Q17.

This question was also generally well answered. In part (a), the mole calculation was well done, although errors such as 9.89 were seen, and most candidates were successful in calculating the number of moles of oxygen. The Ideal gas equation was well known; however, some candidates rearranged it incorrectly. In a small but significant number of instances, incorrect pressure values were used, and a small number of arithmetic errors were found. The explanation of the term *empirical formula*, although frequently incomplete, was rather better answered than in previous years. The calculation of the empirical formula was quite well done, although it was not unusual for candidates to forget to calculate and use the percentage of oxygen in **Y**, to use incorrect *A*r values or to divide the *A*r values by the percentages.

The equation in part (c) was usually correct; however, some candidates wrote equations in which the KNO_3:O_2 ratio was not 2:1, despite having correctly shown that the number of moles of KNO_3 was twice that of O_2 in part (a). Also, it was not unusual to see equations in which oxygen was shown as 'O'.

Q18.

Overall, this question was not as well answered as the equivalent numerical question last year; however, full marks were not uncommon. In part (a), most candidates correctly deduced that number of moles of $HN0_3$, but errors beyond this point were very common. The most common errors concerned the mole ratio and the M_r calculation. Part (b)(i) was generally well answered; a very small proportion of candidates inverted the expression when calculating the number of moles of gas, however, a more common error was to omit the conversion of the pressure from kPa to Pa. Part (b)(ii) was quite poorly answered. Very few candidates recognised that the NO_2:O_2 ratio of 4:1 in the equation meant that the NO_2 accounted for 4/5 of the total moles of gas. It was much more common to see the total number of moles of gas, from part (b)(i) ,being multiplied by a factor other than 4/5. Most candidates correctly converted their answer for the number of moles of NO_2 into a mass. Some M_T errors were seen, the most common being 184 and 62, and, in a very few instances, candidates divided the number of moles by the M_r value

Q19.

The better candidates often gained full marks in part (a). The most common errors were similar to those described in Question 3(a) above. In part (b), despite the request to write equations to show the role of aluminium chloride, many drew a mechanism often containing incorrect curly arrows and were penalised. The electrophilic substitution mechanism was generally well answered although careless drawing of the electrophile with wrong position of the + charge often led to incorrectly linked $COCH_2CH_3$ side chains, with CH_3 or O joined to benzene ring. Many failed to write an equation for the regeneration of the $A1C1_3$ catalyst. In part (c), few realised that hydrolysis of propanoyl chloride forms both propanoic and hydrochloric acids, both of which react with sodium hydroxide. Hence the most common answer was half the correct value. A disappointing number also failed to calculate the correct M_r of propanoyl chloride, the formula for which was given at the start of the question.

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Q23.

This question was in general very well answered. Most candidates were able to display considerable numerical skill and full marks, or near full, marks were very common. Answers to parts (a)(i) and (a) (ii) were almost always correct. Part (a) (iii) was less well done, with some candidates subtracting their answer to part (a) (ii) from that for part (a) (i), rather than deducing that the number of moles of unreacted NaOH must be equal to the number of moles of HC1 used to neutralise it. Many of these candidates then consequentially earned the mark part (a) (iv) by correctly applying the calculation process to their answers to parts (a) (i) and (a) (iii). Most candidates also coped well with part (a) (v); however, the incorrect use of the mole ratio, errors in calculating the M_r value of ammonium sulphate or arithmetical errors were not uncommon. Part (b) was generally very well done, clearly a well-practiced technique. The gas law equation was almost always correct and most candidates correctly calculated the number of moles of ammonia, although a surprisingly large minority used 18 as theM_r value of ammonia. The vast majority of candidates rearranged the equation correctly, however, a small number failed to convert the pressure to Pa. Examiners reported that in a small number of centres candidates had used the units of kPa and dm^3 in their calculations. Candidates were not penalised for using this approach on this occasion but centres are requested to ensure that candidates use the correct metric units of Pa and m^3 in future gas law calculations.

Q27.

This question was, on the whole, well answered, with full marks being frequently earned. Many candidates were able to correctly complete parts (a)(i), (a)(ii) and (a)(iii). However, it was not uncommon to see an answer of 124 for part (a)(iv), which had not been derived from the answer to part (a)(iii). Candidates who assumed the sodium carbonate to be the monohydrate, and thus calculated its M_r value to be 124, rather than basing their calculation on their answer to part (a)(iii), earned no credit in part (a)(iv). Part (b) was also generally well answered but candidates who used 124, rather than 106, for the M_r of Na_2CO_3 lost the first mark for the calculation. Part (c) was similarly well answered by many candidates. A few candidates were unable to rearrange the gas law equation, but the majority of errors related to the incorrect calculation of the number of moles of argon, or to missing/incorrect units.

Q29.

Part (a) was, in general, poorly answered. While the more able candidates coped well, many candidates struggled. Correct answers to parts (a)(i) and (ii) were frequently seen but, in many cases, the answer of 0.0267 was given in part (a)(iii) without use being made of the answers from the previous two parts; the mark for this part was awarded for a correct calculation method, not for simply quoting 0.0267. In part (a)(iv), when attempting to calculate the number of moles of $MgCO_3$, rather more candidates used the value of the total moles of HCl (0.0375 mol) obtained in part (a)(i) than used the actual number of moles which reacted with the $MgCO_3$ (0.0267 mol) obtained in part (a)(iii). The calculation of the mass of $MgCO_3$ was marked consequentially but, as the final percentage of $MgCO_3$ exceeds 100%, the majority of candidates who followed this route chose to invert their percentage calculation, rather than checking for an earlier error in their calculation. A number of other errors were seen in this part, suggesting that many candidates lacked familiarity with this type of calculation. By contrast, the calculation in part (b) was quite well done. The occasional arithmetical error was seen, a few candidates omitted to deduce the percentage of oxygen and the atomic number was occasionally used in place of the relative atomic mass, but most candidates earned full marks in part (b)(i). However, the equation in part (b)(ii) was rarely correct, with errors such as $NaCl_2$, H_2 and SO_3 being very common.

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Q30.

Most candidates correctly stated the ideal gas equation but the calculation which followed was frequently incorrect. The most common errors included rounding the number of moles of ethanol to 0.03 mol and the use of 100 as the value for the pressure. There was a wide range of units suggested for the volume calculated from the ideal gas equation and few candidates were able to convert this volume in m^3 to the required volume in cm^3. The equation in part (b) was usually correctly balanced, but rounding errors were again common in the following calculation. A significant number of candidates divided n by L in this calculation, rather than multiplying the two together. The calculation in part (c) proved to be easy for the more able candidates but posed considerable problems for many others. The calculation of the number of moles of NaCl was often correctly performed but the use of a 1:1 mole ratio between $NaHCO_3$ and $Na2CO_3$ was very common. Some candidates assumed that $NaHCO_3$ was sodium carbonate and used an Mr value of 84 in their calculation. Some novel, and often successful, approaches to this calculation were seen.

Q32.

Overall, this question was well done with many candidates scoring full marks. Some candidates experienced problems with part (a) and were not able to calculate the number of moles of HCl (the use of an Mr of 18 was quite common here) or they incorrectly used the volume of the solution in the final calculation. Part (b) was generally well done with the most common error being to overlook the necessity of dividing by 2 in part (iv) when deducing the Ar of the metal. As a result, selenium was a common wrong answer for the identity of M. Some candidates recorded their answer to parts such as (b)(i) incorrectly in that they showed the concentration as 5.7^{-03}, rather than as 5.7×10^{-3}, presumably as a result of using directly the readout from their calculator in their answer. As a result of calculation errors a fair number of different identities for M were suggested; credit was given as appropriate.

Q34.

This question was answered well by many candidates and high marks were scored. In part (a) there was some confusion between 5 decimal places and five significant figures. Candidates also had difficulty handling powers of ten. Some candidates did not appear to understand part (b); they missed the point and gave an answer suggesting that ammonia had more atoms. Answers to part (c) were usually correct but a common error in the application of the formula n = PV/RT was a failure to convert the pressure of 90.0 kPa into Pascals. Part (d) was answered well but fewer correct answers to part (e) were seen. In part (e)(i) common mistakes were to use the wrong volume of sulphuric acid solution and also to omit the factor of two when calculating the number of moles of ammonia from the moles of sulphuric acid. In part (e) (ii) the M_r of ammonium sulphate was usually correct but weaker candidates did not recognise that the number of moles of ammonium sulphate was the same as the number of moles of sulphuric acid calculated in part (e) (i). In part (f) only the best candidates gave a correct formula for magnesium hydroxide; a very common error was to give the incorrect formula, MgOH.

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Empirical molecular formula Part 2

Name: _____

Class: _____

Date: _____

Time: **349 minutes**

Marks: **313 marks**

Comments:

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Q1.

A hydrocarbon contains 87.8% by mass of carbon and has a relative molecular mass (M_r) of 82.0
The hydrocarbon decolourises bromine water.

Determine the empirical and molecular formulae of the hydrocarbon.
Suggest **two** possible structures for the hydrocarbon.
Name the type of reaction taking place when bromine water reacts with the hydrocarbon.

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

(Total 6 marks)

Q2.

What is the empirical formula of an oxide of nitrogen that contains 26% nitrogen by mass?

A NO_2 ⬭

B N_2O_3 ⬭

C N_2O_5 ⬭

D N_4O_5 ⬭

(Total 1 mark)

Q3.

An experiment was carried out to determine the relative molecular mass (M_r) of a volatile hydrocarbon **X** that is a liquid at room temperature.

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A known mass of **X** was vaporised at a known temperature and pressure and the volume of the gas produced was measured in a gas syringe.

Data from this experiment are shown in the table.

Mass of **X**	194 mg
Temperature	373 K
Pressure	102 kPa
Volume	72 cm^3

(a) Calculate the relative molecular mass of **X**.

Show your working.

Give your answer to the appropriate number of significant figures.

The gas constant, R = 8.31 J K^{-1} mol^{-1}

Relative molecular mass _____

(5)

(b) Analysis of a different hydrocarbon **Y** shows that it contains 83.7% by mass of carbon.

Calculate the empirical formula of **Y**.

Use this empirical formula and the relative molecular mass of **Y** (M_r = 86.0) to calculate the molecular formula of **Y**.

Empirical formula _____

Molecular formula _____

(4)

(Total 9 marks)

Q4.

2.40 g of an explosive, J, contains 0.473 g of nitrogen. J also contains 33.8% carbon and 1.41% hydrogen by mass. The remainder of J is oxygen.

What is the empirical formula of J?

A C_4HNO_2 ⬭

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B CH_2N_2O ⬭

C C_2HNO_2 ⬭

D CHNO ⬭

(Total 1 mark)

Q5.

What is the empirical formula of 4-hydroxypent-2-ene?

A $C_5H_{12}O$ ⬭

B $C_5H_{10}O$ ⬭

C CH_2O ⬭

D C_5H_9OH ⬭

(Total 1 mark)

Q6.

This question is about halogenoalkanes.

(a) Chlorine atoms are formed in the upper atmosphere when ultraviolet radiation causes C–Cl bonds in chlorofluorocarbons (CFCs) to break.

Write **two** equations to show how chlorine atoms catalyse the decomposition of ozone.

1. _____

_____

2. _____

_____

(2)

(b) Chloroethane reacts with potassium hydroxide in the presence of propan-1-ol to form ethene.

State the role of potassium hydroxide and the role of propan-1-ol in the reaction.

Role of potassium hydroxide _____

Role of propan-1-ol _____

(2)

(c) Name and outline a mechanism for the reaction in part **(b)** between chloroethane and potassium hydroxide to produce ethene.

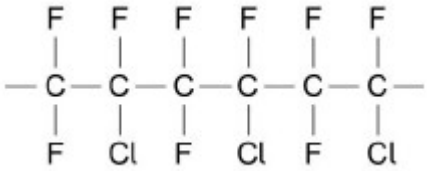
Name of mechanism _____

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Mechanism

(4)

(d) The structure of polymer **A** is shown.



Draw the structure of the monomer used to form polymer **A**.

(1)

(e) Chemical analysis shows that a chlorofluoroalkane, **B**, contains by mass 51.6% fluorine, 32.1% chlorine and no hydrogen.

Chlorine exists as two isotopes, ^{35}Cl and $3^{37}Cl$, in the ratio 3:1
Fluorine only exists as one isotope, ^{19}F.

A mass spectrum of **B** is obtained using electron impact ionisation. The mass spectrum shows three molecular ion peaks at *m/z* = 220, 222 and 224.

Determine the formula of each of the three molecular ions of **B**.

Predict and explain the ratio of the relative abundancies of each of the three molecular ion peaks at *m/z* = 220, 222 and 224.

To gain full marks you must show all your working.

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_____

_____

_____

(6)

(Total 15 marks)

Q7.

Glucose can decompose in the presence of microorganisms to form a range of products. One of these is a carboxylic acid (M_r = 88.0) containing 40.9% carbon and 4.5% hydrogen by mass.

(a) Deduce the empirical and molecular formulas of the carboxylic acid formed.

Empirical formula = _____ Molecular formula = _____

(4)

(b) Ethanol is formed by the fermentation of glucose.
A student carried out this fermentation reaction in a beaker using an aqueous solution of glucose at a temperature of 25 °C in the presence of yeast.

Write an equation for the reaction occurring during fermentation.

_____

(1)

(c) In industry, this fermentation reaction is carried out at 35 °C rather than 25 °C.

Suggest **one** advantage and **one** disadvantage for industry of carrying out the fermentation at this higher temperature.

Advantage _____

_____

Disadvantage _____

_____

(2)

(d) The method used by the student in part (b) would result in the ethanol being contaminated by ethanoic acid.

How does this contamination occur?

_____

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_____

(1)

(e) Give **two** differences between the infrared spectrum of a carboxylic acid and that of an alcohol other than in their fingerprint regions.
Use **Table A** on the Data Sheet.

Difference 1 _____

_____

Difference 2 _____

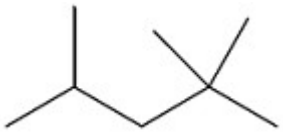
_____

(2)

(Total 10 marks)

Q8.

Isooctane (C_8H_{18}) is the common name for the branched-chain hydrocarbon that burns smoothly in car engines. The skeletal formula of isooctane is shown below.



(a) Give the IUPAC name for isooctane.

_____

(1)

(b) Deduce the number of peaks in the ^{13}C NMR spectrum of isooctane.

5 ⬭

6 ⬭

7 ⬭

8 ⬭

(1)

(c) Isooctane can be formed, together with propene and ethene, in a reaction in which one molecule of an alkane that contains 20 carbon atoms is cracked.

Using molecular formulas, write an equation for this reaction.

_____

(1)

(d) How do the products of the reaction in part (c) show that the reaction is an example of thermal cracking?

_____

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(1)

(e) Deduce the number of monochloro isomers formed by isooctane.
Draw the structure of the monochloro isomer that exists as a pair of optical isomers.

Number of monochloro isomers

_____

Structure

(2)

(f) An isomer of isooctane reacts with chlorine to form only one monochloro compound.

Draw the **skeletal formula** of this monochloro compound.

(1)

(g) A sample of a monochlorooctane is obtained from a comet. The chlorine in the monochlorooctane contains the isotopes ^{35}Cl and ^{37}Cl in the ratio 1.5 : 1.0
Calculate the M_r of this monochlorooctane.

M_r = _____

(2)

(h) Isooctane reacts with an excess of chlorine to form a mixture of chlorinated compounds.
One of these compounds contains 24.6% carbon and 2.56% hydrogen by mass.
Calculate the molecular formula of this compound.

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Molecular formula = _____

(3)

(Total 12 marks)

Q9.

A different kind of kiln is used to manufacture Portland cement. The main active minerals in Portland cement are called alite and belite.

(a) The table shows the composition of a compound found in alite that contains only the elements calcium, silicon and oxygen. Use these percentage by mass data to determine the empirical formula of this compound.

	Ca	**Si**	**O**
% by mass	52.67	12.30	To be calculated

_____

_____

_____

_____

_____

(3)

(b) A compound (Ca_2SiO_4) in belite reacts with water to produce $Ca_3Si_2O_4(OH)_6$ and $Ca(OH)_2$
Write an equation for this reaction.

_____

(1)

(c) Bags of Portland cement are labelled with hazard warnings.
Suggest an item of personal safety equipment, other than eye protection, that the warning label recommends.
Give a reason why this safety equipment is recommended.

Safety equipment _____

Reason _____

(2)

(Total 6 marks)

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Q10.

An organic compound is found to contain 40.0% carbon, 6.7% hydrogen and 53.3% oxygen.

Which of the following compounds could this be?

A Ethanol ⬭

B Ethanoic acid ⬭

C Methanol ⬭

D Methanoic acid ⬭

(Total 1 mark)

Q11.

Compounds containing $Cu2^{+}$, OH^{-} and CO_3^{2-} ions are sometimes described as basic copper carbonates.

(a) Solid $Cu_2(OH)_2CO_3$ is added to an excess of dilute hydrochloric acid.
A solution of copper(II) chloride is formed, together with two other products.

(i) Write an equation for the reaction.

_____

(2)

(ii) Suggest **one** observation that could be made during the reaction.

_____

_____

(1)

(b) A 5.000 g sample of a different basic copper carbonate contains 0.348 g of carbon, 0.029 g of hydrogen and 1.858 g of oxygen.

(i) State what is meant by the term empirical formula.

_____

_____

(1)

(ii) Calculate the empirical formula of this basic copper carbonate.
Show your working.

_____

_____

_____

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_____

_____

_____

_____

_____

(3)

(Total 7 marks)

Q12.

Compound **R** contains 61.0% carbon and 11.9% hydrogen by mass. The remainder is oxygen.
The mass spectrum of **R** contains a molecular ion peak at m/z = 118.

(a) Use these data to show that the molecular formula of **R** is $C_6H_{14}O_2$.

_____

_____

_____

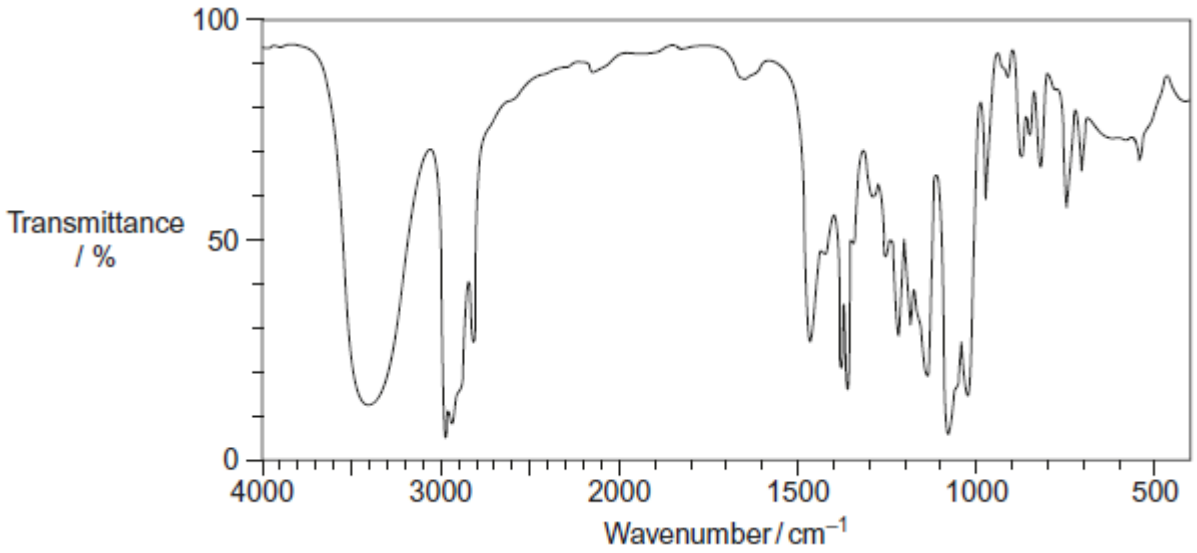
_____

_____

_____

(3)

(b) The infrared spectrum of **R** ($C_6H_{14}O_2$) is shown below.



The proton n.m.r. spectrum of **R** contains five peaks. The chemical shift values, integration ratios and splitting patterns of these peaks are given in the table.

Chemical	3.8	3.2	3.1	1.4	1.1

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shift/ppm					
Integration ratio	2	3	1	2	6
Splitting patterns	triplet	singlet	singlet	triplet	singlet

When **R** is warmed with acidified potassium dichromate(VI) a green solution is formed.

Use **Table A** and **Table B** on the data sheet and all of the data provided in the question to deduce the structure of **R**.

In your answer, explain how you have used the data provided in the question.

(9)

(Total 12 marks)

Q13.

A sample of hydrated nickel sulfate ($NiSO_4.xH_2O$) with a mass of 2.287 g was heated to remove all water of crystallisation. The solid remaining had a mass of 1.344 g.

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(a) Calculate the value of the integer x.
Show your working.

(4)

(b) Suggest how a student doing this experiment could check that all the water had been removed.

(2)

(Total 6 marks)

Q14.

When boric acid (H_3BO_3) is applied as a coating on wood, it acts as a fire retardant by decreasing the rate of combustion.

Thermal decomposition of boric acid takes place in two stages.

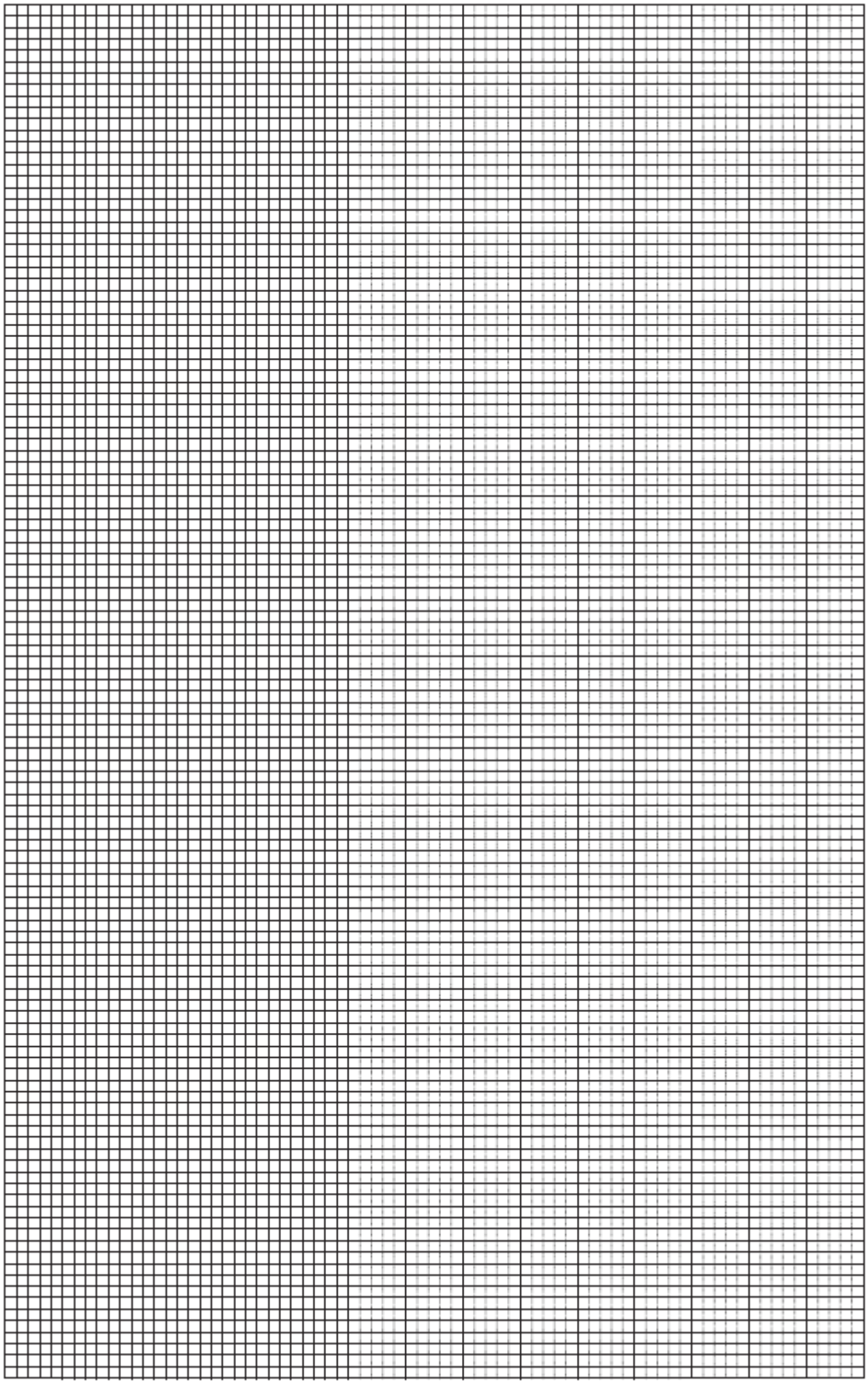
In an experiment a sample of boric acid was heated in a crucible at 170 °C. The results of this experiment are given in the table.

Time of heating / minutes	Mass of crucible and contents / g
0	35.85
5	35.10
10	34.41
15	34.00

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20	33.70
25	33.56
30	33.50
35	33.50

Plot a graph of the results from the table above to show the mass of the crucible and boric acid (*y*-axis) against time of heating on the grid.



(Total 4 marks)

Q15.

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(a) Calcium phosphate reacts with aqueous nitric acid to produce phosphoric acid and calcium nitrate as shown in the equation.

$$Ca_3(PO_4)_2 + 6HNO_3 \longrightarrow 2H_3PO_4 + 3Ca(NO_3)_2$$

(i) A 7.26 g sample of calcium phosphate reacted completely when added to an excess of aqueous nitric acid to form 38.0 cm^3 of solution.

Calculate the concentration, in mol dm^{-3}, of phosphoric acid in this solution.
Give your answer to 3 significant figures.

(5)

(ii) Calculate the percentage atom economy for the formation of calcium nitrate in this reaction.
Give your answer to 1 decimal place.

(2)

(b) Write an equation to show the reaction between calcium hydroxide and phosphoric acid to produce calcium phosphate and water.

(1)

(c) Calcium dihydrogenphosphate can be represented by the formula $Ca(H_2PO_4)_x$ where x is an integer.
A 9.76 g sample of calcium dihydrogenphosphate contains 0.17 g of hydrogen, 2.59 g of phosphorus and 5.33 g of oxygen.

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Calculate the empirical formula and hence the value of x.
Show your working.

(4)

(Total 12 marks)

Q16.

Zinc forms many different salts including zinc sulfate, zinc chloride and zinc fluoride.

(a) People who have a zinc deficiency can take hydrated zinc sulfate ($ZnSO_4.xH_2O$) as a dietary supplement.

A student heated 4.38 g of hydrated zinc sulfate and obtained 2.46 g of anhydrous zinc sulfate.

Use these data to calculate the value of the integer *x* in $ZnSO_4.xH_2O$
Show your working.

(3)

(b) Zinc chloride can be prepared in the laboratory by the reaction between zinc oxide and hydrochloric acid.
The equation for the reaction is

$$ZnO + 2HCl \longrightarrow ZnCl_2 + H_2O$$

A 0.0830 mol sample of pure zinc oxide was added to 100 cm^3 of 1.20 mol dm^{-3}

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hydrochloric acid.

Calculate the maximum mass of anhydrous zinc chloride that could be obtained from the products of this reaction.

(4)

(c) Zinc chloride can also be prepared in the laboratory by the reaction between zinc and hydrogen chloride gas.

$$Zn + 2HCl \longrightarrow ZnCl_2 + H_2$$

An impure sample of zinc powder with a mass of 5.68 g was reacted with hydrogen chloride gas until the reaction was complete. The zinc chloride produced had a mass of 10.7 g.

Calculate the percentage purity of the zinc metal.
Give your answer to 3 significant figures.

(4)

(d) Predict the type of crystal structure in solid zinc fluoride and explain why its melting point is high.

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_____

_____

_____

_____

(3)

(Total 14 marks)

Q17.

There is an experimental method for determining the number of water molecules in the formula of hydrated sodium carbonate. This method involves heating a sample to a temperature higher than 300 °C and recording the change in mass of the sample. The equation for the reaction taking place is

$$Na_2CO_3.10H_2O(s) \longrightarrow Na_2CO_3(s) + 10H_2O(g)$$

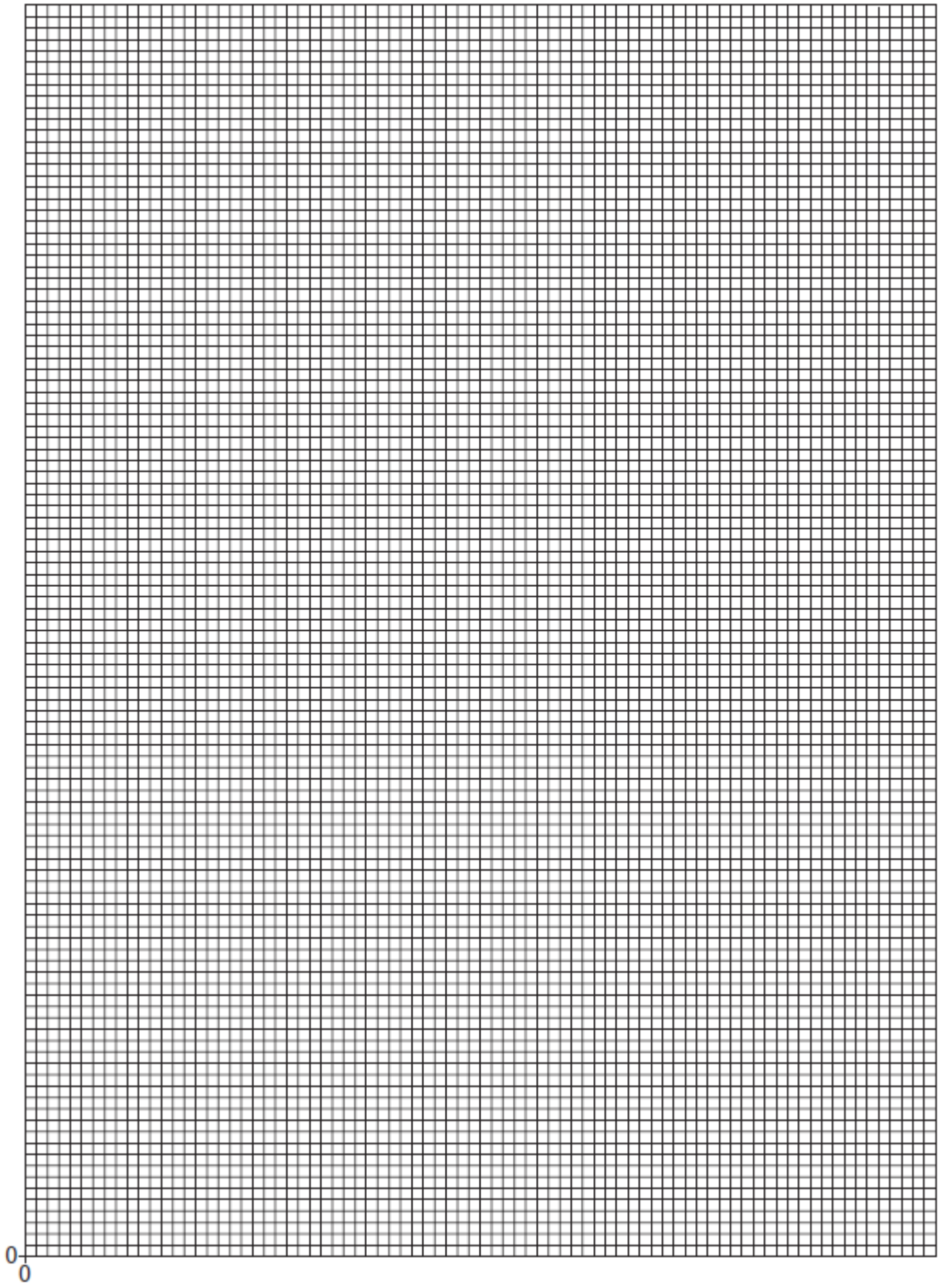
A group of six students carried out this experiment. They each weighed out a sample of hydrated sodium carbonate. They then heated their sample to a temperature higher than 300 °C in a crucible for ten minutes and recorded the final mass after the crucible had cooled. Their results are summarised in the table.

Student	1	2	3	4	5	6
Initial mass / g	2.43	1.65	3.58	1.09	2.82	1.95
Final mass / g	0.90	0.61	1.53	0.40	1.15	0.72

(a) Plot the values of **Initial mass** (y-axis) against **Final mass** on the grid below.

A graph of these results should include an additional point.
Draw a circle on the grid around the additional point that you should include.

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(4)

(b) Draw a best-fit straight line for these results that includes your additional point.

(1)

(c) Identify each student whose experiment gave an anomalous result.

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_____

_____

(1)

(d) All the students carried out the experiment exactly according to this method. Explain why a student that you identified in part (c) obtained an anomalous result.

_____

_____

_____

_____

(2)

(Total 8 marks)

Q18.

The pigment 'Cobalt Yellow' contains an octahedral complex of cobalt(III) and nitrate(III) ions (NO_2^-). Analysis shows that Cobalt Yellow contains 13.0% of cobalt, 18.6% of nitrogen and 25.9% of potassium by mass. The remainder is oxygen.

(a) Use these data to calculate the empirical formula of Cobalt Yellow. Show your working.

_____

_____

_____

_____

_____

_____

_____

(3)

(b) Deduce the structural formula of the cobalt-containing ion in Cobalt Yellow.

_____

(1)

(Total 4 marks)

Q19.

The following table shows the electronegativity values of the elements from lithium to fluorine.

	Li	Be	B	C	N	O	F
Electronegativity	1.0	1.5	2.0	2.5	3.0	3.5	4.0

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(a) (i) State the meaning of the term *electronegativity*.

_____

_____

_____

(2)

(ii) Suggest why the electronegativity of the elements increases from lithium to fluorine.

_____

_____

_____

(2)

(b) State the type of bonding in lithium fluoride.
Explain why a lot of energy is needed to melt a sample of solid lithium fluoride.

Bonding _____

Explanation _____

_____

_____

(3)

(c) Deduce why the bonding in nitrogen oxide is covalent rather than ionic.

_____

_____

(1)

(d) Oxygen forms several different compounds with fluorine.

(i) Suggest the type of crystal shown by OF_2

_____

(1)

(ii) Write an equation to show how OF_2 reacts with steam to form oxygen and hydrogen fluoride.

_____

(1)

(iii) One of these compounds of oxygen and fluorine has a relative molecular mass of 70.0 and contains 54.3% by mass of fluorine.

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Calculate the empirical formula and the molecular formula of this compound.
Show your working.

Empirical formula _____

_____

_____

_____

_____

_____

Molecular formula _____

_____

(4)

(Total 14 marks)

Q20.

(a) Boron trichloride (BCl_3) can be prepared as shown by the following equation.

$$B_2O_3(s) + 3C(s) + 3Cl_2(g) \longrightarrow 2BCl_3(g) + 3CO(g)$$

A sample of boron oxide (B_2O_3) was reacted completely with carbon and chlorine. The two gases produced occupied a total volume of 5000 cm^3 at a pressure of 100 kPa and a temperature of 298 K.

Calculate the mass of boron oxide that reacted.
Give your answer to 3 significant figures.

(The gas constant R = 8.31 J K^{-1} mol^{-1})

_____

_____

_____

_____

_____

_____

_____

_____

_____

(5)

(b) Boron trichloride can also be prepared from its elements.

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Write an equation for this reaction.
Explain why boron trichloride has a trigonal planar shape with equal bond angles.

(3)

(c) (i) Boron trichloride is easily hydrolysed to form two different acids as shown in the following equation.

$$BCl_3(g) + 3H_2O(l) \longrightarrow H_3BO_3(aq) + 3HCl(aq)$$

Calculate the concentration, in mol dm^{-3}, of hydrochloric acid produced when 43.2 g of boron trichloride are added to water to form 500 cm^3 of solution.
Give your answer to 3 significant figures.

(4)

(ii) Boric acid (H_3BO_3) can react with sodium hydroxide to form sodium borate and water.
Write an equation for this reaction.

(1)

(d) Boron trichloride can be reduced by using hydrogen to form pure boron.

$$BCl_3(g) + 1\tfrac{1}{2}\,H_2(g) \longrightarrow B(s) + 3HCl(g)$$

Calculate the percentage atom economy for the formation of boron in this reaction.

Apart from changing the reaction conditions, suggest **one** way a company producing pure boron could increase its profits from this reaction.

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_____

_____

_____

_____

_____

(3)

(e) A different compound of boron and chlorine has a relative molecular mass of 163.6 and contains 13.2% of boron by mass.

Calculate the molecular formula of this compound.
Show your working.

_____

_____

_____

_____

_____

_____

_____

(4)

(Total 20 marks)

Q21.

The element nitrogen forms compounds with metals and non-metals.

(a) Nitrogen forms a nitride ion with the electron configuration $1s^2\ 2s^2\ 2p^6$
Write the formula of the nitride ion.

_____

(1)

(b) An element forms an ion **Q** with a single negative charge that has the same electron configuration as the nitride ion.
Identify the ion **Q**.

_____

(1)

(c) Use the Periodic Table and your knowledge of electron arrangement to write the formula of lithium nitride.

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_____

(1)

(d) Calcium nitride contains 81.1% by mass of the metal.
Calculate the empirical formula of calcium nitride.
Show your working.

_____

_____

_____

_____

_____

_____

(3)

(e) Write an equation for the reaction between silicon and nitrogen to form silicon nitride, Si_3N_4

_____

(1)

(Total 7 marks)

Q22.

Potassium carbonate can also occur as a hydrated compound, $K_2CO_3.xH_2O$.
Analysis of this hydrated compound showed that it contained 11.5% by mass of water.
Determine the value of x. Show your working.

_____

_____

_____

_____

_____

_____

(Total 2 marks)

Q23.

Norgessaltpeter was the first nitrogen fertiliser to be manufactured in Norway. It has the formula $Ca(NO_3)_2$

(a) Norgessaltpeter can be made by the reaction of calcium carbonate with dilute nitric

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acid as shown by the following equation.

$$CaCO_3(s) + 2HNO_3(aq) \longrightarrow Ca(NO_3)_2(aq) + CO_2(g) + H_2O(l)$$

In an experiment, an excess of powdered calcium carbonate was added to 36.2 cm^3 of 0.586 mol dm^{-3} nitric acid.

(i) Calculate the amount, in moles, of HNO_3 in 36.2 cm^3 of 0.586 mol dm^{-3} nitric acid. Give your answer to 3 significant figures.

_____

_____

(1)

(ii) Calculate the amount, in moles, of $CaCO_3$ that reacted with the nitric acid. Give your answer to 3 significant figures.

_____

_____

(1)

(iii) Calculate the minimum mass of powdered $CaCO_3$ that should be added to react with all of the nitric acid.

Give your answer to 3 significant figures.

_____

_____

_____

(2)

(iv) State the type of reaction that occurs when calcium carbonate reacts with nitric acid.

_____

(1)

(b) Norgessaltpeter decomposes on heating as shown by the following equation.

$$2Ca(NO_3)_2(s) \longrightarrow 2CaO(s) + 4NO_2(g) + O_2(g)$$

A sample of Norgessaltpeter was decomposed completely.

The gases produced occupied a volume of 3.50×10^{-3} m^3 at a pressure of 100 kPa and a temperature of 31 °C.
(The gas constant R = 8.31 J K^{-1} mol^{-1})

(i) Calculate the total amount, in moles, of gases produced.

_____

_____

_____

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_____

(3)

(ii) Hence calculate the amount, in moles, of oxygen produced.

_____

_____

(1)

(c) Hydrated calcium nitrate can be represented by the formula $Ca(NO_3)_2.xH_2O$ where x is an integer.

A 6.04 g sample of $Ca(NO_3)_2.xH_2O$ contains 1.84 g of water of crystallisation.

Use this information to calculate a value for x.
Show your working.

_____

_____

_____

_____

_____

_____

(3)

(Total 12 marks)

Q24.

Indium is in Group 3 in the Periodic Table and exists as a mixture of the isotopes ^{113}In and ^{115}In.

(a) Use your understanding of the Periodic Table to complete the electron configuration of indium.

$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^{10}\ 4p^6$ _____

(1)

(b) A sample of indium must be ionised before it can be analysed in a mass spectrometer.

(i) State what is used to ionise a sample of indium in a mass spectrometer.

_____

_____

(1)

(ii) Write an equation, including state symbols, for the ionisation of indium that requires the minimum energy.

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_____

(1)

(iii) State why more than the minimum energy is **not** used to ionise the sample of indium.

_____

_____

(1)

(iv) Give two reasons why the sample of indium must be ionised.

Reason 1 _____

Reason 2 _____

(2)

(c) A mass spectrum of a sample of indium showed two peaks at *m/z* = 113 and *m/z* = 115. The relative atomic mass of this sample of indium is 114.5

(i) Give the meaning of the term *relative atomic mass*.

_____

_____

_____

_____

(2)

(ii) Use these data to calculate the ratio of the relative abundances of the two isotopes.

_____

_____

_____

(2)

(d) State and explain the difference, if any, between the chemical properties of the isotopes ^{113}In and ^{115}In

Difference in chemical properties _____

Explanation _____

(2)

(e) Indium forms a compound **X** with hydrogen and oxygen. Compound **X** contains 69.2% indium and 1.8% hydrogen by mass.
Calculate the empirical formula of compound **X**.

_____

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_____

_____

_____

_____

(3)

(Total 15 marks)

Q25.

There are several oxides of nitrogen.

(a) An oxide of nitrogen contains 25.9% by mass of nitrogen. Determine the empirical formula of this oxide.

_____

_____

_____

_____

(3)

(b) Give **one** reason why the oxide NO is a pollutant gas.

_____

_____

(1)

(c) The oxide NO reacts with oxygen to form nitrogen dioxide. Write an equation for this reaction.

_____

(1)

(d) Explain how NO is produced in the engine of a motor vehicle.

_____

_____

_____

(2)

(e) Write an equation to show how NO is removed from the exhaust gases in motor vehicles using a catalytic converter.

_____

(1)

(Total 8 marks)

Q26.

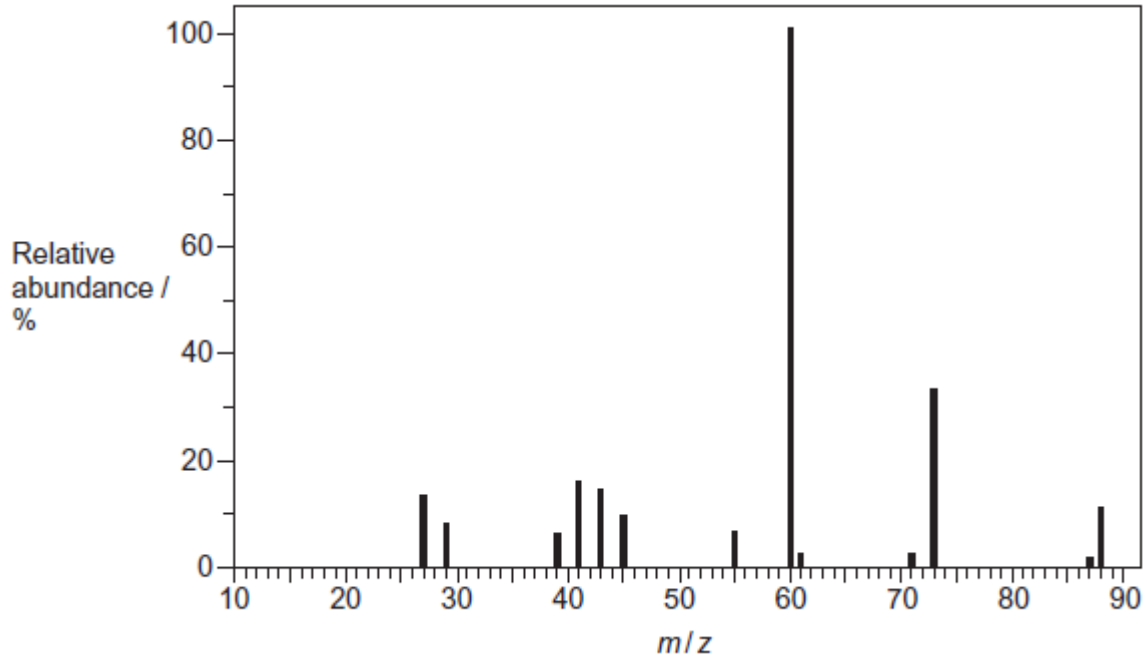
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The manufacturer supplying concentrated ethanoic acid for the production of vinegar also supplied other acids. The label had come off a batch of one of these other acids.
A sample of this unknown acid was analysed and found to contain 54.5% of carbon and 9.10% of hydrogen by mass, the remainder being oxygen.

(a) Use these data to calculate the empirical formula of the unknown acid.
Show your working.

(3)

(b) A sample of the unknown acid was analysed in a mass spectrometer. The mass spectrum obtained is shown below.



Use the mass spectrum to determine the M_r of the unknown acid.

(1)

(c) Use your answers from parts (a) and (b) to determine the molecular formula of the unknown acid.
(If you could not answer part (b), you should assume that the M_r of the acid is 132.0 but this is **not** the correct value.)
Show your working.

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_____

(2)

(Total 6 marks)

Q27.

Under suitable conditions magnesium will react with dilute nitric acid according to the following equation.

$$Mg(s) + 2HNO_3(aq) \rightarrow Mg(NO_3)_2(aq) + H_2(g)$$

A 0.0732 g sample of magnesium was added to 36.4 cm^3 of 0.265 mol dm^{-3} nitric acid. The acid was in excess.

(a) (i) Calculate the amount, in moles, of magnesium in the 0.0732 g sample.

_____

_____

(1)

(ii) Hence calculate the amount, in moles, of nitric acid needed to react completely with this sample of magnesium.

_____

_____

(1)

(iii) Calculate the amount, in moles, of nitric acid originally added to this sample of magnesium.

_____

_____

(1)

(iv) Hence calculate the amount, in moles, of nitric acid that remains unreacted.

_____

_____

(1)

(b) In a second experiment, 0.512 mol of hydrogen gas was produced when another sample of magnesium reacted with dilute nitric acid. Calculate the volume that this gas would occupy at 298 K and 96 kPa. Include units in your final answer.
(The gas constant R = 8.31 J K^{-1} mol^{-1})

_____

_____

_____

_____

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_____

(3)

(c) Concentrated nitric acid reacts with magnesium to form an oxide of nitrogen which contains 30.4% by mass of nitrogen.

Calculate the empirical formula of this oxide of nitrogen. Show your working.

_____

_____

_____

_____

_____

(3)

(Total 10 marks)

Q28.

Some antacid tablets contain sodium hydrogencarbonate, sucrose and citric acid.

(a) Analysis of a pure sample of citric acid showed that it contained 37.50% of carbon and 4.17% of hydrogen by mass, the remainder being oxygen. Use these data to show that the empirical formula of the acid is $C_6H_8O_7$.

_____

_____

_____

_____

(3)

(b) When the antacid tablet is added to water, sodium hydrogencarbonate and citric acid react together to form a gas. Identify this gas.

_____

(1)

(c) A weighed portion of this antacid was added to water. The gas formed was collected and its volume measured.

(i) Draw a diagram to show how this experiment could have been carried out to collect and measure the volume of the gas.

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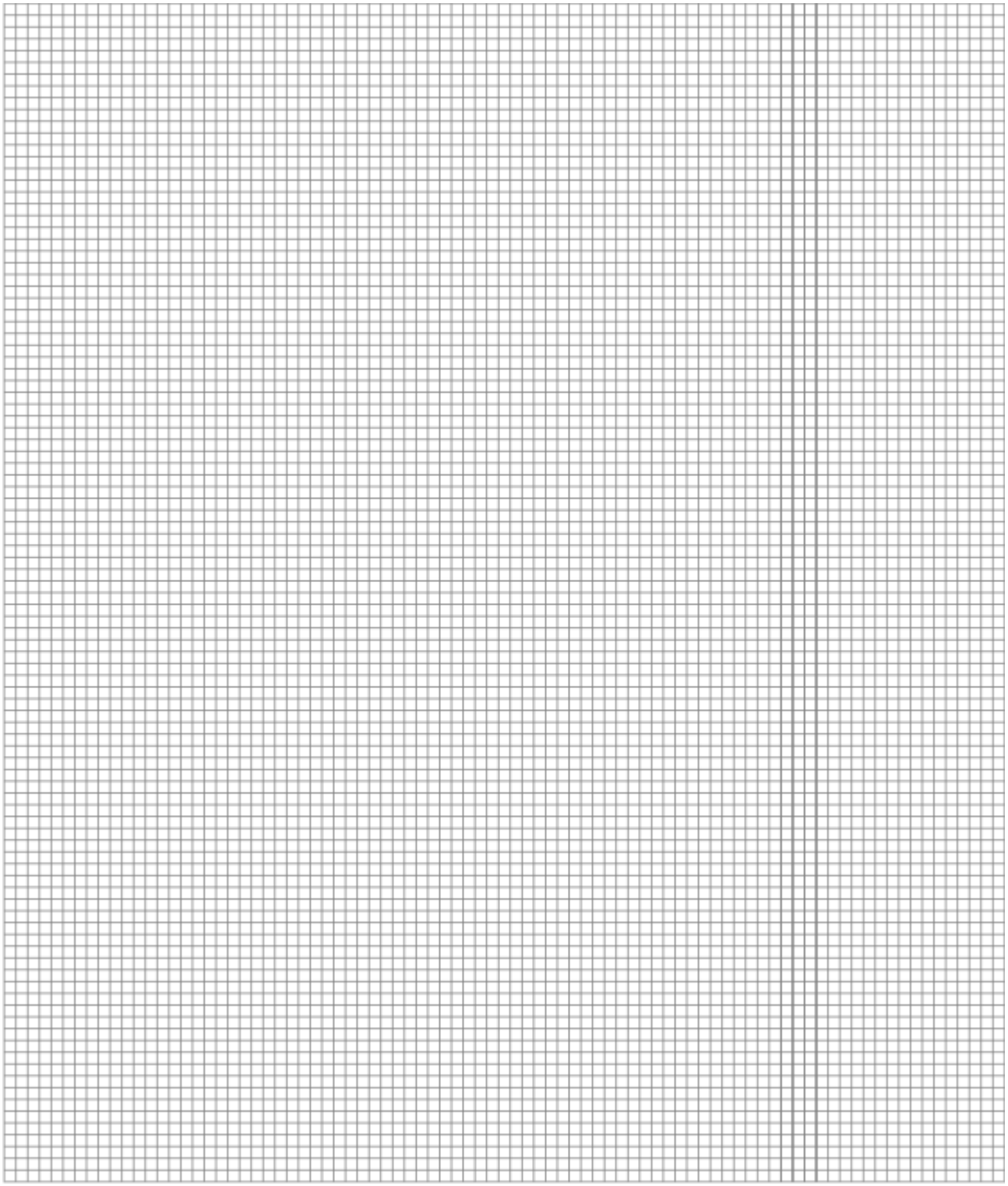
(ii) The experiment was repeated with further weighed portions of the same antacid.

The results are shown below.

Experiment	1	2	3	4	5
Mass of antacid / g	2.60	1.17	0.88	2.31	1.80
Volume of gas collected / cm^3	168	86	57	149	116

1 On the graph paper below, plot a graph of mass of antacid (x-axis) against volume of gas collected.

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(3)

2 Draw a line of best fit on the graph, ignoring any anomalous points.

(1)

3 Use the graph to determine the volume of gas which would have been collected using 2.00 g of antacid.

Volume of gas collected _____

(1)

(d) Suggest **one** reason why the presence of sodium hydrogencarbonate in the

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stomach may cause a person to suffer some extra discomfort for a short time.

_____

(1)

(e) Explain why the value for the M_r of citric acid does not need to be an exact value to deduce the molecular formula of citric acid from its empirical formula.

_____

_____

(2)

(f) Apart from misreading the gas volume, suggest **two** reasons why the volumes of gas collected may be lower than the volumes of gas produced.

Reason 1 _____

_____

Reason 2 _____

_____

(2)

(g) Explain why it is important to record the temperature and pressure when measuring the volume of a gas.

_____

_____

(1)

(h) Suggest why, in an analysis of an antacid, it is important to test samples from more than one bottle of the antacid.

_____

_____

(1)

(i) In the industrial production of sodium hydrogencarbonate, ammonia and carbon dioxide are bubbled through a saturated solution of sodium chloride. The equation for this reaction, and some solubility data, are shown below.

$$NaCl(aq) + NH_3(aq) + CO_2(g) + H_2O(l) \rightarrow NaHCO_3(s) + NH_4Cl(aq)$$

Compound	Solubility in water at 20 °C / g dm^{-3}
sodium chloride	360
sodium hydrogencarbonate	96
ammonium chloride	370

(i) Suggest **one** reason why sodium hydrogencarbonate precipitates from the

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reaction mixture at this temperature.

_____

(1)

(ii) Explain how this reaction could be used to remove carbon dioxide from the gases formed when fossil fuels are burned.

_____

_____

(1)

(j) The thermal decomposition of sodium hydrogencarbonate produces sodium carbonate. The other products are water and carbon dioxide. Write an equation for this thermal decomposition.

_____

(1)

(k) Sodium carbonate is produced on an industrial scale by a multi-step process. The equation which summarises the reactions taking place is shown below.

$$CaCO_3 + 2NaCl \rightarrow CaCl_2 + Na_2CO_3$$

Calculate the percentage atom economy for the production of sodium carbonate by this reaction.

_____

(1)

(Total 20 marks)

Q29.

(a) Nitromethane, CH_3NO_2, is used as an 'energy rich' fuel for motor-racing. It burns in oxygen forming three gases.

$$2CH_3NO_2(l) + 1½O_2(g) \rightarrow 2CO_2(g) + 3H_2O(g) + N_2(g)$$

(i) A 1.00 mol sample of nitromethane was burned in oxygen forming the products shown in the equation above. Calculate the total volume of gases produced at 298 K and 100 kPa (assume that the water is gaseous).

_____

_____

_____

_____

_____

(ii) This combustion reaction is very exothermic and reaches a temperature of 1000 K. Determine the total volume of gases when the temperature is raised to 1000 K at a constant pressure.

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(If you have been unable to determine a volume in your answer to part (a)(i), you may assume it to be 8.61×10^{-4} m^3 but this is not the correct answer).

_____

_____

(5)

(b) It has been suggested that, instead of releasing it into the atmosphere, the carbon dioxide gas evolved during a combustion reaction can be absorbed by sodium hydroxide solution, as shown by the following equation.

$$2NaOH(aq) + CO_2(g) \rightarrow Na_2CO_3(aq) + H_2O(l)$$

(i) Give two reasons why this reaction might not be suitable for the removal of carbon dioxide from the exhaust gases of an engine.

Reason 1 _____

Reason 2 _____

(ii) The sodium hydroxide solution for this reaction can be made on an industrial scale, together with chlorine gas and hydrogen gas, by electrolysis of a dilute solution of sodium chloride. Suggest one commercial advantage and one environmental disadvantage of this industrial process.

Commercial advantage _____

_____

Environmental disadvantage _____

_____

(4)

(c) Nitrogen forms several different oxides. Calculate the empirical formula of an oxide of nitrogen which contains 26% of nitrogen by mass.

_____

_____

_____

_____

(3)

(d) Another oxide of nitrogen, N_2O, decomposes on warming to produce nitrogen and oxygen. Write an equation for the decomposition reaction.

_____

(1)

(e) Internal combustion engines burn fuels in air. Suggest one advantage of using air mixed with N_2O for this purpose.

_____

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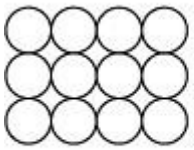
(1)

(Total 14 marks)

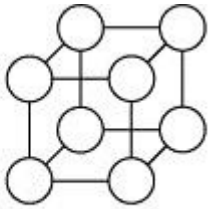
Q30.

At room temperature, both sodium metal and sodium chloride are crystalline solids which contain ions.

(a) On the diagrams for sodium metal and sodium chloride below, mark the charge for each ion.



Sodium metal



Sodium chloride

(2)

(b) (i) Explain how the ions are held together in solid sodium metal.

_____

_____

(ii) Explain how the ions are held together in solid sodium chloride.

_____

_____

(iii) The melting point of sodium chloride is much higher than that of sodium metal. What can be deduced from this information?

_____

_____

(3)

(c) Compare the electrical conductivity of solid sodium metal with that of solid sodium chloride. Explain your answer.

Comparison _____

_____

Explanation _____

_____

_____

(3)

(d) Explain why sodium metal is malleable (can be hammered into shape).

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_____

_____

(1)

(e) Sodium chlorate(V), $NaClO_3$, contains 21.6% by mass of sodium, 33.3% by mass of chlorine and 45.1% by mass of oxygen.

(i) Use the above data to show that the empirical formula of sodium chlorate(V) is $NaClO_3$

_____

_____

_____

_____

_____

(ii) Sodium chlorate(V) may be prepared by passing chlorine into hot aqueous sodium hydroxide. Balance the equation for this reaction below.

..... Cl_2 + ... NaOH → ..... NaCl + $NaClO_3$ + $3H_2O$

(3)

(Total 12 marks)

Q31.

Potassium nitrate, KNO_3, decomposes on strong heating, forming oxygen and solid **Y** as the only products.

(a) A 1.00 g sample of KNO_3 (M_r = 101.1) was heated strongly until fully decomposed into **Y**.

(i) Calculate the number of moles of KNO_3 in the 1.00 g sample.

_____

_____

(ii) At 298 K and 100 kPa, the oxygen gas produced in this decomposition occupied a volume of 1.22×10^{-4} m^3.

State the ideal gas equation and use it to calculate the number of moles of oxygen produced in this decomposition.
(The gas constant R = 8.31 J K^{-1} mol^{-1})

Ideal gas equation _____

Moles of oxygen _____

_____

_____

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_____

_____

(5)

(b) Compound **Y** contains 45.9% of potassium and 16.5% of nitrogen by mass, the remainder being oxygen.

(i) State what is meant by the term *empirical formula*.

_____

_____

(ii) Use the data above to calculate the empirical formula of **Y**.

_____

_____

_____

(4)

(c) Deduce an equation for the decomposition of KNO_3 into **Y** and oxygen.

_____

(1)

(Total 10 marks)

Q32.

(a) Dichloromethane, CH_2Cl_2, is one of the products formed when chloromethane, CH_3Cl, reacts with chlorine.

(i) Name the type of mechanism involved in this reaction and write an equation for each of the steps named below.

Name of type of mechanism _____

Initiation step

_____

First propagation step

_____

Second propagation step

_____

(ii) Write an overall equation for the formation of dichloromethane from chloromethane.

_____

(5)

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(b) A compound contains 10.1% carbon and 89.9% chlorine by mass. Calculate the molecular formula of this compound, given that its relative molecular mass (M_r) is 237.0

_____

_____

_____

_____

_____

(3)

(c) Suggest the formulae of two bromine-containing organic compounds formed when dibromomethane, CH_2Br_2, reacts with bromine.

Compound 1

_____

Compound 2

_____

(2)

(Total 10 marks)

Q33.

(a) Ammonia, NH_3, reacts with sodium to form sodium amide, $NaNH_2$, and hydrogen.

(i) Write an equation for the reaction between ammonia and sodium.

_____

(ii) Draw the shape of an ammonia molecule and that of an amide ion, NH_2^-

In each case show any lone pairs of electrons.

NH_3 NH_2^-

(iii) State the bond angle found in an ammonia molecule.

_____

(iv) Explain why the bond angle in an amide ion is smaller than that in an ammonia molecule.

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_____

_____

_____

_____

(6)

(b) A salt, **X**, contains 16.2% by mass of magnesium, 18.9% by mass of nitrogen and 64.9% by mass of oxygen.

(i) State what is meant by the term *empirical formula*.

_____

_____

(ii) Determine the empirical formula of **X**.

_____

_____

_____

_____

(3)

(Total 9 marks)

Q34.

Propanoic acid reacts with methanol in the presence of a small amount of concentrated sulphuric acid. The empirical formula of the ester formed is

A CH_2O

B $C_2H_6O_2$

C $C_2H_4O_2$

D C_2H_4O

(Total 1 mark)

Q35.

(a) The equation for the reaction between magnesium carbonate and hydrochloric acid is given below.

$$MgCO_3 + 2HCl \rightarrow MgCl_2 + H_2O + CO_2$$

When 75.0 cm^3 of 0.500 mol dm^{-3} hydrochloric acid were added to 1.25 g of impure $MgCO_3$ some acid was left unreacted. This unreacted acid required 21.6 cm^3 of a 0.500 mol dm^{-3} solution of sodium hydroxide for complete reaction.

(i) Calculate the number of moles of HCl in 75.0 cm^3 of 0.500 mol dm^{-3} hydrochloric acid.

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(ii) Calculate the number of moles of NaOH used to neutralise the unreacted HCl.

(iii) Show that the number of moles of HCl which reacted with the $MgCO_3$ in the sample was 0.0267

(iv) Calculate the number of moles and the mass of $MgCO_3$ in the sample, and hence deduce the percentage by mass of $MgCO_3$ in the sample.

Moles of $MgCO_3$ _____

Mass of $MgCO_3$ _____

Percentage of $MgCO_3$ _____

(8)

(b) A compound contains 36.5% of sodium and 25.5% of sulphur by mass, the rest being oxygen.

(i) Use this information to show that the empirical formula of the compound is Na_2SO_3

(ii) When Na_2SO_3 is treated with an excess of hydrochloric acid, aqueous sodium chloride is formed and sulphur dioxide gas is evolved. Write an equation to represent this reaction.

(4)

(Total 12 marks)

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Q1.

M1 C:H = 7.3 : 12.2 seen

*Extended response: **M1** is for working of some sort leading to the formulae.*

*If C_3H_5 and C_6H_{10} are both shown but it is not indicated which formula is which; or the formulas are stated the wrong way round, then allow 1 mark for **M2** and **M3** combined; if both correct formulas are given with only one stated correctly to be the empirical/molecular formula, then allow **M2** and **M3**.*

1

M2 (converting C:H 7.3 : 12.2 to 3:5)
to give empirical formula = C_3H_5

1

M3 molecular formula = C_6H_{10}

1

M4, 5 two possible structures of C_6H_{10} (in any structural form)
cyclic compounds with 6/5/4/3-membered C ring with one double bond, e.g.



or any dienes with 6 C atoms,

or a molecule with a triple bond

***M4** and M5 ignore names given in addition to structures*

*Credit **M4** and M5 for correct names if no structures drawn*

*Apply list principle to structures in **M4** and **M5***

2

M6 (electrophilic) addition

1

Alternative route to C_6H_{10} that could gain credit
***M1** 82/12 gives/suggests 6 C atoms*
***M2** molecular formula = C_6H_{10}*
***M3** empirical formula = C_3H_5*

Alternative route to C_6H_{10} that could gain credit
***M1** 82 × 0.878 = 72, (72/12) = 6 C atoms*
***M2** molecular formula = C_6H_{10}*
***M3** empirical formula = C_3H_5*

***M6** penalise nucleophilic addition; ignore bromination*

[6]

Q2.

C

[1]

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Q3.

(a) **Stage 1**

M1 $n = \frac{PV}{RT}$ **1**

M2 $= \frac{102 \times 10^3 \times 72 \times 10^{-6}}{8.31 \times 373}$ **1**

M3 = 0.0024 / 0.00237 / 0.002369 / 0.0023693 .. **1**

Stage 2

M4 $M_r \left(= \frac{\text{mass}}{\text{moles}}\right) = \frac{0.194}{\textbf{M3}}$ **1**

M5 = 82 (**2sf only**) **1**

*As this is an extended response question, each separate step of correct working is required in **M1–M5***

Correct answer with no working scores 2 marks

***M1** – If expression not written out, **M1** could score from a correct expression for **M2** (even if unit conversions are not correct for **M2**)*

M2** – allow an expression that gives correct value for **M3

***M3** should be at least 2sf (do not allow 0.0023 but do allow 0.00236)*

***M4** must show 0.194 or 194 × 10^{-3} in working to score*

***M5** must be 2sf*

ECF:

- *No ECF within either stage 1 or stage 2 (except for transcription errors)*
- *Allow ECF from stage 1 into stage 2, i.e for **M4** and **M5** based on incorrect **M3**, (but if expression for **M4** is inverted, cannot score **M5**)*
- *(Note that if 72 × 10^{-3} used in **M2**, then **M3** = 2.4, **M5** = 0.082)*

*Ignore units for **M3** and **M5***
*Note that if T = 273 + 373 = 646, **M5** = 140 (2sf)*

(b) **M1** dividing %s by relative atomic masses
C = 83.7/12(.0), H = 16.3/1(.0) **1**

M2 converting (C : H 6.975 : 16.3) to 3 : 7 **1**

M3 empirical formula = C_3H_7 **1**

M4 molecular formula = C_6H_{14} **1**

***M1** & **M2** are for working*

***M3** for C_3H_7 only, marked independently*

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M4 *for C_6H_{14} only, marked independently (ignore additional correct structures)*

Formulae with no working cannot score ***M1*** *or* ***M2***

Alternative method:
M1 *working that shows 83.7% of 86 is 72*
M2 *idea of 72/12 gives 6 C atoms*

Alternative method:
working that shows that C_6H_{14} (or C_3H_7) contains 83.7% C scores ***M1*** *&* ***M2***

[9]

Q4.

C

[1]

Q5.

B

[1]

Q6.

(a) $Cl\bullet + O_3 \longrightarrow ClO\bullet + O_2$

Allow dot in free-radical on either O or Cl.

1

$ClO\bullet + O_3 \longrightarrow 2O_2 + Cl\bullet$

1

(b) (KOH acts as a) base

1

(propan-1-ol acts as a) solvent.

Allow product of reaction between KOH and propan-1-ol / $CH_3CH_2CH_2O^-$ acts as base.

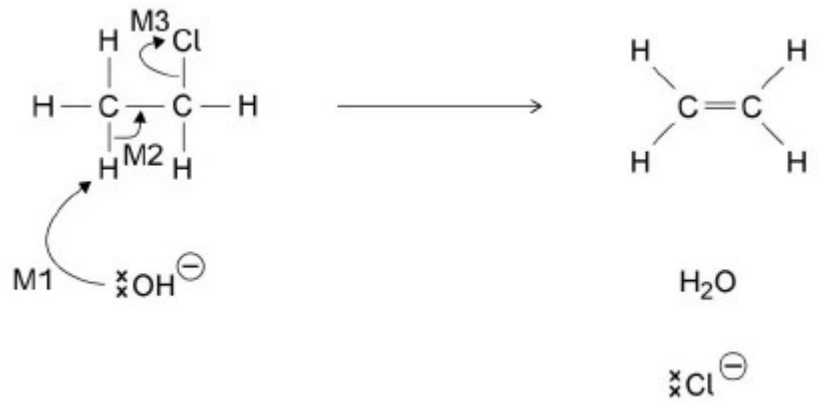
1

(c) (Name of mechanism) Elimination

1

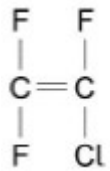
mechanism: 3 arrows (1 mark each).

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3

(d)



1

(e) This question is marked using levels of response. Refer to the Mark Scheme Instructions for Examiners for guidance on how to mark this question.

Level 3

All stages are covered & the explanation of each stage is generally correct and virtually complete. Stages 1 and 2 are supported by correct data. Answer communicates the whole process coherently and shows a logical progression from stage 1 to stage 2 and then stage 3.

Steps in stage 3 are in logical order and working is shown. If there is no working for ratio or statement of ratio then full marks cannot be awarded.

If the formulae of the three molecular ions are not correct (2d) then the student can't access Level 3 (any incorrect chemistry drops the student to the bottom mark within the level they have achieved).

5-6 marks

Level 2

Stage 2 is attempted (**2a-2c** do not need to be explicitly stated) but the calculation may contain inaccuracies **OR** the explanation may be incomplete **OR** first two stages are covered and the explanations are generally correct and virtually complete. Answer is mainly coherent and shows a progression through the first two stages. Some steps in each stage may be incomplete.

If percentage of carbon is missing or incorrect (1a) then student can't access Level 2.

3-4 marks

Level 1

Stage 1 needs to be attempted but may contain inaccuracies.

OR

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Stage 3 attempted but may contain inaccuracies / molecular formula not determined.

Answer includes some isolated statements, but these are not presented in a logical order or show confused reasoning.

1-2 marks

Level 0

Insufficient correct chemistry to warrant a mark.

0 marks

Indicative Chemistry content

Stage 1 (determines empirical formula)

1a *16.3% carbon*

1b *Divide by* A_r

1c *Divide by smallest (0.904)*

1d *Convert ratio in simplest integer (x 2)*

C	Cl	F
$\frac{16.3}{12.0} = 1.358$	$\frac{32.1}{35.5} = 0.904$	$\frac{51.6}{19.0} = 2.716$
$\frac{1.358}{0.904}$	$\frac{0.904}{0.904}$	$\frac{2.716}{0.904}$
3	2	6

Stage 2 (determines formulae of three molecular ions)

2a *For E.F.* M_r *(corresponds to the molecule) = 221*

2b *since* M_r *= 221 lies within molecular ion range 220–224*

2c *Thus empirical formula = molecular formula*

2d *Three correct formulae*

2e *Correct* M_r *for each of three molecules*

$C_3{}^{35}Cl_2F_6^+$	$C_3{}^{35}Cl^{37}ClF_6^+$	$C_3{}^{37}Cl_2F_6^+$
220	222	224

Stage 3 (explains the ratio of 3 molecular ion peaks)

3a *Working*

2b *Correct (simplified) ratio* ***9:6:1***

Note: 9:3:1 will be a common incorrect answer (max 5).

Working:

$C_3{}^{35}Cl_2F_6^+$	$C_3{}^{35}Cl^{37}ClF_6^+$	$C_3{}^{37}Cl_2F_6^+$
220	222	224

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$^{35}Cl_2 = \left(\frac{3}{4}\right)^2 = \frac{9}{16}$	$^{35}Cl^{37}Cl$ and $^{37}Cl^{35} = 2 \times \frac{1}{4} \times \frac{3}{4} = \frac{6}{16}$	$^{37}Cl_2 = \left(\frac{1}{4}\right)^2 = \frac{1}{16}$

[15]

Q7.

(a) Percentage of oxygen by mass = 100 – 40.9 – 4.5 = 54.6

1

	C	H	O
%	40.9	4.5	54.6
Divide by A_r	12	1	16
	= 3.41	= 4.5	= 3.41

1

Divide by smallest =	$\frac{3.41}{3.41} = 1$	$\frac{4.5}{3.41} = 1.32$	$\frac{3.41}{3.41} = 1$
Nearest whole number ratio =	1 × 3	1.32 × 3	1 × 3

= 3 : 3.96 : 3

Nearest integer ratio = 3 : 4 : 3

1

Empirical formula $C_3H_4O_3$

Empirical formula mass = 88 = molecular formula mass

Therefore, molecular formula is same as the empirical formula - $C_3H_4O_3$

1

(b) $C_6H_{12}O_6 \longrightarrow 2C_2H_5OH + 2CO_2$

1

(c) Advantage – ethanol is produced at a faster rate

1

Disadvantage – more energy is used / required in the reaction

1

(d) Air gets in / oxidation occurs

1

(e) Alcohol OH absorption in different place (3230–3550 cm^{-1}) from acid OH absorption (2500–3000 cm^{-1})

1

The C=O in acids has an absorption at 1680–1750 cm^{-1}

1

[10]

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Q8.

(a) 2,2,4-trimethylpentane

1

(b) 5

1

(c) $C_{20}H_{42} \longrightarrow C_8H_{18} + 2C_3H_6 + 3C_2H_4$

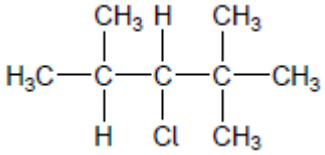
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(d) Mainly alkenes formed

1

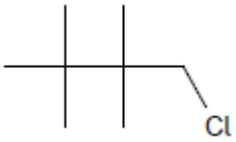
(e) 4 (monochloro isomers)

1



1

(f)



1

(g) $C_8H_{17}{}^{35}Cl = 96.0 + 17.0 + 35.0 = 148.0$
and $C_8H_{17}{}^{37}Cl = 96.0 + 17.0 + 37.0 = 150.0$
Both required

1

M_r of this $C_8H_{17}Cl$ $\frac{(1.5 \times 148.0)}{2.5} + \frac{(1.0 \times 150.0)}{2.5}$ = 148.8

1

(h) $\frac{24.6}{12} \quad \frac{2.56}{1} \quad \frac{72.8}{35.5}$ = 2.05 : 2.56 : 2.05

Simplest ratio = $\frac{2.05}{2.05} : \frac{2.56}{2.05} : \frac{2.05}{2.05}$

= 1 : 1.25 : 1

1

Whole number ratio (× 4) = 4 : 5 : 4

1

MF = $C_8H_{10}Cl_8$

1

[12]

Q9.

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(a) Percentage of oxygen 35.03 **M1**

Values used throughout must be to a minimum of 2 s.f.

1

52.67 / 40.1 12.3 / 28.1 35.03 / 16 **M2**
OR
1.313 0.438 2.189

*If ratios are inverted lose **M2** and **M3***

1

Ca_3SiO_5 **M3**

*If correct formula only is given allow **M3** only.*

1

(b) $2\ Ca_2SiO_4 + 4\ H_2O \rightarrow Ca_3Si_2O_4(OH)_6 + Ca(OH)_2$

Accept multiples and fractions. Ignore state symbols.

1

(c) Gloves / Dust or face-mask

Ignore references to use of fume cupboard.

1

Cement is alkaline / caustic / corrosive / irritant

Accept 'Ca(OH)$_2$ formed is alkaline / caustic / corrosive / irritant'.

1

[6]

Q10.

B

[1]

Q11.

(a) (i) $H_2O + CO_2$ (as products in any equation)

Allow $H_2O + H_2CO_3$

1

$Cu_2(OH)_2CO_3 + 4HCl \rightarrow 2CuCl_2 + 3H_2O + CO_2$

Allow multiples

Ignore states

1

(ii) Bubbles or fizzing or effervescence
Or solid disappears
Or blue(-green) solution

Do not allow dissolves

Ignore CO_2 gas or gas evolved

1

(b) (i) Simplest (whole-number) ratio of atoms of each element in a compound

Allow atoms of Cu, H & O in this compound

1

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(ii) Mass of copper = 2.765
Dividing masses by A_r

1

Cu	C	H	O
$\frac{2.765}{63.5}(=0.0435)$	$\frac{0.348}{12.0}(=0.029)$	$\frac{0.029}{1.0}(=0.029)$	$\frac{1.858}{16.0}(=0.116)$

1

Correct whole number ratio of integers
or
Cu:C:H:O
3:2:2:8
or
Correct empirical formula $Cu_3C_2H_2O_8$

Any order

Ignore $Cu_3(OH)_2(CO_3)_2$

1

[7]

Q12.

(a) Method 1

M1 %O = 27.1

$\frac{61.0}{12.0}$	$\frac{11.9}{1.0}$	$\frac{27.1}{16.0}$
= 5.08	= 11.9	= 1.69

M2 3 7 1

M3 C_3H_7O = 59 which is half of M_r so MF = 2EF

OR

Method 2

M1 61% of 118 = 72.0 and 11.9% of 118 = 14.0

M2 72 + 14 = 86 so oxygen = 32 out of 118

OR 27.1% of 118 = 32.0

M3

$\frac{72.0}{12.0}$	$\frac{14.0}{1.0}$	$\frac{32.0}{16.0}$
= 6	= 14	= 2

Method 3

Alternative using given molecular formula

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M1 $C = \frac{12 \times 6}{118} \times 100 = 61.0\%$

M2 $H = \frac{14 \times 1}{118} \times 100 = 11.9\%$

M3 $O = \frac{16 \times 2}{118} \times 100 = 27.1\%$

3

(b) For this question, marks can be awarded either for a description of how the structure is derived or from the given structure itself. The maximum mark to be awarded is nine from the ten marks listed.

Marks fall into three sections:

- Infrared evidence : two marks are available for use of the infrared evidence, (M1 and M10)
- Chemical evidence: one mark is available for use of the chemical evidence (M2)
- N.m.r. evidence: six marks are available for use of the n.m.r. evidence (M3 – M8 inclusive)

plus one mark (M9) for a completely correct structure.

Suggested procedure for marking

First look at the infrared spectrum: marks M1 and M10 may be scored there or in the written answer.

Then look for use of the acidified potassium dichromate(VI) evidence, (M2).

Then look at the final structure: this may lead to the award of marks M3 to M9 as shown on the structures below.

Beware contradictions, e.g. using the chemical evidence they may state that **R** is a primary or secondary alcohol but then draw a tertiary alcohol. This will lose M2 but may score M3.

The written 'evidence' frequently simply contains extracts from the Table **B** on the Data Sheet and, if only this is given, is unlikely to score many marks.

Described

Or drawn

M1 Infared peak/absorbance at 3400 (cm^{-1}) = O-H alcohol
(reference to ir spectrum needed)

Note: please check the spectrum

If peak at 3000 (cm-1) is identified as acid then cannot score M1 (contradiction)

M10 **Either** no peak between 1680-1750 (cm^{-1}) so no C=O or not aldehyde/acid
OR peak at 1000-1300 (cm^{-1}) so C–O present

Apply list principle to IR analysis for M10

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M2 (Acidified potassium dichromate(VI) turns green) so primary alcohol or secondary alcohol or not tertiary alcohol

Ignore aldehyde here

Lose M2 if just tertiary alcohol in structure

M3 δ = 3.1 singlet or integration = 1 is O-H

Award M3 if structure has 1 O-H group only (can be primary, secondary or tertiary)

Lose M3 if more than one OH group shown

M4 two triplets at 1.4 & 3.8 = $–CH_2–CH_2–$

Allow $–CH_2–CH_2–CH_2–$

M5 δ = 3.8 means CH_2 attached to O (in ether NOT ester)

Allow $O–CH_2–CH_2–CH_2–C$

δ = 1.4 means CH_2 attached to C (but not to C=O)

M6 δ = 1.1 (singlet) integration 6 = 2 × equivalent CH_3 on same C

$–C(CH_3)_2–$

M7 δ = 1.1 singlet so no H attached to $–C(CH_3)_2-$

$R–C(CH_3)_2–R$

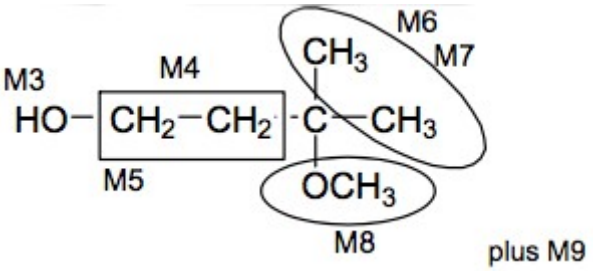
M8 δ = 3.2 singlet integration 3 = $-OCH_3$

$–OCH_3$

M9 For completely correct

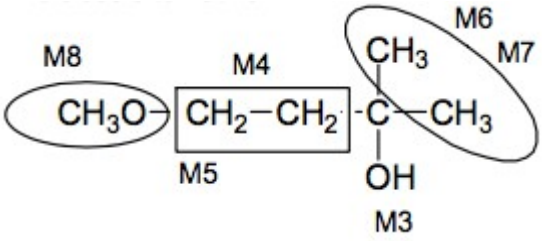
If no structure given then Max 8

R is



plus M9

This close alternative



would not score M9, but could score up to 8 marks

[12]

Q13.

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(a) 0.943 g water (M1)

If Mr of $NiSO_4$ wrong, can allow M1 and M3 from method 1 i.e. max 2

$NiSO_4$	H_2O
$\frac{1.344}{154.8}$ (M2)	$\frac{0.943}{18}$ (M3)
(8.68×10^{-3}	0.052)
1	6 or x = 6 (M4)

Allow Mr = 155

Allow other methods e.g.

M_r ($NiSO_4$) = 58.7 + 32.1 + 64.0 = 154.8

n($NiSO_4$) = $\frac{1.344}{154.8}$ = 0.008682 mol (M1)

M_r ($NiSO_4.xH_2O$) = $\frac{2.287}{0.008682}$ = (263.4) (M2)

so $18x$ = 263.4 − 154.8 = (108.6) (M3)

so x = $\frac{108.6}{18}$ = 6 (M4)

If using alternative method and Mr of $NiSO_4$ wrong, allow ecf to score M2 and M3 only i.e. max 2

4

(b) re-heat

Heat to constant mass = 2 marks

1

check that mass is unchanged

M2 dependent on M1

Allow as alternative:

M1: record an IR spectrum

M2: peak between 3230 and 3550 (cm^{-1})

1

[6]

Q14.

Mass of crucible and boric acid on the y−axis

Axes must be labelled but do not penalise lack of units (unless incorrect).

1

Suitable scale used

Plotted points must cover at least half the printed grid.(both directions).

1

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All points plotted correctly

Allow + / − one small square.

1

Suitable line drawn

Good best−fit line based on their points (+ / − one small square).

Do not award if kinked, doubled or very thick line.

1

[4]

Q15.

(a) (i) M1 - M_r calcium phosphate = 310(.3)

If M_r wrong, lose M1 and M5.

1

M2 - Moles calcium phosphate = $\frac{7.26}{M1}$ (= 0.0234)

0.0234 moles can score M1 and M2.

If M_r incorrect, can score M2 for $\frac{7.26}{M1}$.

Allow M2 and / or M3 to 2 significant figures here but will lose M5 if answer not 1.23.

1

M3 - Moles phosphoric acid = 2 × 0.0234 = 0.0468

Allow student's M2 × 2. If not multiplied by 2 then lose M3 and M5.

1

M4 - Vol phosphoric acid = 0.038(0) dm^3

If not 0.038(0) dm^3 then lose M4 and M5.

1

Conc phosphoric acid = $\frac{0.0468}{0.038(0)}$

M5 = 1.23 (mol dm^{-3})

This answer only – unless arithmetic or transcription error that has been penalised by 1 mark.

Allow no units but incorrect units loses M5.

1

(ii) $\frac{492.3}{688.3} \times 100$ **OR** $\frac{492}{688} \times 100$

1 mark for both M_r correctly placed.

= 71.5%

2

(b) $3Ca(OH)_2 + 2H_3PO_4 \longrightarrow Ca_3(PO_4)_2 + 6H_2O$

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Allow multiples.

1

(c)

Ca	H	P	O
1.67 / 40.1	0.17 / 1	2.59 / 31	5.33 / 16
= 0.042 / 1	0.17 / 4	0.084 / 2	0.333 / 8

If x = 2 with no working, allow M4 only.

Ca = 1.67 g (M1).

1

Mark for dividing by correct A_r in Ca and P (M2).
If M1 incorrect can only score M2.

1

Correct ratio (M3).

1

$CaH_4P_2O_8$ **OR** $Ca(H_2PO_4)_2$ **OR** x = 2

Value of x or correct formula (M4).

1

Alternative

Ca	H_2PO_4
	Ca = 1.67 g (M1).
1.67 / 40.1	8.09 / 97.0
	Mark for dividing by correct A_r / M_r in Ca and H_2PO_4 (M2). *If M1 incorrect can only score M2.*
= 0.042 / 1	0.083 / 2
	Correct ratio (M3).

$CaH_4P_2O_8$ **OR** $Ca(H_2PO_4)_2$ **OR** x = 2

Value of x or correct formula (M4).

[12]

Q16.

(a)

Method 1	Method 2
Mass of H_2O = 4.38−2.46	Percentage of H_2O = 44%
(= 1.92 g)	

If there is an AE in M1 then can score M2 and M3

If M_r incorrect can only score M1

1

$ZnSO_4$ H_2O ZnSO4 H2O

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2.46	1.92	56	44
161.5	18	161.5	18

1

(0.0152	0.107)	(0.347	2.444)
(1 :	7)	(1 :	7)
x = 7		x = 7	

If x = 7 with working then award 3 marks.
Allow alternative methods.
If M1 incorrect due to AE, M3 must be an integer.

1

(b) Moles HCl = 0.12(0)

1

mol $ZnCl_2$ = 0.06(0) ***OR*** 0.12 / 2

1

If M2 incorrect then CE and cannot score M2, M3 and M4.

mass $ZnCl_2$ = 0.06 × 136.4

Allow 65.4 + (2 × 35.5) for 136.4

1

= 8.18(4) (g) ***OR*** 8.2 (g)

Must be to 2 significant figures or more.
Ignore units.

1

(c) Moles $ZnCl_2 = \frac{10.7}{136.4}$ (= 0.0784)

1

OR moles Zn = 0.0784

Mass Zn reacting = 0.0784 × 65.4 = (5.13 g)

M2 is for their M1 × 65.4

1

$$\%\text{ purity of Zn} = \frac{5.13}{5.68} \times 100$$

M3 is M2 × 100 / 5.68 provided M2 is < 5.68

1

= 90.2% ***OR*** 90.3%

Allow alternative methods.
M1 = Moles $ZnCl_2$ = 10.7 (= 0.0784)
136.4
M2 = Theoretical moles Zn = 5.68 (= 0.0869)
65.4

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M3 = M1 × 100 / M2 = (0.0784 × 100 / 0.0869)

M4 = <u>90.2%</u> ***OR*** *<u>90.3%</u>*

1

(d) Ionic

If not ionic CE = 0/3

1

<u>Strong</u> (electrostatic) <u>attraction</u> (between ions)

1

between oppositely charged ions / + and − ions / F^- and Zn^{2+} ions

If IMF, molecules, metallic bonding implied CE = 0/3

1

[14]

Q17.

(a) 'Initial mass' must be the y-axis

If axis unlabelled, use data to decide that 'Initial mass' is on the y-axis.

1

Sensible scale

Do not award this mark if ***plotted points*** *do not cover at least half of the grid.*

Do not award this mark if any plotted point is outside the grid.

1

All points plotted correctly

Allow ± one small square.

1

Point at (0,0) is ringed

1

(b) Best-fit straight line that goes through the origin ± ½ small square

Mark consequentially to plotted points but the line must still go through the origin ± ½ small square.

Lose this mark if the line is doubled or kinked.

If the points are plotted correctly, lose this mark if the line deviates towards the anomalies.

1

(c) Students 3 and 5

Allow masses of 1.15 and 1.53 or 2.82 and 3.58

Mark consequentially to plot.

1

(d) Samples 3 or 5 have not lost all their water

Allow reaction / decomposition incomplete.

1

Sample not heated for enough time / larger masses will take a longer time to dehydrate / decompose

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1

[8]

Q18.

(a) Percentage of oxygen is 42.5% **(M1)**

Allow if shown clearly in the calculation.

1

Co 13.0 / 58.9 = 0.221, N 18.6 / 14 = 1.329,

K 25.9 / 39.1 = 0.662, O 42.5 / 16 = 2.656 **(M2)**

Allow alternative method if chemically correct.

*If A_r has been divided by the percentage, chemical error, lose **M2** and **M3**.*

1

$CoN_6K_3O_{12}$ **(M3)**

Allow in any order.

Correct answer without working scores this mark only.

1

(b) $Co(NO_2)_6^{3-}$

Allow a correct diagram bonding through N or O

Do not allow $CoN_6O_{12}^{3-}$

Must have correct overall charge.

Allow consequential answer from part(a) if the charge on the anion is correct.

1

[4]

Q19.

(a) (i) The power of an atom or nucleus to withdraw or attract electrons ***OR*** *electron density* ***OR*** *a pair of electrons (towards itself)*

Ignore retain

1

In a covalent bond

1

(ii) More protons / bigger nuclear charge

1

Same or similar shielding / electrons in the same shell or principal energy level / atoms get smaller

Not same sub–shell
Ignore more electrons

1

(b) Ionic

If not ionic then CE = 0 / 3
If blank lose M1 and mark on

1

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Strong or many or lots of (electrostatic) attractions (between ions)

If molecules / IMF / metallic / atoms lose M2 + M3, penalise incorrect ions by 1 mark

1

Between + and − ions / between Li^+ and F^- ions / oppositely charged ions

Allow strong (ionic) bonds for max 1 out of M2 and M3

1

(c) Small electronegativity difference / difference = 0.5

Must be comparative

Allow 2 non-metals

1

(d) (i) (simple) molecular

Ignore simple covalent

1

(ii) $OF_2 + H_2O \longrightarrow O_2 + 2HF$

Ignore state symbols
Allow multiples
Allow OF_2written as F_2O

1

(iii) 45.7% O

1

(O F)
(45.7 54.3)
(16 19)

If students get M2 upside down lose M2 + M3
Check that students who get correct answer divide by 16 and 19 (not 8 and 9). If dividing by 8 and 9 lose M2 and M3 but could allocate M4 ie max 2

1

(2.85 2.85)
(1 1)

EF = OF or FO

Calculation of OF by other correct method = 3 marks
Penalise Fl by 1 mark

1

MF (= 70.0 / 35) = O_2F_2 or F_2O_2

1

[14]

Q20.

(a) P = 100 000 (Pa) and V = 5.00 x 10^{-3} (m^3)

M1 is for correctly converting P and V in any expression or list Allow 100 (kPa) and 5 (dm^3) for M1.

1

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$$n = \frac{PV}{RT} = \frac{100\ 000 \times 5.00 \times 10^{-3}}{8.31 \times 298}$$

M2 is correct rearrangement of PV = nRT

1

= 0.202 moles (of gas produced)

This would score M1 and M2.

Therefore $\frac{0.202}{5}$ = 0.0404 moles B_2O_3

M3 is for their answer divided by 5

1

Mass of B_2O_3 = 0.0404 x 69.6

M4 is for their answer to M3 x 69.6

1

= 2.81 (g)

M5 is for their answer to 3 sig figures.
2.81 (g) gets 5 marks.

1

(b) $B + 1.5\ Cl_2 \rightarrow BCl_3$

Accept multiples.

1

3 bonds

1

Pairs repel equally/ by the same amount

Do not allow any lone pairs if a diagram is shown.

1

(c) (i) 43.2/117.3 (= 0.368 moles BCl_3)

1

0.368 x 3 (= 1.105 moles HCl)

Allow their BCl_3 moles x 3

1

Conc HCl = $\frac{1.105 \times 1000}{500}$

Allow moles of HCl × 1000 / 500

1

= 2.20 to 2.22 mol dm^{-3}

Allow 2.2
Allow 2 significant figures or more

1

(ii) $H_3BO_3 + 3NaOH \rightarrow Na_3BO_3 + 3H_2O$

Allow alternative balanced equations to form acid salts.
Allow $H_3BO_3 + NaOH \rightarrow NaBO_2 + 2H_2O$

1

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(d) $\frac{10.8}{120.3}(\times 100)$

Mark is for both M_r values correctly as numerator and denominator.

1

8.98(%)

Allow 9(%).

1

Sell the HCl

1

(e) Alternative method

Cl = 86.8%

Cl = 142 g

1

$$\frac{\text{B}}{\frac{13.2}{10.8}} \qquad \frac{\text{Cl}}{\frac{86.8}{35.5}}$$

$$\frac{B}{\frac{21.6}{10.8}} \qquad \frac{Cl}{\frac{142}{35.5}}$$

1

1.22 *2.45 or ratio 1:2 or BCl_2*

2:4 ratio

1

BCl_2 has M_r of 81.8 so
81.8 x 2 = 163.6
Formula = B_2Cl_4

B_2Cl_4

Allow 4 marks for correct answer with working shown.

Do not allow $(BCl_2)_2$

1

[20]

Q21.

(a) N^{3-} / N^{-3}

1

(b) F^-/ fluoride

Ignore fluorine/F

Penalise Fl

1

(c) Li_3N / NLi_3

1

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(d) $\frac{81.1}{40.1}$ $\frac{18.9}{14}$

M1 for correct fractions

1

(=2.02 = 1.35)

1.5 1 or 3 : 2

M2 for correct ratio

1

Ca_3N_2

If Ca_3N_2 shown and with no working award 3 marks

If Ca_3N_2 obtained by using atomic numbers then lose M1

1

(e) $3\ Si + 2\ N_2 \rightarrow Si_3N_4$

Accept multiples

1

[7]

Q22.

Ratios 88.5 / 138.2 and 11.5 / 18

Correct answer without working scores one mark only.

1

x = 1

Allow $K_2CO_3.H_2O$ / 1:1 ratio / one molecule of water of crystallisation.

M2 can be awarded for a correct method using incorrect ratios.

Allow correct answer if integer or decimal number.

1

[2]

Q23.

(a) (i) 0.0212

Need 3 sig figs

Allow correct answer to 3 sig figs eg 2.12×10^{-2}

1

(ii) 0.0106

Mark is for (a)(i) divided by 2 leading to correct answer 2 sig figs

1

(iii) M_r = 100.1

1.06 g

Allow 100.1 as 'string'

Need 3 sig figs or more

Consequential on (a)(ii) x 100(.1)

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2

(iv) Neutralisation or acid / base reaction

Allow acid / alkali reaction

Apply list principle

1

(b) (i) T = 304(K) and P = 100 000 (Pa)

Only T and P correctly converted

1

$$\frac{100\,000 \times 3.50 \times 10^{-3}}{8.31 \times 304} \text{ OR } n = \frac{PV}{RT}$$

1

0.139 (mol)

Allow <u>0.138 – 0.139</u>

1

(ii) 0.0276 – 0.0278(mol)

Allow answer to (b)(i) divided by 5 leading to a correct answer

Allow 0.028

1

(c) 4.20 g $Ca(NO_3)_2$

1

$Ca(NO_3)_2$ H_2O

$$\frac{4.20}{164(.1)} \qquad \frac{1.84}{18}$$

Mark is for dividing by the correct Mr values

M2 and M3 dependent on correct M1

0.0256 0.102

M2 can be awarded here instead

1 : 3.98

x = 4

If $Ca(NO_3)_2.4H_2O$ seen with working then award 3 marks

Credit alternative method which gives x = 4

1

[12]

Q24.

(a) <u>$4d^{10}\ 5s^2\ 5p^1$</u> in any order

Allow subscripts for numbers

Allow capitals

1

(b) (i) Using an electron gun/(beam of) high energy/fast moving electrons

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Ignore 'knocks out an electron'

1

(ii) $In(g) + e^- \rightarrow In^+(g) + 2e^-$

OR

$In(g) \rightarrow In^+(g) + e^-$

$In(g) - e^- \rightarrow In^+(g)$

The state symbols need not be present for the electron - but if they are they must be (g)

No need to show charge on electron

If I CE = 0

Ignore any equations using M

1

(iii) So no more than 1 electron is knocked out/so only one electron is knocked out/prevent further ionisation

Allow stop 2+ and 3+/other ions being formed

Not to get wrong m/z

1

(iv) Any two processes from

- Accelerate (owtte)
- Deflect (owtte)
- Detect (owtte)

Ignore wrong causes of process

2 max

(c) (i) <u>Average/mean mass of (1) atom(s) (of an element)</u>

1

1/12 mass of one atom of ^{12}C

1

OR

<u>(Average) mass of one mole of atoms</u>

1/12 mass of one mole of ^{12}C

OR

<u>(Weighted) average mass of all the isotopes</u>

1/12 mass of one atom of ^{12}C

OR

Average mass of an atom/isotope compared to C-12 on a scale in which an atom of C-12 has a mass of 12

Not average mass of 1 molecule

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Allow the wording Average mass of 1 atom of an element compared to 1/12 mass atom of ^{12}C (or mass 1/12 atom of ^{12}C)

Allow if moles of atoms on both lines

Accept answer in words

Can have top line × 12 instead of bottom line ÷12

If atoms/moles mixed, max = 1

(ii) $\frac{113x + 115y}{x + y} = 114.5$

Allow idea that there are 4 × 0.5 divisions between 113 and 115

1

ratio (113:115) = 1:3 **OR** 25:75 **OR** 0.5:1.5 etc

Correct answer scores M1 and M2

If 1:3 for In(115):In(113), max = 1

1

(d) None

1

Same no of electrons (in the outer shell)/same electron configuration)

Ignore electrons determine chemical properties/ignore protons

M2 dependent on M1 being correct

1

(e) 29.0%/29% O

If no O calculated, allow M2 if In and H divided by the correct A_r

1

$\frac{69.2}{114.8/114.5}$ $\frac{1.8}{1}$ $\frac{29.0}{16}$

1

or

0.603 1.8 1.81

1 3 3

EF = In H_3O_3

Allow $In(OH)_3$

Do not allow last mark just for ratio 1:3:3

If InO_3H_3 given with no working then allow 3 marks

If I not In, lose M3

1

[15]

Q25.

(a) O = 74.1%

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1

$\frac{25.9}{14}$ $\frac{74.1}{16}$

If atomic numbers or molecular masses are used lose M2

1

1.85 4.63
1 2.5
N_2O_5

1

This ratio alone will not score the final mark. (It would get 2)
Allow 3 marks for N_2O_5

(b) Toxic/poisonous/forms an acidic gas/forms NO_2 which is acidic/ respiratory irritant/forms HNO_3 when NO reacts with water and oxygen/ triggers asthma attacks/greenhouse gas/photochemical smog/ contributes to global warming/formation of acid rain

ignore NO is an acidic gas or NO is acidic in water
Not references to ozone layer

1

(c) $2NO + O_2 \rightarrow 2NO_2$

Accept multiples or fractions of equation
Ignore wrong state symbols

1

(d) Nitrogen/N_2 and oxygen/O_2 combine/react

QWC (not N and O combine)
Not nitrogen in fuel
Allow $N_2 + O_2 \rightarrow 2NO$ for M1 only

1

spark/high temperature/2500-4000 °C

1

(e) $2NO + 2CO \rightarrow N_2 + 2CO_2$

OR

$2NO \rightarrow N_2 + O_2$

Accept multiples or fractions of equation
Ignore wrong state symbols
Allow $C_8H_{18} + 25NO \rightarrow 8CO_2 + 12.5N_2 + 9H_2O$

1

[8]

Q26.

(a) Percentage of oxygen is 36.4%

% of oxygen stated or shown in calculation.

1

Correct calculation of ratios (C 4.54, H 9.10, O 2.28)

Mark is for correct method, dividing % by A_r

1

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Empirical formula C_2H_4O

Allow consequential answer from wrong percentage of oxygen (max 2 marks).

1

(b) 88

Accept 88.0

Do not penalise correct answer in g.

1

(c) Ratio MF / EF of 2 (88 / 44.0 = 2)

If use 132 / 44 = 3, molecular formula $C_6H_{12}O_3$ scores 2 marks.

1

Molecular formula is $C_4H_8O_2$

Accept consequential answers from (a) and (b)

1

[6]

Q27.

(a) (i) 0.00301/ 3.01×10^{-3};

Penalise < 3sf in (a)(i);

Allow $3.01 \times 10^{-3} – 3.05 \times 10^{-3}$.
(for candidates who have used Mg as 24)

1

(ii) 0.00602

Allow correct answer a(i) × 2.

1

(iii) 0.00965/ 9.65×10^{-3};

Allow 0.009646/ 0.0096-0.0097.

1

(iv) 0.00363 moles;

Allow range 0.0035 to 0.0037.
Allow (a)(iii) – 2 (a)(ii) (must be positive).

1

(b) PV = nRT;

Allow all capitals/ lower case.

1

$V = \frac{0.512 \times 8.31 \times 298}{96000}$;

M2 Mark is for <u>all numbers correct</u>.
If units in answer are in dm^3 allow this expression with 96 in denominator.

1

0.0132 m^3/ 13.2 dm^3;

M3 <u>Must have correct units</u>/
allow 13200 cm^3.

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Allow min 2 sig figs in answer.

1

(c) O = 69.6 (%);

1

$\frac{30.4}{14}$ $\frac{69.6}{16}$ 2.17 : 4.35

Use of 7/8 CE then M1 only.

1

(1 : 2) $\underline{NO_2}$

Mark for formula not ratio.
If NO_2 and no working shown then allow 1 mark.
If 69.6% + NO_2 only = 2.
Need to see evidence of M2 working.
Allow M2 conseq on the wrong M1 (ie max 1).

1

[10]

Q28.

(a) percentage of oxygen is 58.33

1

correct calculation of ratios (C 3.125, H 4.17, O 3.645)

1

clearly relates ratios to formula eg
simplifies ratios (C 1, H 1.29, O 1.17) or for H then 3.125 × 8 / 6 = 4.17% etc

1

Notes
* *correct percentage of oxygen can be stated or shown clearly in a calculation*
* *to score final mark must **clearly** show how ratios relate to $C_6H_8O_7$*
* *allow full credit to candidate who correctly finds*
  percentage of oxygen
  calculates M_r
  shows percentage of H is 8 divided by M_r

(b) carbon dioxide / CO_2

1

(c) (i) suitable reaction vessel
eg sealed flask or test-tube with side arm or
eg tube in bung

1

suitable collection method
eg gas syringe / over water in measuring
eg cylinder

1

Notes
* *collection vessel must allow measurement of gas*
* *if apparatus would leak lose second mark*
* *ignore heating*
* *can draw tubing as single line*

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** accept 2D or 3D diagrams*
** do not need labels, and ignore mis-labelling*

(ii) (1) mass on x-axis

1

Notes
** If axes unlabelled use data to decide that mass is on the x-axis*

sensible scales

1

Notes
** lose this mark if the **plotted points** do not cover at least half of the paper*
** lose this mark if the graph plot goes off the squared paper*

plots points correctly ± one square

1

(2) draws appropriate straight line of best fit, omitting point at 1.17g / 86 cm^3

Notes
** lose this mark if the line deviates towards the point at 1.17g / 86 cm^3*
** candidates does not have to extrapolate the line to the origin to score this mark*
** when checking for best fit, candidate's line **must** go through the origin ± one square. Extend candidate's line if necessary*

1

(3) 129 ± 1 cm^3

Notes
** accept this answer **only***

1

(d) CO_2 / gas formed distends stomach / produces wind / increases pressure in stomach

1

(e) molecular formula has to be a simple multiple of the empirical formula

1

so approximate M_r value will distinguish between the options or equivalent wording

1

(f) gas escapes before bung inserted any 2 × 1 for

syringe sticks

carbon dioxide soluble in water

Notes

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** do **not** accept 'operator error' / 'inaccurate equipment' / 'equipment leaks'*

2

(g) volume depends on pressure and temperature

Notes
** do **not** accept 'to get a more accurate result' or equivalent wording without qualification*

1

(h) Tablets could vary between samples or equivalent wording

Notes
** do **not** accept 'to get a more accurate / reliable result' or 'to make a fair test' without qualification*

1

(i) (i) $NaHCO_3$ **least** soluble

1

(ii) exhaust gases passed into mixture of NaCl and NH_3

1

(j) $2NaHCO_3 \rightarrow Na_2CO_3 + CO_2 + H_2O$

Notes
** accept multiples*

1

(k) 106.0 divided by 217.1 × 100 = 48.8%

Notes
** ignore precision of answer*

1

[22]

Q29.

(a) (i) Moles of gas produced = 3

1

$PV = nRT$

1

$V = nRT/P = 3 \times 8.31 \times 298/100000$

1

$= 7.43 \times 10^{-2}\ m^3$

1

(ii) $7.43 \times 10^{-2} \times 1000/298 = 0.249\ m^3$

1

(b) (i) any two from:

exhaust gases hot so would boil the solution away
solution would splash
reaction might be too slow

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would need continuous supply of solution and/or replacement of products

2

(ii) *Commercial advantage* could sell chlorine and/or hydrogen

1

environmental disadvantage generation of electricity likely to lead to release of CO_2 (or chlorine toxic)

1

(c) % O = 74%

1

N:O = 26/14:74/16

1

= 1.86: 4.63 = 1:2.5 therefore formula is N_2O_5

1

(d) $2N_2O \rightarrow 2N_2 + O_2$

1

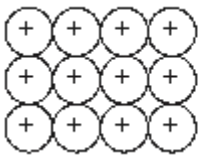
(e) Proportion of O_2 increased leading to higher T (or more complete combustion)

1

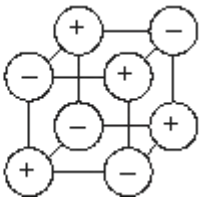
[14]

Q30.

(a)



(1)



(1)

[Diagrams must be complete and accurate]

2

(b) (i) Attraction /electrostatic forces/bonds/attractions between (positive) ions/lattice and delocalised/free electrons/sea of electrons.

[Not metallic bonding]

[Not just 'forces']

1

(ii) Electrostatic attractions/forces between ions or attractions between (oppositely charged) ions/ Na^+ & Cl^-

[Not ionic bonding]

1

(iii) (Here) the ionic bonding in NaCl is stronger/requires more energy to break than the metallic bonding in Na

QoL Accept 'bonding/forces of attraction in NaCl is stronger than in Na'

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[If IMF/molecules/van der Waals'/dipole–dipole mentioned in parts(i) or (ii), then CE = 0 for parts (i) and/or(ii) and CE = 0 for part(iii)]

1

(c) Comparison:
Sodium conducts **and** sodium chloride does NOT conduct

Allow 'only Na conducts'

Accept 'Na conducts, NaCl only conducts when molten'

[Do not accept sodium conducts better than sodium chloride etc.]

1

Explanation:
(Delocalised) electrons flow though the metal

1

Allow e^- move/carry current/are charge carriers/transfer charge.

[Not 'electrons carry electricity']

[Not 'NaCl has no free charged particles']

Ions can't move in solid salt

1

(d) Layers can slide over each other – idea that ions/atoms/particles move

[Not molecules]

[Not layers separate]

1

(e) (i)

Na	Cl	O
$\frac{21.6}{23}$	$\frac{33.3}{35.5}$	$\frac{45.1}{16}$

1

0.9(39)	0.9(38)	2.8(2)
Hence: 1	1	3

Accept backwards calculation, i.e. from formula to % composition, and also accept route via M_r to 23; 35.5; 48, and then to 1:1:3

[If % values incorrectly copied, allow M1 only]

[If any wrong A_r values/atomic numbers used = CE = 0]

1

(ii) $3Cl_2 + 6NaOH \rightarrow 5NaCl + NaClO_3 + 3H_2O$

1

[12]

Q31.

(penalty for sig fig error =1mark per question)

(a) (i) moles $KNO_3 = 1.00/101.1 = 9.89 \times 10^{-3}$ (mol)

1

(ii) $pV = nRT$ or $n = pV/RT$

1

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moles O2 = n = $\frac{pV}{RT}$ = **(1)** $\frac{100000 \times 1.22 \times 10^{-4}}{8.31 \times 298}$ **(1)**

2

= 4.93×10^{-3} (mol)

1

(mark answer first – check back if wrong)
(transcription error lose M3, mark M4 conseq on error)
(if 'untraceable' figures used M3=M4=0)
(if wrong temp conversion – lose M3 – conseq M4)
(if n = RT/pV CE, lose M3 and M4)

(b) (i) simplest/lowest ratio of atoms of each / element/s in a compound / substance / species / entity / molecule

1

(ii)

K	N	O		
$\frac{45.9}{39.1}$	$\frac{16.5}{14}$	$\frac{37.6}{16}$		(1)
1.17	1.18	2.35		(1)
1	1	2	KNO^2	(1)

(M3 tied to M2), (M3 can be transferred from equation if ratio correct but EF not given) (if calc inverted, lose M2 and M3), (if used At N^1 / wrong No for Ar then CE, lose M2 and M3) (if % of O missing, award M2 only)

3

(c) $2KNO_3 \rightarrow 2KNO_2 + O_2$ or fractions/multiples
(accept $2KNO_3 \rightarrow K_2N_2O_4 + O_2$)
(do NOT accept 'Y' in equation)

1

[10]

Q32.

(a) (i) (free–) radical substitution
(both words required for the mark)

1

initiation $Cl_2 \rightarrow 2Cl\cdot$
(credit correct half arrows, but penalise double headed arrows)

1

first propagation $CH_3Cl + Cl\cdot \rightarrow \cdot CH_2Cl + HCl$

1

second propagation $\cdot CH_2Cl + Cl_2 \rightarrow CH_2Cl_2 + Cl$
(penalise the absence of dots on radicals once only)
(penalise radical dot on Cl of CH_2Cl once only)

1

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(ii) $CH_3Cl + Cl_2 \rightarrow CH_2Cl_2 + HCl$

(penalise if any radicals appear in this equation)

1

(b) **M1**: mol C = 10.1/12.0 and mol Cl = 89.9/35.5

1

M2: Ratio 0.842 : 2.53 OR 1: 3 OR CCl3

1

M3: 237.0/Mr of CCl_3 = 237.0/118.5 = 2 Therefore C_2Cl_6

(correct answer gains full credit)

1

OR

M1: 237.0 × 10.1/100 and 237 × 89.9/100

1

M2: Ratio 23.9/12.0 : 213/35.5 OR 2 : 6

1

M3: C_2Cl_6

(correct answer gains full credit)

1

(c) any two from $CHBr_3$ or CBr_4 or $C_2H_2Br_4$ (or $CHBr_2CHBr_2$) or C_2Br_6 (or CBr_3CBr_3)

(ignore HBr or H_2)

(ignore equations and ignore names when given in addition to formulae)

(penalise names alone)

2

[10]

Q33.

(a) (i) $2Na + 2NH_3 \rightarrow 2NaNH_2 + H_2$

(or multiples)

1

(ii) (Missing 'H' penalise once only) [NOT dot-and-cross diagrams]



1

[NOT 90° / 180° angles] (need 2 lp & 'bent' shape)

1

(iii) 107°

1

(iv) More lone pairs on NH_2^-, than on NH_3

1

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Lone pairs repel more than bonding pairs

Must be comparison

(Mark separately)

[NOT repulsion between atoms or between bonds]

1

(b) (i) Simplest ratio of atoms of each element in a compound / substance / species / entity / molecule

1

(ii)

	Mg	N	O
$\frac{16.2}{(24)}$	$\frac{16.2}{24.3}$	$\frac{18.9}{14}$	$\frac{64.9}{16}$
(0.675)	0.667	1.37	4.06
	1	2	6

MgN_2O_6

(Mark M1 first. If any wrong A_r used = CE = 0)

(Accept $Mg(NO_3)_2$ for M3 if above working shown)

1

[9]

Q34.

D

[1]

Q35.

(a) (i) $75.0 \times 10^{-3} \times 0.500 = 0.0375$ (mol) **(1)**

accept 0.037 or 0.038

(ii) $21.6 \times 10^{-3} \times 0.500 = 0.0108$ (mol) **(1)**

accept 0.011

If both (i) and (ii) answers wrong, allow ONE process mark for both correct processes

(iii) 0.0375 - 0.0108 = 0.0267 (mol) **(1)**

Not conseq – must use figures shown

(iv) *Moles of $MgCO_3$* = 0.0267/2 = 0.01335 (mol) **(1)**

allow 0.0134 - 0.0133

Mass of $MgCO_3$ = 0.01335 × 84.3 **(1)**

allow 84

mark conseq on moles $MgCO_3$

= 1.125g **(1)**

accept 1.13g

mark conseq

Percentage $MgCO_3$ = 1.125/1.25 × 100 **(1)**

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mark conseq (check for inversion)

= 90% **(1)**

mark conseq

range = 89.5 - 90.5%

If % expression inverted, lose M4 and M5

8

(b) (i) % oxygen = 38.0 **(1)**

Na = 36.5/23 S = 25.5/32(.1) O = 38.0/16 **(1)**

= 1.587 = 0.794 = 2.375

= 2:1:3 **(1)**

If no % of oxygen Max 1 (allow M2 only)
If % for Na and S transposed, or atomic numbers used, M1 only available

(ii) $Na_2SO_3 + 2HCl \rightarrow 2NaCl + H_2O + SO_2$ **(1)**

allow multiples

allow $SO_3^{2-} + 2H^+ \rightarrow H_2O + SO_2$

4

[12]

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Q1.

Some students could not convert the ratio 7.3 : 13.2 to a whole number ratio, but the question was answered well on the whole and discriminated well.

Q2.

66.4% of students performed this calculation correctly.

Q3.

(a) Most students made some progress with this calculation to find the M_r of a volatile hydrocarbon, but few scored full marks. Key problems were incorrect rearrangement of the ideal gas equation, incorrect unit conversions for volume (from cm^3 to m^3), pressure (from kPa to Pa) and mass (from mg to g). In this question, working was required and each step in the calculation was marked separately. This meant that students who got the correct answer without working, or with incorrect working, were penalised. Some students, who arrived at a correct final value, scored zero marks as they made multiple very significant errors that, by chance, cancelled out. In addition, many students failed to give the final answer to two significant figures (which was based on the gas volume – given as 72 cm^3).

(b) Most students started this question correctly but struggled to convert the ratio 6.975:16.3 to 3:7, with 7:16 and 1:2 being common errors, and so failed to deduce the empirical formula. Some students still managed to deduce the molecular formula using the M_r alone. Again, students could not score full marks on this question without showing full working.

Q9.

The empirical formula calculation in **(a)** was well done with very few errors or omissions seen. The complicated formulae in **(b)** seemed to cause little confusion and only a lack of care caused a loss of the mark. The safety equipment mentioned in **(c)** was usually appropriate but the mention of 'breathing apparatus' by some students was regarded as inappropriate for handling cement bags. The reason for the safety equipment was sometimes poorly described.

Q11.

In part (a)(i) most students were able to deduce that CO_2 and H_2O were the missing products but not all were able to balance the equation. Multiples were common and accepted. Most students deduced correctly that bubbles would be observed in (a)(ii). A statement such as 'CO_2 gas is formed' is not an observation. The definition of the term empirical formula is still not well known. One or more key words, usually atoms of each element, were frequently omitted. The empirical formula calculation in part (b)(ii) was answered well with many students scoring full marks. For those who did not score full marks there was a good attempt at the question with marks one and two being accessed by the majority of students, although a number simplified the ratio by rounding 1.5 up to 2, rather than doubling the entire ratio to obtain the simplest whole number ratio.

Q12.

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Part (a) proved straightforward and most students gained full marks. A number lost the final mark because they did not explain why the empirical formula was half of the molecular formula.

Part (b) proved a challenging question which required a logical approach. It was pleasing to see many excellent answers and nearly a quarter of students scored seven or more marks. In the infrared analysis some students did not include the full name of O-H (alcohol) for the peak at 3400 cm^{-1} whilst some described the adjacent C-H absorption as OH (acid) and lost the first mark.

The outcome of the potassium dichromate(VI) test was not always fully explained and some of those who correctly stated that compound **R** was a primary or secondary alcohol but not a tertiary, then contradicted themselves in their final structure by drawing a tertiary alcohol.

When analysing the nmr data, many simply restated the information on the data sheet without using the integration data and then struggled to 'do the jigsaw' at the end and come up with a structure that fitted everything.

Most students did draw a structure for **R** as required although some only included analysis of the separate peaks and not the overall structure. A few students who drew several suggested structures were penalised if they failed to cross out the extras to leave just one answer.

Q13.

The calculation in part (a) was well answered with many students scoring full marks. For those who did not score full marks there was a good attempt at the question with marks one and three being accessed by the majority of students. Several alternative methods that produced the correct answer were seen and these were all given full credit. There were many varied answers to part (b) that showed students did not understand what should be done in this practical situation. Many students suggested collecting the gas evolved (by various methods) and testing it to check that it was water.

Q14.

Many students failed to do this. A significant few chose a difficult scale to work with....and consequently frequently misplotted one or more of the points. The line was often penalised for "doubling", being too thick or, in quite a few cases, just not being done.

Q15.

The number of correct answers to the unstructured calculation in part (a)(i) was pleasing. However, many students lost marks because they did not use the stoichiometry in the equation to answer the question. Over half of students scored both marks in part (a)(ii) but attempts by the rest were varied. Some could not calculate the M_r correctly, some forgot to multiply by 100 and a few obviously did not know what was meant by the term atom economy. The equation in part (b) was found to be difficult by many students; the biggest error involved an incorrect formula of calcium hydroxide and consequently an incorrect equation. The empirical formula calculation was well done by many students but some scored zero because they did not involve calcium in their working.

Q16.

Some students found no difficulty with the three numerical parts of this question. However, this question proved challenging for many students who often gave a jumble of figures

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with little explanation of where they came from.

Part (a) was the most well answered of the calculations although a small number could not score the first mark. In part (b), most students scored the mark for the number of moles of HCl. However, many students then used 0.083 in their answer and did not realise that the HCl was the limiting reagent. Many added the moles of HCl to the moles of pure zinc oxide whilst others multiplied the moles of HCl by 2 rather than dividing.

Answers to part (c) used various methods with many scoring the first two marks of the alternative method shown in the mark scheme. It should be noted that if an answer requires 3 significant figures, then the calculation should use at least 3 significant figures throughout. If less than this is used and then the answer is given as 3 'significant' figures, this will have introduced error and the final answer will not be within the margin of tolerance allowed. The bonding in part (d) was answered well by the majority of students.

Q17.

(a) In this part, most students completed the graph successfully. The usual problem was a mark being wrongly awarded for plotted points which did not cover half the paper. A number of students did not appreciate the significance of the origin in this type of experiment.

(b) Some teachers were generous when awarding the mark for drawing a line of best fit in this part. In graph questions where the points contain one or more anomalies, the line of best fit must ignore these anomalies to score the mark. The line of best fit mark cannot be awarded when the line itself is poorly drawn or doubled in places.

(c) Many students gave an answer to this part which did not match their own graph. Similarly, students whose line of best fit was poor were occasionally not given a consequential mark for interpreting their own graph correctly.

(d) Answers to this part were often poor and a good deal of vague and incorrect material was given credit.

Q18.

(a) Most students were successful in calculating the empirical formula in this part. Teachers need to beware of awarding full marks for flawed calculations which arrive at the expected answer, even though it is an impossible answer from the method used.

(b) In this part, many students forgot to include the charge on the ion.

Q19.

The definition of electronegativity in part (a)(i) was poorly answered. Common errors included referring to the power of an element rather than an atom to withdraw electrons and many students did not refer to the type of bond. In part (a)(ii), many students failed to score the second mark suggesting that shielding or atomic radius increased. Quite a number of students could not identify the bonding in part (b) correctly. Many of those who could often then contradicted themselves by referring to molecules or atoms rather than ions.

Many students did not refer to the small difference in electronegativity between the two atoms in part (c). Instead, they opted for the more accessible answer of bonding between two non-metals. Part (d)(i) was not answered as well as expected. Many students did not seem aware of the difference between bonding type and crystal structure. The equation in

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part (d)(ii) was generally well answered although some students thought that the formula of hydrogen fluoride was H_2F_2. The calculation in part (d)(iii) was generally well answered although some students divided by 8 and 9 and a significant number of students thought that the molecular formula was 2OF.

Q20.

The unstructured calculation in part (a) was attempted by all but a few students. Most students managed to score two marks. The most common errors were the incorrect conversion of pressure and volume into the appropriate units and a failure to divide the total moles of gas by five. The equation in part (b) was often incorrect with many examples of B_2 and atomic chlorine given. The students who knew that there were three bonding pairs of electrons often did not realise that the repulsions of the bonding pairs were equal. The calculation in part (c)(i) was reasonably well answered. Many students scored the first two marks but then incorrectly multiplied by 500/1000. Very few produced the expected equation in part (c)(ii) although the alternative equations were often seen. Many examples of the incorrect formulae '$NaBO_3$' and 'NaB' in unbalanced equations were also seen. Part (d) was well answered by the majority of students. A wide variety of methods were seen that could score full marks in part (e). The first three marks were usually obtained but the final mark proved elusive. Many students suggested that the molecular formula was $2BCl_2$ rather than the correct answer, B_2Cl_4.

Q21.

A lot of correct answers were seen in part (a) although many students found this difficult and answers giving incorrect charges ranging from –1 to +4 were seen. Some students lost marks by trying to write an equation rather than just stating the ion. In part (b), many students did not refer to an ion in their answer. Many students did not appreciate the –ide ending in part (c) and produced formulae such as $LiNO_3$. Many of those who realised that the formula contained only Li and N gave incorrect formulae such as LiN, LiN_3, Li_4N etc. In the empirical formula calculation in part (d), there were many students who could get no further than the 2.02 :1.35 ratio and weaker students divided the percentage of nitrogen by 28 rather than by 14. A small number of students used incorrect fractions by dividing the relative atomic mass by the percentage and getting Ca_2N_3. The equation in part (e) proved demanding with many students writing atomic nitrogen, N and molecular silicon eg Si_2, Si_8. A few incorrect symbols for silicon were seen ie S rather than Si.

Q22.

The great majority of students scored at least one mark for the empirical formula in this Question. Occasionally a mark was awarded for working when the method chosen made little sense. Dividing the M*r* by the percentage by mass was not worth the mark for working, even if by chance it arrived at the correct answer.

Q23.

Parts (a)(i), (ii) and (iii) were generally well done although many answers were not given to the precision required in the question. Part (a)(iv) was found to be difficult and generated answers such as 'displacement' and 'condensation'. The calculation in part (b)(i) was done well by many candidates but a significant number could not rearrange the equation correctly or convert the given pressure and temperature into the correct units. In part (b)(ii) there was a tendency to divide by 2 or 7. The empirical formula calculation in part (e) differentiated well with weaker candidates usually scoring only one of the available marks.

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Q24.

The electron configuration in part (a) was answered well by a good number of candidates. Part (b)(i) was very well answered. The equation in part (b)(ii) was generally well answered but less able candidates omitted the state symbols. In part (b)(iii), some candidates realised why the minimum energy was used although there were many who simply mentioned saving energy or money. The majority of candidates were able to give two correct reasons why indium should be ionised in part (b)(iv).

The definition in part (c)(i) still continues to confuse many candidates. Common errors included omitting the word 'average' on the top line and giving an incomplete expression on the bottom line. The calculation in part (c)(ii) proved difficult for candidates although a surprising number did get the correct percentage of each isotope. In part (d), most candidates stated that there was no difference in chemical properties and explained their answer well. A surprising number of candidates answered that there was no difference in chemical properties because neutrons had no effect on chemical properties. The empirical formula calculation in part (e) was generally answered well although some candidates got the 0.6:1.8:1.8 ratio and then gave the answer as In_3OH.

Q25.

In the empirical formula calculation in part (a) most candidates arrived at the 1.85 :4.63 ratio but a surprising number of candidates could not convert this into 1:2.5 and then into N_2O_5. In part (b) a large majority of candidates scored the mark although some thought that NO dissolved directly in rain to make acid rain. Part (c) was generally answered well. In part (d) there was much confusion as to where the nitrogen had come from. The most common error was to state that it came from the fuel. In part (e) equations often contained 2N atoms rather than the nitrogen molecule.

Q26.

Few candidates could not make some progress in the empirical formula calculation in this part (a), but many were unable to deduce a M_r value from the spectrum in this part (b). The provision of dummy data in this part (c) allowed most candidates to score at least one of the marks.

Q27.

This was generally well done and candidates appear to be able to do simple numerical questions. There was confusion over the number of decimal places in the answers with some candidates simply writing all the digits from their calculator. In general, answers should be to the same number of significant figures as given in the question. The major problem with part (b) was the conversion of pressure into the correct units and the subsequent effect on the units of the answer. Part (c) was done well by the majority of candidates. It should however be stressed that the answer to an empirical formula calculation is a formula and not simply the ratio of the elements.

Q28.

In part (a) most candidates easily scored the first two marks, but converting the ratios to an empirical formula was more demanding. Some centres virtually awarded this mark by default, even when the candidate's explanation for the third mark was simply wrong.

In part (c)(i) the candidate was required to draw simple apparatus. Many candidates drew a practical set-up that would not work. The common problems were that the gas could not escape from the preparation vessel or that the collection vessel was not graduated and could therefore not record volume. A number of candidates assembled apparatus that was

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unsafe and should not have been awarded any marks at all. Marking of this question was often very generous indeed.

In part (c)(ii) the candidate was required to draw a simple graph. This generated the usual problems with marks being wrongly awarded for plotted points which did not cover half the paper and for graphs containing incorrectly plotted points. If the candidate's graph included the origin, then the candidate's line had to pass through the origin to score the line of best fit mark.

When candidates wrote 'because a gas is produced' as an answer to part (d) they were often credited with a mark. In general, candidates do not receive a mark for basically rewording part of a question rubric. The Marking Guidelines were quite clear that the effect on the human body was needed in a correct answer

Part (e) was, perhaps, the most demanding question of all. Full marks were rarely seen because the great majority of candidates struggled to express themselves clearly. Marking of this question was often very generous indeed. Candidates were often given a mark for any chemical reference to empirical or molecular formula. In this question two distinct ideas were required for the full award. Candidates needed to link molecular formula to empirical formula as a multiple and then say that a small error in the molecular formula mass would still allow a good judgement of which multiplier should have been used.

Marking was often very generous in part (f). When candidates are asked to suggest reasons why an experiment might not deliver the expected result the candidate is expected to suggest something more imaginative than misread the apparatus' or 'the apparatus was faulty'. The Marking Guidelines were quite clear that a reference to when the apparatus was assembled was needed for a gas leak to be worth a mark. The idea of the gas remaining in the flask was not sufficient unless the possibility of the gas dissolving was specifically mentioned.

In part (g) a statement of the Gas Law was often given a mark. 'PV = nRT' is not a sufficient answer since it does not show that the candidate understands what the equation means in regard to the volume of the gas.

In part (i)(i) centres were too generous in the interpretation of the key words in an answer. "Less soluble" and "not very soluble" were not acceptable alternatives to "least soluble".

Centres are asked to check candidates' equations carefully. Some candidates had an incorrect equation for part (j) but were still given a mark.

Q30.

In a surprisingly large proportion of instances, the diagrams were either left blank or were incomplete. Of those candidates who did attempt part (a), most coped well but it was not unusual for the diagram of sodium metal to contain negative charges, or for the sodium chloride diagram to show the same change on adjacent ions. Many of the explanations in part (b) were poorly done. Frequently, the answers to parts (b)(i) and (b)(ii) lacked any reference to the attraction between the relevant species. The most common answer to part (b)(iii) was to state that *ionic bonding is stronger than metallic bonding,* as if this were a universal truth, rather than deducing that this comparison was true in this case. In part (c), candidates frequently referred to sodium being a better conductor that sodium chloride; although some did then go on to clarify matters by explaining that sodium chloride would only conduct when molten. It was very common to see references to *covalent bonds, van der Waals', dipole-dipole* and *intermolecular forces* in this question. In part (c), some good explanations were seen but, all too often, they were vague and incomplete. Many candidates were aware of the importance of delocalised electrons to the conductivity of sodium; however, relatively few described them flowing though the metal.

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The lack of conductivity of sodium chloride was often ascribed to there being no *free electrons* in the salt. Also, a significant minority of candidates simply referred to the presence or absence of *charge carriers,* without identifying them. Very few candidates explained the lack of conductivity of solid sodium chloride in terms of its immobile ions. Parts (d) and (e) were comparatively well answered, although the malleability of sodium being was sometimes attributed to the presence of *weak intermolecular forces.* The empirical formula calculation was usually accurately calculated and the equation correctly balanced.

Q31.

This question was also generally well answered. In part (a), the mole calculation was well done, although errors such as 9.89 were seen, and most candidates were successful in calculating the number of moles of oxygen. The Ideal gas equation was well known; however, some candidates rearranged it incorrectly. In a small but significant number of instances, incorrect pressure values were used, and a small number of arithmetic errors were found. The explanation of the term *empirical formula*, although frequently incomplete, was rather better answered than in previous years. The calculation of the empirical formula was quite well done, although it was not unusual for candidates to forget to calculate and use the percentage of oxygen in **Y**, to use incorrect *A*r values or to divide the *A*r values by the percentages.

The equation in part (c) was usually correct; however, some candidates wrote equations in which the KNO_3:O_2 ratio was not 2:1, despite having correctly shown that the number of moles of KNO_3 was twice that of O_2 in part (a). Also, it was not unusual to see equations in which oxygen was shown as ‘O’.

Q32.

This question usually yielded at least half marks for most candidates. In part (a), the word “substitution” was occasionally omitted. Weaker candidates struggled to present correct propagation steps, but could complete both the initiation step and the overall equation. Centres should encourage candidates to place the unpaired electron on a carbon atom when writing the formula for a free-radical intermediate.

Part (b) caused few problems for many candidates, although several could get no further than a correct empirical formula and then manipulated the numbers to produce an incorrect molecular formula.

In part (c) most candidates could get $CHBr_3$, but a second formula proved elusive for some, with HBr a common incorrect answer.

Q33.

The equation, in part (a) (i), was often correct but some candidates omitted hydrogen altogether, gave its formula as ‘H’ or failed to balance the equation correctly. In part (a) (ii), the shape of NH_3 was generally well known but it was not uncommon to see either no lone pairs, or two lone pairs, on the structure, or for a ‘T’ shape to be drawn. Fewer candidates drew an acceptable structure for the amide ion. The most frequently seen errors were drawings showing the ion as being linear or showing other than two lone pairs. Hydrogen atoms were omitted in some diagrams. The bond angle (107°) present in ammonia was generally well known but a significant number of candidates quoted 109 ½°; other incorrect angles were less frequently seen. The explanation in part (a) (iv) was often vague and unconvincing. Many candidates did not appreciate the significance of the second lone pair of electrons in the ion. Clear explanations of the differences in repulsion provided by bonding pairs and lone pairs were relatively rare. Descriptions of repulsions between lone pair electrons and hydrogen atoms or between bonds, rather than between

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bonding pairs of electrons, were quite common errors. In part (b) (i), answers were often incomplete, with words such as ‘simplest’, ‘atoms of and ‘each element’ being frequently omitted. The empirical formula calculation was generally well done, although the use of incorrect A_r values or the incorrect rounding of answers was not uncommon.

Q35.

Part (a) was, in general, poorly answered. While the more able candidates coped well, many candidates struggled. Correct answers to parts (a)(i) and (ii) were frequently seen but, in many cases, the answer of 0.0267 was given in part (a)(iii) without use being made of the answers from the previous two parts; the mark for this part was awarded for a correct calculation method, not for simply quoting 0.0267. In part (a)(iv), when attempting to calculate the number of moles of $MgCO_3$, rather more candidates used the value of the total moles of HCl (0.0375 mol) obtained in part (a)(i) than used the actual number of moles which reacted with the $MgCO_3$ (0.0267 mol) obtained in part (a)(iii). The calculation of the mass of $MgCO_3$ was marked consequentially but, as the final percentage of $MgCO_3$ exceeds 100%, the majority of candidates who followed this route chose to invert their percentage calculation, rather than checking for an earlier error in their calculation. A number of other errors were seen in this part, suggesting that many candidates lacked familiarity with this type of calculation. By contrast, the calculation in part (b) was quite well done. The occasional arithmetical error was seen, a few candidates omitted to deduce the percentage of oxygen and the atomic number was occasionally used in place of the relative atomic mass, but most candidates earned full marks in part (b)(i). However, the equation in part (b)(ii) was rarely correct, with errors such as $NaCl_2$, H_2 and SO_3 being very common.

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Q1.

When chlorine reacts with trichloromethane, tetrachloromethane, CCl_4, is formed.

(a) (i) Write the overall equation for this reaction.

_____

(ii) State **one** essential condition for this reaction.

_____

(2)

(b) The mechanism for the chlorination of trichloromethane is free-radical substitution, which proceeds by a series of steps. Write equations for the steps named below in this chlorination.

Initiation step

_____

First propagation step

_____

Second propagation step

_____

A termination step

_____

(4)

(Total 6 marks)

Q2.

When a sample of liquid, **X,** of mass 0.406 g was vaporised, the vapour was found to occupy a volume of 2.34×10^{-4} m^3 at a pressure of 110 kPa and a temperature of 473 K.

(a) Give the name of the equation $pV = nRT$.

_____

(1)

(b) Use the equation $pV = nRT$ to calculate the number of moles of **X** in the sample and hence deduce the relative molecular mass of **X.**
(The gas constant $R = 8.31$ J K^{-1} mol^{-1})

*Moles of **X*** _____

_____

_____

*Relative molecular mass of **X*** _____

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_____

(4)

(c) Compound **X,** which contains carbon, hydrogen and oxygen only, has 38.7% carbon and 9.68% hydrogen by mass. Calculate the empirical formula of **X**.

_____

_____

_____

_____

(3)

(d) Using your answers to parts (b) and (c) above, deduce the molecular formula of **X**.

_____

_____

(1)

(Total 9 makrs)

Q3.

The alkanes form an homologous series of hydrocarbons. The first four straight-chain alkanes are shown below.

methane	CH_4
ethane	CH_3CH_3
propane	$CH_3CH_2CH_3$
butane	$CH_3CH_2CH_2CH_3$

(a) (i) State what is meant by the term *hydrocarbon.*

_____

_____

(ii) Give the general formula for the alkanes.

_____

(iii) Give the molecular formula for hexane, the sixth member of the series.

_____

(3)

(b) Each homologous series has its own general formula. State **two** other characteristics of an homologous series.

_____

_____

_____

(2)

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(c) Branched-chain structural isomers are possible for alkanes which have more than three carbon atoms.

(i) State what is meant by the term *structural isomers.*

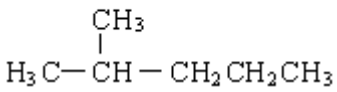
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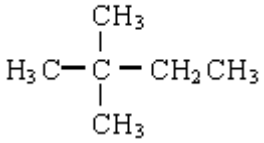
(ii) Name the **two** isomers of hexane shown below.

Isomer 1



Name _____

Isomer 2



Name _____

(iii) Give the structures of **two** other branched-chain isomers of hexane.

Isomer 3 *Isomer 4*

(6)

(d) A hydrocarbon, **W,** contains 92.3% carbon by mass. The relative molecular mass of **W** is 78.0

(i) Calculate the empirical formula of **W**.

_____

_____

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_____

_____

(ii) Calculate the molecular formula of **W**.

_____

_____

(4)

(Total 15 marks)

Q4.

An alkane contains 30 hydrogen atoms per molecule. Its empirical formula is

A C_6H_{15}

B C_7H_{15}

C $C_{14}H_{30}$

D $C_{15}H_{30}$

(Total 1 mark)

Q5.

CH_2O is the empirical formula of

A methanol

B methyl methanoate

C ethane-1,2-diol

D butanal

(Total 1 mark)

Q6.

When $TiCl_4$ is reduced with hydrogen under certain conditions, a new compound is produced which contains 68.9% chlorine by mass. Which one of the following could be the formula of the new compound?

A TiH_2Cl_2

B TiCl

C $TiCl_2$

D $TiCl_3$

(Total 1 mark)

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Q1.

(a) (i) $CHCl_3 + Cl_2 \rightarrow CCl_4 + HCl$ **(1)**

(ii) UV light / sunlight OR <u>high</u> T OR T ≥ 500°C **(1)**

maxT = 1000°C
NOT heat / light
Ignore pressure

2

(b) *Initial step*: $Cl_2 \rightarrow 2Cl^{\cdot}$ **(1)**

Condition could be on first equation arrow

First propagation step: $CHCl_3 + Cl^{\cdot} \rightarrow {}^{\cdot}CCl_3 + HCl$ **(1)**

Second propagation step: ${}^{\cdot}CCl_3 + Cl_2 \rightarrow CCl_4 + Cl\cdot$ **(1)**

A termination step: ${}^{\cdot}CCl_3 + Cl\cdot \rightarrow CCl_4$ **(1)**

OR $2\,{}^{\cdot}CCl_3 \rightarrow C_2Cl_6$

Not $2Cl\cdot \rightarrow Cl_2$
Ignore additional termination steps

4

[6]

Q2.

(a) <u>Ideal</u> gas equation law **(1)**

1

(b) *Moles of **X***: $n = \frac{PV}{RT}$ **(1)** $= \frac{110000 \times 2.34 \times 10^{-4}}{8.31 \times 473}$

$= 6.55 \times 10^{-3}$ **(1)**

6.5 to 6.6 × 10^{-3} , min 2 sig figs

If write $n = \frac{RT}{PV}$ *zero here, but can score* M_r

*Relative molecular mass of **X***: $M_r = \frac{m}{n}$ **(1)**

$= 62$ **(1)**

61.5 to 62.5

4

(c) % oxygen = 51.6 **(2)**

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C =38.7 / 12 H = 9.68 / 1 O = 57.6**(2)** / 16 **(1)**

= 3.23 = 9.68 = 3.23

1 : 3: 1 ∴ CH_3O **(1)**

If no % O or if wrong A_r used then max 1
Correct empirical formula earns all three marks

3

(d) $(\frac{62}{31} \times CH_3O) = C_2H_6O_2$ **(1)**

1

[9]

Q3.

(a) (i) Molecule/compound/consists/composed/made up of hydrogen and carbon only **(1)**

(ii) C_nH_{2n+2} **(1)**

(iii) C_6H_{14} only **(1)**
Do not credit structures alone or in addition.

3

(b) Chemically similar / react in same way / same chemistry
Differ by CH_2
gradation in physical properties OR specified trend e.g. b.p.
same functional group

Any 2, 2 marks 1 + 1
Not same molecular formula

2

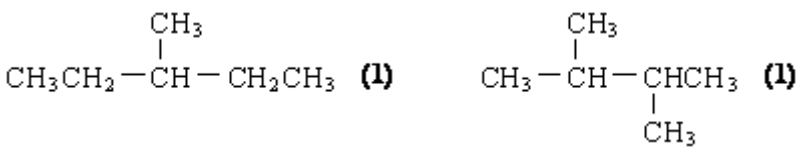
(c) (i) Same molecular formula **(1)**
NOT same Mr

different structural formula / structures **(1)**
(or atoms arranged in different way)
NOT different spatial arrangements
Only credit M2 if M1 correct

(ii) 2-methylpentane **(1)**
2,2-dimethylbutane **(1)**

(iii)

Isomer 3 either order *Isomer 4*



(1) (1)

OR correct condensed / structural formula
Penalise "sticks" once

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Penalise absence of vertical bonds once
penalise badly drawn bonds once (vertical between H atoms)

6

(d) (i) M1 % by mass of H = 7.7(0)% **(1)**
M2 mol H = 7.70 / 1 = 7.70
mol C = 92.3 / 12 = 7.69 **(1)**

M3 (ratio 1:1 ∴) CH

Credit variations for M2 e.g. $78 \times \frac{77}{100} = 6$

and $\frac{78}{12} \times \frac{92.3}{100} = 6$

Correct answer = 3 marks

(ii) (CH has empirical mass of 13 and $\frac{78}{13} = 6$ ∴) C_6H_6 **(1)**

Correct answer 1 mark

4

[15]

Q4.

B

[1]

Q5.

B

[1]

Q6.

D

[1]

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Q1.

Many candidates found parts (a) and (b) difficult. It was obvious from their answers that the conversion from methane to chloromethane had been learned, but the application of this idea to trichloromethane proved difficult. Even when candidates were able to start with a correct formula for trichloromethane, equations were confused, typically with radicals appearing in the overall equation and incorrect products and intermediates throughout both of parts (a) and (b).

Q2.

This question was generally well answered and full marks were quite common. Most, but by no means all, candidates gave the correct name for the equation, and most coped with the empirical formula calculation, with many of even the weaker candidates correctly deducing the empirical formula to be CH_3O. A few candidates omitted to calculate the percentage of oxygen or used atomic numbers rather than mass number in the calculation. Part (b) was often well done, but it was not unusual to see the equations inverted or for the pressure to be used in kPa, rather than in Pa. Errors in part (b) generated some very odd formulae in part (d).

Q3.

This question was generally well answered and it was here that some of the weakest candidates scored most of their marks. In part (a), the necessity to indicate that a hydrocarbon is a compound of hydrogen and carbon only and to recognise that C_6H_{14} is the molecular formula of hexane, rather than $CH_3CH_2CH_2CH_2CH_2CH_3$, were not always appreciated. In this latter context, centres need to understand that a candidate who writes both of these formulae will be penalised for failing to choose the correct answer from the two. Part (b) was generally well answered, but in (c)(i) some very confused answers were seen and those candidates who failed to state that structural isomers have the same molecular formula received no credit. In c(ii) and c(iii), naming and structures were often correct, but penalties were incurred from incomplete names, badly drawn structures or repetition of the structures given in the question. The calculation in part (d)(i) proved relatively straightforward for many candidates, but (d)(ii) caused some problems and a number of blank answers were seen.

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RAM RMM

Name: _____

Class: _____

Date: _____

Time: **176 minutes**

Marks: **164 marks**

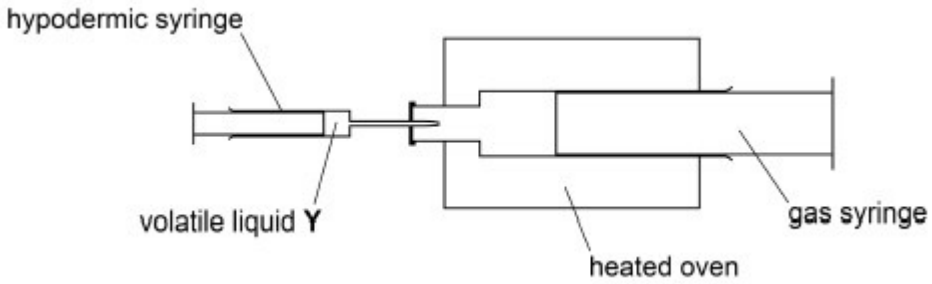
Comments:

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Q1.

A student determined the relative molecular mass, M_r, of an unknown volatile liquid Y in an experiment as shown in the diagram.
The student used a hypodermic syringe to inject a sample of liquid Y into a gas syringe in an oven.
At the temperature of the oven, liquid Y vaporised.

The student's results are shown in the table.



Mass of hypodermic syringe and liquid Y before injection	10.91 g
Mass of hypodermic syringe and liquid Y after injection	10.70 g
Oven temperature	98.1 °C
Atmospheric pressure	102 kPa
Increase in volume in gas syringe after injection of Y	85.0 cm^3

(a) Define the term relative molecular mass (M_r).

Use the experimental results in the table to determine the relative molecular mass of Y.
The gas constant R = 8.31 J K^{-1} mol^{-1}

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_____

_____

_____

_____

(5)

(b) Some of the liquid injected did not evaporate because it dripped into the gas syringe nozzle outside the oven.

Explain how this would affect the value of the M_r of Y calculated from the experimental results.

_____

_____

_____

_____

_____

(2)

(Total 7 marks)

Q2.

This question is about atomic structure.

(a) Write the full electron configuration for each of the following species.

Cl^- _____

Fe^{2+} _____

(2)

(b) Write an equation, including state symbols, to represent the process that occurs when the third ionisation energy of manganese is measured.

_____

_____

(1)

(c) State which of the elements magnesium and aluminium has the lower first ionisation energy.

Explain your answer.

_____

_____

_____

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_____

_____

_____

_____

(3)

(d) A sample of nickel was analysed in a time of flight (TOF) mass spectrometer. The sample was ionised by electron impact ionisation. The spectrum produced showed three peaks with abundances as set out in the table.

m/z	Abundance / %
58	61.0
60	29.1
61	9.9

Give the symbol, including mass number, of the ion that would reach the detector first in the sample.

Calculate the relative atomic mass of the nickel in the sample.

Give your answer to one decimal place.

Symbol of ion _____

Relative atomic mass _____

(3)

(Total 9 marks)

Q3.

This question is about a toxic chloroalkane, **X**, that has a boiling point of 40 °C.

A student carried out an experiment to determine the M_r of **X** by injecting a sample of **X** from a hypodermic syringe into a gas syringe in an oven at 97 °C and 100 kPa. The student's results are set out in **Table 1** and **Table 2**.

Table 1

Mass of hypodermic syringe filled with **X** before injection / g	10.340
Mass of hypodermic syringe with left over **X** after injection / g	10.070

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Mass of **X** injected / g	

Table 2

Volume reading on gas syringe before injection of **X** / cm^3	0.0
Volume of **X** in gas syringe after injection of **X** / cm^3	105.0
Volume of **X** / cm^3	

(a) Complete **Table 1** and **Table 2** by calculating the mass and volume of **X**.

(1)

(b) **X** is known to be one of the following chloroalkanes: CCl_4 $CHCl_3$ CH_2Cl_2 or CH_3Cl

Justify this statement by calculating a value for the M_r of **X** and use your answer to suggest the most likely identity of **X** from this list.

Give your answer for the M_r of **X** to an appropriate precision.
(The gas constant R = 8.31 J K^{-1} mol^{-1})

M_r of **X**

M_r of **X** = _____

Identity of **X**
(If you have been unable to calculate a value for M_r, you may assume that the M_r value is 52. This is **not** the correct value).

Identity of **X** = _____

(5)

(c) Suggest a reason, other than apparatus inaccuracy, why the M_r value determined from the experimental results differs from the actual M_r. Explain your answer.

_____

_____

_____

_____

_____

(2)

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(d) Suggest, with a reason, an appropriate safety precaution that the student should take when using the toxic chloroalkane, **X**, in the experiment.

Safety precaution _____

_____

Reason _____

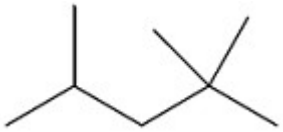
_____

(2)

(Total 10 marks)

Q4.

Isooctane (C_8H_{18}) is the common name for the branched-chain hydrocarbon that burns smoothly in car engines. The skeletal formula of isooctane is shown below.



(a) Give the IUPAC name for isooctane.

_____

(1)

(b) Deduce the number of peaks in the ^{13}C NMR spectrum of isooctane.

5 ○

6 ○

7 ○

8 ○

(1)

(c) Isooctane can be formed, together with propene and ethene, in a reaction in which one molecule of an alkane that contains 20 carbon atoms is cracked.

Using molecular formulas, write an equation for this reaction.

_____

(1)

(d) How do the products of the reaction in part (c) show that the reaction is an example of thermal cracking?

_____

(1)

(e) Deduce the number of monochloro isomers formed by isooctane.
Draw the structure of the monochloro isomer that exists as a pair of optical isomers.

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Number of monochloro isomers

_____

Structure

(2)

(f) An isomer of isooctane reacts with chlorine to form only one monochloro compound.

Draw the **skeletal formula** of this monochloro compound.

(1)

(g) A sample of a monochlorooctane is obtained from a comet. The chlorine in the monochlorooctane contains the isotopes ^{35}Cl and ^{37}Cl in the ratio 1.5 : 1.0
Calculate the M_r of this monochlorooctane.

M_r = _____

(2)

(h) Isooctane reacts with an excess of chlorine to form a mixture of chlorinated compounds.
One of these compounds contains 24.6% carbon and 2.56% hydrogen by mass.
Calculate the molecular formula of this compound.

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Molecular formula = _____

(3)

(Total 12 marks)

Q5.

(a) **Table 1** shows some data about fundamental particles in an atom.

Table 1

Particle	proton	neutron	electron
Mass / g	1.6725×10^{-24}	1.6748×10^{-24}	0.0009×10^{-24}

(i) An atom of hydrogen can be represented as ^{1}H

Use data from **Table 1** to calculate the mass of this hydrogen atom.

_____

(1)

(ii) Which **one** of the following is a fundamental particle that would **not** be deflected by an electric field?

A electron

B neutron

C proton

Write the correct letter, **A**, **B** or **C**, in the box.



(1)

(b) A naturally occurring sample of the element boron has a relative atomic mass of 10.8.
In this sample, boron exists as two isotopes, ^{10}B and ^{11}B

(i) Calculate the percentage abundance of ^{10}B in this naturally occurring sample of boron.

_____

_____

_____

_____

_____

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(2)

(ii) State, in terms of fundamental particles, why the isotopes ^{10}B and ^{11}B have similar chemical reactions.

_____

_____

_____

(1)

(c) Complete **Table 2** by suggesting a value for the third ionisation energy of boron.

Table 2

	First	**Second**	**Third**	**Fourth**	**Fifth**
Ionisation energy / kJ mol^{-1}	799	2420		25 000	32 800

(1)

(d) Write an equation to show the process that occurs when the **second** ionisation energy of boron is measured. Include state symbols in your equation.

_____

(1)

(e) Explain why the second ionisation energy of boron is higher than the first ionisation energy of boron.

_____

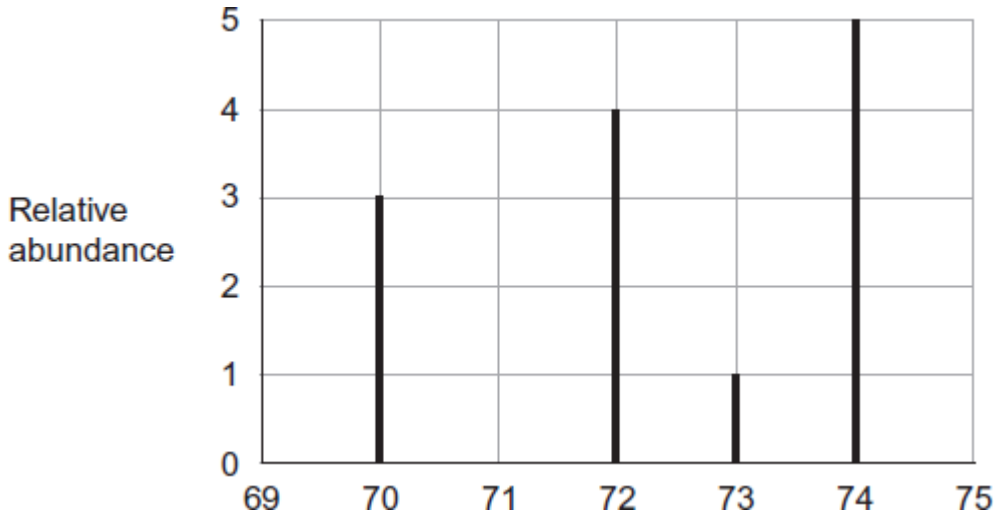
_____

(1)

(Total 8 marks)

Q6.

The mass spectrum of the isotopes of element **X** is shown in the diagram.



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m / z

(a) Define the term *relative atomic mass*.

_____

_____

_____

_____

(2)

(b) Use data from the diagram to calculate the relative atomic mass of **X**.

Give your answer to one decimal place.

_____

_____

_____

_____

_____

_____

(3)

(c) Identify the ion responsible for the peak at 72

_____

(1)

(d) Identify which one of the isotopes of **X** is deflected the most in the magnetic field of a mass spectrometer. Give a reason for your answer.

Isotope _____

Reason _____

(2)

(e) In a mass spectrometer, the relative abundance of each isotope is proportional to the current generated by that isotope at the detector.

Explain how this current is generated.

_____

_____

_____

_____

(2)

(f) **X** and **Zn** are different elements.

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Explain why the chemical properties of ^{70}**X** and ^{70}**Zn** are different.

_____

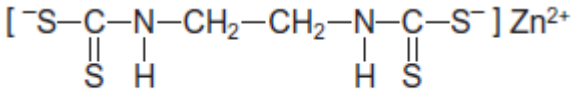
_____

(1)

(Total 11 marks)

Q7.

(a) Because of the toxic nature of the copper(II) ion, a wide range of alternative anti-fungal drugs has been developed for use in agriculture. One example is Zineb.



Zineb

(i) The negative ion in Zineb could act as a bidentate ligand.

On the structure above, draw a ring around each of **two** atoms that could provide the lone pairs of electrons when this ion acts as a bidentate ligand.

(1)

(ii) Calculate the M_r of Zineb. Give your answer to the appropriate precision.

_____

_____

_____

_____

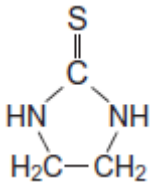
(1)

(iii) Name the functional group formed at each end of the negative ion when all the sulfur atoms in the structure of Zineb are replaced by oxygen atoms.

_____

(1)

(b) Zineb has been investigated for harmful effects. Generally, Zineb has been found to be safe to use in agriculture. It is only slightly soluble in water and is sprayed onto plants. A breakdown product of Zineb is ethylene thiourea (ETU), which is very soluble in water. The structure of ETU is shown below.



Determine the percentage, by mass, of sulfur in ETU (M_r = 102.1).

_____

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_____

_____

(1)

(c) Chromatography is a technique used to show the presence of a small amount of ETU in Zineb.

Outline how this technique is used to separate and identify ETU from a sample of Zineb powder.

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

(4)

(Total 8 marks)

Q8.

(a) Define the term *relative atomic mass*.

An organic fertiliser was analysed using a mass spectrometer. The spectrum showed that the nitrogen in the fertiliser was made up of 95.12% ^{14}N and 4.88% ^{15}N

Calculate the relative atomic mass of the nitrogen found in this organic fertiliser. Give your answer to two decimal places.

_____

_____

_____

_____

_____

_____

_____

(4)

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(b) In a mass spectrometer, under the same conditions, $^{14}N^+$ and $^{15}N^+$ ions follow different paths. State the property of these ions that causes them to follow different paths.

State **one** change in the operation of the mass spectrometer that will change the path of an ion.

_____

_____

_____

_____

(2)

(c) Organic fertilisers contain a higher proportion of ^{15}N atoms than are found in synthetic fertilisers.

State and explain whether or not you would expect the chemical reactions of the nitrogen compounds in the synthetic fertiliser to be different from those in the organic fertiliser. Assume that the nitrogen compounds in each fertiliser are the same.

_____

_____

_____

_____

(2)

(Total 8 marks)

Q9.

(a) Sodium hydrogencarbonate ($NaHCO_3$) can also be used to neutralise ethanoic acid spillages. The equation for this reaction is shown below.

$$CH_3COOH + NaHCO_3 \longrightarrow CH_3COONa + H_2O + CO_2$$

State the ideal gas equation.

_____

(1)

(b) There are several methods by which ethanoic acid is synthesised on an industrial scale. One method is the oxidation of butane in the presence of metal ion catalysts. Balance the equation given below which summarises this reaction.

$$\text{.....}C_4H_{10} + \text{.....}O_2 \longrightarrow \text{.....}CH_3COOH + \text{.....}H_2O$$

(1)

(c) A second method by which ethanoic acid is synthesised involves the oxidative fermentation of ethanol in the presence of bacteria. The equation representing this reaction is given below.

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$$C_2H_5OH + O_2 \longrightarrow CH_3COOH + H_2O$$

In a small scale experiment using this second method it was found that 23.0 g of ethanol produced only 4.54 g of ethanoic acid. Calculate the percentage yield for this experiment.

(2)

(Total 4 marks)

Q10.

Hydrogen peroxide is sold commercially as an aqueous solution containing approximately 60 g dm^{-3} of hydrogen peroxide.

(a) Use data from the Periodic Table to calculate the M_r of hydrogen peroxide. Give your answer to the appropriate precision.

(1)

(b) Calculate the concentration, in mol dm^{-3}, of a solution containing 60.0 g dm^{-3} of hydrogen peroxide.

(1)

(c) The concentration of hydrogen peroxide in a hair bleach is 0.050 mol dm^{-3}. Use your answer from (b) to calculate the dilution factor needed to make the commercial hydrogen peroxide solution suitable for use in this hair bleach. Show your working.

(2)

(Total 4 marks)

Q11.

A mass spectrometer can be used to investigate the isotopes in an element.

(a) Define the term *relative atomic mass* of an element.

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(2)

(b) Element **X** has a relative atomic mass of 47.9

Identify the block in the Periodic Table to which element **X** belongs and give the electron configuration of an atom of element **X**.

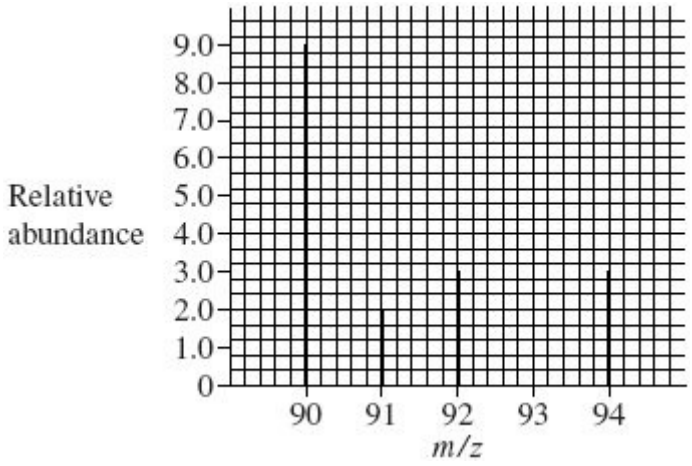
Calculate the number of neutrons in the isotope of **X** which has a mass number 49

(3)

(c) The mass spectrum of element **Z** is shown below.

Use this spectrum to calculate the relative atomic mass of **Z**, giving your answer to one decimal place.

Identify element **Z**.



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_____

(4)

(d) State how vaporised atoms of **Z** are converted into $\mathbf{Z}^+$ ions in a mass spectrometer.

State and explain which of the $\mathbf{Z}^+$ ions formed from the isotopes of **Z** in part (c) will be deflected the most in a mass spectrometer.

_____

_____

_____

_____

_____

_____

_____

(4)

(e) Explain briefly how the relative abundance of an ion is measured in a mass spectrometer.

_____

_____

_____

_____

(2)

(Total 15 marks)

Q12.

(a) (i) Define the term *relative atomic mass* (A_r) of an element.

_____

_____

_____

_____

(2)

(ii) A sample of the metal silver has the relative atomic mass of 107.9 and exists as two isotopes. In this sample, 54.0% of the silver atoms are one isotope with a relative mass of 107.1

Calculate the relative mass of the other silver isotope.

State why the isotopes of silver have identical chemical properties.

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(4)

(b) The isotopes of silver, when vaporised, can be separated in a mass spectrometer.

Name the **three** processes that occur in a mass spectrometer before the vaporised isotopes can be detected.

State how each process is achieved.

(6)

(c) State the type of bonding involved in silver.

Draw a diagram to show how the particles are arranged in a silver lattice and show the charges on the particles.

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(3)

(d) Silver reacts with fluorine to form silver fluoride (AgF).

Silver fluoride has a high melting point and has a structure similar to that of sodium chloride.

State the type of bonding involved in silver fluoride.

Draw a diagram to show how the particles are arranged in a silver fluoride lattice and show the charges on the particles.

Explain why the melting point of silver fluoride is high.

(5)

(Total 20 marks)

Q13.

Magnesium carbonate, $MgCO_3$, can occur as the anhydrous compound, or as hydrates with 2, 3 or 5 molecules of water of crystallisation. All types of magnesium carbonate can be decomposed to form magnesium oxide, an important starting material for many

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processes. This decomposition reaction can be used to identify the type of magnesium carbonate present in a mineral.

A chemist was asked to identify the type of magnesium carbonate present in a mineral imported from France. The chemist weighed a clean dry crucible, and transferred 0.25 g of the magnesium carbonate mineral to the crucible. The crucible was then heated for a few minutes. The crucible was then allowed to cool, and the crucible and its contents were reweighed. This process was repeated until the crucible and its contents had reached constant mass. The mass of the crucible and its contents was then recorded.

The experiment was repeated using different masses of the magnesium carbonate mineral.

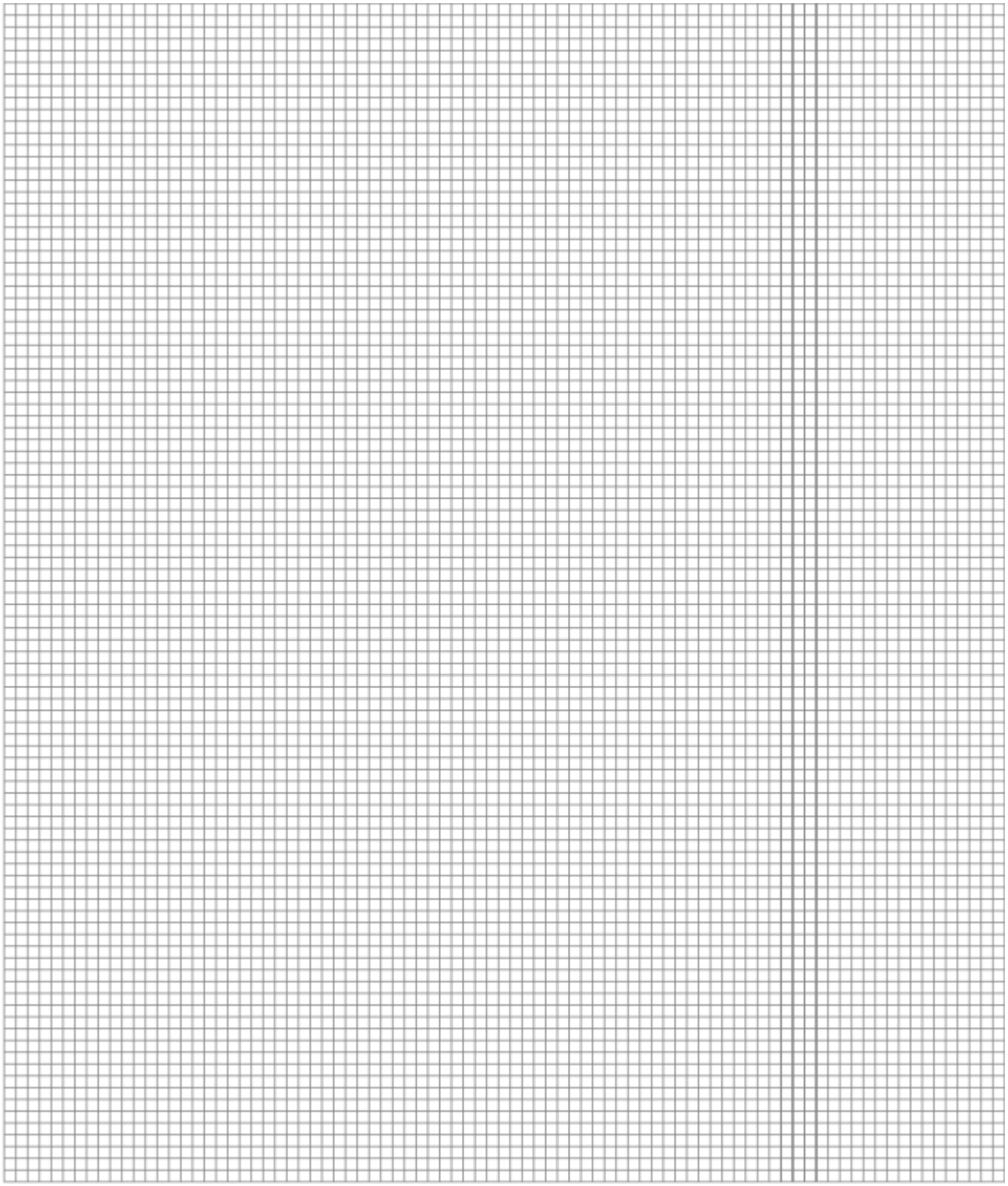
For each experiment the chemist recorded the original mass of the mineral and the mass of magnesium oxide left after heating to constant mass. The chemist's results are shown in the table below.

Experiment	1	2	3	4	5	6
Mass of mineral / g	1.60	1.17	0.74	1.31	1.80	1.34
Mass of magnesium oxide / g	0.54	0.39	0.24	0.44	0.61	0.49

(a) Plot a graph of the mass of the mineral (x-axis) against the mass of magnesium oxide on the grid below.

Draw a straight line of best fit on your graph.

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(4)

(b) Use the graph to determine the mass of the mineral which would have formed 0.50 g of magnesium oxide.

Mass of the mineral _____

(1)

(c) Calculate the amount, in moles, of MgO present in 0.50 g of magnesium oxide.

_____

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_____

(1)

(d) Use your answers from part (b) and from part (c) to calculate the M_r of the magnesium carbonate present in the mineral.

_____

_____

_____

(1)

(e) Use your answer from part (d) to confirm that this mineral is $MgCO_3.2H_2O$

(If you could not complete the calculation in part (d), you should assume that the experimental M_r value is 122.0 This is not the correct answer.)

_____

_____

_____

(1)

(f) Explain why it was **not** necessary to use a more precise balance in this experiment.

_____

_____

(1)

(g) Consider your graph and comment on the results obtained by the chemist. Identify any anomalous results.

Comment _____

_____

Anomalous results _____

_____

(2)

(h) Explain why it was necessary for the chemist to heat the crucible and its contents to constant mass.

_____

(1)

(i) Suggest **one** reason in each case why

(i) small amounts of the mineral, such as 0.10 g, should **not** be used in this experiment.

_____

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_____

(1)

(ii) large amounts of the mineral, such as 50 g, should **not** be used in this experiment.

_____

_____

(1)

(j) Analysis of a different hydrated magnesium carbonate showed that it contained 39.05% by mass of water. Determine the formula of this hydrated magnesium carbonate.

_____

_____

_____

_____

(2)

(k) Magnesium oxide is produced by the thermal decomposition of magnesium carbonate and by the thermal decomposition of magnesium hydroxide. The equations for the reactions taking place are shown below.

Reaction 1 $MgCO_3 \rightarrow MgO + CO_2$
Reaction 2 $Mg(OH)_2 \rightarrow MgO + H_2O$

Show that Reaction 2 has the greater atom economy for the production of magnesium oxide.

_____

_____

(2)

(l) Apart from cost, suggest **one** advantage of using magnesium hydroxide rather than magnesium carbonate to reduce acidity in the stomach.

_____

_____

(1)

(Total 19 marks)

Q14.

The reaction of bromine with ethane is similar to that of chlorine with ethane. Three steps in the bromination of ethane are shown below.

Step **1** $Br_2 \longrightarrow 2Br^{\bullet}$

Step **2** $Br^{\bullet} + CH_3CH_3 \longrightarrow CH_3CH_2^{\bullet} + HBr$

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Step **3** $CH_3CH_2^{\bullet} + Br_2 \longrightarrow CH_3CH_2Br + Br^{\bullet}$

(a) (i) Name this type of mechanism.

_____

(ii) Suggest an essential condition for this reaction.

_____

(iii) Steps **2** and **3** are of the same type. Name this type of step.

_____

(iv) In this mechanism, another type of step occurs in which free-radicals combine. Name this type of step. Write an equation to illustrate this step.

Type of step _____

*Equation*_____

(5)

(b) Further substitution in the reaction of bromine with ethane produces a mixture of liquid organic compounds.

(i) Name a technique which could be used to separate the different compounds in this mixture.

_____

(ii) Write an equation for the reaction between bromine and ethane which produces hexabromoethane, C_2Br_6, by this substitution reaction.

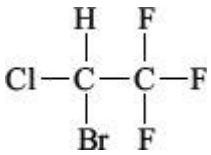
_____

(2)

(c) The compound 1,2-dibromo-1,1,2,2-tetrafluoroethane is used in some fire extinguishers. Draw the structure of this compound.

(1)

(d) Halothane is used as an anaesthetic and has the following structure.



(i) Give the systematic name of *halothane*.

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_____

(ii) Calculate the M_r of halothane.

_____

(iii) Calculate the percentage by mass of fluorine in halothane.

_____

(3)

(Total 11 marks)

Q15.

The relative molecular mass (M_r) of benzene-1,4-dicarboxylic acid is

A 164

B 166

C 168

D 170

(Total 1 mark)

Q16.

(a) State the relative charge and relative mass of a proton, of a neutron and of an electron.
In terms of particles, explain the relationship between two isotopes of the same element.
Explain why these isotopes have identical chemical properties.

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

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(7)

(b) Define the term *relative atomic mass*. An element exists as a mixture of three isotopes.
Explain, in detail, how the relative atomic mass of this element can be calculated from data obtained from the mass spectrum of the element.

(7)
(Total 14 marks)

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Q1.

(a) The sum of $\frac{\text{(weighted) average masses of atoms in formula}}{\text{1/12 mass of an atom of } ^{12}C}$

$\frac{\text{Average mass of one molecule}}{\text{1/12 mass of an atom of } ^{12}C}$

1

Method 1	**Method 2**
Mass of Y = 0.21g	Mass of Y = 0.21g

If incorrect lose M5 also, unless AE

1

$M_r = \frac{mRT}{pV}$ $\quad n = \frac{pV}{RT}$ and $M_r = \frac{m}{n}$

Can be implied in calculations

1

$M_r = \frac{0.21 \times 8.31 \times 371.1}{102000 \times 85x10^{-6}}$ $\quad n = \frac{102000 \times 85x10^{-6}}{8.31 \times 371.1}$ (= 2.81 × 10^{-3})

M4 – awarded for all 3 unit conversions

1

$M_r = 74.7$ $\quad M_r = 74.7$

Allow 75

1

(b) Lower volume recorded

Allow

(Evaporated) mass of gas is less than the recorded mass of liquid / 0.21g (or converse)

1

M_r would be greater (than the real M_r)

Ignore other references to mass

1

[7]

Q2.

(a) Cl^- $1s^2 2s^2 2p^6 3s^2 3p^6$

1

Fe^{2+} $1s^2 2s^2 2p^6 3s^2 3p^6 3d^6$

1

If [Ne] or [Ar] used then Max 1if both correct

Ignore $4s^0$

Allow subscripts

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(b) $Mn^{2+}(g) \rightarrow Mn^{3+}(g) + e^-$

1

States symbols are required

Allow $Mn^{2+}(g) - e^- \rightarrow Mn^{3+}(g)$

Negative charge needed on electron

(c) Al

Mg then CE = 0

1

(Outer) electron in (3)p sublevel / orbital

Not just level or shell

1

Higher in energy / further from the nucleus
so easier to remove OWTTE

Both required for M3

1

Ignore shielding

(d) $^{58}Ni^+$

M1 needs mass and charge – allow subscripts

1

A_r= [(58 × 61.0) + (60 × 29.1) + (61 × 9.9)] / 100

1

A_r= 58.9 must be to 1dp

1

[9]

Q3.

(a) Mass of **X** = 0.270

Volume of **X** = 105.0

Both must be correct

1

(b) pV = nRT

$$\frac{100\,000 \times 105/1000000}{8.31 \times 370} = n$$

1

n = 3.41×10^{-3}

1

M_r = $\frac{\text{mass}}{\text{mol}}$ or $\frac{0.270}{3.41 \times 10^{-3}}$

1

M_r = 79.1

1

Identity of **X** = CH_2Cl_2

If M_r = 52 used, allow CH_3Cl

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1

(c) **M1** The volume of the gas in the syringe (V) is greater than the true volume (because some air leaked into the syringe)

If the M_r value of 52 is used and CH_3Cl is identified in 01.2:

1

M2 M_r = m/n = m × RT/PV so if V is too large, M_r is too small

OR

M1 The temperature measured (T) is less than the temperature of the gas in the syringe (because the syringe heated faster than the oven and the oven temperature was not constant)

M2 M_r = m/n = m × RT/PV so if T is too small, M_r is too small

OR

M1 The measured mass of liquid transferred to the syringe (m) is less than the actual mass transferred

M2 M_r = m/n = m × RT/PV so if m is too small, M_r is too small

***M1** The volume of the gas in the syringe (V) is less than the true volume (because not all the liquid vaporised in the syringe)*

***M2** M_r = m/n = m × RT/PV so if V is too small, M_r is too large*

OR

***M1** The temperature measured (T) is greater than the temperature of the gas in the syringe (because the syringe heated more slowly than the thermometer and the oven temperature was not constant)*

***M2** M_r = m/n = m × RT/PV so if T is too large, M_r is too large*

OR

***M1** The measured mass of liquid transferred to the syringe (m) is greater than the actual mass transferred*

***M2** M_r = m/n = m × RT/PV so if m is too large, M_r is too large*

1

(d) Carry out in a fume cupboard

Do not allow safety glasses / labcoat

1

To avoid toxic vapour

1

[10]

Q4.

(a) 2,2,4-trimethylpentane

1

(b) 5

1

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(c) $C_{20}H_{42} \longrightarrow C_8H_{18} + 2C_3H_6 + 3C_2H_4$

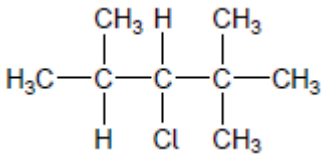
1

(d) Mainly alkenes formed

1

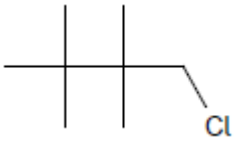
(e) 4 (monochloro isomers)

1



1

(f)



1

(g) $C_8H_{17}{}^{35}Cl = 96.0 + 17.0 + 35.0 = 148.0$
and $C_8H_{17}{}^{37}Cl = 96.0 + 17.0 + 37.0 = 150.0$
Both required

1

M_r of this $C_8H_{17}Cl$ $\frac{(1.5 \times 148.0)}{2.5} + \frac{(1.0 \times 150.0)}{2.5}$ = 148.8

1

(h) $\frac{24.6}{12} \quad \frac{2.56}{1} \quad \frac{72.8}{35.5}$ = 2.05 : 2.56 : 2.05

Simplest ratio = $\frac{2.05}{2.05} : \frac{2.56}{2.05} : \frac{2.05}{2.05}$

= 1 : 1.25 : 1

1

Whole number ratio (× 4) = 4 : 5 : 4

1

MF = $C_8H_{10}Cl_8$

1

[12]

Q5.

(a) (i) 1.6734×10^{-24} (g)
Only.

1.6734×10^{-27} kg
Not 1.67 × 10⁻²⁴ (g).

1

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(ii) **B**

1

(b) (i) $\frac{10x + 11y}{x + y} = 10.8$

OR ratio 10:11 = 1:4 **OR** 20:80 etc

Allow idea that there are 5 × 0.2 divisions between 10 and 11.

1

abundance of ^{10}B is 20(%)

OR

$\frac{10x}{100} + \frac{11(100-x)}{100} = 10.8$

$10x + 1100 - 11x = 1080$

$\therefore x = 1100 - 1080 = 20\%$

Correct answer scores M1 and M2.

1

(ii) Same number of electrons (in outer shell or orbital)

Ignore electrons determine chemical properties.

Same electronic configuration / arrangement

Ignore protons unless wrong.

1

(c) Range between 3500 and 10 000 kJ mol^{-1}

1

(d) $B^+(g) \longrightarrow B^{2+}(g) + e^{(-)}$

$B^+(g) - e^{(-)} \longrightarrow B^{2+}(g)$

$B^+(g) + e^{(-)} \longrightarrow B^{2+}(g) + 2e^{(-)}$

Ignore state symbol on electron even if wrong.

1

(e) Electron being removed from a positive ion (therefore needs more energy) / electron being removed is closer to the nucleus

Must imply removal of an electron.

Allow electron removed from a + particle / species or from a 2+ ion.

Not electron removed from a higher / lower energy level / shell.

Not electron removed from a higher energy sub-level / orbital.

Ignore electron removed from a lower energy sub-level / orbital.

Ignore 'more protons than electrons'.

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Not 'greater nuclear charge'.
Ignore 'greater effective nuclear charge'.
Ignore shielding.

1

[8]

Q6.

(a) Average / mean mass of 1 atom (of an element)
1/12 mass of one atom of ^{12}C

If moles and atoms mixed, max = 1

1

Mark top and bottom line independently.
All key terms must be present for each mark.

1

OR

Average / mean mass of atoms of an element
1/12 mass of one atom of ^{12}C

OR

Average / mean mass of atoms of an element ×12
mass of one atom of ^{12}C

OR

(Average) mass of one mole of atoms
1/12 mass of one mole of ^{12}C

OR

(Weighted) average mass of all the isotopes
1/12 mass of one atom of ^{12}C

OR

Average mass of an atom / isotope (compared to C−12) on a scale in which an atom of C−12 has a mass of 12

This expression = 2 marks.

(b) $$\frac{(70 \times 3) + (72 \times 4) + 73 + (74 \times 5)}{13} = \frac{941}{13}$$

1
1

= 72.4

72.4 only

1

(c) $^{(72)}Ge^{+}$ or germanium^{+}

Must show '+' sign.
Penalise wrong mass number

1

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(d) 70

If M1 incorrect or blank CE = 0/2

Ignore symbols and charge even if wrong.

1

Lowest mass / lowest m/z

Accept lightest.

Accept fewest neutrons.

1

(e) Electron(s) transferred / flow (at the detector)

M1 must refer to electron flow at the detector.

If M1 incorrect CE = 0/2

1

(From detector / plate) to the (+) ion

Do not allow from a charged plate.

1

(f) They do not have the same electron configuration / they have different number of electrons (in the outer shell)

Ignore electrons determine the properties of an atom.

Ignore they are different elements or different number of protons.

1

[11]

Q7.

(a) (i) Two rings only around nitrogen or sulfur

Lose this mark if more than 2 atoms are ringed.

Do not allow two atoms at the same end of the ion.

1

(ii) 275.8

Accept this answer only. Do not allow 276

1

(iii) Carboxylate / COO^-

Allow salt of carboxylic acid or just carboxylic acid.

1

(b) (32.1 / 102.1) = 31.4%

Do not penalise precision but do not allow 1 significant figure.

1

(c) Zineb is mixed with a solvent / water

Max=2 if M1 missed

1

Use of column / paper / TLC

Lose M1 and M2 for GLC

1

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Appropriate collection of the ETU fraction
OR Appropriate method of detecting ETU

Allow ETU is an early fraction in a column or collecting a range of samples over time, lowest retention time / travels furthest on paper or TLC (allow 1 mark for having the longest retention time in GLC).

1

Method of identification of ETU (by <u>comparison</u> with standard using chromatography)

If method completely inappropriate, only M1 is accessible

1

[8]

Q8.

(a) Average/mean mass of (1) atom(s) (of an element)

1

1/12 mass of one atom of ^{12}C

Accept answer in words
Can have top line × 12 instead of bottom line ÷ 12

1

OR

<u>(Average) mass of one mole of atoms</u>
1/12 mass of one mole of ^{12}C

OR

<u>(Weighted) average mass of all the isotopes</u>
1/12 mass of one atom of ^{12}C

OR

Average mass of an atom/isotope compared to C-12 on a scale in which an atom of C-12 has a mass of 12

$$\frac{(95.12 \times 14) + (4.88 \times 15)}{100}$$

Allow 95.12 + 4.88 instead of 100

1

= 14.05

If not to 2 d.p. then lose last mark
Not 14.04

1

(b) ^{15}N is heavier/^{15}N has a bigger m/z/different m/z values

Not different no's of neutrons
Not ionisation potential

1

Electromagnet/electric field/magnet/accelerating potential or voltage/electric current

1

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(c) No difference

1

Same no of electrons (in outer orbital/shell/sub shell)/same electron configuration

M2 dependent on M1
Not just electrons determine chemical properties
Ignore protons

1

[8]

Q9.

(a) pV = nRT

Do not penalise incorrect use of capitals / lower case letters.
Accept correct rearrangement of equation.

1

(b) $\mathbf{2}C_4H_{10} + \mathbf{5}O_2 \rightarrow \mathbf{4}CH_3COOH + \mathbf{2}H_2O$

Accept any correct combination of multiples, including fractions.

1

(c) 23.0 g ethanol produces 30.0 g ethanoic acid

1

15.1% (4.54 ×100 / 30)

Do not penalise precision.
15.1% scores 2 marks.
Accept consequential answer on wrong mass of ethanoic acid for second mark only.

1

[4]

Q10.

(a) 34.0

Penalise precision once

1

(b) 1.76 mol dm^{-3}

1

(c) answer to (b) divided by 0.05

35(.3) on correct figures

1

Shows working

Correct answer only scores this mark
Lose this mark if any units are given for the factor

1

[4]

Q11.

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(a) Average/mean mass of (1) atom(s) (of an element)
1/12 mass of one atom of ^{12}C

1

If moles and atoms mixes Max = 1

1

OR

(Average) mass of one mole of atoms
1/12 mass of one mole of ^{12}C

OR

(Weighted) average mass of all the isotopes
1/12 mass of one atom of ^{12}C

OR

Average mass of an atom/isotope compared to C-12 on a scale in which an atom of C-12 has a mass of 12

This expression = 2 marks

(b) d block

Allow 3d/D
Other numbers lose M1
Ignore transition metals

1

[Ar] $3d^2 4s^2$

1

Can be written in full
Allow subscripts
$3d^2$ and $4s^2$ can be in either order

27

1

(c) $\frac{(90 \times 9) + (91 \times 2) + (92 \times 3) + (94 \times 3)}{17}$

(= 1550)

1

(or ∑ their abundances)

If one graph reading error lose M1 and allow consequential M2 and M3.
If 2 GR errors penalise M1 and M2 but allow consequential M3
If not 17 or ∑ their abundances lose M2 and M3

1

= 91.2

91.2 = 3 marks provided working shown.

1

Zr/Zirconium

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M4 -allow nearest consequential element from M3
accept Zr in any circumstance

1

(d) High energy electrons/bombarded or hit with electrons

accept electron gun

1

knocks out electron(s) (to form ions)

1

Z^+ = 90 deflected most

If not 90 lose M3 and M4
If charge is wrong on 90 isotope lose M3 only
Accept any symbol in place of Z

1

since lowest mass/lowest m/z

Allow lightest

1

(e) (ions hit detector and) cause current/(ions) accept electrons/cause electron flow

QWC

1

bigger current = more of that isotope/current proportional to abundance

Implication that current depends on the number of ions

1

[15]

Q12.

(a) (i) Average/mean mass of 1 atom (of an element);

Average mass of 1 atom × 12.

1

Mass 1/12 atom of ^{12}C;

Mass 1 atom of ^{12}C.
QWC.

1

(ii) Other isotope = 46.0%;

1

$$107.9 = \frac{(54 \times 107.1) + (46 \times ?)}{100};$$

M2 whole expression.

1

108.8;

Answer 108.8 (3 marks).
Answer min 1 d.p..

1

Same electronic configuration/ same number of electrons (in outer shell)/ both have 47 electrons;

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Ignore protons and neutrons unless incorrect.
Not just electrons determine chemical properties.

1

(b) Ionisation;

1

high energy electrons fired at sample;

Allow electron gun /blasted with electrons.

1

Acceleration;

1

With electric field/accelerating potential/potential difference;

Allow by negative plate.

1

Deflection;

1

With electromagnet/ magnet/ magnetic field;

M2 dependent on M1.
M4 dependent on M3.
M6 dependent on M5.

1

(c) (Silver) metallic (bonding);

Vdw/molecules CE=0.

1

Regular arrangement of same sized particles;

1

+ charge in each ion;

Ignore multiple positive charges.
Candidates do not need to show delocalised electrons.

1

(d) Ionic (bonds);

1

Minimum 4 ions shown in 2D square arrangement placed Correctly;

Do not allow multiple charges on ions.

1

Further 3 ions shown correctly in a cubic lattice;

1

Strong (electrostatic) forces/bonds;

If vdw/molecules/covalent mentioned CE = 0 for M4 and M5.

1

Between + and – ions;

Accept between oppositely charged ions.

1

[20]

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Q13.

(a) Mass of mineral on x-axis;

If axes unlabelled use data to decide if mass of mineral is on the x-axis.

1

Sensible continuous scales;

*Lose this mark if the **plotted points** do not cover at least 9 squares by 7.*
Lose this mark if the graph plot goes off the squared paper.
The graph does not have to start at the origin.

1

Plots points correctly ± one square;

Award this mark if the line is close to your line.

1

Draws a best fit straight line

Award this mark if best fit line is consistent with candidate's plotted points.
Lose this mark if line is kinked or doubled.

1

(b) 1.48 or 1.49 or 1.50 or 1.5 (g);

*Accept these answers **only***
Ignore precision of answer.
Allow range 1.48 – 1.5

1

(c) 0.0124 (mol);

Accept 0.012, 0.0125.
Allow answer without working.

1

(d) (1.49 / 0.0124) = 119.4 – 125.0;

Must divide answer to part (b) by answer to part (c) to score first mark.
Allow consequential answer from part (b).
Allow answer without working.
Ignore precision of answer.

1

(e) Answer to part (e) close to 120.3;

Allow consequential answer from part (d).
Allow correct calculation of x

1

(f) $\underline{x}$ must be a whole number;

1

(g) Good / straight line so results good / reliable;

Allow consequential answers from candidate's graph
Do not allow 'so results are accurate'.

1

Anomaly at 1.34 g;

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Allow anomaly clearly indicated on the graph.

1

(h) Ensure reaction / decomposition goes to completion;

Do not allow 'to make fair test' or 'improve reliability'
Accept to 'remove all carbon dioxide <u>and</u> water'.

1

(i) (i) Percentage errors too high / errors in weighing too high;

Do not allow 'to make fair test' or 'improve reliability'
Do not allow 'errors' on its own.

1

(ii) Incomplete decomposition or words to that effect;

Do not allow 'to make fair test' or 'improve reliability'
Do not allow 'takes too long' or 'wastes chemicals'
Do not allow 'not all of the water removed'.

1

(j) 39.05 / 18 = 2.170 and 60.95 / 84.3 = 0.723;

Allow M_r of $MgCO_3.H_2O$ = 138.3

1

$MgCO_3.3H_2O$;

54 / 138.3 + 39.05%
$MgCO_3.3H_2O$ without working scores 1 mark.

1

(k) Atom economy for Reaction 1 is (40.3 / 84.3) x 100 = 47.8%

Maximum 1 mark if no working.
Ignore precision of answers.

1

Atom economy for Reaction 2 is (40.3 / 58.3) x 100 = 69.1%

1

(l) No gas produced <u>in stomach</u> / won't cause wind;

Do not allow 'gas produced' on its own.

1

[19]

Q14.

(a) (i) (free–)radical substitution

(both words required for the mark)

1

(ii) uv light OR sunlight OR <u>high</u> temperature OR 150 °C to 500 °C

1

(iii) Propagation

(ignore "chain", "first", "second" in front of the word propagation)

1

(iv) Termination

1

$\bullet CH_2CH_3 + Br\bullet \longrightarrow CH_3CH_2Br$

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OR $2\bullet CH_2CH_3 \longrightarrow C_4H_{10}$

(penalise if radical dot is obviously on CH_3, but not otherwise)

(penalise $C_2H_5\bullet$)

(credit $2Br\bullet \longrightarrow Br_2$)

(ignore "chain" in front of the word termination)

1

(b) (i) Fractional distillation OR fractionation

(credit gas–liquid chromatography, GLC)

1

(ii) $CH_3CH_3 + 6Br_2 \longrightarrow C_2Br_6 + 6HBr$

(credit C_2H_6 for ethane)

1

(c) Correct structure for CF_2BrCF_2Br drawn out

(penalise "Fl" for fluorine)

1

(d) (i) 2–bromo–2–chloro–1,1,1–trifluoroethane
OR 1–bromo–1–chloro–2,2,2–trifluoroethane

(insist on all numbers, but do not penalise failure to use alphabet)

(accept "flourine" and "cloro" in this instance)

1

(ii) 197.4 only

(ignore units)

1

(iii) (57/197.4 × 100) = 28.9% OR 28.88%

(credit the correct answer independently in part (d)(iii), even if (d)(ii) is blank or incorrectly calculated, but mark consequential on part (d)(ii), if part (d)(ii) is incorrectly calculated, accepting answers to 3sf or 4sf only)

(penalise 29% if it appears alone, but not if it follows a correct answer)

(do not insist on the % sign being given)

(the percentage sign is not essential here, but penalise the use of units e.g. grams)

1

[11]

Q15.

B

[1]

Q16.

(a) Proton: mass 1, charge + 1 **(1)**
Neutron: mass 1, charge 0 **(1)**
Electron mass 1/1840, charge -1 **(1)**

Allow mass = 0, or negligible, or 1/1800 to 1/2000

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Isotopes have the same number of protons **(1)**

OR atomic number

different number of neutrons **(1)**

Isotopes have the same electronic configuration **(1)**

OR same number of electrons

Chemical properties depend on electrons **(1)**

7

(b) $\frac{\text{average (1) mass of an atom/isotopes}}{\text{mass of 1 atom of } {}^{12}C} \times 12$ **(1)**

OR $\frac{\textit{mass of 1 mol of atoms}}{\textit{mass of 1 atom of } {}^{12}C} \times 12$ *or in words*

Spectrum gives (relative) abundance **(1)**

OR % or amount

And *m/z* **(1)**

Multiply *m/z* by relative abundance for each isotope **(1)**

Allow instead of m/z mass no, A_r or actual value from example

Sum these values **(1)**

Divide by the sum of the relative abundances **(1)**

only award this mark if previous 2 given

Max 2 if e.g. has only 2 isotopes

7

[14]

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Q1.

(a) Most students were able to calculate the M_r of the unknown volatile liquid correctly. Many students, however, did not give a correct definition for relative molecular mass or confused this with the definition for relative atomic mass; a good number did not convert the data to take account of the different units. Pleasingly, 59.4% of students scored at least four marks.

(b) This proved to be demanding for many students with well over half of them failing to score; many felt that that the calculated M_r would have been less than the actual M_r. Only a few students considered the impact that a lower volume of gas (using pV=nRT) would have on the calculation of the measured amount of moles.

Q2.

(a) This was surprisingly poorly answered. Many students were unable to write the electronic configuration for Fe^{2+}.

(b) Part (b) was generally well answered, but a significant number of answers had missing state symbols, despite the direct instruction to include them.

(c) Part (c) was quite well answered.

(d) The symbol including mass number was often incorrect. The calculation of A_r was straight- forward and done well by many students.

Q5.

The overall performance in part (a)(i) was disappointing because many students did not know the subatomic particles in the hydrogen atom. The mark in part (a)(ii) was scored by most students. Many students scored both marks in part (b)(i) but several quoted an equation involving *x* and *y* but could not progress beyond that. The majority of students answered part (b)(ii) correctly and part (c) was also generally well done. In part (d), many students used Br instead of B in their equation and some either wrote the wrong ionisation energy or failed to add state symbols. Many answers to part (e) were superficial; many students simply referred to a different proton / electron ratio or the removal of an electron from a different energy level.

Q6.

The definition in part (a) is still not well known. Average or mean was often omitted as was mass. Part (b) was well done although a few students still chose to divide by 100. In part (c), the charge on the ion was often missed out. The most common wrong answer in part (d) was 74 since students were obviously confusing deflection with detection. The majority who chose 70 carried on to give the correct explanation. Answers to part (e) were poor with many students not referring to electrons at all. Most students scored the mark in part (f).

Q7.

(a) In part (i), most students were able to identify two appropriate atoms in the structure, but the ionic nature of Zineb resulted in many students failing to calculate its M*r* correctly in part (ii).In part (iii) proved to be demanding too, ester being the most

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common error.

(b) The simple calculation in this part proved straightforward for most students.

(c) This part highlighted the difficulties students face when applying theoretical ideas. Many students ignored the specific references to Zineb and ETU and wrote at length about the theory of chromatography. It was not uncommon to see long answers that did not specify the type of chromatography to be used, or make any mention of Zineb or ETU. Students were similarly reluctant to use the information in the questions to predict the outcomes for this particular separation. Such non-specific answers received few marks. A significant number of students chose gas chromatography, and even then could not make any use of the information at hand.

Q8.

Answers to the definition in part (a) were variable as always. The most common errors were to miss out the word average/mean on the top line and 1 atom on the bottom line. The calculation was attempted well although some candidates did not give their answer to 2 decimal places. Part (b) was generally well answered. Part (c) answers were varied. Some candidates thought that natural and synthetic compounds would react differently and the ones who knew the reactions were identical often failed to qualify their answer sufficiently well to gain full maks.

Q9.

(a) In this part, the vast majority of candidates correctly stated the ideal gas equation.

(b) In this part, many candidates wrote a correct equation which included fractional numbers of moles. This version of a multiple of the expected answer is acceptable and should have been rewarded with a mark.

(c) This part was poorly answered. Most candidates simply calculated the ratio of the numbers given in the stem and converted to a percentage. This was not worth a mark. Yield calculations must start with the appropriate M_r values to earn any credit.

Q10.

In part (a) some candidates were still not giving M_r values to one decimal place. Part (b) and (c) saw many correct answers but some candidates got into mathematical difficulties after a promising start – one error was the appearance of units in the dilution factor.

Q11.

A substantial number of candidates were not able to produce an exact definition in part (a). Many marks were lost through the omission of vital words such as “mass” or “atom”, or mixing moles and atoms in their answer.

Part (b) was moderately well done but many candidates identified the element rather than the block it was in. The electron configuration was generally well known with the commonest errors being [Ar] $4s^2$ $4d^2$ and $3d^4$. A significant number of candidates could not calculate the number of neutrons and many gave non-integer answers such as 25.9.

In part (c) many candidates were able to calculate the relative atomic mass correctly but did not then identify the element. Weaker candidates included 93 × 0 = 93 in their calculation or divided by 100. A small number used 91.2 as the atomic number and therefore identified protactinium.

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The great majority of candidates scored the first 2 marks in part (d). However, many did not actually identify the isotope, often merely stating that it would be the lightest that would be deflected the most. A disappointing number misinterpreted the mass spectrum and selected 91 because it had the least abundance. A surprising number wrote that the heaviest ions would be deflected the most.

Part (e) was not well answered. Although many candidates knew that detection of ions involved the production of a current, relatively few mentioned the relationship between the size of current and the abundance of ion. Common incomplete answers included “the more ions that hit the detector, the greater the abundance”. A very small number of candidates thought a current was produced by the ion giving electrons to the detector.

Q12.

Many candidates produced good answers here but it must be stressed that the definition of relative atomic mass must be absolutely correct for the award of both marks. Many candidates left out ‘average’ mass or the factor of 12.

Having to find the RAM of one of the isotopes challenged many of those who were unable to manipulate the equation but candidates regularly scored the first two marks and only lost the third calculation mark due to lack of dexterity with rearranging and algebra. The idea of isotopes having the same electron arrangement was generally well known although lots of answers included references to protons and/or neutrons.

Part (b) was well answered with the most common error being the confusion of electric and magnetic field. The processes were very well known. In part (c) there was confusion over metallic and ionic bonding. In part (d) most candidates had the idea of a 3D lattice but errors arose from multiple charges or negative charges on the Ag or like charges next to each other at some point in the lattice. Most candidates realised that ionic bonding was present, but some then contradicted their answers by mentioning intermolecular forces.

Q13.

In part (a) the candidate was required to draw a graph. This generated the usual problems of plotted points which did not cover half the paper and graphs containing incorrectly plotted points. If the candidate’s graph included the origin, then the candidate’s line had to pass through the origin to score the line of best fit mark.

A surprising number of candidates used a non-linear scale for the *x*-axis, and some lost a mark for drawing a doubled line of best fit.

To score the mark in part (d) the candidate had to provide a definite link between the answer to part (c) and the M_r of $MgCO_3.2H_2O$. A large number of candidates simply stated the M_r value and left it to the marker to draw the appropriate conclusion, thereby losing the mark.

Candidates’ answers to part (e) usually missed the point. Very few realised the significance of the number of molecules of water of crystallisation being a whole number.

In part (f) many candidates lost a mark because they did not comment on the quality of their line of best fit. Answers such as ‘the graph shows a positive correlation’ need to be expanded to be worth a mark. Most candidates were able to identify the anomalous result.

In part (g) many candidates lost a mark by referring to a loss of water from the sample, rather than appreciating that the decomposition went further.

A number of candidates still struggled to express themselves in part (h)(i). Many stated

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that ‘small amounts were hard to weigh’ or ‘couldn’t be weighed’, rather than focussing on the significance of the percentage errors in obtaining the mass of small amounts. In part (h)(ii) ‘the experiment takes too long’ or ‘the experiment is too expensive’ were popular choices which were not worth a mark.

Candidates found several valid approaches to answering part (i) and many scored full marks.

If candidates understood the meaning of atom economy, they tended to score full marks on this part. It was surprising however to see how many could not calculate two simple M_r values.

part (l) proved to be the most difficult question of all. There was a wide range of ingenious answers but hardly any candidates made reference to the pressure from a gas produced in the stomach causing discomfort.

Q14.

This was a high scoring question with many scores of eight or more marks. In part (a) candidates were penalised if the radical dot was shown to be on the CH_3 group, rather than as given in the question. In part (b) many equations gave hydrogen as the product rather than hydrogen bromide, suggesting that candidates had difficulty applying the information to a novel situation. Parts (c) and (d) (i) were frequently correct, although the failure to number all of the substituents on the two carbon atoms of halothane was penalised. In part (d) (ii), many candidates had problems using the data to calculate a correct relative molecular mass and the answer of 197.4 was the only response accepted. In part (d) (iii), consequential credit was awarded, with correct answers to either 3 or 4 significant figures being accepted.

Q16.

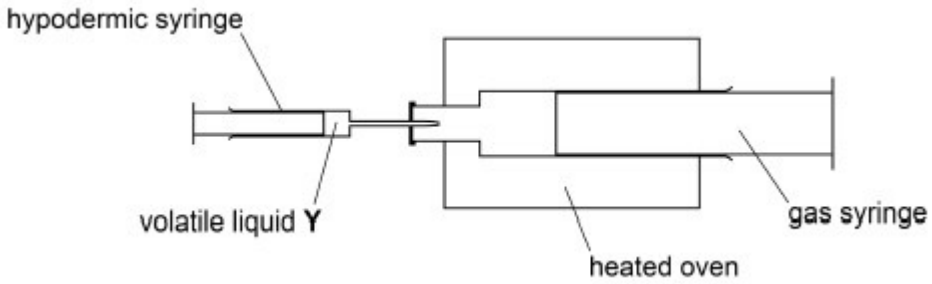
Most candidates scored high marks for part (a) though the final part of the question, requiring an explanation why isotopes have identical chemical properties, was more demanding. Part (b) was also answered well though a considerable number of candidates wasted time by giving detailed but irrelevant information about the operation of the various parts of a mass spectrometer. Candidates were often imprecise about the information that can be obtained from a mass spectrum. Confusion between mass/charge and atomic mass or relative atomic mass was common but did not incur a heavy penalty.

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Q1.

A student determined the relative molecular mass, M_r, of an unknown volatile liquid Y in an experiment as shown in the diagram.
The student used a hypodermic syringe to inject a sample of liquid Y into a gas syringe in an oven.
At the temperature of the oven, liquid Y vaporised.

The student's results are shown in the table.



Mass of hypodermic syringe and liquid Y before injection	10.91 g
Mass of hypodermic syringe and liquid Y after injection	10.70 g
Oven temperature	98.1 °C
Atmospheric pressure	102 kPa
Increase in volume in gas syringe after injection of Y	85.0 cm^3

(a) Define the term relative molecular mass (M_r).

Use the experimental results in the table to determine the relative molecular mass of Y.
The gas constant R = 8.31 J K^{-1} mol^{-1}

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_____

_____

_____

_____

(5)

(b) Some of the liquid injected did not evaporate because it dripped into the gas syringe nozzle outside the oven.

Explain how this would affect the value of the M_r of Y calculated from the experimental results.

_____

_____

_____

_____

_____

(2)

(Total 7 marks)

Q2.

This question is about sodium and some of its compounds.

(a) Use your knowledge of structure and bonding to explain why sodium bromide has a melting point that is higher than that of sodium, and higher than that of sodium iodide.

(6)

(b) When 250 mg of sodium were added to 500 cm^3 of water at 25 °C a gas was produced.

Give an equation for the reaction that occurs.
Calculate the volume, in cm^3, of the gas formed at 101 kPa

The gas constant, R = 8.31 J K^{-1} mol^{-1}

Equation _____

Volume _____ cm^3

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(6)

(c) Calculate the concentration, in mol dm^{-3}, of sodium ions in the solution produced in the reaction in **part (b)**.

Concentration _____ mol dm^{-3}

(1)

(d) Sodium reacts with ammonia to form the compound $NaNH_2$ that contains the NH_2^- ion.

Draw the shape of the NH_2^- ion.
Include any lone pairs of electrons that influence the shape.

Predict the bond angle.
Justify your prediction.

Shape

Bond angle _____

Justification _____

_____

(4)

(Total 17 marks)

Q3.

An experiment was carried out to determine the relative molecular mass (M_r) of a volatile hydrocarbon **X** that is a liquid at room temperature.

A known mass of **X** was vaporised at a known temperature and pressure and the volume of the gas produced was measured in a gas syringe.

Data from this experiment are shown in the table.

Mass of **X**	194 mg
Temperature	373 K
Pressure	102 kPa
Volume	72 cm^3

(a) Calculate the relative molecular mass of **X**.

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Show your working.

Give your answer to the appropriate number of significant figures.

The gas constant, R = 8.31 J K^{-1} mol^{-1}

Relative molecular mass _____

(5)

(b) Analysis of a different hydrocarbon **Y** shows that it contains 83.7% by mass of carbon.

Calculate the empirical formula of **Y**.

Use this empirical formula and the relative molecular mass of **Y** (M_r = 86.0) to calculate the molecular formula of **Y**.

Empirical formula _____

Molecular formula _____

(4)

(Total 9 marks)

Q4.

A 385 cm^3 sample of carbon dioxide at 100 kPa and 25 °C was mixed with 2.89 × 10^{-2} mol of argon. The gas constant, R = 8.31 J K^{-1} mol^{-1}
What is the mole fraction of carbon dioxide in the mixture?

A 0.35 ○

B 0.46 ○

C 0.54 ○

D 0.65 ○

(Total 1 mark)

Q5.

Two sealed flasks with the same volume are left side by side.

Flask **A** contains 4.0 × 10^{-3} mol of methane.

Flask **B** contains 340 mg of a different gas.

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Both gases are at the same temperature and pressure.

Which gas could be in Flask **B**?

A CH_2Cl_2 ⬭

B HBr ⬭

C Kr ⬭

D PF_3 ⬭

(Total 1 mark)

Q6.

A student is provided with 5.00 cm^3 of 1.00 mol dm^{-3} ammonia solution. The student was asked to prepare an ammonia solution with a concentration of 0.050 mol dm^{-3}
What volume of water should the student add?

A 45.0 cm^3 ⬭

B 95.0 cm^3 ⬭

C 100 cm^3 ⬭

D 995 cm^3 ⬭

(Total 1 mark)

Q7.

130 cm^3 of oxygen and 40 cm^3 of nitrogen, each at 298 K and 100 kPa, were placed into an evacuated flask of volume 0.50 dm^3.

What is the pressure of the gas mixture in the flask at 298 K?

A 294 kPa ⬭

B 68.0 kPa ⬭

C 34.0 kPa ⬭

D 13.7 kPa ⬭

(Total 1 mark)

Q8.

This question is about a toxic chloroalkane, **X**, that has a boiling point of 40 °C.

A student carried out an experiment to determine the M_r of **X** by injecting a sample of **X** from a hypodermic syringe into a gas syringe in an oven at 97 °C and 100 kPa. The student's results are set out in **Table 1** and **Table 2**.

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Table 1

Mass of hypodermic syringe filled with **X** before injection / g	10.340
Mass of hypodermic syringe with left over **X** after injection / g	10.070
Mass of **X** injected / g	

Table 2

Volume reading on gas syringe before injection of **X** / cm^3	0.0
Volume of **X** in gas syringe after injection of **X** / cm^3	105.0
Volume of **X** / cm^3	

(a) Complete **Table 1** and **Table 2** by calculating the mass and volume of **X**.

(1)

(b) **X** is known to be one of the following chloroalkanes: CCl_4 $CHCl_3$ CH_2Cl_2 or CH_3Cl

Justify this statement by calculating a value for the M_r of **X** and use your answer to suggest the most likely identity of **X** from this list.

Give your answer for the M_r of **X** to an appropriate precision.
(The gas constant R = 8.31 J K^{-1} mol^{-1})

M_r of **X**

M_r of **X** = _____

Identity of **X**
(If you have been unable to calculate a value for M_r, you may assume that the M_r value is 52. This is **not** the correct value).

Identity of **X** = _____

(5)

(c) Suggest a reason, other than apparatus inaccuracy, why the M_r value determined from the experimental results differs from the actual M_r. Explain your answer.

_____

_____

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_____

_____

_____

(2)

(d) Suggest, with a reason, an appropriate safety precaution that the student should take when using the toxic chloroalkane, **X**, in the experiment.

Safety precaution _____

_____

Reason _____

_____

(2)

(Total 10 marks)

Q9.

Methanol can be manufactured by the reaction of carbon monoxide with hydrogen

$$CO(g) + 2H_2(g) \rightleftharpoons CH_3OH(g)$$

In an experiment, 0.73 mol of carbon monoxide was heated with 1.25 mol of hydrogen. An equilibrium mixture was formed that contained 0.43 mol of methanol.

(a) Calculate the amount, in moles, of each reactant present at equilibrium.

Amount of carbon monoxide = ____ mol

Amount of hydrogen = _____ mol

(2)

(b) Write an expression for the equilibrium constant, K_c, for this reaction.

_____

(1)

(c) In another experiment at a different temperature, the equilibrium mixture contained 0.452 mol of carbon monoxide, 0.106 mol of hydrogen and 0.273 mol of methanol in a flask of volume 9.40×10^3 cm^3.

Calculate the value of the equilibrium constant, K_c, at this temperature and state the units.

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K_c = _____ Units = _____

(4)

(d) The total pressure of this equilibrium mixture in the flask was 482.9 kPa.

Calculate the temperature, in °C, of the equilibrium mixture.
(The ideal gas constant R = 8.31 J mol^{-1} K^{-1})

Temperature = _____ °C

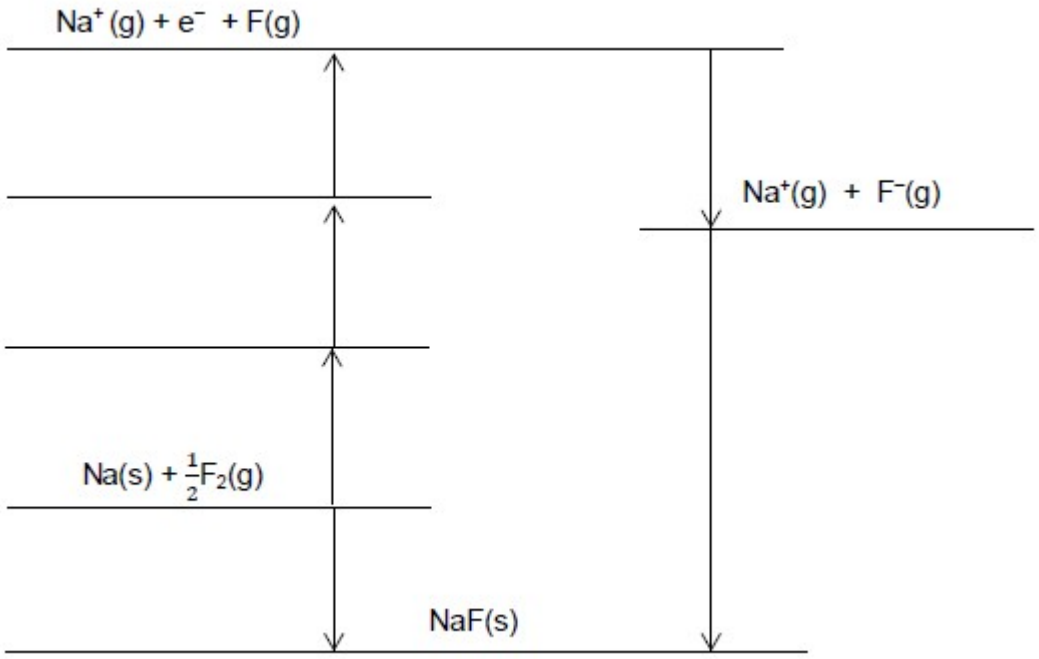
(4)

(Total 11 marks)

Q10.

This question is about sodium fluoride.

(a) Complete the Born–Haber cycle for sodium fluoride by adding the missing species on the lines.



(2)

(b) Use the data in the table and your completed Born–Haber cycle from part **(a)** to calculate the enthalpy of lattice formation of sodium fluoride.

	$\Delta H^\ominus$ / kJ mol^{-1}
Na(s) ⟶ Na(g)	+109

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$Na(g) \longrightarrow Na^+(g) + e^-$	+494
$F_2(g) \longrightarrow 2F(g)$	+158
$F(g) + e^- \longrightarrow F^-(g)$	−348
$Na(s) + \frac{1}{2}F_2(g) \longrightarrow NaF(s)$	−569

Enthalpy of lattice formation _____ kJ mol^{-1}

(2)

(c) Suggest how the enthalpy of lattice formation of NaCl compares with that of NaF

Justify your answer.

How enthalpies of formation compare _____

_____

Justification _____

_____

_____

_____

_____

(3)

(d) Calculate the volume, in cm^3, of fluorine gas at 298 K and 100 kPa required to produce 1.00 g of sodium fluoride by reaction with an excess of sodium.

The gas constant R = 8.31 J^{-1} mol^{-1}

Volume _____ cm^3

(4)

(Total 11 marks)

Q11.

A sample of pure $Mg(NO_3)_2$ was decomposed by heating as shown in the equation below.

$$2Mg(NO_3)_2(s) \longrightarrow 2MgO(s) + 4NO_2(g) + O_2(g)$$

(a) A 3.74×10^{-2} g sample of $Mg(NO_3)_2$ was completely decomposed by heating.

Calculate the total volume, in cm^3, of gas produced at 60.0 °C and 100 kPa.
Give your answer to the appropriate number of significant figures.
The gas constant R = 8.31 $J\ K^{-1}\ mol^{-1}$.

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Total volume of gas = _____ cm^3

(5)

(b) The mass of MgO obtained in this experiment is slightly less than that expected from the mass of $Mg(NO_3)_2$ used.
Suggest **one** practical reason for this.

_____

_____

_____

(1)

(Total 6 marks)

Q12.

Which of these samples of gas contains the largest number of molecules?
The gas constant $R = 8.31\ J\ K^{-1}\ mol^{-1}$.

A $5.0 \times 10^{-4}\ m^3$ at 1.0×10^6 Pa and 300 K ⬭

B $4.0 \times 10^{-3}\ m^3$ at 2.0×10^5 Pa and 400 K ⬭

C $3.0 \times 10^1\ dm^3$ at 3.0×10^4 Pa and 500 K ⬭

D $2.0 \times 10^2\ dm^3$ at 4.0×10^3 Pa and 600 K ⬭

(Total 1 mark)

Q13.

A sample of 2.18 g of oxygen gas has a volume of 1870 cm^3 at a pressure of 101 kPa.

What is the temperature of the gas?
The gas constant is $R = 8.31\ J\ K^{-1}\ mol^{-1}$.

A 167 K ⬭

B 334 K ⬭

C 668 K ⬭

D 334 000 K ⬭

(Total 1 mark)

Q14.

In an experiment to identify a Group 2 metal (X), 0.102 g of X reacts with an excess of

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aqueous hydrochloric acid according to the following equation.

$$X + 2HCl \longrightarrow XCl_2 + H_2$$

The volume of hydrogen gas given off is 65 cm^3 at 99 kPa pressure and 303 K.
The gas constant is R = 8.31 J K^{-1} mol^{-1}.

Which is X?

A Barium ⬭

B Calcium ⬭

C Magnesium ⬭

D Strontium ⬭

(Total 1 mark)

Q15.

Two reactions occurred when the impure quicklime was added to the acid. Calcium oxide reacted according to this equation

$$CaO(s) + 2HCl(aq) \longrightarrow CaCl_2(aq) + H_2O(l)$$

Some carbon dioxide was evolved by the reaction of any remaining calcium carbonate that had not decomposed in the kiln.

$$CaCO_3(s) + 2HCl(aq) \longrightarrow CaCl_2(aq) + H_2O(l) + CO_2(g)$$

The carbon dioxide was collected and its volume was found to be 18.3 dm^3 at a temperature of 25 ºC and pressure of 100 kPa. The gas constant R = 8.31 J K^{-1} mol^{-1}

(a) Calculate the amount, in moles, of carbon dioxide that was given off when the impure quicklime reacted with the hydrochloric acid. Show your working.

_____

_____

_____

_____

_____

(2)

(b) Calculate the amount, in moles, of hydrochloric acid used up by the reaction with calcium carbonate. Show your working.

_____

_____

(1)

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(c) Use your Periodic Table to calculate the relative formula mass of $CaCO_3$
Give your answer to one decimal place.

_____

_____

(1)

(d) Use your answers to part **(a)** and part **(c)** to calculate the mass of calcium carbonate in the sample of quicklime.

_____

_____

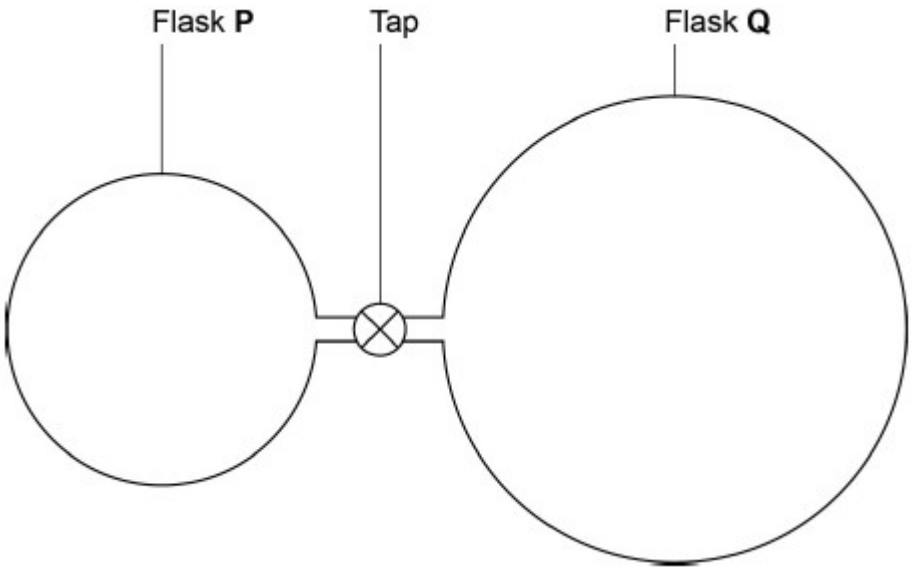
(1)

(Total 5 marks)

Q16.

The diagram represents two glass flasks, **P** and **Q**, connected via a tap.

Flask **Q** (volume = 1.00×10^3 cm^3) is filled with ammonia (NH_3) at 102 kPa and 300 K. The tap is closed and there is a vacuum in flask **P**.
(Gas constant R = 8.31 J K^{-1} mol^{-1})



(a) Calculate the mass of ammonia in flask **Q**.
Give your answer to the appropriate number of significant figures.

_____

_____

_____

_____

_____

(3)

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(b) When the tap is opened, ammonia passes into flask **P**. The temperature decreases by 5 °C. The final pressure in both flasks is 75.0 kPa.
Calculate the volume, in cm^3, of flask **P**.

_____

_____

_____

_____

_____

(3)

(Total 6 marks)

Q17.

30 cm^3 of xenon are mixed with 20 cm^3 of fluorine. The gases react according to the following equation. Assume that the temperature and pressure remain constant.

$$Xe(g) + F_2(g) \rightarrow XeF_2(g)$$

What is the final volume of gas after the reaction is complete?

A 50 cm^3 ⬭

B 40 cm^3 ⬭

C 30 cm^3 ⬭

D 20 cm^3 ⬭

(Total 1 mark)

Q18.

2 mol of ideal gas **X** are stored in a flask of fixed volume.

Which of the following changes would lead to the greatest increase in pressure inside the flask?

A Increasing the temperature from 20 °C to 200 °C ⬭

B Adding another 1 mol of gas **X** into the flask at fixed temperature ⬭

C Adding 0.5 mol of argon gas and increasing the temperature from 20 °C to 150 °C ⬭

D Removing 0.5 mol of gas **X** and increasing the temperature from 20 °C to 300 °C ⬭

(Total 1 mark)

Q19.

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Phosphoric(V) acid (H_3PO_4) is an important chemical. It can be made by two methods. The first method is a two-step process.

(a) In the first step of the first method, phosphorus is burned in air at 500 ºC to produce gaseous phosphorus(V) oxide.

$$P_4(s) + 5O_2(g) \longrightarrow P_4O_{10}(g)$$

220 g of phosphorus were reacted with an excess of air.

Calculate the volume, in m^3, of gaseous phosphorus(V) oxide produced at a pressure of 101 kPa and a temperature of 500 ºC.
The gas constant R = 8.31 J K^{-1} mol^{-1}
Give your answer to 3 significant figures.

(4)

(b) In the second step of the first method, phosphorus(V) oxide reacts with water to form phosphoric(V) acid.

$$P_4O_{10}(s) + 6H_2O(l) \longrightarrow 4H_3PO_4(aq)$$

Calculate the mass of phosphorus(V) oxide required to produce 3.00 m^3 of 5.00 mol dm^{-3} phosphoric(V) acid solution.

(3)

(c) In the second method to produce phosphoric(V) acid, 3.50 kg of $Ca_3(PO_4)_2$ are added to an excess of aqueous sulfuric acid.

$$Ca_3(PO_4)_2(s) + 3H_2SO_4(aq) \longrightarrow 2H_3PO_4(aq) + 3CaSO_4(s)$$

1.09 kg of phosphoric(V) acid are produced.

Calculate the percentage yield of phosphoric(V) acid.

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(4)

(d) Explain whether the first method or the second method of production of phosphoric acid has the higher atom economy.
You are not required to do a calculation.

(1)

(Total 12 marks)

Q20.

Some airbags in cars contain sodium azide (NaN_3).

(a) Sodium azide is made by reacting dinitrogen monoxide gas with sodium amide ($NaNH_2$) as shown by the equation.

$$2NaNH_2 + N_2O \longrightarrow NaN_3 + NaOH + NH_3$$

Calculate the mass of sodium amide needed to obtain 550 g of sodium azide, assuming there is a 95.0% yield of sodium azide.
Give your answer to 3 significant figures.

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(5)

(b) If a car is involved in a serious collision, the sodium azide decomposes to form sodium and nitrogen as shown in the equation.

$$2NaN_3(s) \longrightarrow 2Na(s) + 3N_2(g)$$

The nitrogen produced then inflates the airbag to a volume of 7.50×10^{-2} m^3 at a pressure of 150 kPa and temperature of 35 °C.

Calculate the minimum mass of sodium azide that must decompose.
(The gas constant R = 8.31 J K^{-1} mol^{-1})

(6)

(c) Sodium azide is toxic. It can be destroyed by reaction with an acidified solution of nitrous acid (HNO_2) as shown in the equation.

$$2NaN_3 + 2HNO_2 + 2HCl \longrightarrow 3N_2 + 2NO + 2NaCl + 2H_2O$$

(i) A 500 cm^3 volume of the nitrous acid solution was used to destroy completely 150 g of the sodium azide.

Calculate the concentration, in mol dm^{-3}, of the nitrous acid used.

(3)

(ii) Nitrous acid decomposes on heating.

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Balance the following equation for this reaction.

$$.....HNO_2 \longrightarrow .....HNO_3 + ...NO + ...H_2O$$

(1)

(d) Sodium azide has a high melting point.

Predict the type of bonding in a crystal of sodium azide.
Suggest why its melting point is high.

Type of bonding _____

Reason for high melting point _____

_____

_____

_____

_____

(3)

(e) The azide ion has the formula N_3^-

(i) The azide ion can be represented as $N \equiv N - N^-$

One of these bonds is a co−ordinate bond.

On the following diagram, draw an arrowhead on one of the bonds to represent the direction of donation of the lone pair in the co−ordinate bond.

$$N \equiv N - N^-$$

(1)

(ii) Give the formula of a molecule that has the same number of electrons as the azide ion.

_____

(1)

(iii) Which is the correct formula of magnesium azide?

Tick (✓) **one** box.

Mg_3N ☐

MgN ☐

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MgN_6 ☐

Mg_3N_2 ☐

(1)

(Total 21 marks)

Q21.

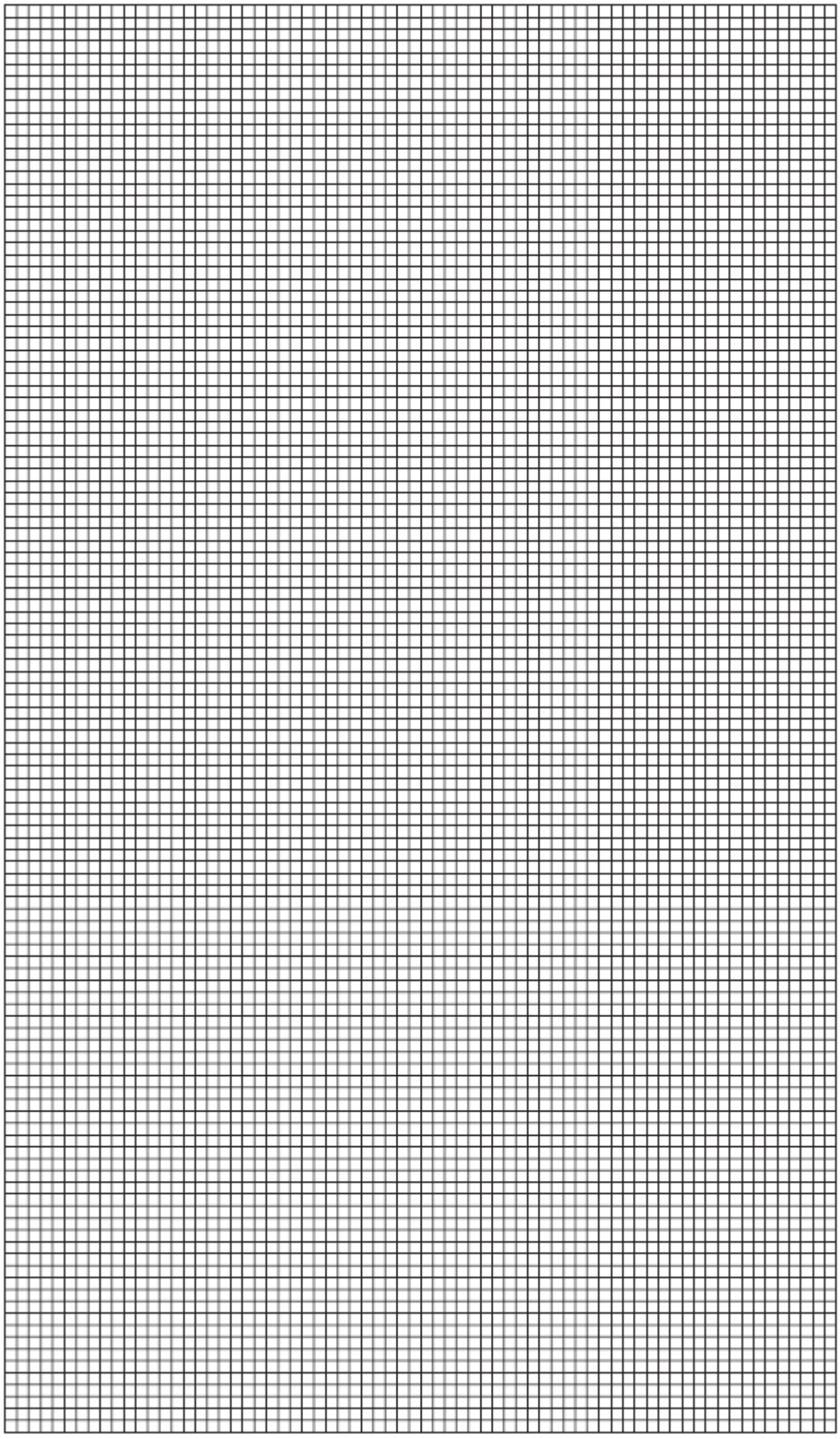
Calamine lotion can contain a mixture of zinc carbonate and zinc oxide in suspension in water. A manufacturer of calamine lotion claims that a sample contains 15.00 g of zinc carbonate and 5.00 g of zinc oxide made up to 100 cm^3 with distilled water.

(a) A chemist wanted to check the manufacturer's claim. The chemist took a 20.0 cm^3 sample of the calamine lotion and added it to an excess of sulfuric acid.
The volume of carbon dioxide evolved was measured over time. The chemist's results are shown in the table.

Time / s	0	15	30	45	60	75	90	105	120	135
Volume / cm^3	0	135	270	380	470	530	560	570	570	570

(i) Plot a graph of the results in the table on the grid. The volume should be on the *y*-axis. Draw a best-fit curve through **all** the points.

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(3)

(ii) Estimate the time taken for the reaction to be completed.

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_____

(1)

(b) (i) The volume of carbon dioxide in part (a) was measured at 293 K and at a pressure of 100 kPa.

Use information from your graph to calculate the maximum amount, in moles, of carbon dioxide evolved from the zinc carbonate in this 20.0 cm^3 sample.

The gas constant, R = 8.31 $J\ K^{-1}\ mol^{-1}$

Show your working.

_____

_____

_____

_____

_____

_____

(3)

(ii) Use your answer to part (i) to calculate the mass of zinc carbonate in the 20.0 cm^3 sample of calamine lotion.

(If you were unable to complete part (i), you may assume that the amount of carbon dioxide evolved was 0.0225 mol. This is **not** the correct answer.)

_____

_____

_____

_____

_____

(2)

(iii) Calculate the difference between your answer to part (ii) and the manufacturer's claim that there are 15.00 g of zinc carbonate in 100 cm^3 of the calamine lotion.

Express this difference as a percentage of the manufacturer's claim.

(If you were unable to complete part (ii), you may assume that the mass of zinc carbonate in the 20 cm^3 sample of calamine lotion was 2.87 g. This is **not** the correct answer.)

Difference _____

Percentage _____

_____

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(2)

(c) Draw a diagram of a suitable apparatus needed to perform the experiment outlined in part (a). Include in your diagram a method for collecting and measuring the carbon dioxide. The apparatus should be airtight.

(2)

(Total 13 marks)

Q22.

When heated, iron(III) nitrate (M_r = 241.8) is converted into iron(III) oxide, nitrogen dioxide and oxygen.

$$4Fe(NO_3)_3(s) \longrightarrow 2Fe_2O_3(s) + 12NO_2(g) + 3O_2(g)$$

A 2.16 g sample of iron(III) nitrate was completely converted into the products shown.

(a) (i) Calculate the amount, in moles, of iron(III) nitrate in the 2.16 g sample. Give your answer to 3 significant figures.

_____

_____

(1)

(ii) Calculate the amount, in moles, of oxygen gas produced in this reaction.

_____

_____

(1)

(iii) Calculate the volume, in m^3, of **nitrogen dioxide** gas at 293 °C and 100 kPa produced from 2.16 g of iron(III) nitrate.
The gas constant is R = 8.31 JK^{-1} mol^{-1}.

(If you have been unable to obtain an answer to part (i), you may assume the number of moles of iron(III) nitrate is 0.00642. This is **not** the correct answer.)

_____

_____

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_____

(4)

(b) Suggest a name for this type of reaction that iron(III) nitrate undergoes.

_____

(1)

(c) Suggest why the iron(III) oxide obtained is pure.
Assume a complete reaction.

_____

_____

(1)

(Total 8 marks)

Q23.

Ammonia is used to make nitric acid (HNO_3) by the Ostwald Process.
Three reactions occur in this process.

Reaction **1** $4NH_3(g) + 5O_2(g) \longrightarrow 4NO(g) + 6H_2O(g)$

Reaction **2** $2NO(g) + O_2(g) \longrightarrow 2NO_2(g)$

Reaction **3** $3NO_2(g) + H_2O(l) \longrightarrow 2HNO_3(aq) + NO(g)$

(a) In one production run, the gases formed in Reaction **1** occupied a total volume of 4.31 m^3 at 25 °C and 100 kPa.

Calculate the amount, in moles, of NO produced.
Give your answer to 3 significant figures.
(The gas constant R = 8.31 J K^{-1} mol^{-1})

_____

_____

_____

_____

_____

_____

(4)

(b) In another production run, 3.00 kg of ammonia gas were used in Reaction **1** and all of the NO gas produced was used to make NO_2 gas in Reaction **2**.

(i) Calculate the amount, in moles, of ammonia in 3.00 kg.

_____

_____

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_____

_____

(2)

(ii) Calculate the mass of NO_2 formed from 3.00 kg of ammonia in Reaction **2** assuming an 80.0% yield.
Give your answer in kilograms.
(If you have been unable to calculate an answer for part (b)(i), you may assume a value of 163 mol. This is **not** the correct answer.)

_____

_____

_____

_____

_____

_____

(3)

(c) Consider Reaction **3** in this process.

$$3NO_2(g) + H_2O(l) \longrightarrow 2HNO_3(aq) + NO(g)$$

Calculate the concentration of nitric acid produced when 0.543 mol of NO_2 is reacted with water and the solution is made up to 250 cm^3.

_____

_____

_____

_____

_____

(2)

(d) Suggest why a leak of NO_2 gas from the Ostwald Process will cause atmospheric pollution.

_____

_____

(1)

(e) Give **one** reason why excess air is used in the Ostwald Process.

_____

_____

(1)

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(f) Ammonia reacts with nitric acid as shown in this equation.

$$NH_3 + HNO_3 \longrightarrow NH_4NO_3$$

Deduce the type of reaction occurring.

_____

(1)

(Total 14 marks)

Q24.

(a) Boron trichloride (BCl_3) can be prepared as shown by the following equation.

$$B_2O_3(s) + 3C(s) + 3Cl_2(g) \longrightarrow 2BCl_3(g) + 3CO(g)$$

A sample of boron oxide (B_2O_3) was reacted completely with carbon and chlorine. The two gases produced occupied a total volume of 5000 cm^3 at a pressure of 100 kPa and a temperature of 298 K.

Calculate the mass of boron oxide that reacted.
Give your answer to 3 significant figures.

(The gas constant R = 8.31 J K^{-1} mol^{-1})

_____

_____

_____

_____

_____

_____

_____

_____

_____

(5)

(b) Boron trichloride can also be prepared from its elements.

Write an equation for this reaction.
Explain why boron trichloride has a trigonal planar shape with equal bond angles.

_____

_____

_____

_____

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(3)

(c) (i) Boron trichloride is easily hydrolysed to form two different acids as shown in the following equation.

$$BCl_3(g) + 3H_2O(l) \longrightarrow H_3BO_3(aq) + 3HCl(aq)$$

Calculate the concentration, in mol dm^{-3}, of hydrochloric acid produced when 43.2 g of boron trichloride are added to water to form 500 cm^3 of solution.
Give your answer to 3 significant figures.

(4)

(ii) Boric acid (H_3BO_3) can react with sodium hydroxide to form sodium borate and water.
Write an equation for this reaction.

(1)

(d) Boron trichloride can be reduced by using hydrogen to form pure boron.

$$BCl_3(g) + 1\tfrac{1}{2}\,H_2(g) \longrightarrow B(s) + 3HCl(g)$$

Calculate the percentage atom economy for the formation of boron in this reaction.

Apart from changing the reaction conditions, suggest **one** way a company producing pure boron could increase its profits from this reaction.

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(3)

(e) A different compound of boron and chlorine has a relative molecular mass of 163.6 and contains 13.2% of boron by mass.

Calculate the molecular formula of this compound.
Show your working.

(4)

(Total 20 marks)

Q25.

The metal lead reacts with warm dilute nitric acid to produce lead(II) nitrate, nitrogen monoxide and water according to the following equation.

$$3Pb(s) + 8HNO_3(aq) \longrightarrow 3Pb(NO_3)_2(aq) + 2NO(g) + 4H_2O(l)$$

(a) In an experiment, an 8.14 g sample of lead reacted completely with a 2.00 mol dm^{-3} solution of nitric acid.

Calculate the volume, in dm^3, of nitric acid required for complete reaction.
Give your answer to 3 significant figures

(3)

(b) In a second experiment, the nitrogen monoxide gas produced in the reaction occupied 638 cm^3 at 101 kPa and 298 K.

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Calculate the amount, in moles, of NO gas produced.
(The gas constant R = 8.31 J K^{-1} mol^{-1})

_____

_____

_____

_____

_____

(3)

(c) When lead(II) nitrate is heated it decomposes to form lead(II) oxide, nitrogen dioxide and oxygen.

(i) Balance the following equation that shows this thermal decomposition.

.....$Pb(NO_3)_2(s)$ ⟶ ..... $PbO(s)$ + ...$NO_2(g)$ + ...$O_2(g)$

(1)

(ii) Suggest **one** reason why the yield of nitrogen dioxide formed during this reaction is often less than expected.

_____

_____

(1)

(iii) Suggest **one** reason why it is difficult to obtain a pure sample of nitrogen dioxide from this reaction.

_____

_____

(1)

(Total 9 marks)

Q26.

Norgessaltpeter was the first nitrogen fertiliser to be manufactured in Norway. It has the formula $Ca(NO_3)_2$

(a) Norgessaltpeter can be made by the reaction of calcium carbonate with dilute nitric acid as shown by the following equation.

$$CaCO_3(s) + 2HNO_3(aq) \longrightarrow Ca(NO_3)_2(aq) + CO_2(g) + H_2O(l)$$

In an experiment, an excess of powdered calcium carbonate was added to 36.2 cm^3 of 0.586 mol dm^{-3} nitric acid.

(i) Calculate the amount, in moles, of HNO_3 in 36.2 cm^3 of 0.586 mol dm^{-3} nitric acid. Give your answer to 3 significant figures.

_____

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_____

(1)

(ii) Calculate the amount, in moles, of $CaCO_3$ that reacted with the nitric acid. Give your answer to 3 significant figures.

_____

_____

(1)

(iii) Calculate the minimum mass of powdered $CaCO_3$ that should be added to react with all of the nitric acid.

Give your answer to 3 significant figures.

_____

_____

_____

(2)

(iv) State the type of reaction that occurs when calcium carbonate reacts with nitric acid.

_____

(1)

(b) Norgessaltpeter decomposes on heating as shown by the following equation.

$$2Ca(NO_3)_2(s) \longrightarrow 2CaO(s) + 4NO_2(g) + O_2(g)$$

A sample of Norgessaltpeter was decomposed completely.

The gases produced occupied a volume of $3.50 \times 10^{-3}\ m^3$ at a pressure of 100 kPa and a temperature of 31 °C.
(The gas constant $R = 8.31\ J\ K^{-1}\ mol^{-1}$)

(i) Calculate the total amount, in moles, of gases produced.

_____

_____

_____

_____

(3)

(ii) Hence calculate the amount, in moles, of oxygen produced.

_____

_____

(1)

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(c) Hydrated calcium nitrate can be represented by the formula $Ca(NO_3)_2.xH_2O$ where x is an integer.

A 6.04 g sample of $Ca(NO_3)_2.xH_2O$ contains 1.84 g of water of crystallisation.

Use this information to calculate a value for x.
Show your working.

_____

_____

_____

_____

_____

_____

(3)

(Total 12 marks)

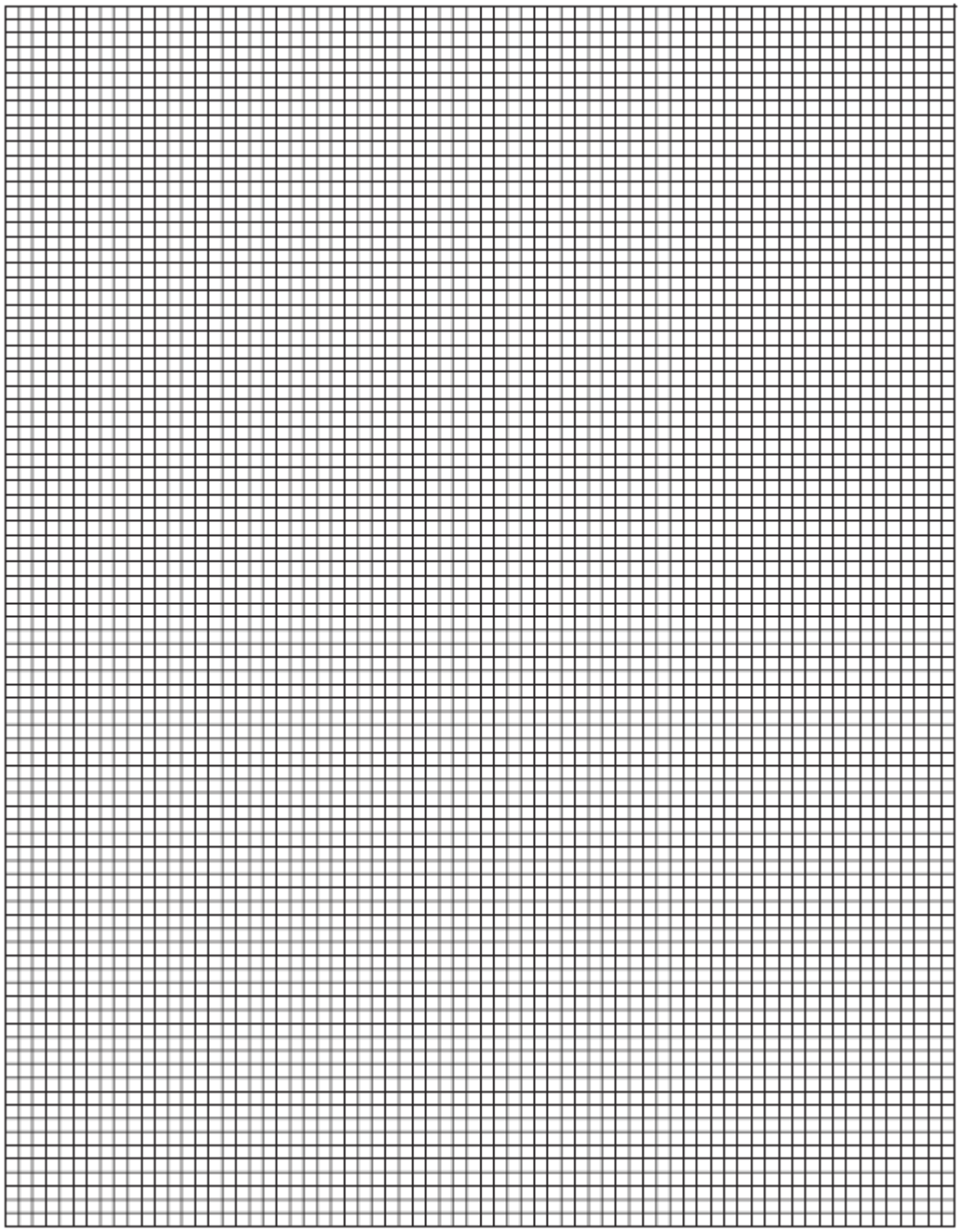
Q27.

(a) A student investigated the acid content of a different crater-lake solution. The student used a 50.0 cm^3 burette to measure out different volumes of this crater-lake solution. Each volume of crater-lake solution was titrated with a 0.100 mol dm^{-3} sodium hydroxide solution. Each titration was repeated. The results are shown below.

Volume of crater-lake solution / cm^3		10.0	20.0	30.0	40.0	50.0
Volume of sodium hydroxide solution / cm^3	Experiment 1	5.85	17.00	20.00	26.50	32.45
	Experiment 2	6.15	13.00	19.90	26.50	32.55
Average titre / cm^3		6.00	15.00	19.95	26.50	32.50

(i) On the graph paper below, plot a graph of average titre (y-axis) against volume of crater-lake solution. Both axes must start at zero.

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(3)

(ii) Draw a line of best fit on the graph.

(1)

(iii) Use the graph to determine the titre that the student would have obtained using a 25.0 cm^3 sample of crater-lake solution.

_____

(1)

(iv) Excluding any anomalous points, which average titre value would you expect to be the least accurate value? Give **one** reason for your choice.

Least accurate average titre _____

Reason _____

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_____

(2)

(b) Another 100 cm^3 sample of crater-lake solution was reacted with an excess of powdered limestone. The gas produced was collected in a gas syringe. The equation for the reaction between the sulfuric(IV) acid in the crater-lake solution and the calcium carbonate in the powdered limestone is shown below.

$$H_2SO_3 + CaCO_3 \longrightarrow CaSO_3 + H_2O + CO_2$$

The volume of gas collected from the reaction of the sulfuric(IV) acid in 100 cm^3 of crater-lake solution with an excess of powdered limestone was 81.0 cm^3 at 298 K and 1.00×10^5 Pa.

(i) State the ideal gas equation.

_____

(1)

(ii) Use the ideal gas equation to calculate the amount, in moles, of carbon dioxide formed.
Show your working.
(The gas constant R = 8.31 J K^{-1} mol^{-1})

_____

_____

_____

_____

(3)

(iii) Use the equation for the reaction and your answer from part (b)(ii) to calculate the minimum mass of calcium carbonate needed to neutralise the sulfuric(IV) acid in 1.00 dm^3 of crater-lake solution.
Show your working.

(If you could not complete the calculation in part (b)(ii) assume that the amount of carbon dioxide is 1.25×10^{-2} mol. This is **not** the correct value.)

_____

_____

_____

_____

(3)

(iv) The percentage by mass of calcium carbonate in the powdered limestone was 95.0%.
Calculate the minimum mass of this powdered limestone needed to neutralise the sulfuric(IV) acid in 1.00 dm^3 of this crater-lake solution.

_____

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_____

(2)

(v) Give **one** reason, other than cost, why limestone rather than solid sodium hydroxide is often used to neutralise acidity in lakes.

_____

_____

(1)

(Total 17 marks)

Q28.

(a) An unknown metal carbonate reacts with hydrochloric acid according to the following equation.

$$M_2CO_3(aq) + 2HCl(aq) \rightarrow 2MCl(aq) + CO_2(g) + H_2O(l)$$

A 3.44 g sample of M_2CO_3 was dissolved in distilled water to make 250 cm^3 of solution. A 25.0 cm^3 portion of this solution required 33.2 cm^3 of 0.150 mol dm^{-3} hydrochloric acid for complete reaction.

(i) Calculate the amount, in moles, of HCl in 33.2 cm^3 of 0.150 mol dm^{-3} hydrochloric acid. Give your answer to 3 significant figures.

_____

_____

(1)

(ii) Calculate the amount, in moles, of M_2CO_3 that reacted with this amount of HCl. Give your answer to 3 significant figures.

_____

_____

(1)

(iii) Calculate the amount, in moles, of M_2CO_3 in the 3.44 g sample. Give your answer to 3 significant figures.

_____

_____

(1)

(iv) Calculate the relative formula mass, M_r, of M_2CO_3 Give your answer to 1 decimal place.

_____

_____

(1)

(v) Hence determine the relative atomic mass, A_r, of the metal M and deduce its identity.

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A_r of M _____

Identity of M _____

(2)

(b) In another experiment, 0.658 mol of CO_2 was produced. This gas occupied a volume of 0.0220 m^3 at a pressure of 100 kPa.
Calculate the temperature of this CO_2 and state the units.
(The gas constant R = 8.31 J K^{-1} mol^{-1})

_____

_____

_____

_____

_____

_____

_____

(3)

(c) Suggest **one** possible danger when a metal carbonate is reacted with an acid in a sealed flask.

_____

_____

(1)

(d) In a different experiment, 6.27 g of magnesium carbonate were added to an excess of sulfuric acid. The following reaction occurred.

$$MgCO_3 + H_2SO_4 \rightarrow MgSO_4 + CO_2 + H_2O$$

(i) Calculate the amount, in moles, of $MgCO_3$ in 6.27 g of magnesium carbonate.

_____

_____

(2)

(ii) Calculate the mass of $MgSO_4$ produced in this reaction assuming a 95% yield.

_____

_____

_____

_____

(3)

(Total 15 marks)

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Q29.

In this question give all your answers to three significant figures.

Magnesium nitrate decomposes on heating to form magnesium oxide, nitrogen dioxide and oxygen as shown in the following equation.

$$2Mg(NO_3)_2(s) \rightarrow 2MgO(s) + 4NO_2(g) + O_2(g)$$

(a) Thermal decomposition of a sample of magnesium nitrate produced 0.741 g of magnesium oxide.

(i) Calculate the amount, in moles, of MgO in 0.741 g of magnesium oxide.

_____

_____

(2)

(ii) Calculate the total amount, in moles, of gas produced from this sample of magnesium nitrate.

_____

_____

(1)

(b) In another experiment, a different sample of magnesium nitrate decomposed to produce 0.402 mol of gas. Calculate the volume, in dm^3, that this gas would occupy at 333 K and 1.00×10^5 Pa.
(The gas constant R = 8.31 J K^{-1} mol^{-1})

_____

_____

_____

_____

(3)

(c) A 0.0152 mol sample of magnesium oxide, produced from the decomposition of magnesium nitrate, was reacted with hydrochloric acid.

$$MgO + 2HCl \rightarrow MgCl_2 + H_2O$$

(i) Calculate the amount, in moles, of HCl needed to react completely with the 0.0152 mol sample of magnesium oxide.

_____

(1)

(ii) This 0.0152 mol sample of magnesium oxide required 32.4 cm^3 of hydrochloric acid for complete reaction. Use this information and your answer to part (c) (i) to calculate the concentration, in mol dm^{-3}, of the hydrochloric acid.

_____

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_____

_____

(1)

(Total 8 marks)

Q30.

(a) Sodium hydrogencarbonate ($NaHCO_3$) can also be used to neutralise ethanoic acid spillages. The equation for this reaction is shown below.

$$CH_3COOH + NaHCO_3 \longrightarrow CH_3COONa + H_2O + CO_2$$

State the ideal gas equation.

_____

(1)

(b) There are several methods by which ethanoic acid is synthesised on an industrial scale. One method is the oxidation of butane in the presence of metal ion catalysts. Balance the equation given below which summarises this reaction.

$$.....C_4H_{10} + ...O_2 \longrightarrow .....CH_3COOH + ...H_2O$$

(1)

(c) A second method by which ethanoic acid is synthesised involves the oxidative fermentation of ethanol in the presence of bacteria. The equation representing this reaction is given below.

$$C_2H_5OH + O_2 \longrightarrow CH_3COOH + H_2O$$

In a small scale experiment using this second method it was found that 23.0 g of ethanol produced only 4.54 g of ethanoic acid. Calculate the percentage yield for this experiment.

_____

_____

_____

(2)

(Total 4 marks)

Q31.

Ammonium sulfate reacts with sodium hydroxide to form ammonia, sodium sulfate and water as shown in the equation below.

$$(NH_4)_2SO_4(s) + 2NaOH(aq) \rightarrow 2NH_3(g) + Na_2SO_4(aq) + 2H_2O(l)$$

(a) A 3.14 g sample of ammonium sulfate reacted completely with 39.30 cm^3 of a sodium hydroxide solution.

(i) Calculate the amount, in moles, of $(NH_4)_2SO_4$ in 3.14 g of ammonium sulfate.

_____

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_____

_____

(2)

(ii) Hence calculate the amount, in moles, of sodium hydroxide which reacted.

_____

(1)

(iii) Calculate the concentration, in mol dm^{-3}, of the sodium hydroxide solution used.

_____

_____

(1)

(b) Calculate the percentage atom economy for the production of ammonia in the reaction between ammonium sulfate and sodium hydroxide.

_____

_____

_____

(2)

(c) Ammonia is manufactured by the Haber Process.

$$N_2 + 3H_2 \rightleftharpoons 2NH_3$$

Calculate the percentage atom economy for the production of ammonia in this process.

_____

_____

(1)

(d) A sample of ammonia gas occupied a volume of 1.53×10^{-2} m^3 at 37 °C and a pressure of 100 kPa.
(The gas constant R = 8.31 J K^{-1} mol^{-1})

Calculate the amount, in moles, of ammonia in this sample.

_____

_____

_____

(3)

(e) Glauber's salt is a form of hydrated sodium sulfate that contains 44.1% by mass of sodium sulfate. Hydrated sodium sulfate can be represented by the formula $Na_2SO_4.xH_2O$ where x is an integer. Calculate the value of x.

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_____

_____

_____

_____

(3)

(Total 13 marks)

Q32.

Under suitable conditions magnesium will react with dilute nitric acid according to the following equation.

$$Mg(s) + 2HNO_3(aq) \rightarrow Mg(NO_3)_2(aq) + H_2(g)$$

A 0.0732 g sample of magnesium was added to 36.4 cm^3 of 0.265 mol dm^{-3} nitric acid. The acid was in excess.

(a) (i) Calculate the amount, in moles, of magnesium in the 0.0732 g sample.

_____

_____

(1)

(ii) Hence calculate the amount, in moles, of nitric acid needed to react completely with this sample of magnesium.

_____

_____

(1)

(iii) Calculate the amount, in moles, of nitric acid originally added to this sample of magnesium.

_____

_____

(1)

(iv) Hence calculate the amount, in moles, of nitric acid that remains unreacted.

_____

_____

(1)

(b) In a second experiment, 0.512 mol of hydrogen gas was produced when another sample of magnesium reacted with dilute nitric acid. Calculate the volume that this gas would occupy at 298 K and 96 kPa. Include units in your final answer.
(The gas constant R = 8.31 J K^{-1} mol^{-1})

_____

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_____

_____

_____

_____

(3)

(c) Concentrated nitric acid reacts with magnesium to form an oxide of nitrogen which contains 30.4% by mass of nitrogen.

Calculate the empirical formula of this oxide of nitrogen. Show your working.

_____

_____

_____

_____

_____

(3)

(Total 10 marks)

Q33.

Some antacid tablets contain sodium hydrogencarbonate, sucrose and citric acid.

(a) Analysis of a pure sample of citric acid showed that it contained 37.50% of carbon and 4.17% of hydrogen by mass, the remainder being oxygen. Use these data to show that the empirical formula of the acid is $C_6H_8O_7$.

_____

_____

_____

_____

(3)

(b) When the antacid tablet is added to water, sodium hydrogencarbonate and citric acid react together to form a gas. Identify this gas.

_____

(1)

(c) A weighed portion of this antacid was added to water. The gas formed was collected and its volume measured.

(i) Draw a diagram to show how this experiment could have been carried out to collect and measure the volume of the gas.

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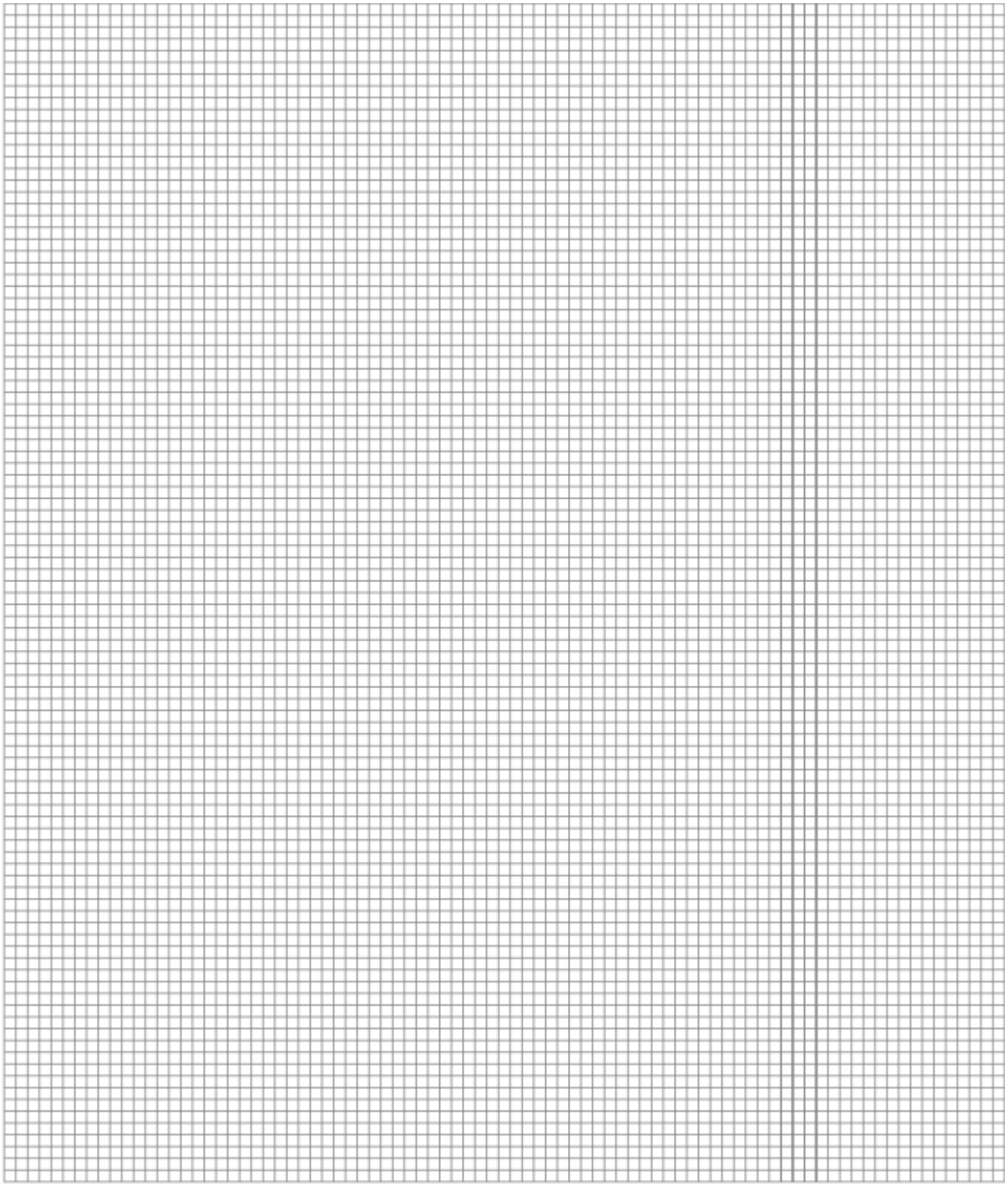
(ii) The experiment was repeated with further weighed portions of the same antacid.

The results are shown below.

Experiment	1	2	3	4	5
Mass of antacid / g	2.60	1.17	0.88	2.31	1.80
Volume of gas collected / cm^3	168	86	57	149	116

1 On the graph paper below, plot a graph of mass of antacid (x-axis) against volume of gas collected.

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(3)

2 Draw a line of best fit on the graph, ignoring any anomalous points.

(1)

3 Use the graph to determine the volume of gas which would have been collected using 2.00 g of antacid.

Volume of gas collected _____

(1)

(d) Suggest **one** reason why the presence of sodium hydrogencarbonate in the

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stomach may cause a person to suffer some extra discomfort for a short time.

_____

(1)

(e) Explain why the value for the M_r of citric acid does not need to be an exact value to deduce the molecular formula of citric acid from its empirical formula.

_____

_____

(2)

(f) Apart from misreading the gas volume, suggest **two** reasons why the volumes of gas collected may be lower than the volumes of gas produced.

Reason 1 _____

_____

Reason 2 _____

_____

(2)

(g) Explain why it is important to record the temperature and pressure when measuring the volume of a gas.

_____

_____

(1)

(h) Suggest why, in an analysis of an antacid, it is important to test samples from more than one bottle of the antacid.

_____

_____

(1)

(i) In the industrial production of sodium hydrogencarbonate, ammonia and carbon dioxide are bubbled through a saturated solution of sodium chloride. The equation for this reaction, and some solubility data, are shown below.

$$NaCl(aq) + NH_3(aq) + CO_2(g) + H_2O(l) \rightarrow NaHCO_3(s) + NH_4Cl(aq)$$

Compound	Solubility in water at 20 °C / g dm^{-3}
sodium chloride	360
sodium hydrogencarbonate	96
ammonium chloride	370

(i) Suggest **one** reason why sodium hydrogencarbonate precipitates from the

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reaction mixture at this temperature.

_____

(1)

(ii) Explain how this reaction could be used to remove carbon dioxide from the gases formed when fossil fuels are burned.

_____

_____

(1)

(j) The thermal decomposition of sodium hydrogencarbonate produces sodium carbonate. The other products are water and carbon dioxide. Write an equation for this thermal decomposition.

_____

(1)

(k) Sodium carbonate is produced on an industrial scale by a multi-step process. The equation which summarises the reactions taking place is shown below.

$$CaCO_3 + 2NaCl \rightarrow CaCl_2 + Na_2CO_3$$

Calculate the percentage atom economy for the production of sodium carbonate by this reaction.

_____

(1)

(Total 20 marks)

Q34.

(a) Nitromethane, CH_3NO_2, is used as an 'energy rich' fuel for motor-racing. It burns in oxygen forming three gases.

$$2CH_3NO_2(l) + 1½O_2(g) \rightarrow 2CO_2(g) + 3H_2O(g) + N_2(g)$$

(i) A 1.00 mol sample of nitromethane was burned in oxygen forming the products shown in the equation above. Calculate the total volume of gases produced at 298 K and 100 kPa (assume that the water is gaseous).

_____

_____

_____

_____

_____

(ii) This combustion reaction is very exothermic and reaches a temperature of 1000 K. Determine the total volume of gases when the temperature is raised to 1000 K at a constant pressure.

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(If you have been unable to determine a volume in your answer to part (a)(i), you may assume it to be 8.61×10^{-4} m^3 but this is not the correct answer).

_____

_____

(5)

(b) It has been suggested that, instead of releasing it into the atmosphere, the carbon dioxide gas evolved during a combustion reaction can be absorbed by sodium hydroxide solution, as shown by the following equation.

$$2NaOH(aq) + CO_2(g) \rightarrow Na_2CO_3(aq) + H_2O(l)$$

(i) Give two reasons why this reaction might not be suitable for the removal of carbon dioxide from the exhaust gases of an engine.

Reason 1 _____

Reason 2 _____

(ii) The sodium hydroxide solution for this reaction can be made on an industrial scale, together with chlorine gas and hydrogen gas, by electrolysis of a dilute solution of sodium chloride. Suggest one commercial advantage and one environmental disadvantage of this industrial process.

Commercial advantage _____

_____

Environmental disadvantage _____

_____

(4)

(c) Nitrogen forms several different oxides. Calculate the empirical formula of an oxide of nitrogen which contains 26% of nitrogen by mass.

_____

_____

_____

_____

(3)

(d) Another oxide of nitrogen, N_2O, decomposes on warming to produce nitrogen and oxygen. Write an equation for the decomposition reaction.

_____

(1)

(e) Internal combustion engines burn fuels in air. Suggest one advantage of using air mixed with N_2O for this purpose.

_____

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(1)
(Total 14 marks)

Q35.

Nitroglycerine, $C_3H_5N_3O_9$, is an explosive which, on detonation, decomposes rapidly to form a large number of gaseous molecules. The equation for this decomposition is given below.

$$4C_3H_5N_3O_9(l) \rightarrow 12CO_2(g) + 10H_2O(g) + 6N_2(g) + O_2(g)$$

(a) A sample of nitroglycerine was detonated and produced 0.350 g of oxygen gas.

(i) State what is meant by the term *one mole* of molecules.

_____

(ii) Calculate the number of moles of oxygen gas produced in this reaction, and hence deduce the total number of moles of gas formed.

Moles of oxygen gas _____

Total moles of gas _____

_____

_____

(iii) Calculate the number of moles, and the mass, of nitroglycerine detonated.

Moles of nitroglycerine _____

_____

Mass of nitroglycerine _____

_____

_____

(7)

(b) A second sample of nitroglycerine was placed in a strong sealed container and detonated. The volume of this container was 1.00×10^{-3} m^3. The resulting decomposition produced a total of 0.873 mol of gaseous products at a temperature of 1100 K.

State the ideal gas equation and use it to calculate the pressure in the container after detonation.

(The gas constant R = 8.31 J $K^{-1}mol^{-1}$)

Ideal gas equation _____

Pressure _____

_____

_____

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(4)

(Total 11 marks)

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Q1.

(a) The sum of $\frac{\text{(weighted) average masses of atoms in formula}}{\text{1/12 mass of an atom of } ^{12}C}$

$\frac{\text{Average mass of one molecule}}{\text{1/12 mass of an atom of } ^{12}C}$

1

Method 1	**Method 2**
Mass of Y = 0.21g	Mass of Y = 0.21g

If incorrect lose M5 also, unless AE

1

$M_r = \frac{mRT}{pV}$ $n = \frac{pV}{RT}$ and $M_r = \frac{m}{n}$

Can be implied in calculations

1

$M_r = \frac{0.21 \times 8.31 \times 371.1}{102000 \times 85x10^{-6}}$ $n = \frac{102000 \times 85x10^{-6}}{8.31 \times 371.1}$ (= 2.81 × 10^{-3})

M4 – awarded for all 3 unit conversions

1

M_r = 74.7 M_r = 74.7

Allow 75

1

(b) Lower volume recorded

Allow

(Evaporated) mass of gas is less than the recorded mass of liquid / 0.21g (or converse)

1

M_r would be greater (than the real M_r)

Ignore other references to mass

1

[7]

Q2.

This question is marked using Levels of Response. Examiners should apply a 'best-fit' approach to the marking.	
Level 3 5-6 marks	All stages are covered and the explanation of each stage is generally correct and virtually complete. Answer is communicated coherently and shows a

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	logical progression from stage 1 to stage 2 and then stage 3. Coherent communication requires that there is a comparison between the types of bonding and that the bonding is correct for each substance.
Level 2 3-4 marks	All stages are covered but the explanation of each stage may be incomplete or may contain inaccuracies OR two stages are covered and the explanations are generally correct and virtually complete. Answer is mainly coherent and shows some progression from stage 1 to stage 2 and then stage 3.
Level 1 1-2 marks	Two stages are covered but the explanation of each stage may be incomplete or may contain inaccuracies OR only one stage is covered but the explanation is generally correct and virtually complete. Answer shows some progression between two stages
Level 0 0 marks	Insufficient correct chemistry to gain a mark.

Indicative chemistry content. Contradictions (eg molecules, IMFs, covalent bonding,) negate statements.

Stage 1 - **Na**
1a) Na has metallic bonding
1b) there is attraction/ bonding between the positive nucleus/ ion and the delocalised electrons in Na
1c) Na has a giant/lattice structure

Stage 2 – **NaBr or NaI**
2a) Ionic bonding in NaBr and/or NaI
2b) There is attraction/ bonding between the + and – ions in NaBr and/or NaI
2c) NaBr and/or NaI have a giant/lattice structure

Stage 2 – **comparison of bonding**
3a) The ionic bonds are stronger (or wtte) than the metallic bonds
3b) there is stronger attraction (or wtte) between the + and – ions in NaBr than in NaI
3c) since the Br^- ion is smaller than the I^- ion

6

(b) **M1** $Na + H_2O \rightarrow NaOH + \frac{1}{2} H_2$

Allow multiples

1

M2 (Mass Na = 0.250 g so moles Na = 0.250/23.0) = 0.0109

CE: If not divided by 23, max 3/5 calculation marks – M3, M4 and M5

AE: If not divided by 1000 and final answer is 1.33×10^5 cm^3 4/5

1

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M3 moles H_2 = 5.43 × 10^{-3} to 5.45 × 10^{-3}

M3 = M2 /2

CE: If incorrect ratio used max 3/5 calculation marks – M2, M4 and M5

1

M4 T = 298 (K) and P = 101000 (Pa)

1

M5 V = nRT/P or (5.435 × 10^{-3} × 8.31 × 298)/101000 or 1.33 × 10^{-4} (m^3)

1

M6 V = 133 – 134 cm^3

Allow to 2 significant figures or more

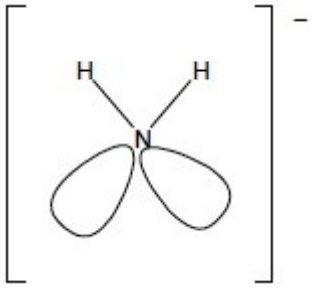
1

(c) Conc = 0.0109/ 500 × 10^{-3} = 0.0217-0.022 (mol dm^{-3})

Allow M2 from question (b)

1

(d) **M1**



Ignore charge and brackets

1

M2 104.5°

Allow 104-106

1

M3 (4) electron pairs repel to be as far apart as possible

1

M4 lp/lp repulsion> lp/bp repulsion (> bp/bp repulsion)

For M4 allow lone pairs repel more than bonding pairs

Mark independently

1

[16]

Q3.

(a) **Stage 1**

M1 $n = \frac{PV}{RT}$

1

M2 $= \frac{102 \times 10^3 \times 72 \times 10^{-6}}{8.31 \times 373}$

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1

M3 = 0.0024 / 0.00237 / 0.002369 / 0.0023693 ..

1

Stage 2

M4 $M_r \left(= \frac{\text{mass}}{\text{moles}}\right) = \frac{0.194}{\textbf{M3}}$

1

M5 = 82 (**2sf only**)

1

*As this is an extended response question, each separate step of correct working is required in **M1–M5***

Correct answer with no working scores 2 marks

***M1** – If expression not written out, **M1** could score from a correct expression for **M2** (even if unit conversions are not correct for **M2**)*

M2** – allow an expression that gives correct value for **M3

***M3** should be at least 2sf (do not allow 0.0023 but do allow 0.00236)*

***M4** must show 0.194 or 194 × 10^{-3} in working to score*

***M5** must be 2sf*

ECF:

- *No ECF within either stage 1 or stage 2 (except for transcription errors)*
- *Allow ECF from stage 1 into stage 2, i.e for **M4** and **M5** based on incorrect **M3**, (but if expression for **M4** is inverted, cannot score **M5**)*
- *(Note that if 72 × 10^{-3} used in **M2**, then **M3** = 2.4, **M5** = 0.082)*

*Ignore units for **M3** and **M5***

*Note that if T = 273 + 373 = 646, **M5** = 140 (2sf)*

(b) **M1** dividing %s by relative atomic masses
C = 83.7/12(.0), H = 16.3/1(.0)

1

M2 converting (C : H 6.975 : 16.3) to 3 : 7

1

M3 empirical formula = C_3H_7

1

M4 molecular formula = C_6H_{14}

1

***M1** & **M2** are for working*

***M3** for C_3H_7 only, marked independently*

***M4** for C_6H_{14} only, marked independently (ignore additional correct structures)*

*Formulae with no working cannot score **M1** or **M2***

Alternative method:
***M1** working that shows 83.7% of 86 is 72*
***M2** idea of 72/12 gives 6 C atoms*

Alternative method:

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*working that shows that C_6H_{14} (or C_3H_7) contains 83.7% C scores **M1** & **M2***

[9]

Q4.

A

[1]

Q5.

A

[1]

Q6.

B

[1]

Q7.

C

[1]

Q8.

(a) Mass of **X** = 0.270

Volume of **X** = 105.0

Both must be correct

1

(b) pV = nRT

$$\frac{100\,000 \times 105/1000000}{8.31 \times 370} = n$$

1

$n = 3.41 \times 10^{-3}$

1

$M_r = {}^{\text{mass}}/_{\text{mol}}$ or ${}^{0.270}/_{3.41 \times 10^{-3}}$

1

$M_r = 79.1$

1

Identity of **X** = CH_2Cl_2

If M_r = 52 used, allow CH_3Cl

1

(c) **M1** The volume of the gas in the syringe (V) is greater than the true volume (because some air leaked into the syringe)

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If the M_r value of 52 is used and CH_3Cl is identified in 01.2:

1

M2 M_r = m/n = m × RT/PV so if V is too large, M_r is too small

OR

M1 The temperature measured (T) is less than the temperature of the gas in the syringe (because the syringe heated faster than the oven and the oven temperature was not constant)

M2 M_r = m/n = m × RT/PV so if T is too small, M_r is too small

OR

M1 The measured mass of liquid transferred to the syringe (m) is less than the actual mass transferred

M2 M_r = m/n = m × RT/PV so if m is too small, M_r is too small

***M1** The volume of the gas in the syringe (V) is less than the true volume (because not all the liquid vaporised in the syringe)*

***M2** M_r = m/n = m × RT/PV so if V is too small, M_r is too large*

OR

***M1** The temperature measured (T) is greater than the temperature of the gas in the syringe (because the syringe heated more slowly than the thermometer and the oven temperature was not constant)*

***M2** M_r = m/n = m × RT/PV so if T is too large, M_r is too large*

OR

***M1** The measured mass of liquid transferred to the syringe (m) is greater than the actual mass transferred*

***M2** M_r = m/n = m × RT/PV so if m is too large, M_r is too large*

1

(d) Carry out in a fume cupboard

Do not allow safety glasses / labcoat

1

To avoid toxic vapour

1

[10]

Q9.

(a) Mol CO = (0.73 − 0.43) = 0.30 (mol)

1

Mol H_2 = (1.25 − 2(0.43)) = 0.39 (mol)

1

(b) $K^c = \dfrac{[CH_3OH]}{[CO][H_2]^2}$

1

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(c) Divides throughout by volume

1

$$K_c = \frac{[0.273/9.40]}{[0.1.06/9.40]^2[0.452/9.40]}$$

1

$$K_c = \frac{0.029}{0.0000061146}$$

$K_c = 4.75 \times 10^3$

1

Unit = $mol^{-2}\ dm^{+6}$

1

(d) $pV = nRT$

$$T = \frac{pV}{nR}$$

1

$n = 0.452 + 0.106 + 0.273 = 0.831$ (mol)

Calculation of moles and substitution of all values

1

$$= \frac{482.9 \times 10^3 \times 9.40 \times 10^{-3}}{0.831 \times 8.31} = 657\ K$$

Correct conversion of p and V

1

= 384 °C

Conversion to °C

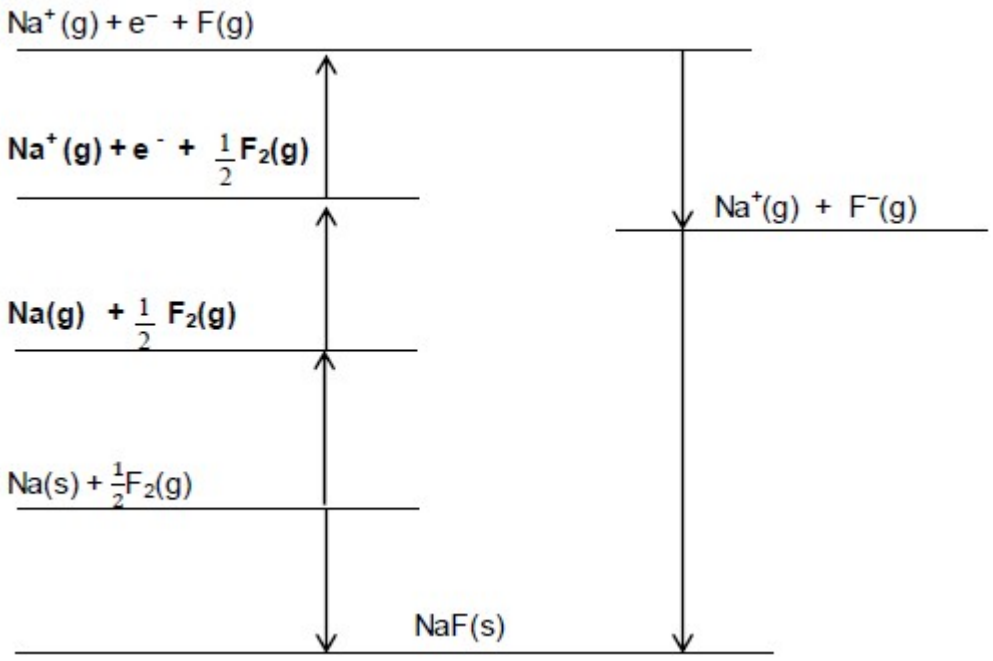
1

[11]

Q10.

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(a)



or
M2 Na(g) + F(g)
M1 Na(s) + F(g)
or
M2 = Na(g) + F(g)
M1 = Na(g) + 0.5F_2(g)

2

(b) LE = −109 − 494 − 158/2 + 348 − 569

1

= −903 (kJ mol^{-1})

1

(c) NaCl enthalpy of lattice formation will be less negative **OR** less exothermic

1

Cl^- ion bigger (than F^-)

1

So attraction of halide ion to Na^+ is weaker
Allow so ionic bonding is stronger

1

(d) Amount of NaF = 1/42 = 2.38 × 10^{-2} mol

1

Amount of F_2 = (2.38 × 10^{-2})/2 = 1.19 × 10^{-2} mol

1

$V = nRT/p$ = (1.19 × 10^{-2} × 8.31 × 298)/100000

1

V = 2.95 × 10^{-4} m^3

= 295 cm^3

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1

[11]

Q11.

(a) Stage 1

M_r for $Mg(NO_3)_2$ = 148.3

Moles of $Mg(NO_3)_2$ = $\frac{3.74 \times 10^{-2}}{148.3}$ = 2.522×10^{-4} mol

Extended response calculation

1

Stage 2

Total moles of gas produced = 5/2 × moles of $Mg(NO_3)_2$

= $5/2 \times 2.522 \times 10^{-4} = 6.305 \times 10^{-4}$

If ratio in stage 2 is incorrect, maximum marks for stage 3 is 2

1

Stage 3

$PV = nRT$ so volume of gas $V = nRT / P$

1

$V = \frac{nRT}{P} = \frac{6.305 \times 10^{-4} \times 8.31 \times 333}{1.00 \times 10^{5}}$ = 1.745×10^{-5} m^3

1

$V = 1.745 \times 10^{-5} \times 1 \times 10^{6} = 17.45$ cm^3 = 17.5 (cm^3)

Answer must be to 3 significant figures (answer could be 17.4 cm^3 dependent on intermediate values)

1

(b) Some of the solid is lost in weighing product / solid is blown away with the gas

1

[6]

Q12.

B

[1]

Q13.

B

[1]

Q14.

B

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[1]

Q15.

(a) n = pV/RT **M1**

Do not accept pV=nRT as the sole working.
Allow correct substitution of numbers.

1

0.739 **M2**

Answer must be to a minimum of 2 s.f.
*Correct answer without working scores **M2** only.*

1

(b) (a) × 2

Answer will often be 1.48 (or 1.5 or 1.478)
Answer must be to a minimum of 2 s.f.

1

(c) 100.1

Answer must be to 1 d.p.

1

(d) (a) × (c)

Answer will often be 74.0
Answer must be to a minimum of 2 s.f.

1

[5]

Q16.

(a) n = PV/RT

If PV=nRT rearranged incorrectly then M3 only

1

$$\frac{102\,000 \times (1.00 \times 10^{-3})}{8.31 \times 300} = n = (4.091456077 \times 10^{-2})$$

1

Mass = M2 × 17 = 0.696 (g) (3 sig figs only)

Allow 0.695 or 0.697

1

(b) If pV = nRT

$$\text{Total volume} = \frac{nRT}{P}$$

Incorrect unit conversion loses M1 only; can get M2/M3 if possible volume obtained

$$= \frac{n \times 8.31 \times 295}{75\,000}$$

= 1.34×10^{-3} m^3

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Inserts correct numbers (inc pressure in Pa)

1

Volume of Q in $m^3 = 1.00 \times 10^{-3}$

Volume of bulb P = $1.34 \times 10^{-3} - 1.00 \times 10^{-3}$

Volume of bulb P = 3.42×10^{-4} m^3

No subtraction M1 only

1

= 342 cm^3 (Allow 310 − 342 cm^3)

Alternative method also worth full credit

(note if mol in M2 of 05.1 rounded to 0.04 this could lead to a final answer of 3.1 × 10^{-4} m^3 so allow range 310 − 342 cm^3

1

[6]

Q17.

C

[1]

Q18.

C

[1]

Q19.

(a) Correct conversion of temperature and pressure (773 and 101 × 10^3)

Correct answer with or without working scores 4 marks

1

No moles P = (220 / 4 × 31.0) = 1.77

Max 2 (M1 and M3) if 31.0 used

(=0.451 m^3 or if 220/31 rounded to 2 sf ie 7.1 then 0.452)

1

V = nRT/P (correct rearrangement **or** insert of values V = 1.77 × 8.31 × 773/101 × 10^3 =0.1128 m^3)

Max 2 (M1 and M3) if 284 (P_4O_{10}) used then 0.0493

1

V = <u>0.113</u> (m^3)

Must be 3 sig figs

1

(b) No moles H_3PO_4 = 3 × 10^3 (dm^3) × 5 = 15,000 (mols)

Correct answer with or without working scores 3 marks

If M1 incorrect then can only score M2

1

No moles phosphorus(V) oxide = $\frac{15000}{4}$ (= 3,750 mols)

$M2 = \frac{M1}{4}$ (process)

If M2 incorrect can only score M1

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1.1 × 10^6 or1.07 × 10^6 or 1.065 × 10^6 (g)
or 1,100 or 1,070 or 1065 kg
or 1.1 or 1.07 or 1.065 tonne

= (3.75 × 10^3 × 284.0)

Min 2 sig fig

1

1

(c) No moles $Ca_3(PO_4)_2$ (= 3.50kg =) $\frac{3500\text{ g}}{310(.3)}$ = 11.28

Correct answer with or without working scores 4 marks

If M1 incorrect can only score M2 and M3

1

Theoretical No. moles H_3PO_4 = 11.28 × 2 = 22.56

If M2 incorrect can only score M1 and M3

1

Theoretical mass H_3PO_4 = 22.56 × 98(.0) = 2211

If M3 incorrect can only score M1and M2

1

or Actual No. moles H_3PO_4 produced = $\frac{1090}{98}$ = 11.12

49 – 49(.312) (%)

$$(\%\text{ yield (moles)} = (\frac{11/.12}{22.56} \times 100)$$

$$\text{or } (\%\text{ yield (mass)} = (\frac{1090}{2211} \times 100)$$

1

(d) Method 1 / (a) & (b) because only one product / no other products formed / atom economy = 100% (even though two steps)

Allow calculations

Do not allow if P_2O_5 is formed

Allow converse explanation

1

[12]

Q20.

(a) M1 550 × $\frac{100}{95}$ = 579 g would be 100% mass

Allow alternative methods.

There are 4 process marks:

1

M2 So $\frac{579}{65}$ = 8.91 moles NaN_3

or

M1 $\frac{550}{65}$ = 8.46 moles NaN_3 (this is 95%)

M2 So 100% would be 8.46 × $\frac{100}{95}$ = 8.91 moles NaN_3

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1: mass ÷ 65
2: mass or moles × 100 / 95 or × 1.05
3: moles NaN_3 × 2
4: moles $NaNH_2$ × 39

1

Then M3 Moles $NaNH_2$ = 8.91 × 2 = (17.8(2) moles)

1

M4 mass $NaNH_2$ = 17.8(2) × 39

1

M5 693 or 694 or 695 (g)
If 693, 694 or 695 seen to 3 sig figs award 5 marks

1

(b) M1 308 K and 150 000 Pa

1

M2 $n = \frac{PV}{RT}$ or $\frac{150\,000 \times 7.5 \times 10^{-2}}{8.31 \times 308}$

1

M3 = 4.4(0) or 4.395 moles N_2
Allow only this answer but allow to more than 3 sig figs

1

M4 Moles NaN_3 = 4.395 × $\frac{2}{3}$ (= 2.93)
M4 is for M3 × $\frac{2}{3}$

1

M5 Mass NaN_3 = (2.93) × 65
M5 is for moles M4 × 65

1

M6 = 191 g
Allow 190 to 191 g allow answers to 2 sig figs or more

1

(c) (i) 150 / 65 = 2.31 moles NaN_3 or 2.31 moles nitrous acid

1

Conc = 2.31 × $\frac{1000}{500}$

M2 is for M1 × 1000 / 500

1

4.6(1) or 4.6(2) (mol dm^{-3})
Only this answer

1

(ii) $3HNO_2 \longrightarrow HNO_3 + 2NO + H_2O$
Can allow multiples

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1

(d) Ionic

If not ionic then CE = 0 / 3

1

Oppositely charged ions / Na^+ and N_3^- ions

Penalise incorrect ions here but can allow M3

1

Strong attraction between (oppositely charged) ions / lots of energy needed to overcome (strong) attractions (between ions)

M3 dependent on M2

1

(e) (i) $N \equiv N \longrightarrow N^-$

Only

1

(ii) CO_2 / N_2O / BeF_2 / HN_3

Allow other correct molecules

1

(iii) MgN_6

Only

1

[21]

Q21.

(a) (i) Uses sensible scales.

*Lose this mark if the **plotted points** do not cover half of the paper.*

Lose this mark if the graph plot goes off the squared paper

Lose this mark if volume is plotted on the x-axis

1

All points plotted correctly

Allow ± one small square.

1

Smooth curve from 0 seconds to at least 135 seconds − the line must pass through or close to all points (± one small square).

Make some allowance for the difficulties of drawing a curve but do not allow very thick or doubled lines.

1

(ii) Any value in the range 91 to 105 s

Allow a range of times within this but not if 90 quoted.

1

(b) (i) Using pV = nRT

This mark can be gained in a correctly substituted equation.

1

$100\,000 \times 570 \times 10^{-6} = n \times 8.31 \times 293$

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Correct answer with no working scores one mark only.

1

n = 0.0234 mol

Do not penalise precision of answer but must have a minimum of 2 significant figures.

1

(ii) Mol of $ZnCO_3$ = 0.0234

Mark consequentially on Q6

M1
1

Mass of $ZnCO_3$ = M1 × 125.4 = 2.9(3) or 2.9(4) g

If 0.0225 used then mass = 2.8(2) g

M2
1

(iii) Difference = (15.00 / 5) − Ans to b

If 2.87 g used then percentage is 4.3

M1
1

Percentage = (M1 / 3.00) × 100

Ignore precision beyond 2 significant figures in the final answer

If 2.82 g used from (ii) then percentage = 6.0

M2
1

(c) A reaction vessel which is clearly airtight round the bung

1

Gas collection over water or in a syringe

Collection vessel must be graduated by label or markings

Ignore any numbered volume markings.

1

[13]

Q22.

(a) (i) 2.16 ÷ 241.8 = 0.00893 or 8.93×10^{-3} (mol)

Penalise if not 3 significant figures.

1

(ii) $n(O_2)$ = 0.00893 × 0.75 (= 0.00670 mol)

Allow part(i) × 0.75 .

1

(iii) M1 = T = 566 K and P = 100 000 Pa

If M1 incorrect can only score M2 and M3.

1

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M2 = Moles NO_2 = 0.0268 (mol)

If M2 incorrect can only score M1 and M3.

Allow moles of NO_2 = student's answer to part (i) × 3.

***OR** part (ii) × 4 and consequential M4.*

Minimum of 2 significant figures.

1

M3 = $V = \frac{nRT}{p}$ **OR** = $\frac{0.0268 \times 8.31 \times 566}{100\,000}$

If M3 incorrect can only score M1 and M2.

1

M4 = 0.00126 (m^3) or 1.26×10^{-3} (m^3)

Allow minimum of 2 significant figures.

Allow no units but incorrect units loses M4.

If 0.00642 moles used:

M2 = Moles NO_2 = 0.0193 mol.

M3 = V = $\frac{nRT}{p} = \frac{0.0193 \times 8.31 \times 566}{100\,000}$.

M4 = 9.06×10^{-4} (m^3) allow 9.06 to 9.08 × 10^{-4}.

1

(b) (Thermal) decomposition

Do not allow catalytic decomposition.

1

(c) Other products are gases / other products escape easily

Allow no other solid (or liquid) product.

1

[8]

Q23.

(a) P = 100 000 Pa and T = 298 K

Wrong conversion of V or incorrect conversion of P / T lose M1 + M3

1

$n = \frac{PV}{RT}$ or $\frac{100\,000 \times 4.31}{8.31 \times 298}$

If not rearranged correctly then cannot score M2 and M3

1

n(total) = 174(.044)

1

n (NO) = $\underline{69.6}$

Allow student's M3 × 4 / 10 but must be to 3 significant figures

1

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(b) (i) $\frac{3000}{17}$

Allow answer to 2 significant figures or more

1

176.5

Allow 176 − 177
But if answer = 0.176 − 0.18 (from 3 / 17) then allow 1 mark

1

(ii) 176.47 × 46 = 8117.62

M1 is for the answer to (b)(i) × 46. But lose this mark if 46 ÷ 2 at any stage
However if 92 ÷ 2 allow M1

1

$8117.62 \times \frac{80}{100}\ (= 6494\ \text{g})$

M2 is for M1 × 80 / 100

1

$\frac{6494}{1000} = 6.5$

M3 is for the answer to M2 ÷ 1000 to min 2 significant figures (kg)

OR

If 163 mol used:
163 × 46 = 7498 (1)

$7498 \times \frac{80}{100} = 5998.4\,\text{g}\,(1)$

6.00 kg (1)

1

(c) $0.543 \times \frac{2}{3}\ (= 0.362)$

if not $\times \frac{2}{3}$ CE = 0/2

1

$0.362 \times \frac{1000}{250} = 1.45\ (\text{mol dm}^{-3})$

Allow 1.447 − 1.5 (mol dm^{-3}) for 2 marks

1

(d) NO_2 contributes to acid rain / is an acid gas / forms HNO_3 / NO_2 is toxic / photochemical smog

Ignore references to water, breathing problems and ozone layer.
Not greenhouse gas

1

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(e) Ensure the ammonia is used up / ensure complete reaction or combustion

OR

Maximise the yield of nitric acid or products

1

(f) Neutralisation

Allow acid vs alkali or acid base reaction

1

[14]

Q24.

(a) P = 100 000 (Pa) and V = 5.00 x 10^{-3} (m^3)

M1 is for correctly converting P and V in any expression or list Allow 100 (kPa) and 5 (dm^3) for M1.

1

$$n = \frac{PV}{RT} = \frac{100\ 000 \times 5.00 \times 10^{-3}}{8.31 \times 298}$$

M2 is correct rearrangement of PV = nRT

1

= 0.202 moles (of gas produced)

This would score M1 and M2.

Therefore $\frac{0.202}{5}$ = 0.0404 moles B_2O_3

M3 is for their answer divided by 5

1

Mass of B_2O_3 = 0.0404 x 69.6

M4 is for their answer to M3 x 69.6

1

= 2.81 (g)

M5 is for their answer to 3 sig figures.

2.81 (g) gets 5 marks.

1

(b) B + 1.5 Cl_2 → BCl_3

Accept multiples.

1

3 bonds

1

Pairs repel equally/ by the same amount

Do not allow any lone pairs if a diagram is shown.

1

(c) (i) 43.2/117.3 (= 0.368 moles BCl_3)

1

0.368 x 3 (= 1.105 moles HCl)

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Allow their BCl_3 moles x 3

1

Conc HCl = $\frac{1.105 \times 1000}{500}$

Allow moles of HCl × 1000 / 500

1

= 2.20 to 2.22 mol dm^{-3}

Allow 2.2

Allow 2 significant figures or more

1

(ii) $H_3BO_3 + 3NaOH \rightarrow Na_3BO_3 + 3H_2O$

Allow alternative balanced equations to form acid salts.

Allow $H_3BO_3 + NaOH \rightarrow NaBO_2 + 2H_2O$

1

(d) $\frac{10.8}{120.3}(\times 100)$

Mark is for both M_r values correctly as numerator and denominator.

1

8.98(%)

Allow 9(%).

1

Sell the HCl

1

(e) Alternative method

Cl = 86.8%

Cl = 142 g

1

B $\frac{13.2}{10.8}$ Cl $\frac{86.8}{35.5}$

B $\frac{21.6}{10.8}$ *Cl* $\frac{142}{35.5}$

1

1.22 *2.45 or ratio 1:2 or BCl_2*

2:4 ratio

1

BCl_2 has M_r of 81.8 so
81.8 x 2 = 163.6
Formula = B_2Cl_4

B_2Cl_4

Allow 4 marks for correct answer with working shown.

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Do not allow $(BCl_2)_2$

1

[20]

Q25.

(a) Mol Pb = 8.14 / 207(.2) (= 0.0393 mol)

M1 and M2 are process marks

1

Mol HNO_3 = 0.0393 × 8 / 3 = 0.105 mol

Allow mark for M1 × 8/3 or M1 × 2.67

1

Vol HNO_3 = 0.105 / 2 = 0.0524 (dm^3)

Accept range 0.0520 to 0.0530

No consequential marking for M3

Answer to 3 sig figs required

1

(b) 101000 (Pa) and 638 × 10^{-6} (m^3)

1

n = pV/RT $\left(= \frac{101000 \times 638 \times 10^{-6}}{8.31 \times 298}\right)$

Can score M2 with incorrect conversion of p and V

If T incorrect lose M1 and M3

1

0.026(0) (mol)

If answer correct then award 3 marks

Allow answers to 2 sig figs or more

26.02 = 1

If transcription error lose M3 only

1

(c) (i) $2Pb(NO_3)_2(s) \rightarrow 2\ PbO(s) + 4NO_2(g) + (1)O_2(g)$

Allow multiples

Allow fractions

1

(ii) Decomposition not complete / side reactions / by-products / some (NO_2) escapes / not all reacts / impure $Pb(NO_3)_2$

Ignore reversible / not heated enough / slow

1

(iii) Hard to separate O_2 from NO_2 / hard to separate the 2 gases

Allow mixture of gases

Not 'all products are gases'

1

[9]

Q26.

(a) (i) 0.0212

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Need 3 sig figs

Allow correct answer to 3 sig figs eg 2.12 x 10^{-2}

1

(ii) 0.0106

Mark is for (a)(i) divided by 2 leading to correct answer 2 sig figs

1

(iii) M_r = 100.1

1.06 g

Allow 100.1 as 'string'

Need 3 sig figs or more

Consequential on (a)(ii) x 100(.1)

2

(iv) Neutralisation or acid / base reaction

Allow acid / alkali reaction

Apply list principle

1

(b) (i) T = 304(K) and P = 100 000 (Pa)

Only T and P correctly converted

1

$$\frac{100\,000 \times 3.50 \times 10^{-3}}{8.31 \times 304} \text{ OR } n = \frac{PV}{RT}$$

1

0.139 (mol)

Allow 0.138 – 0.139

1

(ii) 0.0276 – 0.0278(mol)

Allow answer to (b)(i) divided by 5 leading to a correct answer

Allow 0.028

1

(c) 4.20 g $Ca(NO_3)_2$

1

$Ca(NO_3)_2$ H_2O

$$\frac{4.20}{164(.1)} \qquad \frac{1.84}{18}$$

Mark is for dividing by the correct Mr values

M2 and M3 dependent on correct M1

0.0256 0.102

M2 can be awarded here instead

1 : 3.98

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x = 4

If $Ca(NO_3)_2.4H_2O$ seen with working then award 3 marks

Credit alternative method which gives x = 4

1

[12]

Q27.

(a) (i) Volume of crater-lake solution on x-axis

Do not penalise missing axes labels.

If axes unlabelled use data to decide.

Lose this mark if axes mis-labelled.

1

Sensible scales

*Lose this mark if **plotted points** do not cover at least half the paper or plot goes off the squared paper.*

1

All points plotted correctly +/– one square

1

(ii) Draws appropriate line of best fit, omitting point at 20 cm^3 / 15 cm^3

Lose this mark if the line deviated towards the anomalous result.

Lose this mark if the candidate's line is doubled or kinked.

Candidate does not have to extrapolate to the origin.

1

(iii) 16.5 cm^3 +/– 0.5 cm^3

Accept this answer only.

Do not mark consequentially on candidate's graph.

1

(iv) Value corresponding to 10 cm^3 crater-lake solution / 6.00 cm^3

Must have correct identity for explanation mark.

Accept results aren't concordant.

1

Greatest % error from use of burette

Accept difficult to be accurate with small volumes (owtte).

1

(b) (i) pV = nRT

Accept any correct rearrangement.

Ignore case.

1

(ii) V = 81.0×10^{-6} or 8.1×10^{-5}

1

n = $(1 \times 10^5 \times 81.0 \times 10^{-6}) / (8.31 \times 298)$

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Mark consequentially on candidate's volume.

1

$n = 3.27 \times 10^{-3}$ (mol)

Correct answer without working scores one mark only.

Allow consequential mark using incorrect conversion.

Incorrect units lose this mark.

1

(iii) M_r $CaCO_3$ = 100.1 (M1)

Accept 100 (can score this mark in calculation for M2 and M3).

1

Moles $CaCO_3 = (3.27 \times 10^{-3} \times 10) = 3.27 \times 10^{-2}$ (M2)

Do not penalise lack of units.

Allow b(ii) × 10

Allow 1.25 × 10^{-3} × 10

1

Mass $CaCO_3$ = M1 × M2 (= 3.27 g)

Correct mass without working scores one mark only.

Allow 1.25 × 10^{-2} × 10 × 100.1= 12.5 g

1

(iv) (3.27 / 95) × 100

Accept (b(iii) / 95) × 100.

Do not penalise precision.

1

3.44 g

Do not penalise lack of units.

Using 12.5 g gives 13.2 g

Correct answer without working scores 2 marks.

1

(v) Abundant / readily available

Accept not caustic or alkaline.

Non-corrosive

Accept insoluble so safe to add in excess (owtte).

1

[17]

Q28.

(a) (i) $\underline{4.98 \times 10^{-3}}$

1

Only

(ii) 2.49×10^{-3}

Allow answer to (a)(i) ÷ 2

Allow answers to 2 or more significant figures

1

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(iii) 2.49×10^{-2}

Allow (a)(ii) × 10
Allow answers to 2 or more significant figures

1

(iv) 138.2

3.44 divided by the candidate.s answer to (a)(iii)
138.2 or 138.1 (i.e. to 1 d.p.)

1

(v) (138 – 60) ÷ 2 = 39.1

Allow 39 – 39.1
Allow ((a)(iv) – 60) ÷ 2

1

K/potassium

Allow consequential on candidate's answer to (a)(iv) and (a)(v) if a group 1 metal
Ignore + sign

1

(b) PV = n RT or rearranged

If incorrectly rearranged CE = 0

1

$$T = \frac{0.022 \times 100000}{0.658 \times 8.31}$$

Correct M2 also scores M1

1

402(.3) K (or 129 °C)

allow 402-403K
or 129-130 °C
do not penalise °K
M3 must include units for mark

1

(c) Pressure build up from gas/may explode/stopper fly out/glass shatters/breaks

Penalise incorrect gas

1

(d) (i) M_r = 84.3

If 84 used, max 1

1

$\frac{6.27}{84.3}$ = 0.074(4)

CE if not 84 or 84.3
Allow answers to 2 or more significant figures
M2 = 0.074-0.075

1

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(ii) M1 M_r $MgSO_4$ = 120(.4)
allow 120.3 and 120.1
CE if wrong Mr

1

M2 Expected mass $MgSO_4$ = 0.074(4) × 120(.4) = 8.96 g
Allow 8.8 – 9.0 or candidate's answer to (d)(i) × 120(.4)

1

M3 95% yield = $\frac{8.96 \times 95}{100}$ = 8.51 g
Allow 8.3 – 8.6
M3 dependent on M2

Alternative method

M2 0.074(4) × 95/100 = 0.0707

M3 0.0707 × 120(.4) = 8.51 g
Allow (d)(i) × 95/100
Allow 8.3 – 8.6
M3 dependent on M2

1

[15]

Q29.

(a) (i) M_r MgO = 40.3
If used 40 then penalise this mark but allow consequential M2 (0.0185)

1

0.741/40.3 = 0.0184
0.018 with no M_r shown = 0
Penalise if not 3 sig figs in this clip only

1

(ii) 0.0184 × 5/2 = 0.0460
Allow 0.0459 to 0.0463
Allow their (a)(i) × 5/2 ie allow process mark of × 5/2 but insist on a correct answer being written down
Ignore sig figs

1

(b) pV = nRT

1

(V = $\frac{0.402 \times 8.31 \times 333)}{100\,000}$)
If rearranged incorrectly then lose M1
If this expression correct then candidate has scored first mark

0.0111

1

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Ignore units

11.1 (dm^3)

3 marks for 11.1 (dm^3)
However if 11.1 m^3 or cm^3 allow 2 (ie penalise wrong units in final answer)
Ignore sig figs- but must be 2 sig figs or greater

1

(c) (i) 0.0152 × 2 = 0.0304

Allow 0.03

1

(ii) 0.938 mol dm^{-3}

Allow range 0.92 – 0.94
Minimum 2 sig figs
Allow consequential marking from (c)(i)
Ignore units even if wrong

1

[8]

Q30.

(a) pV = nRT

Do not penalise incorrect use of capitals / lower case letters.
Accept correct rearrangement of equation.

1

(b) $\mathbf{2}C_4H_{10} + \mathbf{5}O_2 \rightarrow \mathbf{4}CH_3COOH + \mathbf{2}H_2O$

Accept any correct combination of multiples, including fractions.

1

(c) 23.0 g ethanol produces 30.0 g ethanoic acid

1

15.1% (4.54 ×100 / 30)

Do not penalise precision.
15.1% scores 2 marks.
Accept consequential answer on wrong mass of ethanoic acid for second mark only.

1

[4]

Q31.

(a) (i) M_r = 132.1

1

132

0.0238

Allow 0.024
Allow 0.0237
Penalise less than 2 sig fig once in (a)

1

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(ii) 0.0476

1

0.0474-0.0476
Allow (a) (i) × 2

(iii) 1.21

Allow consequential from (a) (ii)
ie allow (a) (ii) × 1000/39.30
Ignore units even if wrong

1

(b) $\frac{34 \times 100}{212.1}$

Allow mass or Mr of desired product times one hundred divided by total mass or Mr of reactants/products
If 34/212.1 seen correctly award M1

1

= 16.0(3)%

Allow 16%
16 scores 2 marks

1

(c) 100(%)

Ignore all working

1

(d) PV = nRT or n = $\frac{PV}{RT}$

If rearranged incorrectly lose M1 and M3

1

n = $\frac{100000 \times 1.53 \times 10^{-2}}{8.31 \times 310}$

M2 for mark for converting P and T into correct units in any expression

1

= 0.59(4)

Allow 0.593
M3 consequential on transcription error only not on incorrect P and T

1

(e) (Na_2SO_4) H_2O
(44.1%) 55.9%

M1 is for 55.9

1

44.1/142.1 55.9/18
0.310 3.11
= 1 = 10

Alternative method gives180 for water part = 2 marks

1

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x = 10

X = 10 = 3 marks
10.02 = 2 marks

1

[13]

Q32.

(a) (i) 0.00301/ 3.01 × 10^{-3};

Penalise < 3sf in (a)(i);

Allow 3.01 × 10^{-3} – 3.05 × 10^{-3}.
(for candidates who have used Mg as 24)

1

(ii) 0.00602

Allow correct answer a(i) × 2.

1

(iii) 0.00965/ 9.65 × 10^{-3};

Allow 0.009646/ 0.0096-0.0097.

1

(iv) 0.00363 moles;

Allow range 0.0035 to 0.0037.
Allow (a)(iii) – 2 (a)(ii) (must be positive).

1

(b) PV = nRT;

Allow all capitals/ lower case.

1

$$V = \frac{0.512 \times 8.31 \times 298}{96000};$$

M2 Mark is for <u>all numbers correct</u>.
If units in answer are in dm^3 allow this expression with 96 in denominator.

1

0.0132 m^3/ 13.2 dm^3;

M3 <u>Must have correct units</u>/
allow 13200 cm^3.
Allow min 2 sig figs in answer.

1

(c) O = 69.6 (%);

1

$$\frac{30.4}{14} \quad \frac{69.6}{16} \qquad 2.17 : 4.35$$

Use of 7/8 CE then M1 only.

1

(1 : 2) <u>NO_2</u>

Mark for formula not ratio.

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If NO_2 and no working shown then allow 1 mark.
If 69.6% + NO_2 only = 2.
Need to see evidence of M2 working.
Allow M2 conseq on the wrong M1 (ie max 1).

1

[10]

Q33.

(a) percentage of oxygen is 58.33

1

correct calculation of ratios (C 3.125, H 4.17, O 3.645)

1

clearly relates ratios to formula eg
simplifies ratios (C 1, H 1.29, O 1.17) or for H then 3.125 × 8 / 6 = 4.17% etc

1

Notes
** correct percentage of oxygen can be stated or shown clearly in a calculation*
** to score final mark must **clearly** show how ratios relate to $C_6H_8O_7$*
** allow full credit to candidate who correctly finds*
percentage of oxygen
calculates M_r
shows percentage of H is 8 divided by M_r

(b) carbon dioxide / CO_2

1

(c) (i) suitable reaction vessel
eg sealed flask or test-tube with side arm or
eg tube in bung

1

suitable collection method
eg gas syringe / over water in measuring
eg cylinder

1

Notes
** collection vessel must allow measurement of gas*
** if apparatus would leak lose second mark*
** ignore heating*
** can draw tubing as single line*
** accept 2D or 3D diagrams*
** do not need labels, and ignore mis-labelling*

(ii) (1) mass on x-axis

1

Notes
** If axes unlabelled use data to decide that mass is on the x-axis*

sensible scales

1

Notes

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** lose this mark if the **plotted points** do not cover at least half of the paper*
** lose this mark if the graph plot goes off the squared paper*

plots points correctly ± one square

1

(2) draws appropriate straight line of best fit, omitting point at 1.17g / 86 cm^3

Notes
** lose this mark if the line deviates towards the point at 1.17g / 86 cm^3*
** candidates does not have to extrapolate the line to the origin to score this mark*
** when checking for best fit, candidate's line **must** go through the origin ± one square. Extend candidate's line if necessary*

1

(3) 129 ± 1 cm^3

Notes
** accept this answer **only***

1

(d) CO_2 / gas formed distends stomach / produces wind / increases pressure in stomach

1

(e) molecular formula has to be a simple multiple of the empirical formula

1

so approximate M_r value will distinguish between the options or equivalent wording

1

(f) gas escapes before bung inserted any 2 × 1 for

syringe sticks

carbon dioxide soluble in water

Notes
** do **not** accept 'operator error' / 'inaccurate equipment' / 'equipment leaks'*

2

(g) volume depends on pressure and temperature

Notes
** do **not** accept 'to get a more accurate result' or equivalent wording without qualification*

1

(h) Tablets could vary between samples or equivalent wording

Notes
** do **not** accept 'to get a more accurate / reliable result' or 'to make a fair test'*

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without qualification

1

(i) (i) $NaHCO_3$ **least** soluble

1

(ii) exhaust gases passed into mixture of NaCl and NH_3

1

(j) $2NaHCO_3 \rightarrow Na_2CO_3 + CO_2 + H_2O$

Notes
* *accept multiples*

1

(k) 106.0 divided by 217.1 × 100 = 48.8%

Notes
* *ignore precision of answer*

1

[22]

Q34.

(a) (i) Moles of gas produced = 3

1

PV = *nRT*

1

V = *nRT/P* = 3 × 8.31 × 298/100000

1

= 7.43×10^{-2} m^3

1

(ii) $7.43 \times 10^{-2} \times 1000/298 = 0.249$ m^3

1

(b) (i) any two from:

exhaust gases hot so would boil the solution away
solution would splash
reaction might be too slow
would need continuous supply of solution and/or replacement of products

2

(ii) *Commercial advantage* could sell chlorine and/or hydrogen

1

environmental disadvantage generation of electricity likely to lead to release of CO_2 (or chlorine toxic)

1

(c) % O = 74%

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1

N:O = 26/14:74/16

1

= 1.86: 4.63 = 1:2.5 therefore formula is N_2O_5

1

(d) $2N_2O \rightarrow 2N_2 + O_2$

1

(e) Proportion of O_2 increased leading to higher T (or more complete combustion)

1

[14]

Q35.

(a) (i) Avogadro's number/constant of molecules/particles/species / 6×10^{23}

[Not 'atoms']

1

Or same number of particles as (there are atoms)

[Not molecules]

in 12.(00)g of ^{12}C

1

(ii) *Moles* $O_2 = \frac{0.350}{32}$ *(= 1.09 × 10⁻² mol)*

1

= 29 (× 1.09 × 10^{-2})

[Accept answers via 4 separate mole calculations]

1

= 0.316 – 0.317 mol [answer to 3 + sf]

[Mark conseq on errors in M1/M2] (1)

1

(iii) Moles of nitroglycerine = 4 × 1.09 × 10^{-2} (= 0.0438 mol)

[Mark conseq on their moles of O_2]

1

M_r of nitroglycerine = 227 or number string

1

Moles of nitroglycerine = 227 × 0.0438 = 9.90 – 9.93(g)

[answer to 3+ sf]

[If string OK but final answer wrong then allow M6 but AE for M7]

[Mark conseq on error in M_r] [Penalise wrong units]

[Penalise sig. fig. errors once only in whole question]

(b) pV = nRT **or** $pV = \frac{mRT}{V}$ **or** $p = \frac{mRT}{V}$

1

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$$p = \frac{nRT}{V} = \frac{0.873 \times 8.31 \times 1100}{1.00 \times 10^{-3}}$$

1

= 7980093 **or** 7980 **or** 7.98

[ignore s.f.]

1

units = Pa **or** kPa **or** MPa (as appropriate)

[If error in conversion from Pa, treat as a contradiction of the units mark]

[If transfer error, mark conseq but penalise M2]

[If data from outside of above used, penalise M2 and M3]

[If pV expression incorrectly rearranged, penalise M2 and M3]

[if T = 1373 K used, penalise M2]

1

[11]

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Q1.

(a) Most students were able to calculate the M_r of the unknown volatile liquid correctly. Many students, however, did not give a correct definition for relative molecular mass or confused this with the definition for relative atomic mass; a good number did not convert the data to take account of the different units. Pleasingly, 59.4% of students scored at least four marks.

(b) This proved to be demanding for many students with well over half of them failing to score; many felt that that the calculated M_r would have been less than the actual M_r. Only a few students considered the impact that a lower volume of gas (using pV=nRT) would have on the calculation of the measured amount of moles.

Q2.

(a) This levels-of-response question discriminated very well, with approximately one third of students scoring marks in each of the three levels. Some excellent answers were seen. Some students, however, answered very well initially but then used wrong terminology, for example wrong bonding and/or intermolecular forces in all/some of the substances, and showed contradictions in their answers.

(b) Unfortunately, the equation was often seen with sodium oxide as the product rather than sodium hydroxide. In the calculation, many students did not use the 2:1 ratio from the equation, leading to an answer of 267 cm^3. However, this part of the question also discriminated well, with over 25% of students gaining full marks; most students scored some marks and less than 3% scored zero.

(c) Just under half of the students (48.5%) gave a correct answer; the commonest error was to multiply the amount, in moles, by volume rather than dividing by volume.

(d) This part discriminated well, though only a few students (7%) scored full marks. The structure often had the wrong number of lone pairs and/or the wrong bond angle. That lone pair-lone pair repulsion is greater than bond pair-bond pair repulsion was known by the majority of students.

Q3.

(a) Most students made some progress with this calculation to find the M_r of a volatile hydrocarbon, but few scored full marks. Key problems were incorrect rearrangement of the ideal gas equation, incorrect unit conversions for volume (from cm^3 to m^3), pressure (from kPa to Pa) and mass (from mg to g). In this question, working was required and each step in the calculation was marked separately. This meant that students who got the correct answer without working, or with incorrect working, were penalised. Some students, who arrived at a correct final value, scored zero marks as they made multiple very significant errors that, by chance, cancelled out. In addition, many students failed to give the final answer to two significant figures (which was based on the gas volume – given as 72 cm^3).

(b) Most students started this question correctly but struggled to convert the ratio 6.975:16.3 to 3:7, with 7:16 and 1:2 being common errors, and so failed to deduce the empirical formula. Some students still managed to deduce the molecular formula using the M_r alone. Again, students could not score full marks on this question without showing full working.

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Q5.

A good proportion of students (43.8%) could do this, but many may not have appreciated that the two identical flasks at the same temperature and pressure will contain the same number of gaseous molecules.

Q15.

There was some confusion over unit conversions but the main error related to an incorrect application of the reacting ratio; consequential marking was allowed here.

Q16.

Perhaps because it was similar to questions asked in the previous specification, Question (a) was quite well answered but a common mistake was to use values with incorrect units for the variables in the $pV = nRT$ calculation. Question (b) was much less well answered with many students calculating the total volume of the two flasks but failing to answer the question and give the volume of flask P in cm^3.

Q17.

This question was also not answered correctly by most; this idea has not been tested often in the previous specification so students may not have had much prior experience of the type of question.

Q18.

This question proved to be the most challenging multiple choice question. Errors may have stemmed from some students running short of time and/or not using SI units in the calculations.

Q19.

The calculation in part (a) was answered well with many students scoring full marks. Common mistakes included using a *Mr* of 31 for P_4 or that of phosphorus(V) oxide or misreading the question and starting with 200g of phosphorus. The correct answer to the calculation in part (b) was seen regularly. The most common errors were incorrectly calculating the amount in moles of phosphoric acid since they failed to convert the volume of solution from m_3 into dm_3 or failed to use the factor of 4 from the equation. Part (c) discriminated well. Alternative methods based upon mass or moles were seen and these were all given full credit. The most common error was incorrectly calculating the amount in moles of phosphoric acid since many students failed to convert the given mass in kg into grams. A number of students failed to use the factor of 2 from the equation or misread the question and calculated the percentage yield of sulfuric acid. Part (d) was well answered although there were some students who incorrectly based their answer on moles of product formed and others who thought that a one step process was more economical.

Q20.

The correct answer to the calculation in part (a) was seen regularly, but there were some students who made an attempt at it, gained two or three marks, and then could not complete the calculation. The most common errors were either to ignore the factor of 2 from the equation or multiply by 78 rather than 39. The calculation in part (b) was attempted by almost all students resulting in the full range of marks. The first three marks were regularly seen in students' answers but often this was followed by a failure to multiply by the correct factor from the equation. It was disappointing to note that there

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were still some students who could not rearrange the ideal gas equation correctly. In part (c)(i) many students did not score full marks since they could not convert volume into dm3 and therefore could not give the concentration in mol dm^{-3} as asked for in the question. Many students could not balance the equation in part (c)(ii). Part (d) was well answered although there were some students who thought the azide ion was N^{3-} rather than N^{3-}. The arrow in part (e)(i) was rarely in the right place and it was disappointing to note how many did not use an arrowhead on one of the bonds shown as specified in the question. Part (e)(ii) was not well answered with many students suggesting species that were not molecules; Ti was a common incorrect answer. The whole range of answers was seen in part (e)(iii) but many students were able to identify the correct formula.

Q21.

Part (a)(i) produced the usual crop of poor scales and poor lines of best fit that were curiously accepted by some centres. Additionally, a failure to plot the point at 0,0 should be penalised. Part (a)(ii) was a very easy question and there were many good answers to parts (b)(i) and (ii). Weaker students still have problems with correct substitution and rearrangement of the equation. Part (b)(iii) was a more challenging question and many Centres failed to give credit for a (correct) alternative method. Part (c) again highlighted the need for students to get better training in the drawing of diagrams. This is a communication skill and correct chemical apparatus should be seen – poor bungs and cross-sections were very common and centres were often too lenient in their marking.

Q22.

Most students could calculate the amount in moles in part (a)(i) but some did not give their answer to the required precision. In part (a)(ii), some students did not use the stoichiometry of the equation to answer the question. Many students found part (a)(iii) difficult because they could not calculate the number of moles of NO_2 to substitute into the Ideal Gas equation. The conversion of pressure and temperature into the appropriate units was also often incorrect. Part (b) was not well known and in part (c) many students failed to see the significance of gaseous products.

Q23.

Students are generally confident using the ideal gas equation although some felt the need to convert volume into different units as well. Many students scored three of the possible four marks in part (a) by failing to realise that the question asked about nitrogen oxide only. Some students who realised this still did not quote their answer to the required precision. In part (b), students were more likely to score marks in (b)(i) but a few did not convert to grams in order to calculate the amount in moles. Students found part (b)(ii) difficult with the most common error being the failure to understand the mole ratios in the equation. The calculation in part (c) was not well done by many students since they did not use the balanced equation given and hence did not use the correct mole ratio in their calculation. In part (d), many students referred to nitrogen dioxide as a greenhouse gas and some students failed to score a mark since they gave a list of correct and incorrect answers and were penalised for this. Most students were able to give a correct answer to part (e), although many incorrect answers stated that excess air was needed simply to give a good supply of oxygen. Most students were able to give the correct answer to part (f) although a small, but significant, number quoted exothermic or oxidation.

Q24.

The unstructured calculation in part (a) was attempted by all but a few students. Most students managed to score two marks. The most common errors were the incorrect conversion of pressure and volume into the appropriate units and a failure to divide the

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total moles of gas by five. The equation in part (b) was often incorrect with many examples of B_2 and atomic chlorine given. The students who knew that there were three bonding pairs of electrons often did not realise that the repulsions of the bonding pairs were equal. The calculation in part (c)(i) was reasonably well answered. Many students scored the first two marks but then incorrectly multiplied by 500/1000. Very few produced the expected equation in part (c)(ii) although the alternative equations were often seen. Many examples of the incorrect formulae '$NaBO_3$' and 'NaB' in unbalanced equations were also seen. Part (d) was well answered by the majority of students. A wide variety of methods were seen that could score full marks in part (e). The first three marks were usually obtained but the final mark proved elusive. Many students suggested that the molecular formula was $2BCl_2$ rather than the correct answer, B_2Cl_4.

Q25.

Many students found the unstructured calculation in part (a) difficult. Weaker students divided the mass by 3 × 207.2 and many did not use the 8/3 ratio. Some students obtained the correct volume of nitric acid but then failed to give their answer to the required precision. The calculation in part (b) was generally well answered by the more able students but many weaker students found the conversion of volume into the correct units difficult. The balancing of the equation in part (c)(i) was generally well done although many students attempted to correct their work by writing one number over another leading to unclear answers. It is better to cross out and rewrite numbers. There were many correct answers to part (c)(ii) although answers to part (c)(iii) showed that many students did not realise that it is hard to separate gases. A few students thought that oxygen would be difficult to separate from PbO.

Q26.

Parts (a)(i), (ii) and (iii) were generally well done although many answers were not given to the precision required in the question. Part (a)(iv) was found to be difficult and generated answers such as 'displacement' and 'condensation'. The calculation in part (b)(i) was done well by many candidates but a significant number could not rearrange the equation correctly or convert the given pressure and temperature into the correct units. In part (b)(ii) there was a tendency to divide by 2 or 7. The empirical formula calculation in part (e) differentiated well with weaker candidates usually scoring only one of the available marks.

Q27.

(a) Virtually all candidates scored at least two marks for the graph in this part (i). The usual error was a poor scale, and most centres correctly penalised this. In this part (ii), drawing a straight line of best-fit was more demanding. Some candidates ignored the hint about anomalous points, while a surprising number did not realise that the origin is an extra point in this graph. Some centres were generous when marking best-fit lines.

In this part (iv) proved surprisingly demanding. Even A grade candidates failed to remember that the smallest volume will usually have the greatest error in measurement.

(b) Only the higher-scoring candidates obtained full marks in part (ii). The volume conversion was the usual mistake, although weaker candidates could not rearrange the ideal gas equation correctly. Similarly in part (iii) many candidates failed to scale up by a factor of ten. A number of centres were too harsh here, penalising this error by two marks.

In this part (iv) a majority of candidates could not correctly apply a factor to account

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for a 95% yield. This was an area where some teachers were very generous, ignoring a palpably incorrect method and crediting an answer which looked similar to the correct answer because the candidate had rounded the final figure.

This part (v) saw a number of vague answers, such as 'Limestone won't harm the environment' or incorrect answers such as 'Sodium hydroxide is toxic', wrongly being awarded a mark.

Q28.

The calculations in part (a) discriminated very well. Parts (a)(i) and (a)(ii) were generally well done although some candidates confused three decimal places and three significant figures or gave their answers to only one or two significant figures. Parts (a)(iii) and (a)(iv) proved more difficult. Many candidates did not read the rubric of the question and did not give their answer to one decimal place. Answers to part (a)(v) were varied. Even those candidates who reached the correct M_r could not always calculate the A_r of the metal. Common errors included failing to divide by 2 so the answer given was Se with an A_r of 78.2. The calculation in part (b) was extremely well done. Very few candidates could not rearrange the equation. The errors seen were incorrect conversion of the pressure unit or needlessly converting the volume unit. In part (c), most candidates answered this well with less able candidates suggesting that toxic or flammable gases were produced. The calculation in part (d)(i) was generally well done although many candidates used the Ar of magnesium as 24 rather than 24.3 and rounded their answer to 0.070. Part (d)(ii) discriminated well although it defeated many candidates.

Q29.

Part (a)(i) was done well but the 5/2 ratio in part (a)(ii) proved very difficult for many candidates. The calculation in part (b) was attempted well but the conversion into cubic decimetres proved challenging for a large number of candidates. Part (c)(i) was answered well but part (c)(ii) was less well answered.

Q30.

(a) In this part, the vast majority of candidates correctly stated the ideal gas equation.

(b) In this part, many candidates wrote a correct equation which included fractional numbers of moles. This version of a multiple of the expected answer is acceptable and should have been rewarded with a mark.

(c) This part was poorly answered. Most candidates simply calculated the ratio of the numbers given in the stem and converted to a percentage. This was not worth a mark. Yield calculations must start with the appropriate M_r values to earn any credit.

Q31.

Parts (a)(i) and (ii) were generally answered well although a disappointing number of candidates were unable to calculate the M_r for the given formula correctly in part (a)(i). Candidates should be able to give their answers to three significant figures when this degree of precision is given in the data in the question. Some candidates used only one significant figure or truncated their answers. Part (a) (iii) proved more challenging with many candidates missing out the factor of 1000. Several errors were made in part (b) including using an incorrect total for the M_r of the reactants, using 17 instead of 34 for ammonia, and failing to multiply by 100. Candidates would find it beneficial to learn the definition of atom economy and write it at the start of their answer. A surprising number of candidates failed to answer part (c) correctly. Some attempted a calculation, which was

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not needed, and failed to achieve the correct answer. In part (d) the equation PV= *n*RT was well known but some candidates were unable to rearrange this to calculate *n* or were unable to convert temperature and pressure into the correct units. The empirical formula calculation in part (e) was tackled well by a large number of candidates. Weaker candidates found difficulty getting started and some only calculated the water percentage. Some candidates then divided 55.9 by 18 and gave the answer as 3.

Q32.

This was generally well done and candidates appear to be able to do simple numerical questions. There was confusion over the number of decimal places in the answers with some candidates simply writing all the digits from their calculator. In general, answers should be to the same number of significant figures as given in the question. The major problem with part (b) was the conversion of pressure into the correct units and the subsequent effect on the units of the answer. Part (c) was done well by the majority of candidates. It should however be stressed that the answer to an empirical formula calculation is a formula and not simply the ratio of the elements.

Q33.

In part (a) most candidates easily scored the first two marks, but converting the ratios to an empirical formula was more demanding. Some centres virtually awarded this mark by default, even when the candidate's explanation for the third mark was simply wrong.

In part (c)(i) the candidate was required to draw simple apparatus. Many candidates drew a practical set-up that would not work. The common problems were that the gas could not escape from the preparation vessel or that the collection vessel was not graduated and could therefore not record volume. A number of candidates assembled apparatus that was unsafe and should not have been awarded any marks at all. Marking of this question was often very generous indeed.

In part (c)(ii) the candidate was required to draw a simple graph. This generated the usual problems with marks being wrongly awarded for plotted points which did not cover half the paper and for graphs containing incorrectly plotted points. If the candidate's graph included the origin, then the candidate's line had to pass through the origin to score the line of best fit mark.

When candidates wrote 'because a gas is produced' as an answer to part (d) they were often credited with a mark. In general, candidates do not receive a mark for basically rewording part of a question rubric. The Marking Guidelines were quite clear that the effect on the human body was needed in a correct answer

Part (e) was, perhaps, the most demanding question of all. Full marks were rarely seen because the great majority of candidates struggled to express themselves clearly. Marking of this question was often very generous indeed. Candidates were often given a mark for any chemical reference to empirical or molecular formula. In this question two distinct ideas were required for the full award. Candidates needed to link molecular formula to empirical formula as a multiple and then say that a small error in the molecular formula mass would still allow a good judgement of which multiplier should have been used.

Marking was often very generous in part (f). When candidates are asked to suggest reasons why an experiment might not deliver the expected result the candidate is expected to suggest something more imaginative than misread the apparatus' or 'the apparatus was faulty'. The Marking Guidelines were quite clear that a reference to when the apparatus was assembled was needed for a gas leak to be worth a mark. The idea of the gas remaining in the flask was not sufficient unless the possibility of the gas dissolving was specifically mentioned.

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In part (g) a statement of the Gas Law was often given a mark. ‘PV = nRT’ is not a sufficient answer since it does not show that the candidate understands what the equation means in regard to the volume of the gas.

In part (i)(i) centres were too generous in the interpretation of the key words in an answer. “Less soluble” and “not very soluble” were not acceptable alternatives to “least soluble”.

Centres are asked to check candidates’ equations carefully. Some candidates had an incorrect equation for part (j) but were still given a mark.

Q35.

Part (a)(i) was often poorly answered. Answers in terms of M_r and mass were quite common, as were statements such as the *number of atoms/particles in lg of substance.* Candidates, who correctly defined a mole in terms of the Avogadro constant, often spoiled their answer by misquoting its value or by referring to there being the Avogadro number of atoms, rather than molecules, in a mole of molecules. Some good answers linking the mole to the number of atoms of carbon in 12.00 g of ^{12}C, were seen.

-

In part a(ii), the majority of candidates, when attempting to calculate the number of moles of oxygen formed in the reaction, divided the mass by 16 rather than by 32. Also, in part (a)(iii), a surprising number of candidates used 908, rather than 227, as the M_T for nitroglycerine. Similarly, there were many errors in determining the total number of moles of gas formed; the most common error being 28, rather than 29. As the remaining marks were awarded consequentially, many candidates still achieved a reasonable mark for this calculation. In part (b), the Gas law expression was well known and the question was well answered. However, a significant number of candidates, having correctly calculated the pressure and quoted its units as Pa., thereby earning all 4 marks, chose to convert their answer into larger pressure units. Errors in this conversion were quite common and so the final mark was lost.

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Q1.

The removal of silicon dioxide with limestone in the Blast Furnace can be represented by the following equation.

$$CaCO_3(s) + SiO_2(s) \rightarrow CaSiO_3(l) + CO_2(g)$$

The volume of carbon dioxide, measured at 298 K and 1.01×10^5 Pa, formed in this reaction during the removal of 1.00 tonne (1000 kg) of silicon dioxide is

A 24.5 dm^3

B 408 dm^3

C 24.5 m^3

D 408 m^3

(Total 1 mark)

Q2.

Potassium nitrate, KNO_3, decomposes on strong heating, forming oxygen and solid **Y** as the only products.

(a) A 1.00 g sample of KNO_3 (M_r = 101.1) was heated strongly until fully decomposed into **Y**.

(i) Calculate the number of moles of KNO_3 in the 1.00 g sample.

_____

_____

(ii) At 298 K and 100 kPa, the oxygen gas produced in this decomposition occupied a volume of 1.22×10^{-4} m^3.

State the ideal gas equation and use it to calculate the number of moles of oxygen produced in this decomposition.
(The gas constant R = 8.31 J K^{-1} mol^{-1})

Ideal gas equation _____

Moles of oxygen _____

_____

_____

_____

_____

(5)

(b) Compound **Y** contains 45.9% of potassium and 16.5% of nitrogen by mass, the remainder being oxygen.

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(i) State what is meant by the term *empirical formula*.

_____

_____

(ii) Use the data above to calculate the empirical formula of **Y**.

_____

_____

_____

(4)

(c) Deduce an equation for the decomposition of KNO_3 into **Y** and oxygen.

_____

(1)

(Total 10 marks)

Q3.

(a) Lead(II) nitrate may be produced by the reaction between nitric acid and lead(II) oxide as shown by the equation below.

$PbO + 2HNO_3 \rightarrow Pb(NO_3)_2 + H_2O$

An excess of lead(II) oxide was allowed to react with 175 cm^3 of 1.50 mol dm^{-3} nitric acid. Calculate the maximum mass of lead(II) nitrate which could be obtained from this reaction.

_____

_____

_____

_____

_____

(4)

(b) An equation representing the thermal decomposition of lead(II) nitrate is shown below.

$2Pb(NO_3)_2(s) \rightarrow 2PbO(s) + 4NO_2(g) + O_2(g)$

A sample of lead(II) nitrate was heated until the decomposition was complete. At a temperature of 500 K and a pressure of 100 kPa, the total volume of the gaseous mixture produced was found to be 1.50×10^{-4} m^3.

(i) State the ideal gas equation and use it to calculate the total number of moles of gas produced in this decomposition.
(The gas constant R = 8.31 J K^{-1} mol^{-1})

Ideal gas equation _____

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Total number of moles of gas _____

_____

_____

_____

(ii) Deduce the number of moles, and the mass, of NO_2 present in this gaseous mixture. (If you have been unable to calculate the total number of moles of gas in part (b)(i), you should assume this to be 2.23×10^{-3} mol. This is not the correct answer.)

Number of moles of NO_2 _____

_____

Mass of NO_2 _____

_____

(7)

(Total 11 marks)

Q4.

(a) Ammonium sulphate reacts with aqueous sodium hydroxide as shown by the equation below.

$$(NH_4)_2SO_4 + 2NaOH \rightarrow 2NH_3 + Na_2SO_4 + 2H_2O$$

A sample of ammonium sulphate was heated with 100 cm^3 of 0.500 mol dm^{-3} aqueous sodium hydroxide. To ensure that all the ammonium sulphate reacted, an excess of sodium hydroxide was used.
Heating was continued until all of the ammonia had been driven off as a gas.
The unreacted sodium hydroxide remaining in the solution required 27.3 cm^3 of 0.600 mol dm^{-3} hydrochloric acid for neutralisation.

(i) Calculate the original number of moles of NaOH in 100 cm^3 of 0.500 mol dm^{-3} aqueous sodium hydroxide.

_____

_____

(ii) Calculate the number of moles of HCl in 27.3 cm^3 of 0.600 mol dm^{-3} hydrochloric acid.

_____

_____

(iii) Deduce the number of moles of the unreacted NaOH neutralised by the hydrochloric acid.

_____

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(iv) Use your answers from parts (a) (i) and (a) (iii) to calculate the number of moles of NaOH which reacted with the ammonium sulphate.

_____

_____

(v) Use your answer in part (a) (iv) to calculate the number of moles and the mass of ammonium sulphate in the sample.
(If you have been unable to obtain an answer to part (a) (iv), you may assume that the number of moles of NaOH which reacted with ammonium sulphate equals 2.78×10^{-2} mol. This is not the correct answer.)

Moles of ammonium sulphate _____

_____

Mass of ammonium sulphate _____

_____

(7)

(b) A 0.143g gaseous sample of ammonia occupied a volume of 2.86×10^{-4} m^3 at a temperature ***T*** and a pressure of 100 kPa.

State the ideal gas equation, calculate the number of moles of ammonia present and deduce the value of the temperature ***T***.

(The gas constant $R = 8.31$ J K^{-1} mol^{-1})

Ideal gas equation _____

Moles of ammonia _____

_____

*Value of **T*** _____

_____

_____

_____

_____

(4)

(Total 11 marks)

Q5.

(a) Sodium carbonate forms a number of hydrates of general formula $Na_2CO_3.xH_2O$

A 3.01 g sample of one of these hydrates was dissolved in water and the solution made up to 250 cm^3.
In a titration, a 25.0 cm^3 portion of this solution required 24.3 cm^3 of 0.200 mol^{-1} dm^{-3} hydrochloric acid for complete reaction.

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The equation for this reaction is shown below.

$Na_2CO_3 + 2HCl \rightarrow 2NaCl + H_2O + CO_2$

(i) Calculate the number of moles of HCl in 24.3 cm^3 of 0.200 mol dm^{-3} hydrochloric acid.

_____

(ii) Deduce the number of moles of Na_2CO_3 in 25.0 cm^3 of the Na_2CO_3 solution.

_____

(iii) Hence deduce the number of moles of Na_2CO_3 in the original 250 cm^3 of solution.

_____

(iv) Calculate the M_r of the hydrated sodium carbonate.

_____

_____

(5)

(b) In an experiment, the M_r of a different hydrated sodium carbonate was found to be 250.
Use this value to calculate the number of molecules of water of crystallisation, *x*, in this hydrated sodium carbonate, $Na_2CO_3.xH_2O$

_____

_____

_____

_____

(3)

(c) A gas cylinder, of volume 5.00×10^{-3} m^3, contains 325 g of argon gas.

(i) Give the ideal gas equation.

_____

(ii) Use the ideal gas equation to calculate the pressure of the argon gas in the cylinder at a temperature of 298 K.
(The gas constant $R = 8.31$ J K^{-1} mol^{-1})

_____

_____

_____

_____

(4)

(Total 12 marks)

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Q6.

An equation for the incomplete combustion of butane in oxygen is

$$C_4H_{10} + 4\ \tfrac{1}{2}O_2 \rightarrow 4CO + 5H_2O$$

The volume in dm^3 of oxygen at 295 K and 100 kPa required to burn 0.1 mol of butane to form steam and carbon monoxide only is

A 8.6

B 11

C 12

D 16

(Total 1 mark)

Q7.

Compound **A** is an oxide of sulphur. At 415 K, a gaseous sample of **A**, of mass 0.304 g, occupied a volume of 127 cm^3 at a pressure of 103 kPa.

State the ideal gas equation and use it to calculate the number of moles of **A** in the sample, and hence calculate the relative molecular mass of **A**.
(The gas constant R = 8.31 J K^{-1} mol^{-1})

Ideal gas equation _____

Calculation _____

_____

_____

_____

_____

(Total 5 marks)

Q8.

Sodium hydrogencarbonate decomposes on heating as shown by the equation below.

$$2NaHCO_3 \rightarrow Na_2CO_3 + H_2O + CO_2$$

The volume of carbon dioxide, measured at 298 K and 101 kPa, obtained by heating 0.0500 mol of sodium hydrogencarbonate is

A 613 cm^3

B 1226 cm^3

C 613 dm^3

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D 1226 dm^3

(Total 1 mark)

Q9.

(a) A sample of ethanol vapour, C_2H_5OH (M_r = 46.0), was maintained at a pressure of 100 kPa and at a temperature of 366K.

(i) State the ideal gas equation.

_____

(ii) Use the ideal gas equation to calculate the volume, in cm^3, that 1.36 g of ethanol vapour would occupy under these conditions.
(The gas constant R = 8.31 J K^{-1} mol^{-1})

_____

_____

_____

_____

_____

_____

_____

(5)

(b) Magnesium nitride reacts with water to form magnesium hydroxide and ammonia.

(i) Balance the equation, given below, for the reaction between magnesium nitride and water.

$$Mg_3N_2 + H_2O \rightarrow Mg(OH)_2 + NH_3$$

(ii) Calculate the number of moles, and hence the number of molecules, of NH_3 in 0.263 g of ammonia gas.
(The Avogadro constant L = 6.02 × 10^{23} mol^{-1})

_____

_____

_____

_____

_____

(4)

(c) Sodium carbonate is manufactured in a two-stage process as shown by the equations below.

$$NaCl + NH_3 + CO_2 + H_2O \rightarrow NaHCO_3 + NH_4Cl$$

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$$2NaHCO_3 \rightarrow Na_2CO_3 + H_2O + CO_2$$

Calculate the maximum mass of sodium carbonate which could be obtained from 800 g of sodium chloride.

_____

_____

_____

_____

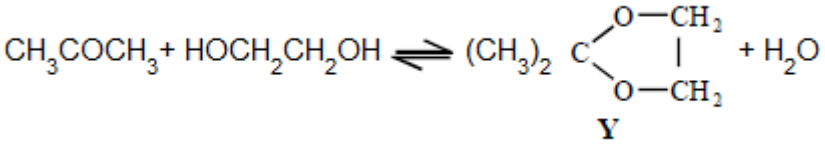
_____

(4)

(Total 13 marks)

Q10.

This question is about the reaction between propanone and an excess of ethane-1,2-diol, the equation for which is given below.



Y

In a typical procedure, a mixture of 1.00 g of propanone, 5.00 g of ethane-1,2-diol and 0.100 g of benzenesulphonic acid, $C_6H_5SO_3H$, is heated under reflux in an inert solvent. Benzenesulphonic acid is a strong acid.

If 1.00 g of propanone was vapourised at 100 °C and 100 kPa pressure, the volume in m^3 of gas formed would be

A 31.0

B 8.31

C 0.534

D 5.34×10^{-4}

(Total 1 mark)

Q11.

When a sample of liquid, **X,** of mass 0.406 g was vaporised, the vapour was found to occupy a volume of 2.34×10^{-4} m^3 at a pressure of 110 kPa and a temperature of 473 K.

(a) Give the name of the equation $pV = nRT$.

_____

(1)

(b) Use the equation $pV = nRT$ to calculate the number of moles of **X** in the sample and hence deduce the relative molecular mass of **X.**

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(The gas constant R = 8.31 J K^{-1} mol^{-1})

*Moles of **X*** _____

_____

_____

*Relative molecular mass of **X*** _____

_____

(4)

(c) Compound **X,** which contains carbon, hydrogen and oxygen only, has 38.7% carbon and 9.68% hydrogen by mass. Calculate the empirical formula of **X**.

_____

_____

_____

_____

(3)

(d) Using your answers to parts (b) and (c) above, deduce the molecular formula of **X**.

_____

_____

(1)

(Total 9 makrs)

Q12.

Nitrogen dioxide dissociates according to the following equation.

$$2NO_2(g) \rightleftharpoons 2NO(g) + O_2(g)$$

When 21.3 g of nitrogen dioxide were heated to a constant temperature, T, in a flask of volume 11.5 dm^3, an equilibrium mixture was formed which contained 7.04 g of oxygen.

(a) (i) Calculate the number of moles of oxygen present in this equilibrium mixture and deduce the number of moles of nitrogen monoxide also present in this equilibrium mixture.

Number of moles Of O_2 at equilibrium _____

_____

Number of moles of NO at equilibrium _____

(ii) Calculate the number of moles in the original 21.3 g of nitrogen dioxide and hence calculate the number of moles of nitrogen dioxide present in this equilibrium mixture.

Original number of moles of NO_2 _____

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_____

Number of moles of NO_2 at equilibrium _____

_____

(4)

(b) Write an expression for the equilibrium constant, K_c, for this reaction. Calculate the value of this constant at temperature T and give its units.

Expression for K_c _____

_____

Calculation _____

_____

_____

_____

_____

(4)

(c) The total number of moles of gas in the flask is 0.683. Use the ideal gas equation to determine the temperature *T* at which the total pressure in the flask is 3.30×10^5 Pa.

(The gas constant $R = 8.31$ J $K^{-1}mol^{-1}$)

_____

_____

_____

_____

_____

(3)

(d) State the effect on the equilibrium yield of oxygen and on the value of K_c when the same mass of nitrogen dioxide is heated to the same temperature *T*, but in a different flask of greater volume.

Yield of oxygen _____

Value of K_c _____

(2)

(Total 13 marks)

Q13.

This question relates to the equilibrium gas-phase synthesis of sulphur trioxide:

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$$

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Thermodynamic data for the components of this equilibrium are:

Substance	$\Delta H_f^{\ominus}$ / kJ mol^{-1}	$S^{\ominus}$ / J K^{-1} mol^{-1}
$SO_3(g)$	−396	+257
$SO_2(g)$	–297	+248
$O_2(g)$	0	+204

This equilibrium, at a temperature of 585 K and a total pressure of 540 kPa, occurs in a vessel of volume 1.80 dm^3. At equilibrium, the vessel contains 0.0500 mol of $SO_2(g)$, 0.0800 mol of $O_2(g)$ and 0.0700 mol of $SO_3(g)$.

At equilibrium in the same vessel of volume 1.80 dm^3 under altered conditions, the reaction mixture contains 0.0700 mol of $SO_3(g)$, 0.0500 mol of $SO_2(g)$ and 0.0900 mol of $O_2(g)$ at a total pressure of 623 kPa. The temperature in the equilibrium vessel is

A 307 °C

B 596 K

C 337 °C

D 642 K

(Total 1 mark)

Q14.

(a) The mass of one mole of $_1$H atoms is 1.0078 g and that of one $_1$H atom is 1.6734×10^{-24} g.
Use these data to calculate a value for the Avogadro constant accurate to five significant figures. Show your working.

_____

_____

_____

(2)

(b) How does the number of atoms in one mole of argon compare with the number of molecules in one mole of ammonia?

_____

(1)

(c) A sample of ammonia gas occupied a volume of 0.0352 m^3 at 298 K and 98.0 kPa.
Calculate the number of moles of ammonia in the sample.
(The gas constant R = 8.31 J K^{-1} mol^{-1})

_____

_____

_____

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_____

(3)

(d) A solution containing 0.732 mol of ammonia was made up to 250 cm^3 in a volumetric flask by adding water. Calculate the concentration of ammonia in this final solution and state the appropriate units.

_____

_____

_____

(2)

(e) A different solution of ammonia was reacted with sulphuric acid as shown in the equation below.

$$2NH_3(aq) + H_2SO_4(aq) \rightarrow (NH_4)_2SO_4(aq)$$

In a titration, 25.0 cm^3 of a 1.24 mol dm^{-3} solution of sulphuric acid required 30.8 cm^3 of this ammonia solution for complete reaction.

(i) Calculate the concentration of ammonia in this solution.

_____

_____

_____

_____

(ii) Calculate the mass of ammonium sulphate in the solution at the end of this titration.

_____

_____

_____

_____

(6)

(f) The reaction of magnesium nitride, Mg_3N_2, with water produces ammonia and magnesium hydroxide. Write an equation for this reaction.

_____

(2)

(Total 16 marks)

Q15.

Which one of the following contains the smallest number of moles of carbon dioxide gas?

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A 2.65 g

B 0.0150 m^3 at 1000 K and 33.0 kPa

C 1.50 dm^3 at 327 °C and 200 kPa

D 1500 cm^3 at 300 K and 100 kPa

(Total 1 mark)

Q16.

On complete combustion, 0.0150 mol of an organic acid produced 735 cm^3 of carbon dioxide (measured at 101 kPa and 298 K). The same amount of acid required 15.0 cm^3 of 2.00 M sodium hydroxide solution for neutralisation. Which one of the following could be the formula of the acid?

A HCOOH

B CH_3COOH

C HOOCCOH

D $HOOCCH_2CH_2COOH$

(Total 1 mark)

Q17.

Which one of the following samples of gas, when sealed into a vessel of volume 0.10 m^3, is at the highest pressure?

A 1.6 g of helium (He) at 100 K

B 1.6 g of methane (CH_4) at 100 K

C 1.6 g of oxygen (O_2) at 600 K

D 1.6 g of sulphur dioxide (SO_2) at 1200 K

(Total 1 mark)

Q18.

What is the volume occupied by 10.8 g of the freon CCl_2F_2 at 100 kPa and 273 K?

A 2.02 dm^3

B 2.05 dm^3

C 2.02 cm^3

D 2.05 cm^3

(Total 1 mark)

Q19.

Which one of the following samples of gas occupies the largest volume?

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A 1.0 g of ozone (O_3) at l00 kPa and 300 K

B 1.0 g of oxygen at 100 kPa and 300 K

C 1.0 g of water vapour at 250 kPa and 450 K

D 1.0 g of methane at 333 kPa and 500 K

(Total 1 mark)

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Q1.

D

[1]

Q2.

(penalty for sig fig error =1mark per question)

(a) (i) moles KNO_3 = 1.00/101.1 = 9.89×10^{-3} (mol)

1

(ii) pV = nRT or n = pV/RT

1

moles O2 = n = $\frac{pV}{RT}$ = **(1)** $\frac{100000 \times 1.22 \times 10^{-4}}{8.31 \times 298}$ **(1)**

2

= 4.93×10^{-3} (mol)

1

(mark answer first – check back if wrong)
(transcription error lose M3, mark M4 conseq on error)
(if 'untraceable' figures used M3=M4=0)
(if wrong temp conversion – lose M3 – conseq M4)
(if n = RT/pV CE, lose M3 and M4)

(b) (i) simplest/lowest ratio of atoms of each / element/s in a compound / substance / species / entity / molecule

1

(ii)

K	N	O		
$\frac{45.9}{39.1}$	$\frac{16.5}{14}$	$\frac{37.6}{16}$		(1)
1.17	1.18	2.35		(1)
1	1	2	KNO^2	(1)

(M3 tied to M2), (M3 can be transferred from equation if ratio correct but EF not given) (if calc inverted, lose M2 and M3), (if used At N^1 / wrong No for Ar then CE, lose M2 and M3) (if % of O missing, award M2 only)

3

(c) $2KNO_3 \rightarrow 2KNO_2 + O_2$ or fractions/multiples

(accept $2KNO_3 \rightarrow K_2N_2O_4 + O_2$)
(do NOT accept 'Y' in equation)

1

[10]

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Q3.

(a) moles $HNO_3 = 175 \times 10^{-3} \times 1.5 = (0.2625$ mol);

1

moles $Pb(NO_3)_2 = ½ \times 0.2625 = (0.131$ mol);

1

M_r $Pb(NO_3)_2 = 331(.2)$;

1

mass $Pb(NO_3)_2 = 331.2 \times 0.131 = 43.5$ g;

(accept 43.2 - 43.8)

(M1 & M2 are process marks. If error in M1, or in M2, do not mark M4 consequentially, i.e. do not award M4)
(if atomic numbers used in M3, do not award M4)

1

(b) (i) $pV = nRT$;

1

$$n = \frac{pV}{RT} = \frac{100000 \times 1.5 \times 10^{-4}}{8.31 \times 500};$$

1

$= 3.61 \times 10^{-3}$;

(If pressure not converted to Pa, max 2)

(If $n = \frac{RT}{pV}$ *used = CE; M2 = M3 = 0)*

1

(ii) moles $NO_2 = 4/5 \times 3.61 \times 10^{-3}$;

[mark is for use of 4/5]

1

$= 2.89 \times 10^{-3}$ *OR* 1.78×10^{-3};

1

M_r $NO_2 = 46$;

1

mass$NO_2 = 46 \times 2.89 \times l0^{-3} = 0.1.33$(g)

OR 0.0821 (g);

(if atomic numbers used, M3 = M4 = 0)

1

[11]

Q4.

(a) (i) $100 \times 10^{-3} \times 0.500 = 5.00 \times 10^{-2}$ (mol)

accept $5 \times 10^{-2} / 0.05$

1

(ii) $27.3 \times 10^{-3} \times 0.600 = 1.64 \times 10^{-2} / 1.638 \times 10^{-2}$ (mol) only

1

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(iii) 1.64×10^{-2} (mol)

Mark conseq on (ii)

1

(iv) $5.00 \times 10^{-2} - 1.64 \times 10^{-2} = 3.36 \times 10^{-2}$ (mol)

Mark conseq on (i) & (iii)

1

(v) $3.36 \times 10^{-2} \times ½ = 1.68 \times 10^{-2}$ (mol)

If 2.78×10^{-2} used 1.39×10^{-2}

Mark conseq on (iv)

1

$1.68 \times 10^{-2} \times 132(.1)$ **or** $1.39 \times 10^{-2} \times 132(.1)$

Mark for M_r

1

= 2.22 g **or** 1.83 g

1

(b) pV = nRT

1

$n = \frac{0.143}{17}$ = $8.4(1) \times 10^{-3}$ (mol)

1

$T = \frac{pV}{nR} = \frac{100000 \times 2.86 \times 10^{-4}}{8.31 \times 8.4 \times 10^{-3}}$ (1)

1

= 408.5 – 410.5 (K)

Mark conseq on moles

Note *Sig. fig. penalty - apply once if single sf given, unless calc works exactly*

1

[11]

Q5.

(a) (i) 4.86×10^{-3}

1

(ii) 2.43×10^{-3}

(mark conseq on (a)(i))

1

(iii) 2.43×10^{-2}

(mark conseq on (a)(ii))

1

(iv) $3.01/2.43 \times 10^{-2}$

(mark conseq on (a)(iii))

1

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124

(Do not allow 124 without evidence of appropriate calculation in (a)(iii))

1

(b) $M_r(Na_2CO_3) = 106$
M_r (xH_2O) = 250 –106 = 144 *(mark conseq on M1)*
x = 8 *(mark conseq on M2)*

(Penalise sf errors once only)

3

(c) (i) PV = nRT

1

(ii) Moles A_r = 325/39.9 = 8.15

(accept M_r = 40)

1

P = nRT/V = (8.15 × 8.31 × 298)/5.00 × 10^{-3}
= 4.03 × 10^6 Pa or = 4.03 × 10^3 kPa

Range = 4.02 × 10^6 Pa to 4.04 × 10^6 Pa

(If equation incorrectly rearranged, M3 & M4 = 0 If n =325, lose M2)

(Allow M1 if gas law in (ii) if not given in (i))

2

[12]

Q6.

B

[1]

Q7.

Ideal gas equation: pV = nRT **(1)**

Calculation: n = pV/RT = $\frac{103000 \times 127 \times 10^{-6}}{(8.31 \times 415)}$ **(1)**

mark for volume conversion fully correct

= 3.79 × 10^{-3} (mol) **(1)**

range 3.79 × 10^{-3} to 3.8 × 10^{-3}

M_r = m/n = .304/3.79 × 10^{-3} = 80.1 **(1)**

range 80 – 80.3
min 2 s.f. conseq
If 'V' wrong lose M2; 'p' wrong lose M3; 'inverted' lose M3 and M4

[5]

Q8.

A

[1]

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Q9.

(a) (i) $pV = nRT$ **(1)**

(ii) Moles ethanol = n = 1.36/46 (=0.0296 mol) **(1)**

$V = nRT/p = \frac{0.0296 \times 8.31 \times 366}{100000}$ **(1)**

if V = p/nRT lose M3 and M4

$= 8.996 \times 10^{-4}$ (m^3) **(1)**

$= 899$ (900) cm^3 **(1)** *range = 895 – 905*

*If final answer = 0.899 award (2 + M1); if = 0.899 dm^3 **or** if = 912 award (3 + M1)*

***Note:** If 1.36 **or** 46 or 46/1.36 used as number of moles (**n**) then M2 and M4 not available*

***Note:** If pressure = 100 then, unless answer = 0.899 **dm^3**, deduct M3 and mark consequentially*

5

(b) (i) $Mg_3N_2 + \mathbf{6}H_2O \rightarrow \mathbf{3}Mg(OH)_2 + \mathbf{2}NH_3$ **(1)**

(ii) Moles $NH_3 = \frac{0.263}{17}$ (=0.0155 mol) **(1)**

Number of molecules of $NH_3 = 0.0155 \times 6.02 \times 10^{23}$ **(1)**

[mark conseq] = 9.31×10^{21} **(1)**
[range 9.2×10^{21} to 9.4×10^{21}]

*Conseq (**min** 2 sig fig)*

4

(c) Moles NaCl = 800/58.5 (= 13.68) **(1)**

Moles of $NaHCO_3$ = 13.68 **(1)**

Moles of $Na2CO_3$ = 13.68/2 = 6.84 **(1)**

Mass of Na_2CO_3 = 6.84 × 106 = 725 g **(1)** **[**range = 724 – 727]

[1450 g (range 1448 – 1454) is worth 3 marks]

Accept valid calculation method, e.g. reacting masses or calculations via the mass of sodium present. Also, candidates may deduce a direct 2:1 ratio for $NaCl:Na_2CO_3$

4

[13]

Q10.

D

[1]

Q11.

(a) Ideal gas equation law **(1)**

1

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(b) *Moles of **X***: $n = \frac{PV}{RT}$ **(1)** $= \frac{110000 \times 2.34 \times 10^{-4}}{8.31 \times 473}$

$= 6.55 \times 10^{-3}$ **(1)**

6.5 to 6.6 × 10^{-3} , min 2 sig figs

If write n = $\frac{RT}{PV}$ *zero here, but can score M_r*

*Relative molecular mass of **X***: $M_r = \frac{m}{n}$ **(1)**

= 62 **(1)**

61.5 to 62.5

4

(c) % oxygen = 51.6 **(2)**

C =38.7 / 12 H = 9.68 / 1 O = 57.6**(2)** / 16 **(1)**

= 3.23 = 9.68 = 3.23

1 : 3: 1 ∴ CH_3O **(1)**

If no % O or if wrong A_r used then max 1
Correct empirical formula earns all three marks

3

(d) ($\frac{62}{31}$ × CH_3O) = $C_2H_6O_2$ **(1)**

1

[9]

Q12.

(a) (i) *Number of moles of O_2 at equilibrium:* $\frac{7.04}{32}$ = 0.22 **(1)**

Number of moles of NO at equilibrium: 0.44 **(1)**
OR 2 × mol of oxygen

3

(ii) *Original number of moles of NO_2:* $\frac{21.3}{46}$ = 0.46(3) **(1)**

Number of moles of NO_2 at equilibrium:
0.46(3) – 0.44 = 0.02(3) **(1)**
OR conseq on mol NO above

1

(b) *Expression for K_C*: $K_C = \frac{[NO]^2[O_2]}{[NO_2]}$ **(1)**

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Calculation: $K_C = \frac{\left(\frac{0.44}{11.5}\right)^2 \times \left(\frac{0.22}{11.5}\right)}{\left(\frac{0.023}{11.5}\right)^2}$ = 7.0(0) mol dm^{-3}

(1) (1) (1)

If mol NO_2 = 0.02; K_C = 9.26 (9.3)
or conseq on values from (a)
If vol missed, score only K_C and units
If K_C wrong: max 2 for correct use of vol and conseq units
If K_C wrong and no vol: max 1 for conseq units

3

(c) pV = nRT **(1)**

$T = \frac{pV}{nR} = \frac{(3.30 \times 10^5) \times (11.5 \times 10^{-3})}{0.683 \times 8.31}$ **(1)** =

(1) for using 11.5 × 10^{-3} as V

T = 669 K **(1)**

4

(d) *Yield of oxygen:* increased **(1)**
Value of K_c: no effect **(1)**

2

[13]

Q13.

D

[1]

Q14.

(a) L = $\frac{1.0078}{1.6734 \times 10^{-24}}$ **(1)** or $\frac{\text{mass of 1 mol}}{\text{mass of 1 atom}}$

must show working

= 6.0225 × 10^{23} **(1)**

Ignore wrong units
NB answer only scores 1

2

(b) equal **(1)**

Or same or 1:1

1

(c) PV = nRT (or n = $\frac{PV}{RT}$) **(1)**

= $\frac{98000 \times 0.0352}{8.31 \times 298}$ **(1)**

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= 1.39 **(1)**

Allow 1.390 to 1.395
ignore units even if incorrect
answer = 1.4 loses last mark

3

(d) $0.732 \times \frac{1000}{250} = 2.93$ **(1)** $mol.dm^{-3}$ **(1)**

OR M, mol/dm^3, $mol.l^{-1}$
allow 2.928 to 2.93
Note unit mark tied to current answer but allow unit mark if answer = 2.9 or 3

2

(e) (i) moles $H_2SO_4 = \frac{25}{1000} \times 1.24 = 0.0310$ **(1)**

If use $m_1v_1 = m_2v_2$ scores 3 if answer is correct otherwise zero

moles NH_3 in 30.8 $cm^3 = 0.0310 \times 2 = 0.0620$ **(1)**

Mark is for ×2
CE if × 2 not used

moles of NH_3 in 1 $dm^3 = 0.620 \times \frac{1000}{30.8} = 2.01$ **(1)** $(mol\ dm^{-3})$

Allow 2.010 to 2.015
No units OK, wrong units lose last mark

(ii) moles $(NH_4)_2SO4$ = moles $H_2SO_4 = 0.310$ **(1)**

Allow consequential wrong moles in part (i) if clear H_2SO_4=$(NH_4)SO_4$
Wrong formula for $(NH_4)_2SO_4$ CE=0

M_r $(NH_4)_2SO_4 = 132.1$ **(1)**

Allow (132)

mass = moles × $M_r = 0.0310 \times 132.1 = 4.10$ **(1)**

if moles of $(NH_4)_2SO_4$ not clear CE
(g) wrong unit loses mark
Allow 4.09 – 4.1 – 4.11

6

(f) $Mg_3N_2 + 6H_2O \rightarrow 3Mg(OH)_2 + 2NH_3$

Formulae (1)
Balanced equation (1)

2

[16]

Q15.

B

[1]

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Q16.

C

[1]

Q17.

A

[1]

Q18.

A

[1]

Q19.

C

[1]

Q2.

This question was also generally well answered. In part (a), the mole calculation was well done, although errors such as 9.89 were seen, and most candidates were successful in calculating the number of moles of oxygen. The Ideal gas equation was well known; however, some candidates rearranged it incorrectly. In a small but significant number of instances, incorrect pressure values were used, and a small number of arithmetic errors were found. The explanation of the term *empirical formula*, although frequently incomplete, was rather better answered than in previous years. The calculation of the empirical formula was quite well done, although it was not unusual for candidates to forget to calculate and use the percentage of oxygen in **Y**, to use incorrect *A*r values or to divide the *A*r values by the percentages.

The equation in part (c) was usually correct; however, some candidates wrote equations in which the KNO_3:O_2 ratio was not 2:1, despite having correctly shown that the number of moles of KNO_3 was twice that of O_2 in part (a). Also, it was not unusual to see equations in which oxygen was shown as 'O'.

Q3.

Overall, this question was not as well answered as the equivalent numerical question last year; however, full marks were not uncommon. In part (a), most candidates correctly deduced that number of moles of $HN0_3$, but errors beyond this point were very common. The most common errors concerned the mole ratio and the M_r calculation. Part (b)(i) was generally well answered; a very small proportion of candidates inverted the expression when calculating the number of moles of gas, however, a more common error was to omit the conversion of the pressure from kPa to Pa. Part (b)(ii) was quite poorly answered. Very few candidates recognised that the NO_2:O_2 ratio of 4:1 in the equation meant that the NO_2 accounted for 4/5 of the total moles of gas. It was much more common to see the total number of moles of gas, from part (b)(i) ,being multiplied by a factor other than 4/5. Most candidates correctly converted their answer for the number of moles of NO_2 into a mass. Some M_T errors were seen, the most common being 184 and 62, and, in a very few instances, candidates divided the number of moles by the M_r value

Q4.

This question was in general very well answered. Most candidates were able to display considerable numerical skill and full marks, or near full, marks were very common. Answers to parts (a)(i) and (a) (ii) were almost always correct. Part (a) (iii) was less well done, with some candidates subtracting their answer to part (a) (ii) from that for part (a) (i), rather than deducing that the number of moles of unreacted NaOH must be equal to the number of moles of HC1 used to neutralise it. Many of these candidates then consequentially earned the mark part (a) (iv) by correctly applying the calculation process to their answers to parts (a) (i) and (a) (iii). Most candidates also coped well with part (a) (v); however, the incorrect use of the mole ratio, errors in calculating the M_r value of ammonium sulphate or arithmetical errors were not uncommon. Part (b) was generally very well done, clearly a well-practiced technique. The gas law equation was almost always correct and most candidates correctly calculated the number of moles of ammonia, although a surprisingly large minority used 18 as theM_r value of ammonia. The vast majority of candidates rearranged the equation correctly, however, a small number failed to convert the pressure to Pa. Examiners reported that in a small number of centres candidates had used the units of kPa and dm^3 in their calculations. Candidates were not penalised for using this approach on this occasion but centres are requested to ensure

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that candidates use the correct metric units of Pa and m^3 in future gas law calculations.

Q5.

This question was, on the whole, well answered, with full marks being frequently earned. Many candidates were able to correctly complete parts (a)(i), (a)(ii) and (a)(iii). However, it was not uncommon to see an answer of 124 for part (a)(iv), which had not been derived from the answer to part (a)(iii). Candidates who assumed the sodium carbonate to be the monohydrate, and thus calculated its M_r value to be 124, rather than basing their calculation on their answer to part (a)(iii), earned no credit in part (a)(iv). Part (b) was also generally well answered but candidates who used 124, rather than 106, for the M_r of Na_2CO_3 lost the first mark for the calculation. Part (c) was similarly well answered by many candidates. A few candidates were unable to rearrange the gas law equation, but the majority of errors related to the incorrect calculation of the number of moles of argon, or to missing/incorrect units.

Q7.

Generally, this question was poorly done. Most candidates were able to quote the gas law equation correctly. Some fully correct calculations were seen but errors were common, especially in the conversion of the volume to m^3 and the pressure to Pa. In some cases, the gas law equation was incorrectly rearranged to give n = RT/pV. A significant minority of candidates made no attempt to deduce the M_r value of the gas, while others were content to quote ridiculous answers, such as 4.44×10^{-11}, rather than checking their calculation for errors.

Q9.

Most candidates correctly stated the ideal gas equation but the calculation which followed was frequently incorrect. The most common errors included rounding the number of moles of ethanol to 0.03 mol and the use of 100 as the value for the pressure. There was a wide range of units suggested for the volume calculated from the ideal gas equation and few candidates were able to convert this volume in m^3 to the required volume in cm^3. The equation in part (b) was usually correctly balanced, but rounding errors were again common in the following calculation. A significant number of candidates divided n by L in this calculation, rather than multiplying the two together. The calculation in part (c) proved to be easy for the more able candidates but posed considerable problems for many others. The calculation of the number of moles of NaCl was often correctly performed but the use of a 1:1 mole ratio between $NaHCO_3$ and $Na2CO_3$ was very common. Some candidates assumed that $NaHCO_3$ was sodium carbonate and used an Mr value of 84 in their calculation. Some novel, and often successful, approaches to this calculation were seen.

Q11.

This question was generally well answered and full marks were quite common. Most, but by no means all, candidates gave the correct name for the equation, and most coped with the empirical formula calculation, with many of even the weaker candidates correctly deducing the empirical formula to be CH_3O. A few candidates omitted to calculate the percentage of oxygen or used atomic numbers rather than mass number in the calculation. Part (b) was often well done, but it was not unusual to see the equations inverted or for the pressure to be used in kPa, rather than in Pa. Errors in part (b) generated some very odd formulae in part (d).

Q12.

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Despite the formula of oxygen gas appearing both in the equation and on the answer line, an appreciable number of candidates incorrectly used O_2 = 16 in their calculation of the number of moles of oxygen. Despite this, credit was given for deducing that the number of moles of NO would be twice that of oxygen. The original number of moles of NO_2 was usually correctly calculated, although a significant minority of candidates used M_r = 92 rather than the correct value of 46. Credit was given for the number of moles of NO_2 at equilibrium consequent on correct use of their figures.

In part (b) the expression for K_c was usually correct with only a few giving an inverse expression or failing to use square brackets. In the subsequent calculation, however, many forgot that the volume of the flask did not cancel and needed to be used in the K_c calculation. Many candidates gave very approximate answers. The data given in the question were all to three significant figures and answers should reflect this.

The hint to use the ideal gas equation in part (c) was taken and very few candidates were unable to calculate a value for the temperature. Unfortunately in many of the answers the need to convert the units of volume to m3 was overlooked.

In part (d) most candidates correctly deduced that the yield of oxygen would increase in a flask of greater volume, but weaker candidates also thought that the value of K_c would change.

Q14.

This question was answered well by many candidates and high marks were scored. In part (a) there was some confusion between 5 decimal places and five significant figures. Candidates also had difficulty handling powers of ten. Some candidates did not appear to understand part (b); they missed the point and gave an answer suggesting that ammonia had more atoms. Answers to part (c) were usually correct but a common error in the application of the formula n = PV/RT was a failure to convert the pressure of 90.0 kPa into Pascals. Part (d) was answered well but fewer correct answers to part (e) were seen. In part (e)(i) common mistakes were to use the wrong volume of sulphuric acid solution and also to omit the factor of two when calculating the number of moles of ammonia from the moles of sulphuric acid. In part (e) (ii) the M_r of ammonium sulphate was usually correct but weaker candidates did not recognise that the number of moles of ammonium sulphate was the same as the number of moles of sulphuric acid calculated in part (e) (i). In part (f) only the best candidates gave a correct formula for magnesium hydroxide; a very common error was to give the incorrect formula, MgOH.

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Q1.

This question is about sodium fluoride (NaF).

Some toothpastes contain sodium fluoride.
The concentration of sodium fluoride can be expressed in parts per million (ppm).
1 ppm represents a concentration of 1 mg in every 1 kg of toothpaste.

(a) A 1.00 g sample of toothpaste was found to contain 2.88×10^{-5} mol of sodium fluoride.

Calculate the concentration of sodium fluoride, in ppm, for the sample of toothpaste.
Give your answer to 3 significant figures.

Concentration of sodium fluoride _____ ppm

(4)

(b) Sodium fluoride is toxic in high concentrations.
Major health problems can occur if concentrations of sodium fluoride are greater than 3.19×10^{-2} g per kilogram of body mass.

Deduce the maximum mass of sodium fluoride, in mg, that a 75.0 kg person could swallow without reaching the toxic concentration.

Mass of sodium fluoride _____ mg

(1)

(c) The concentration of sodium fluoride in a prescription toothpaste is 2800 ppm.

Use your answer to Question (b) to deduce the mass of toothpaste, in kg, that a 75.0 kg person could swallow without reaching the toxic concentration.

Mass of toothpaste _____ kg

(1)

(d) Identify the diagram in the figure below that shows the correct relative sizes of the ions in sodium fluoride.
Justify your answer.

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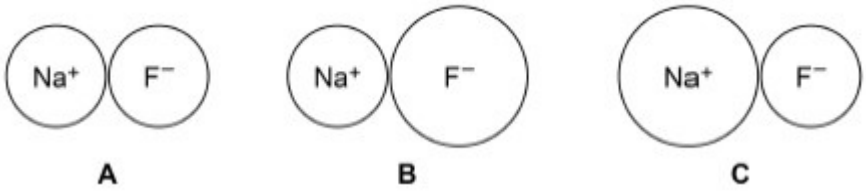


Diagram _____

Justification _____

_____

_____

_____

_____

_____

_____

(3)

(Total 9 marks)

Q2.

How many protons are there in 6.0 g of nitrogen gas?

Avogadro constant, $L = 6.022 \times 10^{23}$ mol^{-1}

A 1.3×10^{23} ⬭

B 9.0×10^{23} ⬭

C 1.8×10^{24} ⬭

D 3.6×10^{24} ⬭

(Total 1 mark)

Q3.

A sample of bromine was analysed in a time of flight (TOF) mass spectrometer and found to contain two isotopes, ^{79}Br and ^{81}Br

After electron impact ionisation, all of the ions were accelerated to the same kinetic energy (KE) and then travelled through a flight tube that was 0.950 m long.

(a) The $^{79}Br^+$ ions took 6.69×10^{-4} s to travel through the flight tube.

Calculate the mass, in kg, of one ion of $^{79}Br^+$

Calculate the time taken for the $^{81}Br^+$ ions to travel through the same flight tube.

The Avogadro constant, $L = 6.022 \times 10^{23}$ mol^{-1}

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$KE = \frac{1}{2} mv^2$ where m = mass (kg) and v = speed (m s^{-1})

$v = \frac{d}{t}$ where d = distance (m) and t = time (s)

Mass of one ion of $^{79}Br^+$ _____ kg

Time taken by $^{81}Br^+$ ions _____ s

(5)

(b) Explain how ions are detected and relative abundance is measured in a TOF mass spectrometer.

_____

_____

_____

_____

_____

_____

(2)

(Total 7 marks)

Q4.

A solution of volume 500 cm^3 contains 150 g of ammonia.

What is the concentration, in mol dm^{-3}, of ammonia in this solution?

A 0.51 ⬭

B 8.82 ⬭

C 16.7 ⬭

D 17.6 ⬭

(Total 1 mark)

Q5.

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A gas cylinder contains 5.0 kg of propane.

How many propane molecules are in the cylinder?

The Avogadro constant, $L = 6.022 \times 10^{23}$ mol^{-1}

A 6.8×10^{22} ○

B 7.2×10^{22} ○

C 6.8×10^{25} ○

D 7.2×10^{25} ○

(Total 1 mark)

Q6.

Which sample of liquid has the greatest volume?

A 500 mg of pentane (density = 0.63 g cm^{-3}) ○

B 650 mg of propan-1-ol (density = 0.80 g cm^{-3}) ○

C 1.20 g of dichloromethane (density = 1.33 g cm^{-3}) ○

D 1.30 g of trichloromethane (density = 1.48 g cm^{-3}) ○

(Total 1 mark)

Q7.

This question is about sodium and some of its compounds.

(a) Use your knowledge of structure and bonding to explain why sodium bromide has a melting point that is higher than that of sodium, and higher than that of sodium iodide.

(6)

(b) When 250 mg of sodium were added to 500 cm^3 of water at 25 °C a gas was produced.

Give an equation for the reaction that occurs.
Calculate the volume, in cm^3, of the gas formed at 101 kPa

The gas constant, R = 8.31 J K^{-1} mol^{-1}

Equation _____

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Volume _____ cm^3

(6)

(c) Calculate the concentration, in mol dm^{-3}, of sodium ions in the solution produced in the reaction in **part (b)**.

Concentration _____ mol dm^{-3}

(1)

(d) Sodium reacts with ammonia to form the compound $NaNH_2$ that contains the NH_2^- ion.

Draw the shape of the NH_2^- ion.
Include any lone pairs of electrons that influence the shape.

Predict the bond angle.
Justify your prediction.

Shape

Bond angle _____

Justification _____

_____

(4)

(Total 17 marks)

Q8.

Which of these contains the greatest number of atoms?

A 127 mg of iodine ⬭

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B 1.54×10^{-4} kg of phosphorus ⬭

C 81.0 mg of carbon dioxide ⬭

D 1.70×10^{-4} kg of ammonia ⬭

(Total 1 mark)

Q9.

Which sample contains the most molecules?

The Avogadro constant, $L = 6.022 \times 10^{23}$ mol^{-1}

A 2.10×10^{22} molecules of methane, CH_4 ⬭

B 1.00 g of oxygen, O_2 ⬭

C 65.0 mg of hydrogen, H_2 ⬭

D 0.0300 mol of ethane, C_2H_6 ⬭

(Total 1 mark)

Q10.

A sample of titanium was ionised by electron impact in a time of flight (TOF) mass spectrometer. Information from the mass spectrum about the isotopes of titanium in the sample is shown in the table.

m/z	46	47	48	49
Abundance / %	9.1	7.8	74.6	8.5

(a) Calculate the relative atomic mass of titanium in this sample.

Give your answer to one decimal place.

Relative atomic mass of titanium in this sample _____

(2)

(b) Write an equation, including state symbols, to show how an atom of titanium is ionised by electron impact and give the m/z value of the ion that would reach the detector first.

Equation _____

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m/z value _____

(2)

(c) Calculate the mass, in kg, of one atom of ^{49}Ti

The Avogadro constant $L = 6.022 \times 10^{23}\,mol^{-1}$

Mass _____ kg

(1)

(d) In a TOF mass spectrometer the time of flight, t, of an ion is shown by the equation

$$t = d\sqrt{\frac{m}{2E}}$$

In this equation *d* is the length of the flight tube, m is the mass, in kg, of an ion and *E* is the kinetic energy of the ions.

In this spectrometer, the kinetic energy of an ion in the flight tube is $1.013 \times 10^{-13}\,J$

The time of flight of a $^{49}Ti^{+}$ ion is $9.816 \times 10^{-7}\,s$

Calculate the time of flight of the $^{47}Ti^{+}$ ion.

Give your answer to the appropriate number of significant figures.

Time of flight _____ s

(3)

(Total 8 marks)

Q11.

Analysis of a sample of a chemical with formula $C_{22}H_{30}N_6O_4S$, showed that it contained 0.0195 mol of carbon.

What mass of nitrogen was present in the sample?

A 0.041 g ⬭

B 0.057 g ⬭

C 0.074 g ⬭

D 0.420 g ⬭

(Total 1 mark)

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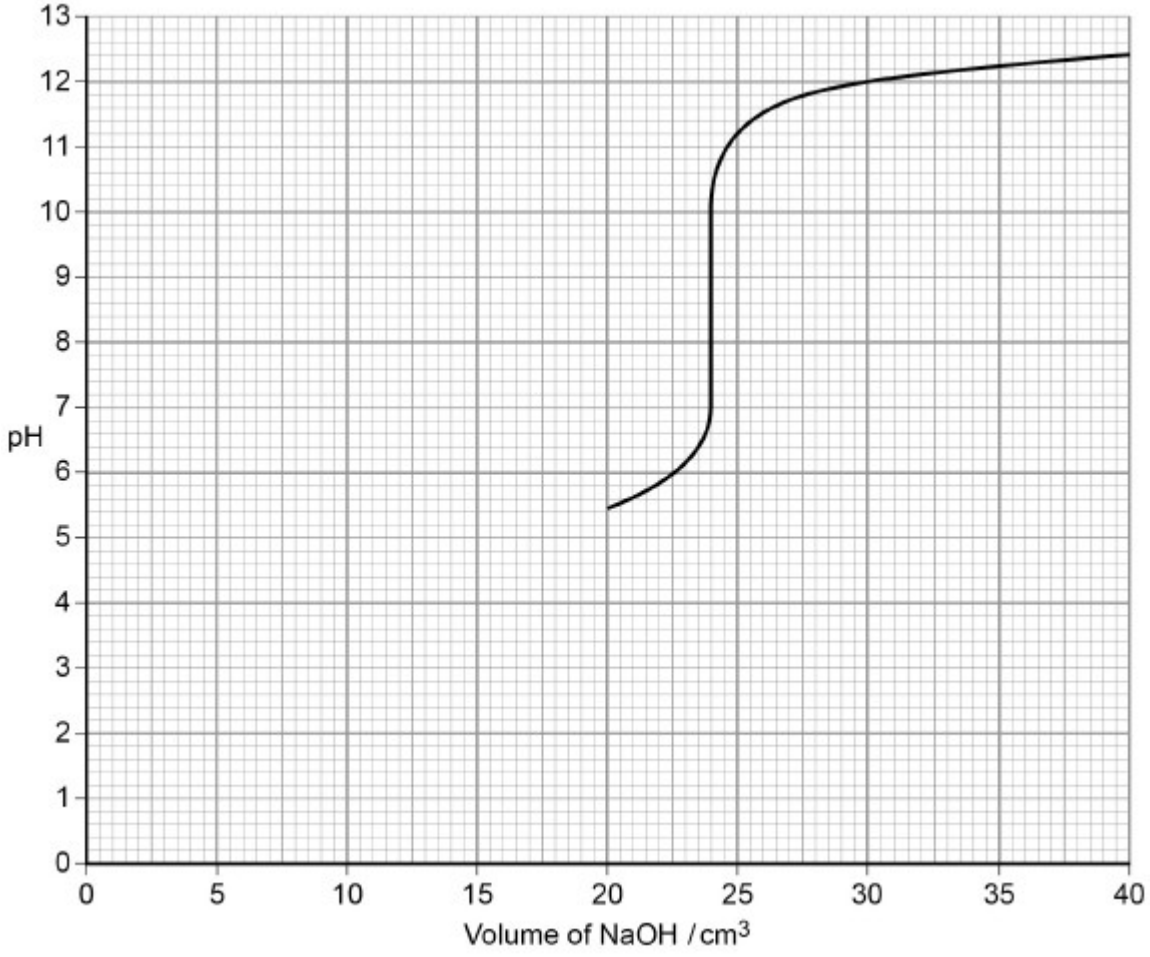
Q12.

A 0.100 mol dm^{-3} solution of sodium hydroxide was gradually added to 25.0 cm^3 of a solution of a weak acid, HX, in the presence of a suitable indicator.

A graph was plotted of pH against the volume of sodium hydroxide solution, as shown in the figure below.

The first pH reading was taken after 20.0 cm^3 of sodium hydroxide solution had been added.

The acid dissociation constant of HX, K_a, = 2.62 × 10^{-5} mol dm^{-3}



(a) The pH range of an indicator is the range over which it changes colour.

Suggest the pH range of a suitable indicator for this titration.

_____

(1)

(b) Give the expression for the acid dissociation constant of HX.

K_a =

(1)

(c) Calculate the concentration of HX in the original solution.

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Concentration _____ mol dm^{-3}

(2)

(d) Calculate the pH of the solution of HX before the addition of any sodium hydroxide.

(If you were unable to calculate a value for the concentration of HX in part (c) you should use a value of 0.600 mol dm^{-3} in this calculation. This is not the correct value.)

pH of HX _____

(2)

(e) Calculate the pH of the solution when half of the acid has reacted.

pH of solution _____

(1)

(f) Plot your answers to part (d) and part (e) on the grid in the figure above.

Use these points to sketch the missing part of the curve between 0 and 20 cm^3 of NaOH solution added.

(2)

(Total 9 marks)

Q13.

A solution of lead(II) chloride (M_r = 278.2) contains 1.08 g of $PbCl_2$ in 100 cm^3 of solution. In this solution, the lead(II) chloride is fully dissociated into ions.

What is the concentration of chloride ions in this solution?

A 3.88 × 10^{-3} mol dm^{-3} ○

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B 7.76×10^{-3} mol dm^{-3} ○

C 3.88×10^{-2} mol dm^{-3} ○

D 7.76×10^{-2} mol dm^{-3} ○

(Total 1 mark)

Q14.

What is the number of atoms in 0.0100 mol of NH_3?
(The Avogadro constant L = 6.022×10^{23} mol^{-1})

A 6.02×10^{25} ○

B 1.20×10^{23} ○

C 1.81×10^{22} ○

D 2.41×10^{22} ○

(Total 1 mark)

Q15.

Which of the following contains the most chloride ions?

A 15 cm^3 of 3.40×10^{-2} mol dm^{-3} aluminium chloride solution ○

B 30 cm^3 of 5.50×10^{-2} mol dm^{-3} calcium chloride solution ○

C 40 cm^3 of 2.30×10^{-2} mol dm^{-3} hydrochloric acid ○

D 45 cm^3 of 2.20×10^{-2} mol dm^{-3} sodium chloride solution ○

(Total 1 mark)

Q16.

Which of these contains the most molecules?

A 0.0311 kg of carbon dioxide, CO_2 ○

B 29.6 g of carbon monoxide, CO ○

C 2.22×10^4 mg of oxygen, O_2 ○

D 13.3 g of ozone, O_3 ○

(Total 1 mark)

Q17.

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Which of the following contains the most chloride ions?

A 10 cm^3 of 3.30×10^{-2} mol dm^{-3} aluminium chloride solution ⬭

B 20 cm^3 of 5.00×10^{-2} mol dm^{-3} calcium chloride solution ⬭

C 30 cm^3 of 3.30×10^{-2} mol dm^{-3} hydrochloric acid ⬭

D 40 cm^3 of 2.50×10^{-2} mol dm^{-3} sodium chloride solution ⬭

(Total 1 mark)

Q18.

CCl_4 is an effective fire extinguisher but it is no longer used because of its toxicity and its role in the depletion of the ozone layer. In the upper atmosphere, a bond in CCl_4 breaks and reactive species are formed.

(a) Identify the condition that causes a bond in CCl_4 to break in the upper atmosphere. Deduce an equation for the formation of the reactive species.

Condition _____

Equation

_____

(2)

(b) One of the reactive species formed from CCl_4 acts as a catalyst in the decomposition of ozone.

Write **two** equations to show how this species acts as a catalyst.

Equation 1

_____

Equation 2

_____

(2)

(c) A small amount of the freon CF_3Cl with a mass of 1.78×10^{-4} kg escaped from a refrigerator, into a room of volume 100 m^3. Assuming that the freon is evenly distributed throughout the air in the room, calculate the number of freon molecules in a volume of 500 cm^3.
Give your answer to the appropriate number of significant figures.

The Avogadro constant = 6.02×10^{23} mol^{-1}.

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Number of molecules = _____

(3)

(Total 7 marks)

Q19.

In an experiment to identify a Group 2 metal (X), 0.102 g of X reacts with an excess of aqueous hydrochloric acid according to the following equation.

$$X + 2HCl \longrightarrow XCl_2 + H_2$$

The volume of hydrogen gas given off is 65 cm^3 at 99 kPa pressure and 303 K.
The gas constant is R = 8.31 J K^{-1} mol^{-1}.

Which is X?

A Barium ⬭

B Calcium ⬭

C Magnesium ⬭

D Strontium ⬭

(Total 1 mark)

Q20.

The oxidising agent in solution **A** is sodium bromate(V), $NaBrO_3$. A laboratory technician wanted to make up enough of this solution for use in a class practical.

Calculate the mass of sodium bromate(V) needed to prepare 5.00 dm^3 of a 5.00 × 10^{-3} mol dm^{-3} solution.

Show your working. Give your answer to the appropriate precision.

_____

_____

_____

(Total 2 marks)

Q21.

This question is about a white solid, $MHCO_3$, that dissolves in water and reacts with hydrochloric acid to give a salt.

$$MHCO_3 + HCl \longrightarrow MCl + H_2O + CO_2$$

A student was asked to design an experiment to determine a value for the M_r of $MHCO_3$.
The student dissolved 1464 mg of $MHCO_3$ in water and made the solution up to 250 cm^3.
25.0 cm^3 samples of the solution were titrated with 0.102 mol dm^{-3} hydrochloric acid. The results are shown in the table.

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	Rough	1	2	3
Initial burette reading / cm^3	0.00	10.00	19.50	29.25
Final burette reading / cm^3	10.00	19.50	29.25	38.90
Titre / cm^3	10.00	9.50	9.75	9.65

(a) Calculate the mean titre and use this to determine the amount, in moles, of HCl that reacted with 25.0 cm^3 of the $MHCO_3$ solution.

_____

_____

_____

_____

_____

(3)

(b) Calculate the amount, in moles, of $MHCO_3$ in 250 cm^3 of the solution.
Then calculate the experimental value for the M_r of $MHCO_3$.
Give your answer to the appropriate number of significant figures.

_____

_____

_____

_____

(3)

(c) The student identified use of the burette as the largest source of uncertainty in the experiment.

Using the same apparatus, suggest how the procedure could be improved to reduce the percentage uncertainty in using the burette.

Justify your suggested improvement.

Suggestion _____

_____

Justification _____

_____

_____

(2)

(d) Another student is required to make up 250 cm^3 of an aqueous solution that contains a known mass of $MHCO_3$. The student is provided with a sample bottle containing the $MHCO_3$.

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Describe the method, including apparatus and practical details, that the student should use to prepare the solution.

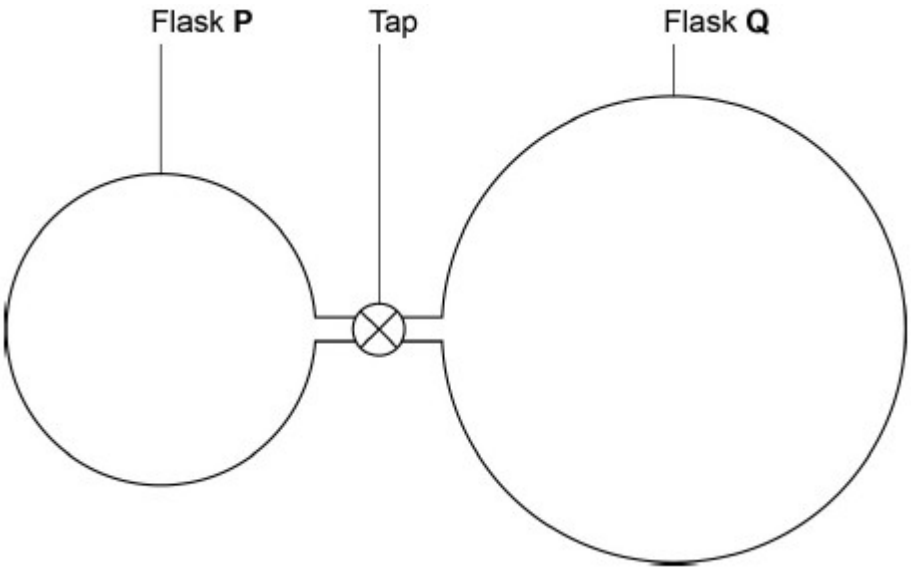
(6)

(Total 14 marks)

Q22.

The diagram represents two glass flasks, **P** and **Q**, connected via a tap.

Flask **Q** (volume = 1.00×10^3 cm^3) is filled with ammonia (NH_3) at 102 kPa and 300 K. The tap is closed and there is a vacuum in flask **P**.
(Gas constant R = 8.31 $J\ K^{-1}\ mol^{-1}$)



(a) Calculate the mass of ammonia in flask **Q**.
Give your answer to the appropriate number of significant figures.

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_____

_____

_____

_____

_____

(3)

(b) When the tap is opened, ammonia passes into flask **P**. The temperature decreases by 5 °C. The final pressure in both flasks is 75.0 kPa.
Calculate the volume, in cm^3, of flask **P**.

_____

_____

_____

_____

_____

(3)

(Total 6 marks)

Q23.

There are 392 mol of pure gold in a bar measuring 10 cm by 10 cm by 40 cm.
What is the density of gold in kg dm^{-3}?

A 193 ⬭

B 19.3 ⬭

C 1.93 ⬭

D 0.193 ⬭

(Total 1 mark)

Q24.

In a car airbag, sodium azide (NaN_3) decomposes to form sodium metal and nitrogen gas.

$$2NaN_3(s) \longrightarrow 2Na(s) + 3N_2(g)$$

The sodium metal then reacts with potassium nitrate to produce more nitrogen gas.

$$10Na(s) + 2KNO_3(s) \longrightarrow N_2(g) + 5Na_2O(s) + K_2O(s)$$

If 2.00 mol of sodium azide react in this way, how many molecules of N_2 will be formed?
(The Avogadro constant L = 6.022×10^{23} mol^{-1})

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A 2.41×10^{24} ⬭

B 1.93×10^{24} ⬭

C 1.81×10^{24} ⬭

D 9.63×10^{23} ⬭

(Total 1 mark)

Q25.

When an aqueous solution of ethanoic acid reacts with magnesium, the progress of reaction can be followed using the equipment shown in **Figure 1** to measure the volume of hydrogen produced.

Figure 1

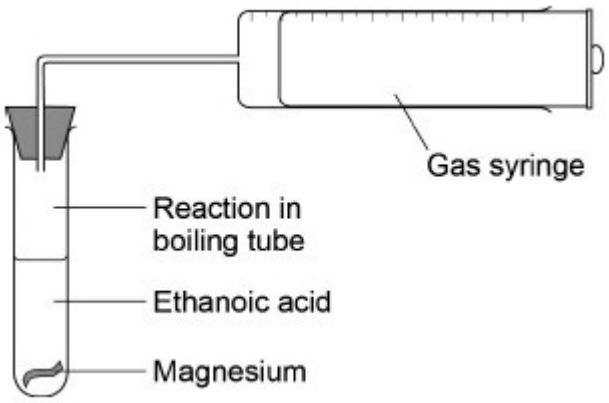
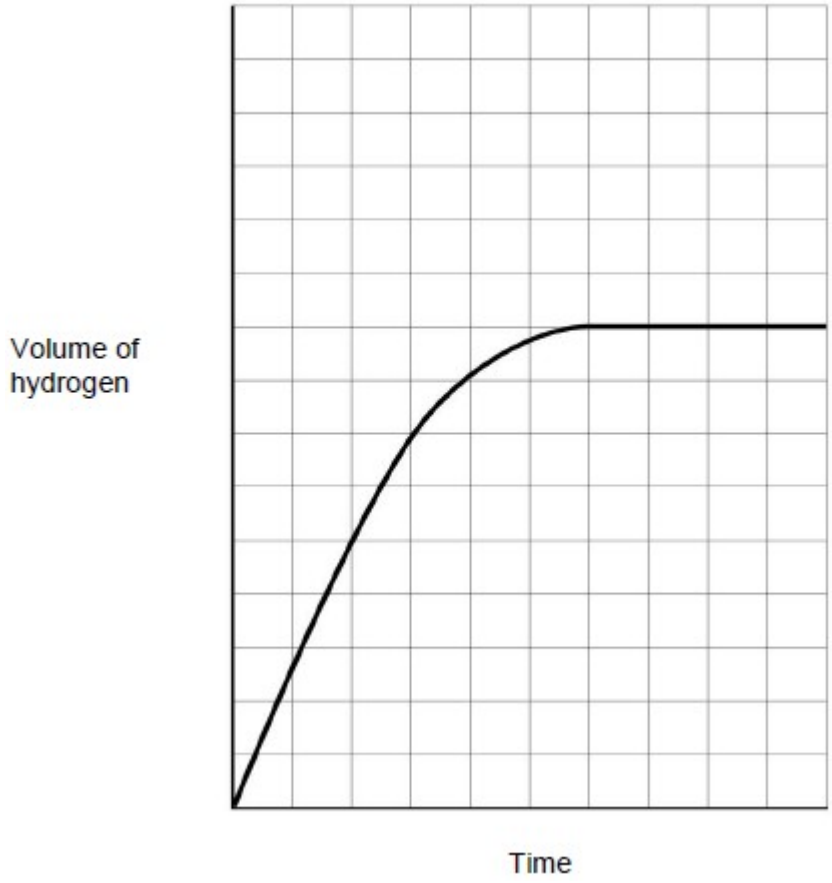


Figure 2 shows how the volume of hydrogen produced varies with time when 396 mg of magnesium are added to 30.0 cm^3 of 0.600 mol dm^{-3} ethanoic acid.

Figure 2

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(a) The equation for the reaction between ethanoic acid and magnesium is shown.

$$2CH_3COOH(aq) + Mg(s) \longrightarrow (CH_3COO)_2Mg(aq) + H_2(g)$$

With the aid of calculations, show that the magnesium is in excess in this reaction.

(3)

(b) The reaction was repeated using 20 cm^3 of 0.800 mol dm^{-3} of ethanoic acid solution with all other conditions the same. The magnesium was still in excess.

Sketch a line on **Figure 2** to show how the volume of hydrogen produced varies with time in this second experiment.

Space for working.

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(2)
(Total 5 marks)

Q26.

Refrigerants are substances used to cool refrigerators and freezers. Until recently, many of the compounds used as refrigerants were chlorofluorocarbons (CFCs), but these are now known to form chlorine radicals. CFCs have been phased out in many countries by international agreement.

(a) Write **two** equations to show how chlorine radicals react with ozone molecules in the upper atmosphere.

1. _____

2. _____

(2)

(b) Chloropentafluoroethane is a CFC that has been used as a refrigerant.

Draw its displayed formula.

(1)

(c) 1,1,1-trifluoroethane (CF_3CH_3) is one of the molecules that has been used as a refrigerant in place of CFCs.

Explain why 1,1,1-trifluoroethane does not lead to the depletion of the ozone in the upper atmosphere.

_____

_____

_____

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(1)

(d) One of the steps in the synthesis of 1,1,1-trifluoroethane (CF_3CH_3) is the reaction of 1,1-difluoroethane (CHF_2CH_3) with fluorine in a free-radical substitution reaction.

Write **two** equations to represent the propagation steps in this conversion of CHF_2CH_3 into CF_3CH_3

Propagation step 1

_____

Propagation step 2

_____

(2)

(e) A refrigerator contains 1.41 kg of 1,1,1-trifluoroethane (CF_3CH_3).

Calculate the number of molecules of 1,1,1-trifluoroethane in the refrigerator. Give your answer to an appropriate number of significant figures.
(The Avogadro constant L = 6.022×10^{23} mol^{-1})

_____

_____

_____

(2)

(f) There are growing concerns about the use of 1,1,1-trifluoroethane as a refrigerant as it is a greenhouse gas that absorbs some of Earth's infrared radiation.

Give **one** reason why bonds in molecules such as carbon dioxide and 1,1,1-trifluoroethane absorb infrared radiation.

_____

_____

(1)

(Total 9 marks)

Q27.

The M_r of hydrated copper sulfate ($CuSO_4.5H_2O$) is 249.6.

Which of the following is the mass of hydrated copper sulfate required to make 50.0 cm^3 of a 0.400 mol dm^{-3} solution?

A 3.19 g ⬭

B 3.55 g ⬭

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C 3.71 g ⬭

D 4.99 g ⬭

(Total 1 mark)

Q28.

Zinc forms many different salts including zinc sulfate, zinc chloride and zinc fluoride.

(a) People who have a zinc deficiency can take hydrated zinc sulfate ($ZnSO_4.xH_2O$) as a dietary supplement.

A student heated 4.38 g of hydrated zinc sulfate and obtained 2.46 g of anhydrous zinc sulfate.

Use these data to calculate the value of the integer *x* in $ZnSO_4.xH_2O$
Show your working.

(3)

(b) Zinc chloride can be prepared in the laboratory by the reaction between zinc oxide and hydrochloric acid.
The equation for the reaction is

$$ZnO + 2HCl \longrightarrow ZnCl_2 + H_2O$$

A 0.0830 mol sample of pure zinc oxide was added to 100 cm^3 of 1.20 mol dm^{-3} hydrochloric acid.

Calculate the maximum mass of anhydrous zinc chloride that could be obtained from the products of this reaction.

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_____

_____

(4)

(c) Zinc chloride can also be prepared in the laboratory by the reaction between zinc and hydrogen chloride gas.

$$Zn + 2HCl \longrightarrow ZnCl_2 + H_2$$

An impure sample of zinc powder with a mass of 5.68 g was reacted with hydrogen chloride gas until the reaction was complete. The zinc chloride produced had a mass of 10.7 g.

Calculate the percentage purity of the zinc metal.
Give your answer to 3 significant figures.

_____

_____

_____

_____

_____

_____

_____

_____

(4)

(d) Predict the type of crystal structure in solid zinc fluoride and explain why its melting point is high.

_____

_____

_____

_____

_____

_____

(3)

(Total 14 marks)

Q29.

Norgessaltpeter was the first nitrogen fertiliser to be manufactured in Norway. It has the formula $Ca(NO_3)_2$

(a) Norgessaltpeter can be made by the reaction of calcium carbonate with dilute nitric

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acid as shown by the following equation.

$$CaCO_3(s) + 2HNO_3(aq) \longrightarrow Ca(NO_3)_2(aq) + CO_2(g) + H_2O(l)$$

In an experiment, an excess of powdered calcium carbonate was added to 36.2 cm^3 of 0.586 mol dm^{-3} nitric acid.

(i) Calculate the amount, in moles, of HNO_3 in 36.2 cm^3 of 0.586 mol dm^{-3} nitric acid. Give your answer to 3 significant figures.

_____

_____

(1)

(ii) Calculate the amount, in moles, of $CaCO_3$ that reacted with the nitric acid. Give your answer to 3 significant figures.

_____

_____

(1)

(iii) Calculate the minimum mass of powdered $CaCO_3$ that should be added to react with all of the nitric acid.

Give your answer to 3 significant figures.

_____

_____

_____

(2)

(iv) State the type of reaction that occurs when calcium carbonate reacts with nitric acid.

_____

(1)

(b) Norgessaltpeter decomposes on heating as shown by the following equation.

$$2Ca(NO_3)_2(s) \longrightarrow 2CaO(s) + 4NO_2(g) + O_2(g)$$

A sample of Norgessaltpeter was decomposed completely.

The gases produced occupied a volume of 3.50×10^{-3} m^3 at a pressure of 100 kPa and a temperature of 31 °C.
(The gas constant R = 8.31 J K^{-1} mol^{-1})

(i) Calculate the total amount, in moles, of gases produced.

_____

_____

_____

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_____

(3)

(ii) Hence calculate the amount, in moles, of oxygen produced.

_____

_____

(1)

(c) Hydrated calcium nitrate can be represented by the formula $Ca(NO_3)_2.xH_2O$ where x is an integer.

A 6.04 g sample of $Ca(NO_3)_2.xH_2O$ contains 1.84 g of water of crystallisation.

Use this information to calculate a value for x.
Show your working.

_____

_____

_____

_____

_____

_____

(3)

(Total 12 marks)

Q30.

Nitroglycerine, $C_3H_5N_3O_9$, is an explosive which, on detonation, decomposes rapidly to form a large number of gaseous molecules. The equation for this decomposition is given below.

$$4C_3H_5N_3O_9(l) \rightarrow 12CO_2(g) + 10H_2O(g) + 6N_2(g) + O_2(g)$$

(a) A sample of nitroglycerine was detonated and produced 0.350 g of oxygen gas.

(i) State what is meant by the term *one mole* of molecules.

_____

(ii) Calculate the number of moles of oxygen gas produced in this reaction, and hence deduce the total number of moles of gas formed.

Moles of oxygen gas _____

Total moles of gas _____

_____

_____

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(iii) Calculate the number of moles, and the mass, of nitroglycerine detonated.

Moles of nitroglycerine _____

_____

Mass of nitroglycerine _____

_____

_____

(7)

(b) A second sample of nitroglycerine was placed in a strong sealed container and detonated. The volume of this container was 1.00×10^{-3} m^3. The resulting decomposition produced a total of 0.873 mol of gaseous products at a temperature of 1100 K.

State the ideal gas equation and use it to calculate the pressure in the container after detonation.

(The gas constant R = 8.31 J $K^{-1}mol^{-1}$)

Ideal gas equation _____

Pressure _____

_____

_____

_____

(4)

(Total 11 marks)

Q31.

The removal of silicon dioxide with limestone in the Blast Furnace can be represented by the following equation.

$$CaCO_3(s) + SiO_2(s) \rightarrow CaSiO_3(l) + CO_2(g)$$

The minimum mass of calcium carbonate needed to remove 1.00 tonne (1000 kg) of silicon dioxide is

A 0.46 tonne

B 0.60 tonne

C 1.67 tonne

D 2.18 tonne

(Total 1 mark)

Q32.

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The removal of silicon dioxide with limestone in the Blast Furnace can be represented by the following equation.

$$CaCO_3(s) + SiO_2(s) \rightarrow CaSiO_3(l) + CO_2(g)$$

The volume of carbon dioxide, measured at 298 K and 1.01×10^5 Pa, formed in this reaction during the removal of 1.00 tonne (1000 kg) of silicon dioxide is

A 24.5 dm^3

B 408 dm^3

C 24.5 m^3

D 408 m^3

(Total 1 mark)

Q33.

(a) Complete the following table.

	Relative mass	Relative charge
Neutron		
Electron		

(2)

(b) An atom has twice as many protons as, and four more neutrons than, an atom of ^9Be. Deduce the symbol, including the mass number, of this atom.

_____

(2)

(c) Draw the shape of a molecule of $BeCl_2$ and the shape of a molecule of Cl_2O. Show any lone pairs of electrons on the central atom. Name the shape of each molecule.

$BeCl_2$ *Cl_2O*

Name of shape _____ *Name of shape* _____

(4)

(d) The equation for the reaction between magnesium hydroxide and hydrochloric acid is shown below.

$$Mg(OH)_2(s) + 2HCl(aq) \rightarrow MgCl_2(aq) + 2H_2O(l)$$

Calculate the volume, in cm^3, of 1.00 mol dm^{-3} hydrochloric acid required to react completely with 1.00 g of magnesium hydroxide.

_____

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_____

_____

_____

_____

_____

(4)

(Total 12 marks)

Q34.

When 0.10 g of propane was burned the quantity of heat evolved was 5.0 kJ. The enthalpy of combustion of propane in kJ mol^{-1} is

A −800

B −1500

C −2200

D −2900

(Total 1 mark)

Q35.

Silver oxide, Ag_2O, can be reduced by passing hydrogen gas over the heated oxide. The maximum mass of silver that could be obtained from 2.32 g of silver oxide is

A 2.02 g

B 2.06 g

C 2.12 g

D 2.16 g

(Total 1 mark)

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Q1.

(a) M_r NaF = 42(.0)

Incorrect M_r loses M1 & M4

1

Mass NaF in 1 g = $2.88 \times 10^{-5} \times 42.0$ (= 1.210 (1.2096) $\times 10^{-3}$ g)

1

Mass NaF in 1 kg = 1.210 (1.2096) g

M3 = M2 × 1000 (g)

Units, if given, must match answer

1

(Mass in mg = 1210 (1209.6) mg)

Concentration of NaF = <u>1210</u> (ppm)

Allow 1.21 × 10^3 ppm

1

(b) Toxic mass = $3.19 \times 10^{-2} \times 75 \times 1000$
= 2390 mg

Allow 2393

1

(c) Mass of toothpaste needed = $\frac{2390}{2800}$
= 0.854 kg

Mark consequential to (b)

(b) ÷ 2800 (to at least 2 sig fig)

Allow 0.85 - 0.86 kg

1

(d) B

If not B, allow M2 only

If blank, read on.

1

Both Na^+ and F^- same electron arrangement ($1s^2 2s^2 2p^6$) or isoelectronic

Electronegativity, molecules or IMF = CE, M1 only

1

Sodium (ion) has more protons <u>so attracts (outer) electrons closer</u> / Sodium (ion) has more protons <u>so stronger attractions for (outer) electrons</u>

Ignore shielding, higher charge density, atomic radius

If reference to fluorine rather than fluoride, then penalise 1 mark only

1

[9]

Q2.

C

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[1]

Q3.

(a) = 79 / (1000 × 6.022 × 10^{23}) = 1.31 × 10^{-25} kg

1

Then either follow **method 1** (or **method 2** below)

Do not mix and match methods

Method 1

$V_{79} = \frac{d}{t}$ = 0.950 / 6.69 × 10^{-4}

= 1420 ms^{-1}

In method 1, M2 can be awarded in M3

1

KE = ½ mv^2

= ½ × 1.312 × 10^{-25} × $(1420)^2$

= 1.32 × 10^{-19} J

Mark consequential to their velocity and mass. Allow mass of 79 etc.

1

$V_{81} = \sqrt{(\frac{2KE}{m})}$

= √ 1.963 × 10^6

= 1.40 × 10^3 ms^{-1}

(allow 1.398 × 10^3 - 1.402 × 10^3)

Mark consequential to their velocity and mass. Allow mass of 81 etc.

1

$t = \frac{d}{v} = \frac{0.950}{v_{81}}$

= 6.80 × 10^{-4} s

Mark consequential to their M4

Accept 6.77 – 6.80 × 10^{-4} s

1

Method 2

$m_1(d/t_1)^2 = m_2 (d/t_1)^2$

or

$m_1 / t_1^2 = m_2 / t_2^2$

1

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$t_2^2 = t_1^2 (m_2/m_1)$
Or
$t_2^2 = (6.69 \times 10^{-4})2 \times (81/79)$

1

$t_2^2 = 4.59 \times 10^{-7}$

Mark consequential to their M3

1

$t = 6.77 \times 10^{-4}$ s

Mark consequential to their M4
Accept 6.77 – 6.80 × 10^{-4} s

1

(b) ion hits the detector / negative plate <u>and</u> gains an electron

1

Not positive plate

(relative) abundance is proportional to (the size of) the current

1

[7]

Q4.

D

[1]

Q5.

C

[1]

Q6.

C

[1]

Q7.

This question is marked using Levels of Response. Examiners should apply a 'best-fit' approach to the marking.	
Level 3 5-6 marks	All stages are covered and the explanation of each stage is generally correct and virtually complete. Answer is communicated coherently and shows a logical progression from stage 1 to stage 2 and then stage 3. Coherent communication requires that there is a comparison between the types of bonding and that the bonding is correct for each substance.
Level 2	All stages are covered but the explanation of each

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3-4 marks	stage may be incomplete or may contain inaccuracies OR two stages are covered and the explanations are generally correct and virtually complete. Answer is mainly coherent and shows some progression from stage 1 to stage 2 and then stage 3.
Level 1 1-2 marks	Two stages are covered but the explanation of each stage may be incomplete or may contain inaccuracies OR only one stage is covered but the explanation is generally correct and virtually complete. Answer shows some progression between two stages
Level 0 0 marks	Insufficient correct chemistry to gain a mark.

Indicative chemistry content. Contradictions (eg molecules, IMFs, covalent bonding,) negate statements.

Stage 1 - **Na**
1a) Na has metallic bonding
1b) there is attraction/ bonding between the positive nucleus/ ion and the delocalised electrons in Na
1c) Na has a giant/lattice structure

Stage 2 – **NaBr or NaI**
2a) Ionic bonding in NaBr and/or NaI
2b) There is attraction/ bonding between the + and – ions in NaBr and/or NaI
2c) NaBr and/or NaI have a giant/lattice structure

Stage 2 – **comparison of bonding**
3a) The ionic bonds are stronger (or wtte) than the metallic bonds
3b) there is stronger attraction (or wtte) between the + and – ions in NaBr than in NaI
3c) since the Br^- ion is smaller than the I^- ion

6

(b) **M1** $Na + H_2O \rightarrow NaOH + \frac{1}{2} H_2$

Allow multiples

1

M2 (Mass Na = 0.250 g so moles Na = 0.250/23.0) = 0.0109

CE: If not divided by 23, max 3/5 calculation marks – M3, M4 and M5

AE: If not divided by 1000 and final answer is 1.33 × 10^5 cm^3 4/5

1

M3 moles H_2 = 5.43 × 10^{-3} to 5.45 × 10^{-3}

M3 = M2 /2

CE: If incorrect ratio used max 3/5 calculation marks – M2, M4 and M5

1

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M4 T = 298 (K) and P = 101000 (Pa)

1

M5 V = nRT/P or (5.435 × 10^{-3} × 8.31 × 298)/101000 or 1.33 × 10^{-4} (m^3)

1

M6 V = 133 – 134 cm^3

Allow to 2 significant figures or more

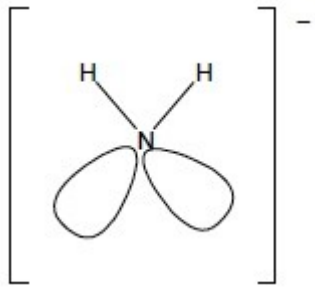
1

(c) Conc = 0.0109/ 500 × 10^{-3} = 0.0217-0.022 (mol dm^{-3})

Allow M2 from question (b)

1

(d) **M1**



Ignore charge and brackets

1

M2 104.5°

Allow 104-106

1

M3 (4) electron pairs repel to be as far apart as possible

1

M4 lp/lp repulsion> lp/bp repulsion (> bp/bp repulsion)

For M4 allow lone pairs repel more than bonding pairs

Mark independently

1

[16]

Q8.

D

[1]

Q9.

A

[1]

Q10.

(a) $$\frac{(46 \times 9.1) + (47 \times 7.8) + (48 \times 74.6) + (49 \times 8.5)}{100} = \frac{4782.5}{100}$$

1

= 47.8

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Correct answer scores 2 marks.
Allow alternative methods.
Allow 1dp or more.
Ignore units

1

(b) $Ti(g) \longrightarrow Ti^{+}(g) + e^{-}$

or $Ti(g) + e^{-} \longrightarrow Ti^{+}(g) + 2e^{-}$

or $Ti(g) - e^{-} \longrightarrow Ti^{+}(g)$

State symbols essential
Allow electrons without $^{-}$ charge shown.

1

46

1

(c) $8.1(37) \times 10^{-26}$

1

(d) M1 is for re-arranging the equation

$$d = t\sqrt{\frac{2E}{m}} \quad \text{or} \quad d = \frac{t}{\sqrt{\frac{m}{2E}}} \quad \text{or} \quad d^2 = t^2 \times \frac{2E}{m}$$

Allow t α square root of m

1

$$d = t_{47}\sqrt{\frac{2E}{47 \times 10^{-3} / L}} = t_{49}\sqrt{\frac{2E}{49 \times 10^{-3} / L}}$$

Or

d = 1.5(47)

This scores 2 marks
Allow this expression for M2

$$\frac{t_{47}}{\sqrt{47}} = \frac{t_{49}}{\sqrt{49}}$$

1

$= 9.6(14) \times 10^{-7}$

Correct answer scores 3 marks.

1

[8]

Q11.

C

[1]

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Q12.

(a) 7–10.2

any range (i.e. 2 values) within this range

1

(b) $K_a = \frac{[H^+][X^-]}{[HX]}$

ALLOW H_3O^+ for H^+ and A for X
IGNORE $[H^+]^2/[HX]$
must be square brackets
IGNORE state symbols

1

(c) Amount NaOH = $(24.0 \times 0.100)/1000 = 2.40 \times 10^{-3}$ mol

(= amount HX)

Conc HX = $2.40 \times 10^{-3}/0.025 = 0.0960$ mol dm^{-3}

ecf for M1/0.025

(d) ($K_a = 2.62 \times 10^{-5} = [H^+]^2/0.0960$)

$[H^+] = \sqrt{(2.62 \times 10^{-5} \times 0.0960)}$ (= 1.59×10^{-3} mol dm^{-3})

ecf from part (c) $[H^+] = \sqrt{(2.62 \times 10^{-5} \times$ ans to part (c))
From alternative data
$[H^+] = \sqrt{(2.62 \times 10^{-5} \times 0.600)}$ (= 3.96×10^{-3} mol dm^{-3})

(pH = –log 1.59×10^{-3} =) 2.80 (must be 2 or more dp)

1

pH = 2.40 (must be 2 or more dp)
M2 dependent on a calculation of $[H^+]$

1

(e) (pH at half-neutralisation = pK_a)

= –log 2.62×10^{-5} = 4.58 (must be 2 or more dp)

ALLOW 1dp if already penalised in part (d)

1

(f) Both points plotted correctly and line touches both points

ecf from (d) and (e) within 1 small square

1

<u>Line steeper at start</u> then levels (to show buffering)

Mark independently

1

[9]

Q13.

D

[1]

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Q14.

D

[1]

Q15.

B

[1]

Q16.

B

[1]

Q17.

B

[1]

Q18.

(a) UV light

1

$CCl_4 \longrightarrow CCl_3\bullet + \bullet Cl$

1

(b) $Cl\bullet + O_3 \longrightarrow ClO\bullet + O_2$

1

$ClO\bullet + O_3 \longrightarrow Cl\bullet + 2O_2$

1

(c) M_r of CF_3Cl = 104.5

Moles freon = $1.78 \times 10^{-4} \times 10^3 / 104.5 = 1.70 \times 10^{-3}$

1

Number of molecules = $1.70 \times 10^{-3} \times 6.02 \times 10^{23} = 1.02 \times 10^{21}$

1

Molecules in 500 cm^3 = $(1.02 \times 10^{21} \times 500 \times 10^{-6}) / 100$
= 5.10×10^{15}

Allow answer in the range $5.10–5.13 \times 10^{15}$
Answer must be given to this precision

1

[7]

Q19.

B

[1]

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Q20.

M_r of sodium bromate(V) = 150.9
and
Mol sodium bromate(V) = 5.00 x (5.00 x 10^{-3}) = 0.0250 **M1**

*Lose **M1** if 151 used (final answer may appear as 3.78).*

1

Mass sodium bromate(V) = 0.025 x 150.9 = 3.77 g **M2**

*Lose **M2** if answer not to 3 sig figs.*

*Correct answer without working scores **M2** only.*

1

[2]

Q21.

(a) Selects correct titres

If 3 or more titres used them MAX 1 for conseq M3

1

$$\text{mean titre} = \frac{9.75 + 9.65}{2}$$

= 9.7(0) cm^3
Calculates mean

1

mol HCL = 0.102 × 9.70/1000 = 9.89 × 10^{-4}
(allow 9.9 × 10-4 for M3 but check not via 4 titres in which case only 1 mark)

Calculates mol (working or result gains credit)

9.92 × 10^{-4} scores 1 if all 4 titres used

9.83 × 10^{-4} scores 1 if titres 1,2, and 3 used

1

(b) mol $MHCO_3$ = ANS 3.1 × 10 (= 9.89 × 10^{-3})

Use ecf if wrong mean calculated above

1

$$\text{Mr} = \frac{1464/1000}{M1}$$

1

Mr = 148 (3sf)

Allow ecf following wrong mass conversion

1

(c) Suggestion: Use a larger mass of solid OR use a more concentrated solution of $MHCO_3$ OR less concentrated / more dilute solution of HCl OR more $MHCO_3$

1

Cannot score justification mark unless suggestion correct, but suggestion could be after justification

Justification: So a larger titre/reading will be needed OR larger volume of HCl

Assume reference to the solution means the $MHCO_3$

1

(d) This question is marked using levels of response.

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Level 3
Must use volumetric flask to access level 3
Answer is communicated coherently and shows a logical progression from stage 1 to stage 2 then stage 3.

All stages are covered and the description of each stage is complete

6 marks

All stages are covered but up to 2 omissions/errors from different stages. If 2 omissions/errors from same stage only level 2 possible

5 marks

Level 2
Answer is mainly coherent and shows progression from stage 1 to stage 3

All stages are covered but 3 omissions/errors

4 marks

All stages are attempted

3 marks

Level 1
Answer includes isolated statements but these are not presented in a logical order or show confused reasoning.

2 stages attempted

2 marks

1 stage attempted

1 mark

Level 0
Insufficient correct chemistry to gain a mark.

0 marks

Indicative Chemistry content

Stage 1*: transfers known mass of solid*

a) Weigh the sample bottle containing the solid on a (2 dp) balance

b) Transfer to beaker and reweigh sample bottle*

c) Record the difference in mass

Or

d) Place beaker on balance and tare*

e) Transfer solid into beaker

f) Record mass

Or

g) Known mass provided

*h) Transfers (known) mass into beaker**

i) Wash all remaining solid from sample bottle into beaker

Allow use of weighing boat

**Allow other suitable glassware including volumetric flask*

Stage 2*: Dissolves in water*

a) Add distilled / deionised water

b) Stir (with a glass rod) or swirl

c) Until all solid has dissolved

Stage 3*: Transfer, washing and agitation*

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a) Transfer to <u>volumetric / graduated</u> flask. Allow if a clear description/diagram given eg long necked flask with 250 cm^3 mark

b) With washings

c) Make up to 250 cm^3 / mark with water

d) Shakes/inverts/mixes

6

[14]

Q22.

(a) n = PV/RT

If PV=nRT rearranged incorrectly then M3 only

1

$$\frac{102\,000 \times (1.00 \times 10^{-3})}{8.31 \times 300} = n = (4.091456077 \times 10^{-2})$$

1

Mass = M2 × 17 = 0.696 (g) (3 sig figs only)

Allow 0.695 or 0.697

1

(b) If pV = nRT

$$\text{Total volume} = \frac{nRT}{P}$$

Incorrect unit conversion loses M1 only; can get M2/M3 if possible volume obtained

$$= \frac{n \times 8.31 \times 295}{75\,000}$$

$= 1.34 \times 10^{-3}$ m^3

Inserts correct numbers (inc pressure in Pa)

1

Volume of Q in $m^3 = 1.00 \times 10^{-3}$

Volume of bulb P = $1.34 \times 10^{-3} - 1.00 \times 10^{-3}$

Volume of bulb P = 3.42×10^{-4} m^3

No subtraction M1 only

1

= 342 cm^3 (Allow 310 − 342 cm^3)

Alternative method also worth full credit

(note if mol in M2 of 05.1 rounded to 0.04 this could lead to a final answer of 3.1×10^{-4} m^3 so allow range 310 − 342 cm^3

1

[6]

Q23.

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B

[1]

Q24.

B

[1]

Q25.

(a) **Method 1**

Allow working throughout to 2sf

M1 Moles of Mg = 0.396/24.3 = 0.0163

1

M2 Moles of CH_3COOH = 0.600 × 30.0/1000 = 0.018

1

M3 Mark for showing Mg is in excess: either
0.018 mol of CH_3COOH reacts with 0.009 mol of Mg OR
0.0163 mol of Mg reacts with 0.0326 mol of CH_3COOH
OR 0.0073 mol of Mg is in excess

1

If candidate gets 16.3 mol (as not converted mg to g) in method 1 or 3 then can only score 1 mark maximum (M2)

Accept other valid calculations that show the Mg is in excess

Method 2

M1 Moles of CH_3COOH = 0.600 × 30.0/1000 = 0.018

M2 Moles of Mg that would react with this = 0.009

M3 Mass of Mg needed = 24.3 × 0.009 = 0.219 g which is less than 0.396 g OR
Moles of Mg = 0.0163 which is more than 0.009 required

Method 3

M1 Moles of Mg = 0.396/24.3 = 0.0163

M2 Moles of CH_3COOH that would react with this = 0.0326

M3 Volume of CH_3COOH needed = 0.0326 / 0.60 = 0.0543 dm^3 (54.3 cm^3) which is more than 0.030 dm^3 (30 cm^3)

(b) M1 Line starts at origin and is steeper

1

M2 (moles CH_3COOH = 0.800 × 20/1000 = 0.016) line levels out on 8th line up (line below the original 9th line)

M2 for line on 8th line on grid (original on 9th line) – allow some leniency so long as clear it ends at (or very close to) the 8th line; and line does not significantly wobble

1

[5]

Q26.

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(a) M1 $\bullet Cl + O_3 \longrightarrow \bullet ClO + O_2$

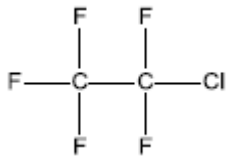
1

M2 $\bullet ClO + O_3 \longrightarrow \bullet Cl + 2O_2$

1

M1 and M2 could be in either order
Credit the dot anywhere on the radical
Penalise absence of dot once only
Individual multiples acceptable but both need to be doubled if
two marks are to be awarded
Ignore state symbols

(b)



Must be displayed formula

1

(c) Does not contain Cl or does not release Cl (atoms/radicals)
or no C-Cl bonds
or C-F bond(s) strong / does not break / no F (atom/radicals) released

1

(d) M1 $CHF_2CH_3 + \bullet F \longrightarrow \bullet CF_2CH_3 + HF$

1

M2 $\bullet CF_2CH_3 + F_2 \longrightarrow CF_3CH_3 + \bullet F$

1

M1 and M2 could be in either order
Credit the dot anywhere on the radical
Penalise absence of dot once only

(e) M1 moles CF_3CH_3 = 1410/84(.0) (=16.8, 16.79 mol)

1

M2 molecules = M1 × $6.022 \times 10^{23} = 1.01 \times 10^{25}$ (3sf only)

1

Correct answer scores both marks
Allow M2 for M1 × Avogadro with answer to 3 sf (but must have attempted to calculate moles for M1)
Ignore incorrect units

(f) (bonds) vibrate/stretch/bend OR (as bonds) are polar
NOT polar molecules; 'they' = bonds

1

[9]

Q27.

D

[1]

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Q28.

(a)

Method 1	Method 2
Mass of H_2O = 4.38−2.46	Percentage of H_2O = 44%
(= 1.92 g)	

If there is an AE in M1 then can score M2 and M3
If M_r incorrect can only score M1

1

$ZnSO_4$	H_2O	ZnSO4	H2O
2.46	1.92	56	44
161.5	18	161.5	18

1

(0.0152	0.107)	(0.347	2.444)
(1 :	7)	(1 :	7)
x = 7		x = 7	

If x = 7 with working then award 3 marks.
Allow alternative methods.
If M1 incorrect due to AE, M3 must be an integer.

1

(b) Moles HCl = 0.12(0)

1

mol $ZnCl_2$ = 0.06(0) ***OR*** 0.12 / 2

1

If M2 incorrect then CE and cannot score M2, M3 and M4.

mass $ZnCl_2$ = 0.06 × 136.4
Allow 65.4 + (2 × 35.5) for 136.4

1

= 8.18(4) (g) ***OR*** 8.2 (g)
Must be to 2 significant figures or more.
Ignore units.

1

(c) Moles $ZnCl_2$ = $\frac{10.7}{136.4}$ (= 0.0784)

1

OR moles Zn = 0.0784

Mass Zn reacting = 0.0784 × 65.4 = (5.13 g)
M2 is for their M1 × 65.4

1

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$$\%\,\text{purity of Zn} = \frac{5.13}{5.68} \times 100$$

M3 is M2 × 100 / 5.68 provided M2 is < 5.68

1

= 90.2% ***OR*** 90.3%

Allow alternative methods.

M1 = Moles $ZnCl_2$ = 10.7 (= 0.0784)
136.4

M2 = Theoretical moles Zn = 5.68 (= 0.0869)
65.4

M3 = M1 × 100 / M2 = (0.0784 × 100 / 0.0869)

*M4 = 90.2% **OR** 90.3%*

1

(d) Ionic

If not ionic CE = 0/3

1

Strong (electrostatic) attraction (between ions)

1

between oppositely charged ions / + and − ions / F^- and Zn^{2+} ions

If IMF, molecules, metallic bonding implied CE = 0/3

1

[14]

Q29.

(a) (i) 0.0212

Need 3 sig figs

Allow correct answer to 3 sig figs eg 2.12 x 10^{-2}

1

(ii) 0.0106

Mark is for (a)(i) divided by 2 leading to correct answer 2 sig figs

1

(iii) M_r = 100.1

1.06 g

Allow 100.1 as 'string'

Need 3 sig figs or more

Consequential on (a)(ii) x 100(.1)

2

(iv) Neutralisation or acid / base reaction

Allow acid / alkali reaction

Apply list principle

1

(b) (i) T = 304(K) and P = 100 000 (Pa)

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Only T and P correctly converted

1

$$\frac{100\,000 \times 3.50 \times 10^{-3}}{8.31 \times 304} \text{ OR } n = \frac{PV}{RT}$$

1

0.139 (mol)

Allow <u>0.138 – 0.139</u>

1

(ii) 0.0276 – 0.0278(mol)

Allow answer to (b)(i) divided by 5 leading to a correct answer

Allow 0.028

1

(c) 4.20 g $Ca(NO_3)_2$

1

$Ca(NO_3)_2$ H_2O

$$\frac{4.20}{164(.1)} \qquad \frac{1.84}{18}$$

Mark is for dividing by the correct Mr values

M2 and M3 dependent on correct M1

0.0256 0.102

M2 can be awarded here instead

1 : 3.98

x = 4

If $Ca(NO_3)_2.4H_2O$ seen with working then award 3 marks

Credit alternative method which gives x = 4

1

[12]

Q30.

(a) (i) Avogadro's number/constant of molecules/particles/species / 6×10^{23}

[Not 'atoms']

1

Or same number of particles as (there are atoms)

[Not molecules]

in 12.(00)g of ^{12}C

1

(ii) *Moles O_2 = $\frac{0.350}{32}$ (= 1.09 × 10^{-2} mol)*

1

= 29 (× 1.09 × 10^{-2})

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[Accept answers via 4 separate mole calculations]

1

= 0.316 – 0.317 mol [answer to 3 + sf]

[Mark conseq on errors in M1/M2] (1)

1

(iii) Moles of nitroglycerine = $4 \times 1.09 \times 10^{-2}$ (= 0.0438 mol)

[Mark conseq on their moles of O_2]

1

M_r of nitroglycerine = 227 or number string

1

Moles of nitroglycerine = 227 × 0.0438 = 9.90 – 9.93(g)

[answer to 3+ sf]

[If string OK but final answer wrong then allow M6 but AE for M7]

[Mark conseq on error in M_r] [Penalise wrong units]

[Penalise sig. fig. errors once only in whole question]

(b) $pV = nRT$ **or** $pV = \frac{mRT}{V}$ **or** $p = \frac{nRT}{V}$

1

$p = \frac{nRT}{V} = \frac{0.873 \times 8.31 \times 1100}{1.00 \times 10^{-3}}$

1

= 7980093 **or** 7980 **or** 7.98

[ignore s.f.]

1

units = Pa **or** kPa **or** MPa (as appropriate)

[If error in conversion from Pa, treat as a contradiction of the units mark]

[If transfer error, mark conseq but penalise M2]

[If data from outside of above used, penalise M2 and M3]

[If pV expression incorrectly rearranged, penalise M2 and M3]

[if T = 1373 K used, penalise M2]

1

[11]

Q31.

C

[1]

Q32.

D

[1]

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Q33.

(penalty for sig fig error =1 mark per question)

(a) neutron: relative mass = 1 relative charge = 0
(not 'neutral')

1

electron: relative mass = 1/1800 → 0/negligible *or*

5.56 × 10–4 → 0 relative charge = –1

1

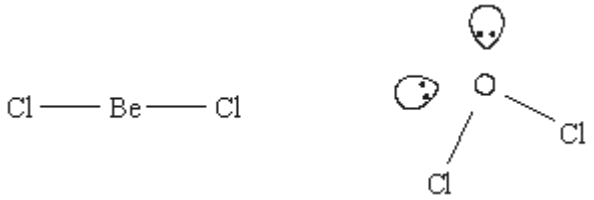
(b) $^{17}O/O^{17}$ mass number (*Do not accept 17.0*)

1

oxygen symbol 'O'
(if 'oxygen' + — 'mass number = 17'(1))
(if 'oxygen'+ — 'mass number = 17'(0))
(if at N^0 given but ≠ 8, treat as 'con' for M2)
(if lp on Be, diagram = 0)
(ignore bond angles)
(not dot and cross diagrams)

1

(c)



2

QoL Linear **(1)** bent / V-shaped / angular **(1)**
(mark name and shape independently)
(accept (distorted) tetrahedral)
(if balls instead of symbols, lose M1 – can award M2)
(penalise missing 'Cl' once only)
(not 'non-linear')

2

(d) M_r ($Mg(NO_3)_2$ = 58(.3) *(if At N^0 used, lose M1 and M2)*

1

moles $Mg(OH)_2$ = 0.0172 (conseq on wrong M2) (answer to 3+ s.f.)

1

moles HCl = 2 × 0.0172 = 0.0344 *or* 0.0343 (mol) *(process mark)*

1

vol HCl = $\frac{0.0343 \times 1000}{1}$ = 34.3 – 34.5 (cm^3) *(unless wrong unit)*
*(if candidate **used** 0.017 or 0.0171 lose M2)*
(just answer with no working, if in range = (4).
if, say, 34 then =(2))

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(if not 2:1 ratio, lose M3 and M4)
(if work on HCl, CE = 0/4)

1

[12]

Q34.

C

[1]

Q35.

D

[1]

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Q1.

(a) Almost all students were able to give the correct Mr for sodium fluoride but many became confused by the different units involved in this question. Students should be advised that they should explain their working for each step in a calculation. When only numbers were provided in an answer, it was not clear what students were calculating in each step.

(b) A good number of students (39.9%) were able to determine the maximum mass of sodium fluoride that a 75.0 kg person could swallow without reaching a toxic concentration, although a few struggled with the conversion to mg.

(c) Many students completed this calculation with the figures upside-down and so were unable to score. A surprisingly high proportion of students (16%) made no attempt whatsoever at this question.

(d) Many students were unable to identify the correct relative sizes – many stated that both ions were the same size because they had the same number of electrons, without considering the impact of the protons. Other students did not appreciate that both ions were isoelectronic.

Q2.

The most common answer (D) was incorrect and was the value that was twice the correct answer.

Q3.

(a) This question proved demanding for most students. A good number were able to calculate the mass of the $^{79}Br^{+}$ ion. Very few students realised that most of the quantities cancelled down during the calculation and took time to calculate the velocity of the $^{79}Br^{+}$ ion in order to then work out the kinetic energy. This velocity was frequently calculated well but the remaining marks then proved a challenge for students. Some completed numerous calculation steps only to give a time for the $^{81}Br^{+}$ ion that was the same as the time for the $^{79}Br^{+}$ ion.

(b) Only a few students understood that when the ion reaches the detector it gains an electron, whereas many understood that the size of the current was proportional to the abundance of the ion.

Q4.

The majority of students (67.5%) answered this question correctly.

Q5.

Most students (70.6%) could correctly find the number of molecules in a sample of propane. The most common incorrect answer used C_3H_6 rather than C_3H_8 as the formula of propane.

Q6.

Most students (55.6%) could correctly find the liquid that had the greatest volume from its mass and density.

Q7.

(a) This levels-of-response question discriminated very well, with approximately one third of students scoring marks in each of the three levels. Some excellent answers were seen. Some students, however, answered very well initially but then used wrong terminology, for example wrong bonding and/or intermolecular forces in all/some of the substances, and showed contradictions in their answers.

(b) Unfortunately, the equation was often seen with sodium oxide as the product rather than sodium hydroxide. In the calculation, many students did not use the 2:1 ratio from the equation, leading to an answer of 267 cm^3. However, this part of the question also discriminated well, with over 25% of students gaining full marks; most students scored some marks and less than 3% scored zero.

(c) Just under half of the students (48.5%) gave a correct answer; the commonest error was to multiply the amount, in moles, by volume rather than dividing by volume.

(d) This part discriminated well, though only a few students (7%) scored full marks. The structure often had the wrong number of lone pairs and/or the wrong bond angle. That lone pair-lone pair repulsion is greater than bond pair-bond pair repulsion was known by the majority of students.

Q8.

Although 47.7% of students gained this mark, all three distractors attracted significant numbers of students.

Q9.

Students found this question challenging (38.8% correct), possibly from a lack of familiarity with using the Avogadro constant.

Q10.

(a) This was generally well answered, though a few students added the abundances incorrectly.

(b) Most students gave the correct equation, but some used the wrong state symbols or omitted them. The identity of the isotope was well known but some students lost a mark by using the symbol for the atom rather than the *m/z* value.

(c) The most common error was a failure to convert from grams into kilograms.

(d) Only the best students gained all three marks. All marks were available, even for those students who had not answered part (c), or who had the wrong answer for it. Some students were unable to re-arrange the equation. Students who appreciated that the distance travelled was common to both ions usually went on to get the correct answer, but a large number of students scored zero or one mark.

Q11.

There was no evidence that students were short of time on this calculation at the end of the paper and a good number (41.8%) completed it successfully.

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Q12.

(a) Nearly 60% of students recognised that the working range should correspond to the vertical section of the titration curve.

(b) Over 80% of students recognised this expression, with the commonest error being to show it as $[H^+]^2/[HX]$.

(c) This question was another that illustrated the importance of paying attention to the information in the stem of a question. A significant number of students attempted to answer this question using the expression for K_a, instead of recognising that this is a titration and that the end-point allows the amount of NaOH to be calculated, and hence the amount and concentration of the acid. Perhaps students did not recognise that that the end point of the titration could be obtained easily from the graph.

(d) The provision of alternative data ensured that students who had difficulty with part (c) were not disadvantaged here and over 50% gained full marks. Data in the stem were again crucial here.

(e) The idea that pH = pK_a at half-equivalence was not recognised by many, so only 26% of students gained this mark.

(f) A mark was often lost as a result of students assuming that half-equivalence was at 10 or 15 cm^3 and so plotting incorrectly. Many also failed to remember the need to show an initial steep section before buffering 'levels off' the curve.

Q20.

This question was done well with the usual proviso regarding an understanding of precision.

Q21.

Only the most able students answered this question correctly. It was noted that many students selected incorrect titres in (a) limiting them to 1 mark out of 3. Consequential marking allowed students to score full marks for (b) but (c) was answered poorly showing a lack of practical experience. Question (d) was marked using a levels of response mark scheme that tested students' ability to give a logical description of a common practical technique. Many students were able to access at least 3 marks but few scored the full 6. It was not uncommon to see some students describe the titration technique itself and in so doing fail to address the question asked.

Q22.

Perhaps because it was similar to questions asked in the previous specification, Question (a) was quite well answered but a common mistake was to use values with incorrect units for the variables in the $pV = nRT$ calculation. Question (b) was much less well answered with many students calculating the total volume of the two flasks but failing to answer the question and give the volume of flask P in cm^3.

Q25.

Reaction rates and limiting reagent

The best students knew in (a) that the magnesium was in excess by calculation, but other students were confused. Some failed to convert mg to g. Many students wrote numbers with no explanation of what they represented. Many statements were seen of the type:

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‘0.6 × 0.03 = 0.018/2 = 0.009’, which is an incorrect mathematical statement. To score full marks, students had to explain how their calculation showed the magnesium was in excess. Many students realised in (b) that the second reaction was faster than the first and drew their line steeper, but few could determine that 8/9ths of the volume of hydrogen would be formed.

Q26.

Free radical reactions

In (a) the two equations showing how chlorine radicals destroy ozone were quite well known. Many students in (b) could draw the correct displayed formula of chloropentafluoroethane. Many students in (c) could explain why 1,1,1-trifluoroethane did not lead to ozone depletion. The simplest answer was that it contains no chlorine, but credit was given for students who stated that the C-F bonds were strong and so fluorine radicals were not released. Students in (d) found the two propagation steps to convert CHF_2CH_3 into CF_3CH_3 more challenging, but a pleasing number could do this. The most common mistake was to remove a Hydrogen atom from the wrong Carbon atom in the first step. Students found (e) - the calculation for the number of molecules - challenging. Some had little idea where to start while many others failed to convert kg to g and/or give their final answer to the correct number of significant figures. Few students knew (f) that molecules with vibrating polar bonds absorb IR radiation.

Q28.

Some students found no difficulty with the three numerical parts of this question. However, this question proved challenging for many students who often gave a jumble of figures with little explanation of where they came from.

Part (a) was the most well answered of the calculations although a small number could not score the first mark. In part (b), most students scored the mark for the number of moles of HCl. However, many students then used 0.083 in their answer and did not realise that the HCl was the limiting reagent. Many added the moles of HCl to the moles of pure zinc oxide whilst others multiplied the moles of HCl by 2 rather than dividing.

Answers to part (c) used various methods with many scoring the first two marks of the alternative method shown in the mark scheme. It should be noted that if an answer requires 3 significant figures, then the calculation should use at least 3 significant figures throughout. If less than this is used and then the answer is given as 3 ‘significant’ figures, this will have introduced error and the final answer will not be within the margin of tolerance allowed. The bonding in part (d) was answered well by the majority of students.

Q29.

Parts (a)(i), (ii) and (iii) were generally well done although many answers were not given to the precision required in the question. Part (a)(iv) was found to be difficult and generated answers such as ‘displacement’ and ‘condensation’. The calculation in part (b)(i) was done well by many candidates but a significant number could not rearrange the equation correctly or convert the given pressure and temperature into the correct units. In part (b)(ii) there was a tendency to divide by 2 or 7. The empirical formula calculation in part (e) differentiated well with weaker candidates usually scoring only one of the available marks.

Q30.

Part (a)(i) was often poorly answered. Answers in terms of M_r and mass were quite

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common, as were statements such as the *number of atoms/particles in lg of substance.* Candidates, who correctly defined a mole in terms of the Avogadro constant, often spoiled their answer by misquoting its value or by referring to there being the Avogadro number of atoms, rather than molecules, in a mole of molecules. Some good answers linking the mole to the number of atoms of carbon in 12.00 g of ^{12}C, were seen.

-

In part a(ii), the majority of candidates, when attempting to calculate the number of moles of oxygen formed in the reaction, divided the mass by 16 rather than by 32. Also, in part (a)(iii), a surprising number of candidates used 908, rather than 227, as the M_T for nitroglycerine. Similarly, there were many errors in determining the total number of moles of gas formed; the most common error being 28, rather than 29. As the remaining marks were awarded consequentially, many candidates still achieved a reasonable mark for this calculation. In part (b), the Gas law expression was well known and the question was well answered. However, a significant number of candidates, having correctly calculated the pressure and quoted its units as Pa., thereby earning all 4 marks, chose to convert their answer into larger pressure units. Errors in this conversion were quite common and so the final mark was lost.

Q33.

On the whole, this question was well answered. The relative masses and charges of neutrons and electrons were generally well known but errors were not uncommon. Some candidates reversed the contents of the *mass* and *charge* columns, suggesting that they had rote learned a table with a different layout of columns.

Part (b) was quite well done but errors such as ^{17}Be, ^{13}O, $^{17.0}O$ and ^{16}O were not uncommon.

While many candidates correctly deduced the shapes of the molecules in part (c), the presence of a lone pair of electrons on the Be atom, or one/three lone pairs of electrons on the O atom, was quite common. The shape of the $BeCl_2$ molecule was well known but there was considerable confusion regarding the shape of the Cl_2O molecule. Many candidates gave *tetrahedral* as the shape of this molecule. While the distribution of electron pairs around the oxygen atom might be described as *tetrahedral*, this is not the shape produced by the atoms in the molecule. Many candidates described the shape in appropriately by using the terms *bent*, *V-shaped* and *angular*. The use of *tetrahedral* was accepted in this examination but this may not be the case in future examinations. A significant number of candidates used the term *bent linear* when describing the shape of Cl_2O molecules; this was treated as a contradiction and so earned no credit. A significant number of candidates attempted to show the shapes of these molecules using dot-and-cross diagrams; these were not accepted.

The calculation in part (d) was correctly performed by many candidates, but errors such as the use of incorrect *M*r values or the use of an incorrect mole ratio were quite common. A small but significant number of candidates assumed the use of a known mass of HCl and ignore the 1.00 g of $Mg(OH)_2$ stipulated in the question; such answered earned no credit.

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Q1.

In a reaction which gave a 27.0% yield, 5.00 g of methylbenzene were converted into the explosive 2,4,6-trinitromethylbenzene (TNT) (M_r = 227.0). The mass of TNT formed was

A 1.35 g

B 3.33 g

C 3.65 g

D 12.34 g

(Total 1 mark)

Q2.

(a) Ammonium sulphate reacts with aqueous sodium hydroxide as shown by the equation below.

$$(NH_4)_2SO_4 + 2NaOH \rightarrow 2NH_3 + Na_2SO_4 + 2H_2O$$

A sample of ammonium sulphate was heated with 100 cm^3 of 0.500 mol dm^{-3} aqueous sodium hydroxide. To ensure that all the ammonium sulphate reacted, an excess of sodium hydroxide was used.
Heating was continued until all of the ammonia had been driven off as a gas.
The unreacted sodium hydroxide remaining in the solution required 27.3 cm^3 of 0.600 mol dm^{-3} hydrochloric acid for neutralisation.

(i) Calculate the original number of moles of NaOH in 100 cm^3 of 0.500 mol dm^{-3} aqueous sodium hydroxide.

_____

_____

(ii) Calculate the number of moles of HCl in 27.3 cm^3 of 0.600 mol dm^{-3} hydrochloric acid.

_____

_____

(iii) Deduce the number of moles of the unreacted NaOH neutralised by the hydrochloric acid.

_____

(iv) Use your answers from parts (a) (i) and (a) (iii) to calculate the number of moles of NaOH which reacted with the ammonium sulphate.

_____

_____

(v) Use your answer in part (a) (iv) to calculate the number of moles and the mass of ammonium sulphate in the sample.

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(If you have been unable to obtain an answer to part (a) (iv), you may assume that the number of moles of NaOH which reacted with ammonium sulphate equals 2.78×10^{-2} mol. This is not the correct answer.)

Moles of ammonium sulphate _____

_____

Mass of ammonium sulphate _____

_____

(7)

(b) A 0.143g gaseous sample of ammonia occupied a volume of 2.86×10^{-4} m^3 at a temperature ***T*** and a pressure of 100 kPa.

State the ideal gas equation, calculate the number of moles of ammonia present and deduce the value of the temperature ***T***.

(The gas constant $R = 8.31$ J K^{-1} mol^{-1})

Ideal gas equation _____

Moles of ammonia _____

_____

Value of ***T*** _____

_____

_____

_____

_____

(4)

(Total 11 marks)

Q3.

(a) Sodium carbonate forms a number of hydrates of general formula $Na_2CO_3.xH_2O$

A 3.01 g sample of one of these hydrates was dissolved in water and the solution made up to 250 cm^3.
In a titration, a 25.0 cm^3 portion of this solution required 24.3 cm^3 of 0.200 mol^{-1} dm^{-3} hydrochloric acid for complete reaction.

The equation for this reaction is shown below.

$Na_2CO_3 + 2HCl \rightarrow 2NaCl + H_2O + CO_2$

(i) Calculate the number of moles of HCl in 24.3 cm^3 of 0.200 mol dm^{-3} hydrochloric acid.

_____

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(ii) Deduce the number of moles of Na_2CO_3 in 25.0 cm^3 of the Na_2CO_3 solution.

_____

(iii) Hence deduce the number of moles of Na_2CO_3 in the original 250 cm^3 of solution.

_____

(iv) Calculate the M_r of the hydrated sodium carbonate.

_____

_____

(5)

(b) In an experiment, the M_r of a different hydrated sodium carbonate was found to be 250.
Use this value to calculate the number of molecules of water of crystallisation, *x*, in this hydrated sodium carbonate, $Na_2CO_3.xH_2O$

_____

_____

_____

_____

(3)

(c) A gas cylinder, of volume 5.00×10^{-3} m^3, contains 325 g of argon gas.

(i) Give the ideal gas equation.

_____

(ii) Use the ideal gas equation to calculate the pressure of the argon gas in the cylinder at a temperature of 298 K.
(The gas constant $R = 8.31$ J K^{-1} mol^{-1})

_____

_____

_____

_____

(4)

(Total 12 marks)

Q4.

The following two-stage method was used to analyse a mixture containing the solids magnesium, magnesium oxide and sodium chloride.

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Stage 1
A weighed sample of the mixture was treated with an excess of dilute hydrochloric acid. The sodium chloride dissolved in the acid. The magnesium oxide reacted to form a solution of magnesium chloride. The magnesium also reacted to form hydrogen gas and a solution of magnesium chloride. The hydrogen produced was collected.

(a) Write equations for the two reactions involving hydrochloric acid.

(2)

(b) State how you would collect the hydrogen. State the measurements that you would make in order to calculate the number of moles of hydrogen produced. Explain how your results could be used to determine the number of moles of magnesium metal in the sample.

(6)

Stage 2
Sodium hydroxide solution was added to the solution formed in **Stage 1** until no further precipitation of magnesium hydroxide occurred. This precipitate was filtered off, collected, dried and heated strongly until it had decomposed completely into magnesium oxide. The oxide was weighed.

(c) Write equations for the formation of magnesium hydroxide and for its decomposition into magnesium oxide.

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(3)

(d) When a 2.65 g sample of the mixture of the three solids was analysed as described above, the following results were obtained.

Hydrogen obtained in **Stage 1** 0.0528 mol

Mass of magnesium oxide obtained in **Stage 2** 6.41 g

Use these results to calculate the number of moles of original magnesium oxide in 100 g of the mixture.

(4)

(Total 15 marks)

Q5.

(a) One isotope of sodium has a relative mass of 23.

(i) Define, in terms of the fundamental particles present, the meaning of the term *isotopes*.

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_____

_____

(ii) Explain why isotopes of the same element have the same chemical properties.

_____

_____

(iii) Calculate the mass, in grams, of a single atom of this isotope of sodium.
(The Avogadro constant, *L*, is 6.023×10^{23} mol^{-1})

_____

_____

_____

(5)

(b) Give the electronic configuration, showing all sub-levels, for a sodium atom.

_____

(1)

(c) Explain why chromium is placed in the d block in the Periodic Table.

_____

_____

(1)

(d) An atom has half as many protons as an atom of ^{28}Si and also has six fewer neutrons than an atom of ^{28}Si. Give the symbol, including the mass number and the atomic number, of this atom.

_____

(2)

(Total 9 marks)

Q6.

(a) The equation for the reaction between magnesium carbonate and hydrochloric acid is given below.

$$MgCO_3 + 2HCl \rightarrow MgCl_2 + H_2O + CO_2$$

When 75.0 cm^3 of 0.500 mol dm^{-3} hydrochloric acid were added to 1.25 g of impure $MgCO_3$ some acid was left unreacted. This unreacted acid required 21.6 cm^3 of a 0.500 mol dm^{-3} solution of sodium hydroxide for complete reaction.

(i) Calculate the number of moles of HCl in 75.0 cm^3 of 0.500 mol dm^{-3} hydrochloric acid.

_____

(ii) Calculate the number of moles of NaOH used to neutralise the unreacted HCl.

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_____

_____

(iii) Show that the number of moles of HCl which reacted with the $MgCO_3$ in the sample was 0.0267

_____

(iv) Calculate the number of moles and the mass of $MgCO_3$ in the sample, and hence deduce the percentage by mass of $MgCO_3$ in the sample.

Moles of $MgCO_3$ _____

_____

Mass of $MgCO_3$ _____

_____

Percentage of $MgCO_3$ _____

_____

_____

(8)

(b) A compound contains 36.5% of sodium and 25.5% of sulphur by mass, the rest being oxygen.

(i) Use this information to show that the empirical formula of the compound is Na_2SO_3

_____

_____

_____

_____

_____

_____

(ii) When Na_2SO_3 is treated with an excess of hydrochloric acid, aqueous sodium chloride is formed and sulphur dioxide gas is evolved. Write an equation to represent this reaction.

_____

_____

(4)

(Total 12 marks)

Q7.

Use the information below to answer this question.

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A saturated solution of magnesium hydroxide, $Mg(OH)_2$, contains 0.1166 g of $Mg(OH)_2$ in 10.00 dm^3 of solution. In this solution the magnesium hydroxide is fully dissociated into ions.

Which one of the following is the concentration of $Mg^{2+}(aq)$ ions in the saturated solution?

A 2.82×10^{-2} mol dm^{-3}

B 2.00×10^{-3} mol dm^{-3}

C 2.82×10^{-3} mol dm^{-3}

D 2.00×10^{-4} mol dm^{-3}

(Total 1 mark)

Q8.

(a) A sample of ethanol vapour, C_2H_5OH (M_r = 46.0), was maintained at a pressure of 100 kPa and at a temperature of 366K.

(i) State the ideal gas equation.

_____

(ii) Use the ideal gas equation to calculate the volume, in cm^3, that 1.36 g of ethanol vapour would occupy under these conditions.
(The gas constant R = 8.31 J K^{-1} mol^{-1})

_____

_____

_____

_____

_____

_____

_____

(5)

(b) Magnesium nitride reacts with water to form magnesium hydroxide and ammonia.

(i) Balance the equation, given below, for the reaction between magnesium nitride and water.

$$Mg_3N_2 + H_2O \rightarrow Mg(OH)_2 + NH_3$$

(ii) Calculate the number of moles, and hence the number of molecules, of NH_3 in 0.263 g of ammonia gas.
(The Avogadro constant L = 6.02×10^{23} mol^{-1})

_____

_____

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_____

_____

_____

(4)

(c) Sodium carbonate is manufactured in a two-stage process as shown by the equations below.

$$NaCl + NH_3 + CO_2 + H_2O \rightarrow NaHCO_3 + NH_4Cl$$

$$2NaHCO_3 \rightarrow Na_2CO_3 + H_2O + CO_2$$

Calculate the maximum mass of sodium carbonate which could be obtained from 800 g of sodium chloride.

_____

_____

_____

_____

_____

(4)

(Total 13 marks)

Q9.

Which one of the following contains the greatest number of moles of methanol? (The Avogadro number (L) is 6.02×10^{23}, the relative molecular mass (M_r) of methanol is 32.)

A 6.6×10^{22} molecules

B 3.3 g of methanol

C 2.5×10^{-3} m^3 of methanol vapour at 300 K and 100 kPa

D 70 cm^3 of 1.5 M aqueous methanol

(Total 1 mark)

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Q1.

B

[1]

Q2.

(a) (i) $100 \times 10^{-3} \times 0.500 = 5.00 \times 10^{-2}$ (mol)

accept $5 \times 10^{-2} / 0.05$

1

(ii) $27.3 \times 10^{-3} \times 0.600 = 1.64 \times 10^{-2} / 1.638 \times 10^{-2}$ (mol) only

1

(iii) 1.64×10^{-2} (mol)

Mark conseq on (ii)

1

(iv) $5.00 \times 10^{-2} - 1.64 \times 10^{-2} = 3.36 \times 10^{-2}$ (mol)

Mark conseq on (i) & (iii)

1

(v) $3.36 \times 10^{-2} \times ½ = 1.68 \times 10^{-2}$ (mol)

If 2.78×10^{-2} used 1.39×10^{-2}

Mark conseq on (iv)

1

$1.68 \times 10^{-2} \times 132(.1)$ **or** $1.39 \times 10^{-2} \times 132(.1)$

Mark for M_r

1

= 2.22 g **or** 1.83 g

1

(b) pV = nRT

1

$n = \frac{0.143}{17}$ = $8.4(1) \times 10^{-3}$ (mol)

1

$T = \frac{pV}{nR} = \frac{100000 \times 2.86 \times 10^{-4}}{8.31 \times 8.4 \times 10^{-3}}$ (1)

1

= 408.5 – 410.5 (K)

Mark conseq on moles

***Note** Sig. fig. penalty - apply once if single sf given, unless calc works exactly*

1

[11]

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Q3.

(a) (i) 4.86×10^{-3}

1

(ii) 2.43×10^{-3}

(mark conseq on (a)(i))

1

(iii) 2.43×10^{-2}

(mark conseq on (a)(ii))

1

(iv) $3.01/2.43 \times 10^{-2}$

(mark conseq on (a)(iii))

1

124

(Do not allow 124 without evidence of appropriate calculation in (a)(iii))

1

(b) $M_r(Na_2CO_3) = 106$
M_r (xH_2O) = 250 –106 = 144 *(mark conseq on M1)*
x = 8 *(mark conseq on M2)*
(Penalise sf errors once only)

3

(c) (i) PV = nRT

1

(ii) Moles A_r = 325/39.9 = 8.15
(accept M_r = 40)

1

P = nRT/V = $(8.15 \times 8.31 \times 298)/5.00 \times 10^{-3}$
= 4.03×10^6 Pa or = 4.03×10^3 kPa
Range = 4.02×10^6 Pa to 4.04×10^6 Pa
(If equation incorrectly rearranged, M3 & M4 = 0 If n =325, lose M2)
(Allow M1 if gas law in (ii) if not given in (i))

2

[12]

Q4.

(a) $Mg + 2HCl \rightarrow MgCl_2 + H_2$

1

$MgO + 2HCl \rightarrow MgCl_2 + H_2O$
Allow ionic equations

1

(b) Hydrogen collection
Using a gas syringe or measuring cylinder/ graduated vessel over water

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Allow if shown in a diagram

1

Measurements (i) P 1
(ii) T 1
(iii) V 1

Use ideal gas equation to calculate mol hydrogen or mass/*M*r
Mol H_2 = mol Mg (Mark consequentially to equation)

2

(c) $MgCl_2 + 2NaOH \rightarrow Mg(OH)_2 + 2NaCl$ Species

1

Balanced

1

Allow an ionic equation

$Mg(OH)_2 \rightarrow MgO + H_2O$

1

(d) ***Allow 2 significant figures in these calculations and ignore additional figures***

EITHER

Mol MgO obtained stage 2 = mass MgO/*M*rMgO

1

= 6.41/ 40.(3) = 0.159 *Allow 0.16*

Allow method mark if formula of magnesium oxide or M_r incorrect

1

Moles of Mg = moles of H_2 hence

Mol original MgO = mol MgO from stage 2 - mol H_2

1

= 0.159 – 0.0528 = 0.106 *Allow 0.11*

Mark consequentially to moles of magnesium oxide determined above

OR

Mass MgO formed from Mg = 0.0528 × M_r MgO {or 40.(3)} **(1)**

= 2.13 g

Allow 2.1 ***(1)***

Allow method mark if formula of magnesium oxide or Mr incorrect

Mass original MgO = total mass MgO - mass formed from Mg **(1)**

= 6.41 – 2.13 = 4.28 g *Allow 4.3* **(1)**

Mark consequentially mass of magnesium oxide determined above

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NB

As there is an error in part (d), the mass of sample should have been 6.25 NOT 2.65, award full marks to any candidate who has crossed out their correct first answer.

1

[15]

Q5.

(a) (i) Atoms with the same number of protons / proton number **(1)**

NOT same atomic number

with different numbers of neutrons **(1)**

***NOT** different mass number / fewer neutrons*

(ii) Chemical properties depend on the number or amount of (outer) electrons **(1)** OR, isotopes have the same electron configuration / same number of e^-

(iii) $23/6.023 \times 10^{23}$ **(1)**

CE = 0 if inverted or multiplied

tied to M1 $3.8(2) \times 10^{-23}$ [2-5 sig figs] **(1)**

5

(b) $1s^2\ 2s^2\ 2p^6\ 3s^1$ **(1)**

accept subscripted figures

1

(c) Highest energy e^- / outer e^-s / last e^- in (3)d sub-shell **(1)**

OR d sub-shell being filled / is incomplete
OR highest energy sub-shell is (3)d
NOT transition element / e^- configuration ends at 3d
Q of L

1

(d) $^{15}_{7}N$ N correct symbol **(1)**

allow N^{15}_{7}

Mass number = 15 AND atomic number = 7 **(1)**

2

[9]

Q6.

(a) (i) $75.0 \times 10^{-3} \times 0.500 = 0.0375$ (mol) **(1)**

accept 0.037 or 0.038

(ii) $21.6 \times 10^{-3} \times 0.500 = 0.0108$ (mol) **(1)**

accept 0.011

If both (i) and (ii) answers wrong, allow ONE process mark for both correct processes

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(iii) 0.0375 - 0.0108 = 0.0267 (mol) **(1)**

Not conseq – must use figures shown

(iv) *Moles of $MgCO_3$* = 0.0267/2 = 0.01335 (mol) **(1)**

allow 0.0134 - 0.0133

Mass of $MgCO_3$ = 0.01335 × 84.3 **(1)**

allow 84

mark conseq on moles $MgCO_3$

= 1.125g **(1)**

accept 1.13g

mark conseq

Percentage $MgCO_3$ = 1.125/1.25 × 100 **(1)**

mark conseq (check for inversion)

= 90% **(1)**

mark conseq

range = 89.5 - 90.5%

If % expression inverted, lose M4 and M5

8

(b) (i) % oxygen = 38.0 **(1)**

Na = 36.5/23 S = 25.5/32(.1) O = 38.0/16 **(1)**

= 1.587 = 0.794 = 2.375

= 2:1:3 **(1)**

If no % of oxygen Max 1 (allow M2 only)
If % for Na and S transposed, or atomic numbers used, M1 only available

(ii) $Na_2SO_3 + 2HCl \rightarrow 2NaCl + H_2O + SO_2$ **(1)**

allow multiples

allow $SO_3^{2-} + 2H^+ \rightarrow H_2O + SO_2$

4

[12]

Q7.

D

[1]

Q8.

(a) (i) pV = nRT **(1)**

(ii) Moles ethanol = n = 1.36/46 (=0.0296 mol) **(1)**

$V = nRT/p = \frac{0.0296 \times 8.31 \times 366}{100000}$ **(1)**

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if V = p/nRT lose M3 and M4

= 8.996×10^{-4} (m^3) **(1)**
= 899 (900) cm^3 **(1)** *range = 895 – 905*

*If <u>final</u> answer = 0.899 award (2 + M1); if = 0.899 dm^3 **or** if = 912 award (3 + M1)*

***Note:** If 1.36 **or** 46 or 46/1.36 used as number of moles (**n**) then M2 and M4 not available*
***Note:** If pressure = 100 then, unless answer = 0.899 **dm^3**, deduct M3 and mark consequentially*

5

(b) (i) $Mg_3N_2 + \mathbf{6}H_2O \rightarrow \mathbf{3}Mg(OH)_2 + \mathbf{2}NH_3$ **(1)**

(ii) Moles NH_3 = $\frac{0.263}{17}$ (=0.0155 mol) **(1)**

Number of molecules of NH_3 = $0.0155 \times 6.02 \times 10^{23}$ **(1)**

[mark conseq] = 9.31×10^{21} **(1)**
[range 9.2×10^{21} to 9.4×10^{21}]

*Conseq (**min** 2 sig fig)*

4

(c) Moles NaCl = 800/58.5 (= 13.68) **(1)**

Moles of $NaHCO_3$ = 13.68 **(1)**

Moles of $Na2CO_3$ = 13.68/2 = 6.84 **(1)**

Mass of Na_2CO_3 = 6.84 × 106 = 725 g **(1)** **[**range = 724 – 727]

[1450 g (range 1448 – 1454) is worth 3 marks]

Accept valid calculation method, e.g. reacting masses or calculations via the mass of sodium present. Also, candidates may deduce a direct 2:1 ratio for NaCl:Na_2CO_3

4

[13]

Q9.

A

[1]

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Q2.

This question was in general very well answered. Most candidates were able to display considerable numerical skill and full marks, or near full, marks were very common. Answers to parts (a)(i) and (a) (ii) were almost always correct. Part (a) (iii) was less well done, with some candidates subtracting their answer to part (a) (ii) from that for part (a) (i), rather than deducing that the number of moles of unreacted NaOH must be equal to the number of moles of HC1 used to neutralise it. Many of these candidates then consequentially earned the mark part (a) (iv) by correctly applying the calculation process to their answers to parts (a) (i) and (a) (iii). Most candidates also coped well with part (a) (v); however, the incorrect use of the mole ratio, errors in calculating the M_r value of ammonium sulphate or arithmetical errors were not uncommon. Part (b) was generally very well done, clearly a well-practiced technique. The gas law equation was almost always correct and most candidates correctly calculated the number of moles of ammonia, although a surprisingly large minority used 18 as theM_r value of ammonia. The vast majority of candidates rearranged the equation correctly, however, a small number failed to convert the pressure to Pa. Examiners reported that in a small number of centres candidates had used the units of kPa and dm^3 in their calculations. Candidates were not penalised for using this approach on this occasion but centres are requested to ensure that candidates use the correct metric units of Pa and m^3 in future gas law calculations.

Q3.

This question was, on the whole, well answered, with full marks being frequently earned. Many candidates were able to correctly complete parts (a)(i), (a)(ii) and (a)(iii). However, it was not uncommon to see an answer of 124 for part (a)(iv), which had not been derived from the answer to part (a)(iii). Candidates who assumed the sodium carbonate to be the monohydrate, and thus calculated its M_r value to be 124, rather than basing their calculation on their answer to part (a)(iii), earned no credit in part (a)(iv). Part (b) was also generally well answered but candidates who used 124, rather than 106, for the M_r of Na_2CO_3 lost the first mark for the calculation. Part (c) was similarly well answered by many candidates. A few candidates were unable to rearrange the gas law equation, but the majority of errors related to the incorrect calculation of the number of moles of argon, or to missing/incorrect units.

Q4.

Although there were many correct equations given in answer to part (a) it is sad to report that a large number of candidates lost marks in this section as they did not know, or could not deduce, the formulae of magnesium oxide and magnesium chloride. Others devised an equation for a reaction between NaCl and HCl. As expected, most candidates stated correctly that hydrogen could be collected in either a gas syringe or a measuring cylinder and the volume of gas could be measured. These two marks were not awarded to candidates who stated that they would collect hydrogen in a test tube and determine the amount by weight. Sadly, many candidates failed to make clear statements that the pressure, the temperature and the volume of gas would need to be measured before they could use the ideal gas equation, or its equivalent, to calculate the number of moles of hydrogen produced. Most candidates made the link between the moles of hydrogen produced and the moles of magnesium metal reacted. This mark was awarded consequentially to the equation given in part (a).

In part (c) many candidates gave correct equations for the formation of magnesium hydroxide and for its decomposition into magnesium oxide. Common errors included an

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incorrect formula for magnesium hydroxide and the use of Mg rather than Mg^{2+} when writing an ionic equation for the formation of magnesium hydroxide.

As a transcription error had been made in part (d) of this question, when the mass of sample was given as 2.65 g rather than 6.25 g, candidates were not required to complete the last part of this calculation in order for full marks to be awarded. Most candidates began their answer by using the data to calculate the number of moles of magnesium oxide in 6.41 g. Good candidates then deduced that the number of moles of magnesium oxide formed from the original magnesium in the sample was equal to the number of moles of hydrogen obtained in Stage 1. A simple subtraction then enabled them to determine the number of moles of original magnesium oxide in the sample provided. Candidates who completed these two steps correctly were awarded full marks. A small number of candidates chose to calculate the mass of magnesium oxide obtained from the original mass of magnesium and then subtracted this from the total mass of magnesium oxide obtained in stage 2. Full marks were also awarded if these two steps were completed correctly. Some of those who used this alternative method realised that the mass of magnesium oxide they had calculated was greater than the mass of the original sample. Full marks were awarded to any candidate who, having discovered this apparent error, crossed out their work and then made a further attempt to answer the question.

Q5.

Many good answers were seen here and high marks were quite common. However, candidates frequently ignored the instruction in (a)(i) to define *isotopes* in terms of fundamental particles, and offered a definition based wholly, or in part, on mass number and atomic number. In (a)(ii), the link between chemical properties and electron configuration was well known but many candidates attempted to establish a link between proton, neutron or mass numbers and chemical properties. The calculation in (a)(iii) was often poorly done, the most common errors being to invert the expression or to multiply the mass number by *L*. Part (b) was generally well answered, although a few candidates gave the electron arrangement showing 23 electrons. Similarly, part (c) was generally well answered, however, some candidates referred to electrons being in the *d block*, while a small minority offered nonsense explanations. Most candidates correctly identified nitrogen as the element in part (d), but $^{14}_{7}N$ was a common error.

Q6.

Part (a) was, in general, poorly answered. While the more able candidates coped well, many candidates struggled. Correct answers to parts (a)(i) and (ii) were frequently seen but, in many cases, the answer of 0.0267 was given in part (a)(iii) without use being made of the answers from the previous two parts; the mark for this part was awarded for a correct calculation method, not for simply quoting 0.0267. In part (a)(iv), when attempting to calculate the number of moles of $MgCO_3$, rather more candidates used the value of the total moles of HCl (0.0375 mol) obtained in part (a)(i) than used the actual number of moles which reacted with the $MgCO_3$ (0.0267 mol) obtained in part (a)(iii). The calculation of the mass of $MgCO_3$ was marked consequentially but, as the final percentage of $MgCO_3$ exceeds 100%, the majority of candidates who followed this route chose to invert their percentage calculation, rather than checking for an earlier error in their calculation. A number of other errors were seen in this part, suggesting that many candidates lacked familiarity with this type of calculation. By contrast, the calculation in part (b) was quite well done. The occasional arithmetical error was seen, a few candidates omitted to deduce the percentage of oxygen and the atomic number was occasionally used in place of the relative atomic mass, but most candidates earned full marks in part (b)(i). However, the equation in part (b)(ii) was rarely correct, with errors such as $NaCl_2$, H_2 and SO_3 being very common.

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Q8.

Most candidates correctly stated the ideal gas equation but the calculation which followed was frequently incorrect. The most common errors included rounding the number of moles of ethanol to 0.03 mol and the use of 100 as the value for the pressure. There was a wide range of units suggested for the volume calculated from the ideal gas equation and few candidates were able to convert this volume in m^3 to the required volume in cm^3. The equation in part (b) was usually correctly balanced, but rounding errors were again common in the following calculation. A significant number of candidates divided n by L in this calculation, rather than multiplying the two together. The calculation in part (c) proved to be easy for the more able candidates but posed considerable problems for many others. The calculation of the number of moles of NaCl was often correctly performed but the use of a 1:1 mole ratio between $NaHCO_3$ and $Na2CO_3$ was very common. Some candidates assumed that $NaHCO_3$ was sodium carbonate and used an Mr value of 84 in their calculation. Some novel, and often successful, approaches to this calculation were seen.

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