PEARSON EDEXCEL A-LEVEL CHEMISTRY · 9CH0

CHEMISTRY



EXAM QUESTION PACK

TOPIC 5: FORMULAE, EQUATIONS AND AMOUNTS OF SUBSTANCE

SCORE	PERCENTAGE
/537	%

STEMUP

These questions belong to Pearson Edexcel, not to us.

The examination questions and mark schemes in this pack were written and published by Pearson Edexcel. They are past assessment materials, reproduced here so that students can revise from them.

What we do not own

STEMUP is not affiliated with Pearson Edexcel and does not own, and makes no claim to own, any of the question or mark scheme material in this pack. Pearson has not endorsed, approved or been involved in the production of it. Pearson, Edexcel and the qualification titles used here belong to their respective owners and appear for identification only.

Where to find the originals

Pearson publishes its past papers and mark schemes free of charge. Always check the current specification at qualifications.pearson.com before you revise, because content and wording can change between series.

If you hold the rights to any material in this pack and would like it amended or removed, contact admin@stemup.co.uk and we will act on it.

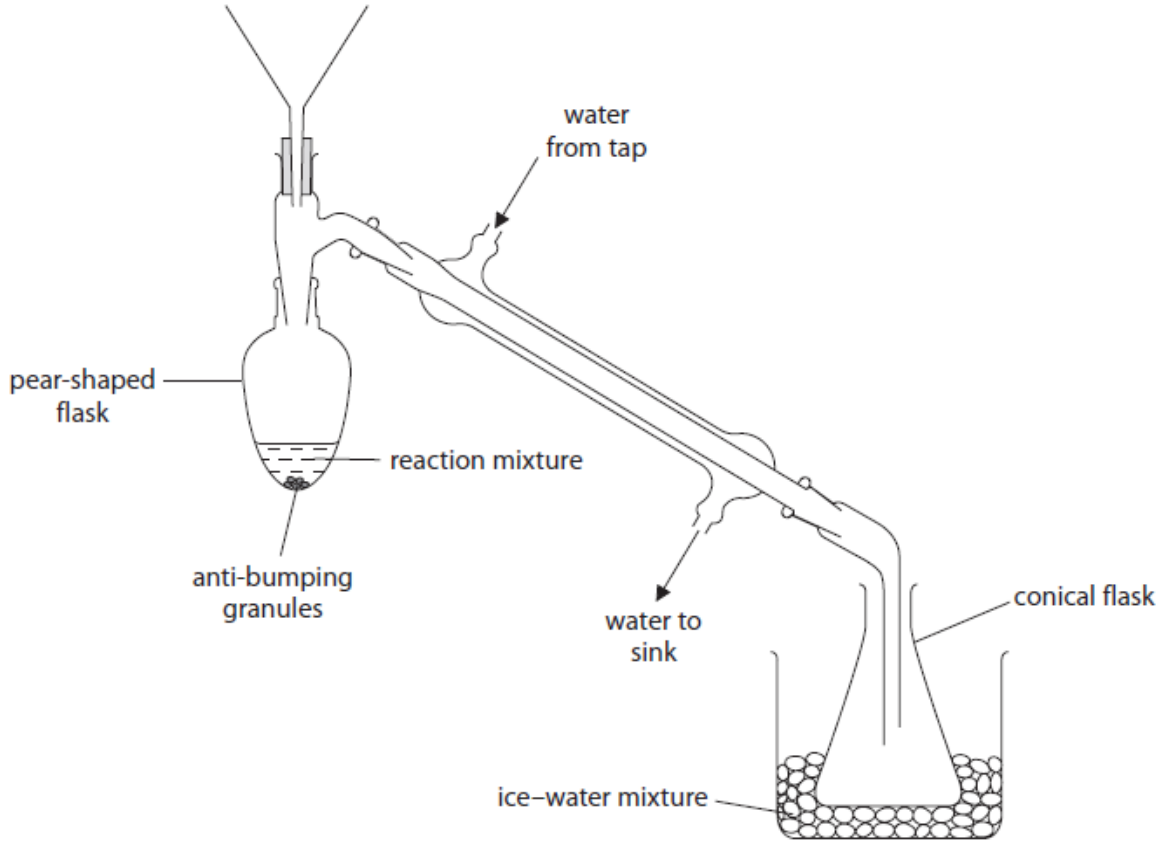
Q1.

This question is about the preparation of a sample of the ketone, 3-methylbutan-2-one.

A student's research suggested that 3-methylbutan-2-one may be prepared by oxidising 3-methylbutan-2-ol with acidified potassium dichromate(VI) solution.

The student sets up the apparatus as shown in the diagram. You may assume that all the equipment is suitably clamped.

The student adds dilute sulfuric acid to the pear-shaped flask. A mixture of potassium dichromate(VI) and 3-methylbutan-2-ol is then added slowly to the dilute sulfuric acid in the flask.



Once the essential changes are made to the apparatus, the pear-shaped flask is heated. The distillate formed is collected in the conical flask.

On testing the distillate with pH paper, it is found that its pH is 2. The student suggests that this pH is due to the formation of 3-methylbutanoic acid.

(i) Give a reason why 3-methylbutanoic acid cannot be formed in the reaction.

(1)

.....

.....

.....

.....

(ii) Deduce the **formula** of the compound that could cause the distillate to have a pH value of 2.

(1)

(iii) Solid sodium carbonate is added to the distillate. The sodium carbonate disappears and fizzing occurs.

Write an equation, including state symbols, for the reaction that occurs between sodium carbonate and the compound you have identified in (ii).

(2)

(Total for question = 4 marks)

Q2.

This question is about an experiment to determine the equilibrium constant, K_c , for an esterification reaction producing propyl ethanoate. The equation for the reaction is

$$\underset{\text{ethanoic acid}}{CH_3COOH(l)} + \underset{\text{propan-1-ol}}{CH_3CH_2CH_2OH(l)} \rightleftharpoons \underset{\text{propyl ethanoate}}{CH_3COOCH_2CH_2CH_3(l)} + H_2O(l)$$

In an experiment to determine the equilibrium constant, K_c , the following steps were carried out.

- 6.0 cm^3 of ethanoic acid (0.105 mol), 6.0 cm^3 of propan-1-ol (0.080 mol) and 2.0 cm^3 of dilute hydrochloric acid were mixed together in a sealed boiling tube.
  In this pre-equilibrium mixture, there is 0.111 mol of water
- The mixture was left for one week, at room temperature and pressure, to reach equilibrium
- The equilibrium mixture and washings were transferred to a volumetric flask and the solution made up to exactly 250.0 cm^3 using distilled water
- 25.0 cm^3 samples of the **diluted** equilibrium mixture were titrated with a solution of sodium hydroxide, concentration 0.200 mol dm^{-3}, using phenolphthalein as the indicator
- The mean titre was 23.60 cm^3 of 0.200 mol dm^{-3} sodium hydroxide solution.

(a) State the role of the hydrochloric acid in the esterification reaction.

(1)

.....

.....

(b) (i) Calculate the total amount, in moles, of acid present in the **volumetric flask** in the equilibrium mixture.

(2)

(ii) The 2.0 cm^3 of dilute hydrochloric acid contained 0.00400 mol of $H^+(aq)$ ions.

Use this and your answer to part (b)(i) to calculate the amount, in moles, of ethanoic acid present in the equilibrium mixture.

(1)

(c) (i) The initial mixture in the boiling tube contained 0.105 mol of ethanoic acid.

Use your answer to (b)(ii) to calculate the amount, in moles, of ethanoic acid that reacted to form the ester in the equilibrium mixture.

(1)

(ii) Use information given in the method, and your answer to (c)(i), to calculate the amounts, in moles, of propan-1-ol, propyl ethanoate and water that are present in the equilibrium mixture.

(3)

Moles of propan-1-ol at equilibrium

.....

Moles of propyl ethanoate at equilibrium

.....

Moles of water at equilibrium

.....

(d) (i) Write the expression for the equilibrium constant, K_c , for this reaction.

$$CH_3COOH(l) + CH_3CH_2CH_2OH(l) \rightleftharpoons CH_3COOCH_2CH_2CH_3(l) + H_2O(l)$$

(1)

(ii) Explain why it is possible, in this case, to calculate K_c using equilibrium amounts in moles, rather than equilibrium concentrations.

(2)

.....

.....

.....

.....

(iii) Calculate the value of K_c.

Give your answer to an appropriate number of significant figures.

(2)

(e) The pink colour of the phenolphthalein fades after the end-point of the titration has been reached.

Give a possible explanation for this observation.

(2)

.....

.....

.....

.....

(f) Explain what you could do to confirm that one week is sufficient time for the mixture to reach equilibrium.

(2)

.....

.....

.....

.....

(g) A student repeated the experiment, but left the mixture in a water bath at 40 °C until equilibrium was reached.

$$CH_3COOH(l) + CH_3CH_2CH_2OH(l) \rightleftharpoons CH_3COOCH_2CH_2CH_3(l) + H_2O(l) \qquad \Delta_r H^{\ominle} = +21.4\,kJ\,mol^{-1}$$

Deduce the effect, if any, on this student's value for K_c compared with that obtained in part (d)(iii).

(2)

.....

.....

.....

.....

.....

.....

(Total for question = 19 marks)

Q3.

This question is about alkanes and their reactions.

A student researched the reaction of propane with bromine and found that the reaction could be used to make 1-bromopropane.

$$C_3H_8(g) + Br_2(l) \rightarrow C_3H_7Br(l) + HBr(g)$$

(i) The first step of the reaction involves

(1)

☒ **A** heterolytic bond fission to form free radicals

☒ **B** heterolytic bond fission to form ions

☒ **C** homolytic bond fission to form free radicals

☒ **D** homolytic bond fission to form ions

(ii) Calculate the atom economy by mass for the formation of 1-bromopropane in the reaction in (i).

(2)

(iii) A source from the internet gave the percentage yield for this reaction as 31.0%.

The best explanation for the low percentage yield of 1-bromopropane in this reaction is

(1)

☒ **A** bromine is very unreactive

☒ **B** a gaseous reactant always gives a low yield

☒ **C** the reaction is very slow

☒ **D** the reaction produces a mixture of organic products

(iv) Calculate the volume of propane, in dm^3, measured at room temperature and

pressure, that is needed to produce 14.7 g of 1-bromopropane, assuming a percentage yield of 31.0%.
Give your answer to an appropriate number of significant figures.

[Molar gas volume at r.t.p. = 24.0 dm^3 mol^{-1}]

(3)

(Total for question = 7 marks)

Q4.

An experiment to determine the equilibrium constant for the reaction between sodium fluoride solution and magnesium hydroxide is carried out.

100 cm^3 of sodium fluoride solution, of concentration 0.250 mol dm^{-3}, is added to a conical flask. Excess solid magnesium hydroxide is added and the mixture is left for 24 hours to reach equilibrium.

The mixture is filtered and 25.0 cm^3 of the solution is removed and titrated with hydrochloric acid.

11.70 cm^3 of 0.100 mol dm^{-3} HCl(aq) is required to neutralise the NaOH formed.

(a) Draw a dot-and-cross diagram of the ions in $Mg(OH)_2$.
Show outer electrons only.

(2)

(b) (i) Use the data to calculate the equilibrium constant, K_c for the reaction between NaF and $Mg(OH)_2$.
Give your answer to an appropriate number of significant figures and give the units, if any.

$$2NaF(aq) + Mg(OH)_2(s) \rightleftharpoons 2NaOH(aq) + MgF_2(s)$$

(5)

(b) (ii) The experiment was repeated on different days.
Justify whether this would improve the reliability of the data collected.

(1)

.....

.....

.....

.....

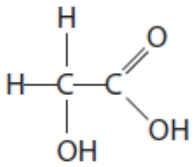
(Total for question = 8 marks)

Q5.

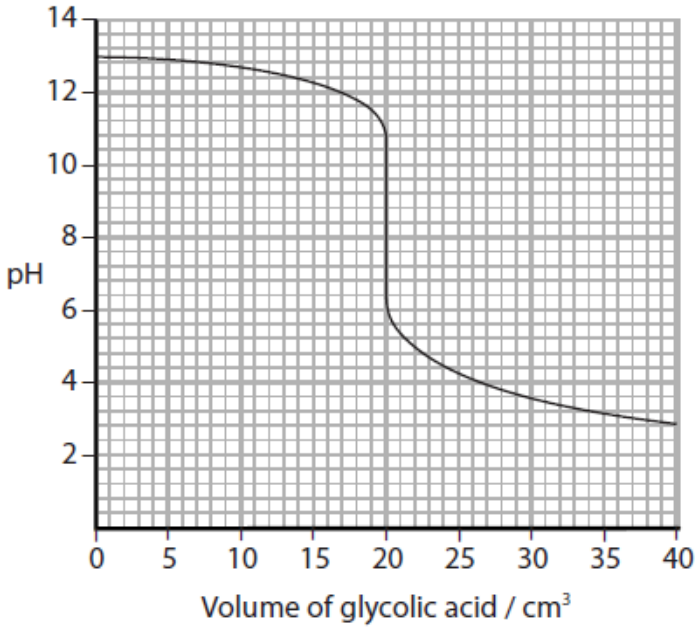
2-Hydroxyethanoic acid, also known as glycolic acid, $CH_2OHCOOH$, is an alpha hydroxy acid used in some skincare products.

It has a K_a value of 1.5×10^{-4} mol dm^{-3}.

The structure of glycolic acid is



The titration curve for adding glycolic acid to 25.0 cm^3 of 0.100 mol dm^{-3} sodium hydroxide is shown.



(i) Use the information given in your Data Booklet to select a suitable indicator for this titration, including the colour change you would expect to see.

Justify your selection.

(3)

.....

.....

.....

.....

.....

.....

(ii) What is the concentration of this glycolic acid in mol dm^{-3}?

(1)

☒ **A** 0.080

☒

B 0.100

☒ **C** 0.125

☒ **D** 0.250

(iii) The pH of the solution containing just sodium glycolate and water is

(1)

☒ **A** 2.8

☒ **B** 6.0

☒ **C** 8.3

☒ **D** 11.0

(Total for question = 5 marks)

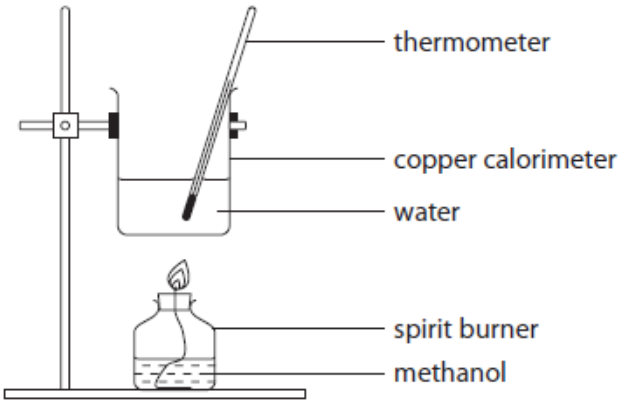
Q6.

This question is about the enthalpy change of combustion of methanol.

A teacher asked two students to carry out a practical task to determine the enthalpy change of combustion of methanol.
Both students were provided with the same apparatus and chemicals.
The following procedure was provided for the students.

Procedure

- Measure out 150 cm^3 of distilled water, using a 250 cm^3 measuring cylinder.
- Transfer the water to a copper calorimeter and note the initial temperature of the water (to the nearest 0.5°C) in **Table 1**.
- Weigh the spirit burner containing methanol and record its mass in **Table 1**.
- Place the spirit burner under the copper calorimeter, as shown in the diagram.
- Ignite the spirit burner and burn the methanol, whilst stirring the water with the thermometer.
- After heating the water for three minutes, extinguish the flame and immediately record the **highest** temperature reached by the water.
- As soon as possible, reweigh the spirit burner containing the methanol and record its mass in **Table 1**.



The results of Student 1 are recorded in **Table 1**.

Mass of spirit burner plus methanol before burning / g	213.47
Mass of spirit burner plus methanol after burning / g	211.87
Mass of methanol burned / g	
Highest temperature of the water / °C	64.5
Initial temperature of the water / °C	22.0
Temperature change of the water / °C	

Table 1

(a) Complete **Table 1**, giving the values to an appropriate number of decimal places.

(2)

(b) Write the equation that represents the reaction that occurs when the standard enthalpy change of combustion of methanol, $CH_3OH(l)$, is measured. Include state symbols.

(2)

(c) Use Student 1's result to calculate the enthalpy change of combustion of methanol in kJ mol^{-1}.
Give your answer to an appropriate number of significant figures.

Specific heat capacity of water = 4.18 J g^{-1} °C^{-1}
Density of water = 1.00 g cm^{-3}

(4)

(d) Student 1 compared the experimental value for the enthalpy change of combustion of methanol obtained in part (c) with the standard value given on the internet.
The student's value was **less exothermic** than the standard value.

Student 1 decided to evaluate the uncertainty in the measurements made in this experiment.

(i) Student 1 used a 250 cm^3 measuring cylinder to measure the volume of 150 cm^3 distilled water. The uncertainty in this volume measurement is ±1 cm^3.

Calculate the percentage uncertainty in the volume of distilled water that Student 1 measured in

the experiment.

(1)

(ii) Compare and contrast the use of a 250 cm^3 measuring cylinder to measure out the 150 cm^3 distilled water with the use of a 25 cm^3 measuring cylinder (uncertainty ±0.2 cm^3 for each volume measurement) six times to measure the same volume.

(3)

.....

.....

.....

.....

.....

.....

.....

(iii) Student 1 calculated the uncertainties in the remaining measurements. However, Student 1 realised that the measurement uncertainties did **not** explain the difference between the experimental value for the enthalpy change of combustion of methanol calculated in part (c) and the value obtained from the internet.

Other than human error, give **three** reasons for the difference in the values.

(3)

.....

.....

.....

.....

.....

.....

(e) Student 1 decided to repeat the experiment.

Student 1 used the copper calorimeter and water from the first experiment and recorded the initial temperature as 60.0°C.
Student 1 burned **exactly** the same mass of methanol as in the first experiment.

Explain, with a reason, how the value for the enthalpy change of combustion of methanol from this experiment would differ, if at all, from the value obtained in the first experiment.

(2)

.....

.....

.....

.....

.....

.....

(f) Student 2 followed the **original** instructions provided, but extinguished the flame after **four** minutes rather than after three minutes.

Explain how the value calculated by Student 2 for the enthalpy change of combustion of methanol compared with that obtained in Student 1's first experiment.

(2)

.....

.....

.....

.....

(g) Another student, Student 3, used the results from Student 1's first experiment to find the enthalpy change of combustion of methanol. Student 3 incorrectly used a value of 46.0 g mol^{-1} for the molar mass of methanol.

State and justify how this mistake would affect the calculated value for the enthalpy change of combustion of methanol.

(2)

.....

.....

.....

.....

(Total for question = 21 marks)

Q7.

A student carried out an investigation to determine the value of ***x*** in hydrated magnesium nitrate(III), $Mg(NO_2)_2 \bullet \boldsymbol{x}H_2O$, using three different methods.

Method 1

- The student prepared an aqueous solution by dissolving 1.15 g of $Mg(NO_2)_2 \bullet \boldsymbol{x}H_2O$ in distilled water, making up the solution to 250.0 cm^3 in a volumetric flask and shaking the mixture.
- The student titrated this solution against 25.0 cm^3 portions of an acidified solution of 0.0200 mol dm^{-3} potassium manganate(VII), $KMnO_4(aq)$.

Method 2

- The student mixed a solution of $Mg(NO_2)_2 \bullet \boldsymbol{x}H_2O$ with an excess of aqueous sodium carbonate solution, $Na_2CO_3(aq)$.
- The student obtained a precipitate of magnesium carbonate, $MgCO_3(s)$, and determined the mass of this precipitate.

Method 3

- The student heated a known mass of $Mg(NO_2)_2 \bullet \boldsymbol{x}H_2O(s)$.
- The student determined the mass of the anhydrous residue formed.

Method 1 – Titration

The student filled the burette with the solution made from $Mg(NO_2)_2 \bullet \boldsymbol{x}H_2O$.

In each titration

- 25.0 cm^3 of 0.0200 mol dm^{-3} $KMnO_4(aq)$ was transferred to a conical flask using a pipette.
- An excess of dilute sulfuric acid was added to the conical flask and the mixture heated.
- $Mg(NO_2)_2(aq)$ was added from the burette until the end-point was reached.

The student's titration results are shown in the table (the rough titration results have **not** been included in the table).

Titration number	1	2	3
Final burette reading / cm^3	23.95	48.05	23.85
Initial burette reading / cm^3	0.80	24.50	0.65
Titre / cm^3			
Concordant titres (✓)			
Mean titre / cm^3			

(a) Complete the table.

(2)

(b) Deduce the colour change that the student would see at the end-point in this titration.

(1)

From ..... to
.....

(c) In the titration reaction, 2 mol MnO_4^- react with 5 mol NO_2^-.

Calculate the number of moles of NO_2^-, in the 250 cm^3 of solution prepared by the student and hence the value of ***x*** in $Mg(NO_2)_2 \cdot xH_2O$.
Give your answer to the nearest whole number.

(5)

(d) The half-equations for the reaction in the titration are

$MnO_4^- + 8H^+ + 5e^- \rightarrow Mn^{2+} + 4H_2O$

$NO_2^- + H_2O \rightarrow NO_3^- + 2H^+ + 2e^-$

Use these half-equations to derive the overall ionic equation for the reaction between manganate(VII) and nitrate(III) ions in acidic conditions.
State symbols are not required.

(2)

Method 2 – Precipitation

The student used the following procedure.

- Dissolve a known mass of $Mg(NO_2)_2 \cdot xH_2O$ in distilled water.
- Add an excess of aqueous sodium carbonate solution, $Na_2CO_3(aq)$, to obtain a precipitate of magnesium carbonate, $MgCO_3(s)$.

$$Mg^2+(aq) + CO_3^{2-}(aq) \rightarrow MgCO_3(s)$$

- Weigh a piece of filter paper.
- Filter the mixture from the above reaction through the pre-weighed filter paper.
- Wash the precipitate of $MgCO_3(s)$ with distilled water.
- Dry the filter paper and precipitate in a desiccator.
- Reweigh the filter paper and the precipitate.
- Calculate the value of ***x*** from the results obtained.

The student found that the value of ***x*** calculated using **Method 2** was different from that obtained using **Method 1**. This difference occurred despite having used a pure sample of the hydrated salt and without making any errors in technique during the experiment.

The student found out from a data book that the compound magnesium carbonate is very slightly soluble in water.

(e) Explain how, if at all, the very slight solubility of magnesium carbonate in water would affect the value calculated for ***x***.

(2)

.....

.....

.....

.....

(f) The student planned to obtain any dissolved magnesium carbonate by evaporating the filtrate, and then weighing the residue.

Criticise this student's plan.

(2)

.....

.....

.....

.....

Method 3 – Thermal decomposition

NOTE: On heating, $Mg(NO_2)_2 \cdot \boldsymbol{x}H_2O(s)$ loses its water of crystallisation and **then** undergoes further decomposition to give magnesium oxide, MgO.

The student used the following procedure.

- Weigh an empty crucible.
- Add some $Mg(NO_2)_2 \cdot \boldsymbol{x}H_2O(s)$ and then reweigh the crucible plus contents.
- Heat the crucible plus contents and allow to cool.
- Weigh the crucible plus magnesium oxide residue.
- Use these data to calculate a value for ***x***.

The student's results are shown in the table.

Mass of crucible / g	18.02
Mass of crucible + $Mg(NO_2)_2 \cdot \boldsymbol{x}H_2O$ / g	18.84
Mass of crucible + MgO residue / g	18.27

(g) Identify how the student should ensure that the hydrated salt was fully decomposed.

(1)

.....

.....

(h) The student carried out an evaluation of the results obtained from **Method 3**

Identify **two** modifications to the method that would enable the student to lower the percentage uncertainty in the measurement of the mass of the solid residue.

(2)

.....

.....

.....

.....

(Total for question = 17 marks)

Q8.

The gas phase reaction between hydrogen and iodine is reversible.

$$H_2(g) + I_2(g) \rightleftharpoons 2HI(g)$$

(a) (i) Write the expression for the equilibrium constant, K_c, for this reaction.

(1)

(ii) If the starting concentration of both hydrogen and iodine was **a** mol dm^{-3} and it was found that 2**y** mol dm^{-3} of hydrogen iodide had formed once equilibrium had been established, write the K_c expression in terms of **a** and **y**.

(2)

(b) The expression for the equilibrium constant in (a)(ii) can be rearranged as shown.

$$\mathbf{y} = \frac{\mathbf{a}\sqrt{K_c}}{2+\sqrt{K_c}}$$

In an experiment, air was removed from a 1 dm^3 flask and amounts of hydrogen and iodine gases were mixed together such that their initial concentrations were both **a** mol dm^{-3}. This mixture was allowed to reach equilibrium at 760 K. The equilibrium concentration of iodine was then measured.

The experiment was repeated for various initial concentrations, **a** mol dm^{-3}, and the results recorded in the table.

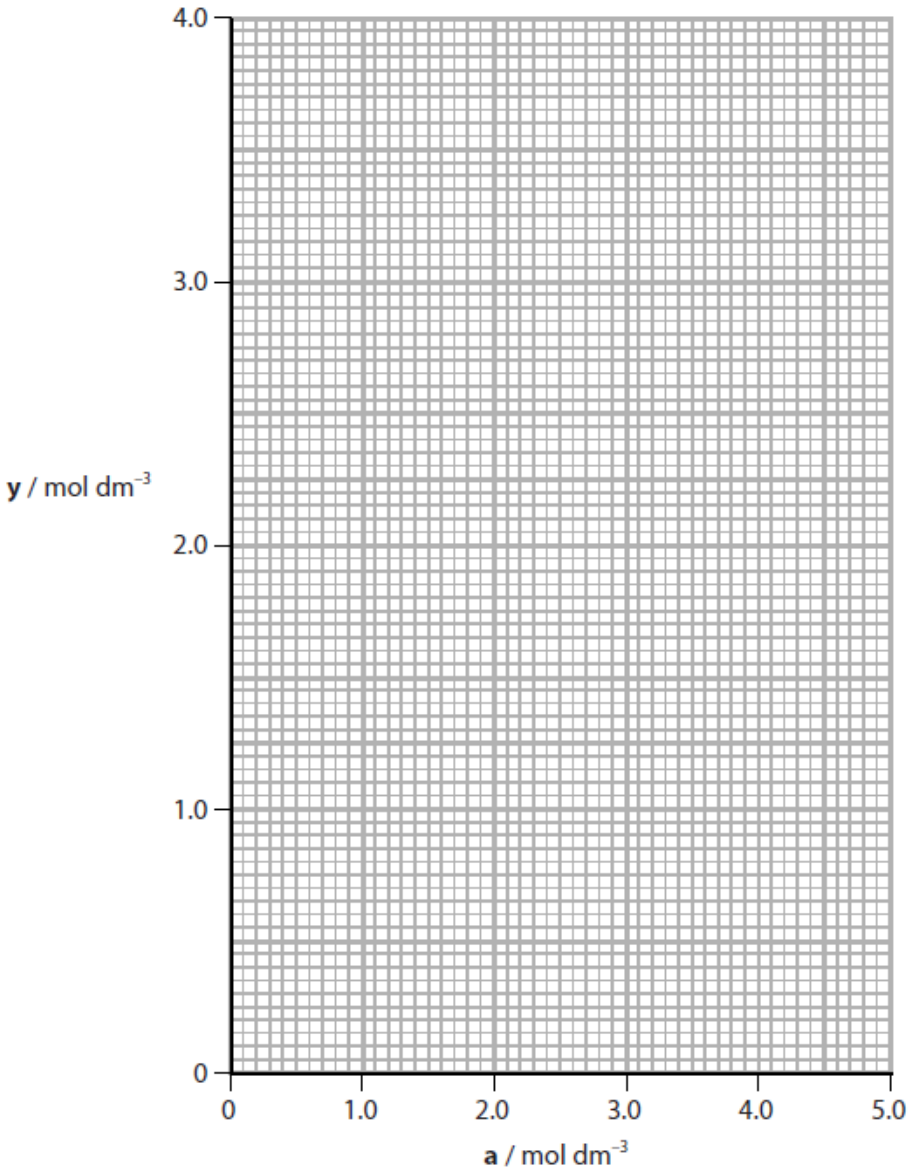
(i) Complete the table to give the two remaining values of **y** mol dm^{-3}, to **two** decimal places.

(1)

a / mol dm^{-3}	$[I_2]_{eq}$ / mol dm^{-3}	y / mol dm^{-3}
0.20	0.02	0.18
0.80	0.25	0.55
1.50	0.37	
2.10	0.57	1.53
2.80	0.65	2.15
3.80	0.87	
4.90	1.15	3.75

(ii) Plot a graph to show how **y** mol dm^{-3} varies with the initial concentrations of hydrogen and iodine, **a** mol dm^{-3}.

(2)



(iii) Determine the gradient of your graph.

Show your working on the graph.

(2)

(iv) Use your answer to (b)(iii) and the expression $y = \frac{a\sqrt{K_c}}{2+\sqrt{K_c}}$ to calculate the value of K_c.

(2)

(c) Identify a safety issue associated with this experiment.

(1)

.....

.....

(d) One of the experiments in part (b) was repeated using the same molar quantities of hydrogen and iodine but in a 500 cm^3 flask instead of the 1 dm^3 flask.

Deduce the effect, if any, that this would have on the rate of reaction and on the value of K_c calculated.

(2)

.....

.....

.....

.....

(e) The equation for the reaction between hydrogen and iodine is

$$H_2(g) + I_2(g) \rightleftharpoons 2HI(g) \qquad \Delta H = -9.6 \text{ kJ mol}^{-1}$$

(i) Explain the effect, if any, on the value of K_c when the temperature is increased.

(2)

.....

.....

.....

.....

(ii) On your graph in (b)(ii), draw and label the line you would expect if the experiment was carried out at 1000 K instead of 760 K.

(1)

(Total for question = 16 marks)

Q9.

Some alcohols can be oxidised by acidified sodium dichromate(VI), $Na_2Cr_2O_7$.

Balance the ionic half-equation for the reduction of the dichromate(VI) ion.

Give the colours of all of the species involved, or state colourless if appropriate.

(2)

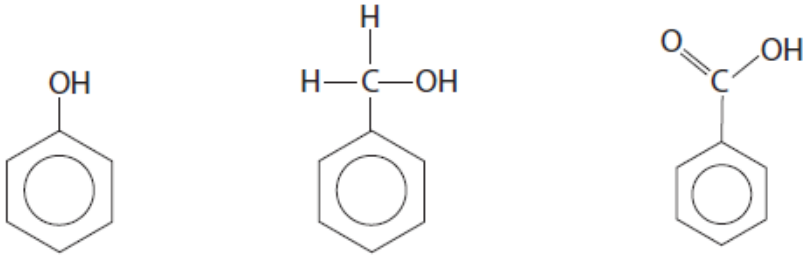
$$Cr_2O_7^{2-} + \ldots\ldots H^+ + \ldots\ldots e^- \rightarrow \ldots\ldots Cr^{3+} + \ldots\ldots H_2O$$

Colour ....

(Total for question = 2 marks)

Q10.

This is a question about the analysis of three aromatic substances with —OH groups.



phenol phenylmethanol benzoic acid

When burned in air, these aromatic compounds undergo **incomplete** combustion.

(i) Calculate the percentage composition by mass of carbon in both phenylmethanol and benzoic acid.

(3)

(ii) Give the expected observation when these aromatic compounds undergo incomplete combustion.

(1)

.....

.....

(iii) Identify another **type** of organic compound which will also produce the same observation as in (ii).

(1)

.....

(iv) These combustion experiments must be carried out in a fume cupboard.



Explain why the front window of the fume cupboard must be below the safety line even with the exhaust fan switched on.

(2)

.....

.....

.....

.....

.....

.....

(Total for question = 7 marks)

Q11.

Sodium can form three oxides:

sodium oxide, Na_2O
sodium peroxide, Na_2O_2
sodium superoxide, NaO_2

It has been suggested that sodium superoxide could be used in spacecraft to regenerate oxygen.

Oxygen needs to be replaced in a spacecraft because an astronaut oxidises glucose, according to the equation:

$$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$$

Sodium superoxide can regenerate oxygen according to the equation:

$$4NaO_2 + 2CO_2 \rightarrow 2Na_2CO_3 + 3O_2$$

In order to maintain the correct percentage of oxygen in the air, any excess carbon dioxide could be removed by using sodium oxide.

$$Na_2O + CO_2 \rightarrow Na_2CO_3$$

Calculate the mass of sodium oxide that would be required to remove the excess carbon dioxide when exactly 880 g of sodium superoxide is reacted per day.

You can assume that an astronaut oxidises 2 mol of glucose each day.

(4)

Q12.

This question is about carbon monoxide, CO, which is a toxic and colourless gas used widely in the chemical industry.

Carbon monoxide can be made by the thermal decomposition of sodium ethanedioate.

$$Na_2C_2O_4 \rightarrow Na_2CO_3 + CO$$

Calculate the atom economy, by mass, for the production of carbon monoxide in this reaction.

(2)

(Total for question = 2 marks)

Q13.

This question is about a dicarboxylic acid **Y** which is present in some citrus fruits.

Y contains only the elements carbon, hydrogen and oxygen.

A solution was prepared using 4.34 g of the dicarboxylic acid **Y** made up to a volume of 250 cm^3 with distilled water.

A 25.0 cm^3 sample of this solution was then titrated using sodium hydroxide solution, NaOH(aq), of concentration 0.320 mol dm^{-3}.

The mean titre of sodium hydroxide solution was 26.10 cm^3.

Calculate the molar mass of **Y** using the titration data, and hence deduce its structure. You must show your working.

(5)

(Total for question = 5 marks)

Q14.

This question is about alkenes with the molecular formula C_5H_{10}.

A sample of pent-1-ene, with a mass of 1.33 g, is warmed to 60 °C in a sealed container. The volume of the container is 500 cm^3.

Calculate the pressure inside the container.
Include units and give your answer to an appropriate number of significant figures.

[Gas constant (R) = 8.31 J mol^{-1} K^{-1}]

(4)

(Total for question = 4 marks)

Q15.

Answer the question with a cross in the box you think is correct ☒ . If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒ .

The equation for the complete combustion of butane is

$$2C_4H_{10}(g) + 13O_2(g) \rightarrow 8CO_2(g) + 10H_2O(l)$$

What is the minimum volume of oxygen, at room temperature and pressure (r.t.p.), needed for the complete combustion of 0.200 mol of butane?

[Molar volume of a gas at r.t.p. = 24.0 dm^3 mol^{-1}]

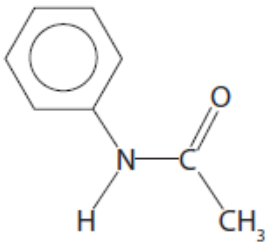
(1)

- ☒ **A** 4.8 dm^3
- ☒ **B** 9.6 dm^3
- ☒ **C** 31.2 dm^3
- ☒ **D** 62.4 dm^3

(Total for question = 1 mark)

Q16.

Antifebrin was the trade name for N-phenylethanamide which was used as a painkiller until paracetamol was discovered.



Antifebrin

A tablet with a total mass of 500 mg contained 3.10×10^{-3} mol of paracetamol.

Calculate the percentage by mass of paracetamol in the tablet, quoting your answer to an appropriate number of significant figures.

(2)

(Total for question = 2 marks)

Q17.

This question is about acids and buffer solutions.

A commercial nitric acid solution, $HNO_3(aq)$, has a concentration of 15.9 mol dm^{-3}. A 15.0 cm^3 sample was made up to 100 cm^3 by adding deionised water.

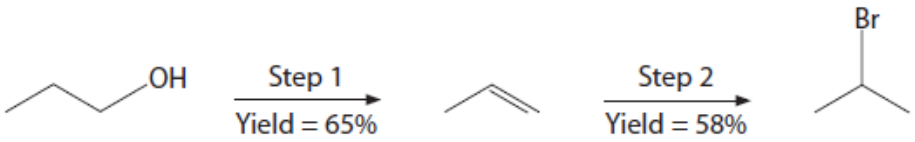
Calculate the pH of this diluted solution.

(2)

(Total for question = 2 marks)

Q18.

2-bromopropane can be produced from propan-1-ol as shown in the sequence.



Calculate the mass of 2-bromopropane produced from 3.0g of propan-1-ol in this sequence.

(3)

Q19.

A 0.403 g sample of sodium peroxide was reacted with water:

$$Na_2O_2 + 2H_2O \rightarrow 2NaOH + H_2O_2$$

The hydrogen peroxide produced was determined by titration with a solution containing cerium(IV) ions. In this reaction the hydrogen peroxide is converted into oxygen.

$$H_2O_2 \rightarrow 2H^+ + O_2 + 2e^-$$

The hydrogen peroxide solution reacted with exactly 24.85 cm^3 of a 0.420 mol dm^{-3} solution of cerium(IV) ions, Ce^{4+}.

Deduce the formula of the cerium ion present in the final solution. Support your answer with a calculation.

(4)

Q20.

Cinnamon is a spice that is extracted from the bark of the cinnamon tree.

It is extracted by crushing the soft bark with water, and then steam distilling the mixture to produce cinnamon oil.

Cinnamic acid contains a carboxylic acid functional group and is a monobasic acid.

1.78 g of cinnamic acid is reacted with 250 cm^3 of 0.500 mol dm^{-3} NaOH.

25.0 cm^3 of the resulting solution was titrated with 0.400 mol dm^{-3} HCl.

28.25 cm^3 was needed for complete neutralisation.

Calculate the M_r of cinnamic acid, giving your answer to one decimal place.

(5)

Q21.

15 cm^3 of a gaseous hydrocarbon requires 90 cm^3 of oxygen for complete combustion, both volumes being measured at 15°C and 1 atm. The formula of the hydrocarbon is

☒ **A** C_4H_6

☒ **B** C_4H_8

☒ **C** C_4H_{10}

☒ **D** impossible to calculate without knowing the molar volume of gases under these conditions.

(Total for question = 1 mark)

Q22.

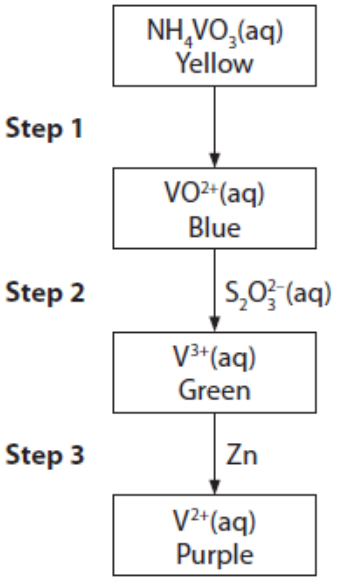
The element vanadium exists in a variety of oxidation numbers in its compounds.

(a) Calculate the oxidation number of vanadium in the compound NH_4VO_3.

(1)

.....

(b) NH_4VO_3 forms VO_2^+ in solution and can be reduced stepwise to form the ion, $V^{2+}(aq)$.



(i) Use the Data Booklet to give a suitable reducing agent for **Step 1** in order to only produce the blue solution.

(1)

.....

.....

(ii) Give a possible reason why the reducing agent you choose may not be suitable.

(1)

.....

.....

(iii) Explain what you would see during **Step 1**.

(2)

.....

.....

.....

.....

(iv) Justify the choice of reducing agent for **Step 2**.
Write an equation for the reaction. State symbols are not required.

(2)

.....

.....

.....

.....

Q23.

This question is about the chemistry of hydrated magnesium nitrate, $Mg(NO_3)_2.xH_2O$.

In an experiment, a sample of hydrated magnesium nitrate, $Mg(NO_3)_2.xH_2O$, with a mass of 0.765 g, was dissolved in water and reacted with an excess of sodium hydroxide solution, NaOH(aq).
The precipitate of magnesium hydroxide, $Mg(OH)_2$, produced was removed and dried. The mass of the dried sample was 0.174 g.

(i) Draw dot-and-cross diagrams for the ions in magnesium hydroxide.
Show the outer electrons only.

(2)

(ii) Use the experimental data to calculate the value for x in the formula $Mg(NO_3)_2.xH_2O$.
You **must** show all your working.

(5)

(Total for question = 7 marks)

Q24.

This question is about some redox reactions of chlorine, bromine and iodine.

Chlorine undergoes disproportionation when it reacts with **hot** aqueous sodium hydroxide solution.

(i) Complete the ionic equation for this reaction. State symbols are not required.

(1)

..... Cl_2 + ... OH^- → ..... Cl^- + ... ClO_3^- + ... H_2O

(ii) Explain, in terms of oxidation numbers, why this is a disproportionation reaction.

(2)

.....

.....

.....

.....

.....

.....

(Total for question = 3 marks)

Q25.

The compound 2-phenylethyl propanoate is a synthetic oil used in some fragrances due to its rose-like aroma.

Combustion analysis of 1.56 g of 2-phenylethyl propanoate, in a laboratory, produced 4.26 g of $CO_2(g)$ and 1.10 g of $H_2O(l)$.

Show that the data is consistent with the molecular formula of 2-phenylethyl propanoate, $C_{11}H_{14}O_2$.

(4)

Q26.

Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

This question is about hydrocarbons.

When hydrocarbons undergo complete combustion, there is a change in the total volume of gases.

(i) Ethane burns in excess oxygen.

$$2C^{2}H_6(g) + 7O_2(g) \rightarrow 4CO_2(g) + 6H_2O(g)$$

All gas volumes are measured at the same temperature and pressure when water is a gas.

What is the **increase** in the total volume when 100 cm^3 of ethane is burned in excess oxygen?

(1)

☒ **A** 50 cm^3

☒ **B** 100 cm^3

☒ **C** 200 cm^3

☒ **D** 500 cm^3

(ii) A combustion experiment was carried out using conditions under which water was a liquid.

A cyclic hydrocarbon, C_xH_y, was mixed with excess oxygen and ignited.
Under the conditions of the experiment, this hydrocarbon was gaseous and had a volume of 25 cm^3.

The equation for the complete combustion of C_xH_y is

$$C_xH_y(g) + (x + \frac{y}{4})O_2(g) \rightarrow xCO_2(g) + \frac{y}{2}H_2O(l)$$

The total gas volume **decreased** by 75 cm^3.
The remaining gases were shaken with aqueous sodium hydroxide and the total gas volume **decreased** by a further 125 cm^3.

All gas volumes were measured at the same temperature and pressure.

Suggest the identity of the cyclic hydrocarbon by calculating the molecular formula of C_xH_y.
Include the **skeletal formula** of the cyclic hydrocarbon.

(3)

(Total for question = 4 marks)

Q27.

This question is about the compound potassium bromate, $KBrO_3$.

Potassium bromate decomposes on heating.

$$2KBrO_3 \rightarrow 2KBr + 3O_2$$

Calculate the maximum volume of oxygen, in dm^3, measured at room temperature and pressure (r.t.p.), that could be produced from the complete decomposition of 5.20 g of potassium bromate.

[Molar volume of gas at r.t.p. = 24.0 dm^3 mol^{-1}]

(3)

(Total for question = 3 marks)

Q28.

Transition metals form complex ions.

Hydrated chromium(III) chloride, $CrCl_3 \cdot 6H_2O$, dissolves in water to form a number of different complex ions containing both chloride and water ligands.

The general formula of these complex ions is $[Cr(H_2O)_x(Cl)_y]^{(3-y)+}$

In an experiment, 0.10 mol of a complex reacted with excess silver nitrate solution to produce 0.20 mol of silver chloride.

Chloride ions which are ligands within the complex do not react with silver nitrate.

Deduce the formula of this chromium(III) complex ion. Justify your answer.

(2)

.....

.....

.....

.....

.....

.....

(Total for question = 2 marks)

Q29.

The equation for the reaction between iodine and propanone is:

$$CH_3COCH_3(aq) + I_2(aq) \rightarrow CH_3COCH_2I(aq) + H^+(aq) + I^-(aq)$$

The kinetics of this reaction were studied.

(a) The order of the reaction with respect to iodine was determined by preparing a mixture of solutions of iodine and sulfuric acid in a conical flask. A solution of propanone was then added and a timer started. After one minute, a 10.0 cm^3 sample of the reaction mixture was removed. Further 10.0 cm^3 samples of the reaction mixture were removed at regular time intervals during the experiment.

After removal, each sample was immediately added to sodium hydrogencarbonate solution and then titrated with sodium thiosulfate solution to determine the concentration of iodine.

The table shows the volumes and initial concentrations of the substances in one experiment.

Substance	Volume / cm^3	Concentration / mol dm^{-3}
iodine	50	0.020
sulfuric acid	20	2.5
propanone	25	2.0

(i) Deduce, by calculation of the amounts used, whether propanone or iodine was in excess.

(2)

(ii) Name the piece of apparatus which is most suitable for measuring the volume of sulfuric acid.

(1)

.....

.....

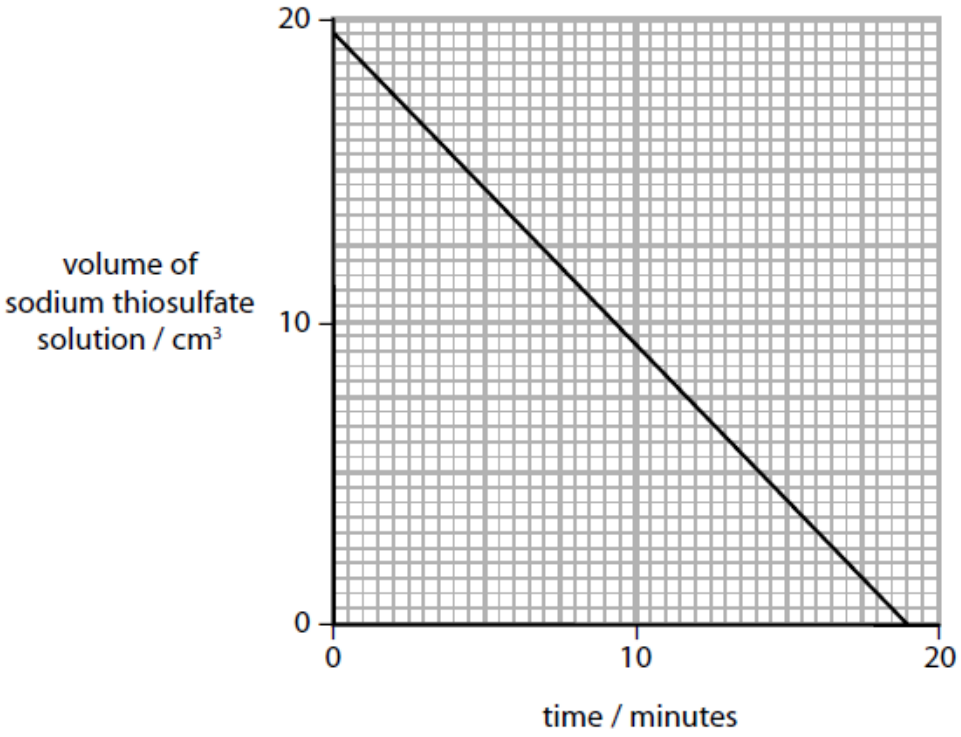
(iii) Name the piece of apparatus which is most suitable for removing the sample from the reaction mixture.

(1)

.....

.....

(b) The graph shows the results of titrating the samples of the reaction mixture.



Explain how you can deduce the order of reaction with respect to iodine from this graph.

(2)

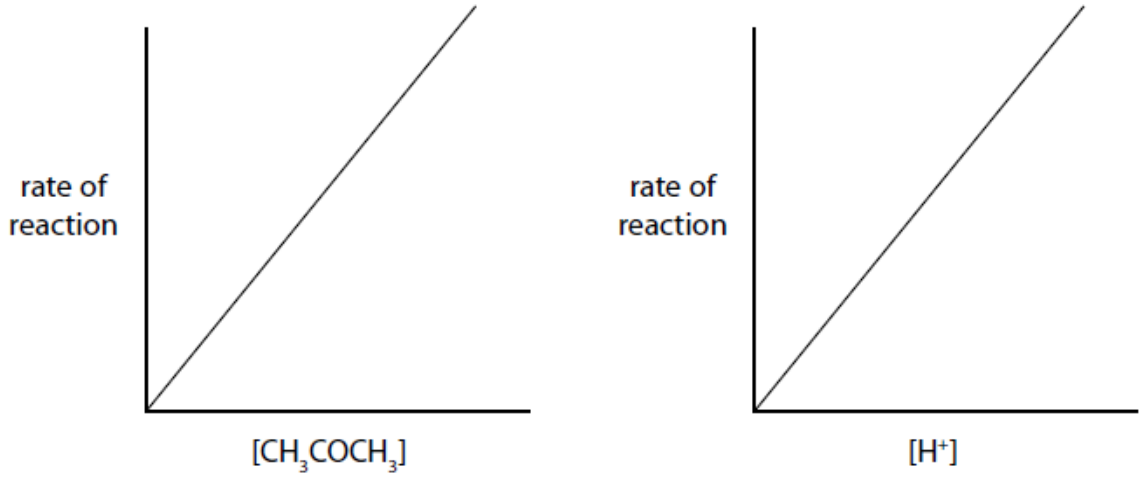
.....

.....

.....

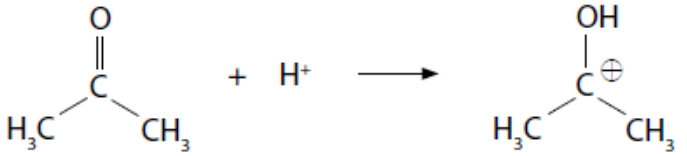
.....

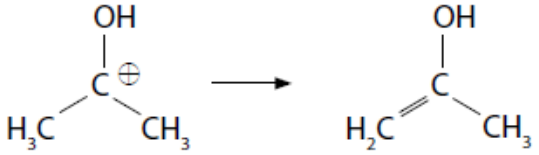
(c) These graphs were obtained in other experiments to determine the order of reaction with respect to propanone and to sulfuric acid.

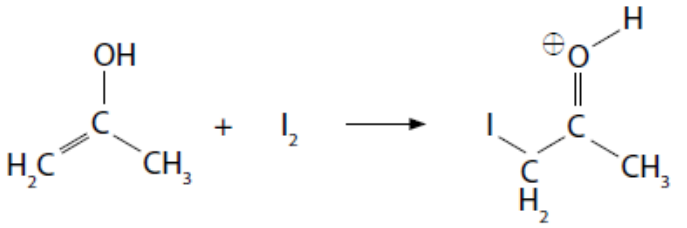


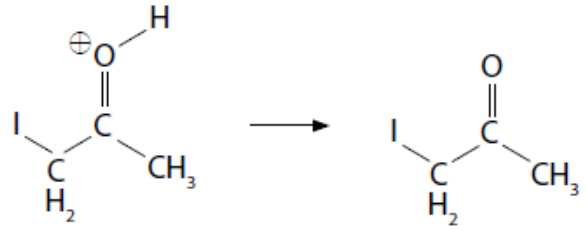
Use these graphs and your answer from part (b) to comment on whether this proposed mechanism for the reaction is correct.

(3)

step 1  fast

step 2  slow

step 3  fast

step 4  fast

.....

.....

.....

.....

.....

.....

Q30.

This question is about hydrocarbons.

0.28 g of a gaseous hydrocarbon, **J**, was burned in excess oxygen.
0.88 g of carbon dioxide and 0.36 g of water were formed.
The volume of 0.28g of **J** at 1.01×10^5 Pa and 298 K is 123 cm^3.

Use this information to show that the molecular formula of J is C_4H_8.

(4)

Q31.

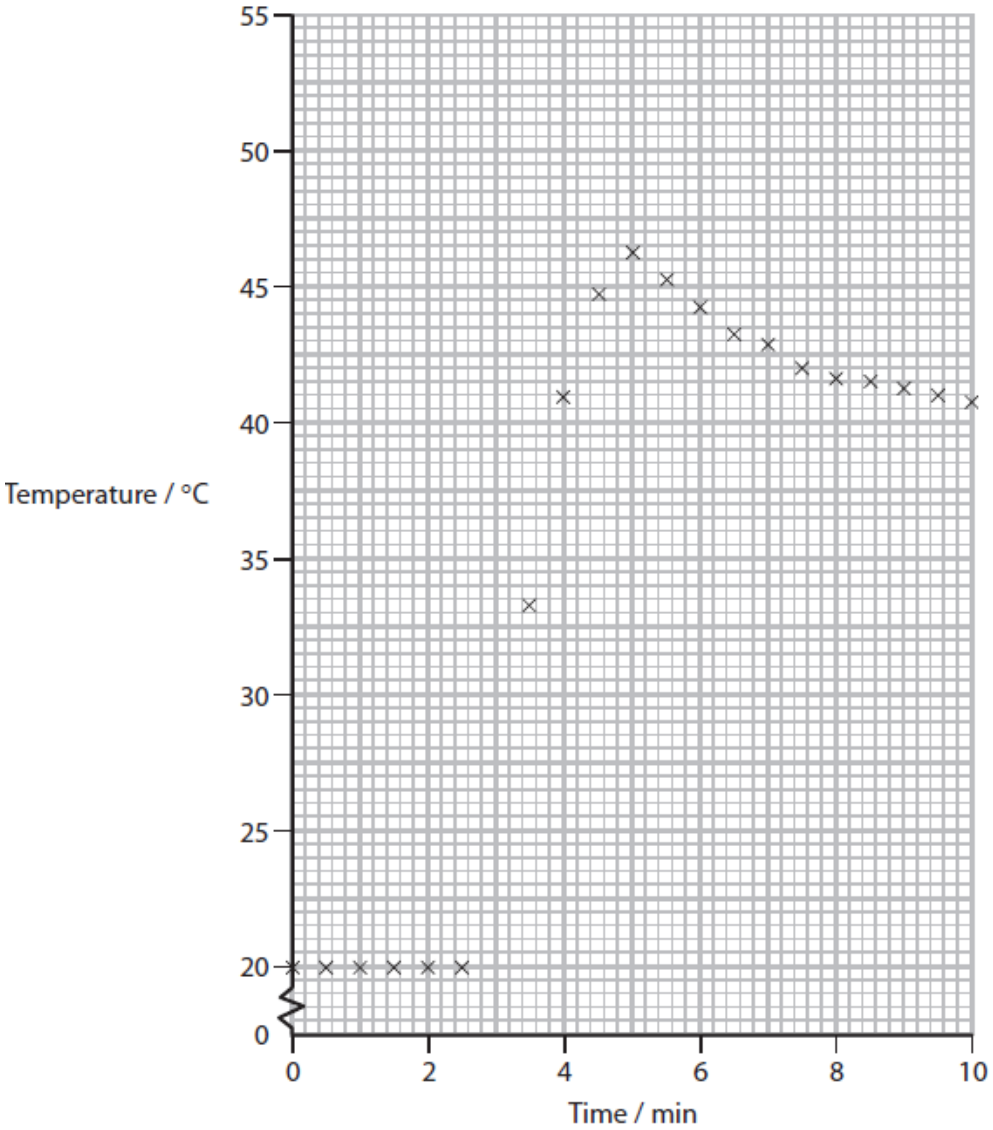
An experiment is carried out to determine the enthalpy change of the reaction between copper(II) sulfate solution and zinc.

$$CuSO_4(aq) + Zn(s) \rightarrow Cu(s) + ZnSO_4(aq)$$

The procedure is:

- measure out 25.0 cm^3 of 0.720 mol dm^{-3} copper(II) sulfate solution, using a pipette, into a polystyrene cup
- weigh out an excess of zinc granules
- place a thermometer into the cup. Stir and record the temperature to the nearest 0.1°C every 30 seconds, for 2½ minutes
- at 3 minutes, add the zinc granules to the cup
- gently stir the mixture and record the temperature every 30 seconds until a total time of 10 minutes is reached.

The data collected is shown on the graph.



(a) Extrapolate the graph and hence determine the maximum temperature change for the reaction.

(2)

Maximum temperature change = ... °C

(b) (i) Explain why an extrapolation is required to determine an accurate measure of the maximum temperature change.

(2)

.....

.....

.....

.....

(ii) Explain how the experiment could be amended to allow a value for the maximum temperature change to be determined without the need for an extrapolation.

(2)

.....

.....

.....

.....

(c) Calculate the enthalpy change for the reaction, $\Delta_r H$. Give your answer to an appropriate number of significant figures.

(4)

(d) The accepted value of $\Delta_r H$ for this reaction is -217 kJ mol^{-1}.

(i) Calculate the percentage error in this experiment.

(1)

(ii) Give reasons why the experimental value calculated in (c) is different from the accepted value.

(2)

.....

.....

.....

.....

(iii) In the same experiment, another student used a polystyrene cup that contained some distilled water left over from rinsing the cup.

Explain what effect, if any, this would have on the value for the enthalpy change calculated by this student, compared to the answer in (c).

(2)

.....

.....

.....

.....

(Total for question = 6 marks)

Q32.

This question is about an experiment to determine the equilibrium constant, K_c, for the reaction between ethanoic acid and ethanol to form ethyl ethanoate and water.

Two sealed test tubes were prepared.

The first test tube contained 0.0400 mol ethanoic acid, 0.0400 mol of ethanol and 0.20 cm^3 of concentrated hydrochloric acid.

The second test tube contained 0.0400 mol ethyl ethanoate, 0.0400 mol of water and 0.20 cm^3 of concentrated hydrochloric acid.

After standing at 25°C for two weeks, to ensure equilibrium is reached, the contents of each test tube were separately titrated with 0.200 mol dm^{-3} sodium hydroxide solution.

0.20 cm^3 of concentrated hydrochloric acid was also titrated with the same sodium hydroxide solution.

(a) (i) Using data from the Data Booklet, calculate the volume, in cm^3, of 0.0400 mol of ethanoic acid.

(2)

(ii) What would be the best piece of apparatus to measure out the volumes of the liquids for the sealed test tubes?

(1)

.....

(iii) Suggest a reason why the test tubes were sealed.

(1)

.....

.....

(iv) Suggest a suitable indicator for the titration of the equilibrium mixture in either test tube, with the expected colour change. Justify your suggestion.

(3)

Indicator

.....

Colour change from ..... to .....

Justification

.....

.....

(b) In this experiment, the following titres were obtained.

Titration	Volume of 0.200 mol dm^{-3} sodium hydroxide solution/cm^3
Contents of first test tube	77.10
Contents of second test tube	77.05
0.20 cm^3 concentrated hydrochloric acid	11.70

(i) Write the equation for the reaction between ethanoic acid and ethanol to form ethyl ethanoate and water, using structural formulae. State symbols are not required.

(1)

(ii) Calculate the number of moles of ethanoic acid present at equilibrium in the first test tube.

(2)

(iii) Deduce the number of moles of ethanol present at equilibrium in the first test tube.

(1)

(iv) Calculate the number of moles of ethyl ethanoate formed at equilibrium in the first test tube.

(1)

(v) Write an expression for the equilibrium constant, K_c, for the reaction.
Assuming the number of moles of water and ethyl ethanoate present at equilibrium are the same, calculate the equilibrium constant, K_c.

(2)

(vi) Explain why the equilibrium constant for this reaction has no units.

(1)

.....

.....

(vii) Why, in fact, is the number of moles of water present in the equilibrium mixture greater than the number of moles of ethyl ethanoate?

(1)

.....

.....

(c) (i) What is the type of reaction that took place in each test tube?

(2)

First test tube

.....

Second test tube

.....

*(ii) Comment on the value of the titre for the equilibrium mixture in the second test tube compared to the first test tube.

What characteristic feature of equilibrium reactions is demonstrated by the values of these titres?

(2)

.....

.....

.....

.....

(iii) State the role of the concentrated hydrochloric acid in the equilibrium reaction.

(1)

.....

.....

(Total for question = 21 marks)

Q33.

Aqueous copper(II) sulfate reacts with an excess of aqueous ammonia to give a dark blue solution.

The dark blue solution contains the octahedral complex ion, $[Cu(NH_3)_x(H_2O)_y]^{2+}$.

The formula of this complex ion is determined by colorimetry, using this method:

- Make up six different mixtures of 1.00 mol dm^{-3} aqueous ammonia and 0.500 mol dm^{-3} aqueous copper(II) sulfate and water.
- Filter the mixtures to remove any precipitate that forms.
- The filtrate is a dark blue solution that contains the complex ion, $[Cu(NH_3)_x(H_2O)_y]^{2+}$.
- Place the dark blue solution into a colorimeter and measure the absorbance of the solution.

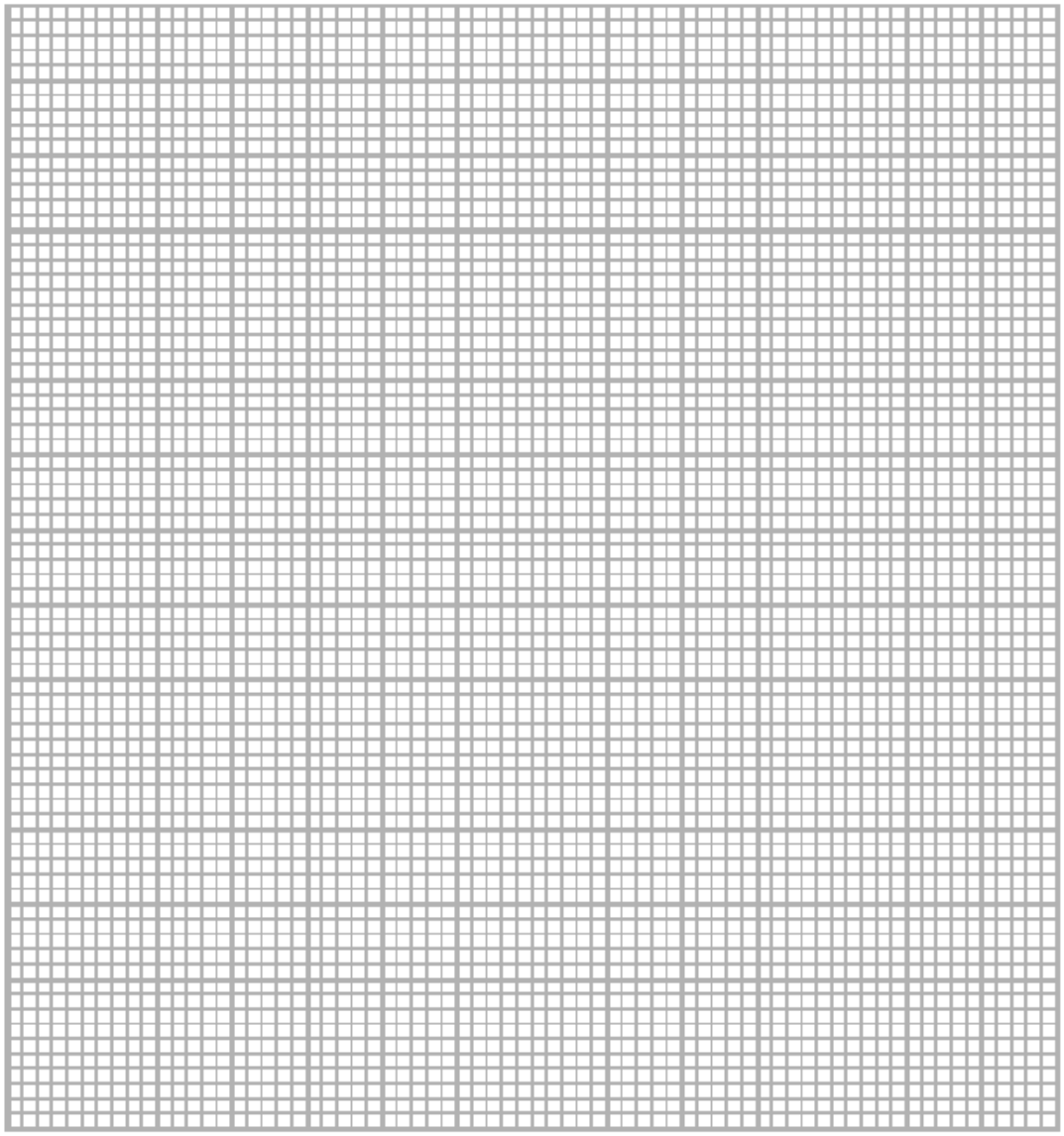
The table shows the absorbance of each mixture.

	Mixture					
	1	2	3	4	5	6
Volume of 0.500 mol dm^{-3} $CuSO_4(aq)$ / cm^3	5.00	5.00	5.00	5.00	5.00	5.00
Volume of 1.00 mol dm^{-3} $NH_3(aq)$ / cm^3	3.00	6.00	9.00	12.00	15.00	18.00
Volume of $H_2O(l)$ / cm^3	17.00	14.00	11.00	8.00	5.00	2.00
Absorbance	0.25	0.50	0.76	0.84	0.84	0.84

(a) Plot a graph of absorbance against volume of $NH_3(aq)$ on the grid opposite.

Draw a straight line of best fit through the first three points and another straight line of best fit through the last three points. Extend both lines so that they cross.

(2)



(b) (i) Use the graph to determine the smallest volume of 1.00 mol dm^{-3} $NH_3(aq)$ required to completely react with 5.00 cm^3 of 0.500 mol dm^{-3} of $CuSO_4$ solution

(1)

(ii) Calculate the amount, in moles, of $CuSO_4$ in 5.00 cm^3 of 0.500 mol dm^{-3} solution.

(1)

(iii) Calculate the amount of NH_3, in moles, present in the volume of $NH_3(aq)$ in (b)(ii).

(1)

(iv) Deduce the values of x and y in the formula of the complex ion $[Cu(NH_3)_x(H_2O)_y]^{2+}$.

(1)

x = ... y = ...

(c) The precipitate formed is copper (II) hydroxide.

Write an ionic equation to show the formation of copper(II) hydroxide from its ions. Include state symbols.

(2)

Q34.

A group of students analysed a hydrated salt with the formula $KH_3(C_2O_4)_{\mathbf{y}}$. $\mathbf{z}H_2O$ where **y** and **z** are whole numbers.

The students carried out experiments to determine the values of **y** and **z**.

(a) Experiment 1 – to determine the value of **y**

One student was provided with a 0.0235 mol dm^{-3} solution of the salt.

25.0 cm^3 portions of the salt solution were acidified with excess dilute sulfuric acid and heated to about 60 °C.

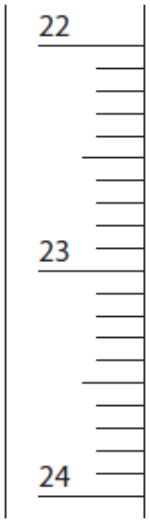
Each portion was titrated with 0.0203 mol dm^{-3} potassium manganate(VII).

The results of four titrations are shown in the table.

Titration number	1	2	3	4
Final burette reading / cm^3	23.85	47.20	24.05	48.10
Initial burette reading / cm^3	0.00	24.00	0.50	25.00
Titre / cm^3	23.85	23.20	23.55	23.10

(i) Complete the diagram to show the final burette reading in **Titration 1**.

(2)



(ii) Explain why this student should use a mean titre of 23.15 cm^3 and not

23.43 cm^3 in the calculation.

(2)

.....

.....

.....

.....

(iii) The uncertainty in each burette reading is ±0.05 cm^3.

Calculate the percentage uncertainty in the titre volume of potassium manganate(VII) solution used in **Titration 2**.

(1)

(iv) The equation for the reaction is

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

Deduce, by calculation, the value of **y**, to the nearest whole number, in the formula $KH_3(C_2O_4)_{\mathbf{y}}.\ \mathbf{z}H_2O$.

Use the mean titre of 23.15 cm^3 and other data from **Experiment 1**.

You **must** show your working.

(4)

(b) **Experiment 2** – to determine the value of **z**

Another student wrote an account of the method for this experiment.

A crucible was weighed.

A sample of the hydrated salt was added to the crucible and it was reweighed.

The crucible and salt were heated to remove the water of crystallisation and then allowed to cool.

The crucible and contents were weighed again.

Results

Mass of crucible	*= 19.56 g*
Mass of crucible + $KH_3(C_2O_4)_{\mathbf{y}}.\mathbf{z}H_2O$	*= 22.97 g*
Mass of crucible + $KH_3(C_2O_4)_{\mathbf{y}}$	*= 22.52 g*

(i) Deduce, by calculation, the value of **z**, to the nearest whole number, in the

formula $KH_3(C_2O_4)_{\mathbf{y}}.\ \mathbf{z}H_2O$.

You must use the data from **Experiment 2** and your value of **y** in (a)(iv).

You **must** show your working.

(3)

(ii) A third student carried out Experiment 2 and calculated a value of **z** that was lower than expected.

This student evaluated the experiment and gave two suggestions for **z** being lower.

Suggestion **1**
"Some of the crystals jumped out of the crucible while it was being heated."

Suggestion **2**
"It was difficult to tell when all the water of crystallisation had been lost."

Evaluate these two suggestions to decide whether they could account for the lower value of **z** obtained from the experimental results.

Include an explanation of the effect each suggestion would have on the calculated value of **z** and how the method could be improved to prevent these errors.

(5)

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

(Total for question = 17 marks)

Q35.

The enthalpy change for the decomposition of sodium hydrogencarbonate can be determined indirectly using Hess's Law.

$$2NaHCO_3(s) \xrightarrow{\Delta_r H} Na_2CO_3(s) + H_2O(l) + CO_2(g)$$

A student carried out two experiments.

Experiment 1 involved the reaction between sodium hydrogencarbonate and hydrochloric acid.

The student used the following procedure:

- use a measuring cylinder to measure 50 cm^3 of 2.00 mol dm^{-3} hydrochloric acid and pour it into a polystyrene cup
- measure the initial temperature of the acid
- weigh the test tube containing sodium hydrogencarbonate
- tip the sodium hydrogencarbonate into the hydrochloric acid in the polystyrene cup, stir the mixture and record the lowest temperature reached
- weigh the empty test tube.

Results

Measurement	Value
Mass of test tube + $NaHCO_3$ / g	21.23
Mass of empty test tube / g	15.61
Mass of $NaHCO_3$ used / g	
Initial temperature / °C	21.0
Final temperature / °C	14.4
Temperature fall / °C	

(i) Complete the table.

(1)

(ii) Show, by calculation, that the hydrochloric acid is in excess.
You must show your working.

$$NaHCO_3(s) + HCl(aq) \rightarrow NaCl(aq) + H_2O(l) + CO_2(g)$$

(2)

(iii) Calculate the enthalpy change for the reaction between sodium hydrogencarbonate and hydrochloric acid, using the results of the experiment.
Include a sign and units in your answer.

Assume: mass of reaction mixture = 50.0 g
specific heat capacity of the reaction mixture = 4.18 J g^{-1} $°C^{-1}$

(3)

(Total for question = 6 marks)

Q36.

This question is about equilibrium systems.

Sulfur dioxide and oxygen form an equilibrium with sulfur trioxide.

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$$

The composition of an equilibrium mixture at 698 K and a total pressure of 2.40 atm is shown in the table.

Substance	$SO_2(g)$	$O_2(g)$	$SO_3(g)$
Number of moles /mol	0.0160	0.0120	0.772

(i) Calculate the value of K_p at this temperature.

Include units, if appropriate.

(5)

(ii) Calculate the number of sulfur dioxide molecules present in this equilibrium mixture.

(1)

(iii) Deduce, by referring to K_p, how the number of sulfur dioxide molecules will change if more oxygen is added to the equilibrium mixture.

(2)

.....

.....

.....

.....

(Total for question = 8 marks)

Q37.

This is a question about catalytic converters in car exhaust systems.

In the UK, the exhaust emissions of a petrol-fuelled vehicle must be less than 1.00 g of carbon monoxide per kilometre.

What is the maximum number of carbon monoxide molecules that can be emitted per kilometre for a vehicle to meet this regulation?

(1)

☒ **A** 1.37×10^{22}

☒ **B** 2.15×10^{22}

☒ **C** 6.02×10^{23}

☒ **D** 1.69×10^{25}

(Total for question = 1 mark)

Q38.

This question is about flame tests for Group 1 and 2 metal ions.

Explain, with reference to electron transitions, the formation of the colour in a flame test.

(3)

.....

.....

.....

.....

.....

.....

.....

.....

.....

(Total for question = 3 marks)

Q39.

The solid compound V_2O_5 is used as a heterogenous catalyst in industry to speed up the reaction between oxygen and sulfur dioxide gas.

The reaction has two stages:

Stage 1 $SO_2(g) + V_2O_5(s) \rightarrow SO_3(g) + 2VO_2(s)$

Stage 2 $2VO_2(s) + ½O_2(g) \rightarrow V_2O_5(s)$

(i) Write the equation for the overall reaction. State symbols are not required.

(1)

*(ii) Explain the catalytic behaviour of V_2O_5 in this reaction.

(6)

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

Q40.

Hess's law can be used to determine enthalpy changes for reactions which cannot be obtained directly.
An example is the reaction of anhydrous copper(II) sulfate with water to form hydrated copper(II) sulfate, $CuSO_4.5H_2O$.

The following outline procedure was carried out.

Step **1** 42.75 g of deionised water was weighed out in a polystyrene cup and the temperature measured.

Step **2** 0.0250 mol of hydrated copper(II) sulfate was added to the water in the polystyrene cup with stirring, making a total of 45.00 g of water.

Step **3** The temperature change was recorded.

Step **4** Steps **1** to **3** were repeated using 45.00 g of deionised water and 0.0250 mol of anhydrous copper(II) sulfate.

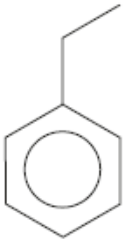
Calculate the mass of 0.0250 mol of hydrated copper(II) sulfate, $CuSO_4.5H_2O$.

(2)

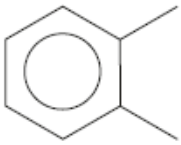
(Total for question = 2 marks)

Q41.

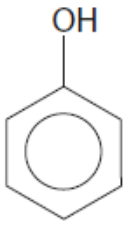
This question is about the arenes, ethylbenzene, xylene, and phenol, which can be identified in wine samples using gas chromatography.



ethylbenzene



xylene



phenol

A student carried out an experiment to determine the molar mass of xylene.

The student's sample of xylene vapour had a mass of 0.271 g.

At a temperature of 165 °C and a pressure of 118 kPa, this sample had a volume of 70.5 cm^3.

Use the Ideal Gas Equation to calculate the molar mass, in g mol^{-1}, of this sample.

Give your answer to an appropriate number of significant figures.

You **must** show your working.

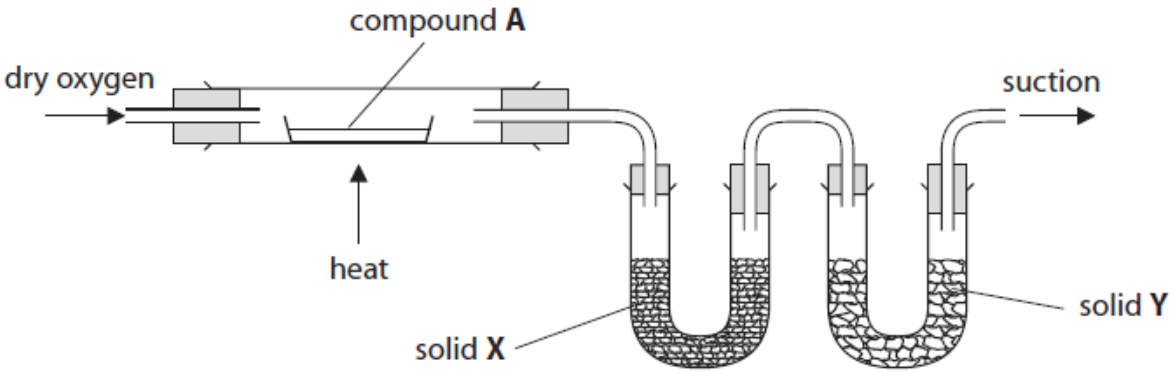
(4)

(Total for question = 4 marks)

Q42.

A compound **A**, known to contain only the elements carbon, hydrogen and oxygen, was subjected to detailed analysis.

(a) A sample of **A** was burned completely in the apparatus shown below. Solid **X** absorbed the water formed in the combustion and solid **Y** absorbed the carbon dioxide.



(i) Explain why the oxygen must be dry.

(1)

.....

.....

.....

.....

(ii) Suggest a suitable substance to use as solid **X**.

(1)

.....

.....

(iii) Suggest a suitable substance to use as solid **Y**.

(1)

.....

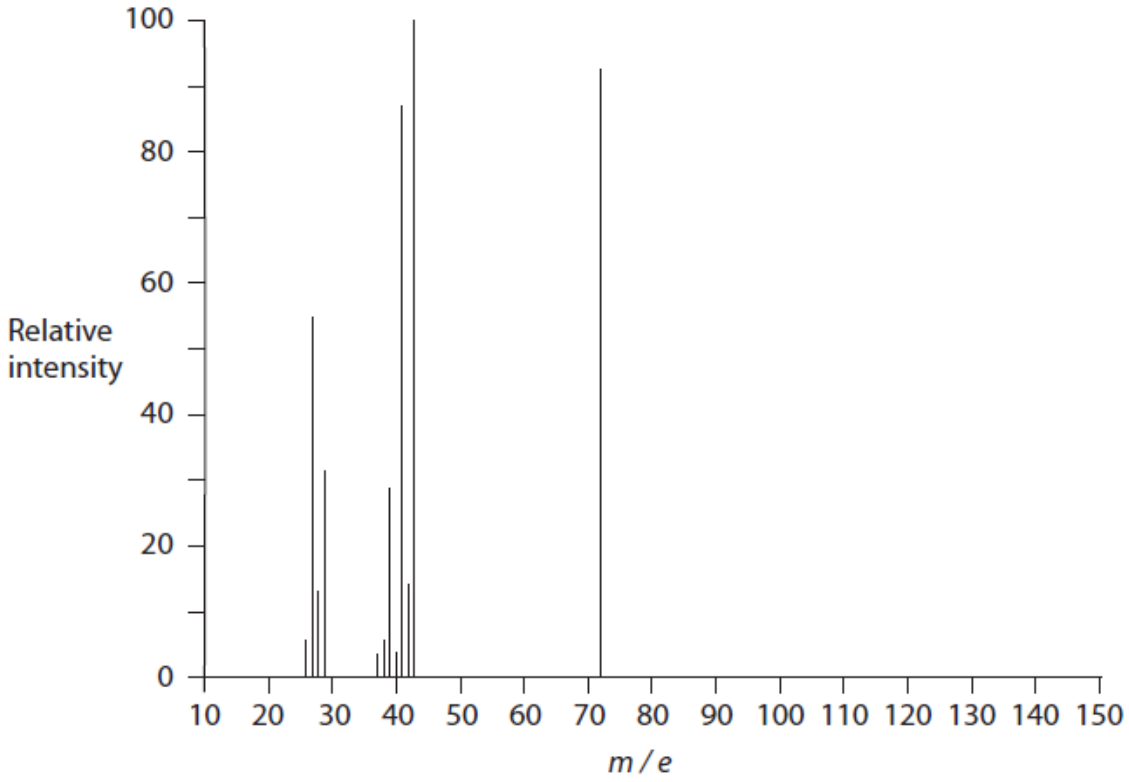
.....

(iv) 3.60 g of compound **A** was burned completely. The mass of solid **X** increased by 3.60 g and the mass of solid **Y** increased by 8.80 g.

Use these data to calculate the empirical formula of compound **A**.
You **must** show your working.

(5)

(b) The mass spectrum of **A** is shown below.



(i) Identify the molecular ion peak and hence deduce the molecular formula of **A**.

(2)

.....

.....

(ii) Given that **A** does **not** have a ring structure, suggest the **structural** formulae of three of the species that might cause the peak at *m*/*e* = 43 in the mass spectrum of **A**.

(3)

*(c) The low resolution nmr spectrum of **A** has three peaks in the ratio 6:1:1. Draw the structure of **A** and show how your structure is consistent with the nmr data.

(3)

.....

.....

.....

.....

(Total for question = 16 marks)

Q43.

The decomposition of hydrogen iodide to form iodine and hydrogen is an equilibrium reaction.

$$2HI(g) \rightleftharpoons I_2(g) + H_2(g)$$

The equilibrium was investigated by taking sealed tubes containing the same mass of hydrogen iodide and heating them at 700 K for some time. At this temperature, the equilibrium takes about two days to be established.

The tubes were rapidly cooled to room temperature, which maintained the equilibrium concentrations, because at this temperature the reaction is extremely slow.

Each tube was opened under an aqueous solution of potassium iodide, which dissolved the hydrogen iodide and the iodine. The amount of iodine was found by titration and the composition of the equilibrium mixture calculated. From the number of moles of each substance at equilibrium, and the volume of the tubes, the equilibrium concentrations were calculated.

(a) (i) How would the appearance of the contents of a tube change as it was cooled to room temperature?

(2)

.....

.....

.....

(ii) How could you show that equilibrium had been established?

(2)

.....

.....

.....

.....

(b) The equilibrium concentrations of one experiment are shown in the table below.

[HI] /mol dm^{-3}	[H_2] /mol dm^{-3}	[I_2] /mol dm^{-3}
0.00353	0.00048	0.00048

*(i) The volume of the tube in this experiment was 30 cm^3. Calculate the initial mass of hydrogen iodide. Show your working.

(5)

(ii) Write an expression for the equilibrium constant, K_c, at 700 K.

(1)

(iii) Calculate the value for this equilibrium constant.

(1)

(iv) Does this equilibrium constant have units? Explain your answer.

(1)

.....

.....

.....

(c) The equation for the reaction at 700 K can also be written

$$HI(g) \rightleftharpoons \tfrac{1}{2}H_2(g) + \tfrac{1}{2}I_2(g)$$

(i) Write the equilibrium constant, K_c', for this reaction.

(1)

(ii) Using the same equilibrium concentrations as below, calculate the equilibrium constant, K_c'.

Deduce the relationship between this value and the value calculated in part (b)(iii).

(2)

[HI] /mol dm^{-3}	[H_2] /mol dm^{-3}	[I_2] /mol dm^{-3}
0.00353	0.00048	0.00048

(d) Consider the following equilibrium reaction.

$$2HI(g) \rightleftharpoons I_2(s) + H_2(g)$$

For this reaction $K_p = \dfrac{P_{H_2}}{P_{HI}^2}$

Use the expression for K_p to explain the effect of an increase in total pressure on the position of the equilibrium.

(3)

.....

.....

.....

.....

.....

.....

(Total for question = 18 marks)

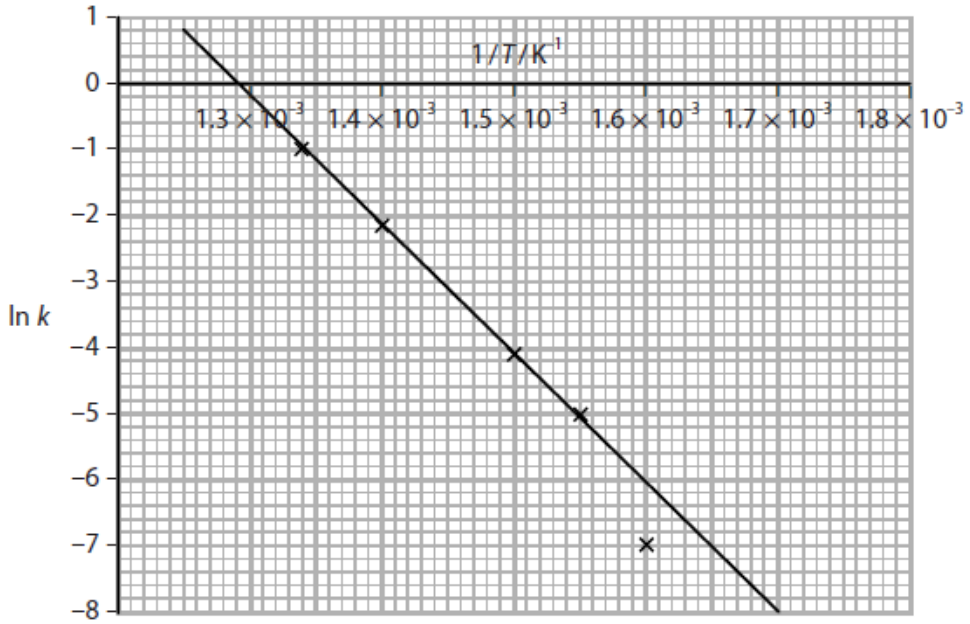
Q44.

This question is about the reaction kinetics of an 'iodine clock' reaction.

One example of an 'iodine clock' reaction that involves the iodate(V) ions and iodide ions in acidic solution is

$$IO_3^-(aq) + 5I^-(aq) + 6H^+(aq) \rightarrow 3I_2(aq) + 3H_2O(l)$$

Another 'iodine clock' reaction produced data that enabled the following graph of ln k against $1/T$ to be drawn.



(i) The Arrhenius equation can be expressed as

$$\ln k = -\frac{E_a}{R} \times \left[\frac{1}{T}\right] + \text{constant}$$

From the gradient of the graph, determine the activation energy, E_a , for this reaction.

Include a sign and units in your answer.

(3)

(ii) Give a reason for the point at ln $k = -7$ **not** being included in the line drawn on the graph.

(1)

.....

.....

(Total for question = 4 marks)

Q45.

This question is about redox reactions.

Manganese(IV) oxide, MnO_2 , and manganate(VII) ions, MnO_4^- , react in alkaline solution to form manganate(VI) ions, MnO_4^{2-} .

(i) Write the **ionic** equation for this reaction.

State symbols are not required.

(2)

(ii) Give a reason why this reaction is **not** disproportionation.

(1)

.....

.....

.....

.....

(Total for question = 3 marks)

Q46.

Compound **C** is a pink crystalline solid containing two cations and one anion.

Three tests were carried out on **C**. The observation made for each test was recorded in the table.

Test	Observation	Inference
Test 1 Aqueous sodium hydroxide was added to solid **C** and the mixture warmed The gas evolved was tested with damp red litmus paper	The red litmus paper turned blue	The gas evolved was ..... One of the cations in **C** is .....
Test 2 Concentrated hydrochloric acid was added to an aqueous solution of **C**	The pink solution turned blue	The other cation in **C** is ..... The formula of the complex ion in the blue solution is .....
Test 3 Dilute hydrochloric acid and aqueous barium chloride were added to an aqueous solution of **C**	A white precipitate formed	The white precipitate is ..... The anion in **C** is .....

(b) Write the **ionic** equation for the reaction between the cation in **C** and sodium hydroxide producing the gas in **Test 1**.

State symbols are not required.

(1)

(Total for question = 1 mark)

Q47.

Benzene

Benzene was first discovered by Michael Faraday in London in 1825. He identified it by distilling a liquid obtained from condensing a gas produced by heating whale oil.

In 1834, Mitscherlich discovered the same liquid could be obtained by heating benzoic acid with lime.

Benzene is now produced from petroleum. Petroleum is fractionally distilled and benzene is obtained from the hexane in the naphtha fraction.

Hexane is heated to about 770 K. It then passes to a reactor where it reacts to form cyclohexane and hydrogen. The cyclohexane is then dehydrogenated to form benzene. Other aromatic products like methylbenzene and dimethylbenzenes are also produced. The aromatic products are separated by further distillation.

Benzene is the starting compound for a large number of useful chemicals and materials. For example it is used to make the polymer, poly(phenylethene).

(a) Write an equation for the reaction between benzoic acid and lime, calcium oxide. State symbols are not required.

(1)

(b) Deduce, with references to oxidation numbers, what has happened to the carbon in the conversion of cyclohexane to benzene.

(2)

.....

.....

.....

.....

Q48.

Tests are carried out on aqueous solutions of two salts, **X** and **Y**.

X contains one cation and one anion.

The observations for each test are recorded in the table.

(i) Complete the table by writing the names or formulae of the species.

(2)

Test	Observation	Inference
Test 1 Add aqueous sodium hydroxide to an aqueous solution of **X**	A green precipitate forms The precipitate turns brown on the top after a few minutes	The cation in **X** is .....
Test 2 To an aqueous solution of **X**, add dilute hydrochloric acid followed by aqueous barium chloride	A white precipitate forms	The anion in **X** is .....

(ii) Write the ionic equation for the reaction between the cation in **X** and aqueous sodium hydroxide in **Test 1**. Include state symbols.

(2)

(iii) Give a reason why the green precipitate turns brown on the top after a few minutes.

(1)

.....

.....

.....

(iv) Give a reason why dilute hydrochloric acid is needed in **Test 2**.

(1)

.....

.....

.....

(Total for question = 6 marks)

Q49.

The halogens are elements in Group 7 of the Periodic Table.

Halide ions can be identified by their reaction with silver nitrate.

(i) Write the **ionic** equation for the reaction between aqueous solutions of sodium iodide and silver nitrate.
Include state symbols.

(2)

(ii) A solution containing 0.010 mol of a halide ion was reacted with excess silver nitrate and produced 1.88 g of precipitate.

Identify the halide ion.
Justify your answer.

(2)

.....

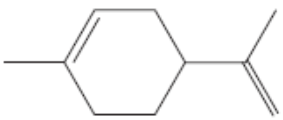
.....

(Total for question = 4 marks)

Q50.

This question is about hydrocarbons.

Limonene is obtained from the oil in lemon peel and it is the only alkene present.



0.500 g of the oil reacted with exactly 30.6 cm^3 of a solution of bromine dissolved in cyclohexane with a concentration of 0.200 mol dm^{-3}.

Calculate the percentage by mass of limonene in the oil.
Give your answer to an appropriate number of significant figures.

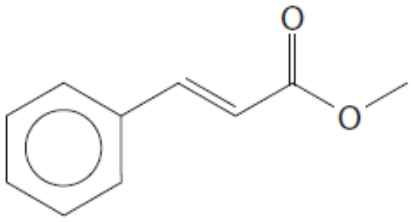
Assume that there is nothing else in the oil that reacts with bromine.

(4)

(Total for question = 4 marks)

Q51.

Methyl cinnamate, $C_{10}H_{10}O_2$, is a white crystalline solid used in the perfume industry.



methyl cinnamate

Calculate the mass of carbon in 2.34 g of methyl cinnamate.

(2)

(Total for question = 2 marks)

Q52.

Complexes involve ligands forming dative covalent bonds with a central cation; the number of dative covalent bonds is the coordination number of the cation in the complex. Complexes may be positive, negative or neutral. The ligands may be neutral or negatively charged, but are never positively charged. The ligands must have a lone pair of electrons. In some complexes the central atom is neutral, as is the case with nickel carbonyl which is used in the Mond process for the purification of nickel:

$$Ni(s) + 4CO(g) \rightleftharpoons Ni(CO)_4(g)$$

The formation of complexes is typical of transition metals but other elements also form complexes. Zinc, which is a d block element but not a transition metal, and aluminium, which is a Group 3 element, both form complexes. Transition metal complexes are usually coloured, but if the interaction between the ligand and the central ion is very strong, then the resulting complex may well be colourless. This is the case with the complex $[FeF_6]^{3-}$.

The ligand in a complex affects its redox properties and this is apparent from considering the

relevant standard electrode potentials. For example, with copper(II) species:

$$[Cu(H_2O)_6]^{2+}(aq) + 2e^- \rightleftharpoons Cu(s) + 6H_2O(l) \quad E^{\ominus} = +0.34\,V$$

$$[Cu(H_2O)_2(NH_3)_4]^{2+}(aq) + 2e^- \rightleftharpoons Cu(s) + 2H_2O(l) + 4NH_3(aq) \quad E^{\ominus} = -0.05\,V$$

Complexes are industrially important, for example in the purification of nickel mentioned above and in the extraction of gold which involves the complex $[Au(CN)_2]^-$.

Complex formation is used in estimating the concentrations of metal ions in solution. Examples of this are the use of EDTA in titration and dimethylglyoxime in gravimetric analysis. Complexes are also used in qualitative analysis, for example, in Tollens' reagent. This reagent is usually prepared by the addition of sodium hydroxide solution to an aqueous solution of silver nitrate followed by aqueous ammonia. The resulting solution contains diamminesilver(I) ions.

(a) The hydrated copper(II) ion is classed as a complex but the hydrated sodium ion is not. By considering the interaction between the water molecules and the sodium ion, explain why the hydrated sodium ion is **not** considered to be a complex.

(2)

.....

.....

.....

.....

(b) Suggest how the aluminium ion is able to form dative covalent bonds in its complexes such as $[AlF_6]^{3-}$.

(1)

.....

.....

.....

*(c) (i) Transition metal complexes are usually coloured. Explain how the colours occur.

(4)

.....

.....

.....

.....

.....

.....

.....

.....

(ii) Why are zinc complexes such as $[Zn(NH_3)_4]^{2+}$ colourless?

(1)

.....

.....

(iii) Suggest why the strong interactions between the F^- ligands and Fe^{3+} ion result in the complex $[FeF_6]^{3-}$ being colourless.

(2)

.....

.....

.....

.....

(d) Use the standard electrode potentials given in the passage to predict whether it is feasible for thiosulfate ions, $S_2O_3^{2-}$, to reduce copper(II) ions to copper. Consider the case when the copper(II) ions are dissolved in water, and when they are dissolved in aqueous ammonia. Give chemical equations to support your answer.

(3)

The relevant redox reaction for thiosulfate ions is

$$S_4O_6^{2-}(aq) + 2e^- \rightleftharpoons 2S_2O_3^{2-}(aq) \quad E^{\ominus} = +0.09\,V$$

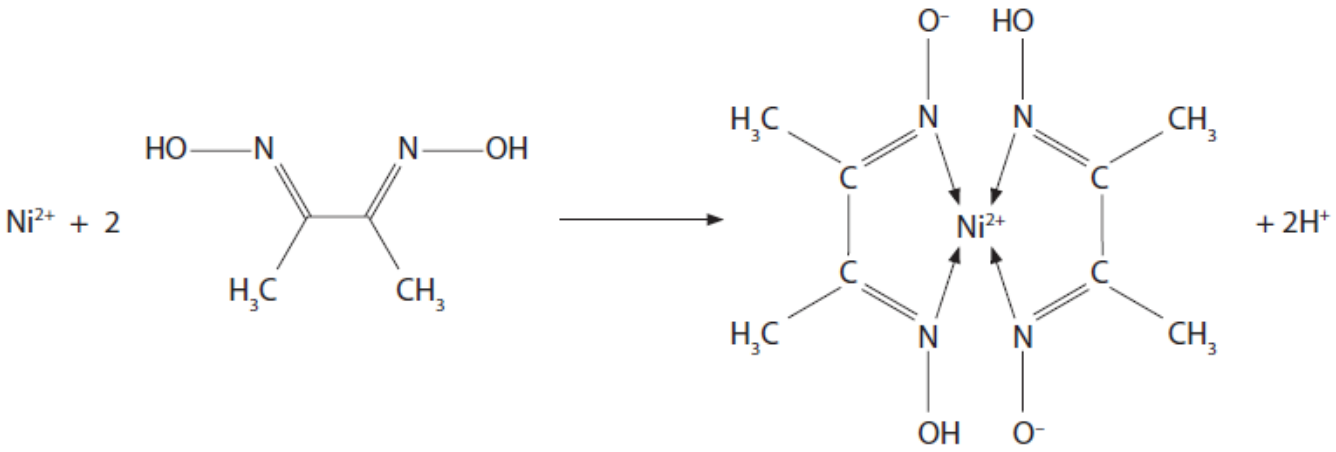
.....

.....

.....

(e) The proportion of nickel in nisil, an alloy of nickel and silicon used in thermocouples, may be determined by the following gravimetric analysis.

Finely ground nisil is dissolved in concentrated hydrochloric acid and, after neutralization, excess dimethylglyoxime dissolved in ethanol is added to the solution formed. The resulting red precipitate is filtered, washed, dried and weighed. The equation for the formation of the precipitate is



(i) State the coordination number of the nickel in the complex ion.

(1)

.....

(ii) In an experiment, 1.02 g of nisil formed 4.82 g of the complex. Calculate the percentage by mass of nickel in the alloy. The molar mass of the complex is 288.7 g mol^{-1}.

(2)

(Total for question = 16 marks)

Q53.

This question is about the identification of a Group 2 carbonate.

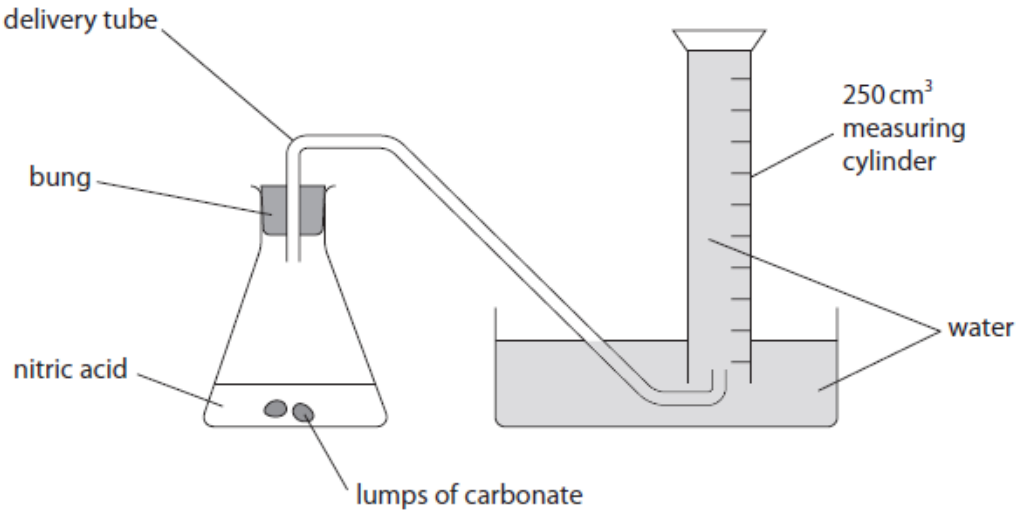
A chemistry teacher found a bottle containing lumps of a white solid. The original label was missing from the bottle. However, someone had written 'Group 2 carbonate' on the bottle. The lumps of the anhydrous white solid were pure and dry.

The chemistry teacher tried to identify the carbonate with the help of three students.
The three students worked under identical conditions and shared the same weighing balance.

Student **1** recognised that if an acid is added to a carbonate, carbon dioxide is evolved. The student decided to measure the volume of carbon dioxide evolved when the Group 2 carbonate reacts with excess nitric acid.

The student knew that 1 mol of a Group 2 carbonate produces 1 mol of carbon dioxide.

Student **1** set up the apparatus shown below.



- Student **1** weighed out some of the Group 2 carbonate and added it to a 250 cm^3 conical flask.
- Student **1** then added 100 cm^3 of 0.200 mol dm^{-3} nitric acid to the conical flask and replaced the bung.
- Student **1** measured the volume of gas collected in the inverted measuring cylinder at room temperature and pressure (r.t.p.) when all the Group 2 carbonate had reacted.
- Student **1** obtained the results shown in Table 1.

Measurement		Value
Mass of weighing bottle and carbonate	/ g	13.247
Mass of empty weighing bottle	/ g	12.431
Mass of carbonate used	/ g	.....
Volume of acid used	/ cm^3	100
Volume of gas collected	/ cm^3	225

Table 1

(a) Complete Table 1 to show the mass of the carbonate used.

(1)

(b) Calculate the amount, in moles, of carbon dioxide collected in the measuring cylinder at r.t.p.

(1)

(c) Calculate the molar mass of the Group 2 carbonate to an appropriate number of significant figures and hence deduce the identity of the Group 2 metal.

(4)

(d) Student **2** carried out the same experiment as Student **1**, using the same mass of the Group 2 carbonate.

Student **2** made no errors in their measurements or calculations but obtained a value for the

molar mass which was 10 g mol^{-1} greater than the value obtained by Student **1**.

(i) Explain **one** procedural error which could have resulted in Student **2** obtaining a molar mass greater than that of Student **1**.

(2)

.....

.....

.....

.....

.....

.....

(ii) It was later discovered that Student **2** had used 110 cm^3 of 0.200 mol dm^{-3} dilute nitric acid, instead of 100 cm^3 of 0.200 mol dm^{-3} dilute nitric acid.

Give a reason why this mistake would **not** have affected Student **2**'s result.

No calculation is required.

(1)

.....

.....

(iii) The teacher noticed that Student **2** had used the Group 2 carbonate in powdered form rather than in lumps.

Explain how, if at all, this would affect the rate of reaction and the final volume of gas produced in the reaction.

(2)

.....

.....

.....

.....

.....

(e) Student **3** suggested a different experiment.

Student **3** realised that, by heating the carbonate, carbon dioxide would be lost and an oxide would remain.

Student **3** decided to measure the change in mass of the carbonate and to use this information to calculate its molar mass.

- Student **3** weighed an empty test tube.
- Using a spatula, Student **3** added some of the carbonate to the test tube.
- The test tube containing the carbonate was then weighed.
- The test tube and its contents were heated to constant mass.
- The results obtained by Student **3** are shown in Table 2.

Measurement		Value
Mass of carbonate + test tube	/ g	20.447
Mass of oxide + test tube	/ g	20.205
Mass of empty test tube	/ g	19.996

Table 2

(i) Write an equation, including state symbols, for the thermal decomposition of a Group 2 carbonate, MCO_3, where M represents the metal.

(1)

(ii) Using Student **3**'s results, calculate the molar mass of the Group 2 carbonate.

(3)

(f) Student **3** used the same balance as Student **1**.

Give a reason why the mass of the carbonate measured by Student **3** has a greater percentage uncertainty than that measured by Student **1**.

(1)

.....

.....

.....

.....

(g) Student **3** noticed that on heating the test tube some solid was lost.

Explain how this would affect the calculated value for the molar mass of the Group 2 carbonate.

(2)

.....

.....

.....

.....

.....

.....

(Total for question = 18 marks)

Q54.

The propulsion system of a torpedo is powered by sulfur hexafluoride, SF_6, in an exothermic reaction with solid lithium.

The equation for the reaction of sulfur hexafluoride with lithium is:

$$SF_6(g) + 8Li(s) \rightarrow Li_2S(s) + 6LiF(s) \qquad \Delta_r H^{\ominus} = -2\,934 \text{ kJ mol}^{-1}$$

(a) Calculate the mass of lithium needed to react with 398 kg of sulfur hexafluoride.
Give your answer to an appropriate number of significant figures.

[Molar masses: SF_6 = 146.1g mol^{-1}; Li = 6.90 g mol^{-1}]

(3)

Mass of lithium needed = ... kg

(b) The table gives the standard molar entropies, $S^{\ominus}$, at 298 K, of $SF_6(g)$, Li(s), $Li_2S(s)$ and LiF(s).

	$SF_6(g)$	Li(s)	$Li_2S(s)$	LiF(s)
$S^{\ominus}$ / $JK^{-1}mol^{-1}$	+292	+29.1	+63.0	+35.6

Calculate the standard total entropy change, $\Delta S^{\ominus}_{total}$ total, at 298 K, for the reaction between sulfur hexafluoride and lithium. Include units in your final answer.

(4)

$\Delta S^{\ominus}_{total}$.....

(c) The reaction between sulfur hexafluoride and lithium is started using a fuse.
Justify the need for a fuse, in view of your answer to part (b).

(2)

.....

.....

.....

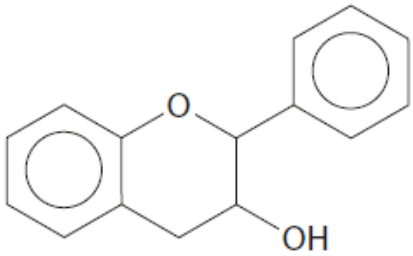
.....

.....

.....

Q55.

The compound flavan-3-ol is found in tea, fruit and wine.



Give the molecular formula for flavan-3-ol.

(1)

.....

(Total for question = 1 mark)

Q56.

This question is about some halogens and their compounds.

A student carries out experiments to determine the order of reactivity of three halogens: bromine, chlorine and iodine.
The student is provided with aqueous solutions of the following five substances:

- bromine
- iodine
- potassium chloride
- potassium bromide
- potassium iodide.

The student has **no** access to chlorine gas or chlorine water.

The student uses cyclohexane, an organic solvent, to identify the halogen present at the end of each experiment.

The student carries out the **smallest** number of experiments required to determine the order of reactivity of the halogens.

Describe the experiments and the expected observations.

Include in your answer **ionic** equations for any reactions that occur.

State symbols are **not** required.

(5)

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

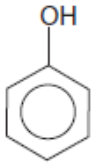
.....

.....

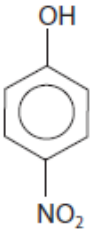
(Total for question = 5 marks)

Q57.

Phenol is a feedstock in the production of many organic molecules.

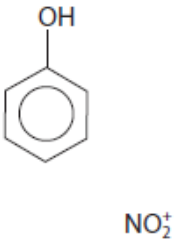


Phenol can be nitrated to produce 4-nitrophenol.



(i) The mechanisms of the nitration of phenol and of benzene are similar. Complete the diagram, using curly arrows, to show a possible mechanism for the reaction between the electrophile, NO_2^+, and phenol to produce 4-nitrophenol.

(3)



(ii) What is the mass, in grams, of 4-nitrophenol produced from 0.94 g of phenol if the yield of this isomer is 15%?

(1)

☒ **A** 0.14

☒ **B** 0.21

☒ **C** 0.68

☒ **D** 1.39

(iii) Draw **two** structural isomers of 4-nitrophenol which have a benzene ring.

(1)

(Total for question = 5 marks)

Q58.

Answer the question with a cross in the box you think is correct ☒ . If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒ .

The halogens are elements in Group 7 of the Periodic Table.

Sodium chlorate(I) is a bleaching agent.

(i) Sodium chlorate(I) can be made by the reaction of chlorine with sodium hydroxide.

Show, by using oxidation numbers, that this reaction is disproportionation.

$$2NaOH + Cl_2 \rightarrow NaClO + NaCl + H_2O$$

(2)

.....

.....

(ii) A different bleaching agent can be made by the reaction of chlorine with sodium hydroxide under different conditions.

Balance this equation.

$$.....NaOH + ...Cl_2 \rightarrow NaClO_3 + ...NaCl + ...H_2O$$

(1)

(iii) What conditions are required for the reaction in (b)(ii)?

(1)

☒ **A** cold and dilute alkali

☒ **B** cold and concentrated alkali

☒ **C** hot alkali

☒ **D** excess chlorine

(Total for question = 4 marks)

Q59.

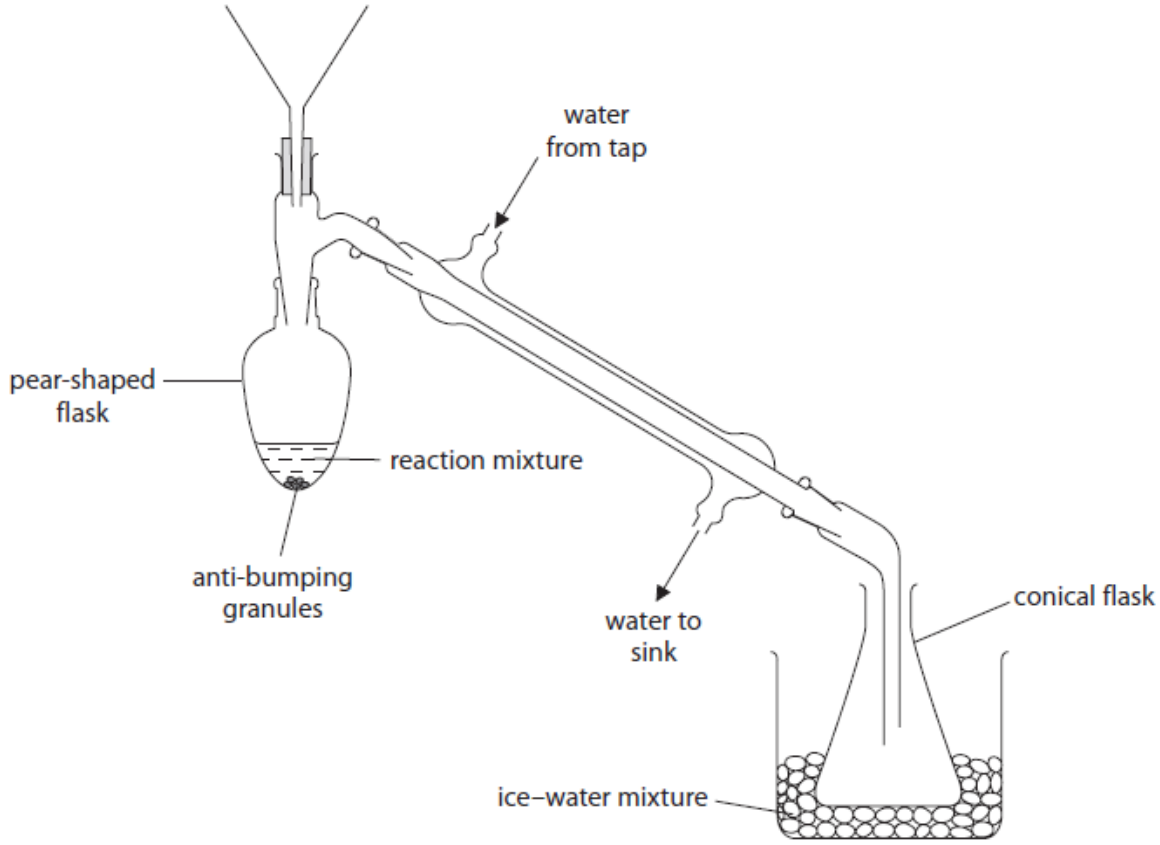
This question is about the preparation of a sample of the ketone, 3-methylbutan-2-one.

A student's research suggested that 3-methylbutan-2-one may be prepared by oxidising

3-methylbutan-2-ol with acidified potassium dichromate(VI) solution.

The student sets up the apparatus as shown in the diagram. You may assume that all the equipment is suitably clamped.

The student adds dilute sulfuric acid to the pear-shaped flask. A mixture of potassium dichromate(VI) and 3-methylbutan-2-ol is then added slowly to the dilute sulfuric acid in the flask.



The sample of purified 3-methylbutan-2-one is found to have a mass of 2.15 g.
This mass of 3-methylbutan-2-one represents a yield of 62.5% by mass.

(i) Write an equation, using **molecular** formulae, for the oxidation of 3-methylbutan-2-ol to 3-methylbutan-2-one.

Use [O] to represent the oxidising agent.

(2)

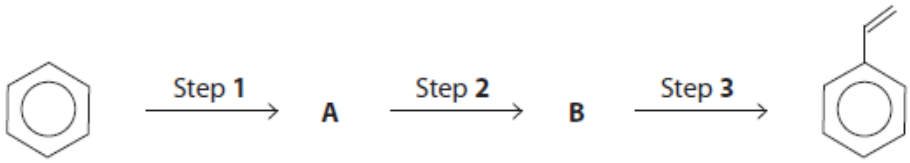
(ii) Calculate the mass of 3-methylbutan-2-ol that the student uses at the start of the preparation.

(2)

(Total for question = 4 marks)

Q60.

Phenylethene, commonly known as styrene, is an important substance in the production of polystyrene which is used for some types of plastic packaging. Phenylethene can be made from benzene in a three-step synthesis.



Calculate the percentage by mass of carbon in phenylethene, giving your answer to an appropriate number of significant figures.

(2)

(Total for question = 2 marks)

Q61.

1-bromobutane can be prepared from butan-1-ol and hydrogen bromide.

$$CH_3CH_2CH_2CH_2OH + HBr \rightarrow CH_3CH_2CH_2CH_2Br + H_2O$$

Hydrogen bromide can be made from sodium bromide and 50% concentrated sulfuric acid.

(a) The steps for the preparation of impure 1-bromobutane are summarised.

Step **1** Dissolve the sodium bromide in distilled water in a pear-shaped flask and then add 20.0 cm^3 of butan-1-ol.

Step **2** Surround the flask with an ice bath to **cool the mixture**, before adding concentrated sulfuric acid drop by drop.

Step **3** Remove the flask from the ice bath and add a few **anti-bumping granules** to the reaction mixture.

Step **4** Set up the apparatus for **heating under reflux**. Heat the mixture in the flask for 30 minutes and then allow the apparatus to cool.

Step **5** Rearrange the apparatus for distillation and heat the mixture until no more 1-bromobutane distils over.

(i) Parts of the method are given in **bold** type in Steps **2**, **3** and **4**.

Give a reason why each of these parts is necessary.

(3)

.....

.....

.....

.....

.....

.....

.....

.....

.....

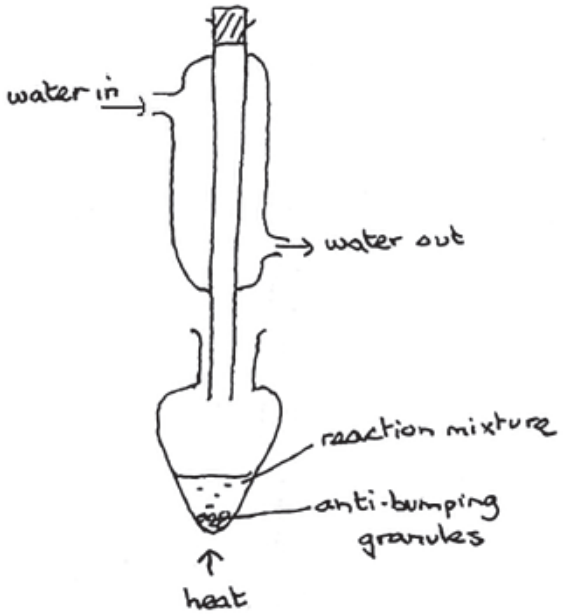
.....

.....

.....

.....

(ii) A student drew a diagram of the apparatus used for heating under reflux in Step **4**. There are three errors in the apparatus shown in the diagram.
Assume the apparatus is suitably clamped.



Identify the three errors, including the effect of each error.

(3)

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

(iii) The student corrected the errors.

While the mixture was heating under reflux, the student noticed a small amount of a brown vapour was formed.

Explain why the brown vapour forms.

(2)

.....

.....

.....

.....

(b) The distillate collected in Step **5** is a mixture consisting of two layers.

There is an aqueous layer and a layer containing impure 1-bromobutane.

Data

Densities:

water	$1.00\,g\,cm^{-3}$
butan-1-ol	$0.81\,g\,cm^{-3}$
1-bromobutane	$1.27\,g\,cm^{-3}$

Boiling temperature of 1-bromobutane = 102 °C

The steps for the purification of the 1-bromobutane are summarised.

Step **6** Transfer the mixture from Step **5** to a separating funnel and remove the aqueous layer.

Step **7** Wash the impure 1-bromobutane with concentrated hydrochloric acid in the separating funnel.

Remove the aqueous layer.

Step **8** Add aqueous sodium hydrogencarbonate to the impure 1-bromobutane in the separating funnel.

Step **9** Shake the mixture in the separating funnel and, from time to time, invert the funnel and open the tap.

Step **10** Collect the 1-bromobutane layer from Step **9** in a small conical flask.

Add anhydrous sodium sulfate and swirl the flask until the liquid becomes clear.

Step **11** Decant the 1-bromobutane into a clean pear-shaped flask and redistil it. Measure the volume of 1-bromobutane produced.

(i) State the position of the aqueous layer in the separating funnel at the start of Step **6**. Justify your answer.

(1)

.....

.....

(ii) Concentrated hydrochloric acid is used to remove any unreacted butan-1-ol in the mixture in Step **7**.

Give the reasons for carrying out Steps **8**, **9** and **10**.

(3)

.....

.....

.....

.....

.....

.....

.....

.....

.....

(iii) Give a suitable temperature **range** over which to collect the pure 1-bromobutane in the redistillation in Step **11**.

(1)

.....

(iv) The volume of 1-bromobutane collected was 12.0 cm^3.

Calculate the number of molecules of 1-bromobutane produced in this experiment.

Give your answer to an appropriate number of significant figures.

(2)

(Total for question = 15 marks)

Q62.

This question is about the chemistry of iodine compounds and hydrocarbons.

Iodine monochloride (ICl) reacts with unsaturated compounds such as sunflower oil.

The number of grams of iodine from iodine monochloride that reacts with 100 g of an oil or fat is known as the iodine value and is used to compare levels of unsaturation in different oils and fats.

An excess of iodine monochloride, 11.0 g, was mixed with 6.40 g of sunflower oil. The remaining unreacted iodine monochloride was treated with excess potassium iodide to liberate iodine.

$$ICl + KI \rightarrow KCl + I_2$$

The liberated iodine was titrated with sodium thiosulfate solution of concentration 0.500 mol dm^{-3}. 21.20 cm^3 of this solution was required to completely react with the liberated iodine.

$$I_2 + 2Na_2S_2O_3 \rightarrow 2NaI + Na_2S_4O_6$$

(i) Calculate the amount, in mol, of sodium thiosulfate that reacted with the liberated iodine and hence calculate the amount (in mol) of liberated iodine.

(2)

(ii) Use your answer to (i) and the initial mass of iodine monochloride, 11.0 g, to calculate the iodine value of the oil.

(5)

Q63.

* An excess of magnesium was added to 100 cm^3 of 0.0540 mol dm^{-3} HCl(aq).
The same mass of magnesium, from the same sample, was added to 100 cm^3 of 0.0540 mol dm^{-3} HCOOH(aq).

Both reactions were carried out at the same temperature.
Compare and contrast the total volume of hydrogen evolved, and the rate at which it will be evolved, in the two reactions.

(6)

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

Q64.

Many vehicles are fitted with airbags which provide a gas-filled safety cushion to protect the occupant of the vehicle if there is a crash.

(a) The first reaction in airbags is the thermal decomposition of sodium azide, NaN_3, to form sodium and nitrogen gas.

(i) Write the equation for this decomposition of sodium azide.

State symbols are not required.

(1)

(ii) In the reaction in (i), a typical airbag is inflated by about 67 dm^3 of gas.

Calculate the **minimum mass** of sodium azide, in grams, needed to produce this volume of gas. Use the Ideal Gas Equation and give your answer to an appropriate number of significant figures.

For the purpose of this calculation, assume that the temperature is 300 °C and the pressure is 140 000 Pa.

(4)

(b) The second reaction in the airbag is between the sodium produced in the reaction (a)(i) and potassium nitrate.

$$\ldots\ldots Na + \ldots\ldots KNO_3 \rightarrow \ldots\ldots K_2O + \ldots\ldots Na_2O + \ldots\ldots N_2$$

Balance the above equation, justifying your answer in terms of the changes in oxidation numbers.

(3)

.....

.....

(c) The third reaction in the airbag is between the metal oxides and silicon dioxide.

State the type of reaction taking place and justify why this reaction is necessary.

(3)

.....

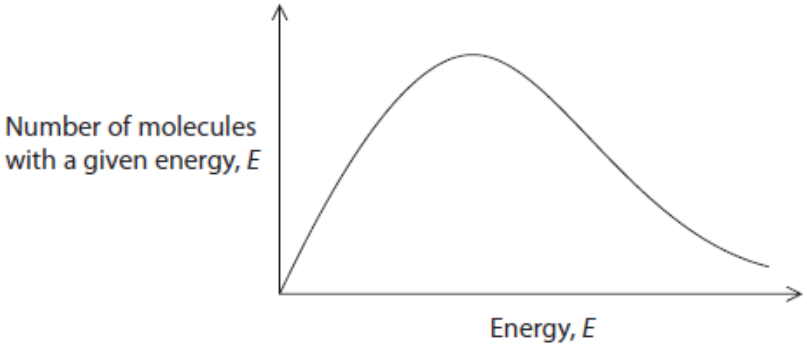
.....

.....

.....

.....

(d) The Maxwell-Boltzmann distribution diagram shows the molecular energies for the gaseous system immediately after the airbag has been deployed.



What is the change in shape of the curve when the airbag **cools**?

(1)

☒ **A** the peak would shift to the left and be higher

☒ **B** the peak would shift to the left and be lower

☒ **C** the peak would shift to the right and be higher

☒ **D** the peak would shift to the right and be lower

(Total for question = 12 marks)

Q65.

(a) When iron(II) sulfate is dissolved in water, the iron(II) ions are slowly oxidized to iron(III) ions by oxygen dissolved in the water.

(i) Write the two ionic half-equations for this redox reaction in **acid** conditions.
State symbols are not required.

(1)

(ii) Hence write the overall ionic equation for the reaction. State symbols are not required.

(1)

(b) 6.90 g of iron(II) sulfate crystals ($FeSO_4 \cdot 7H_2O$) was dissolved in distilled water and the solution made up to 250 cm^3 in a volumetric flask. After 24 hours, 25.0 cm^3 portions of this solution were pipetted into a conical flask and titrated against acidified potassium manganate(VII) solution with a concentration of 0.0195 mol dm^{-3}. The mean titre was 24.90 cm^3.

(i) Write the ionic equation showing that 1 mol of manganate(VII) ions oxidizes 5 mol of iron(II) ions in acid conditions. State symbols are not required.

(1)

(ii) What is the colour of the solution in the conical flask at the end-point of the titration?

(1)

.....

* (iii) Calculate the amount of Fe^{2+} ions in 250 cm^3 of the solution after it had been left to stand for 24 hours. Hence calculate the percentage of the iron(II) ions that had been oxidized between the preparation of the solution and the titration. The molar mass of $FeSO_4 \cdot 7H_2O$ is 277.9 g mol^{-1}.

(5)

(iv) Suggest, with an explanation, the appropriate number of significant figures to give for the answer to (b)(iii).

(1)

.....

.....

.....

(c) The most stable oxidation states in iron compounds are +2 and +3, but others do exist, for example in the ferrate(VI) ion, FeO_4^{2-}. The ionic half-equation for the conversion of ferrate(VI) to iron(III) is

$$FeO_4^{2-}(aq) + 8H^+(aq) + 3e^- \rightleftharpoons Fe^{3+}(aq) + 4H_2O(l) \qquad E^{\ominus} = +2.20\,V$$

(i) Ferrate(VI) decomposes in neutral or acid solution, but is stable in alkali.
Suggest why this is so.

(1)

.....

.....

.....

(ii) Write the equation for the disproportionation of iron(III) into iron(II) and ferrate(VI) in aqueous solution. State symbols are not required.

(2)

(iii) Use standard electrode potential values to determine the thermodynamic feasibility of this disproportionation.

(2)

(Total for question = 15 marks)

Q66.

Chlorine compounds take part in many redox reactions.

(a) State, in terms of electron transfer, what is meant by the term oxidising agent.

(1)

.....

.....

(b) Chlorine dioxide gas, ClO_2, is used to whiten flour. It is unstable and hence is prepared in situ by the reaction:

$$2ClO_3^-(aq) + SO_2(g) + H^+(aq) \rightarrow 2ClO_2(g) + HSO_4^-(aq)$$

Explain, using oxidation numbers, which species is acting as the oxidising agent in this reaction.

(2)

.....

.....

.....

.....

(c) Chlorine dioxide reacts in alkaline solution to form a mixture of ClO_2^- and ClO_3^- ions.

(i) Write an equation for this reaction. State symbols are not required.

(2)

(ii) Give the reason why this reaction is disproportionation.

(1)

.....

.....

.....

Q67.

This question is about extracting benzoic acid from a mixture of benzoic acid, C_6H_5COOH, and phenol, C_6H_5OH.

The following steps were carried out.

Step **1** A suitable mass of the mixture was placed in a separating funnel and some ether added. The funnel was shaken to dissolve the mixture.

Step **2** Aqueous sodium hydrogencarbonate was added to the separating funnel, and the contents shaken.

Step **3** Once the reaction was complete, the two layers were allowed to separate.

Step **4** The lower aqueous layer was removed and placed in a beaker.

Step **5** The ether layer in the separating funnel was washed with deionised water and the washings added to the beaker.

Step **6** Hydrochloric acid was added to the aqueous solution in the beaker to precipitate the benzoic acid.

Step **7** The impure benzoic acid was filtered under reduced pressure.

Step **8** The impure benzoic acid was purified by recrystallisation.

Step **9** The melting temperature of the purified benzoic acid was measured and compared with the literature value of 122 °C.

Benzoic acid can be purified in Step **8** because of its high solubility in hot water and low solubility in cold water.

Calculate the maximum number of benzoic acid molecules that can dissolve in 50.0 cm^3 of cold water if the solubility is 1.70 g per 1000 cm^3.

(3)

(Total for question = 3 marks)

Q68.

This question is about some redox reactions of chlorine, bromine and iodine.

An **excess** of aqueous potassium bromide was added to chlorine water and the solution turned orange.

(i) Write an equation for this reaction. State symbols are not required.

(1)

(ii) Silver nitrate solution was added to the mixture in (i) and excess dilute ammonia solution was then added to the precipitate formed.

Only some of the precipitate dissolved.

Deduce why only **some** of the precipitate dissolved.

(3)

.....

.....

.....

.....

.....

.....

(iii) Aqueous potassium bromide was added to aqueous iodine, instead of chlorine water. There was no reaction.

Give a reason why no reaction occurred.

(1)

.....

.....

(Total for question = 5 marks)

Q69.

Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

The standard molar enthalpy change of neutralisation is the enthalpy change when an acid and an alkali react under standard conditions to form one mole of water.

An experiment was carried out to determine the enthalpy change of neutralisation for the reaction between propanoic acid and sodium hydroxide.

The equation for this reaction is

$$CH_3CH_2COOH(aq) + NaOH(aq) \rightarrow CH_3CH_2COO^-Na^+(aq) + H_2O(l)$$

50.0 cm^3 of sodium hydroxide solution, of concentration 1.00 mol dm^{-3}, was placed in a polystyrene cup. The initial temperature was measured.

(i) Which piece of equipment has the **smallest** measurement uncertainty for the measurement of 50.0 cm^3 of sodium hydroxide solution?

(1)

		Equipment	Measurement uncertainty for **each** reading
☒	**A**	burette	±0.05 cm^3
☒	**B**	50 cm^3 measuring cylinder	±1 cm^3
☒	**C**	25 cm^3 pipette	±0.06 cm^3
☒	**D**	50 cm^3 pipette	±0.08 cm^3

(ii) 50.0 cm^3 of propanoic acid solution, of concentration 1.00 mol dm^{-3}, was added and thoroughly mixed with the sodium hydroxide solution in the polystyrene cup.

The maximum temperature rise was 6.5 °C.

Calculate the enthalpy change of neutralisation for propanoic acid, in kJ mol^{-1}, giving your answer to the **nearest whole number**.

[Assume density of the mixture = 1.00 g cm^{-3}, specific heat capacity of the mixture = 4.18 J g^{-1} $°C^{-1}$]

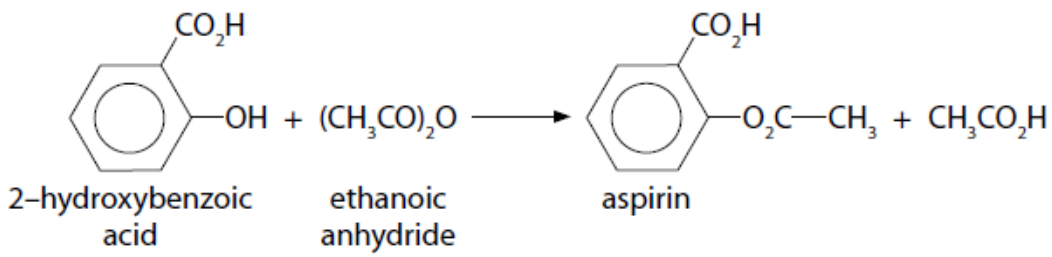
(3)

(Total for question = 4 marks)

Q70.

This question is about the chemistry of the alcohol functional group.

The painkiller aspirin can be synthesised by the reaction between 2-hydroxybenzoic acid, which contains a hydroxyl group, and ethanoic anhydride, using concentrated phosphoric acid as a catalyst. The reagents are heated under reflux, then the excess ethanoic anhydride is removed by reacting it with water.



(i) The percentage yield for this synthesis is 65%.

Calculate the mass of aspirin you would obtain using 2.0 g of 2-hydroxybenzoic acid.

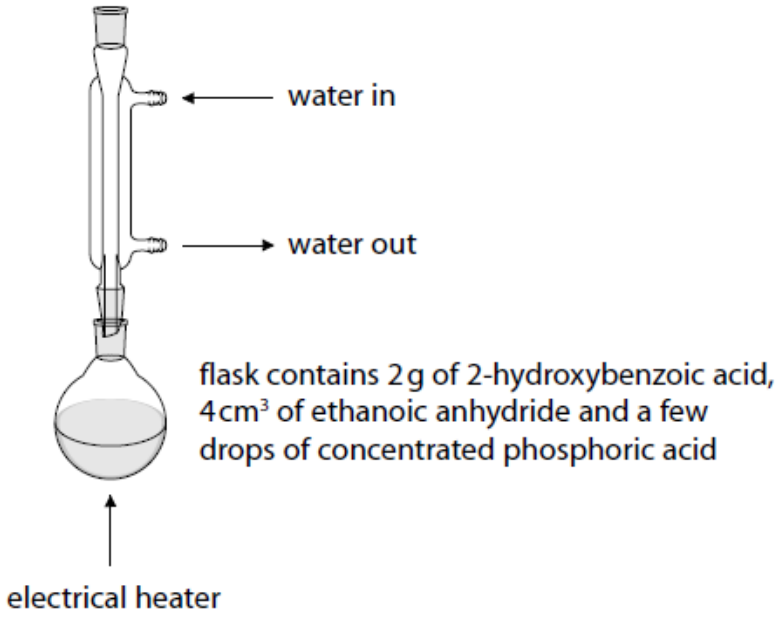
(3)

(ii) The diagram shows a proposed set-up of apparatus used for the stage of the synthesis that requires heating under reflux.

Identify **three** improvements that should be made to this set-up. Give a reason for each improvement made.

You may assume suitable clamps are used.

(6)



.....

.....

.....

.....

.....

.....

.....

.....

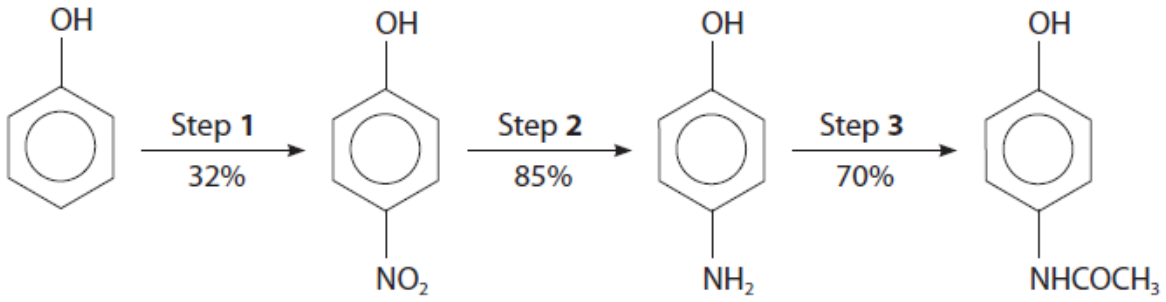
.....

.....

.....

Q71.

The painkiller paracetamol can be synthesised from phenol in three steps.
The percentage yield for each step is shown.



Calculate the minimum mass of phenol needed to synthesise 1.00 kg of paracetamol.
[M_r values: paracetamol = 151.0 phenol = 94.0]

(3)

(Total for question = 3 marks)

Q72.

Aqueous silver nitrate is used as a test for halide ions. A student decides to carry out this test on a solution of magnesium chloride. The bottle of solid magnesium chloride shows the formula $MgCl_2.6H_2O$.

(a) The student dissolves a small amount of $MgCl_2.6H_2O$ in water and adds aqueous silver nitrate, $AgNO_3(aq)$, to the solution.

(i) Calculate the molar mass of $MgCl_2.6H_2O$

(1)

Molar mass = ... g mol^{-1}

(ii) State what the student would see after adding the aqueous silver nitrate.

(1)

.....

(iii) Write an ionic equation for this reaction. Include state symbols.

(1)

(b) Using aqueous silver nitrate, it is sometimes difficult to distinguish between chloride, bromide and iodide ions.

Describe how aqueous ammonia can be used to distinguish between these three ions.

(3)

.....

.....

.....

.....

.....

.....

.....

(Total for question = 6 marks)

Q73.

This question is about amines.

Compare and contrast the basicity of phenylamine and butylamine.

(3)

.....

.....

.....

.....

.....

.....

.....

(Total for question = 3 marks)

Q74.

This question is about a titration experiment carried out by a group of students to determine the concentration of a solution of ethanoic acid using sodium hydroxide.

The teacher carried out the experiment and obtained the following results.

Mass of sodium hydroxide used to make 250.0 cm^3 solution = 3.80 g

Volume of ethanoic acid solution = 25.00 cm^3

Mean titre of sodium hydroxide = 11.90 cm^3

$$CH_3COOH(aq) + NaOH(aq) \rightarrow CH_3COONa(aq) + H_2O(l)$$

Calculate the concentration of the ethanoic acid solution in **g dm^{-3}**.
Give your answer to an appropriate number of significant figures.

(5)

(Total for question = 5 marks)

Q75.

This question is about a titration experiment carried out by a group of students to determine the concentration of a solution of ethanoic acid using sodium hydroxide.

A student weighed about 4.00 g of sodium hydroxide pellets and added them to a beaker containing 50 cm^3 of deionised water.

The mixture was stirred with a glass rod to dissolve the pellets and to give a homogenous solution.

The solution was poured through a funnel into a 250.0 cm^3 volumetric flask and deionised water was added up to the mark and then the flask was shaken.

(i) Describe how you would ensure that all the sodium hydroxide was transferred to the volumetric flask.

(2)

.....

.....

.....

.....

.....

.....

(ii) A student adds deionised water above the mark and shakes the flask.

State why the procedure has to be restarted rather than using a teat pipette to remove the excess water.

(1)

.....

.....

.....

.....

(Total for question = 3 marks)

Q76.

This question is about a titration experiment carried out by a group of students to determine the concentration of a solution of ethanoic acid using sodium hydroxide.

Two students each cleaned a burette, then poured sodium hydroxide solution into their burettes.

(i) Student 1 used a funnel to pour sodium hydroxide solution into the burette.

Give **two** steps needed before the student takes the initial burette reading.

(2)

.....

.....

.....

.....

(ii) Student 2 cleaned the burette by rinsing it with deionised water immediately before filling it with the sodium hydroxide
solution.

Give the effect, if any, on the value of the first titre. Justify your answer.

(1)

.....

.....

.....

(Total for question = 3 marks)

Q77.

This question is about a titration experiment carried out by a group of students to determine the concentration of a solution of ethanoic acid using sodium hydroxide.

Each student used a pipette to measure 25.0 cm^3 of the ethanoic acid solution into four separate conical flasks and added an indicator.

The results of one student's titrations are shown in the table.

Titration number	1	2	3	4
Final burette reading / cm^3	13.00	25.50	37.90	50.00
Initial burette reading / cm^3	0.25	13.00	25.50	37.90
Titre / cm^3				
Concordant titres (✓)				

(i) Complete the table.

(1)

(ii) The low titre for titration **4** was queried by the teacher. The student had wanted to refill the burette and continue the
titration but had been told the measurement uncertainty would increase if this was done.

Calculate the total percentage measurement uncertainty if the burette had been refilled to 0.00, and then a further 0.30 cm^3 had been added from the burette, to the conical flask.

The measurement uncertainty for each burette reading is ±0.05 cm^3.

(1)

(Total for question = 2 marks)

Q78.

Brass is an alloy of copper and zinc.

A sample of brass was weighed on a balance, reading to two decimal places. The mass of the sample was recorded as 5.00 g.

This sample of brass was reacted with excess concentrated nitric acid and the resulting solution was made up to 250 ^{3} in a volumetric flask using distilled water.

25.0 cm^3 portions were taken from this solution using a pipette. Each portion was neutralised by adding sodium carbonate solution; and excess potassium iodide solution was then added. The liberated iodine was titrated with 0.250 mol dm^{-3} sodium thiosulfate solution, using a freshly prepared solution of starch as indicator.

The mean titre was 22.70 cm^3.

(i) Use the equation for the reaction to give two observations when nitric acid reacts with copper.

$$Cu(s) + 2NO_3^-(aq) + 4H^+(aq) \rightarrow Cu^{2+}(aq) + 2NO_2(g) + 2H_2O(l)$$

(2)

.....

.....

.....

.....

(ii) Complete the equation for the reaction between iodine and thiosulfate ions. Include state symbols.

(1)

$I_2(aq) + 2S_2O_3^{2-}(aq) \rightarrow$

(iii) Copper(II) ions react with iodide ions to form iodine.

$$2Cu^{2+}(aq) + 4I^-(aq) \rightarrow 2CuI(s) + I_2(aq)$$

Calculate the percentage by mass of copper in the brass. Give your answer to an appropriate number of significant figures.

(5)

(iv) A student wants to identify the piece of apparatus that contributes most to measurement uncertainties in this experiment, so that the procedure can be modified.

The percentage measurement uncertainty is marked on the pipette as ±0.24%, and on the volumetric flask as ±0.08%.

By using appropriate calculations for the other apparatus used, deduce the **most** significant source of measurement uncertainty in this procedure.

(2)

.....

.....

.....

.....

.....

.....

Q79.

This question is about transition metals and transition metal complexes.

Aqueous vanadium(II) chloride, $VCl_2(aq)$, can be oxidised by bubbling gaseous chlorine, $Cl_2(g)$, through the solution in the absence of air.

40.0 cm^3 of 0.100 mol dm^{-3} VCl_2 solution was oxidised by 144 cm^3 of chlorine gas, at room temperature and pressure (r.t.p.).
The chlorine was reduced to chloride ions, according to the half-equation

$$Cl_2(g) + 2e^- \rightarrow 2Cl^-(aq)$$

[Molar volume of a gas at r.t.p. = 24.0 dm^3 mol^{-1}]

(i) Use these data to calculate the final oxidation state of vanadium.
You **must** show your working.

(5)

(ii) State the initial and final colours you would see as the chlorine bubbles through the aqueous vanadium(II) chloride, $VCl_2(aq)$.

(2)

.....

.....

(Total for question = 7 marks)

Q80.

Answer the question with a cross in the box you think is correct ☒ . If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒ .

What is the total number of **ions** in 26.4 g of ammonium sulfate, $(NH_4)_2SO_4$?

[Molar mass of $(NH_4)_2SO_4$ = 132 g mol^{-1} Avogadro constant = 6.0×10^{23} mol^{-1}]

☐ **A** 4.0×10^{22}

☐ **B** 1.2×10^{23}

☐ **C** 2.4×10^{23}

☐ **D** 3.6×10^{23}

(Total for question = 1 mark)

Q81.

Traditionally, high-flying aircraft and Formula 1 racing cars have had their tyres inflated with nitrogen gas instead of air. Recently, this practice has been extended to some other cars.

A car tyre is filled with nitrogen gas to a volume of 8.98 dm^3 and a pressure of 207 kPa at 20 °C.

(i) Using the Ideal Gas Equation, calculate the mass of nitrogen gas, in grams, present in the car tyre under these conditions. Give your answer to an appropriate number of significant figures.

(3)

(ii) During a car journey, the tyres become warm. Use the Ideal Gas Equation to deduce the effect that this has on the pressure in the tyres.

(1)

.....

.....

(Total for question = 4 marks)

Q82.

(a) This question is about the analysis of an unknown carboxylic acid **X** by three students.

The students analyse the mass spectrum of **X** and find that it has a molecular ion peak at $m / z =$ 116.

The three students each propose a different structural formula for compound **X**.

Structure 1 HOOCCH==CHCOOH

Structure 2 $HOCH_2CH==CHCH_2COOH$

Structure 3 $CH_3CH_2CH_2CH_2CH_2COOH$

The students are given the infrared spectrum of **X**.

(i) State **two** wavenumber ranges of the infrared absorptions providing evidence that compound **X** is a carboxylic acid. Include the bonds responsible.

(2)

.....

.....

.....

.....

(ii) One of the students suggests that this infrared spectrum and the data in the Data Booklet **alone** could be used to identify which of the three proposed structures is **X**.

Show that this student's suggestion is correct. Include relevant infrared data in your answer.

(3)

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

(b) The students decide to carry out an acid-base titration to obtain further information about compound **X**.

Each student uses solid sodium hydroxide, NaOH, to prepare a solution of concentration 0.140 mol dm^{-3}.

Calculate the mass, in grams, of solid sodium hydroxide that each student should weigh out to prepare 250.0 cm^3 of a 0.140 mol dm^{-3} solution.

(2)

(c) Each of the students makes up 250.0 cm^3 of 0.140 mol dm^{-3} sodium hydroxide solution in a volumetric flask and titrates this solution with the same solution of **X** of known concentration.

Student A

- correctly prepares the 0.140 mol dm^{-3} sodium hydroxide solution and pipettes a volume of 10.0 cm^3 of the solution into a conical flask
- fills a burette with the solution of **X** and carries out a titration
- repeats the procedure until obtaining concordant results
- obtains a mean titre of 10.20 cm^3.

Student B

- dissolves the sodium hydroxide in distilled water and transfers the solution to a volumetric flask
- adds more distilled water to the volumetric flask and mixes the solution
- notices that the volumetric flask has been filled with distilled water several cm^3 beyond the graduation mark
- realises the mistake, removes the extra solution and discards it
- pipettes 10.0 cm^3 of the sodium hydroxide solution into a conical flask and titrates this with the solution of **X**.

Student C

- correctly prepares the 0.140 mol dm^{-3} sodium hydroxide solution
- washes a conical flask thoroughly with distilled water and pipettes 10.0 cm^3 of the sodium hydroxide solution into the wet conical flask
- titrates the contents of the conical flask with the solution of **X**.

(i) Explain how, if at all, Student **B**'s mistake affects the value of the titre.

(2)

.....

.....

.....

.....

(ii) Explain how, if at all, Student **C**'s use of a wet conical flask affects the value of the titre.

(2)

.....

.....

.....

.....

(iii) Student **A** uses three pieces of apparatus to measure volumes in this experiment.

- The burette has an uncertainty of ±0.05 cm^3 for each volume reading
- The volumetric flask has an uncertainty of ±0.30 cm^3 for the volume
- The pipette has an uncertainty of ±0.04 cm^3 for the volume

Show by calculation which volume measurement has the lowest percentage uncertainty.

(3)

(d) Student **A** calculates the correct value for the molar mass of compound **X**, using the mean titre of 10.20 cm^3. The results indicate that **X** has **structure 1**.

Structure 1 HOOCCH==CHCOOH

Structure 2 $HOCH_2CH{=}{=}CHCH_2COOH$

Structure 3 $CH_3CH_2CH_2CH_2CH_2COOH$

(i) Write the equation for the reaction between **structure 1** and sodium hydroxide solution. State symbols are not required.

(2)

(ii) Deduce the value that would have been obtained for the mean titre if the structural formula of **X** had been **structure 2**.

Justify your answer.

(2)

.....

.....

.....

.....

.....

(e) The students could have identified the three structures using chemical tests.

Complete the table to show whether or not the suggested structures react with bromine water and when heated with acidified potassium dichromate(VI).

Use a tick (✓) if a reaction occurs.

Use a cross (✗) if no reaction occurs.

(2)

Structure	Test with bromine water	Test with acidified potassium dichromate(VI)
HOOCCH═CHCOOH		
$HOCH_2CH═CHCH_2COOH$		
$CH_3CH_2CH_2CH_2CH_2COOH$		

(f) The structure HOOCCH==CHCOOH has two stereoisomers.

(i) Draw the structures of these stereoisomers.

(2)

***E*-isomer**

***Z*-isomer**

(ii) State why HOOCCH==CHCOOH has *E*/*Z* isomers.

(2)

.....

.....

.....

.....

.....

.....

(Total for question = 24 marks)