

OCR A-LEVEL CHEMISTRY B (SALTERS) • H433

CHEMISTRY



EXAM QUESTION PACK

ELEMENTS OF LIFE (EL): FORMULAE, EQUATIONS AND AMOUNT OF SUBSTANCE

SCORE

/662

PERCENTAGE

%

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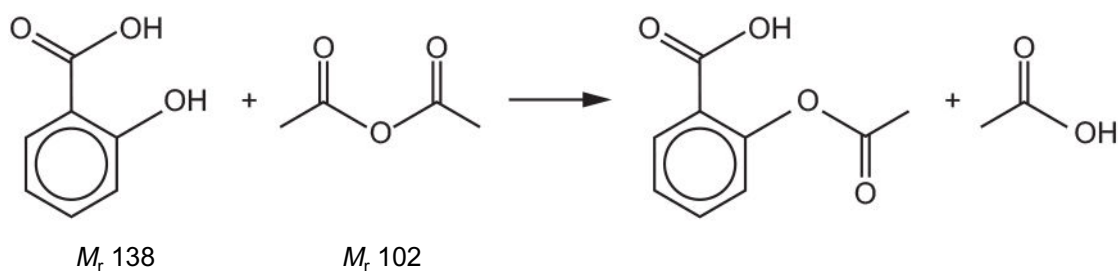
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- 1 Aspirin is synthesised by the reaction below.



What is the atom economy of this reaction for producing aspirin?

- A 25%
- B 43%
- C 50%
- D 75%

Your answer

[1]

- 2 When all the water is driven off from 11.89 g of $\text{NiCl}_2 \cdot x\text{H}_2\text{O}$, the residue weighs 6.49 g.

What is the value of x ?

- A 2
- B 3
- C 4
- D 6

Your answer

[1]

- 3 Ancient paintings have been discovered in caves. The paintings were made using *ochre*, a natural pigment. Ochre owes its colour to the presence of $\text{FeO}(\text{OH}) \cdot n\text{H}_2\text{O}$.

- (i) Give the oxidation state of Fe in $\text{FeO}(\text{OH}) \cdot n\text{H}_2\text{O}$ and complete the electron configuration for the iron ion in the compound.

oxidation state _____ [1]

electron configuration:

$1s^2 2s^2$ _____ [1]

- (ii) When heated gently, 1.282 g of $\text{FeO}(\text{OH}) \cdot n\text{H}_2\text{O}$ loses 0.216 g of water.

Calculate the value of n in the formula of ochre, showing your working.

$n =$ _____ [2]

- (iii) On stronger heating, the same sample lost another 0.140 g to form Fe_3O_y .

Calculate the value of y in Fe_3O_y .

$y =$ _____ [2]

4(a) In the volcanic crater at Solfatara, near Naples, the air smells of sulfur dioxide. Crystals of sulfur can be seen on the ground, together with orange ammonium sulfide.

Sulfur dioxide can be represented as a sulfur atom with double bonds to each of two oxygen atoms.

(i) Draw a '*dot-and-cross*' diagram for this structure.

[2]

(ii) Explain why this molecule is 'V-shaped'.

Predict the bond angle.

[3]

(iii) Ozone has a similar **shape** to sulfur dioxide, with an oxygen atom replacing the sulfur atom. Oxygen, however, can only have a maximum of eight electrons in its outer shell.

Suggest a possible '*dot-and-cross*' diagram for ozone.

[2]

(iv) Sulfur dioxide gives rise to 'acid rain' in the atmosphere.

Write an equation that shows how sulfur dioxide forms aqueous hydrogen ions in the atmosphere.

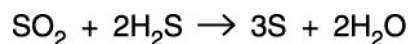
Show state symbols.

[2]

(b)

- (i) The element sulfur can be formed by the reaction of hydrogen sulfide with sulfur dioxide, as shown in the equation below.

Write the oxidation states of sulfur on the dotted lines below the equation.



.....

[3]

- (ii) 44.3 g of SO_2 are mixed with 44.3 g of H_2S .

Calculate the maximum mass of sulfur that could be formed.

Show your working.

mass of S = ... g [3]

- (iii) The element sulfur has a simple molecular structure.

Predict **two** physical properties of sulfur, apart from solubility and boiling point, and explain how these are related to the structure.



In your answer, you should make it clear how your points link together.

[4]

(c) Ammonium sulfide crystals, $(\text{NH}_4)_2\text{S}$, are also found in the volcanic crater.

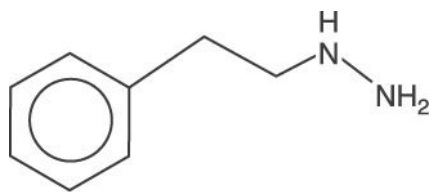
(i) Write the electron configuration (in terms of s and p sub-shells) for a sulfide ion, S^{2-} .

[1]

(ii) Ammonium sulfide, $(\text{NH}_4)_2\text{S}$, reacts with sodium hydroxide to form sodium sulfide.

Suggest an equation for this reaction.

[2]



phenelzine

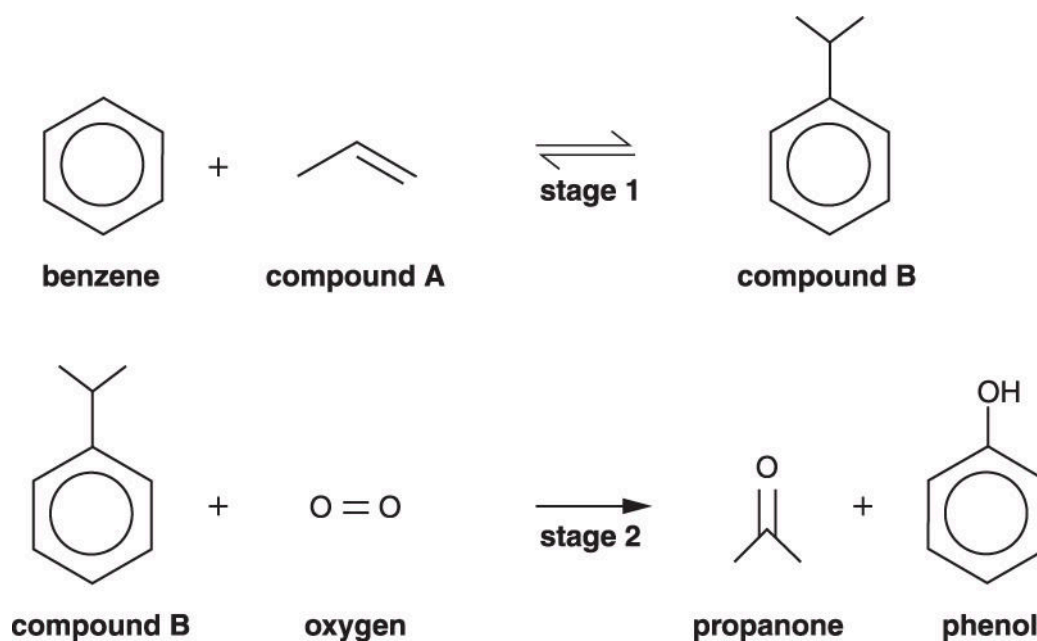
(i) Give the molecular formula of phenelzine.

-----[1]

(ii) Give and explain the H-N-H bond angle in phenelzine.

-----[3]

6(a) Propanone and phenol are useful organic compounds. They are both manufactured from benzene by the two-stage process shown below.



(i) Name compound A.

-----[1]

(ii) The reaction in **stage 1** is described as a *Friedel-Crafts* reaction.

Give **one** similarity and **one** difference between this reaction and most other Friedel-Crafts reactions. Give your answer in terms of the **reactants** and **products**.

Similarity -----

Difference -----

[2]

(b) **Stage 1** is carried out at 250 °C and 30 atmospheres pressure in the gas phase. The reaction is exothermic.

- (i) Describe and explain the effect of increased pressure on the reaction in **stage 1**.

Answer in terms of the equilibrium yield and rate.



In your answer, you should relate your explanation to the equation for the reaction.

[4]

- (ii) Describe and explain the effect (if any) of increasing the temperature on the **equilibrium constant** for **stage 1**.

Suggest why a temperature lower than 250 °C is **not** used.

[2]

- (iii) What is the atom economy of the whole process (stages 1 and 2 taken together)?

Explain why this is beneficial to the environment.

[2]

7(a) Calcium carbide, CaC_2 , can be made by reacting calcium oxide with carbon at high temperatures.

Write a possible equation for the formation of calcium carbide from calcium oxide, CaO .

[1]

- (b) Calcium carbide is heated with nitrogen under pressure. Calcium cyanamide is formed.



Calcium cyanamide is used as a fertiliser because it reacts with water to give ammonia, NH_3 .

- (i) Suggest an equation for the reaction of calcium cyanamide with water.

[2]

- (ii) The formation of calcium cyanamide is an example of 'nitrogen fixation' as it converts atmospheric nitrogen to its compounds.

Suggest and explain why there are not many nitrogen fixation reactions.

[1]

- (iii) Explain why nitrogen fixation is important for plants.

[1]

- (iv) Calculate the percentage by mass of nitrogen in calcium cyanamide.

Give your answer to an **appropriate** number of significant figures.

Percentage = _____ % [2]

- 8 On complete combustion, a sample of a hydrocarbon produces 33 g of carbon dioxide and 18 g of water.

What is the empirical formula of this hydrocarbon?

- A C_3H_8
- B CH_2
- C C_2H_4
- D C_3H_4

Your answer

[1]

- 9 38.49 g of $\text{MgSO}_4 \cdot x\text{H}_2\text{O}$ crystals were heated to drive off the water. 18.79 g of solid remained.

What is the value of x ?

- A 1
- B 2
- C 6
- D 7

Your answer

[1]

- 10 Strontium oxide reacts with water to form an alkaline solution.

What mass of water would react with 10 g strontium oxide?

- A 0.94 g
- B 1.7 g
- C 1.9 g
- D 3.5 g

Your answer

[1]

11 What mass of sodium hydroxide should be dissolved in 250 cm^3 of water to make a solution that has a concentration of 0.05 mol dm^{-3} ?

- A 0.0125 g
- B 0.5 g
- C 2 g
- D 8 g

Your answer

[1]

- 12 Aqueous solutions of $\text{Ce}(\text{SO}_4)_2$ and KMnO_4 can be used as oxidising agents in redox titrations. In both cases reactions are carried out in acidic solutions.

(i) KMnO_4 should **not** be acidified with hydrochloric acid.

Select and use data from the table below to determine which acid can be used with Ce^{4+} to oxidise Cl^- .

Explain your answer.

Half-reaction	$E^\ominus / \text{V}$
$\text{Ce}^{4+} + \text{e}^- \rightleftharpoons \text{Ce}^{3+}$	+1.28 measured in $1 \text{ mol dm}^{-3} \text{ HCl(aq)}$
$\text{Cl}_2 + 2\text{e}^- \rightleftharpoons 2\text{Cl}^-$	+1.36
$\text{Ce}^{4+} + \text{e}^- \rightleftharpoons \text{Ce}^{3+}$	+1.44 measured in $1 \text{ mol dm}^{-3} \text{ H}_2\text{SO}_4(\text{aq})$
$\text{MnO}_4^- + 8\text{H}^+ + 5\text{e}^- \rightleftharpoons \text{Mn}^{2+} + 4\text{H}_2\text{O}$	+1.51

[3]

(ii) A student devises an experiment to find out how much cerium is present in an impure sample of ceria, CeO_2 .

First the student converts 2.5 g of powdered ceria into 100 cm^3 of a solution of $\text{Ce}(\text{SO}_4)_2$ in sulfuric acid. Then 25.0 cm^3 of this $\text{Ce}(\text{SO}_4)_2$ solution is titrated with a standard solution of arsenic(III) in sulfuric acid. In the reaction Ce^{4+} is reduced to Ce^{3+} .

1.00 dm^3 of solution is made up by dissolving 0.250 mol of As_2O_3 in sulfuric acid. The arsenic is present in the solution as AsO_3^{3-} ions. 25.0 cm^3 samples of the $\text{Ce}(\text{SO}_4)_2$ solution required an average titre of 3.00 cm^3 of this AsO_3^{3-} solution.

The half-equation for the oxidation of AsO_3^{3-} ions is given below.



Calculate the percentage purity of the student's ceria sample.

Show **all** your working.

Give your answer to an **appropriate** number of significant figures.

percentage purity = _____ % [5]

- (iii) Suggest one improvement to the student's method that will reduce the percentage error in the answer to (ii) without changing the apparatus.

Give a reason for your choice.

----- [1]

- (iv) Calculate the number of oxygen atoms in 2.5 g of **pure** ceria, CeO_2

Show **all** your working.

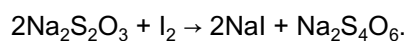
number of atoms = _____ [2]

- (v) Ceria is also used as a heterogeneous oxidation catalyst for self-cleaning ovens. Ceria is incorporated on the surface of the inside panels of an oven.

Describe how a heterogeneous catalyst works.

----- [4]

- 13 Sodium thiosulfate reacts with iodine as shown in the equation below.



What volume of $0.0300 \text{ mol dm}^{-3}$ sodium thiosulfate is needed to react with 25.0 cm^3 of $0.0500 \text{ mol dm}^{-3} \text{ I}_2$?

- A 20.8 cm^3
B 30.0 cm^3
C 41.7 cm^3
D 83.3 cm^3

Your answer

[1]

- 14 Many compounds extracted from coal tar were used as raw materials for the chemical industry in the late 19th century.

One of these compounds was phenol which can be converted to 2-hydroxybenzoic acid.

Some students make a sample of aspirin which is contaminated with 2-hydroxybenzoic acid.

The students obtained 29.5 g aspirin (M_r 180) and the yield was 69.5%.

What mass of 2-hydroxybenzoic acid was used in the reaction?

mass of 2-hydroxybenzoic acid = _____ g [2]

15(a) Concrete contains calcium hydroxide, $\text{Ca}(\text{OH})_2$, and is alkaline when damp. The steel reinforcements in concrete do **not** corrode in an alkaline environment. When the calcium hydroxide reacts with carbon dioxide from the air to form calcium carbonate, 'carbonatation' occurs and the pH falls. The increased acidity can cause the steel to corrode.

(i) Write the equation for carbonatation.

[1]

(ii) Calculate the mass of calcium carbonate that is formed when 15 cm^3 of carbon dioxide (measured at room temperature and pressure) react with excess calcium hydroxide.

Give your answer to an **appropriate** number of significant figures.

mass = _____ g [2]

(b) Carbonatation produces calcium carbonate. The carbonate ion is alkaline in aqueous solution.

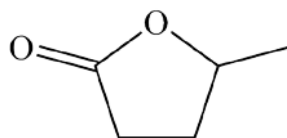
(i) Write an equation for the reaction that occurs between the carbonate ion and water.

[1]

(ii) Explain how the carbonatation reaction in (a)(i) accounts for the fall in pH.

[2]

16(a) The compound 'GMV' is a potential 'green fuel' as it can be made from glucose and can be blended with petrol.



GMV

- (i) Write an equation, using molecular formulae, for the complete combustion of GMV to carbon dioxide and water.

[2]

- (ii) Calculate the ratio of the masses of carbon dioxide produced by burning equal masses of GMV and hexane.

Show **all** your working.

ratio = _____ [3]

- (iii) A scientist says that the result in (ii) is an indication of the relative effects on the environment when GMV and hexane are used as vehicle fuels.

Discuss this statement.

----- [2]

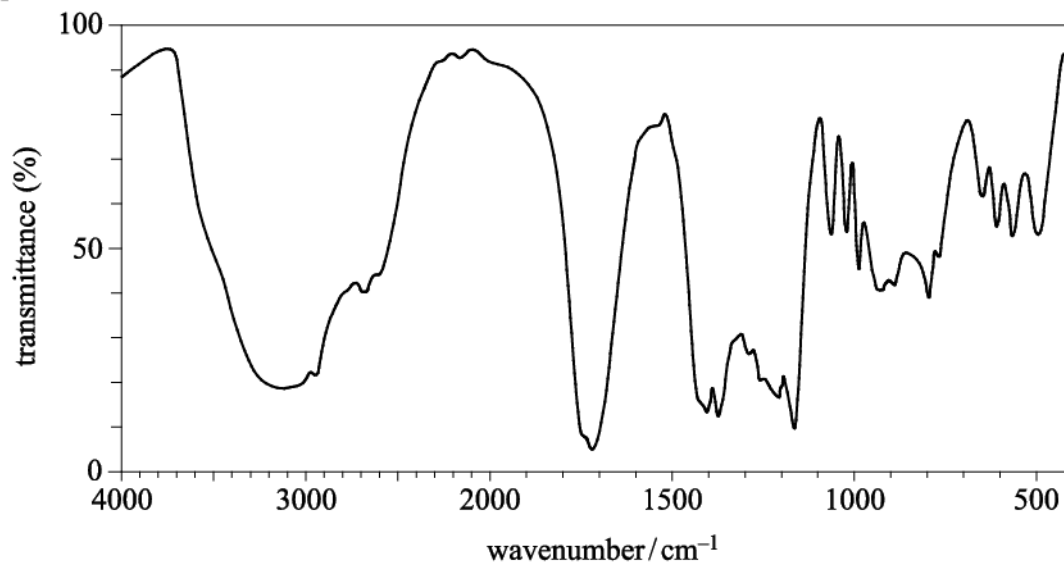
(b) * Compound G is an intermediate in the manufacture of GMV from glucose.

Compound G has the following composition by mass:

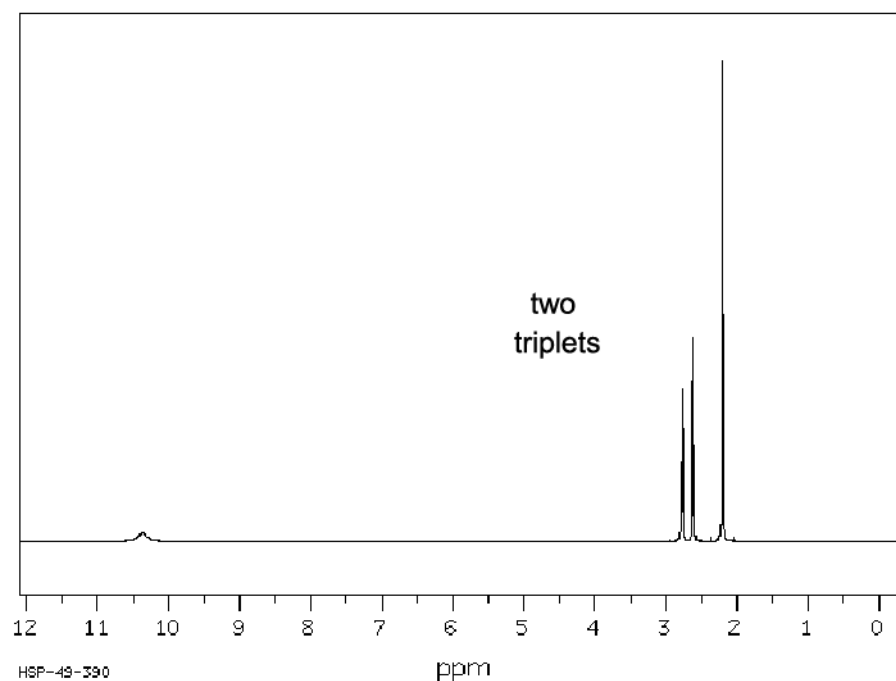
C, 51.72%; H, 6.90%; O, 41.38%

Compound G has IR and ^1H NMR spectra as shown below.

IR spectrum:



^1H NMR spectrum:



Use all this information to work out the structure of compound G.

In your answer give evidence to support your choice of structure.

[6]

[1]

[1]

- (i) Draw, in the space below, the **skeletal formula** of the structure you would expect to obtain when ambrinol (Fig. 2) reacts with bromine.

[1]

- (ii) How many peaks would you expect in the ^{13}C NMR spectrum of ambrinol?

[1]

- (iii) Give the number of chiral centres in ambrinol.

Explain how you arrived at your answer.

[2]

- (iv) Discuss whether or not you would expect the enantiomers of ambrinol to smell the same.

[2]

- (b) Describe chemical tests, resulting in colour changes, by which you could distinguish between vanillin, guaiacol and benzaldehyde (Fig. 3).

Include a positive reaction for each substance.

[4]

- (c) Explain the significance of the graph (shown in Fig. 3) to Turin's theory.

Give the cause of the peak just above 3000 cm^{-1} .

[3]

- (d) This part of the question explores Turin's use of isotopes to support his theory.

- (i) State the meaning of the term *isotopes*, using the terms *atomic number* and *mass number*.

Give the number of neutrons in an atom of deuterium and an atom of ^{13}C .

meaning: -----

number of neutrons: -----

[2]

- (ii) A sample of carbon dioxide contains 98.89% ^{12}C , the rest being ^{13}C .

Calculate the A_r value for the carbon in the carbon dioxide to **two** decimal places.

$A_r =$ _____ [1]

(iii) Draw the **skeletal formula** of 'acetophenone'.

State the difference between this molecule and 'acetophenone-d₈' (**page 5**).

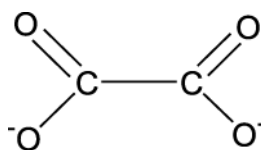
----- [2]

(iv) * Discuss examples from the article that support Turin's theory and **not** the 'lock and key' theory.

----- [6]

- 19 *Bar Keeper's Friend* is a powdered cleaning agent invented over 100 years ago and still in use today. It is particularly effective at removing rust stains.

The active ingredients are the ethanedioate ion, shown below, and ethanedioic acid.



Ethanedioate ion

A student decides to investigate how *Bar Keeper's Friend* removes rust stains. The student finds that the ethanedioate ions act as bidentate ligands which form complexes with Fe^{3+} ions.

The student also investigates whether ethanedioic acid $(\text{COOH})_2$ undergoes a redox reaction with Fe^{3+} ions.

Half-reaction	$E^\ominus/V$
$2\text{CO}_2 + 2\text{H}^+ + 2\text{e}^- \rightleftharpoons (\text{COOH})_2$	-0.43
$\text{Fe}^{3+} + \text{e}^- \rightleftharpoons \text{Fe}^{2+}$	+0.77

- (i) Use data from the table to explain why $(\text{COOH})_2$ and Fe^{3+} ions react.

----- [2]

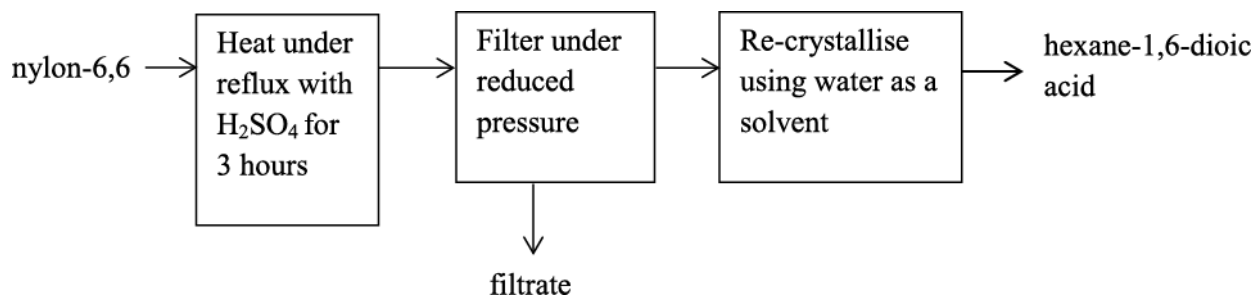
- (ii) Write an ionic equation for the reaction between $(\text{COOH})_2$ and Fe^{3+} in solution.

[2]

- (iii) Draw arrows in the appropriate boxes to show the outer electron configurations for Fe^{2+} and Fe^{3+} .

	3d	4s
Fe^{2+}		
Fe^{3+}		

20(a) Scientists are investigating how best to recycle polymers including nylon-6,6. One approach is to break the polymer down into its monomers which can be re-used. The following flow chart shows how hexane-1, 6-dioic acid can be produced from nylon-6, 6.



(i) What is meant by *heating under reflux*?

----- [2]

(ii) Draw a labelled diagram to show how crystals of hexane-1, 6-dioic acid can be collected by filtration under reduced pressure.

[3]

(iii) Describe the main steps involved in carrying out the recrystallization of hexane-1, 6-dioic acid using water as a solvent.

In your account, describe what property of hexane-1, 6-dioic acid this process depends upon.

[4]

(iv) 0.40 g of pure hexane-1, 6-dioic acid ($M_r = 146$) are obtained from 2.0 g of nylon-6, 6.

Calculate the percentage yield of the reaction.

yield = _____ % [2]

(b) The student adds excess sodium hydroxide solution to the filtrate. The student notices that the mixture develops a 'fishy' smell characteristic of an amine.

Suggest the shortened structural formula of the compound responsible for the 'fishy' smell.

[1]

21(a) This question refers to the Fig. 1 that is provided as an insert to this paper.

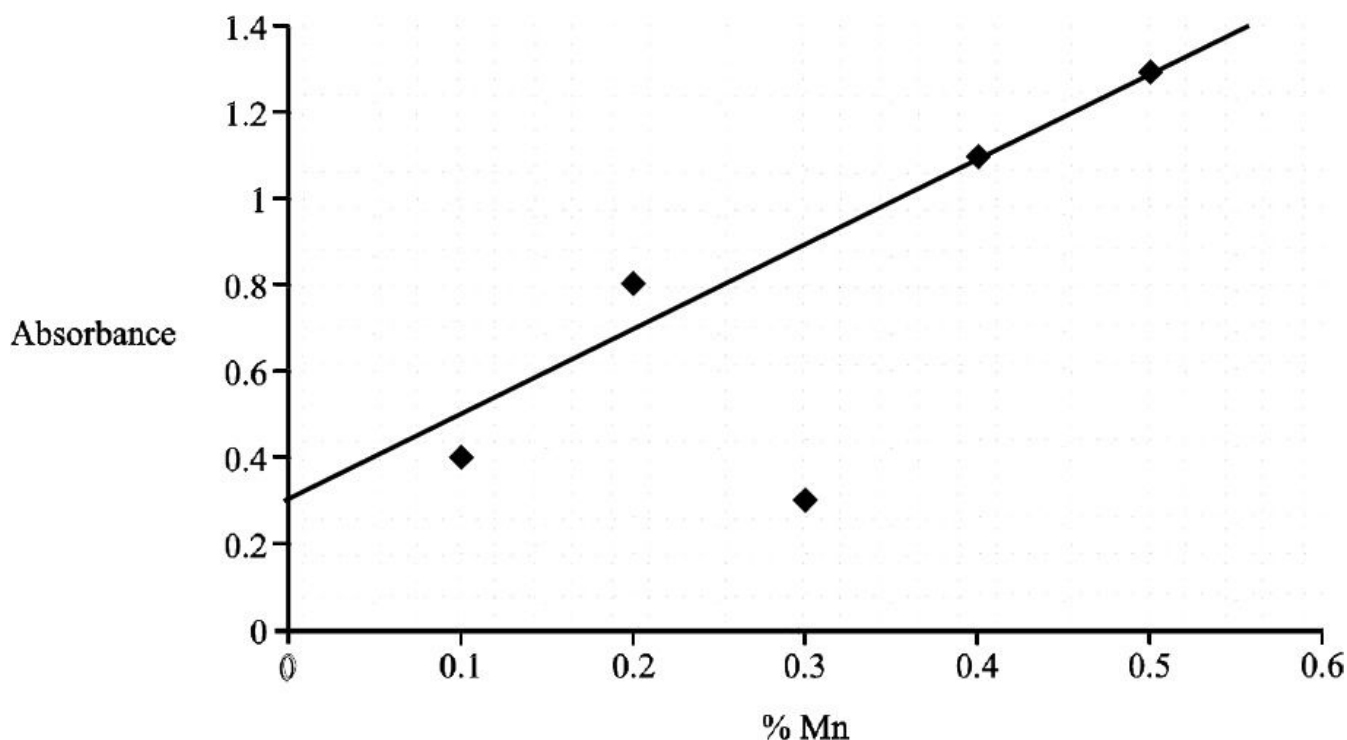


Fig. 1 % Mn against absorbance

- (i) Name a suitable piece of apparatus (with its size) that could be used to measure 25 cm³ of dilute sulfuric acid into the conical flask in **Part 1**.

----- [1]

- (ii) Suggest **two** reasons why the conical flask in **Part 1** was fitted with a bung carrying a capillary tube, apart from loss of spray.

----- [2]

- (iii) Use the student's results in **Part 1** to calculate the percentage of iron in the paper clip.

Show **all** your working.

percentage of iron = _____ % [4]

(b)

- (i) In **Part 2**, the student was given a solution labelled '2% Mn'.

Calculate the concentration (in g dm^{-3}) of a solution of potassium manganate(VII) that contains the same concentration of Mn as would be in 100 cm^3 of a solution made from 0.25 g of paper clips if they contained '2% Mn' by mass.

Show **all** your working.

concentration = _____ g dm^{-3} [3]

- (ii) Explain why a '2% Mn' solution made by dissolving potassium manganate(VII) crystals would be more accurate than a '0.5% Mn' solution made using the same method.

----- [1]

- (iii) * Describe how the student could use the '2% Mn' solution and a colorimeter to produce a calibration curve suitable for finding the concentration of manganese in the paper clip solution.

[6]

- (iv) How could the student have improved the line drawn on the calibration graph in **Part 2** without doing further experiments?

[1]

- (v) Use the line drawn by the student on the calibration graph to read off a value for the % Mn in the paper clip solution.

[1]

(c)

- (i) In which titration could some of the paper clip solution have been spilled from the pipette onto the bench while it was being transferred to the conical flask?

Explain your answer.

[2]

- (ii) The student suggests that the concentration of the MnO_4^- ions in the solution made from the paper clips could be determined by titrating it against a standard solution of Fe^{2+} ions.

Why would this method **not** give an accurate result?

[1]

- (d) Suggest another method, other than using a titration or a colorimeter, that the student could use to find the concentration of Fe^{2+} ions in a solution made from paper clips.

-----[1]

22(a) Water purity is an important environmental concern.

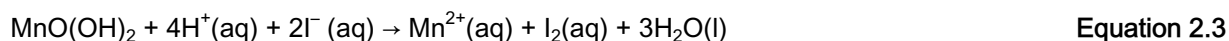
In general, high concentrations of dissolved oxygen indicate a low level of water pollution.

The 'Winkler' method, based on redox reactions, can be used to calculate the amount of dissolved oxygen in water.

An environmental laboratory uses the 'Winkler' method to measure the amount of dissolved oxygen in a sample of treated water.

Manganese(II) sulfate, potassium iodide and acid can be added to the water sample and the liberated iodine is titrated with thiosulfate.

The key reactions (labelled **Equations 2.1 to 2.4**) in the Winkler method are shown below:



.....



(i) **Equation 2.1** does **not** represent a redox reaction.

Name the **type** of reaction represented by **Equation 2.1**.

-----[1]

(ii) Write the oxidation states of Mn and I on the dotted answer lines below **Equation 2.3**.

[2]

(b) A 50 cm^3 sample of water at 293 K was tested.

It was found that 10.50 cm^3 of a $2.5 \times 10^{-3} \text{ mol dm}^{-3}$ solution of thiosulfate was required to react with the iodine produced in **Equation 2.3**.

(i) State the indicator you would use, and the colour change you would see in this titration.

----- [2]

(ii) Determine the concentration of dissolved oxygen in the water sample.

Give your answer to an **appropriate** number of significant figures.

concentration = _____ mol dm^{-3} [4]

(iii) The concentration of dissolved oxygen in water is more commonly expressed in parts per million, ppm, by mass.

The maximum solubility of oxygen in water at 293 K is $2.8 \times 10^{-4} \text{ mol dm}^{-3}$.

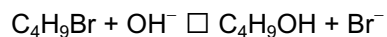
Calculate this concentration in ppm.

You may assume the density of water is 1.0 g cm^{-3} .

concentration = _____ ppm [2]

23(a) A group of students set out to investigate the rate of hydrolysis of 1-bromobutane.
The reaction is relatively slow with water but much quicker with hydroxide ions (OH^-).

1-bromobutane reacts with sodium hydroxide solution as follows:



(i) Name the mechanism of this reaction.

-----[2]

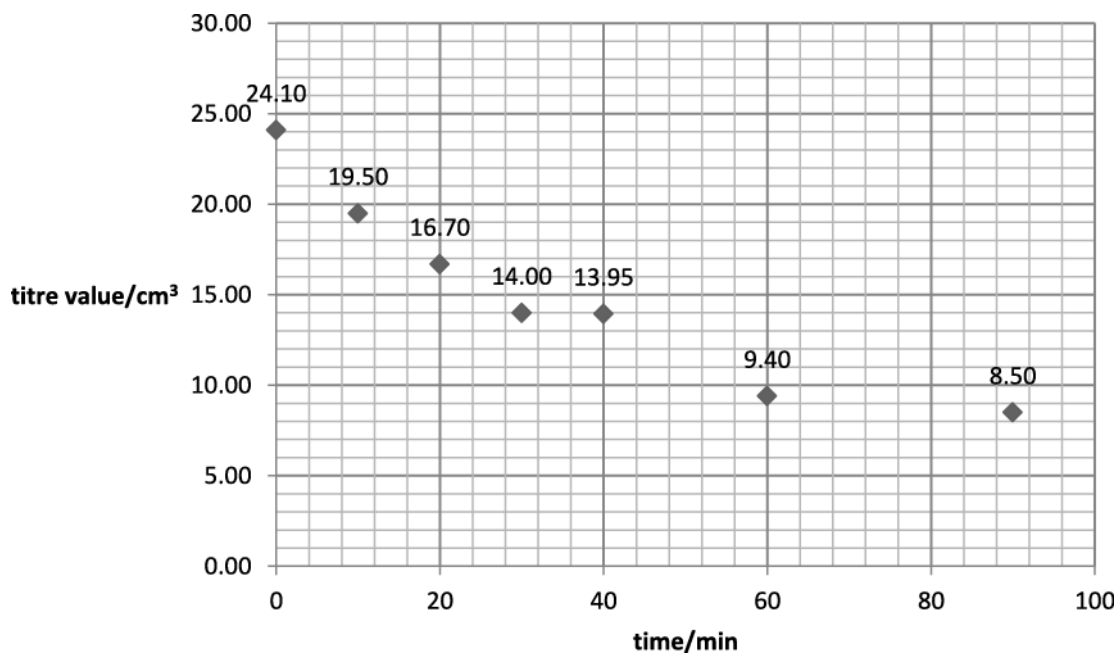
(ii) Name the **type** of bond fission occurring in this reaction.

-----[1]

(b) Equimolar quantities of 1-bromobutane and sodium hydroxide are mixed at 40°C.

The concentration of hydroxide ions is determined at various times by removing 10.0 cm³ of the mixture, adding it to 20 cm³ of iced water in a conical flask, and titrating with a 0.125 mol dm⁻³ solution of hydrochloric acid.

The group's results are plotted below.



(i) Suggest why the reactant mixture was added to a larger volume of iced water.

-----[1]

(ii) Use the information given and the data on the graph to calculate the initial concentration of the sodium hydroxide solution.

initial concentration = _____ mol dm⁻³ [2]

(iii) Further investigations by the group suggested that the reaction was second order **overall**.

Write **two** rate equations which would be consistent with this suggestion.

rate = _____

rate = _____

[1]

- (iv) Use the graph to calculate the initial rate of reaction, in $\text{mol dm}^{-3} \text{ min}^{-1}$.

Show on the graph how you calculated the initial rate.

rate = _____ $\text{mol dm}^{-3} \text{ min}^{-1}$ [3]

- (v) Use the initial rate, along with your answer to (ii) above, to calculate the value of the rate constant, k , including the units, for this reaction at 40°C .

rate constant, k = _____ units _____ [2]

- Describe and explain how they can use aqueous silver nitrate in their investigation, and what conclusions they should be able to make.

[6]

24(a) One way of measuring the amount of an alkene in a sample is by titrating it with standard bromine solution. This method enables a value for the bromine number of the sample to be calculated.

The bromine number is the mass (in g) of bromine, Br₂, absorbed by 100 g of a sample.

Calculate the bromine number of a pure sample of hexa-2,4-diene (C₆H₁₀).

Give your answer to the nearest whole number.

bromine number = _____ [2]

(b) A student decides to determine the bromine number of a solution of hexa-2,4-diene in cyclohexane.

The student makes a bromine solution as follows. 100 cm³ of an acidified solution of 0.167 mol dm⁻³ KBr is reacted with 100 cm³ of 0.0500 mol dm⁻³ KBrO₃. The total volume is 200 cm³.

The equation for the reaction is given below.



(i) Show that the KBrO₃ is in excess.

- (ii) 10.0 g of the hexa-2,4-diene solution required 82.0 cm³ of the bromine solution to produce the first permanent yellow tinge to the mixture.

Calculate the bromine number of the hexa-2,4-diene solution.

Give your answer to the nearest whole number.

bromine number = _____ [5]

(c) Hexa-2,4-diene, $\text{CH}_3\text{CH}=\text{CHCH}=\text{CHCH}_3$, can form several *E* / *Z* isomers.

(i) Give **two** reasons why *E*/*Z* isomers exist.

[2]

(ii) Draw structural diagrams to represent all the *E* / *Z* isomers.

Label the appropriate parts of each formula with **E** or **Z**.

[4]

(d) To ensure that the alkene is fully brominated in the reaction, a mercury catalyst is sometimes used.

Explain how transition metals can act as heterogeneous catalysts.

[3]

25(a) Calcium chloride, CaCl_2 , is used with sodium chloride to melt ice.

The lowering of the freezing point of water is proportional to the number of moles of **particles** dissolved.

A 1.0 mol dm^{-3} solution of NaCl freezes at -3.7°C .

Calculate the freezing point of a solution of CaCl_2 that contains the same **mass** of solute per dm^3 as the NaCl solution.

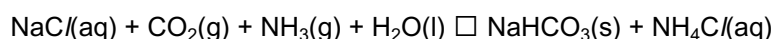
freezing point = _____ $^\circ\text{C}$ [3]

- (b) Calcium chloride is made by the Solvay process. This also produces another useful substance, sodium carbonate.

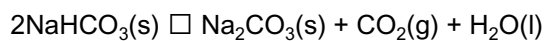
The Solvay process consists of the following reactions:



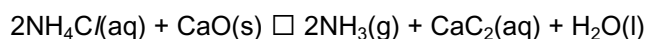
Equation 2.1



Equation 2.2



Equation 2.3



Equation 2.4

- (i) Write an equation in the box for the overall reaction that occurs to form just two products.

[2]

- (ii) State the atom economy of the Solvay process and explain why this is important for the environment.

----- [1]

- (c) Give the systematic names of NaHCO_3 and NH_4Cl .

NaHCO_3 -----

NH_4Cl ----- [2]

(d) The reaction in **Equation 2.1** has a positive ΔS_{sys} .

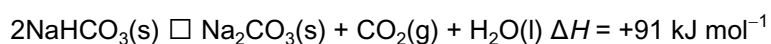


Equation 2.1

Explain the term *entropy* and give **one** reason why ΔS_{sys} is positive for this reaction.

[2]

(e) The standard entropies for the compounds in **Equation 2.3** are given below.



Equation 2.3

Compound	$S^\ominus / \text{J K}^{-1} \text{ mol}^{-1}$
$\text{NaHCO}_3(\text{s})$	+102
$\text{Na}_2\text{CO}_3(\text{s})$	+135
$\text{CO}_2(\text{g})$	+214
$\text{H}_2\text{O}(\text{l})$	+70

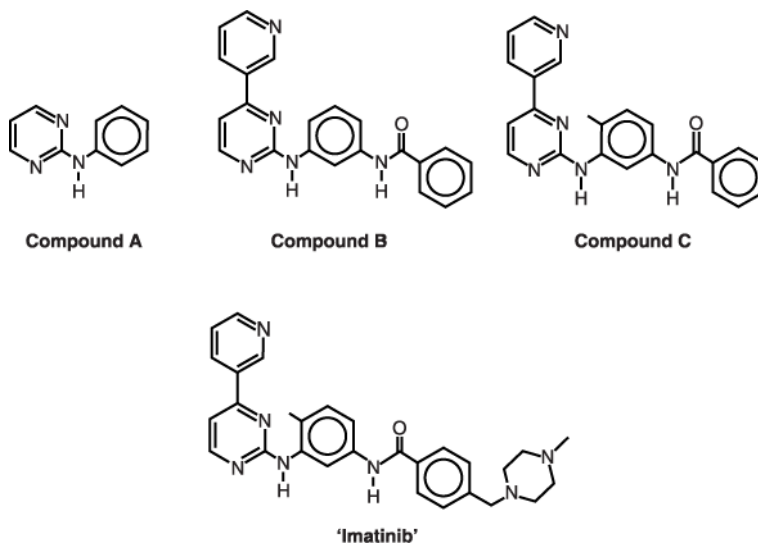
Calculate the minimum temperature for the reaction in **Equation 2.3** to occur.

Show all your working.

minimum temperature = _____ K **[3]**

26(a) 'Imatinib' is a drug that was designed to combat leukaemia, a cancer of the blood. 'Imatinib' was developed as a result of work on three different compounds (A, B and C).

Compound A was found to have anti-leukaemia effects. Compound B was then found to be more effective and compound C more specific. 'Imatinib' was developed from compound C.



An extra group is added to compound C to make 'Imatinib' more soluble in water.

Suggest how the extra group does this.

-----[1]

(b) 'Imatinib' works by interfering with the function of an enzyme that only exists in cells affected by leukaemia. Thus the cells are unable to grow.

(i) All the compounds above have the same pharmacophore.

Draw a ring around the pharmacophore on the structure of 'Imatinib' above.

[1]

(ii) Suggest how this pharmacophore interferes with the function of the enzyme.

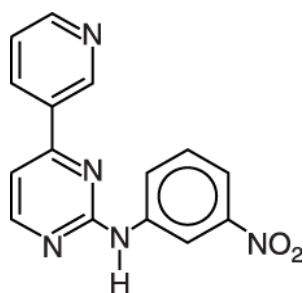
Suggest why compound C is more specific than compound B.



In your answer you should use appropriate technical terms, spelled correctly.

[4]

- (c) Compound **A** can be converted into another compound, **D**, shown below. This uses two reactions, one of which is nitration.



Compound D

- (i) Give the reagents and conditions for the laboratory conversion of benzene to nitrobenzene.

----- [2]

- (ii) Use the *Data Sheet* to **name** the reagents needed to convert the nitro group in compound **D** to an amine group. A new compound, **E**, is formed.

----- [1]

- (iii) Compound **E** is converted to compound **B** in a laboratory at room temperature.

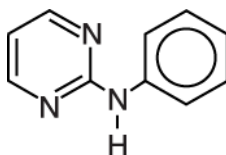
Name the functional group formed, and give the formula and name of a suitable reagent.

name of functional group formed -----

formula of reagent -----

name of reagent ----- [3]

(d) The structure of compound A is shown again below.

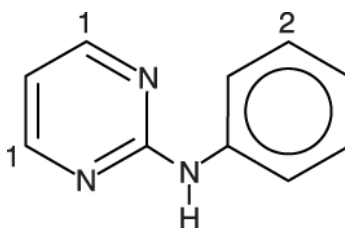


Compound A

(i) Write the molecular formula of compound A.

-----[1]

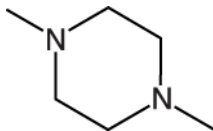
(ii) Indicate the number of peaks in the proton NMR of compound A by using numbers for each different proton environment on the structure below. Some numbers have been added already.



Compound A

[2]

(e)



The ring structure is not planar.

State a value for the bond angle and name the shape around the nitrogen atoms in the structure. Explain how this bond angle arises.

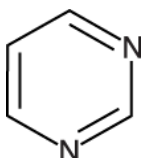
Draw a diagram to suggest a 3D shape for the ring.



In your answer you should make it clear how the points you make are linked together.

[5]

(f)



The ring structure is planar and has a similar electronic structure to benzene.

Suggest how the electrons are arranged in this structure.

[3]

27(a) Some students set out to make a sample of dry crystals of the soluble salt strontium chloride. They react excess strontium carbonate with hydrochloric acid.

They place the acid in a beaker and add spatula measures of strontium carbonate to the acid while stirring.

Describe the rest of their procedure.

[4]

(b)

- (i) Write an equation for the reaction that occurs in the previous question to form SrCl_2 .
Show state symbols.

[2]

- (ii) Calculate the mass of strontium carbonate that will react with 50 cm^3 of 2.0 mol dm^{-3} hydrochloric acid.

mass = _____ g [2]

(c) The strontium chloride formed is a hydrated salt with formula $\text{SrCl}_2 \cdot x\text{H}_2\text{O}$.

The students take 2.00 g of the dry salt, dissolve it in water and add an excess of silver nitrate solution so the total volume is 200 cm^3 . They filter off the precipitate of silver chloride, wash it and heat it to constant mass to remove all the water.

(i) Suggest how the students would 'heat the silver chloride to constant mass'.

----- [2]

(ii) 2.16 g of silver chloride, AgCl , is formed.

Calculate the value of x in $\text{SrCl}_2 \cdot x\text{H}_2\text{O}$.

$x =$ ----- [4]

(iii) A student says that the mass of silver chloride formed is not accurate because silver chloride is slightly soluble in water.

The solubility product of AgCl is $2.0 \times 10^{-10} \text{ mol}^2 \text{ dm}^{-6}$.

Use calculations to comment on the student's statement.

----- [2]

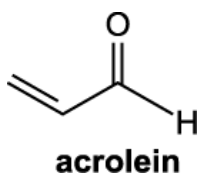
(iv) Another hydrated strontium chloride has formula $\text{SrCl}_2 \cdot 2\text{H}_2\text{O}$.

Calculate the percentage loss in mass when all the water is driven off by heating.

loss in mass = ----- % [1]

28(a) The smell of burning fat is caused mainly by the presence of 'acrolein'. This is formed by the decomposition of propane-1,2,3-triol from the fat.

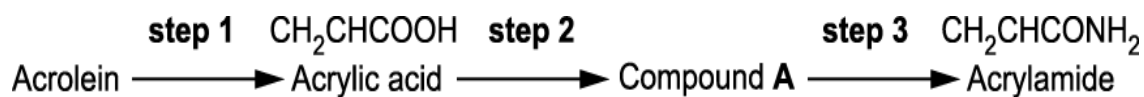
Acrolein is a colourless liquid that has many uses in organic chemistry.



Write in the box an equation for the decomposition of propane-1,2,3-triol to acrolein. Use **molecular** formulae.

[2]

(b) Acrolein can be converted to 'acrylamide' in a laboratory, using the pathway below.



(i) Draw the **full** structural formula of compound A, which is an acyl chloride.

[1]

(ii) Give suitable reagents for steps 2 and 3.
(You may need to refer to the *Data Sheet*)

step 2: _____

step 3: _____

[2]

(iii) A student obtains 0.55 g of acrylamide from acrolein (M_r 56.0) using this pathway and calculates that this is a 3.0% yield.

Calculate the mass of acrolein that the student started with.

Give your answer to an **appropriate** number of significant figures.

mass = _____ g [2]

The main effect of adding sodium chloride is to lower the freezing point of the water.

- (i) The lowering of the freezing point of a liquid depends on the amount, in mol, of **particles** of solute dissolved in a certain volume.

1.00 mol of particles dissolved in 100 cm^3 of water lowers the freezing point by 18.6 K.

Calculate the freezing point of a 1.00 mol dm^{-3} solution of NaCl.

freezing point = _____ °C [2]

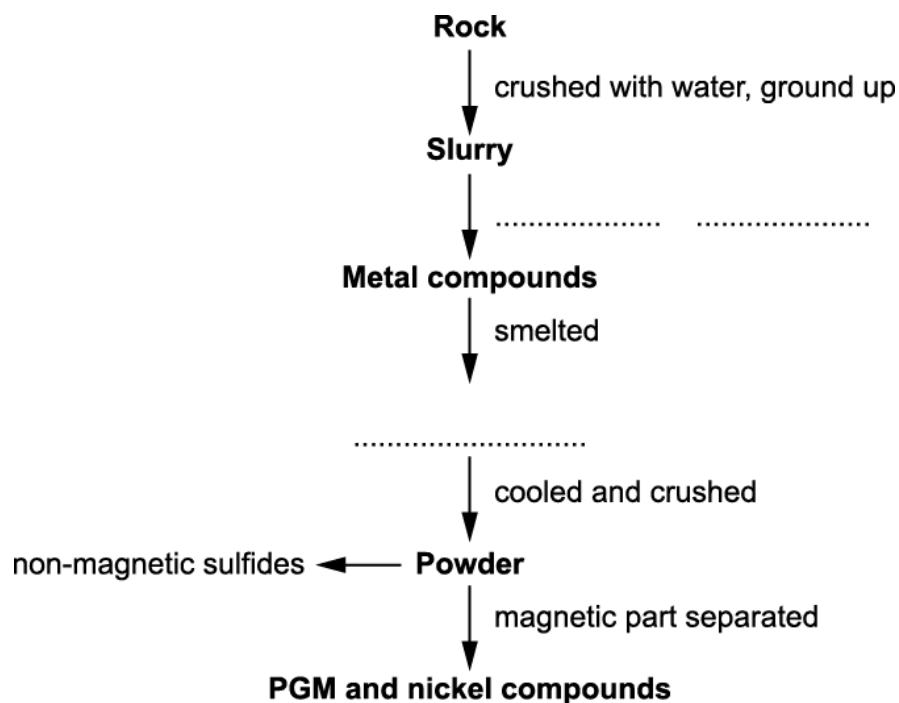
- (ii) The freezing point depression of a 0.50 mol dm^{-3} solution of CaCl_2 is $-2.8\text{ }^\circ\text{C}$.

Some students try to verify this. They use a balance reading to the nearest gram and make up the solution in a 1.0 dm^3 measuring cylinder, graduated in 20 cm^3 units. They measure the temperature using a thermometer marked in $^\circ\text{C}$.

Which piece of apparatus gives the greatest uncertainty in the overall measurement? Show your calculations and give your reasoning.

----- [3]

- (i) Write words on the dotted lines to complete the flowchart below to summarise the extraction of PGM from rocks.



[1]

- (ii) Suggest an equation for the reaction of one of the 'non-magnetic sulfides' with sulfuric acid to form a sulfate.

[1]

- (iii) How is the metal obtained from the solution of its sulfate?

[1]

(b)

- (i) Suggest **two** reasons why PGM are used in catalytic converters rather than other equally effective catalysts.

----- [1]

- (ii) Write the equation for a reaction in which both CO and NO are removed from exhaust gases in a catalytic converter.

[1]

- (c) Complete the electron configuration of Rh^{3+} , by comparison with Co^{3+} .

[Kr] ----- [1]

(d)

- (i) $[\text{Ru}_2\text{OCl}_{10}]^{4-}$ has an oxygen atom connecting two Ru atoms.

Draw a three-dimensional diagram to suggest the shape of this ion. Give the co-ordination number of Ru in your structure.

co-ordination number ----- [2]

- (ii) Suggest a **name** for the shape of $[\text{AuCl}_4]^-$.

----- [1]

- (e) Give the formula of a 'bulky organic monocation' from the article and explain why three such species are needed by $[\text{MC}_6]^{3-}$.

----- [2]

(f) Estimate how much faster $[\text{Ag}(\text{H}_2\text{O})_2]^+$ exchanges chloride ions compared with $[\text{Ru}(\text{H}_2\text{O})_6]^{3+}$.

----- [1]

(g) Give the equation for a ligand exchange reaction of copper involving ammonia. Give the starting and finishing colours involved.

[2]

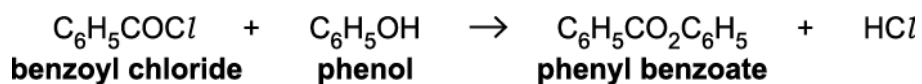
(h) A student says that silver(I) salts are colourless because the d subshells are not split by the ligands.

Discuss this statement. (Ag has the same outer electron configuration as Cu.)

----- [3]

- [6]

31 Two students aim to prepare a sample of phenyl benzoate using the reaction below.



The students weigh out the phenol in a weighing bottle and shake it with excess alkaline benzoyl chloride.

They collect and purify their product and weigh it in a sample bottle.

The students' results are given below.

Mass of weighing bottle + phenol / g	27.70
Mass of weighing bottle after emptying / g	22.68
Mass of sample bottle / g	6.16
Mass of sample bottle + purified phenyl benzoate / g	11.50
Melting point of phenyl benzoate / °C	67–69

(i) Calculate the percentage yield of the phenyl benzoate.

percentage yield = _____ % [3]

(ii) Suggest why the percentage yield is relatively low.

----- [1]

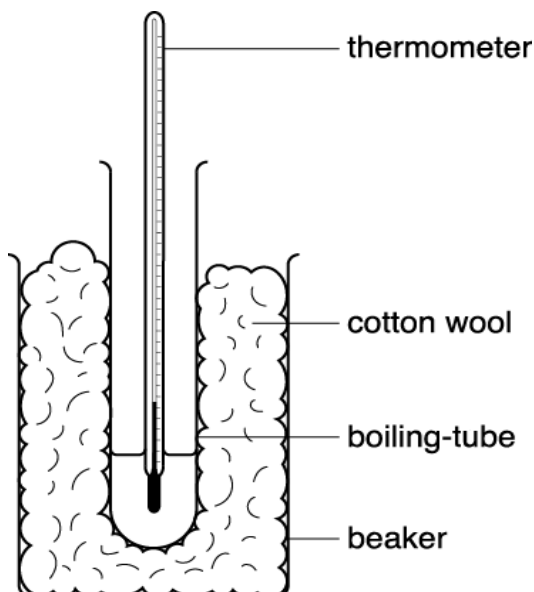
(iii) A textbook value for the melting point of phenyl benzoate is 69 °C.

Comment on the purity of the sample produced by the students.

----- [1]

32(a) A group of students set out to investigate the cooling effect caused by liquids evaporating.
 The faster a liquid evaporates the greater the cooling effect.
 They want to see if this is linked to the strength of the intermolecular bonding in the liquids.

The students go on to investigate whether mixing pairs of the liquids results in a temperature change.
 They used the following apparatus and the results for two pairs of the liquids are shown in **Table 3.2**.



Liquid A	Liquid B	Starting temperature, Liquid A / °C	Starting temperature, Liquid B / °C	Finishing temperature on mixing / °C	Temperature change, ΔT / °C
Ethanol	cyclohexane	23.0	23.0	19.5	3.5
pentane	2-methylbutane	23.0	23.0	23.0	0.0

Table 3.2

(i) Explain the purpose of the cotton wool.

 ----- [1]

(ii) When the pairs of liquid A and liquid B are mixed, there are three possible intermolecular bonds between the molecules in the mixture.

These are A-A, B-B and A-B intermolecular bonds.

Explain the temperature change in the ethanol/cyclohexane mixture shown in **Table 3.2**, in terms of the intermolecular bonds A-A, B-B, and A-B.

----- [2]

(iii) Using ideas of bond breaking and making, suggest why there is no temperature change in the pentane/2-methylbutane mixture.

----- [1]

- (b) A student reads that molecules of trichloromethane, CHCl_3 , and methyl ethanoate, $\text{CH}_3\text{COOCH}_3$, do not form hydrogen bonds with themselves, but when mixed, do so with each other. See Fig 3.1 below.

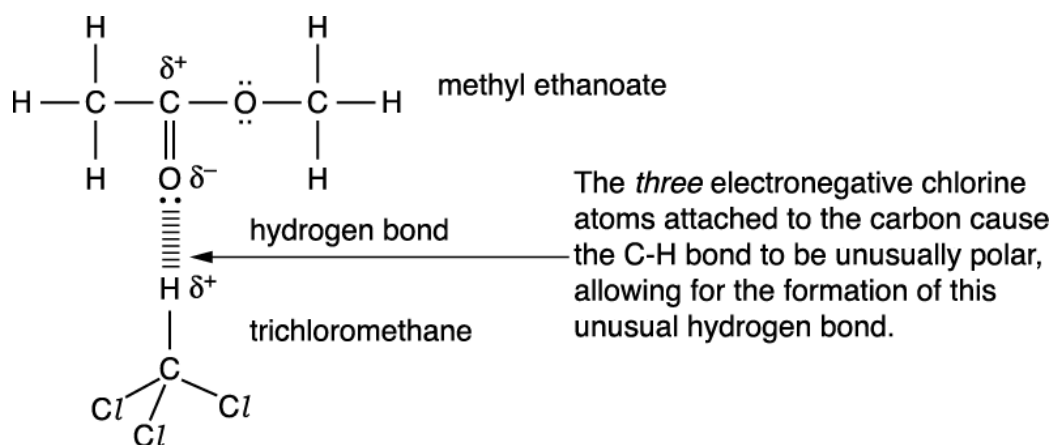


Fig. 3.1

The student tries to measure the strength of the hydrogen bond between molecules of the liquids. They are given the following data.

Liquid	Density / g cm^{-3}	Specific heat capacity / $\text{J g}^{-1} \text{K}^{-1}$
Trichloromethane	1.48	0.96
methyl ethanoate	0.93	2.10

Table 3.3

- (i) Using the same apparatus as in the previous question part, the student mixes equimolar quantities of the two liquids and measures the temperature change.

Calculate the volumes of the two liquids you need to mix in order to give a solution that contains 0.15 moles of each liquid.

Give your answer to an **appropriate** number of significant figures.

volume of trichloromethane = _____ cm^3

volume of methyl ethanoate = _____ cm^3

[3]

- (ii) Suggest a piece of apparatus that would be most suitable for measuring out your calculated volumes.

----- [1]

- (iii) The student measures a temperature rise of $11.0\text{ }^{\circ}\text{C}$ when the calculated volumes are mixed.

Calculate the heat energy transferred to each liquid and hence the strength, in kJ mol^{-1} , of the hydrogen bond between molecules of the liquids.

Liquid	Density / g cm^{-3}	Specific heat capacity / $\text{J g}^{-1} \text{K}^{-1}$
trichloromethane	1.48	0.96
methyl ethanoate	0.93	2.10

strength of hydrogen bond = _____ kJ mol^{-1} [3]

33(a) This question refers to the *Practical Insert* that is provided as an insert to this paper.

- (i) Suggest and explain a mistake in the student's procedure which may have led to the titre values in the first set of results showing an increase.

----- [2]

- (ii) Choose suitable values from the student's second set of titration results to calculate the concentration of the original sulfamic acid solution.

Give your answer to **two** significant figures.

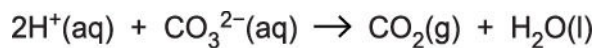
concentration = _____ mol dm⁻³ [4]

- (iii) The concentration of sulfamic acid solution given on the bottle of limescale remover is slightly lower than the student's value.

Suggest how the sodium hydroxide solution may have caused this difference.

----- [2]

(b) In **Part B** of the experiment, sulfamic acid reacts with excess carbonate as in the equation below.



(i) Use the data from the results section in **Part B** of the insert to calculate the M_r of the sulfamic acid.

You may assume that all the acid reacts and that the reaction takes place at room temperature and pressure.

$M_r =$ _____ [4]

(ii) The measuring cylinder used to collect the carbon dioxide has an uncertainty of $\pm 1 \text{ cm}^3$. Calculate the percentage uncertainty in the volume of CO_2 measured.

percentage uncertainty = _____ % [1]

(iii) Suggest one procedural error that could result in the student's value being higher than the accurate value of 97.1.

_____ [1]

34 25 cm^3 0.50 mol dm^{-3} HCl is reacted with excess magnesium.

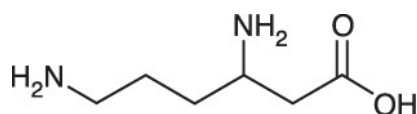
What mass of MgCl_2 is produced in solution?

- A 0.15 g
- B 0.60 g
- C 1.19 g
- D 2.38 g

Your answer

[1]

35 The amino acid beta-lysine has the structure shown.



25.0 cm^3 of a $0.0100 \text{ mol dm}^{-3}$ solution of beta-lysine is titrated separately with $0.0150 \text{ mol dm}^{-3}$ hydrochloric acid and $0.0200 \text{ mol dm}^{-3}$ sodium hydroxide.

Which row represents the correct volumes of solution that react with the lysine?

	Volume $0.0150 \text{ mol dm}^{-3} \text{ HCl/cm}^3$	Volume $0.0200 \text{ mol dm}^{-3} \text{ NaOH/cm}^3$
A	8.33	50.0
B	16.7	12.5
C	33.3	12.5
D	33.3	25.5

Your answer

[1]

36(a) Bromine is increasingly used as an alternative to chlorine to treat water, as it is less affected by sunlight. Both chlorine and bromine are extracted from seawater.

Bromine is obtained by the reaction between chlorine and bromide ions.

- (i) Give an ionic equation for the reaction and explain which is the oxidising agent in the reaction.

----- [2]

- (ii) In the Dead Sea the concentration of bromide ions is higher than in other seas. Much bromine extraction is carried out near the Dead Sea.

Some Dead Sea water has a chloride ion concentration of 20.8% (mass of solute per volume of solution). The bromide concentration is 500 mg per 100 cm³.

Calculate the ratio of the chloride ion concentration to the bromide ion concentration, both measured in mol dm⁻³.

ratio [Cl⁻]: [Br⁻] = ----- :1 [3]

- (iii) Many of the industries using bromine are sited near the Dead Sea to avoid transportation of the bromine.

Suggest **two** reasons why transportation of bromine is dangerous.

1

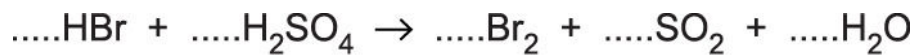
2

----- [1]

- (b) Students investigate the hydrogen halides, HCl , HBr , and HI . They warm NaCl , NaBr and NaI with concentrated sulfuric acid.

In the case of NaBr and NaI , the halogen is produced in addition to the hydrogen halide.

Use oxidation states (or some other method) to balance the following equations:



[2]

37(a) Esters have many uses in organic chemistry, including in polymers.

Some students want to determine the equilibrium constant for the esterification reaction in **equation 33.1** in acidic conditions.



They set up their experiment with known masses of ethanol, ethanoic acid and concentrated sulfuric acid catalyst.

They place the reactants in a stoppered bottle and wait a week for equilibrium to be established.

Suggest how the students could find the amount of ethanoic acid in the bottle at equilibrium.

----- [2]

- (b) By using the method from (a), the students find that the amount of ethanoic acid present at equilibrium is 0.123 mol.

They produce the table below.

Substance	Mass present at the start / g	Amount present at the start / mol	Amount present at equilibrium / mol
ethanol	15.8		
ethanoic acid	21.0		0.123
ethyl ethanoate	0	0	
water	0	0	

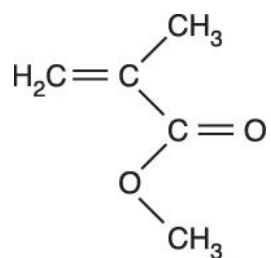
Carry out appropriate calculations to fill in the blanks in the table.

Use figures from the table to work out a value for the equilibrium constant, K_c , of the reaction in equation 33.1.

$K_c =$ _____ [4]

- (c) Another ester is the monomer for the polymer polymethyl methacrylate or PMMA. PMMA is often used to make lightweight transparent materials as a replacement for glass.

The monomer has the structure shown below.



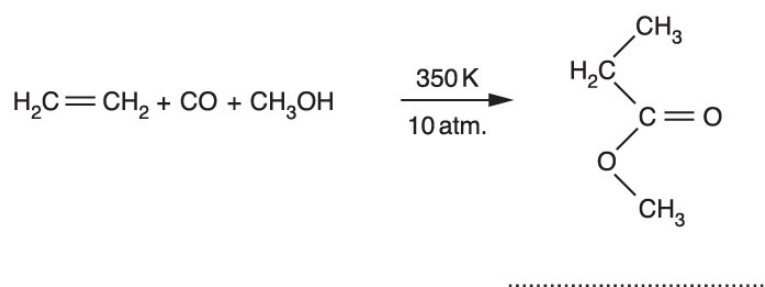
Draw the structural formula for **one** repeating unit of the polymer.

[1]

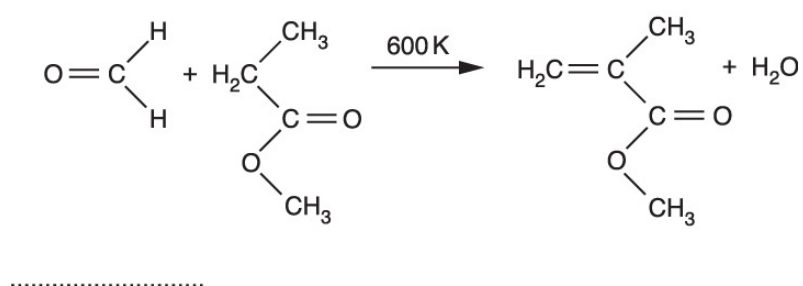
(d) The monomer can be made in the following reaction sequence.

Give the systematic names of two of the compounds on the dotted lines below their structures.

Stage 1:



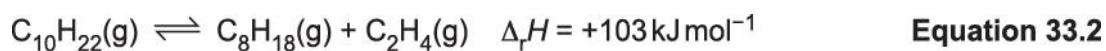
Stage 2:



[1]

- (e) The ethene used in **stage 1** comes from thermal cracking of long chain alkanes from crude oil in the presence of steam.

One such reaction is shown below.



Substance	Entropy / $\text{J mol}^{-1} \text{K}^{-1}$
$\text{C}_{10}\text{H}_{22}$	+425.9
C_8H_{18}	+361.1
C_2H_4	+219.5

Use the entropy values given to find the minimum temperature needed for the forward reaction to be feasible.
Give your answer to an **appropriate** number of significant figures.

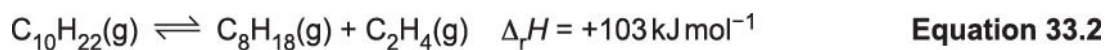
minimum temperature = _____ K [3]

- (f) Give the effects that the following changes have on the value of K_c for the reaction in **equation 33.2**.

Change	Increased temperature	Increased pressure	Use of a catalyst
Effect on K_c			

[2]

(g) The yield of the reaction in **equation 33.2** is typically 50%.



Calculate the volume (in dm^3) of ethene produced when 25.0 kg of decane are cracked at 900 K and a pressure of 150 kPa.

volume of ethene = _____ dm^3 [3]

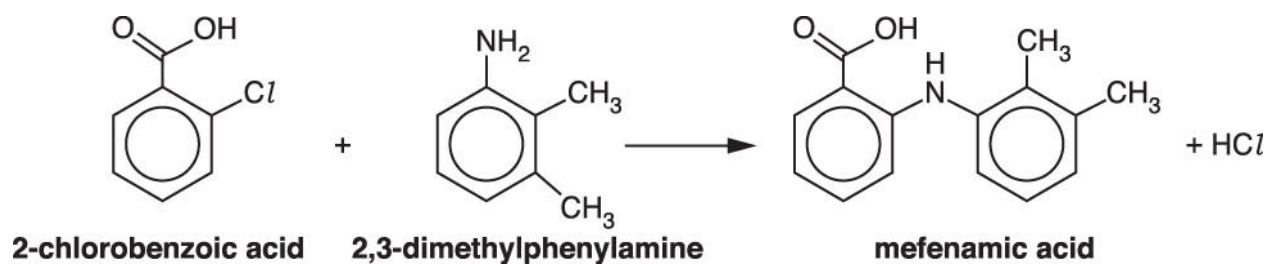
(h) An alternative method of obtaining ethene is catalytic cracking using zeolite catalysts.

Explain the advantage to the environment of this method over steam cracking.

----- [1]

38(a) Coal tar provides the raw materials for many painkilling drugs and dyestuffs. One such drug, 'mefenamic acid', is also being investigated as a possible treatment for Alzheimer's disease. Mefenamic acid is made from 2,3-dimethylphenylamine.

The reaction to form mefenamic acid is shown below.



The yield of the reaction is 52%.

Calculate the mass of 2-chlorobenzoic acid (in kg) needed to produce 15.0 kg of mefenamic acid.

mass = _____ kg [3]

- (b) *The structure of mefenamic acid can be investigated by a combination of spectroscopic techniques.

Describe and explain the appearance of the infrared spectrum and mass spectra, and how they could be used to identify mefenamic acid.

[6]

- 39 Students decide to investigate the solubility of calcium hydroxide by shaking solid calcium hydroxide with deionised water and filtering the mixture to remove undissolved solid. They then titrate the dissolved hydroxide ions with hydrochloric acid.

(i) They titrate 25.0 cm^3 of their saturated solution of calcium hydroxide with $0.0400 \text{ mol dm}^{-3} \text{ HCl}$.

Their results are shown below.

	Trial	Repeat 1	Repeat 2	Repeat 3	Repeat 4
Titre/ cm^3	15.00	13.80	13.90	14.00	14.60

Use their results to find the solubility product of calcium hydroxide.

solubility product of calcium hydroxide = _____

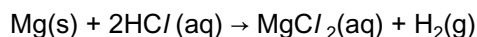
units _____ [4]

- (ii) Describe and explain what difference they would see in their titre if they repeated their titration with saturated magnesium hydroxide solution.

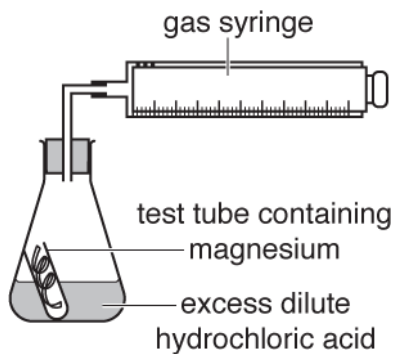
 _____ [1]

40(a) Two students decide to study the reaction of magnesium with dilute hydrochloric acid to find the order of this reaction with respect to the acid.

The equation for the reaction is:



The students use the following apparatus:



The students run **five** experiments each using a different concentration of hydrochloric acid.

They use the same length of magnesium ribbon each time.

(i) Why was the length of the magnesium ribbon kept the same?

----- [1]

(ii) 50 cm³ acid is used each time.

The concentration ranged from 0.1 to 0.5 mol dm⁻³.

Calculate the **maximum** mass of magnesium ribbon that would completely react with the acid in **all** five experiments.

mass = ----- g [3]

- (iii) Calculate the maximum length of magnesium ribbon needed to completely react with the acid in all the experiments.

The mass per unit length of Mg ribbon = $1.3 \times 10^{-2} \text{ g cm}^{-1}$

length = ----- cm [1]

- (b) The students predict that the reaction will be second order with respect to acid.

Write the rate equation that would be appropriate for this prediction.

----- [1]

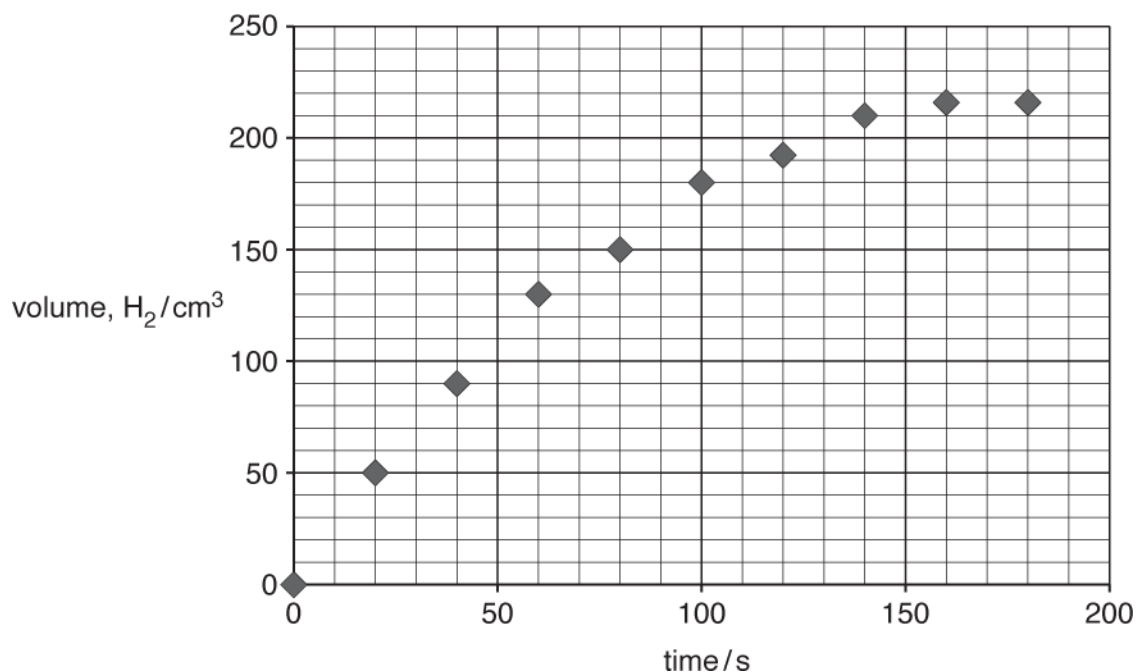
- (c) The students plot a graph of volume of hydrogen against time.

The graph of the results when the concentration of hydrochloric acid is 0.5 mol dm^{-3} is shown below.

Draw a line of best fit on the graph.

Use your line of best fit to calculate the initial rate of reaction at this concentration and give the units.

Show your working on the graph.



initial rate ----- units ----- [5]

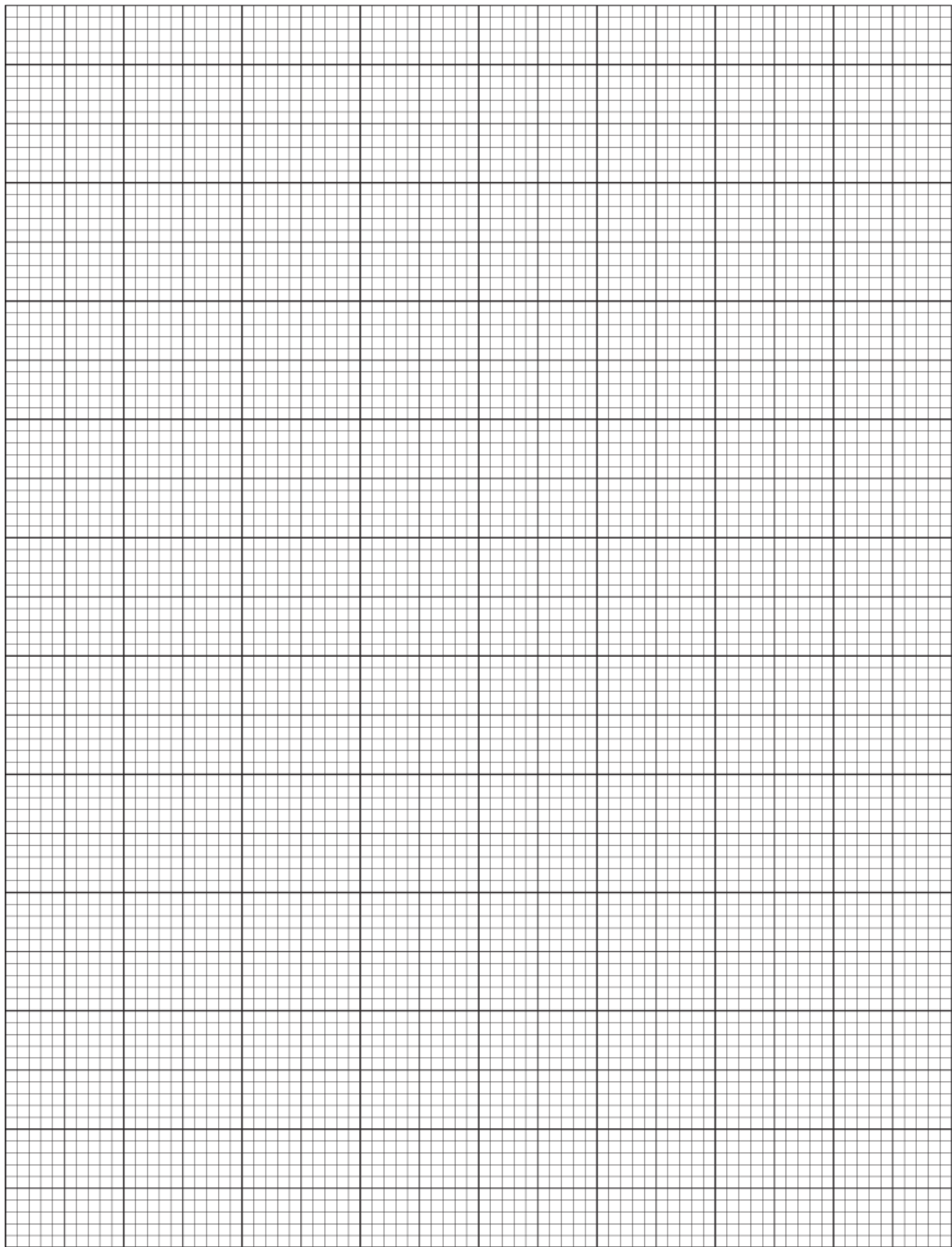
- (d) The students decide to measure the activation enthalpy for the reaction.

They repeat the experiment at different temperatures using a fixed concentration of acid.

The following table shows the data from their experiments.

$\ln k$	Temperature / °C	Temperature, T/K	$1/T / \text{K}^{-1} (\times 10^{-3})$
-5.46	15.6	288.6	3.47
-4.92	30.3	303.3	3.30
-4.34	45.0	318.0	3.14
-3.73	65.0	338.0	2.96

Use the data to plot a suitable graph on page 9 and work out the activation enthalpy for the reaction.



activation enthalpy = ... kJ mol⁻¹ [6]

41(a)

(See Insert for H433/02, June 2017)

- (i) Name the piece of apparatus which is most suitable for removing the 25.0 cm^3 of the Cu^{2+} ion solution.

----- [1]

- (ii) Use the student's results in the *Practical Insert* to work out an average titre that the student should use in calculating the amount of Cu^{2+} in the 'coin solution'.

average titre = ----- cm^3 [1]

- (iii) Use your answer from (a)(ii) to calculate the percentage by mass of copper in the coin.
Give your answer to an **appropriate** number of significant figures.

percentage by mass of copper in coin =----- % [4]

- (iv) The student considers the uncertainties of measurement in the experiment.

The percentage measurement uncertainty marked on the apparatus used to transfer the 25 cm^3 of the 'copper' solution is $\pm 0.24\%$.

The volumetric flask is marked $\pm 0.08\%$.

Calculate the measurement uncertainties of the other pieces of apparatus used.

Which piece of apparatus contributes most to the measurement uncertainty in this experiment?

[2]

- (v) Name another method that the student could use to find the concentration of Cu^{2+} ions in the 'coin solution'.

-----[1]

42 What is a possible mass number of a magnesium isotope?

- A 12
- B 23.99
- C 24
- D 24.3

Your answer

[1]

43 5.6 g of Fe ($A_r = 56$) and 4.0 g of S ($A_r = 32$) are heated in air until no further reaction occurs.

All the iron is converted to FeS and the rest of the sulfur forms SO₂.

What is the mass (in grams) of the sulfur dioxide formed?

- A 1.6
- B 4.0
- C 8.0
- D 10.4

Your answer

[1]

44 A student has 25 cm^3 of a $0.014 \text{ mol dm}^{-3}$ solution.

How much water should be added to make the solution $0.010 \text{ mol dm}^{-3}$?

A 10 cm^3

B 14 cm^3

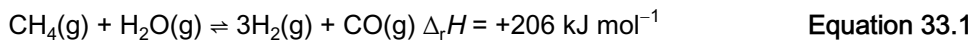
C 35 cm^3

D 49 cm^3

Your answer

[1]

45(a) An important source of hydrogen is from the steam reforming reaction shown below.



The steam reforming reaction shown in **equation 33.1** makes hydrogen. Much of the hydrogen is used in the manufacture of ammonia.

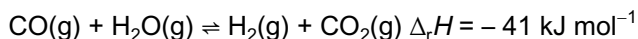
- (i) Calculate the atom economy of the reaction in **equation 33.1** when making hydrogen.

atom economy = ----- % [1]

- (ii) How is carbon monoxide described when it is formed alongside the required product (hydrogen)?

----- [1]

- (b) The carbon monoxide can be used in the exothermic water gas shift reaction.



The water gas shift reaction often takes place in the same industrial plant as steam reforming.

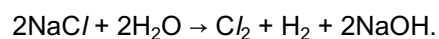
Suggest **two** advantages of the water gas shift reaction taking place with steam reforming.

1

2

----- [2]

46(a) Chlorine is manufactured by the electrolysis of sodium chloride solution. The equation is shown below.



A sodium chloride solution contains 24.0% of sodium chloride by mass.

1.0 tonne of this solution is electrolysed.

Calculate the mass of chlorine produced (in tonnes).

Give your answer to an **appropriate** number of significant figures.

mass of chlorine = ----- tonnes [3]

(b) Hydrogen chloride can be prepared by reacting potassium chloride with concentrated sulfuric acid.

Give the equation for the reaction.

[1]

- (c) The reaction in (e) is repeated with potassium iodide.
The hydrogen iodide formed is oxidised to iodine and the sulfuric acid is reduced to hydrogen sulfide.

Give the oxidation states of the elements in the compounds.

iodine in HI ----- iodine in I₂ -----

sulfur in H₂SO₄ ----- sulfur in H₂S -----

Use these oxidation states to write a balanced equation for the reaction of HI with H₂SO₄.

Equation

[3]

- 47 Calculate the volume of carbon dioxide (in dm^3) at 298 K and 95.0 kPa that could be captured by reacting it with 1.00 kg of MgO.

volume = ----- dm^3 [3]

48(a) Sodium ethanoate is used as an 'acidity regulator' in foods.

Sodium ethanoate, CH_3COONa , can be made by reacting solutions of ethanoic acid, CH_3COOH , and sodium carbonate, Na_2CO_3 , in the laboratory.

(i) Write an equation for this reaction.

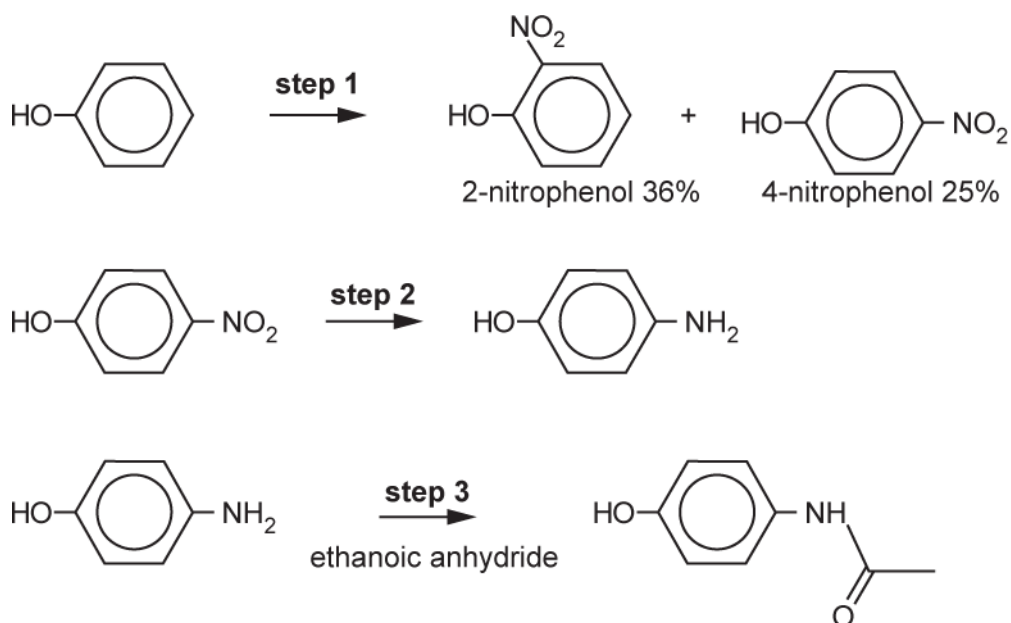
[2]

(ii) Calculate the volume (in cm^3) of $0.500 \text{ mol dm}^{-3}$ Na_2CO_3 that would react with 25.0 cm^3 of $0.450 \text{ mol dm}^{-3}$ CH_3COOH .

volume of $\text{Na}_2\text{CO}_3 = \text{-----} \text{ cm}^3$ [2]

(b) The ethanoate ion forms an alkaline solution in water.
Write an equation to show this.

[1]



- (i) The students want to make 5.0 g of 4-nitrophenol in **step 1**.
Calculate the mass of phenol they should start with.

Give your answer to an **appropriate** number of significant figures.

mass of phenol = ----- g [2]

- (ii) The two nitrophenols formed can be separated since they have different boiling points. 2-nitrophenol has a lower boiling point than 4-nitrophenol. This is because internal hydrogen bonding can occur in 2-nitrophenol.

Draw the structure of 2-nitrophenol with the -OH and -NO_2 groups shown as **full structural formulae**; show where the internal hydrogen bond would form.

[2]

(iii) Name the **type** of reaction that occurs in **step 2** and name the functional group that has been formed.

Type of reaction

Functional group formed

[1]

(iv) Write an equation for the reaction in **step 3**.

Use **skeletal** formulae for the organic compounds.

[2]

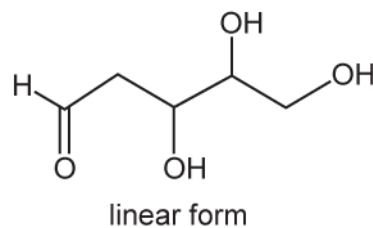
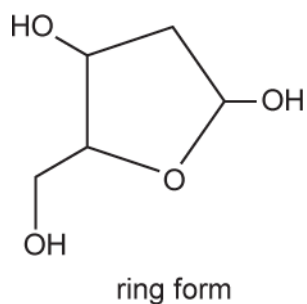
(v) The students purify the product from **step 3** by recrystallisation from water.

Describe the steps in the recrystallisation of a solid product from water. Indicate how insoluble and soluble impurities are removed.

----- [4]

50(a) Deoxyribose, $C_5H_{10}O_4$, has a vital role in our biochemistry as a component of DNA.

Deoxyribose exists in solution as several forms, two of which are shown below.



(i) Circle **all** the chiral centres on **both** structures above.

[1]

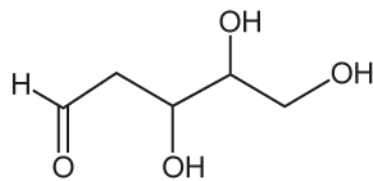
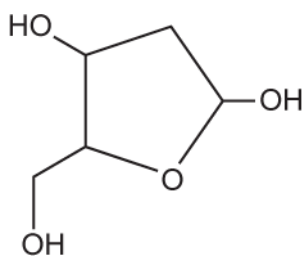
(ii) Name the functional group that is present in the linear form only.

-----[1]

(iii) Describe a laboratory test for the functional group identified in (a)(ii).

-----[2]

(iv) Circle a primary alcohol group on each structure below, giving a reason for your choice.



Reason

[2]

- (v) Explain why the reaction in which the linear form changes to the ring form is **not** condensation.

[1]

- (vi) Complete the equation that shows the reaction when the linear form changes to the ring form.
 $\text{--CHO} + \text{HO--} \rightarrow$

[1]

- (b) In DNA, deoxyribose is always present as the ring form.

The primary alcohol group in the ring form of deoxyribose and the alcohol group on the adjacent carbon condense with phosphate groups.

A sugar-phosphate backbone is formed.

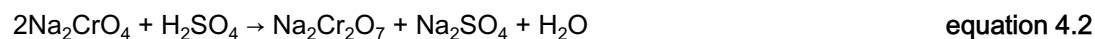
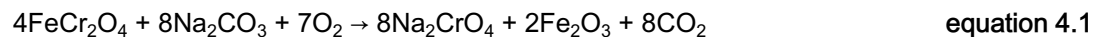
Draw a section of the sugar-phosphate backbone.

Show one deoxyribose and two phosphate groups.

[2]

51(a) Chromium is a metal with many uses, one of which is the production of a shiny chromium plating on steel.

Chromium is made from its ore chromite, FeCr_2O_4 , by the following reactions. Iron has one of its common oxidation states in chromite.



- (i) Complete the table below showing the oxidation states of chromium species in the equations above. For each equation state whether chromium has been reduced, oxidised or neither.

Equation no.	Oxidation state of Cr in reactant	Oxidation state of Cr in product	Has Cr been oxidised, reduced or neither?
4.1			
4.2			
4.3			
4.4			

[4]

- (ii) Calculate the maximum mass of chromium (in kg) that could be obtained from 1000 g of chromite.

mass = _____ kg [2]

(b) Chromium plating is carried out using a solution of chromium(III) chloride with a graphite anode.

(i) Write the electron configuration of a Cr^{3+} ion, using sub-shells and atomic orbitals.

-----[1]

(ii) Draw a labelled diagram of a simple apparatus to carry out chromium plating of a steel object in a student laboratory.

[3]

(iii) Write a half-equation for the cathode reaction in the cell in (b)(ii).

[1]

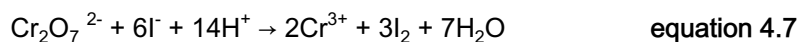
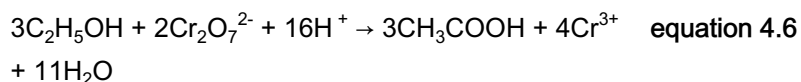
(iv) A 'mole of electrons' is 96 500 coulombs and a coulomb is a current of 1 amp flowing for 1 second.

Calculate the time (in hours) needed to deposit 26 g of chromium at a current of 5.0 amps in the cell in (b)(ii).

time = ----- hours [3]

(c) The concentration of an ethanol solution can be measured using the following steps.

- add excess acidified dichromate, $\text{Cr}_2\text{O}_7^{2-}$, some of which reacts with the ethanol.
- add excess iodide that reacts with the remaining dichromate.
- titrate the iodine produced with sodium thiosulfate.



- (i) Some students add acid and 20.0 cm^3 of $0.200 \text{ mol dm}^{-3} \text{ Cr}_2\text{O}_7^{2-}$ to 25.0 cm^3 of a 'low-alcohol' beer.

They add excess iodide ions and find that the iodine produced reacts with 27.6 cm^3 of $0.100 \text{ mol dm}^{-3} \text{ Na}_2\text{S}_2\text{O}_3$.

Calculate the concentration of the ethanol in the beer (in mol dm^{-3}) and then the percentage of ethanol (in g per 100 cm^3).

concentration of ethanol = ... mol dm^{-3}

% ethanol = ... g/100 cm^3 [6]

- (ii) Suggest one assumption the students have to make when giving their result.

----- [1]

- 52 Magnesium sulfate, MgSO_4 , has a variety of uses in agriculture and in medicine. It exists in the solid state as a hydrated salt, $\text{MgSO}_4 \cdot x\text{H}_2\text{O}$.

In order to find the value of x in the formula, a student follows the procedure below.

A known mass of magnesium sulfate crystals is dissolved in water. Aqueous sodium carbonate is added to precipitate magnesium carbonate, MgCO_3 .



Describe how the student would use the results of the experiment to find a value for x . Suggest possible sources of inaccuracy and how they might be overcome.

- 53 An unsaturated carboxylic acid has an M_r of 280.
70 g of the acid is saturated by 1.0 g of hydrogen.

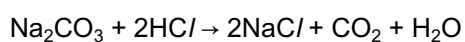
How many C=C bonds are there in one molecule of the acid?

- A 1
B 2
C 4
D 8

Your answer

[1]

- 54 Sodium carbonate reacts with hydrochloric acid as shown in the equation.



What mass (in grams) of Na_2CO_3 will react exactly with 50 cm^3 of 2.0 mol dm^{-3} HCl ?

- A 0.05
B 5.3
C 10.6
D 21.2

Your answer

[1]

55(a) A company was investigating the corrosion of metal parts used in oil rigs in the North Sea.

Chemists took two identical bolts. One was unused and the other had been exposed to the seawater for several weeks. They reacted each bolt with dilute sulfuric acid. All the unreacted iron was converted to $\text{Fe}^{2+}(\text{aq})$ ions and the rust reacted to form $\text{Fe}^{3+}(\text{aq})$.

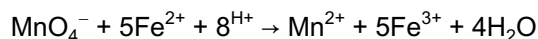
Describe how the chemists would dissolve one bolt and make the solution up to 1.00 dm^3 .

[2]

- (b) The chemists then titrated 10.0 cm^3 portions of their solutions with a solution of $0.200 \text{ mol dm}^{-3}$ potassium manganate(VII).

The MnO_4^- ions oxidise the Fe^{2+} to Fe^{3+} and the Fe^{3+} ions do not react.

The equation for the reaction is given below.

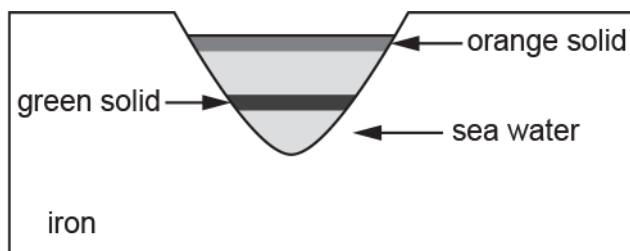


Use the titration results below to find the mass of the bolt that had rusted away.

Type of bolt	Average volume of $0.200 \text{ mol dm}^{-3}$ KMnO_4 used in the titration / cm^3
Unused bolt	17.92
Rusted bolt	9.75

mass of bolt that had rusted away = ----- g [3]

- (c) The iron rusted in small dips in the surface. The chemists noticed a green solid that turned orange at the surface of the water.



- (i) Give the half-equations for the processes occurring during the rusting.

[2]

- (ii) What are the **formulae** of the green and orange solids?

Green solid

Orange solid

[1]

- (iii) Suggest why rusting takes place faster in seawater than in rainwater.

.....
..... [1]

(d) Give the electron configuration of the Fe^{2+} ion.

-----[1]

The chemists investigated making the bolts from a nickel-copper alloy that has high strength and resistance to corrosion.

They reacted the alloy with sulfuric acid and filtered off the unreacted solid, which they found was copper.

(e) Use the electrode potentials in the table below to explain why only the nickel reacts.

Half reaction	$E^\ominus / \text{V}$
$\text{Ni}^{2+}(\text{aq}) + 2\text{e}^- \rightleftharpoons \text{Ni}(\text{s})$	- 0.25
$2\text{H}^+(\text{aq}) + 2\text{e}^- \rightleftharpoons \text{H}_2(\text{g})$	0.00
$\text{Cu}^{2+}(\text{aq}) + 2\text{e}^- \rightleftharpoons \text{Cu}(\text{s})$	+ 0.34

-----[2]

(f) The solution they obtained was green due to $[\text{Ni}(\text{H}_2\text{O})_6]^{2+}$. The chemists added some EDTA^{4-} solution and the colour changed to blue. EDTA^{4-} is a polydentate ligand.

(i) Suggest why the colour changes as the EDTA^{4-} is added and name the type of reaction taking place.

----- [1]

(ii) In a separate experiment, 25.0 cm^3 of a $0.250 \text{ mol dm}^{-3}$ $[\text{Ni}(\text{H}_2\text{O})_6]^{2+}$ solution is found to react exactly with 41.7 cm^3 of $0.150 \text{ mol dm}^{-3}$ EDTA^{4-} solution.

Calculate the formula of the complex ion that nickel forms with EDTA^{4-} .

formula of the complex ion = ----- [2]

In order to make ammonium nitrate fertiliser, ammonia is oxidised to nitric acid in several stages shown by equations 36.4–36.6.



The nitric acid formed is reacted with more ammonia.



(i) Use oxidation states or some other method to balance **equation 36.4**. [1]

(ii) The overall yield of the reactions in **equations 36.4 – 36.6** is 77%.
The yield of ammonium nitrate in **equation 36.7** can be taken as 100%.

What mass (in tonnes) of ammonia is needed to make 25 tonnes of ammonium nitrate?

mass of ammonia needed = ... tonnes **[4]**

(iii) Describe a test that would identify nitrate ions.

----- **[4]**

57(a)

A 25.0 g sample of Hg_2Cl_2 is vaporised at 400°C and a pressure of 101 kPa.

A student assumes that the formula of the gaseous mercury chloride molecules is Hg_2Cl_2 .

Calculate the volume of gas, in dm^3 , that would be expected under these conditions.

volume of gas = ----- dm^3 [3]

(b) An equilibrium, represented by **equation 2.1**, exists between the solid Hg_2Cl_2 and its ions in solution.



The solubility of the solid Hg_2Cl_2 in a saturated solution at 298 K is $3.5 \times 10^{-4} \text{ g dm}^{-3}$.

Calculate the solubility product, K_{sp} , for Hg_2Cl_2 at 298 K. Include the units.

Give your answer to an **appropriate** number of significant figures.

solubility product, K_{sp} = ----- units ----- [5]

58(a) Iodine, I_2 , is an essential dietary element. The recommended maximum daily intake of iodine for an adult is 1.5×10^{-4} g (150 μ g).

A group of chemistry students read that fish is a good source of iodine in the form of iodide ions. They decide to extract the iodine from 600 g of fish.

The students blend the fish in a food processor with 100 cm³ of water, leave it to stand overnight and then filter the mixture into a beaker.

One of the students suggests that if they add silver nitrate solution they can confirm the presence of iodide ions in the solution.

- (i) Describe what the students would observe if the only halide ion present in the solution was the iodide.

-----[1]

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

[1]

- (b) The students pour the filtered mixture into a separating funnel containing 20 cm³ of hexane, 5 cm³ of dilute sulfuric acid and 5 cm³ of hydrogen peroxide solution.

Iodine is formed and dissolves in the hexane layer which goes purple. The purple layer is separated from the aqueous layer and transferred to a conical flask.

The purple coloured solution is titrated with standard 0.0010 mol dm⁻³ sodium thiosulfate solution. The end point is indicated by the disappearance of the purple colour.

- (i) The hydrogen peroxide oxidises the iodide ions in the fish to iodine.

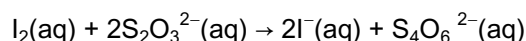
Write a half equation for this oxidation reaction.

Explain why this reaction is classified as oxidation.

Half equation

Explanation [1]

- (ii) The equation for the titration reaction is given below.



Name the element oxidised in this reaction. Give its oxidation state before and after the reaction.

Element oxidised

Oxidation state before reaction Oxidation state after reaction [2]

- (iii) The students obtained an average titre of 5.30 cm³ of 0.0010 mol dm⁻³ sodium thiosulfate.

Calculate the **mass** of iodine in µg in a **120 g** portion of fish.

Give your answer to **two** significant figures.

mass of iodine = ... μg [4]

- (iv) One of the students suggests that the titre value is too small and will lead to an unacceptably high percentage error.

Calculate the percentage error based on the students' titre value.

percentage error = ... % [1]

- (v) Suggest how the experiment could be modified to improve the accuracy of the result.

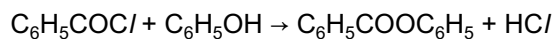
.....

.....

..... [1]

59(a) This question refers to the Practical material that is supplied as Insert for H433/03, June 2018.

The equation for the reaction producing phenyl benzoate is as follows:



- (i) Draw a structural formula for phenyl benzoate, showing the bonding in the ester group.

[1]

- (ii) Use the student results to calculate the percentage yield of phenyl benzoate obtained from the practical.

percentage yield = ----- % [3]

(b)

- (i) In **step 8** of the procedure the water reacts with any remaining benzoyl chloride.

Write the equation for this reaction.

[1]

- (ii) Suggest and explain the reason for **step 13** in the procedure.

----- [1]

- (iii) Describe the practical procedure used to measure the melting point of an organic solid.
You **do not** need to discuss the type of melting point apparatus you use.

----- [3]

- (iv) What information can the students get from their melting point?

----- [1]

- (v) The recrystallisation procedure uses ethanol as the solvent.

Give the key properties needed by a solvent to be effective in recrystallisation.

----- [1]

- Comment on the validity of this statement.
- You should describe any possible observations to back up your comments.

You should describe any possible observations to back up your comments.

[4]

Propene, C_3H_6 , can be made by cracking longer-chain hydrocarbons.

- [1]

- mass of propene = ----- kg [2]

61(a) This question concerns the article The Strange Story of Napoleon's Wallpaper that is supplied as Insert for H433/02, June 2018.

One reason arsenic is poisonous because it reacts with –SH groups in amino acids.

Suggest how the removal of –SH groups might interfere with the way these amino acids form proteins.

----- [1]

(b) Arsenate(V) can replace phosphate(V) in nucleic acids.

Draw the skeletal formula of a DNA nucleotide containing thymine and with As instead of P.

(c) Write an equation for the reaction of a solution of As^{3+} with hydrogen sulfide. Show state symbols. [2]

[2]

(d) A Marsh test is carried out for arsenic in a sample of As_2O_3 .

(i) Draw a labelled diagram of a suitable apparatus, showing the reactants and products.

[3]

(ii) Write equations for the formation and decomposition of arsine in the apparatus.

[2]

(e) The structure of Scheele's green can be represented as $\text{Cu}^{2+}(\text{AsO}_2\text{OH})^{2-}$.

(i) Suggest a '*dot-and-cross*' diagram for the anion in Scheele's green.

[2]

(ii) State which part of Scheele's green is responsible for the green colour.

-----[1]

(f) State and explain the C–As–C bond angle in trimethylarsine.

[4]

(g) Summarise the evidence that Napoleon was killed by his wallpaper.

[3]

62(a) Some students heat a sample of $\text{MgCO}_3 \cdot 3\text{H}_2\text{O}$ to try to make MgCO_3 .

Calculate the percentage loss in mass they will obtain if they succeed.

percentage loss in mass = ... % [2]

- (b) 'Morton's salt'TM contains a mixture of sodium chloride with magnesium carbonate. It is advertised using the slogan 'When it rains it pours' indicating that the table salt is free-flowing in humid weather.

Magnesium carbonate is hygroscopic (absorbs water) and forms hydrated salts, eg $\text{MgCO}_3 \cdot 3\text{H}_2\text{O}$, but does not dissolve. This stops the sodium chloride absorbing water.

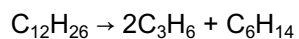
The students continue to heat the MgCO_3 formed and realise that the compound is decomposing, giving off CO_2 gas.

The students want to obtain 200 cm^3 CO_2 at 290 K and 99 kPa.

What mass of MgCO_3 should they heat?

mass of MgCO_3 = ... g [3]

- 63 Long chain alkanes can be cracked to provide better fuels and raw materials for the chemical industry. One such cracking reaction is shown in **equation 31.1**.



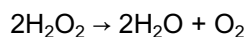
Equation 31.1

In a cracking reaction 1.50 tonnes of dodecane ($\text{C}_{12}\text{H}_{26}$) produce 478 kg of hexane (C_6H_{14}).

Calculate the percentage yield of the reaction in **equation 31.1**.

percentage yield = ----- % [3]

64(a) Why does human hair turn grey? Studies have shown that this is caused by lower levels of the enzyme catalase in hair follicles. Catalase catalyses the breakdown of hydrogen peroxide as shown in **equation 3.1**.



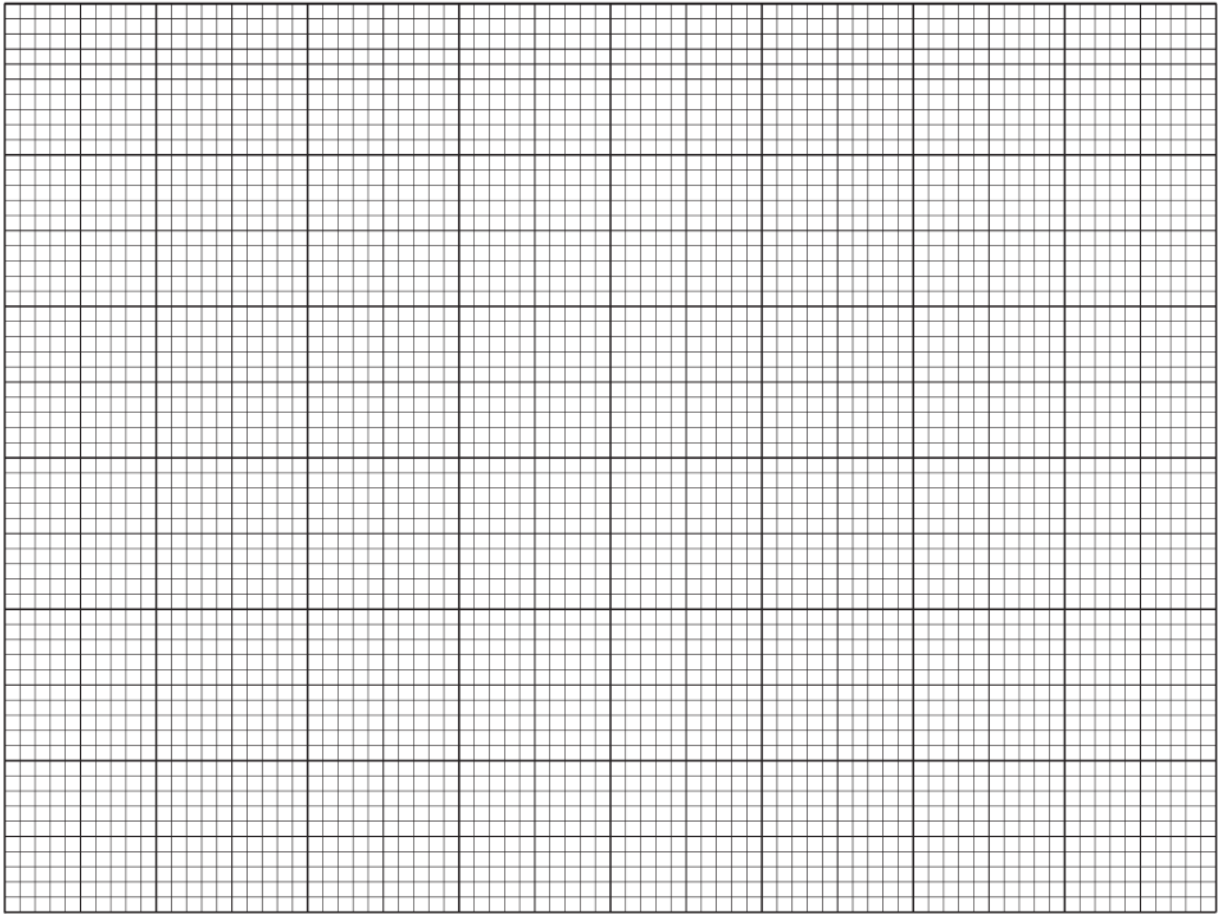
Equation 3.1

When levels of hydrogen peroxide increase, the melanin (dye) in the hair is bleached.

*Some students are given a solution of catalase and solutions of hydrogen peroxide of different concentrations. They study the rate of reaction in **equation 3.1**.

They determine the relative initial rates of reaction at the different hydrogen peroxide concentrations, using the volume of oxygen produced.

Suggest the procedure they follow, including how the students should process their results. You may include a diagram as part of your answer.



[4]

(c) A student says that the graph shows that the decomposition of hydrogen peroxide is first order with respect to both the hydrogen peroxide concentration and the catalase concentration.

- (i) Write the rate equation that would follow from the student's statement.
Give the units of the rate constant.

Rate equation:

Units of rate constant -----

[2]

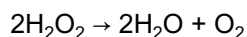
- (ii) Explain why the student is incorrect and give the correct information.

[3]

- (d) Hydrogen peroxide concentration is often measured as 'volume strength'.
1 cm³ of '1 volume' hydrogen peroxide produces 1 cm³ of oxygen at RTP.

Calculate the 'volume strength' of the 0.35 mol dm⁻³ hydrogen peroxide used by the students.

Equation 3.1



Give your answer to an **appropriate** number of significant figures.

'volume strength' = ----- volume [3]

- (e) The students have 20.0 cm³ 0.35 mol dm⁻³ H₂O₂ and wish to make a 0.05 mol dm⁻³ solution.

How much water should they add?

volume of water to add = ----- cm³ [2]

- 65 Which statement about an atom of ²³Na is correct?

- A It is an isomer of sodium.
- B It has an atomic number of 23.
- C It has 12 neutrons in its nucleus.
- D It has a mass number of 11.

Your answer

[1]

66 A student adds 10 cm^3 of water to 12 cm^3 of a 0.010 mol dm^{-3} solution.

What is the resulting concentration in mol dm^{-3} ?

A 0.0045

B 0.0055

C 0.0083

D 0.018

Your answer

[1]

67 0.125 mol of CuO is reacted with excess sulfuric acid and the solution allowed to crystallise.

What mass of hydrated copper sulfate, $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$, is formed if the yield is 75.0% ?

A 15.0 g

B 20.0 g

C 23.4 g

D 31.2 g

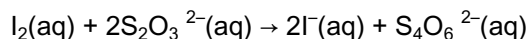
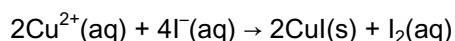
Your answer

[1]

68 Two students want to find the concentration of Cu^{2+} ions in some seawater from near a hot vent.

They use a titration method involving potassium iodide and sodium thiosulfate.

The potassium iodide is oxidised to iodine by the Cu^{2+} ions and the liberated iodine is titrated with sodium thiosulfate of known concentration.



(i) Name a suitable indicator the students should use and give the expected colour change observed.

Indicator -----

Colour change observed ----- [1]

(ii) The students are supplied with $0.020 \text{ mol dm}^{-3}$ sodium thiosulfate. The students add excess potassium iodide to 50 cm^3 of the seawater and titrate with the sodium thiosulfate.

They find that their mean titre is only 0.95 cm^3 of sodium thiosulfate solution.

Use the students' results to calculate the concentration of Cu^{2+} ions in milligrams per dm^3 of seawater.

concentration = ... mg dm^{-3} [3]

(iii) Calculate the percentage uncertainty in a titre of 0.95 cm^3 .

percentage uncertainty = ...% [1]

(iv) What could the students do to reduce this percentage uncertainty to around 0.5%?

Describe their experimental method.

[2]

Suggest why the titre values in **Table 2** increase from sample 1 to sample 4.

----- [1]

(b) The students use a titre value of 8.00 cm^3 to calculate the mass of iron in the spinach in sample 4.

(i) Show how the students calculated the value of 8.00 cm^3 as their titre for the calculation.

----- [1]

(ii) Foods ‘high’ in iron usually contain more than 4 mg of iron per 100 g of foodstuff. A student states that the data in **Tables 1 and 2** show that spinach is ‘high in iron’.

Comment on the student’s statement.

Show calculations to support your comments, using the data for **sample 4**.

----- [4]

(c) A student suggests that the titre values in the experiment are too small and give an unacceptable error for the final answer.

(i) Calculate the percentage uncertainty in titre 1 for **sample 4**.

percentage uncertainty = ... %[1]

(ii) The students want to reduce the percentage uncertainty in the titre values, while using the same equipment.

Suggest **two** ways in which they can do this.

1

.....

2

.....

[2]

70 Compound A can be made by the reaction in Fig. 1.2.

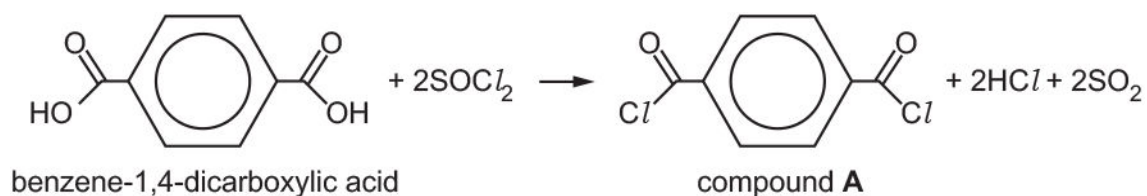


Fig. 1.2

Calculate the mass of compound A that can be made from 32 g of benzene-1,4-dicarboxylic acid if the yield is 67%.

Give your answer to the nearest whole number.

mass of compound A = ... g [2]

71 *Strontium oxide reacts with water to form strontium hydroxide, $\text{Sr}(\text{OH})_2$.

The solubility of strontium hydroxide in water at room temperature is around 10 g dm^{-3} .

A student is given a saturated solution of strontium hydroxide, normal titration equipment and a variety of different concentrations of hydrochloric acid.

The student wishes to find an accurate value for the concentration of the solution in mol dm^{-3} .

Describe in full a suitable procedure and indicate how the result would be calculated.

[6]

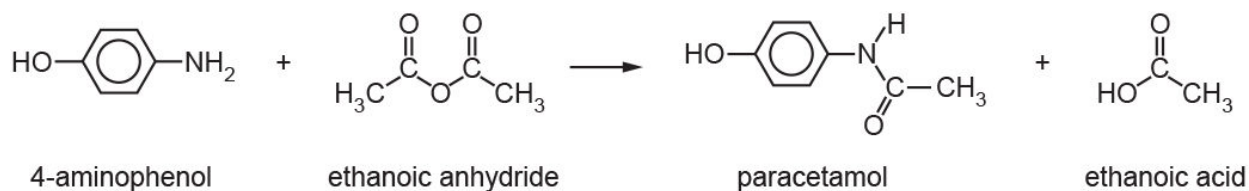


Fig. 2.1

The students carried out the reaction in Fig 2.1. They then recrystallised their paracetamol sample.

The students started with a mass of 2.1 g of 4-aminophenol and used excess ethanoic anhydride.

The mass of the dried recrystallised paracetamol produced was 1.5 g.

Calculate the percentage yield for the students' reaction.

Give your answer to an **appropriate** number of significant figures.

percentage yield = ... % [3]

73 A student is investigating the properties of some s-block metals and their compounds.

The student is given a sample of an unknown Group 2 carbonate MCO_3 .

The student is told to heat the sample to constant mass and use the results to identify the Group 2 carbonate.

(i) Explain the term 'heat to constant mass'.

----- [1]

(ii) 4.00 g of a metal carbonate MCO_3 gives 1.91 g of MO on heating to constant mass.

Identify metal M in MCO_3 showing a suitable calculation.

metal M is [3]

74(a) The two isomers of propanol, $\text{C}_3\text{H}_7\text{OH}$, can be used as fuels.

A student measures the enthalpy change of combustion of propan-1-ol, $\text{C}_3\text{H}_7\text{OH}$. The apparatus used is shown in Fig. 3.1.

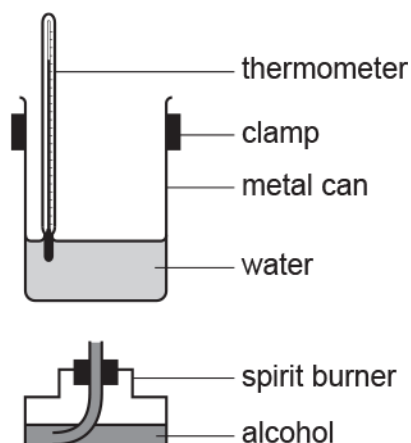


Fig. 3.1

The student's results are shown in Table 3. 1.

Mass of spirit burner + propan-1-ol	43.11 g
Mass of spirit burner + propan-1-ol after burning	42.92 g
Initial temperature of water	19.7 °C
Final temperature of water	31.2 °C
Mass of water in metal can	100 g

Table 3.1

Use the results in Table 3.1 to calculate a value for the enthalpy change of combustion of propan-1-ol, $\Delta_c H$, in kJ mol^{-1} .

Enthalpy change of combustion of propan-1-ol, $\Delta_c H = \dots\dots\dots \text{kJ mol}^{-1}$ [3]

(b) The data book value for the enthalpy change of combustion of propan-1-ol is $-2021 \text{ kJ mol}^{-1}$.

(i) One reason for the difference is heat loss to the surroundings.

Suggest **two** other reasons for the difference between the experimental value and the data book value.

1

.....

2

.....

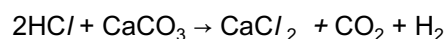
[2]

(ii) Describe **one** addition to the apparatus in Fig. 3.1 that would improve the accuracy of the experimental value for the enthalpy change of combustion.

.....

..... [1]

75 100 cm^3 0.75 mol dm^{-3} hydrochloric acid is added to 2.5 g calcium carbonate ($M_r = 100$).



What volume of CO_2 , in cm^3 , is produced at RTP?

- A 600
- B 900
- C 1800
- D 3600

Your answer

[1]

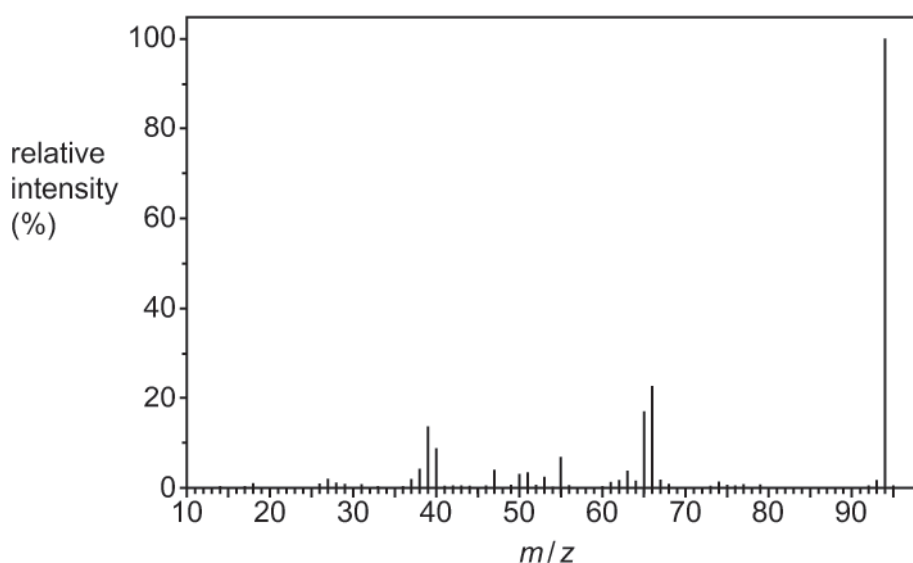
Propene can be reacted with benzene in the presence of oxygen to produce two useful products, **A** and **B**.

A student did some tests on the products and recorded their observations below. The student also obtained data about each product.

Student's tests on **Product A**:

Test	Observations
Add a drop of universal indicator.	orange colour produced
Add sodium carbonate solution.	no effervescence
Add neutral iron(III) chloride solution.	purple colour seen

The mass spectrum of **Product A**:



Student's tests on **Product B**:

Test	Observations
Add a drop of universal indicator.	stays green
Test with Tollens' reagent.	no change seen
React with NaBH_4 .	B is reduced to an alcohol

Composition of **Product B**:

Element	C	H	O
Percentage by mass	62.1	10.3	27.6

Identify products **A** and **B** giving evidence from the student's observations and the data provided.

[illegible]

77 Some students want to find the concentration of chloride ions in seawater. They look up a method in a textbook.

They dilute the seawater and then titrate with standard silver nitrate, AgNO_3 , solution.

The students first dilute the seawater by pipetting 20.0 cm^3 of seawater into a 100 cm^3 volumetric flask and making up to the mark with deionised water.

25.0 cm^3 of the diluted seawater solution required 26.50 cm^3 $0.100 \text{ mol dm}^{-3}$ silver nitrate solution.

Calculate the concentration of chloride ions in the undiluted seawater.

concentration of chloride ions in seawater = ... mol dm^{-3} [3]

78 Some students make an electrochemical cell, using two different half cells as shown in Table 2. 2.

Half-reaction	E° / V
$\text{Cu}^{2+}(\text{aq}) + 2\text{e}^{-} \rightleftharpoons \text{Cu}(\text{s})$	+0.34
$2\text{IO}_3^{-}(\text{aq}) + 12 \text{H}^{+}(\text{aq}) + 10\text{e}^{-} \rightleftharpoons \text{I}_2(\text{aq}) + 6\text{H}_2\text{O}(\text{l})$	+1.19

Table 2.2

(i) Write an equation for the reaction that occurs when the cell delivers a current.

[2]

(ii) Draw a labelled diagram to show how the $\text{IO}_3^{-} / \text{I}_2$ electrode is made up.

You do **not** need to give concentrations.

[2]

(iii) The students are told that in a standard $\text{IO}_3^{-} / \text{I}_2$ electrode $[\text{IO}_3^{-}] = [\text{I}_2]$.

They plan to prepare 40 cm^3 of the solution for the electrode by mixing 20 cm^3 of $0.08 \text{ mol dm}^{-3} \text{ I}_2(\text{aq})$ with 20 cm^3 of $\text{IO}_3^{-}(\text{aq})$.

Calculate the concentration of IO_3^{-} needed so that $[\text{IO}_3^{-}]^2 = [\text{I}_2]$.

$[\text{IO}_3^{-}] = \dots\dots\dots \text{mol dm}^{-3}$ [3]

79(a) 'Fumaric acid' is used as an acidity regulator in food. 'Maleic acid' is a stereoisomer of fumaric acid. The structure of the two acids are shown in Fig. 4.1.

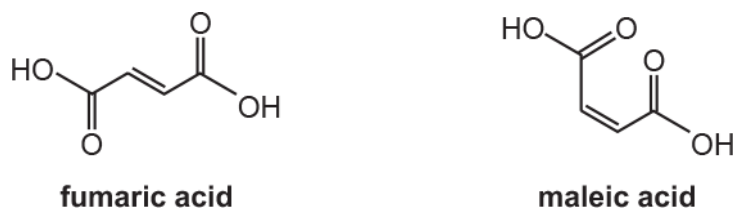


Fig. 4.1

- (i) Describe chemical tests that can be carried out in a laboratory to identify the two functional groups in both acids.

[2]

- (ii) A solution has 2.32 g dm^{-3} of maleic acid.

Calculate the volume (in cm^3) of 2.0 mol dm^{-3} NaOH(aq) that would completely neutralise 250 cm^3 of the solution.

volume = ... cm^3 [3]

(b)

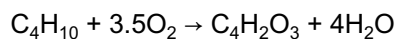
- (i) Give the **empirical** formula of both acids.

[1]

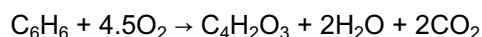
- (ii) Give the systematic name for **maleic acid**.

[2]

- (c) Maleic anhydride, C₄H₂O₃, can be made industrially by oxidising butane or benzene.



Reaction 1



Reaction 2

- (i) Use calculated atom economies to suggest, with a reason, which reaction is used more.

[2]

- (ii) Suggest another reason why the reaction selected in (g)(i) is preferred.

[1]

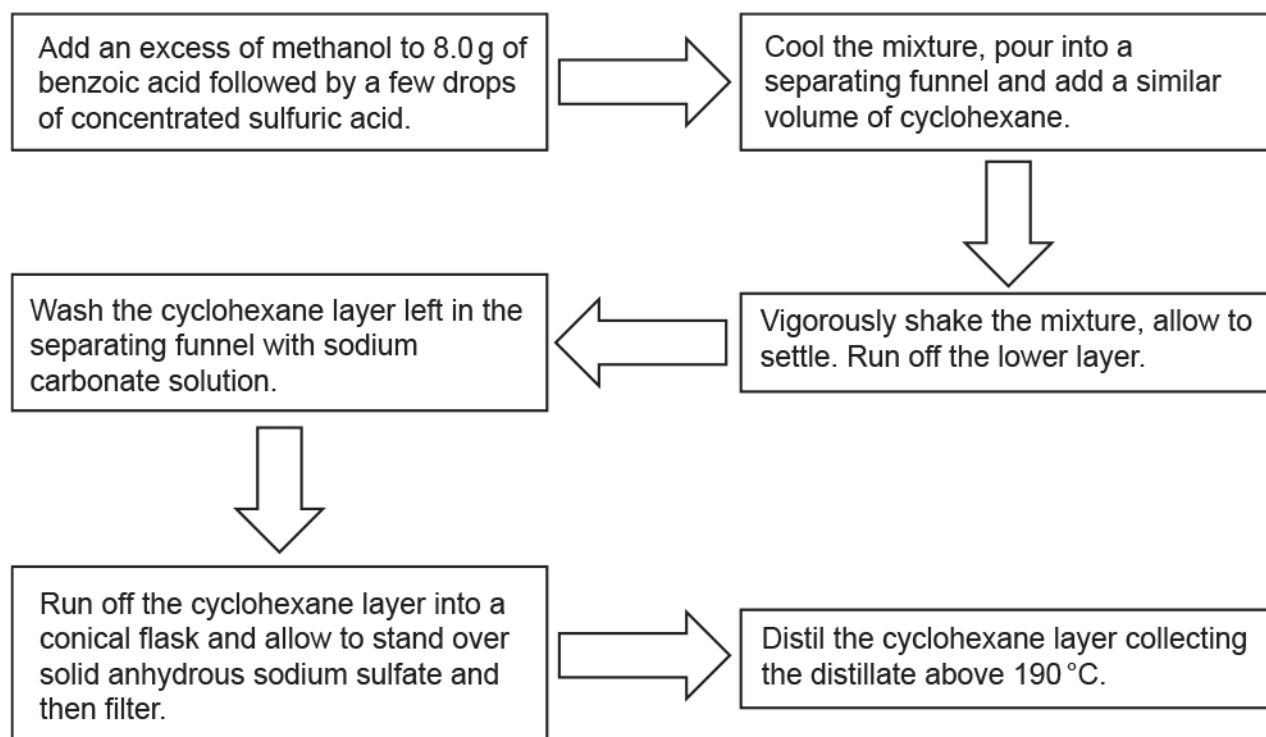
- (iii) Calculate the maximum mass of maleic anhydride, C₄H₂O₃, (in kg) that could be made from 15 m³ of butane (measured at RTP).

Give your answer to an **appropriate** number of significant figures.

mass of maleic anhydride = ... kg [2]

80(a) Methyl benzoate is a liquid at room temperature and has a boiling point of 200 °C.

The steps in a procedure for preparing and purifying the simple ester, methyl benzoate, are shown in the flow chart.



Give the reasons for the following experimental procedures in the flow chart:

(i) adding cyclohexane

----- [1]

(ii) adding sodium carbonate solution

----- [1]

(iii) standing the cyclohexane layer over solid anhydrous sodium sulfate

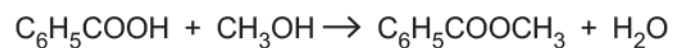
----- [1]

(iv) collecting the distillate above 190 °C

----- [1]

(b) A student followed the procedure in the flow chart and obtained 5.46 g of methyl benzoate.

The equation for the preparation is:



benzoic acid methanol methyl benzoate

Calculate the percentage yield of methyl benzoate.

Give your answer to an **appropriate** number of significant figures.

percentage yield = ... % [4]

- 81 The Dead Sea has high concentrations of salts, especially chlorides and bromides.
Chlorine and bromine factories have developed next to the Dead Sea.

Many of the industries using chlorine and bromine as raw materials are located nearby. This avoids transporting these substances over long distances.

The concentration of bromide ions in water from the Dead Sea is 5 g dm^{-3} .

Calculate the number of bromide ions in 1 cm^3 of Dead Sea water.

Give your answer to an **appropriate** number of significant figures.

number of bromide ions = ... [3]

END OF QUESTION PAPER

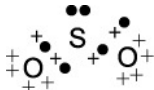
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
1			D	1 AO 2.8	Examiner's Comments This was very well done, candidates understood atom economy well and the provision of the M_r values for the reagents saved the candidates time and reduced the incidence of arithmetical errors, allowing them to concentrate on the key idea. Again, the working was seen in the white space around the question.
			Total	1	
2			D	1 AO 2.8	Examiner's Comments Most candidates worked this out correctly, although some chose B, perhaps as there were 0.3 moles of water.
			Total	1	
3		i	+3 ✓ 1s ² 2s ² 2p ⁶ 3s ² 3p ⁶ 3d ⁵ ✓	2	NOT 3+ or 3 ALLOW capital letters but numbers must be superscripts. ALLOW ecf for Fe²⁺ only (3d⁶) ALLOW repetition of '1s²2s²', IGNORE 4s⁰ Examiner's Comments This was well done with most candidates giving +3 as the oxidation state and 2p⁶3s²3p⁶3d⁵ as the configuration. 3d³4s² was rarely seen.
		ii	Amount of water = 0.216/18 = 0.012 mol ✓ (Mass of anhydrous = 1.066 = 0.012 mol so) $n = 1$ ✓	2	Mark separately $n = 1$ on the answer line (without first marking point) scores second mark only Examiner's Comments Many correctly calculated the moles of water (and anhydrous salt) as 0.012 and obtained the correct answer of $n=1$. It was often difficult to see the method of those who got another answer for n.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		iii	Amount Fe = 0.012 mol = 0.670 g Mass O = 1.066 – 0.670 – 0.140 = 0.256 ✓ Amount O = 0.256/16 = 0.016, y = 4 ✓ OR 1 mole FeO(OH) → $\frac{1}{3}$ mole Fe₃O_x so 0.012 mol → 0.004 mol 0.004 moles have a mass of (1.066- 0.14)g = 0.926g ✓ 1 mole weighs 0.926/0.004 = 231.5g Mass of the 3 Fe atoms subtracted = 64g so 4 moles of O y = 4 ✓	2	working must be checked look for mass O = 0.256 or 0.004 moles weigh 0.926g for 1 mark y = 4 without coherent working scores 1 Examiner's Comments A very few candidates managed to get through this tricky calculation, usually spotting that 0.926g of Fe₃O_y represented 0.004 moles, which led to y = 4.
			Total	6	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
4	a	i	 both double bonds correct ✓ completely correct ✓	2	ALLOW electrons in lone pairs that are not close together Give BOD wherever possible on rubbing out etc. ALLOW double bonds as '• • x x' or • x x • IGNORE shape ALLOW other symbols for dots and crosses Examiner's Comments Most could draw the dot and cross diagram for sulfur dioxide, the commonest error being to place two lone pairs on the sulfur.
		ii	1. three groups / sets / regions of electrons / areas of electron density (around S) ✓ 2. (electrons / [as for 1.]) repel and get as far away from each other as possible/ repel to minimise repulsion ✓ 3. 120° ✓	3	1. IGNORE 'electron pairs/ bonds/ bonding pairs' 2. IGNORE 'bonds' and 'pairs' IGNORE 'repel as much as possible' 3. ALLOW 115 - 125 Mark separately No ecf Examiner's Comments Again, most could answer this fairly familiar question, though some lost marks because they talked about pairs of electrons rather than 'areas of electron density'.
		iii	 One oxygen with dative bond and three lone pairs ✓ completely correct ✓	2	See guidance in 5ai ALLOW structure with dative bond and double bond reversed. Examiner's Comments Some candidates spotted that a dative bond would solve the problem and then produced a correct structure, though some of these were let down by a failure to count electrons.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		iv	$\text{SO}_2(\text{g} / \text{aq}) + \text{H}_2\text{O}(\text{l} / \text{g}) \rightleftharpoons 2\text{H}^+(\text{aq}) + \text{SO}_3^{2-}(\text{aq})$ OR $\text{SO}_2(\text{g} / \text{aq}) + \text{H}_2\text{O}(\text{l} / \text{g}) \rightleftharpoons \text{H}^+(\text{aq}) + \text{HSO}_3^-(\text{aq})$ equation ✓ state symbols ✓	2	ALLOW arrow instead of $\rightleftharpoons$. ALLOW equations with oxygen forming SO_4^{2-} or HSO_4^- [eg $2\text{SO}_2(\text{g} / \text{aq}) + 2\text{H}_2\text{O}(\text{l} / \text{g}) + \text{O}_2(\text{g}) \rightleftharpoons 4\text{H}^+(\text{aq}) + 2\text{SO}_4^{2-}(\text{aq})$] ss mark can be awarded if equation is unbalanced but correct species are present (and only those). Examiner's Comments A few candidates wrote a correct equation, forming either SO_3^{2-} or HSO_3^-. A number of equations had an unbalanced SO_3^- formed and many tried to form sulfate without realising they could never balance the equation without involving oxygen molecules – for which a correctly balanced equation would have been perfectly acceptable.
	b	i	$\text{SO}_2 + 2\text{H}_2\text{S} \longrightarrow 3\text{S} + 2\text{H}_2\text{O}$ +4 ✓ -2 ✓ 0 ✓	3	NOT sign after numbers, but give one mark for 4+ AND 2- Examiner's Comments Most candidates scored full marks here, though several got one of the oxidation states wrong.
		ii	1. BOTH moles $\text{SO}_2 = 44.3/64(.1)$ or 0.69 AND moles $\text{H}_2\text{S} = 44.3/34(.1)$ or 1.3 ✓ 2. SO_2 in excess / H_2S is limiting (AW)✓ 3. mass S formed (= $1.3 \times 1.5 \times 32.1$) = 62.6 g [62.4 if 32 used as A_r]✓ (Allow any number between 62.4 and 63)	3	ALLOW any numbers rounding to 0.69 and 1.3 ALLOW ecf from 1. to 2. and 3. Answer alone scores third mark only Answers from use of moles of SO^2 (allow any number between 66 and 67) can score mark 3. but not 2. ALLOW 2 or more sf Examiner's Comments Some candidates worked out the moles of SO_2 and H_2S, realised that there was excess SO_2, said so and then calculated the mass of sulfur from the mass of H_2S. This was a case where explanation was necessary, hence the clue 'Show your working' in the question. Others scored one mark for working out the mass of sulfur using the moles of SO_2.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		iii	low mpt ✓ weak intermolecular bonds / weak instantaneous dipole-induced dipole bonds ✓ non-conductor/ poor conductor (of electricity)/good insulator ✓ no ions/ no charged particles / no free (or delocalised) electrons ✓	4	QWC: second mark in each pair depends on first being scored. IGNORE 'S is a gas' IGNORE 'not ionic' IGNORE 'in solution' IGNORE references to solubility or boiling point or strength Examiner's Comments Some candidates identified lack of conductivity and low melting point and gave reasons for these. Credit was not given for those who said sulfur was a gas, partly because it had been described as a solid earlier in the question.
	c	i	$1s^2 2s^2 2p^6 3s^2 3p^6$ / [Ne] $3s^2 3p^6$ ✓	1	ALLOW capital letters but electron numbers must be superscripts Examiner's Comments Only half the candidates scored here. Most of the others wrote the configuration of the S^{2+} ion, while some gave the configuration of a sulfur atom.
		ii	$(NH_4)_2S + 2NaOH \rightarrow 2NH_3 + Na_2S + 2H_2O$ Na_2S as a product ✓ completely correct ✓	2	ALLOW $(NH_4)_2S + 2NaOH \rightarrow 2NH_4OH + Na_2S$ IGNORE state symbols NOT formulae or equation containing ions formulae must be represented in conventional way but... ALLOW otherwise correct balanced equation forming $(Na)_2S$ for 1 mark Examiner's Comments Many candidates could write the correct formula for sodium sulfide and then could go on to write and balance an equation forming the sulfide and 'ammonium hydroxide' or ammonia and water. Candidates must be aware that chemists have definite conventions for writing formulae and that use of extraneous brackets, such as $(Na)_2S$ and $(NH_4)OH$ are not acceptable.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
			Total	22	
5		i	$C_8H_{12}N_2$ ✓	1	ALLOW elements in any order
		ii	109° ✓ four pairs / groups / sets of electrons / four areas of electron density (around N) ✓ repel and get as far away from each other as possible / minimise repulsion ✓	3	ALLOW 106 - 110° ALLOW three bonding pairs and one lone pair 3rd point must be in terms of electrons repelling IGNORE bonds repelling IGNORE '(repel) as much as possible' Mark separately Examiner's Comments Most could work out the molecular formula, though some tripped over the number of hydrogen atoms. There was high scoring on the question concerning the bond angle around nitrogen, though some forgot the lone pair and said there were only three areas of electron density around the nitrogen atom.
			Total	4	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
6	a	i	propene ✓	1	NOT prop-1-ene
		ii	similarity: C-C bond formed / C atom attached to benzene OR alkylation OR hydrocarbon (chain)(AW) attached / substituted / added ✓ difference: no use of halogen compound OR only one product / no HC/ (or H⁺) formed / lost ✓	2	IGNORE references to alkenes as reactants ALLOW 'eliminated' Examiner's Comments Most named the compound correctly as propene and many could compare the reaction with a normal Friedel Crafts reaction.
	b	i	1. more / greater / higher yield OR more / greater amount of compound B / product ✓ 2. fewer molecules / particles / moles on right-hand side / product <i>ora</i> ✓ 3. molecules / particles.... in smaller volume / space (not area) OR ...closer together OR ...more concentrated AW ✓ 4. greater frequency of collisions AND faster rate (of reaction) AW ✓	4	IGNORE 'equilibrium moves to the right' unless it indicates which side has fewer moles QWC marking point 1 depends on marking point 2 being scored 'molecules have increased energy' CONs this point marking points 3 and 4 can be marked separately 4. frequency must be implied (not just 'more collisions') IGNORE 'chance of collision' Examiner's Comments Was the physical part and many scored full marks. Errors in part (i) included a failure to say which was the side with fewer moles, that the concentration of the particles was greater and that the frequency of collisions was greater.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		ii	(Forward) reaction exothermic (ora) AND equilibrium constant smaller AW ✓ Rate (too) slow(er)/takes too long to reach equm below 250 AW ✓	2	IGNORE 'equilibrium moves to the left' but 'equilibrium moves to left (AW) in endothermic direction' will score first part of marking point. IGNORE 'compromise' Examiner's Comments Most scored the marks.
		iii	100% ✓ no waste (product) (to be disposed of) ✓	2	IGNORE 'high' IGNORE reference to toxic / harmful NOT 'no by-product' Examiner's Comments This showed a good understanding of atom economy. The rare error was to hedge bets by saying 'less waste', rather than 'no waste'.
			Total	11	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
7	a		$\text{CaO} + 3\text{C} \rightarrow \text{CO} + \text{CaC}_2$ OR $2\text{CaO} + 5\text{C} \rightarrow \text{CO}_2 + 2\text{CaC}_2$ ✓	1	IGNORE state symbols Examiner's Comments Required understanding of inorganic chemistry that was possessed by some candidates. Many gave oxygen as a possible product, which candidates should have realised would not form in the presence of hot carbon.
	b	i	$\text{CaCN}_2 + 3\text{H}_2\text{O} \rightarrow \text{CaCO}_3 + 2\text{NH}_3$ ✓✓	2	<i>For one mark:</i> • correct substances but unbalanced equation • the correct balanced equation with an error (eg $\text{Ca}(\text{CO}_3)$) • $\text{CaCN}_2 + 3\text{H}_2\text{O} \rightarrow \text{CaO} + \text{CO}_2 + 2\text{NH}_3$ • $\text{CaCN}_2 + 4\text{H}_2\text{O} \rightarrow \text{Ca}(\text{OH})_2 + \text{CO}_2 + 2\text{NH}_3$ Examiner's Comments Required understanding of inorganic chemistry that was possessed by some candidates. Many gave oxygen as a possible product in part (a) which candidates should have realised would not form in the presence of hot carbon.
		ii	(nitrogen is unreactive / inert) (nitrogen) has a (strong) triple bond ~~($\text{O}=\text{N}=\text{N}$)~~ ✓ OR high (AW) (activation) energy / enthalpy... ... to break bond	1	Examiner's Comments Was better, with more candidates suggesting that CaO and CO ₂ would be formed, though CaCO ₃ was the more likely product. Many candidates correctly suggested a triple (or strong) bond between the nitrogen atoms and some went on to say that nitrogen compounds were needed for plant growth.

Mark Scheme

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		iii	nitrogen compounds are needed (by plants) for: growth / making protein / making amino acids / DNA ✓	1	ALLOW for 'nitrogen compounds': named (appropriate) nitrogen compounds or 'nitrates' or 'ammonium ions' (or formulae) IGNORE references to fertilisers Examiner's Comments Lack of the word 'compounds' caused some loss of the mark.
		iv	$(28 \times 100 / 80.1 =) 35.0\%$ ✓ to 3sf ✓	2	Any answer that rounds to 35 scores first mark Second mark is for correct answer to 3sf i.e. 35.0 Examiner's Comments Involved a simple mole calculation, which most got right. Realisation that atomic mass data is to three significant figures was slightly more complicated.
			Total	7	
8			A	1	
			Total	1	
9			D	1	
			Total	1	
10			B	1	
			Total	1	
11			B	1	
			Total	1	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
12		i	$E^\ominus$ of $\text{Ce}^{4+}/\text{Ce}^{3+}$ in $\text{H}_2\text{SO}_4(\text{aq})$ is more positive than $E^\ominus$ of Cl_2/Cl^- ✓ So will oxidise Cl^- to Cl_2 ✓ In $\text{HCl}(\text{aq})$ $E^\ominus$ of $\text{Ce}^{4+}/\text{Ce}^{3+}$ is less positive so will not oxidise Cl^- to Cl_2 AND so $\text{H}_2\text{SO}_4(\text{aq})$ is used ✓	3	ALLOW less negative ALLOW more negative
		ii	FIRST CHECK ANSWER ON ANSWER LINE answer = 83% to 2 sig figs award 5 marks $n(\text{AsO}_3^{3-})$ used in titration = $3.00/1000 \times 0.500$ OR 0.00150 (mol) (conc. of AsO_3^{3-} is double that of As_2O_3) ✓ $n(\text{Ce}^{4+})$ used in titration = $2 \times (3.00/1000 \times 0.500)$ OR 2×0.00150 OR 0.00300 (mol) ✓ M_r of CeO_2 = 172.1 ✓ mass CeO_2 present in 100 cm^3 of solution = $4 \times 172.1 \times 0.00300 = 2.0652 \text{ g}$ ✓ % purity of CeO_2 sample = $2.0652 \times 100/2.5 = 83\%$ to 2 sig figs ✓	5	ALLOW ECF from first marking point ALLOW ECF from second marking point
		iii	Use a more dilute AsO_3^{3-} solution to increase volume of titre / reduce % error in titre OR Use more ceria sample to increase volume of titre / reduce % error in titre ✓	1	
		iv	FIRST CHECK ANSWER ON ANSWER LINE answer = 1.7×10^{22} atoms of oxygen award 2 marks $n(\text{CeO}_2) = 2.5/172.1 = 0.01453$ (mol) ✓ $n(\text{O}) = 0.01453 \times 2 = 0.02905$ (mol)	2	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		iv	$0.02905 \times 6.02 \times 10^{23} = 1.7 \times 10^{22}$ atoms of oxygen ✓		ALLOW ECF from first marking point ALLOW 2 or more sig figs
		v	Reactants adsorbed onto surface of catalyst and form bonds to surface (AW) ✓ Bonds within reactants weaken and break ✓ New bonds form (AW) ✓ Products formed desorb / leave from catalyst (AW) ✓	4	
			Total	15	
13			D	1	
			Total	1	
14			FIRST CHECK ANSWER ON ANSWER LINE answers rounding to 32.5 (g) award 2 marks Moles of aspirin made = $29.5/180$ AND moles of 2-hydroxybenzoic acid = $(29.5 \times 100)/(180 \times 69.5) = 0.236$ ✓ = 32.5 (g) (Multiplication by 138) ✓	2	ALLOW 3 or more sf
			Total	2	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
15	a	i	$\text{CO}_2 + \text{Ca(OH)}_2 \rightarrow \text{CaCO}_3 + \text{H}_2\text{O}$ ✓	1	IGNORE state symbols
		ii	FIRST CHECK THE ANSWER ON THE ANSWER LINE mass = 0.0625 award 1 mark mass = 0.063 g to 2 sig figs award 2 marks moles $\text{CO}_2 = 15/24000$ OR 6.25×10^{-4} ✓ mass $\text{CaCO}_3 = (6.25 \times 10^{-4} \times 100) = 0.063$ g to 2 sig figs ✓	2	ALLOW ECF from first marking point
	b	i	$\text{CO}_3^{2-} + \text{H}_2\text{O} \rightleftharpoons \text{HCO}_3^- + \text{OH}^-$ OR $\text{CO}_3^{2-} + \text{H}_2\text{O} \rightleftharpoons \text{CO}_2 + 2\text{OH}^-$ ✓	1	ALLOW equilibrium signs IGNORE state symbols
		ii	CaCO_3 is less soluble / weaker base than Ca(OH)_2 ✓ so fewer OH^- (aq) ions are present (as Ca(OH)_2 reacts / CaCO_3 forms) ✓	2	
			Total	6	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
16	a	i	$\text{C}_5\text{H}_8\text{O}_2 + 6\text{O}_2 \rightarrow 5\text{CO}_2 + 4\text{H}_2\text{O}$ Correct molecular formula of GMV ✓ Balanced equation (with ECF) ✓	2	IGNORE state symbols
		ii	FIRST CHECK THE ANSWER ON THE ANSWER LINE ratio = 1 : 1.4 or more sig figs (1.395....) award 3 marks mass CO_2 per mole GMV = $5 \times 44 = 220 \text{ g}$ mass CO_2 per mole hexane = $6 \times 44 = 264 \text{ g}$ ✓ M_r values GMV 100; hexane 86 ✓ ratio $(220/100) : (264/86) = 1 : 1.40$ ✓	3	OR moles CO_2 per mole fuel ALLOW ECF from first marking point
		iii	Comparison of CO_2 is important as it is a greenhouse gas / contributes to global warming ✓ Should be CO_2 per kJ released on burning (AW) ✓	2	

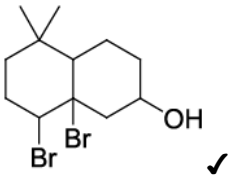
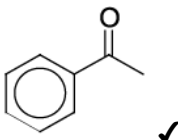
Mark Scheme

Question		Answer/Indicative content	Marks	Guidance
	b	<i>* Please refer to point 10 of the marking instructions of this mark scheme for guidance on how to mark this question.</i> Level 3 (5–6 marks) Candidate identifies the structure of the compound correctly, the evidence for this identification uses information from composition by mass AND IR spectrum AND proton NMR spectrum. <i>The identification is clear and logically structured. The evidence selected is relevant and fully supports the identification.</i> Level 2 (3–4 marks) Candidate identifies the compound as a keto-acid, the evidence for this identification uses information from composition by mass AND EITHER IR spectrum (both points) OR proton NMR spectrum OR using information from IR spectrum AND proton NMR spectrum. <i>The identification has a logical structure. The evidence selected is in the most-part relevant and supports the identification.</i> Level 1 (1–2 marks) Candidate makes an attempt at identifying the compound and the evidence to support this identification uses EITHER information from composition by mass OR IR spectrum OR proton NMR spectrum. <i>The identification is basic and communicated in an unstructured way. The evidence selected is limited and the relationship to the identification may not be clear.</i> 0 marks No response or no response worthy of credit.	6	Indicative scientific points may include: Compound is $\text{CH}_3\text{COCH}_2\text{CH}_2\text{COOH}$ Composition by mass: $\text{C}_5\text{H}_8\text{O}_3$ calculated. IR spectrum: - COOH from IR at 3200-3600 (no OH at 3200-3600/3640). Proton NMR: (any 3) 4 proton environments - peak at 10.5 indicates COOH - peaks at 2.2-2.7 indicate (three) Cs next to (a single) C=O - singlet at 2.2 indicates C with no Hs on adjacent carbons AND triplets at 2.6 and 2.8 indicate Cs with one adjacent CH_2.
		Total	13	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
17		i	$\text{Cu}^{2+} + 2\text{I}^- \rightarrow \text{CuI} + \frac{1}{2} \text{I}_2$ OR doubled ✓	1	IGNORE state symbols
		ii	copper(I) iodide ✓	1	ALLOW a gap between 'copper' and '(I)'
			Total	2	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
18	a	i		1	ALLOW any unambiguous formula clearly displaying the structure of the compound.
		ii	11 ✓	1	
		iii	two ✓ (because ambrinol has two) asymmetric carbon atoms / carbon atoms surrounded by 4 different groups ✓	2	
		iv	yes, because same bonds ✓ hence same vibrations ✓	2	ALLOW: no, based on analogy with named compound ✓ (e.g. carvone) for which enantiomers smell different ✓
	b		vanillin and guaiacol are phenols ✓ purple colour with FeCl_3 ✓ benzaldehyde and vanillin are aldehydes ✓ acid dichromate goes green OR Tollens' reagent OR AgNO_3 and NH_3 ... give silver (mirror) OR Fehlings solution gives red precipitate ✓	4	
	c		IR spectrum that shows how bonds vibrate ✓ Shows similarity between spectra of vanillin and combination of guaiacol and benzaldehyde (AW) ✓ C-H in arenes ✓	3	
	d	i	(atoms with) same atomic number AND different mass number ✓ 1 and 7 ✓	2	must mention both terms
		ii	12.01 ✓	1	
		iii	 all hydrogen atoms replaced with deuterium atoms ✓	2	Correct skeletal formula required. ALLOW 'H'/'proton' for 'hydrogen atom' and 'D' for deuterium atom To score, answer must state that all the atoms are replaced.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		iv	<i>* Please refer to point 10 of the marking instructions of this mark scheme for guidance on how to mark this question.</i> Level 3 (5–6 marks) Supporting evidence for Turin's theory AND evidence to discredit the lock and key theory have been correctly identified. There is a clear discussion related to both theories. <i>The evidence selected is relevant and substantiated. The discussion shows a well-developed line of reasoning for the choices of evidence, which is clear and logically structured.</i> <i>Candidate demonstrates a clear and confident knowledge of relevant technical language (names of compounds, 'deuterated', 'vibrate').</i> Level 2 (3–4 marks) Supporting evidence for Turin's theory AND evidence to discredit lock and key theory have been correctly identified although there is a limited attempt to discuss them. <i>The evidence selected is in the most-part relevant.</i> <i>The discussion has some structure but is limited in scope.</i> <i>Candidate demonstrates a sound grasp of technical language (one spelling error).</i> Level 1 (1–2 marks) Evidence for Turin's theory has been identified OR Evidence against lock and key theory <i>The information is supported by limited evidence and the relationship to the evidence may not be clear. The discussion is basic and communicated in an unstructured way.</i> <i>Candidate demonstrates a basic grasp of</i>	6	Indicative scientific points may include: Statements to support Turin's theory • deuterated acetophenone smells different (from non-deuterated form) • deuterated benzaldehyde smells different (from non-deuterated form) • because H and D have different masses and hence C–D and C–H vibrate differently • C¹² and C¹³ exchange does not affect smell, since masses only differ slightly • structures of deuterated acetophenone and benzaldehyde given. Statements to discredit Lock and Key • since structures are similar, lock and key theory would not predict difference (AW). • structurally related molecules can smell utterly different.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
			<i>relevant technical language (several spelling errors).</i> 0 marks No response or no response worthy of credit.		
			Total	24	
19		i	The $E^\ominus$ of $\text{CO}_2/(\text{COOH})_2$ half cell is more negative / less positive than that of the $\text{Fe}^{3+}/\text{Fe}^{2+}$ half cell $(\text{COOH})_2$ will release electrons / reduce Fe^{3+} OR Fe^{3+} will gain electrons / oxidise $(\text{COOH})_2$ ✓	2	ALLOW abbreviated descriptions of half cells as 'Fe^{3+}' etc (since there are only two of them) IGNORE 'greater than', 'less than'
		ii	$2\text{Fe}^{3+} + (\text{COOH})_2 \rightarrow 2\text{Fe}^{2+} + 2\text{CO}_2 + 2\text{H}^+$ species ✓ balancing with correct species ✓	2	
		iii	Fe^{2+} double arrow in one 3d box, single arrows (same direction) in the other 3d boxes. 4s box empty ✓ Fe^{3+} single arrows in all 3d boxes (same direction). 4s box empty ✓	2	
			Total	6	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
20	a	i	Boiling a mixture ✓ AND condensing / cooling the vapour to return it to the flask ✓	2	
		ii	Diagram showing a funnel with a filter paper above a perforated plate ✓ fitting into a flask or tube with a side arm ✓ indication of removal of air from the flask through the side arm ✓	3	ALLOW water flow through a tube connected to the side arm
		iii	Dissolve crystals in minimum of hot water ✓ Cool solution (to produce crystals) ✓ Filter off crystals AND wash with cold solvent ✓ Hexane-1, 6-dioic acid is more soluble in hot water than in cold water ✓	4	'Minimum' amount of water MUST be stated
		iv	FIRST CHECK THE ANSWER ON THE ANSWER LINE yield = 31% award 2 marks M_r (repeat unit) = 226 $n(\text{nylon-6, 6}) = 2.0 / 226 = 0.00885 \text{ (mol)} \checkmark$ $n(\text{hexane-1, 6-dioic acid}) = 0.40 / 146 = 0.00274 \text{ (mol)}$ $0.00274 / 0.00885 \times 100 = 31 \text{ (\%)} \checkmark$ OR theoretical yield of acid = $0.00885 \times 146 = 1.29 \text{ g}$ $\text{yield} = \frac{0.40}{1.29} \times 100 = 31 \text{ (\%)} \checkmark$	2	ALLOW ECF from first marking point ALLOW 31.0
	b		('Fishy smell' caused by) $\text{H}_2\text{N}(\text{CH}_2)_6\text{NH}_2 \checkmark$	1	
			Total	12	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
21	a	i	25 / 50 / 100 cm ³ measuring cylinder ✓	1	Capacity of measuring cylinder MUST be given DO NOT ALLOW pipette or burette or syringe
		ii	To allow hydrogen to escape ✓ To prevent air getting in (and oxidising Fe ²⁺ to Fe ³⁺) ✓	2	IGNORE to stop spray escaping
		iii	FIRST CHECK THE ANSWER ON THE ANSWER LINE percentage of iron = 98.1% award 4 marks Select appropriate titres $\frac{22.50 + 22.55 + 22.45}{3} = 22.50$ ✓ $n(\text{MnO}_4^-) = 22.50 \times \frac{0.02}{1000} = 0.00045$ (mol) ✓ $n(\text{Fe}^{2+})$ in 250 cm ³ = 0.00045 × 5 × 10 = 0.0225 (mol) ✓ % iron = $\frac{0.0225 \times 55.8}{1.28} \times 100 = 98.1\%$ % ✓	4	 ALLOW ECF from incorrect selection of data ALLOW 98% or 98.09%
	b	i	FIRST CHECK THE ANSWER ON THE ANSWER LINE concentration = 0.14 (g dm ⁻³) award 3 marks Mass of Mn = $\frac{2}{100} \times 0.25 = 0.005$ g ✓ $n(\text{KMnO}_4)$ in 100 cm ³ = $n(\text{Mn}) = 0.005 / 54.9 = 0.000091$ mol ✓ concentration of KMnO ₄ = 0.000091 × 158 × 10 = 0.14 (g dm ⁻³) ✓	3	 ALLOW ECF from first marking point ALLOW 0.144 (g dm ⁻³)
		ii	(Larger mass of KMnO ₄ dissolved so) smaller weighing error ✓	1	

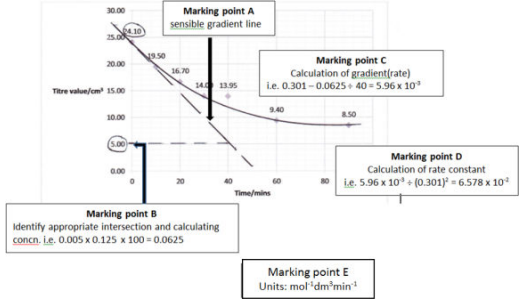
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		iii	<i>* Please refer to point 10 of the marking instructions of this mark scheme for guidance on how to mark this question.</i> Level 3 (5–6 marks) Applies knowledge of colorimetry to give a detailed step by step method to allow the production of suitable calibration curve over a suitable range of data. Detail about the dilutions and filters required will be included. <i>The method is detailed, clear and logically structured. The measurements are carefully considered to ensure the calibration curve covers the appropriate range.</i> Level 2 (3–4 marks) Applies knowledge of colorimetry to give steps which allow the production of a suitable calibration curve from the 2% Mn solution over a suitable range of data. <i>The method is suitable and in a logical order. Measurements are included to allow an appropriate calibration curve to be produced. Response may lack the fine details of dilution / appropriate filter.</i> Level 1 (1–2 marks) Applies knowledge of colorimetry to give a basic set of steps to produce a calibration curve from the 2% Mn solution. <i>The method is basic and unstructured. There is little or no detail in the description of steps</i> 0 marks No response or no response worthy of credit.	6	Indicative scientific points may include: Steps (italics indicate details that would differentiate higher level from lower level answers): • Dilute 2% Mn solution <i>using burettes and pipettes</i> • To include range 0.1 to 0.4% <i>includes volumes to achieve dilution (these could include 2 cm³ of 2% + 8 cm³ of water to give 0.4%, or details of a serial dilution,)</i> • Mix each dilution thoroughly <i>to ensure standard solution</i> • Makes a zero reading (on the colorimeter) <i>using water / base solvent</i> • Selects an appropriate filter / wavelength <i>chooses green-blue filter OR sets (spectrophotometer) to green-blue</i> • Measures absorbance of diluted solutions <i>ensure each sample is in a clean cuvette</i> • Plot absorbance against dilution <i>and draw line of best fit</i>
		iv	The line should be drawn through the zero–zero point ✓	1	
		v	0.17% ✓	1	ALLOW between 0.16 and 0.18%

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
	c	i	Titration 4 ✓ (because) it requires the smallest volume of KMnO_4 solution ✓	2	
		ii	The solution contains nitric acid / potassium iodate(VII) that would also oxidise Fe^{2+} ✓	1	ALLOW the solution contains other oxidising agents
	d		Use the solution in an electrochemical cell ✓	1	
			Total	23	
22	a	i	precipitation	1	
		ii	$+4 \quad -1 \quad +2 \quad 0$ 	2	reactants ✓ products ✓ ALLOW 1 mark if + signs omitted but is otherwise correct.
	b	i	Starch ✓ blue / black to white ✓	2	allow black allow colourless for white
		ii	FIRST CHECK THE ANSWER ON THE ANSWER LINE IF concentration = $1.3 \times 10^{-4} \text{ (mol dm}^{-3}\text{)}$ award 4 marks $10.50 \times (2.5 \times 10^{-6}) = 2.625 \times 10^{-5} \text{ mole thio}$ ✓ from $(2.625 \times 10^{-5} / 4) = 6.57 \times 10^{-6} \text{ mol of O}_2$ ✓ Conc. is $6.57 \times 10^{-6} \times 1000/50 = 1.314 \times 10^{-4} \text{ moldm}^{-3}$ ✓ concentration = $1.3 \times 10^{-4} \text{ (mol dm}^{-3}\text{)}$ to 2 sig figs (0.00013) ✓	4	
		iii	FIRST CHECK THE ANSWER ON THE ANSWER LINE IF concentration = 9.0 (ppm) award 2 marks mass of $\text{O}_2 = 2.8 \times 10^{-4} \times 32 = 8.96 \times 10^{-3} \text{ g in 1000g water}$ ✓ concentration = = 9.0 (ppm)	2	ALLOW 2 or more sf
			Total	11	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
23	a	i	substitution ✓ nucleophilic ✓	2	
		ii	heterolytic ✓	1	
	b	i	slow down reaction (so time for titration) ✓	1	ALLOW 'stop reaction' IGNORE quench
		ii	FIRST CHECK THE ANSWER ON THE ANSWER LINE IF initial concentration = 0.301(25) (mol dm ⁻³) award 2 marks 24.10 × 0.125 × 10 ⁻³ = 3.0125 × 10 ⁻³ mole of acid ✓ conc. of OH ⁻ = 3.0125 × 10 ⁻³ × 100 = 0.301(25) (mol dm ⁻³) ✓	2	ALLOW 2 or more sf
		iii	Two of; Rate = k[RBr][OH ⁻] Rate = k[RBr] ² Rate = k[OH ⁻] ² ✓	1	
		iv	(A) curve drawn with gradient line cutting y axis at t = 0 ✓ (B) concentration calculated at appropriate intercept with y axis see scan ✓ (C) calculating gradient(rate) = difference in concentration ÷ 40 ✓	3	ALLOW ECF from part ii Graph scan 
		v	(D) correct substitution in k = rate ÷ (0.301) ² and evaluation ✓ (E) correct units mol ⁻¹ dm ³ min ⁻¹ ✓	2	

Mark Scheme

Question		Answer/Indicative content	Marks	Guidance
	c	* Please refer to point 10 of the marking instructions of this mark scheme for guidance on how to mark this question. Level 3: 5–6 marks Learners demonstrate knowledge and understanding of the method with an explanation of the steps followed AND Learners describe some of the observations AND Learners suggest a sound conclusion. <i>The ideas are logical and well-structured providing significant clarity in the communication of the science.</i> Level 2: 3–4 marks Learners demonstrate knowledge and understanding of the method with some explanation of the steps followed AND EITHER Learners describe some of the observations OR Learners suggest a sound conclusion. <i>There is partial structuring of the ideas with the communication of the science generally clear.</i> Level 1: 1–2 marks Learners demonstrate knowledge and understanding of the method with no explanation of the steps followed AND EITHER Learners describe some of the observations OR Learners suggest a sound conclusion. <i>The ideas expressed are poorly structured and do not contribute to the communication of the science.</i> Level 0: (no marks) <i>No response or no response worthy of credit.</i>	6	Expected chemical / practical points include: Method • dissolve halogenoalkanes in ethanol in test tubes • stand in beaker of hot water • add solution of silver nitrate • start timing Explanation of steps ➤ ethanol – co-solvent / halogeno's don't dissolve in water ➤ hot water needed reaction too slow in cold ➤ equal amounts / volumes of reactant for 'fair test' Observations • precipitate forms / tubes go cloudy • note time on first appearance Explanation of observations ➤ precipitates caused by halide ions reacting with silver ions / formation of insoluble silver halides ➤ colours and equations Conclusion ➤ shorter time means faster rate • rate of hydrolysis in order iodo(fastest), bromo and chloro. ➤ bond strengths increase in above order

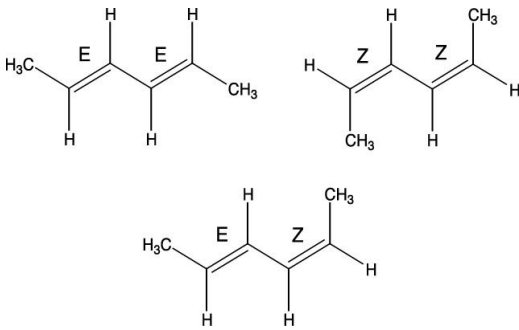
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
			Total	18	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
24	a		moles of C_6H_{10} in 100 g = $100/82.0 = (1.22) \checkmark$ bromine number = $100/82.0 \times 2 \times 159.8 = 390 \checkmark$	2	ECF ALLOW M_r for bromine = 160 IGNORE g units with answer Examiner's Comments Most candidates correctly calculated the moles of C_6H_{10} but many of these were unable to convert this into the bromine number. (390)
	b	i	Method 1 MOLES moles of $BrO_3^- = 0.005$ AND moles of $Br^- = 0.0167 \checkmark$ to be in excess moles of BrO_3^- has to be $> (0.0167/5 =) 0.00334 \text{ mol dm}^{-3} \checkmark$ Method 2 CONCENTRATIONS $[BrO_3^-] = 0.0250$ AND $[Br^-] = 0.0835 \checkmark$ to be in excess $[BrO_3^-]$ has to be $> (0.0835/5 =) 0.0167 \text{ mol dm}^{-3} \checkmark$	2	must have words as well as numbers for 2nd mark Examiner's Comments Generally well attempted by a variety of methods but many not using words to explain their calculation and subsequent understanding.
		ii	moles of Br^- (forming Br_2) = $0.167 \times 100 / 1000$ or $(0.0167) \checkmark$ moles of Br_2 reacted with 10 g sample = $0.0167 \times 3/5 \checkmark$ $\times 82/200 \checkmark = (0.00411)$ mass of Br_2 reacted with 10 g sample = $0.0167 \times 3/5 \times 82/200 \times 159.8 = (0.656 \text{ g}) \checkmark$ bromine number = $0.0167 \times 3/5 \times 82/200 \times 159.8 \times 10 = 6.56 = 7 \checkmark$	5	Alternative method: moles of Br_2 formed in reaction in $200 \text{ cm}^3 = 0.0167 \times 3/5 = (0.01002) \checkmark$ $[Br_2] = 0.0167 \times 3/5 \times 5 = (0.501) \checkmark$ moles of Br_2 used in adding to sample = $0.501 \times 82/1000 = 0.0411 \checkmark$ mass of Br_2 added to 10.0 g sample = $0.0411 \times 159.8 = (6.56) \text{ g} \checkmark$ bromine number = 7 $\checkmark$ ECF throughout calculation IGNORE g units with answer $\checkmark$ Examiner's Comments Only the most able scored full marks with their working often clearly presented. The majority usually got off on the wrong foot, calculating moles of the C_6H_{10} and thereafter losing their way Some ignored the request for a whole number. (7).

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
	c	i	restrictive rotation about C=C bonds ✓ two different atoms / groups attached to both carbon atoms of the C=C bond ✓	2	ALLOW C=C bonds cannot rotate ALLOW 'lack of free rotation' NOT just 'double bonds' IGNORE functional Examiner's Comments Well understood, although some asymmetric carbons were still in evidence.
		ii	1 mark for each correct isomer provided no more than 3 ✓✓✓ 1 mark for labels drawn correctly on the 3 correct structures ✓ 	4	extra structures are each CON to one isomer mark already scored (watch out for E-Z and Z-E which is a CON) ALLOW skeletal structures Examiner's Comments Some very good attempts but only the best gained full marks. Frequently E / Z and Z / E isomers were both included. Labelling was often good though some just focused on drawing structural formulae for molecules with one C=C bond and hence only one label.
	d		atoms / transition metals (on surface) can use d (and s) electrons / subshell / orbital(s) ✓ to form (weak) bonds to / interactions with reactants ✓ providing a route of lower E_a ✓	3	IGNORE orbital numbers ALLOW chemisorption BUT NOT adsorption Examiner's Comments Many began by unnecessarily filling up the answer space by explaining the phrase 'heterogeneous catalyst'. Further discussion either involved a catalytic theory based on an intermediate or variable oxidation states. Candidates often managed the final mark for lowering the activation enthalpy.
			Total	18	

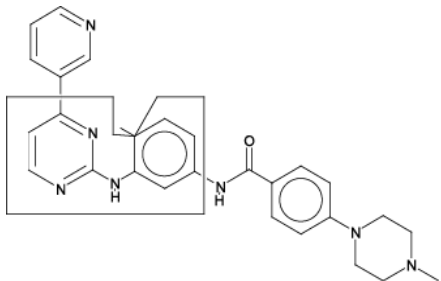
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
25	a		moles $\text{CaCl}_2 = 58.5/111.1$ or $0.527\checkmark$ lowering of fpt for $\text{CaCl}_2 = 3.7 \times 0.527 \times 1.5 (= 2.9)$ so fpt is -2.9°C multiplication by 1.5 $\checkmark$ rest $\checkmark$	3	Allow ecf from mpts 1 to 2 <i>without reference to working:</i> -2.9 on answer line scores 3 2.9 scores 2 $-1.9(48....)$(or -1.95) scores 2 1.9 etc scores 1 ALLOW slightly different values after checking any intermediate rounding ALLOW 2 or more significant figures Examiner's Comments Some candidates worked out the moles of CaCl_2, multiplied this by 1.5 to get moles of particles and then by 3.7 to get the depression. A common error was to omit the factor of 1.5. Others got the M_r ratio up the wrong way.
	b	i	$\text{CaCO}_3 + 2\text{NaCl} \rightarrow \text{Na}_2\text{CO}_3 + \text{CaCl}_2 \checkmark\checkmark$	2	Unbalanced equation with just these species OR <i>Balanced</i> equation involving CaO, CO_2 instead of CaCO_3 scores 1 mark IGNORE state symbols IGNORE omission of plus signs or arrow if meaning is clear Examiner's Comments Most managed to unravel the equations given to get the overall equation for the reaction between calcium carbonate and sodium chloride to give sodium carbonate and calcium chloride.
		ii	Atom economy 100% AND No waste or both products useful$\checkmark$	1	Examiner's Comments This was another high-scoring question with most candidates spotting that it was 100% atom economy and that this resulted in no waste. Comments like 'little waste' did not score.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
	c		sodium hydrogencarbonate ✓ ammonium chloride ✓	2	allow 'sodium hydrogen carbonate' and (l) after sodium (but not ammonium) Examiner's Comments A gratifyingly large number of candidates could name sodium hydrogencarbonate and ammonium chloride. Occasional errors were to put oxidation states after the carbonate or the ammonium.
	d		Entropy is a measure of disorder or number of ways of arrangement/distribution of molecules/particles/energy quanta ✓ (more) gas formed has more/higher entropy/disorder/ways of arrangement ✓	2	ALLOW 'disorder' or 'ways of arrangement' for 'entropy' NOT arrangement of a molecule IGNORE 'more molecules formed' needs to be mention of gas formed and it having higher/more entropy Examiner's Comments Defining entropy presented few problems. Many spotted that a gas was evolved but fewer clearly stated that gases had higher entropy than solids.
	e		$\Delta S_{\text{sys}} = (+) 215 \text{ (J K}^{-1} \text{ mol}^{-1})$ ✓ $T = \Delta H / \Delta S_{\text{sys}}$ OR $T = 91000/215$ ✓ $T = (+)423 \text{ (K)}$ ✓	3	ALLOW ecf from each step Second marking point can subsume first ALLOW two or more significant figures Negative answers do not score the third marking point even if they follow by ecf. If 423 shows in working but 424 given, mark can be awarded. Correct answer on answer line scores 3 marks Examiner's Comments This calculation was often done correctly. Negative answers scored few marks.
			Total	13	

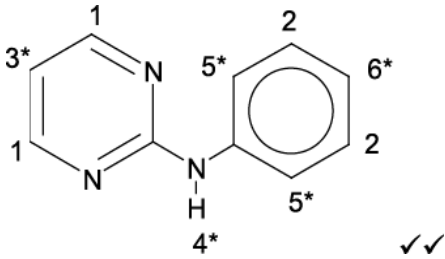
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
26	a		the N atoms hydrogen bond (to water)	1	Examiner's Comments Most realised that hydrogen bonding was the key but not all mentioned the nitrogen atoms in this context.
	b	i		1	ALLOW lines cutting bonds to do so anywhere on the bond. Examiner's Comments Many circled the correct structure, omitting the methyl group, which was impressive. Including the methyl group was the common error.
		ii	<i>shape</i>: it has correct shape/ similar shape to substrate/ complementary shape to the enzyme/active site ✓ <i>binds</i>: to fit into/binds/bonds with active site ✓ <i>blocking</i>: blocking it to <u>substrate</u>/competing with <u>substrate</u> AW → C: C fits into one/fewer enzyme(s) OR resembles the substrate more/ fits/binds better OR forms more/stronger imb AW ✓	4	QWC: word 'substrate' must be used and spelled correctly to score third marking point. This must be comparative can score first mark here Examiner's Comments There were some good, well expressed, answers here. Many stated that the pharmacophore had the same shape as the substrate and thus fitted into the active site of the enzyme, competing with the substrate. C fitted better which made it more specific. Some omitted reference to shape or said that the shape was complementary to the substrate or the same as the active site. Many wrote that C had an extra methyl group without further detail.

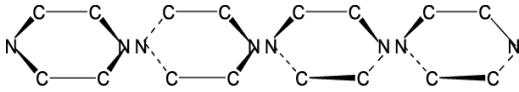
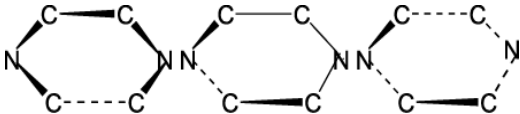
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
	c	i	conc nitric and sulfuric acids ✓ (below) 55 °C ✓	2	ALLOW formulae. 'Conc'/'concentrated'/'c.' must be mentioned once somewhere 'reflux' is CON Mark separately Examiner's Comments Most gave concentrated nitric and sulfuric acids and below 55°C. The commonest error was to omit the 'conc'.
		ii	tin and concentrated/conc hydrochloric acid	1	IGNORE formulae IGNORE 'hydrogen chloride' Examiner's Comments This was another 'read the question' moment. The question asked for 'names' but many gave formulae. The question was asking candidates to interpret the formulae on the Data Sheet.
		iii	(secondary) amide ✓ C ₆ H ₅ COCl ✓ benzoyl chloride ✓	3	ALLOW C₆H₅CO-O-COC₆H₅ ALLOW molecular formulae and any type of structural formula ecf: Name can match formula but only for benzoic anhydride or benzoic acid. Examiner's Comments Most knew 'amide' and many thought erroneously that the reagent was benzoic acid. 'Error carried forward' was available for the name, but many got it wrong. The correct reagent was benzoyl chloride and few got this and even fewer got both name and formula.
	d	i	C ₁₀ H ₉ N ₃	1	ALLOW elements in any order Examiner's Comments Most got this correct (C₁₀H₉N₃).

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		ii		2	Asterisked numbers can be transposed two marks for completely correct; <i>one mark if:</i> '5' and '5' shown as the same (NOT 1) and different from others on right-hand ring and '4' shown as an unique no. OR all correct except for the omission of a number on the NH ALLOW '4' above N Examiner's Comments A few candidates correctly worked out that there were six peaks and labelled the structure correctly. Those who thought that there were three equivalent protons on each ring were often able to gain partial credit through the mark-scheme.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
	e		109 (⁰) ✓ pyramidal ✓ 4 groups/pairs of electrons/ 4 areas of electron density ✓ (electrons) repel and get as far away from each other as possible ✓ diagram of either chair or boat or 3D structure (wedges and dashes) ✓ eg award the mark to: 	5	ALLOW 105 – 110 IGNORE 'trigonal', 'triangular' and 'tetrahedral' no ecf from angle on 3rd mark. QWC Do not award third mark if angle incorrect ALLOW 'minimise repulsion' IGNORE 'repel as much as possible' Examples shown are not exhaustive. Four adjacent atoms connected by the same three symbols is incorrect (no mark) eg:  IGNORE CH₃ groups on nitrogen or hydrogens or lone pairs or bond angles Examiner's Comments This was well answered though most got the correct angle of 109° caused by four areas of electron density, fewer realised that the shape around the nitrogen atoms was pyramidal, not tetrahedral. The diagram clearly took candidates out of their comfort zone but many who attempted it got an acceptable structure.
	f		Each atom in the ring contributes one electron ✓ electrons delocalised ✓ two rings of electrons above and below ring (of atoms)/ plane/atoms/ molecule ✓	3	ALLOW N atoms contribute two/lone pair electrons must make it clear there are two rings Examiner's Comments Most realised that they were basically describing benzene. Almost all said 'delocalised' and many said 'two rings above and below the plane of the C-N ring'. There were again problems of communication, for example 'a ring, above and below...'. Some realised that each C and N atom contributed one electron.
			Total	23	

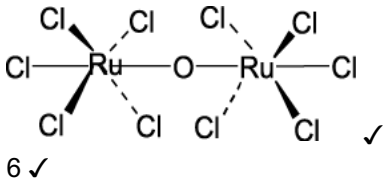
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
27	a		add until no more fizzing ✓ filter ✓ evaporate and allow to crystallise ✓ filter (or pick out crystals) and dry ✓	4	ALLOW until no more dissolves
	b	i	$\text{SrCO}_3(\text{s}) + 2\text{HCl}(\text{aq}) \rightarrow \text{SrCl}_2(\text{aq}) + \text{H}_2\text{O}(\text{l})$ equation ✓ state symbols ✓	2	ALLOW state symbol mark if formulae or balancing wrong but no species is missing or extra.
		ii	FIRST CHECK THE ANSWER ON ANSWER LINE If answer = 7.4 (g) award 2 marks amount HCl = $2 \times 50/1000$ OR $0.1(0)$ ✓ mass $\text{SrCO}_3 = (0.1 \times 147.6 \times 0.5) = 7.4$ (g) ✓	2	ALLOW ecf from first mark to second or from wrong formula for SrCO_3 in (b)(i) ALLOW 2 or more sf
	c	i	Heat, cool (in desiccator), weigh, ✓ Repeat until mass constant ✓	2	
		ii	FIRST CHECK THE ANSWER ON ANSWER LINE If answer = 6 award 4 marks amount AgCl = $2.16/143.4$ OR 1.506×10^{-2} ✓ amount $\text{SrCl}_2 = 0.5 \times 2.16/143.4$ OR 7.531×10^{-3} ✓ $M_r \text{SrCl}_2 \cdot x\text{H}_2\text{O} = (2/7.531 \times 10^{-3}) = 266$ ✓ $x = ((266 - 158.6)/18) = 6$	4	ALLOW ecf Second mark subsumes first OR mass $\text{SrCl}_2 = 7.531 \times 10^{-3} \times 158.6$ (or 1.19g) and mass $\text{H}_2\text{O} = 2 - 1.19 = 0.81$ g ✓ $(0.81/18) = 0.045 / (1.19/158.6) = 0.0075 = 6$ ✓
		iii	Solubility of silver chloride = $\sqrt{K_{sp}} = 1.4 \times 10$ (mol dm ⁻³) ✓ Moles in 200 cm ³ 3×10^{-6} which is negligible compared with 1.5×10^{-2} ✓	2	OR compare masses 4×10^{-4} g with 1.19g
		iv	$(36 \times 100/194.6) = 18.5$ or 18(%) ✓	1	ALLOW more sf
			Total	17	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
28	a		$C_3H_8O_3 \rightarrow C_3H_4O + 2H_2O$ one organic molecular formula correct ✓ completely correct ✓	2	
	b	i	$ \begin{array}{c} \text{H} \quad \text{H} \quad \text{Cl} \\ \quad \quad \\ \text{H}-\text{C}=\text{C}-\text{C} \\ \quad \quad \quad \\ \quad \quad \quad \text{O} \end{array} $ ✓	1	
		ii	SOCl_2 ✓ NH_3 ✓	2	ALLOW 'thionyl chloride' or 'sulfur dichloride oxide' ALLOW 'ammonia' Mark separately
		iii	FIRST CHECK THE ANSWER ON ANSWER LINE If answer = 14 (g) award 2 marks amount acrolein = $0.55 \times 100 / (3 \times 71)$ OR 0.258 mol ✓ mass acrolein = $0.258 \times 56 = 14$ (g) (2 sf) ✓	2	14.5 or 14.46... score 1 mark
			Total	7	
29		i	FIRST CHECK THE ANSWER ON ANSWER LINE If answer = -3.72 ($^{\circ}\text{C}$), to 2 or more sf, award 2 marks particles per $\text{dm}^3 = 2.00$ ✓ $\text{fpt} = 2 \times 0.1 \times 18.6 = -3.72$ ($^{\circ}\text{C}$) ✓	2	ALLOW ecf
		ii	mass of $\text{CaCl}_2 = 56$ g ✓ Uncertainties in mass and volume are: 56 ± 0.5 AND 1% OR 2sf AND 1000 ± 10 AND 1% OR 2sf OR 3 sf✓ Uncertainty in temp $0.5 \times 100 / 3$ AND 17% OR 1sf, so least precise/biggest uncertainty ✓	3	ALLOW 56 ± 01 AND 2% ALLOW ecf from first marking point ALLOW 1.0 ± 0.05 AND 5% to score last mark, comparisons must all be in %s or all in sf ALLOW ecf in statement of which is least precise/uncertain
			Total	5	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
30	a	i	froth/detergent flotation AND matte ✓	1	
		ii	$\text{NiS} + \text{H}_2\text{SO}_4 \rightarrow \text{NiSO}_4 + \text{H}_2\text{S}$ OR $\text{CuS} + \text{H}_2\text{SO}_4 \rightarrow \text{CuSO}_4 + \text{H}_2\text{S}$	1	IGNORE state symbols
		iii	electrolysis	1	
	b	i	high melting AND unreactive	1	
		ii	$2\text{CO} + 2\text{NO} \rightarrow \text{N}_2 + 2\text{CO}_2$	1	ALLOW halves or multiples IGNORE state symbols
	c		4d^6	1	
	d	i		2	ALLOW bridging oxygen bonding in axial or equatorial positions IGNORE brackets and charges.
		ii	square planar OR tetrahedral	1	
	e		R_2NH_2^+ ✓ 3 + balances 3– (AW) ✓	2	
	f		$10^7 - 10^{10}$ or any value in that range ✓	1	
	g		$[\text{Cu}(\text{H}_2\text{O})_6]^{2+} + 4\text{NH}_3 \rightarrow [\text{Cu}(\text{NH}_3)_4(\text{H}_2\text{O})_2]^{2+} + 4\text{H}_2\text{O}$ ✓ (light)blue dark blue/violet/purple/mauve ✓	2	ALLOW $[\text{Cu}(\text{H}_2\text{O})_6]^{2+} + 6\text{NH}_3 \rightarrow [\text{Cu}(\text{NH}_3)_6]^{2+} + 6\text{H}_2\text{O}$ IGNORE state symbols
	h		Wrong: d subshells still split ✓ Ag^+ is d^{10} OR Ag has full d subshell ✓ so no movement possible (AW) ✓	3	

Mark Scheme

Question		Answer/Indicative content	Marks	Guidance
	i	<i>*Please refer to the marking instructions on page 4 of this mark scheme for guidance on how to mark this question.</i> Level 3 (5–6 marks) Describes in detail the methods of extraction and gives chemical details from the article of all three compounds. <i>There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.</i> Level 2 (3–4 marks) Describes in detail the methods of extraction of all three compounds AND Gives the chemical details from the article for either Pd, Pt or Os <i>There is a line of reasoning presented with some structure. The information presented is relevant and supported by some evidence.</i> Level 1 (1–2 marks) Outlines the methods of extractions for of all three compounds AND Gives the chemicals details from the article for either Pd, Pt or Os. OR Describes in detail the method of extraction for one of the compounds and gives chemical details from the article concerning this compound. <i>The information is basic and communicated in an unstructured way. The information is supported by limited evidence and the relationship to the evidence may not be clear.</i> 0 marks No response or no response worthy of credit	6	Indicative Scientific points include: Description of extraction of Pd: - extracted by ligand exchange - followed by dissolving in organic solvent Chemical details from article concerning Pd: - equation, eg $[\text{Pd}(\text{H}_2\text{O})_6]^{2+}(\text{aq}) + 4\text{Cl}^-(\text{aq}) \rightarrow [\text{PdCl}_4]^{2-}(\text{aq}) + 6\text{H}_2\text{O}(\text{l})$ - this reaction is much slower for other PGMs Description of extraction of Pt: - anion exchange - reacted with $\text{R}_2\text{NH}_2^+ \text{Cl}^-$. Chemical details from article concerning Pt: $2[\text{R}_2\text{NH}_2^+ \text{Cl}^-] + [\text{PtCl}_6]^{2-}(\text{aq}) \rightleftharpoons (\text{R}_2\text{NH}_2^+)_2 [\text{PtCl}_6]^{2-} + 2\text{Cl}^-$ $(\text{R}_2\text{NH}_2^+)_2 [\text{PtCl}_6]^{2-}$ is soluble in organic solvents whereas the equivalent salts of other PGMs have lower solubility. Description of extraction of Os: - oxidation - oxide volatile and can be removed by heating Chemical details from article concerning Os: - oxidised to OsO_4 - may be mixed with RuO_4
		Total	23	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
31		i	FIRST CHECK THE ANSWER ON ANSWER LINE If answer = 50.5(0) – 51.0 (%) award three marks Correct use of masses from table for both phenol used (5.02 g) and phenyl benzoate formed (5.34 g) ✓ Correct calculation for moles used(0.0534) and hence mass for 100% conversion (moles × 198) = 10.57 ✓ Correct % yield calculation $5.34 \div 10.57 \times 100 = 50.50(\%)$ ✓	3	ALLOW ecf's after first step ALLOW three or more sf ALLOW moles of phenol used (0.0534) and moles of phenyl benzoate formed = $5.34/198$ OR 0.0270 % yield (= $0.0270/0.0534 \times 100$) = 50.56% evaluated
		ii	ANY one of: Reaction did not go to completion/incomplete reaction Loss of solid in transfer between apparatus AW ✓	1	ALLOW side reactions occur/ by-products formed ALLOW specific side reactions e.g. benzoyl chloride formed benzoic acid in the water solvent/ benzoate ions in the alkaline conditions
		iii	Melts over temperature range/Lower mp indicates presence of impurities / very close to literature value so level of impurities small AW ✓	1	ALLOW statements such as 'sharpness (small range) suggests near purity'
			Total	5	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
32	a	i	Reduce heat exchange/AW with surroundings	1	DO NOT ALLOW reduce heat loss/gain on own IGNORE insulation
		ii	More energy used in breaking A-A (and B-B) bonds than 'given back' when A-B bonds form ✓ This suggests A-B bonds are weaker than A-A (and B-B) bonds ✓	2	
		iii	Intermolecular bonds broken and made all of similar strength/A-A,B-B,A-B imbs have similar strength✓	1	
	b	i	FIRST CHECK THE ANSWER ON ANSWER LINE If both answers = 12 (cm ³) award three marks Mass of each liquid = 0.15 × M _r (trichloromethane = 17.9(25); methyl ethanoate = 11.1) ✓ Vol = mass ÷ density (17.925 ÷ 1.48 = 12.11; 11.1 ÷ 0.93 = 11.9) ✓ Appropriate sig figs(2) ... = 12 (cm ³) and 12 (cm ³)✓	3	
		ii	Burette	1	ALLOW graduated pipette
		iii	FIRST CHECK THE ANSWER ON ANSWER LINE If answer = 2.9(...) or 3 (kJmol ⁻¹) award three marks E = m × c × ΔT for each (trichloromethane 17.925 × 0.96 × 11.0 = 189.2(88)J) (methyl ethanoate 11.1 × 2.10 × 11.0 = 256.4(1)J) ✓ Total energy transfer (189.2(88) + 256.4(1) = 445.6(98)J ✓ per mole (of H-bond) = 445.6(98) ÷ 0.15 = 2971.3(2)Jmol ⁻¹ = 2.9/3(kJmol ⁻¹) ✓	3	
			Total	11	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
33	a	i	did not mix/invert sulfamic acid solution ✓ solution more concentrated at bottom ✓	2	
		ii	FIRST CHECK THE ANSWER ON ANSWER LINE If answer = $0.087 \text{ (mol dm}^{-3}\text{)}$ award four marks takes average of two concordant results (= 21.825)✓ calculates moles of hydroxide (= 2.183×10^{-3})✓ uses eqn to determine moles of acid (= 2.183×10^{-2}) ✓ calculates concn. (i.e. mol per dm^3) to 2sig figs = $0.087 \text{ (mol dm}^{-3}\text{)}$ ✓	4	
		iii	solid absorbs water so mass/ concentration of sodium hydroxide actually dissolved is less✓ titre value therefore greater giving high result ✓	2	
	b	i	FIRST CHECK THE ANSWER ON ANSWER LINE If answer = $98.6/99$ award four marks moles of CO_2 produced $146/24000 = 6.083 \times 10^{-3}$ ✓ uses eqn. to determine moles of acid (above ans. $\times 2$) = 1.217×10^{-2} ✓ 1.217×10^{-2} moles = 1.20g ✓ scales mass up to give mass of 1 mole of acid i.e. $1.20/1.217 \times 10^{-2} = 98.6(03)\text{g}$ ✓	4	
		ii	$1/146 \times 100 = 0.68(\dots)/0.7 \text{ (%)}$ ✓	1	DO NOT ALLOW ecf's
		iii	some of gas lost when putting on bung OR some of gas dissolves	1	
			Total	14	
34			B	1	
			Total	1	
35			C	1	
			Total	1	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
36	a	i	$\text{Cl}_2 + 2\text{Br}^- \rightarrow 2\text{Cl}^- + \text{Br}_2$ ✓ Chlorine is the oxidising agent: it gains electrons OR oxidation state lowered ✓	2	ALLOW reference to oxidation state of Br increasing or Cl decreasing
		ii	FIRST CHECK THE ANSWER ON THE ANSWER LINE If the answer = 93.6 award 3 marks Moles of Cl^- ions/dm ³ : $208/35.5 = 5.86$ ✓ Moles of Br ions/dm ³ : $5/79.9 = 0.0626$ ✓ Ratio $5.86/0.0626 = 93.6$ ✓	3	ALLOW 2 or more significant figures ALLOW in moles per 100 cm ³
		iii	Bromine is toxic OR volatile ✓	2	ALLOW poisonous DO NOT ALLOW harmful
	b		$2\text{HBr} + \text{H}_2\text{SO}_4 \rightarrow \text{Br}_2 + \text{SO}_2 + 2\text{H}_2\text{O}$ ✓ $8\text{HI} + \text{H}_2\text{SO}_4 \rightarrow 4\text{I}_2 + \text{H}_2\text{S} + 4\text{H}_2\text{O}$ ✓	2	ALLOW '1' instead of no number in front of H ₂ SO ₄ etc.
			Total	8	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance																				
37	a		Titrate the equilibrium mixture with alkali/NaOH of known concentration (to find total moles of acid) ✓ Subtract moles of (H ₂ SO ₄) catalyst ✓	2																					
	b		FIRST CHECK THE ANSWER ON THE ANSWER LINE If answer = 3.61 award 4 marks <table><tr><th>Sub-stance</th><th>Mass at start</th><th>Amount present at the start</th><th>Amount present at equilibrium</th></tr><tr><td>ethanol</td><td>15.8</td><td>15.8/46 (= 0.343)</td><td>(0.343 – [0.35 – 0.123]) = 0.116</td></tr><tr><td>ethanoic acid</td><td>21.0</td><td>21.0/60 (= 0.35(0))</td><td>0.123</td></tr><tr><td>ethyl ethan-oate</td><td>0</td><td>0</td><td>[0.35–0.123 =] 0.227</td></tr><tr><td>Water</td><td>0</td><td>0</td><td>0.227</td></tr></table> One mark for both amounts at start ✓ One mark for amount of ethanol at equilibrium ✓ One mark for amounts of ester and water at equilibrium ✓ $K_c = 0.227^2 / (0.123 \times 0.116) = 3.61$ ✓	Sub-stance	Mass at start	Amount present at the start	Amount present at equilibrium	ethanol	15.8	15.8/46 (= 0.343)	(0.343 – [0.35 – 0.123]) = 0.116	ethanoic acid	21.0	21.0/60 (= 0.35(0))	0.123	ethyl ethan-oate	0	0	[0.35–0.123 =] 0.227	Water	0	0	0.227	4	ALLOW ecf throughout ALLOW other answers (to 2 or more sf) by using various rounding during calculation.
Sub-stance	Mass at start	Amount present at the start	Amount present at equilibrium																						
ethanol	15.8	15.8/46 (= 0.343)	(0.343 – [0.35 – 0.123]) = 0.116																						
ethanoic acid	21.0	21.0/60 (= 0.35(0))	0.123																						
ethyl ethan-oate	0	0	[0.35–0.123 =] 0.227																						
Water	0	0	0.227																						
	c		 <chem>CCC(=O)OC</chem> ✓	1	ALLOW any unambiguous structure IGNORE brackets or 'n'																				
	d		Methyl propanoate AND methanal ✓	1																					

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance								
	e		FIRST CHECK THE ANSWER ON THE ANSWER LINE If answer = (+)666(K) award 3 marks $\Delta S_{\text{sys}} = (+) 154.7 \text{ (J K}^{-1} \text{ mol}^{-1}) \checkmark$ $T = \Delta H / \Delta S_{\text{sys}}$ OR $T = 103000 / 154.7 \checkmark$ $T = (+)666 \text{ (K)} \checkmark$	3									
	f		<table border="1"><tr><td>Change</td><td>Increase d temper ature</td><td>Increase d pressure</td><td>Use of a catalyst</td></tr><tr><td>Effect on K_c</td><td>Increase</td><td>No change</td><td>No change</td></tr></table> $\checkmark \checkmark$	Change	Increase d temper ature	Increase d pressure	Use of a catalyst	Effect on K_c	Increase	No change	No change	2	All 3 correct 2 2 correct 1
Change	Increase d temper ature	Increase d pressure	Use of a catalyst										
Effect on K_c	Increase	No change	No change										
	g		FIRST CHECK THE ANSWER ON THE ANSWER LINE If answer = 4390(dm ³) award 3 marks Unit conversion, $n = 25000 / 142$, $p = 150000$, $\checkmark$ Use of $pV = nRT$ and 50% yield, $V = 0.5 \times 25000 \times 8.314 \times 900 / 142 \times 150000 \checkmark$ Evaluation and conversion to dm ³ 4390 $\checkmark$	3	ALLOW 2 or more sf								
	h		Allows reaction to occur at lower temp AND less energy used $\checkmark$	1									
			Total	17									

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
38	a		FIRST CHECK THE ANSWER ON THE ANSWER LINE If answer = 18.7(kg) award 3 marks Moles Mefenamic acid required = $15000/241$ (= 62.24) ✓ Moles 2-clorobenzoic acid needed = ans to 1st point $\times 100/52$ (=119.69) ✓ Mass 2-clorobenzoic acid needed = ans to 2nd point $\times 156.5/1000$ = 18.7 (kg) ✓	3	ALLOW ecf throughout ALLOW 2 or more sf
	b		<i>*Please refer to the marking instructions on page 4 of this mark scheme for guidance on how to mark this question.</i> Level 3 (5–6 marks) Describes the appearance of the infrared and mass spectra in detail. AND Clearly explains how mol mass, fragmentation and fingerprint region confirm identity. <i>There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.</i> Level 2 (3–4 marks) Describes the appearance of the infrared. OR Describes the appearance of the mass spectra in detail. AND Clearly explains how mol mass, fragmentation and fingerprint region confirm identity. <i>There is a line of reasoning presented with some structure. The information presented is relevant and supported by some evidence.</i> Level 1 (1–2 marks) Describes the appearance of the infrared. OR Describes the appearance of the mass	6	Indicative scientific points may include: Absorbances on Infrared: • About 3300-3500 N-H amines • 2500-3300 O-H carboxylic acid • 1700-1725 C=O carboxyl ic acid • 1450-1650 several peaks Arenes • 3000-3100 C-H arenes • About 2850-2950 C-H alkyl groups Mass spectrum peaks • Molecular ion peak at 241 (allow ecf from (c)) • suggestion of a fragment (eg 196 – COOH missing) Identification of structure: • Fingerprint region unique to compound • Compare with database to confirm identity • Molecular ion gives relative molecular mass which matches that of mefenamic acid. • Fragments consistent with functional groups present

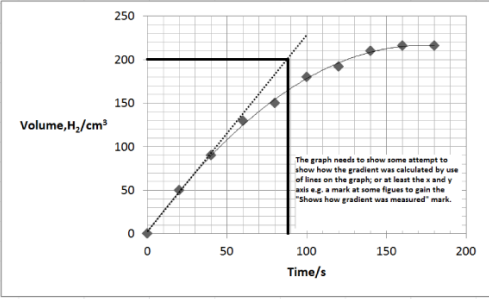
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
			spectra. OR Clearly explains how mol mass, fragmentation and fingerprint region confirm identity. <i>The information is basic and communicated in an unstructured way. The information is supported by limited evidence and the relationship to the evidence may not be clear.</i> 0 marks No response or no response worthy of credit		
			Total	9	
39		i	FIRST CHECK THE ANSWER ON THE ANSWER LINE If answer = $5.47 \times 10^{-6} \text{ mol}^3 \text{ dm}^{-9}$ award 4 marks Mean titre = 13.90 (exclude trial and anomaly)✓ Concentration of OH^- = $13.90 \times 0.04/25 = 0.02224 \text{ mol dm}^{-3}$✓ Concentration of Ca^{2+} is therefore $0.02224/2 = 0.01112 \text{ mol dm}^{-3}$✓ $K_{\text{sp}} = 0.0111 \times 0.0222^2 = 5.47 \times 10^{-6}$ AND units $\text{mol}^3 \text{ dm}^{-9}$✓	4	ALLOW answers that round to 5.5×10^{-5}
		ii	Titre would be (much) lower as magnesium hydroxide is less soluble ✓	1	
			Total	5	

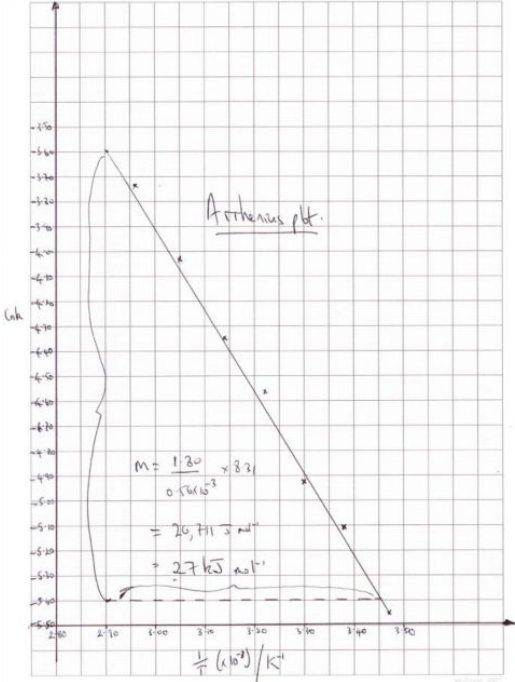
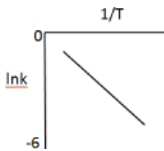
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
40	a	i	Any one of: ✓ - amount / mass of Mg remains constant - only changes in acid concentration affect rate - surface area of magnesium is constant	1	ALLOW Because it is the limiting reactant DO NOT ALLOW 'fair test' / <i>to keep the variables the same</i> Examiner's Comments This question was straightforward but candidates should be made aware that vague answers such as 'fair test' will not receive credit at this level.
		ii	FIRST CHECK ANSWER LINE If answer = 0.06(075) (g) award 3 marks Moles acid at lowest concentration = $0.05 \times 0.1 = 0.005$ ✓ moles Mg will be half above = 0.0025 ✓ mass $0.0025 \times 24.3 = 0.06(075)$ (g) ✓	3	any sig figs ALLOW ecf's from MP1 – typically the use of 0.5 as the acid concentration (gives a value of 0.3(...); award two marks) Examiner's Comments A large number of candidates chose to base their calculation on the highest concentration of acid used in the experiment instead of the lowest, nevertheless error carried forward marks were commonly scored.
		iii	Length = m / d $0.06 / 1.3 \times 10^{-2} = 4.6 / 4.67 / 4.7$ (cm) ✓	1	ecf on ii (the above 0.3 value gives 23(.....)here Examiner's Comments This question was straightforward and well answered.
	b		Rate = $k[\text{acid}]^2$ ✓	1	ALLOW H^+ or hydrochloric acid or HCl(aq) for 'acid' Presence of Mg in eqn is a CON unless $[\text{Mg}]^0$ Examiner's Comments This question was well answered. The most common mistake was the inclusion of magnesium in the equation.

Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
c	Draws a tangent to curve ✓ tangent line runs through zero ✓ Shows how gradient measured eg 230/100(see graph below) ✓  2.30 (+/- 0.5) cm³s⁻¹ ✓	5	Without the curve drawn first mark cannot be scored Expect to see <u>lines on graph</u> for this mark (often tricky – scanning) DO NOT ALLOW “tangents” which cut the curve ecf's on gradient DO NOT ALLOW Conversion to moles (dm⁻³) for either of last two marks Examiner's Comments Candidates generally scored well on this question; however a significant number could have scored more marks if they had followed the instruction in the stem to 'show your working on the graph'. In this question, to access all the marking points, examiners were expecting to see a tangent line to a curve drawn through the data points, as well as construction lines showing how the slope of the tangent had been calculated. The units were simply cm³s⁻¹.

Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
d	Axes correct (lnk and 1/T and unit for 1/T)✓ Scales sensible ✓ Straight line plot ✓ $-E_a/R$ or Gradient $\times R = E_a$✓ Evaluation: Sign + or no sign ✓ Numerical Value 27 +/- 3 when rounded to two sf kJmol⁻¹) ✓ 	6	- As in answer! - Scales should take up at least half graticule and be evenly distributed - Data points should cluster around / on line (graph does DO NOT ALLOW need to be extrapolated to show intercept or start at zero) - Mark for correct relationship i.e Gradient = $-E_a / R$ or Gradient $\times R$ (or shown with the numbers eg grad $\times 8.31$) - Correct evaluation and conversion to kJ (NO ecf from gradient mark) The graph opposite is plotted in the same fashion as Fig 7 in the CI 4 in the text book, it could also of course be plotted as in Fig 8 in the text book i.e.  Award 4 marks for correct answer on answer line + MP's 1 and 2 if scored Correct answer with negative sign scores 3 (+ MP's 1 and 2) Examiner's Comments This question, requiring the transfer of data from one form to another before analysis, was pleasingly well attempted by many candidates. There were marks available not only for the numerical answer, but also for the way the data had been transferred to the graticule, including labelling of axes, use of graph area, point plotting and line of best fit. Candidates should note that an activation energy value will not have a minus sign.
	Total	17	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
41	a	i	(25cm ³) <u>Volumetric</u> pipette	1	DO NOT ALLOW Bulb / graduated pipette Examiner's Comments The most suitable apparatus to use in this experiment is a <u>volumetric</u> pipette. A large number of candidates were imprecise in their answer and lost this mark.
		ii	Calculates titre values and Uses average of titre 2, 3, 4 = 22.60 (cm ³) ✓	1	Examiner's Comments The average of titres 2, 3 and 4 give a value of 22.60. Examiners expected to see the answer to two decimal points in order to score the mark.
		iii	FIRST CHECK ANSWER LINE If answer = 80.6 (%) award 4 marks Moles of thiosulfate = $0.200 \times 0.02260 = 4.52 \times 10^{-3}$ ✓ Moles of Cu in original 250cm ³ = 4.52×10^{-2} ✓ Mass of Cu = $(4.52 \times 10^{-2}) \times 63.5 = 2.8702\text{g}$ ✓ % = $2.87655/3.56 = 80.624$ (%) 80.6 sf mark ✓	4	No working but answer of 81 scores 3 marks (loses sf) 3sf Examiner's Comments This proved the most discriminating question on the whole paper. Candidates usually successfully calculated the number of moles of thiosulfate used in the titration, but then commonly got confused by the ratio, often wrongly dividing by two. The scaling up by 10 was also missed in many cases, though multiplying by 63.5 often score on error carried forward. The final answer was needed to 3 sig. figs. in order to score the final evaluation mark.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		iv	Burette error = $0.10/22.60 \times 100 = 0.44\%$ Electric balance = $0.005/3.56 \times 100 = 0.14\%$ (biggest error burette)	1	Mark for calculations DO NOT ALLOW decision on which apparatus gives biggest error Examiner's Comments This question was disappointingly answered. The calculation of uncertainties has become increasingly important in GCE specifications in recent years. This question expected candidates to calculate the percentage uncertainties associated with the electric balance and the use of the burette in the titration.
		v	Colourimetry / gravimetric/cell emf's	1	ALLOW an actual method e.g. <i>react with sodium hydroxide – weigh.</i> ALLOW gravimetric type detail such as precipitate and find mass produced. DO NOT ALLOW pH change DO NOT ALLOW Calorimetry Examiner's Comments Examiners were expecting a different type of method in answer to this question e.g. colorimetry or gravimetric.
	b		<i>Please refer to the marking instructions on page 5 of this mark scheme for guidance on how to mark this question.</i> Level 3 (5 – 6 marks) Describes main points of the technique and most of fine detail under all three headings <i>There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.</i> Level 2 (3 – 4 marks) Describes the main points of the technique and some of the fine details under all three headings OR most of fine detail under two of headings <i>There is a line of reasoning presented with some structure. The information presented</i>	6	indicative scientific points may include: <u>Main points</u> - weigh the (approximate) mass of the solute / thiosulfate required to make up a known volume of standard solution - dissolve in water in a beaker - Transfer the solution to a clean, rinsed <u>volumetric / graduated</u> flask, make up to mark <u>Fine detail</u> <u>General</u> - weighed out on an minimum 2dp balance - deionized / distilled water used

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
			<i>is relevant and supported by some evidence.</i> Level 1 (1 – 2 marks) A limited treatment using main points + some fine detail under any of the headings <i>There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.</i> 0 marks <i>No response or no response worthy of credit.</i>		<i>Solid transfer</i> • mass of solute is the <u>difference</u> between the mass of the weighing bottle and solute and the weighing bottle once emptied • stir the mixture in the beaker to dissolve the solute. • using a (filter) funnel to transfer to volumetric flask • Rinse the beaker and stirring rod well with deionised water, making sure that all the washings go into the volumetric flask. <i>Technique to make up solution.</i> • Add deionised water to the solution, swirling at intervals to mix the contents, and use a dropping pipette, near mark until • <u>bottom of the meniscus</u> is level with the mark on the neck of the flask – when you are looking at it at eye level. • Insert the stopper in the flask and invert it several times to thoroughly mix the contents. Examiner's Comments Weaker candidates found this extended writing question more difficult than the one in Question 1(c). Answers sometimes drifted away from the making of a standard solution from a solid into serial dilution, or even reactions in acid, nevertheless there were still a significant number of excellent answers.
			Total	15	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
42			C	1	Examiner Comments Multiple Choices Questions: Q1–Q30 In general, this section was well done. The questions involving calculations proved most difficult and scores were lower in the final 4 questions where deciding how many of the responses were correct gave more scope for error.
			Total	1	
43			A	1	
			Total	1	
44			A	1	
			Total	1	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
45	a	i	$6 \times 100 / (16 + 18) = 17.6/17.65/18 \checkmark$	1	ALLOW 2 or more sf Examiner Comments This question was well done, although a few people did not account for 3 moles of hydrogen being formed.
		ii	Co-product $\checkmark$	1	ALLOW 'waste product' DO NOT ALLOW By-product Examiner Comments Co-product is a term that many candidates did not know.
	b		Any 2 from: $\checkmark\checkmark$ - Stops the release of/removes toxic/poisonous/dangerous/polluting CO OR no need to transport/remove CO OR uses up/re-uses CO (Exothermic) reaction provides heat, saving fuel/heating steam reforming/endothermic reaction - Higher yield of hydrogen/more hydrogen/higher atom economy/less waste.	2	Any 2 from: 1 relating to utilisation of CO 2 energy considerations 3 yield of hydrogen/atom economy/waste NOT 'no waste'/100% atom economy as CO₂ is still a waste product. If more than 2 reasons are given, mark the first 2. Examiner Comments Many candidates listed impacts linked to the use of the CO but often missed the second marking point by not emphasising that more H₂ is produced or that one reaction is exothermic and hence can provide energy for the other endothermic reaction.
			Total	4	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
46	a		FIRST CHECK ANSWER ON ANSWER LINE If answer = 0.15 award 3 marks If sf incorrect, award 2 marks to anything rounding to 0.15. Moles of NaCl = $2.4 \times 10^5 / 58.5$ OR 4.1026×10^3 ✓ Moles of Cl₂ produced $0.5 \times 2.4 \times 10^5 / 58.5$ OR 2.0513×10^3 ✓ Mass Cl₂ = $\{0.5 \times 2.4 \times 10^5 / 58.5\} \times 71 = 0.15$ tonnes evaluated to 2sf ✓	3	ALLOW ecf 1 Calculation of moles NaCl 2 Use of ratio ÷ 2 or x 0.5 for a calculated no of moles 3 Moles Cl₂ to mass, unit conversion and 2 sf Examiner Comments A significant number got this calculation correct, although, of these a relatively high proportion lost a mark through not giving the answer to the correct number of significant figures. Of the rest, a minority did not divide by 2 to account for the mole ratio or used the atomic mass of chlorine, some did not convert to moles at all.
	b		$\text{H}_2\text{SO}_4 + \text{KCl} \rightarrow \text{KHSO}_4 + \text{HCl}$ ✓	1	ALLOW $\text{H}_2\text{SO}_4 + 2\text{KCl} \rightarrow \text{K}_2\text{SO}_4 + 2\text{HCl}$ ALLOW elements in any order in KHSO₄ IGNORE state symbols Examiner Comments This question was well done.
	c		I, -1 and 0 ✓ S, +6 and -2 ✓ $8\text{HI} + \text{H}_2\text{SO}_4 \rightarrow 4\text{I}_2 + \text{H}_2\text{S} + 4\text{H}_2\text{O}$ ✓	3	NOT signs after the numbers. ALLOW ecf on signs after numbers for second point. ALLOW '8H⁺ + 8I⁻' for '8HI' IGNORE state symbols Examiner Comments The oxidation states were rarely incorrect, but constructing the equation was more difficult for some candidates.
			Total	7	

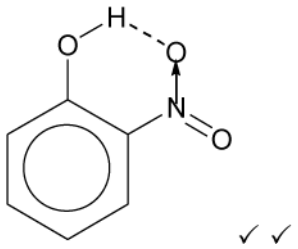
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
47			FIRST CHECK ANSWER ON ANSWER LINE If answer = 647 (2 or more sf) award 3 marks Moles CO₂ absorbed = 1000/40.3 (= 24.81) ✓ Volume CO₂ absorbed = ans to 1st point x 8.31 x 298/95000 (= 0.647) ✓ Evaluation and conversion to dm³ (x1000) = 647 dm³ ✓	3	ALLOW ecf throughout ALLOW 2 or more sf 1 Moles of MgO calculated = moles CO₂ absorbed 2 Correct substitution into $V = nRT/p$ 3 Evaluation and unit conversion Examiner Comments This question was well done, many perfect answers and many that just didn't get the final unit conversion into dm³ at the end.
			Total	3	

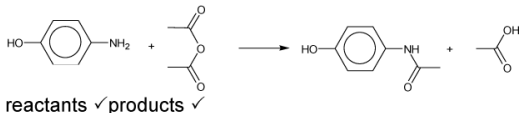
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
48	a	i	$2\text{CH}_3\text{COOH} + \text{Na}_2\text{CO}_3 \rightarrow 2\text{CH}_3\text{COONa} + \text{CO}_2 + \text{H}_2\text{O}$ formulae ✓ balancing of correct formulae ✓	2	ALLOW any unambiguous formulae (including molecular formulae) ALLOW H_2CO_3 as a product in a balanced equation for 1 mark IGNORE state symbols Examiner's Comment: (i) Most candidates were able to score both marks here, when only 1 mark was awarded this was usually for identifying H_2CO_3 incorrectly as a product of the reaction.
		ii	FIRST CHECK ANSWER LINE If answer = 11.25 or 11.3 (cm^3) award 2 marks amount $\text{CH}_3\text{COOH} = 25 \times 0.450/1000$ OR 0.01125(mol) ✓ volume $\text{Na}_2\text{CO}_3 (= 0.5 \times 0.01125 \times 1000/0.500) = 11.25 (\text{cm}^3)$ ✓	2	ALLOW ecf from 1:1 ratio in a(i) ALLOW 3 or more sf Examiner's Comment: In this calculation candidates used the appropriate equation to determine the number of moles of ethanoic acid, and then to determine the volume of sodium carbonate required (11.25cm^3). Where candidates had not given the correct equation in a(i) credit was allowed for correctly calculating a volume based upon their answer, usually calculating a value of 22.5cm^3 from an equation with a 1:1 ratio of reactants.
	b		$\text{CH}_3\text{COO}^- + \text{H}_2\text{O} \rightleftharpoons \text{CH}_3\text{COOH} + \text{OH}^-$	1	IGNORE state symbols ALLOW arrow for equilibrium sign Examiner's Comment: Most candidates scored this mark successfully.
			Total	5	

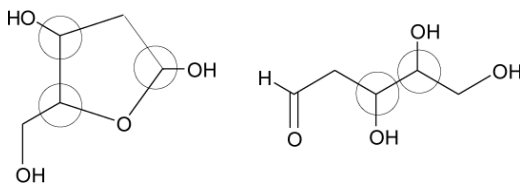
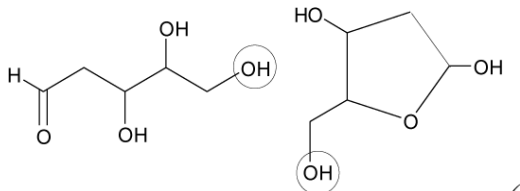
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
49		i	FIRST CHECK ANSWER LINE If answer = 13.5 / 14(g) award 2 marks amount 4- nitrophenol = 5.0/139 OR 0.03597 (mol) AND mass phenol to give 100% = 5.0 × 94/139 OR 3.381 (g) ✓ scaling by 100/25 to get 13.5 / 14 (g) ✓	2	ALLOW ecf Any number scaled by 100/25 and to 2 or 3 sf scores second mark (if first mark not scored) Examiner's Comment: Where candidates failed to score here was in not correctly scaling up their calculated mass of phenol from 3.38g to 13.5g or 14g(2sf).
		ii		2	ALLOW on NO₂ group: • double bond to either oxygen with a single or dative bond to the other • one and a half' bonds to each oxygen One mark for correct bonding within NO₂ group One mark for hydrogen bond between correct H and O (even if bonding wrong) Examiner's Comment: Many candidates struggled with this question, suggesting that they are unfamiliar with the bonding within the NO₂ group, but, in many cases they did correctly identify where the internal hydrogen bond would form and so scored 1 mark.
		iii	reduction AND amine	1	Examiner's Comment: This question was not very well answered, very few candidates recognised that the conversion from a NO₂ functional group into a NH₂ functional group is an example of a reduction reaction and so failed to score this mark.

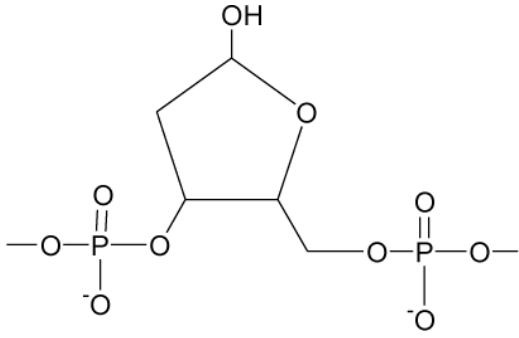
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		iv	 reactants ✓ products ✓	2	IGNORE non-skeletal formulae / ambiguous attachments Allow correct use of Ethanoyl chloride for 1 mark Examiner's Comment: This question was generally well answered. Most candidates drew appropriate skeletal structures for the reactants, and it was pleasing to see so many correct representations for the anhydride, and subsequently identifying the products of the reaction.
		v	dissolve in minimum volume of <u>hot</u> water / solvent ✓ filter (hot solution) removing insoluble impurities ✓ allow to crystallise / AW ✓ filter, soluble impurities removed / remain in solution ✓	4	ALLOW wash (and dry) crystals - soluble impurities are washed away ✓ Examiner's Comment: There were very few blank responses to this question. Candidates often identified the steps involved in the process and could communicate this effectively. Weaker candidates often lost marks for not correctly identifying where insoluble impurities were removed, or for failing to identify the removal of soluble impurities at the end of the process. The quality of response may be linked to the use of this task within the set of expected practical's that candidates are expected to undertake as they move through the course.
			Total	11	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance										
50	a	i		1	All 5 Carbon atoms must be circled Examiner's Comment: The most common error here involved candidates failing to identify that the carbon atom bonded to the OH group of the pentose ring was also a chiral centre and so did not score this mark.										
		ii	aldehyde ✓	1	NOT carbonyl here Examiner's Comment: Most candidates scored this mark with the only common error was identification of the functional group as a carboxylic acid rather than an aldehyde.										
		iii	<table border="1"><tr><td colspan="2"><i>one form</i></td></tr><tr><td>test 1 mark ✓</td><td>result linked to appropriate test 1 mark ✓</td></tr><tr><td>heat with Fehling's / Benedicts solution</td><td>(brick) red ppt</td></tr><tr><td>add Tollens' reagent and warm</td><td>silver mirror / AW</td></tr><tr><td>heat with acid dichromate</td><td>goes green</td></tr></table>	<i>one form</i>		test 1 mark ✓	result linked to appropriate test 1 mark ✓	heat with Fehling's / Benedicts solution	(brick) red ppt	add Tollens' reagent and warm	silver mirror / AW	heat with acid dichromate	goes green	2	Reagents may be specified (eg 'silver nitrate and ammonia' for Tollens') Examiner's Comment: Many candidates scored at least 1 mark, with the most common error being to incorrectly identify the reaction conditions associated with the tests, however where the test was identified the correct result was given and scored the appropriate mark.
<i>one form</i>															
test 1 mark ✓	result linked to appropriate test 1 mark ✓														
heat with Fehling's / Benedicts solution	(brick) red ppt														
add Tollens' reagent and warm	silver mirror / AW														
heat with acid dichromate	goes green														
		iv	 OH / it is attached to a C with 2H / one C-C bond / attached to a carbon that is only bonded to one other carbon / R group ✓	2	Both OH groups must be circled Examiner's Comment: Well answered. Candidates correctly identified the correct OH groups and explained why these groups were primary alcohol groups.										
		v	Water / a small molecule is not produced / both have same molecular formula	1	Examiner's Comment: Again, a well answered question. The vast majority of candidates recognised that water / a small molecule was not a product of the reaction.										
		vi	–CHO + HO– → –CH(OH)–O–	1	ALLOW any unambiguous representation Examiner's Comment: Very few candidates scored this mark, and many left the space for the answer blank.										

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
	b		 correct bonding in phosphates ✓ correct connection of phosphates AND correct ring structure ✓	2	Examiner's Comment: This question was attempted by the majority of candidates, however, very few candidates scored more than one mark, with a significant number scoring 0. The most common error was the failure of candidates to realise that when the phosphate groups bond to the deoxyribose ring that all of the hydrogen atoms are lost in the formation of water, and therefore when candidates left OH groups attached to the central phosphorous atom this cost them one mark. However, it was pleasing to note that they did know where the phosphate groups bonded to the ring and so the second mark for showing the correct connection of the phosphate groups to the pentose ring was often awarded.
			Total	10	

Mark Scheme

Question			Answer/Indicative content				Marks	Guidance
51	a	i	Equation no.	Oxidation state of Cr in reactant	Oxidation state of Cr in product	Has Cr been oxidised, reduced or neither?	4	Mark each row separately Penalise (+) omitted /3+ etc once only Examiner's Comment: This question, was very well answered, most candidates correctly calculated the oxidation state of the Chromium atom in the various species and correctly stated the change that occurred in each step of the reaction sequence.
			4.1	+3	+6	oxidised		
			4.2	+6	+6	neither		
			4.3	+6	+3	reduced		
			4.4	+3	0	reduced		
		ii	FIRST CHECK ANSWER LINE If answer = 0.46 or rounding to 0.465 (kg) award 2 marks amount chromite = 1000/223.8 OR 4.468 (mol) V mass Cr = 2 x 4.468 x 52/1000 = 0.46467 (kg) ✓				2	ALLOW 2 or more sf ALLOW 0.232kg for 1 mark Examiner's Comment: This calculation was attempted by most candidates, with many scoring full marks. Most scored one mark for correctly calculating the number of moles of chromite in 1000g of chromite, but if they did not appreciate that there were 2 atoms of Cr in the ore then they did not score the second mark for the mass of chromium being 0.465(kg).
	b	i	1s ² 2s ² 2p ⁶ 3s ² 3p ⁶ 3d ³				1	ALLOW any sized letters but numbers must be superscripts Accept [Ar] 3d³ ALLOW 4s⁰ Examiner's Comment: This question was well answered by most candidates, the only common error was to give the outer electron structure as 4s² 3d¹.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		ii	beaker (etc) with solution and two electrodes with battery / power supply connected ✓ solution labelled chromium(III) chloride / CrCl_3 / Cr^{3+} ✓ +ve electrode / anode labelled 'graphite' AND –ve electrode / cathode labelled 'steel (object)'. ✓	3	If two beaker diagram drawn, allow 1 mark for a steel electrode inserted into a chromium(III)chloride solution Ignore battery convention UNLESS polarity of electrodes not otherwise indicated Examiner's Comment: This question produced a variety of diagrams. Many candidates recognised the need for a power supply and a solution containing the correct electrolyte, but a common error was to use graphite electrodes for both the anode and cathode, or to label the anode as being the steel object. Another common error was to draw a diagram containing a two beakers, a salt bridge, and a high resistance voltmeter, however, provided that they labelled one of the electrodes as a steel electrode (not an anode) and had this inserted into a $\text{Cr}^{3+}(\text{aq})$ solution they could still score 1 mark. Very few candidates did not attempt this question, and almost all who did scored at least 2 marks.
		iii	$\text{Cr}^{3+} + 3\text{e}^{(-)} \rightarrow \text{Cr}$ ✓	1	IGNORE state symbols ALLOW ecf from labelled cathode half cell if present in b(ii) Examiner's Comment: A common error in this question was that the equation was written as if the Cr atom was being ionised rather than the Cr^{3+} ion being reduced.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		iv	FIRST CHECK ANSWER LINE If answer = 8 (hours) award 3 marks moles of electrons = $3 \times 26/52$ OR 1.5 ✓ time = $1.5 \times 96500/5$ OR 28950 (sec) ✓ time in hours = $28950/3600 = 8(.04)$ (hours) ✓	3	ALLOW ecf ALLOW any sf If final answer rounds to 2.7 hours scores 2 Examiner's Comment: This calculation was attempted by most candidates, with many scoring at least two marks. The most common error made was not recognising that each Cr^{3+} ion required 3 electrons to become reduced, and so the required number of moles of electrons was 1.5 rather than 0.5, consequently many candidates calculated the time required as 2.7hours and so scored 2 marks. The correct expected answer being $3 \times 2.7 = 8.1$ hours.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
	c	i	FIRST CHECK ANSWER LINE If answer = 0.977 (g/100cm³) on second answer line award 6 marks If answer = 0.21 (mol dm⁻³) on first answer line award 5 marks amount Cr₂O₇²⁻ init. = $20 \times 0.2/1000$ OR 4×10^{-3} (mol) ✓ amount Na₂S₂C₃ = $27.6 \times 0.1/1000$ OR 2.76×10^{-3} (mol) ✓ amount Cr₂C₇²⁻ left = $2.76 \times 10^{-3}/6$ OR 4.6×10^{-4} (mol) ✓ amount Cr₂C₇²⁻ used = 3.54×10^{-3} (mol) ✓ conc ethanol = $(1.5 \times 3.54 \times 10^{-3} \times 40)$ = 0.212(4) (mol dm⁻³) ✓ % (= 0.0212×46) = 0.975/0.977 (g/100cm³) ✓	6	ALLOW two or more sf ALLOW ecf throughout. Examiner's Comment: A pleasing aspect of this question was that there were very few candidates who did not attempt it. However, it posed a challenge to weaker students who struggled to organise their response and so produced a set of numbers where it was difficult to identify what they were trying to do. It is hoped that centres will spend some time when they are preparing candidates for this paper in trying to ensure that they realise that it is vital in this type of calculation to try to identify what they are trying to work out. Where candidates did do this they often scored some marks, usually for calculating the number of moles of dichromate and thiosulfate used. But after this many candidates scaled up or down with no reference made to what they were attempting and it became very difficult to give them any further marks as the numbers produced often did not bear any resemblance to those given in the mark scheme. Where candidates did correctly calculate the concentration of the ethanol the only subsequent error was in calculating the percentage as 9.77 rather than 0.977 as they had not recognised the units as g per 100cm³ and had simply converted from mol dm⁻³ to g dm⁻³.
		ii	no other oxidising agents / reducing agents in the beer	1	Examiner's Comment: Very few candidates scored this mark. Most gave answers linked to all of the ethanol reacting with the dichromate, and failed to consider that there could have been other substances in the beer that might have interfered with the reaction.
			Total	21	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance								
52			<i>Please refer to the marking instructions on page 5 of this mark scheme for guidance on how to mark this question.</i> Level 3 (5–6 marks) Gives a clear account with at least 1 fine detail point in all 3 sections. <i>There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.</i> Level 2 (3–4 marks) Gives a point from each of the 3 sections. OR Gives an account of 2 areas, both including a fine detail point. <i>There is a line of reasoning presented with some structure. The information presented is relevant and supported by some evidence.</i> Level 1 (1–2 marks) Makes at least 2 relevant points. <i>There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.</i> 0 marks No response or no response worthy of credit.	6	Indicative scientific points might include: AO3.2 Make judgements – Interpret practical procedure 1 Use of ppt • Weigh ppt Fine detail: • Filter to collect ppt • Rinse ppt with distilled / deionized water • Dry precipitate. This may be in the remedies for inaccuracy 2 Use of mass of ppt to find x • Find moles of MgCO_3 Fine detail: • Appreciation that mass ppt related to moles MgSO_4 • Subtract mass of MgSO_4 from original mass of crystals to find mass of water • calculate no. moles water and find the ratio. 3 AO3.4 Develop and refine At least one point from: <table><tr><th>Inaccuracy</th><th>Remedy (fine detail)</th></tr><tr><td>Not Enough sodium carbonate added to precipitate all the magnesium ions or not all MgSO_4 dissolved</td><td>Add excess sodium carbonate Add more water</td></tr><tr><td>Mass of ppt inaccurate due to water</td><td>dry ppt IGNORE means of drying</td></tr><tr><td>Losses of substances when filtering / pouring etc</td><td>Rinse all containers with distilled water and add to the filter.</td></tr></table>	Inaccuracy	Remedy (fine detail)	Not Enough sodium carbonate added to precipitate all the magnesium ions or not all MgSO_4 dissolved	Add excess sodium carbonate Add more water	Mass of ppt inaccurate due to water	dry ppt IGNORE means of drying	Losses of substances when filtering / pouring etc	Rinse all containers with distilled water and add to the filter.
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Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
					Examiner Comments This proved a challenging question as it asked candidates to respond to an unfamiliar method. A significant number of candidates scored level 3, but some thought the addition of sodium carbonate was a titration or they reacted the carbonate and collected the gas given off. Sources of inaccuracy often involved using a better balance.
			Total	6	
53			B	1	Examiner's Comments C was the most frequently seen answer as candidates did not use 2 as the molecular mass of hydrogen in calculating moles
			Total	1	
54			B	1	Examiner's Comments The majority of candidates scored here.
			Total	1	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
55	a		Dissolve bolt in warm sulfuric acid ✓ Transfer to 1 dm ³ <u>volumetric</u> flask, (transfer washings) and make up to the mark (AW) ✓	2	Conc sulfuric acid is CON <u>Examiner's Comments</u> This was a question that proved one of the most difficult, both in terms of low scores and omission rates. The ideas we were looking for were practical points on how to dissolve the bolt. The first was dissolving the bolt, many candidates selected a solvent other than sulfuric acid despite it being given in the stem of the question, some even chose water. Very few realised that heat would be needed. The second point was making the solution up to 1 dm³. We expected the use of a volumetric flask here and making up to the line.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance						
	b		FIRST CHECK THE ANSWER ON THE ANSWER LINE If answer = 45.6 or rounds to 46 (g) award 3 marks Moles of MnO_4^- not needed by the rusty nail $= (0.01792 - 0.00975) \times 0.2 (= 1.634 \times 10^{-3})$ ✓ Moles of Iron rusted in 10cm^3 solution $= 5 \times 1.634 \times 10^{-3} (= 8.17 \times 10^{-3})$ ✓ In 1dm^3 mass $= 0.817 \times 55.8 = 45.6(\text{g})$ ✓	3	ALLOW 2 or more sf ALLOW ECF between steps An answer rounding to 0.46 scores 2 (omission of the factor of 100 from 10cm^3 to 1000cm^3) <u>Examiner's Comments</u> Most candidates were able to score some of the marks here. The most frequently scored was the multiplication of the moles of MnO_4^- by 5. Other marks were lost because the final answer was not multiplied by 100 (to account for the fact that 10cm^3 portions were titrated), or the difference between the titration results was not used. Sometimes 2 calculations were done with the subtraction as the final step – this was an acceptable alternative route. Exemplar 5 <table border="1"><thead><tr><th>Type of bolt</th><th>Average volume of 0.200mol dm^{-3} KMnO_4 used in the titration / cm^3</th></tr></thead><tbody><tr><td>Unused bolt</td><td>17.92</td></tr><tr><td>Rusted bolt</td><td>9.75</td></tr></tbody></table> $\frac{9.75}{1000} \times 0.2 = 1.95 \times 10^{-3} \text{ moles } \text{KMnO}_4 \text{ (rusted)}$ $\times 5 = 9.75 \times 10^{-3} \text{ moles Fe}$ $\times 55.8 = 0.54405 \text{ g}$ $\frac{17.92}{1000} \times 0.2 = 3.584 \times 10^{-3} \text{ moles } \text{KMnO}_4 \text{ (unused bolt)}$ $\times 5 = 0.01792 \times 55.8 = 0.9997 \text{ g (1)}$ $1 - 0.54405 = 0.4559$ ✓✓ mass of bolt that had rusted away = 0.4559 g [3] This is an example where the subtraction has been done at the end. The final mark is not scored as the mass has not been scaled up to 1dm^3.	Type of bolt	Average volume of 0.200mol dm^{-3} KMnO_4 used in the titration / cm^3	Unused bolt	17.92	Rusted bolt	9.75
Type of bolt	Average volume of 0.200mol dm^{-3} KMnO_4 used in the titration / cm^3										
Unused bolt	17.92										
Rusted bolt	9.75										
	c	i	$\text{O}_2 + 2\text{H}_2\text{O} + 4\text{e}^- \rightarrow 4\text{OH}^-$ ✓ $\text{Fe} \rightarrow \text{Fe}^{2+} + 2\text{e}^-$ OR $\text{Fe} - 2\text{e}^- \rightarrow \text{Fe}^{2+}$ ✓	2	ALLOW halved ALLOW reversible reactions shown either direction Extra half equations beyond 2 CONs 1 mark each <u>Examiner's Comments</u> The process of rusting was not well known, and d block chemistry in general proved challenging. Sometimes correct half equations were contradicted by extra ones.						

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		ii	Green solid is $\text{Fe}(\text{OH})_2$ AND orange solid is $\text{Fe}_2\text{O}_3 \cdot x\text{H}_2\text{O}$	1	ALLOW $\text{Fe}(\text{OH})_3$, $[\text{Fe}(\text{OH})_2(\text{H}_2\text{O})_4]$, $[\text{Fe}(\text{OH})_3(\text{H}_2\text{O})_3]$ <u>Examiner's Comments</u> This was well answered and we accepted the formulae of iron(III) oxide or hydroxide for the orange solid.
		iii	(Faster in salt water as) more (dissolved) ions (make it a better conductor) ✓ More OH^- ions is CON	1	ALLOW '(water acts as a) 'salt bridge' and sea water contains a higher concentration of ions' ALLOW (the salt) acts as an electrolyte <u>Examiner's Comments</u> Very few candidates knew the answer to this. A few had memorised the definition provided in text books..
	d		$\text{Fe}^{2+} 1s^2 2s^2 2p^6 3s^2 3p^6 3d^6$ ✓	1	IGNORE $4s^0$ IGNORE working elsewhere. No of electrons in orbitals must be superscripts NOT $[\text{Ar}] \dots$ <u>Examiner's Comments</u> More than half of the candidates scored here. The main reason for not getting the mark was ending the electron configuration with $4s^2$, $3d^4$. There were a significant number with the numbers as subscripts.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance								
	e		Ni(/Ni²⁺) electrode potential is more negative than H₂(H⁺) AND thus H⁺ can oxidise Ni to Ni²⁺ (ORA) ✓ Cu(/Cu²⁺) electrode potential is more positive than H₂(H⁺) so H⁺ cannot oxidise Cu to Cu²⁺ (ORA) ✓	2	ALLOW answers in terms of electron flow instead of oxidation We need a comment about each metal in relation to hydrog <u>Examiner's Comments</u> This was a difficult question. Many answers compared the electrode potentials of nickel and copper with each other rather than with hydrogen. They also answered in terms of Cu²⁺ ions being reduced, when the point of the exercise is that there are none. Exemplar 6 Nickel only reacts because ~~the~~ Ni/Ni²⁺ has a more negative E° than 2H⁺/H₂ so is oxidised because electrons flow from negative to positive [2] This is an example has a very clear explanation of why nickel reacts but has not mentioned copper. Exemplar 7 <table><thead><tr><th>Half reaction</th><th>E°/V</th></tr></thead><tbody><tr><td>Ni²⁺(aq) + 2e⁻ ⇌ Ni(s)</td><td>-0.25</td></tr><tr><td>2H⁺(aq) + 2e⁻ ⇌ H₂(g)</td><td>0.00</td></tr><tr><td>Cu²⁺(aq) + 2e⁻ ⇌ Cu(s)</td><td>+0.34</td></tr></tbody></table> Cu²⁺/Cu half cell is more positive than the Ni²⁺/Ni half cell. This means Cu²⁺ is reduced to Cu and Ni oxidised to Ni²⁺. Ni²⁺ can react with H₂SO₄ more. [2] This is an example where neither of the metal electrode potentials has been compared with the hydrogen half-cell.	Half reaction	E°/V	Ni ²⁺ (aq) + 2e ⁻ ⇌ Ni(s)	-0.25	2H ⁺ (aq) + 2e ⁻ ⇌ H ₂ (g)	0.00	Cu ²⁺ (aq) + 2e ⁻ ⇌ Cu(s)	+0.34
Half reaction	E°/V												
Ni ²⁺ (aq) + 2e ⁻ ⇌ Ni(s)	-0.25												
2H ⁺ (aq) + 2e ⁻ ⇌ H ₂ (g)	0.00												
Cu ²⁺ (aq) + 2e ⁻ ⇌ Cu(s)	+0.34												

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
	f	i	Reaction is ligand substitution/exchange AND new ligand splits the d-orbitals differently ✓	1	ALLOW new complex ion has a different colour ALLOW nucleophilic substitution <u>Examiner's Comments</u> Most candidates knew this was ligand substitution, but the explanations were less clear. Some thought the blue was due to Cu^{2+} .
		ii	FIRST CHECK THE ANSWER ON THE ANSWER LINE If answer = $[\text{Ni}(\text{EDTA})]^{2-}$ award 2 marks Moles of $\text{Ni}^{2+} = 0.025 \times 0.25 = 6.25 \times 10^{-3}$ AND Moles EDTA = $0.0417 \times 0.15 = 6.26 \times 10^{-3}$ ✓ Ratio is 1:1 so formula is $[\text{Ni}(\text{EDTA})]^{2-}$ ✓	2	DO NOT ALLOW charges inside brackets <u>Examiner's Comments</u> The majority of candidates scored at least 1 mark on this question for getting the mole ratios as 1:1. The second mark may not have been scored due to extra water ligands in the final complex, incorrect charges or an incorrect number of EDTA ligands despite the 1:1 ratio having been calculated.
			Total	15	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
56		i	$4\text{NH}_3 + 5\text{O}_2 \rightarrow 4\text{NO} + 6\text{H}_2\text{O}$ ✓	1	ALLOW multiples, halves
		ii	FIRST CHECK ANSWER ON ANSWER LINE If answer = 12 (tonnes) award 4 marks Moles of NH_4NO_3 needed = $25 \times 10^6 / 80$ $(= 3.125 \times 10^5)$ ✓ Moles of NH_3 needed to make nitric acid = $(100 \times 3.125 \times 10^5) / 77$ ✓ Total moles of ammonia = $3.125 \times 10^5 +$ $(100 \times 3.125 \times 10^5) / 77 = 7.18 \times 10^5$ moles ✓ Mass = $7.18 \times 10^5 \times 17 = 1.22 \times 10^7$ g, 12 (tonnes) ✓	4	ALLOW 2 or more sf ALLOW ECF between stages MP1 convert to tonnes and then divide by 80 MP2 $\times 100 / 77$ MP3 Total moles ammonia (to make nitric acid + ammonia needed for salt) MP4 $\times 17$ and evaluation and conversion to tonnes <u>Examiner's Comments</u> This was designed to be a high demand question and relatively few scored the full 4 marks. However, there were scores of 1-3 on many occasions. The first mark was relatively easy, but to get the correct number of moles of ammonium nitrate the tonnes had to be converted to grams and this was not always done.
		iii	Add NaOH and Devarda's alloy or Al powder and warm ✓ Test gas with indicator paper/ red litmus/ rod dipped in HCl turns blue/ dense white fumes (due to ammonia) ✓	2	Reagents and heat needed Test and positive result for ammonia needed ALLOW Brown Ring Test (add Fe_2SO_4 solution followed by conc H_2SO_4) – a brown ring forms at the layer interface <u>Examiner's Comments</u> There were instances where candidates had simply forgotten this factual information. In other cases, marks were lost for omitting one of the reagents or not heating. Sometimes the colour change of the litmus paper was the incorrect way round.
			Total	7	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
57	a		FIRST CHECK ANSWER ON THE ANSWER LINE If answer = 2.93 or 2.94 (dm³) award 3 marks Moles (n) assuming $\text{Hg}_2\text{Cl}_2 = 25.0/472.2 = 0.0529/0.053 \checkmark$ $\text{Volume} = \frac{nRT}{P}$ and substitution of correct values i.e. n (0.0529/0.053), R(8.314), T(673), p(101000), $\checkmark$ evaluation including conversion to $\text{dm}^3 = 2.93/2.94 (\text{dm}^3) \checkmark$	3	N.B. 0.0529 gives 2.93, 0.053 gives 2.94 ALLOW ecf's from marking points one and two (the latter likely to be wrong units) Any appearance, stated or not, of 25/472.2 OR 0.0529/0.053 Look for any ecf on marking points 1 and 2 <u>Examiner's Comments</u> A pleasing number of candidates were successful in this calculation. The careful laying out of the steps in the calculation also allowed examiners to be able to award error carried forwards marks on a wrong final answer. Typical errors in the calculation included calculating the wrong value for the formula mass of Hg_2Cl_2 and a failure to convert from m^3 to dm^3.
	b		FIRST CHECK THE ANSWER ON ANSWER LINE If answer = $1.6 \times 10^{-18} \text{ mol dm}^{-9}$ award 5 marks Molar mass of $\text{Hg}_2\text{Cl}_2 = 472.2 \checkmark$ Solubility Hg_2Cl_2 in $\text{mol dm}^{-3} = 3.5 \times 10^{-4} \div 472.2 \times 7.41 \times 10^{-7} \checkmark$ $K_{sp} = (7.41 \times 10^{-7}) \times (2 \times 7.41 \times 10^{-7})^2 \checkmark$ $= 1.6 \times 10^{-18} \checkmark$ Units = $\text{mol}^3\text{dm}^{-9} \checkmark$ irrespective of answer BUT if MASS concentration is used in the calculation the ecf on the units must be in terms of grammes see Guidance	5	Figure of 7.41×10^{-7} is worth 2 marks alone The $\times 2$ is commonly missed giving an answer of 4.1×10^{-19} and with correct units this answer should be awarded 4 marks. Calculations must be carried out on number of moles and NOT mass, but can allow sig fig mark and units mark if units are $\text{g}^3 \text{ dm}^{-9}$. Look for ecf on units off K_{sp} equation. Must be 2 sig figs to score this mark (ecf off last marking point e.g. from above) <u>Examiner's Comments</u> There were a good number of fully correct answers, although some candidates used mass rather than moles. Units were generally correct even when mass was used. This question in particular showed good discrimination.
			Total	8	

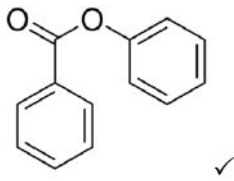
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
58	a	i	(pale) yellow precipitate ✓	1	<u>Examiner's Comments</u> This question was particularly well-answered.
		ii	$\text{Ag}^+(\text{aq}) + \text{I}^-(\text{aq}) \rightarrow \text{AgI}(\text{s})$ ✓	1	All correct, allow IAg. Allow multiples. <u>Examiner's Comments</u> Done well, however a minority used Ag^{2+} and some candidates wrote full equations. For questions which require writing of equations, candidates are encouraged to check that they write the type of equation specified in the question stem.
	b	i	$2\text{I}^- \rightarrow \text{I}_2 + 2\text{e}^-$ ✓ loss of electrons	1	one mark for both correct ALLOW description of oxidation in terms of oxidation state of iodine increasing (from -1 to 0)
		ii	Sulfur ✓ +2, +2½ ✓	2	Sign needed NO ecf for iodine or oxygen
		iii	FIRST CHECK THE ANSWER ON ANSWER LINE If answer = 130 (µg) award 4 marks Mole of thio = $0.0053 \times 0.010 = 5.30 \times 10^{-6}$ and moles of iodine = half above 2.65×10^{-6} ✓ Mass of iodine = above $\times 253.8 = 6.72 \times 10^{-4}$ ✓ Mass of iodine in 120g = above $\div 5 = 1.345 \times 10^{-4}\text{g}$ ✓ 130(µg) (2 sig figs) ✓	4	ALLOW calculation method (and appropriate progress marks) where moles of I_2 in a 120g sample are calculated first, then mass. Look for any ecfs. This value has to be calculated from correct conversion to microgrammes <u>Examiner's Comments</u> The relationship between micrograms and grams caused some problem with a number of candidates being unable to convert between them A number of answers were given to 3 or more significant figures. The need to use the formula mass of molecular iodine, I_2 was commonly missed, with the atomic mass of iodine used instead.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		iv	% error = $\frac{0.1}{5.3} \times 100 = 1.886/1.9(\%)$	1	1.89 <u>Examiner's Comments</u> This question proved difficult for many candidates. Common errors included answers being a factor of 10 too big. Some candidates also forgot that, as two burette readings are necessary to take a titre reading (initial and final), the uncertainty for individual readings (0.05 cm ³) must be doubled when calculating the percentage uncertainty.
		v	Dilute/lower concentration of thiosulphate solution OR increase mass of cod used OR increase volume of iodine solution used ✓	1	IGNORE answers which suggest more repeats needed, / "bigger"/"larger" sample <u>Examiner's Comments</u> Many candidates simply wanted to repeat the number of titrations involved without realising that accuracy is about closeness to the 'correct value'. This is improved by a method which gives a greater titre value (reducing the percentage error), hence using less concentrated standard thiosulfate .
			Total	11	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
59	a	i		1	ALLOW formulae of benzene rings using circle (and showing hydrogens) the key for the mark is the ester bonding correct. Benzene structure is needed NOT cycloalkane NOT C₆H₅ <u>Examiner's Comments</u> This calculation could be approached either by using 'reacting masses' or moles and both methods were used in about equal measure. Some errors in the calculation of formula mass crept in but with error carried forwards still gained marks.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		ii	FIRST CHECK THE ANSWER ON ANSWER LINE If answer = 39.65/40(%) award 3 marks Reacting mass ratio = 94 : 198 ✓ Theoretical mass of phenyl benzoate formed = $\frac{198}{94} \times 4.91$ = 10.34 ✓ % yield = $\frac{4.10}{10.34} \times 100 = 39.65/40(\%)$ ✓	3	ALLOW range of answers allowing for early rounding 39.65 – 41.41% ALLOW Moles phenol = $4.91/94 = 0.05223$ ✓ Moles phenyl benzoate = $4.1/198 = 0.0207$ ✓ % yield = $0.0207/0.05223 \times 100 = 39.65$ ✓ If candidate has simply used the two calculated masses and has 83.5% (84%) allow one mark ✓ ALLOW ecfs from marking points 1 and 2 <u>Examiner's Comments</u> The response of many candidates did not describe the basic practical steps needed to get the sample into a suitable tube for determining the melting point of the solid (as described in the course text book). The most commonly scored marking point was for the identification of the range over which the solid melted. Exemplar 3 <i>Melting point determination, Seal one end of a glass capillary and dip the solid granules to the bottom. Gently heat the capillary in a suitable liquid, remove when solid starts to melt and when it stops. Record temperature.</i> [3] This response succinctly describes the practical procedure when melting point capillary tubes are used to determine melting point, including how to get the solid to the bottom of the tube.
	b	i	$C_6H_5COCl + H_2O \rightarrow C_6H_5COOH + HCl$ ✓	1	ALLOW correct structural formulae or correct mixtures of formulae
		ii	Test used to see whether any (unreacted) phenol (left), (would go purple if some remained) ✓	1	Both ideas needed

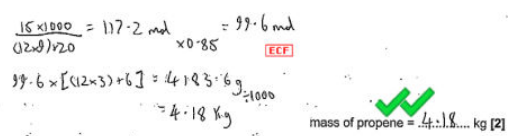
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		iii	Seal/melt end of melting point/capillary tube (in Bunsen) ✓ Tap/tip/pack a small amount of solid to bottom of tube ✓ Put tube in mp apparatus, allow temperature to rise <u>slowly</u> until solid melts OR record when it first starts to melt and when it finishes ✓	3	If unusual methods used please contact team leaders e.g. Siwoloboff's method, melting point bench
		iv	Indicates the presence of impurities / purity ✓	1	ALLOW simply- indicates purity of product
		v	Solute must have high solubility(in solvent) when hot, but low when cold/ AW ✓	1	DO NOT allow doesn't react with the product

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
	c		if more than one spot shows up on tlc ✓ phenyl benzoate impure ✓ ORA for mp 1 and 2 however cannot assess overall purity/cannot tell how pure or impure it is ✓ not quantitative / is qualitative ✓	4	Diagrams can be used here ALLOW 'quantity' or references to % by mass of product Examiner's Comments  Misconception A significant number of candidates did not understand that R_f values did not address the requirement for describing what you would expect to see on a thin layer chromatography of the product mixture. To address the description statement examiners were expecting to see comments on spotting patterns, for either a pure or impure product, on the chromatogram. Exemplar 4 The student is correct, but this will only provide a ~~quantitative~~ ^{qualitative} analysis, not a quantitative one. If the sample is impure, then the phenyl benzoate spot would split into various different spots, with these other spots having R_f values equal to that of phenol or benzoyl chloride. If these spots appear, then the sample is impure and if they don't then the sample is pure. However, these spots will appear no matter the concentrations of the impurities in the sample, so you wouldn't be able to obtain a percentage purity value from thin-layer chromatography. A titration would be needed to get that. A strong answer; the expected observations asked for in the stem of the question have been addressed as well as the broad idea of the method giving only a qualitative measure of the level of purity/impurity.
			Total	15	

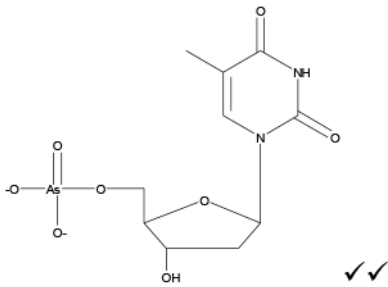
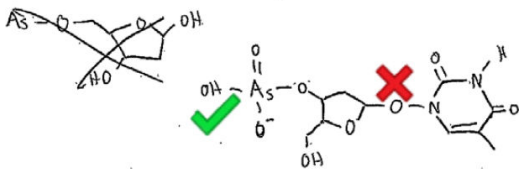
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
60		i	$C_9H_{20} \rightarrow 2C_3H_6 + C_3H_8$	1	IGNORE state symbols
		ii	FIRST CHECK ANSWER ON ANSWER LINE If answer = 8.4 (kg) award 2 marks (amount nonane) = $15000/128$ OR $117(\dots\dots)$ (mol) ✓ mass propene (= $2 \times 117 \times 0.85 \times 42/1000$) = 8.4 (kg) ✓	2	ALLOW ecf from incorrect equation in c(i) eg if one propene molecule as a product, then 4.2 on the answer line scores 2 marks. ALLOW $15/128 = 0.117$ for MP1 Examiner's Comments These two questions were generally well attempted. Many candidates correctly constructed the equation in part (i), and used this to arrive at the correct mass of propene in part (ii). Candidates who were less successful generally gave the formula of hexane as a product in part (i) and subsequently arrived at a value of 4.2 kg in part (ii). This was allowed for both marks as an example of the use of error carried forward from an incorrect equation in (i). Exemplar 2  mass of propene = 4.18 kg [2] This candidate has used the incorrect equation in (i) but use of error carried forward (ecf) in (ii) resulted in 2 marks being credited.
			Total	3	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
61	a		will not allow formation of S-S bonds	1	ALLOW idea that As interferes with sulfur bridges / S-S bonds in the protein Examiner's Comments Question 5 required that centres had given candidates time and opportunity to study the pre-release article "The Strange Story of Napoleon's Wallpaper". It was anticipated that teachers would have spent some time discussing some of the chemistry within the article. The focus of the article should have prompted teachers to guide candidates towards looking at the properties and reactivity of Group V elements, nitrogen and phosphorous. These could be used to predict some of the reactions and properties of arsenic by extending the group trend(s). In part (a) most candidates recognised that the removal of the –SH groups would interfere with the ability of the protein to form the correct tertiary structure. However, to score the mark here they had to make it clear that the arsenic was preventing the formation of S—S bonds (disulfide bridges). It was pleasing to see that in the vast majority of responses that this was the answer given.

Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
b		2	ALLOW arsenate group partially, or fully protonated bonded to either OH group on the ribose ring for 2 marks Correct structure with one error scores 1 mark <u>Examiner's Comments</u> In part (b) candidates needed to make use of the relevant section from the Data Sheet provided. They needed to select the appropriate sugar structure (deoxyribose) and derive the structure of thymine. Finally they needed to substitute As for P in the phosphate group and then join the fragments together in order to produce the correct structure. Many candidates succeeded in this and scored both of the marks available. The two most commonly seen errors were the inclusion of a bridging O atom between the thymine molecule and the deoxyribose ring, or the omission of the C=C within the thymine structure. Exemplar 11  Exemplar response showing the incorrect depiction of a bridging O between thymine and the deoxyribose ring

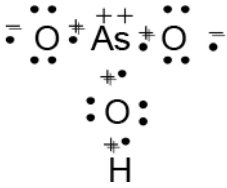
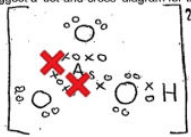
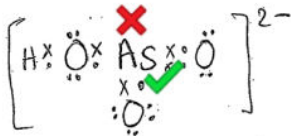
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
	c		$2\text{As}^{3+}(\text{aq}) + 3\text{H}_2\text{S}(\text{g})/(\text{aq}) \rightarrow \text{As}_2\text{S}_3(\text{s}) + 6\text{H}^+(\text{aq})$ balanced equation ✓ Correct state symbol for As_2S_3 ✓	2	<u>Examiner's Comments</u> This was found difficult by candidates, with. Most candidates did not realise the need to balance the charges within the equation and so gave $3\text{H}_2(\text{g})$ as a product rather than $6\text{H}^+(\text{aq})$, losing 1 mark. Many gave the formula of $\text{As}_2\text{S}_3(\text{s})$ in an unbalanced equation, and this was allowed for 1 mark.
	d	i	generating flask containing zinc, sulfuric acid and As_2O_3 ✓ heated tube leaving flask ✓ silvery-black film / Arsenic (metal) labelled ✓	3	ALLOW 'sample' for As_2O_3 IGNORE closed tube <u>Examiner's Comments</u> This was a well answered question and most candidates scored full marks. There were some examples of apparatus that, whilst being impractical or potentially dangerous, did match to the description given in the pre-release material. The marks were not for designing something that would meet today's Health and Safety requirements, but for recognising candidates' ability to extrapolate a description into a suitable diagram of a set up that might work. Therefore sealed tubes, or open tubes with hydrogen escaping near a naked flame, did not result in the loss of any marks. The only common error evident was in failing to label the apparatus appropriately (e.g. failing to label where the arsenic metal would be deposited, or failing to label the heating of the glass tube leaving the reaction flask) Marks were lost through carelessness rather than an inability to produce a suitable diagram..

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		ii	$\text{As}_2\text{O}_3 + 6\text{H}_2 \rightarrow 2\text{AsH}_3 + 3\text{H}_2\text{O} \checkmark$ $2\text{AsH}_3 \rightarrow 2\text{As} + 3\text{H}_2 \checkmark$	2	ALLOW $\text{As}_2\text{O}_3 + 6\text{Zn} + 6\text{H}_2\text{SO}_4 \rightarrow 2\text{AsH}_3 + 3\text{H}_2\text{O} + 6\text{ZnSO}_4$ for equation 1 IGNORE state symbols <u>Examiner's Comments</u> Many candidates did not write a balanced equation for the formation of arsine in the reaction vessel, but were able to write a balanced equation for the decomposition of arsine to form arsenic and hydrogen as the products and so scored 1 mark here. In the first equation a common error that was observed was the inclusion of oxygen gas, O_2, as one of the products of an otherwise balanced equation, which resulted in the mark not being credited.

Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
e i	 8 electrons around As atom ✓ completely correct including lone pair on As ✓	2	ALLOW 'spare' electrons on oxygen as different symbol or the same as others on that oxygen IGNORE overall charge of 2- Examiner's Comments A number of candidates identified the anion present in <i>Scheele's Green</i>, but were unable to then draw the appropriate dot and cross diagram. The most common errors were to produce diagrams containing double bonds to one or more oxygen atom giving ten or more electrons around the central As atom, failing to include a lone pair of electrons on the As atom, and failing to check that each oxygen atom satisfied the octet rule. Exemplar 12 (e) The structure of Scheele's green can be represented as $\text{Cu}^{2+}(\text{AsO}_2\text{OH})^{2-}$. (i) Suggest a 'dot-and-cross' diagram for the anion in Scheele's green.  Commonly seen incorrect dot and cross diagram for bonding of Scheele's Green anion. Exemplar 13 (e) The structure of Scheele's green can be represented as $\text{Cu}^{2+}(\text{AsO}_2\text{OH})^{2-}$. (i) Suggest a 'dot-and-cross' diagram for the anion in Scheele's green.  No lone pair on central As atom, but each atom has its full complement of electrons around its outer shell arrived at by drawing a double bond to one of the oxygen atoms.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		ii	Cu^{2+} (ion) ✓	1	ALLOW Copper(II) / copper ion <u>Examiner's Comments</u> Most candidates scored this mark as they recognised that coloured substances usually contain a transition metal ion, and so gave Cu^{2+} or copper(II) as their answer. The only common errors were the omission of the charge on the ion, or the omission of the oxidation state after the name of the element.
	f		107.5 (°) ✓ Four pairs of electrons (around As) ✓ Repel and get as far away as possible / move apart to minimise repulsion ✓ Lone pair : bond pair repulsion > bond pair : bond pair repulsion / lone pair repels more (than bond pair) / lone pair takes up more room (AW) ✓	4	ALLOW 107 – 108 ALLOW 'areas of electron density'/'groups of electrons' for 'pairs of electrons' / 3 bonding pairs AND 1 lone pair must be clear that it is electrons repelling to score third mark <u>Examiner's Comments</u> Most candidates scored at least three marks here, and many went on to score all four marks. The only common omission was in failing to make it clear that the lone pair of electrons present on the central arsenic atom had a stronger repulsion on the bonding pairs of electrons and that this produced the bond angle of 107.5°.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
	g		Any three from: arsenic found in Napoleon's hair ✓ wallpaper (might have) contained arsenic /contained Scheele's Green ✓ Dampness / mould on the wallpaper released toxic arsenic vapours ✓ wallpaper poisoned others ✓	3	ALLOW (wallpaper) linked to Gosio's Disease <u>Examiner's Comments</u> Most of the candidates were able to provide a response here that scored two if not all three marks. They had clearly studied the pre-release material appropriately and were able to summarise the three key pieces of evidence accurately. Where candidates only scored two marks was often a result of omitting marking point 1 – that traces of arsenic were found in the sample of Napoleon's hair. Most candidates made the link between the Scheele's Green pigment found in the wall paper sample, and that the island environment would have caused the paper to become mouldy. This would then result in releasing toxic arsenic compounds as a vapour that Napoleon would have been exposed to over a period of time.
			Total	20	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
62	a		FIRST CHECK ANSWER ON ANSWER LINE If answer = 39(%) award 2 marks M_r values $MgCO_3 \cdot 3H_2O$ 138.3 and $3H_2O$ 54 ✓ % loss = $5400/138.3 = 39(\%)$ ✓	2	If answer rounds to 39(%) award 2 marks ALLOW ecf from incorrect calculation of M_r values ALLOW calculation of $MgCO_3 / MgCO_3 \cdot 3H_2O = 61\%$ (% retained) for 1 mark <u>Examiner's Comments</u> This question required candidates to use the information from the stem of the question to identify that when the salt was heated, the loss in mass was due to water being evaporated. Using the information provided they should have calculated the M_r for the hydrated salt, and then the M_r for the moles of water lost. Using these two values they should then have derived the percentage loss in mass. Many candidates calculated the M_r of the hydrated salt correctly, but then calculated the mass of 3 moles of water and subtracted this from the mass of the hydrated salt. This gave them a figure of 84.3 which they then used in their calculation, arriving at the incorrect figure of 61% for the loss in mass. These responses did score 1 mark for the error carried forward (ecf) from the incorrect calculation of M_r values.

Mark Scheme

Question		Answer/Indicative content	Marks	Guidance
	b	FIRST CHECK ANSWER ON ANSWER LINE If answer = 0.69 (g) award 3 marks (rearranges ideal gas equation) $n = PV/RT$ ✓ (substitution of values into rearranged equation) $n = 99000 \times 200 \times 10^{-6} / 8.314 \times 290 (= 8.212 \times 10^{-3} \text{ mol}) \checkmark$ (Uses $m = n \times M_r$ to calculate mass of Magnesium Carbonate) $\text{mass} = (84.3 \times 8.212 \times 10^{-3}) = 0.69(2\dots) \text{ (g)} \checkmark$	3	ALLOW ecf (If gas equation is inverted and values substituted correctly and evaluated the answer arrived at is 10265, award 2 marks) (If final answer rounds to 690(g) award 2 marks as candidate has failed to convert 200cm^3 correctly but has done everything else appropriately) <u>Examiner's Comments</u> This was the first question where candidates were required to carry out a multi-step calculation. It required them to rearrange a familiar equation, and then to convert the data provided into the required standard units. Whilst many candidates were able to carry out the first part of the task, there were many examples of candidates struggling with the conversion of units, particularly from cm^3 to m^3 for the volume of gas. In this instance credit was allowed where the candidate had rearranged the ideal gas equation correctly and had then used the correct equation to calculate the required mass of magnesium carbonate from their incorrectly calculated number of moles. Exemplar 1 $\text{Mg} \rightarrow \text{MgCO}_3$ $\text{MgCO}_3 \rightarrow \text{MgCO}_2$ What mass of MgCO_3 should they heat? $PV = nRT$ $n = \frac{PV}{RT}$ $n = 8.212 \text{ moles.}$ $M_r = 84.3$ $n = \frac{99 \times 10^3 \times 0.2}{8.314 \times 290}$ mass of $\text{MgCO}_3 = 692 \text{ g [3]}$ Example of the most common incorrect final answer, as a result of failing to convert 200cm^3 correctly.
		Total	5	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
63			FIRST CHECK THE ANSWER ON THE ANSWER LINE If answer = 63(%) or rounds to 63.0(%) award 3 marks Moles of $C_{12}H_{26} = 1.5 \times 10^6 / 170 (=8.824 \times 10^3) \checkmark$ Expected yield of $C_6H_{12} = 8.824 \times 10^3 \times 86 (=7.589 \times 10^5 \text{ g or } 758.9 \text{ kg}) \checkmark$ % yield = $478 \times 100 / 758.9 = 63.0(\%)$ (2 or more sf) $\checkmark$	3	ALLOW alternative method: Moles of hexane = $478000 / 86 = (5.558 \times 10^3) \checkmark$ % yield = $5.558 \times 10^3 \times 100 / 8.824 \times 10^3 = 63.0 \checkmark$ A correctly rounded answer to 1sf scores 1 If units incorrectly converted ALLOW ECF for second mark <u>Examiner's Comments</u> It was good to see a number of completely correct responses, but also a significant number that had just used masses, not moles. Most were able to convert the units successfully.
			Total	3	

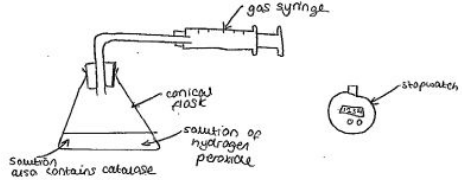
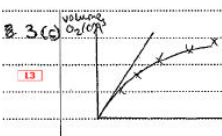
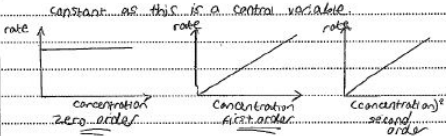
Mark Scheme

Question		Answer/Indicative content	Marks	Guidance
64	a	<i>Please refer to the marking instructions on page 6 of this mark scheme for guidance on how to mark this question.</i> Level 3 (5 – 6 marks) Detailed procedure with most key variables identified and includes some relevant fine detail (may or may not include a diagram). AND Explains clearly how to process results. <i>There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.</i> Level 2 (3 – 4 marks) Workable procedure with some variables identified may include some relevant fine detail (may or may not include a diagram). AND Attempts to explain how to process results. <i>There is a line of reasoning presented with some structure. The information presented is relevant and supported by some evidence.</i> Level 1 (1 – 2 marks) Outline of procedure with some variables given (may or may not include a diagram). OR Attempts to explain how to process results. <i>There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.</i> Level 0 <i>No response or no response worthy of credit.</i>	6	Indicative scientific points include: AO3.3 Development of a practical procedure by analysing information <i>Key variables may include:</i> • flask with peroxide; • same volume of peroxide solutions • keep concentration (and volume) of catalase • constant • vary peroxide concentration; • volume of oxygen measured in gas syringe or • over water; <i>Fine detail may include:</i> • means of adding catalase / starting reaction; • time for certain volume of oxygen to be produced • record volume of oxygen produced at fixed time • intervals • suitable apparatus for measuring volumes of solutions • suggests appropriate volume of gas to be collected • suggests appropriate time intervals for measuring volume of gas AO3.1 Processing results <i>Makes reference to</i> (plots) graph of volume of oxygen produced • against time; • measures slope at the origin / time $t = 0$; • rate proportional to $1/\text{time}$ for a small volume of • oxygen to be produced • uses $\text{rate} = \text{vol of oxygen}/\text{time}$ • use of smallest rate value to calculate relative • rates NB: Some of the above indicative science may be addressed as part of a labelled

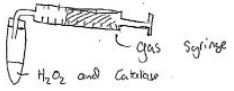
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
					diagram – accept any relevant diagram even if poorly drawn. Allow sketch graph labelled as evidence of method used to process experimental data collected. <u>Examiner's Comments</u> This Level of Response question was well tackled by the vast majority of candidates. Most candidates scored at Level 2, with higher ability candidates regularly scoring at Level 3. There were two strands to this question that candidates needed to address; (i) designing a suitable procedure giving essential details (including some relevant fine detail), and (ii) explaining how they would process the data that they had collected. This is a practical procedure that candidates should be familiar with. Candidates should be able to describe a suitable workable method for this reaction, and indeed this was often the case. Many candidates produced diagrams of the apparatus which were a good indicator that their response was likely to be at least at Level 2 in the first strand. The second strand of this question provided an element of discrimination. Candidates were required to explain how they would process their results; some produced outlines of the graphs that they would plot indicating the tangent to be drawn, which again gave examiners a quick idea of what the appropriate level was likely to be. However, whilst many knew that they needed to produce a graph, they often suggested using a concentration vs rate graph, which was incorrect within the context of this question. This often meant that candidates who had produced a very detailed method were limited to Level 2 as the processing strand was weak. Where candidates did not address one of the strands within their response,

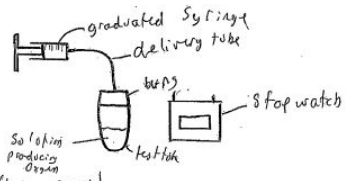
Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
			unfortunately this resulted in them being limited to Level 1. Exemplar 6  Known • Measure out equal volumes of different concentrations of hydrogen peroxide solution (eg. 25.0 cm³) using a burette or volumetric pipette. A clean, dry pipette can be used to run the solution into a clean conical flask. • Add a fixed volume of enzyme ~~catalase~~ catalase solution to the conical flask, stopper the flask and start the stop watch. The conical flask should be connected to a gas syringe to collect the oxygen gas formed. • At equal time intervals (eg. every 10 seconds) measure the volume of oxygen in the gas syringe to the nearest 0.05 cm³. • Keep doing this for 2 minutes, or until no more gas is produced. Repeat this procedure for all different concentrations of hydrogen peroxide. • Record results in a table of volume of oxygen (cm³) against time (s) and use this to plot a graph of volume of oxygen against time. * Please see back page for the rest *  Draw a line of best fit. Draw a tangent to the curve at time $t=0$ and use the gradient to work out the initial rate of reaction. Then plot a graph of initial rate (y-axis) against concentration of hydrogen peroxide. This will tell you the rate of reaction with H_2O_2. The amount of catalase needs to be kept constant as this is a control variable.  rate concentration zero order concentration first order concentration second order Level 3 response, scoring 6 marks. This includes all key variables, and a significant amount of fine detail, explaining clearly how to process the results collected. The answer continues onto additional space of answer booklet. Whilst this was a Level 3 response, the candidate could have made their answer more succinct. Candidates are advised that

Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
			the answer space provided should be sufficient to gain full marks for Level of Response questions, without needing to continue onto the additional answer space. In this case, the candidate could have omitted the superfluous discussion and diagrams of rate-concentration graphs they have included at the end of their response. The suggested procedure could also have been written more concisely whilst retaining sufficient detail to receive full credit. Exemplar 7  The student will firstly produce equal moles of Catalase and H_2O_2 and the same concentration of Catalase. They will be used. Produce at least 5 different H_2O_2 concentrations. The student will measure the volume of gas being produced for each different concentration of H_2O_2 for a set interval of time (2 mins) using a stopwatch. This means for each concentration of H_2O_2 you will know the volume of O_2 produced by the recordings of the gas syringe after the set time of 20 minutes. Repeat the procedure 10 times for each H_2O_2 concentration. The student can plot a graph of ~~concentration~~ volume of H_2O_2 produced vs time (x-axis). Next plot the volume of H_2O_2 concentration. Draw a line of best fit for each of the graphs produced for each H_2O_2 concentration. Next produce a tangent at $t=0$ for each H_2O_2 concentration graph and calculate gradient of tangents ($\frac{\Delta y}{\Delta x}$) and they will know the initial rate of reactions for each H_2O_2 concentration. Level 2 response, scoring 4 marks. A workable procedure is outlined, but lacks fine detail which would have allowed the candidate to progress to Level 3. Good explanation of processing of results.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance															
					Exemplar 8  Method 1) Place a known volume of hydrogen peroxide in the test tube. Add the catalyst. Start the timer and place the bung in the top of the test tube. 2) Record how long 50 cm³ of oxygen takes to be produced. Record the final time. 3) Repeat 3 times with the same volume. 4) Increase volume of hydrogen peroxide by 10 cm³ and repeat for 6 results. Process Results - 50 of oxygen = 1 cm³ - Find moles of O₂ produced with $n = \frac{pV}{RT}$ - 1:2 ratio. ~~double~~ the n_{O_2} for moles of H₂O₂ - $n = CV$ - concentration of hydrogen peroxide = $\frac{\text{moles}}{\text{Volume}}$ Level 1 response scoring 2 marks. Provides an outline of a method that might work but makes no reference to the use of time to calculate a rate value.															
b	i	<table><tr><th>[H₂O₂]/ mol dm⁻³</th><th>(relative) rate</th></tr><tr><td>0.05</td><td>1.0</td></tr><tr><td>0.10</td><td>2.1</td></tr><tr><td>0.15</td><td>3.0</td></tr><tr><td>0.20</td><td>3.8</td></tr><tr><td>0.25</td><td>4.0</td></tr><tr><td>0.30</td><td>4.1</td></tr><tr><td>0.35</td><td>4.1</td></tr></table>	[H ₂ O ₂]/ mol dm ⁻³	(relative) rate	0.05	1.0	0.10	2.1	0.15	3.0	0.20	3.8	0.25	4.0	0.30	4.1	0.35	4.1	2	First mark for labelled columns (or rows). ALLOW 'concentration of H₂O₂' for [H₂O₂], Evidence of units required for Hydrogen peroxide. Accept 'au/arb' for relative rate but no other units allowed. Other units = CON Second mark for correct values, all concentration values to 2 dp, rate values to 1dp. IGNORE inclusion of temperature
[H ₂ O ₂]/ mol dm ⁻³	(relative) rate																			
0.05	1.0																			
0.10	2.1																			
0.15	3.0																			
0.20	3.8																			
0.25	4.0																			
0.30	4.1																			
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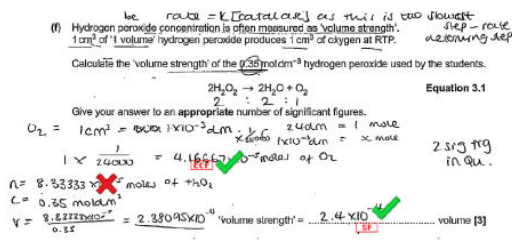
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		ii	labelled axes (ignore units) with rate as y-axis✓ plot points correctly✓ draws best fit line ✓ (must go through the origin) each scale chosen to take up more than half axis ✓	4	ALLOW +/- ½ small square Line should pass through at least 5 points / pass within 1 small square of their plotted points <u>Examiner's Comments</u> This question was generally well answered, with most candidates scoring at least 4 marks, and many scoring the full 6 marks. The only common errors were in part (i) the inclusion of some units for the rate of reaction column, and in (ii) reversing the x and y axis. Some candidates did lose one mark in part (ii) for failing to choose an appropriate scale to use that should have taken up a minimum of half the space available.
	c	i	Rate = $k[\text{H}_2\text{O}_2]$ ✓ [catalase] ✓ $\text{dm}_3 \text{ mol}^{-1} \text{ s}^{-1}$ ✓	2	ALLOW [enzyme] for [catalase], (must have 'rate =' at start of their expression) ALLOW units in any order <u>Examiner's Comments</u> This was a tricky question for many candidates. Most struggled to work out the units for the rate constant. The only other common error was the omission of "rate =" at the start of the rate equation.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		ii	peroxide: first order initially ✓ then zero order ✓ catalase: no evidence since concentration not changed (AW)✓	3	ALLOW concentration of catalase kept constant <u>Examiner's Comments</u> There were a lot of varied responses to this question. The majority of candidates scored at least one mark, but very few scored all three. Many candidates used the graph in d(ii) to state that 'up to 0.2mol dm^{-3} (or, at low concentration) the reaction is first order with respect to hydrogen peroxide as the graph is a straight line'. Some also scored a second mark for realising that when the graph levelled off the rate became zero order as no matter how the concentration of peroxide changed, there was no further change in rate. They then tended to link this to the idea of the active sites being saturated. Very few candidates identified that the statement was incorrect with regard to catalase as the catalase concentration was kept constant in this reaction.
	d		FIRST CHECK ANSWER ON ANSWER LINE If answer = 4.2 award 3 marks $(0.35/2 =) 0.175$ mol oxygen per dm^3 peroxide ✓ volume strength $(= 24 \times 0.175) = 4.2$ ✓ answer to 2sf ✓	3	If answer = 8.4 award 2 marks for candidate failing to convert 0.35 to 0.175 ALLOW ecf from incorrect calculation of number of moles Any calculated value to 2sf scores 1 mark. <u>Examiner's Comments</u> This question was a good discriminator , producing a full range of marks from 3 to 0. Lower ability candidates often struggled to score any marks here. Higher ability candidates also found this challenging. The most common mark was credited for

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Question			Answer/Indicative content	Marks	Guidance
					identifying that the molar ratio between the peroxide and oxygen was 2:1, and so the moles of O₂ should be 0.175 (or 1.75×10^{-4} if converted from dm³ to cm³). Where candidates subsequently lost marks was in the next step for not realising that because oxygen is a gas, they needed to multiply their calculated number of moles by 24(dm³) or 24000(cm³) to then arrive at the final answer. This question included a mark that was for displaying their working, in order that where a candidate had not spotted the molar ratio, or had calculated the number of moles of oxygen by a different method, then examiners could award a mark for the use of '× 24 (or 24,000)' as an error carried forward with the final mark being for converting their calculated value to 2 significant figures. A candidate who simply gave an incorrect final answer to this question scored 0, whereas candidates who did not arrive at the correct final answer but had displayed their working often scored 2 marks. Exemplar 9  Calculation showing working being given credit, even though final answer is incorrect.
	e		FIRST CHECK ANSWER ON ANSWER LINE If answer = 120 (cm³) award 2 marks (total volume =) $20 \times 0.35/0.05$ OR 140 (cm³) ✓ volume to add = 120 (cm³) ✓	2	ALLOW 140(cm³) even on the answer line for 1 mark Examiner's Comments Generally well answered. Most candidates scored at least one mark for arriving at an answer of 140 cm³, as they did not subtract the initial 20 cm³ of peroxide solution.
			Total	22	

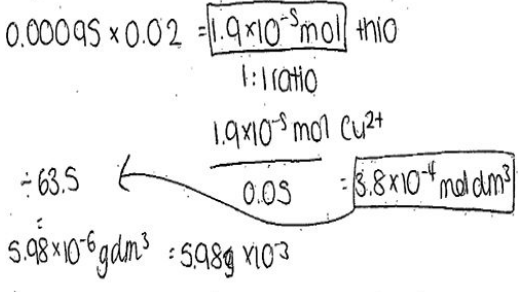
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Question			Answer/Indicative content	Marks	Guidance
65			C	1 AO 1.1	
			Total	1	
66			B	1 AO 2.8	<u>Examiner's Comments</u> This was a difficult question, and many gave the correct answer. B, the answer obtained by multiplying the concentration by 10/12, was often seen.
			Total	1	
67			C	1 AO 2.8	<u>Examiner's Comments</u> This was well done, although in some cases the water of crystallisation was not included and candidates consequently selected option A.
			Total	1	

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68		i	Starch AND blue/black to colourless ✓	1 AO 1.2	NOT purple <u>Examiner's Comments</u> This proved a difficult question; many candidates used phenolphthalein, others had the colour change the wrong way round or described the change when the starch was added (straw colour to blue black).

Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
	ii FIRST CHECK ANSWER ON ANSWER LINE If answer = 24.1 (mg dm⁻³) award 3 marks Ratio thio: Cu²⁺ is 1:1 AND moles thio is $0.95 \times 0.02/1000 = 1.9 \times 10^{-5}$ ✓ Moles Cu²⁺ per dm³ = $1.9 \times 10^{-5} \times 1000/50 = 3.8 \times 10^{-4}$ ✓ Mass Cu²⁺ is answer x 63.5 x1000 (mg) ✓	3 AO 2.8 x 3	ALLOW two or more sf Moles thio AND ratio thio: Cu²⁺ (may be implied) Moles Cu²⁺ per dm³ Mass Cu²⁺ and conversion to mg 3.8×10^{-4} on answer line scores 2 1.9×10^{-5} on answer line does not score mp1 unless ratio to Cu²⁺ ions is clearly stated or implied Examiner's Comments Many candidates scored full marks for this, but a significant proportion also scored 0. The conversion from grams to milligrams was not always correct, and the ratios of moles and converting moles to mass gave some candidates problems. If the working was clear, which was not always the case, credit could be given for the correct steps. Exemplar 7  In this response the extremely clear working allows the award of marking points 1 and 2, but not 3 as they have divided by the atomic mass of copper instead of multiplying.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		iii	$0.1 \times 100/0.95 = 10.5 / 11 (\%)$	1 AO 2.8	ALLOW 2 or more sf rounding to 11 <u>Examiner's Comments</u> Some candidates were possibly put off by the large % error and divided it by 10. Some omitted to account for using a burette twice in a titration.  OCR support Guidance on calculating uncertainties is provided in the Practical Skills handbook (appendix 4, https://www.ocr.org.uk/Images/208932-chemistry-practical-skills-handbook.pdf) and can be shared with students.
		iv	Dilute their thiosulfate by a factor of 20 to give a titre of approx. 19 cm^3 ✓ Use a (volumetric) pipette to withdraw 50 cm^3 into a volumetric flask and make up to the mark with water ✓	2 AO 3.4 3.3	ALLOW a dilution factor consistent with answer to 34 e(iii) ALLOW use more seawater as long as 1 dm^3 is specified (either directly or by calculation.) If 34 e(iii) is incorrect ALLOW volume of seawater consistent with the error. (This option precludes access to mp2) Method of doing the dilution, ALLOW any final volume of solution of 100 cm^3 or above. <u>Examiner's Comments</u> This was a challenging question. Many answers suggested diluting the thiosulfate or using a larger volume of sea water but did not specify quantities. Almost no answers gave any details as to how the dilution could be done. There was a similar question on the 2018 paper about making solutions, also one of the lowest scoring questions. Many answers just suggested more repeats or a burette with better resolution.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
					Exemplar 8 They firstly would want to dilute the Sodium thiosulphate solution. This would cause the titre volume to increase. Also could concentrate the potassium iodide. [2] This response had the right idea but did not specify quantities. Exemplar 9 Dilute the Sodium thiosulfate solution, hence increasing the titre amount & therefore reducing the uncertainty. Make the Sodium thiosulfate solution around 20x more dilute so its concentration was $1 \times 10^{-3} \text{ mol dm}^{-3}$. Do this by adding 20 cm³ of water to 1 cm³ of ^{thiosulfate} solution, and then using this instead. This had made good suggestions but is not quite clear enough on experimental detail.
			Total	7	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
69	a		iron compound(s) only gradually coming out of spinach into solution/takes time for iron compounds to dissolve ORA	1(AO 3.2)	Look for change in concentration over time / time implied <u>Examiner's Comments</u> Careful reading of the Practical insert is a necessity to answer questions that follow from the practical procedure. It was clear that many candidates did not spot that the length of time the spinach was left in the acid was the crucial factor here.
	b	i	Average of 7.95 and 8.05 / concordant titres	1(AO 3.4)	Enter text here.
		ii	$\text{mol MnO}_4^- = 5.0 \times 10^{-6} \times 8.00 \times 10^{-3} = 4.0 \times 10^{-8} \checkmark$ $\text{mol of 'iron' in original solution} = 4.0 \times 10^{-8} \times 5 \times 10 = 2.0 \times 10^{-6} \checkmark$ $\text{mass} = \text{above} \times 55.8 = 1.12 \times 10^{-4} \text{ g} = 0.112\text{mg} \checkmark$ $\text{Mass in } 100\text{g} = \mathbf{0.112 \times}$ AND 'not high' (ora) $\checkmark$	4(AO 2.8 x3)(AO 3.1)	ALLOW numbers to 2 or more sf. ALLOW ecf throughout For 100/5.1 allow 20 in the calculation The last mark is for the conversion to mg in 100g AND not high (ecf would still apply) (However, note some students have converted the mg to a % by mass iron i.e. 0.00219 is less than 0.004 – this fine) <u>Examiner's Comments</u> This was one of the most discriminating questions on the paper. Clarity of working by many candidates allowed examiners to award a significant number of 'ecf' marks. Common mistakes included failing to correct back to 250 cm ³ (but calculation often proceeded correctly thereafter); not converting to mg and/or not converting to 100g for the final step.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
	c	i	tolerance on titre $2 \times 0.05\text{cm}^3 = 0.10$ AND %error = $\frac{0.1}{8}$	1(AO 2.8)	ALLOW 1.2 (%) <u>Examiner's Comments</u> The idea of uncertainties arising from certain techniques and measurements is an important concept in science (Specification mathematical requirement M1.3). Candidates found this question challenging, suggesting that they find the calculation of percentage uncertainty difficult.  OCR support The Practical Skills handbook contains information on the calculation of uncertainties (in Appendix 4, Measurements) which can be shared with students: https://www.ocr.org.uk/Images/208932-chemistry-practical-skills-handbook.pdf .
		ii	greater mass of spinach ✓ lower concentration of MnO_4^- ✓	2(AO 3.4)	NOT bigger leaves ALLOW larger/greater volume of iron/spinach solution <u>Examiner's Comments</u> This question differentiated well with higher ability candidates understanding how to reduce percentage uncertainty. Lower ability candidates often missed the statement in the question stem 'while using the same equipment', and provided answers about accuracy of apparatus. e.g. 'use a more accurate burette' or precision of measurements e.g. 'take more readings'.
			Total	9	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
70			FIRST CHECK THE ANSWER ON ANSWER LINE If answer = 26 (g) award 2 marks Amount benzene-1,4-dicarboxylic acid = $32/166 = 0.19 \text{ mol}$ ✓ Mass compound A = $0.19 \times 0.67 \times 203 = 26 \text{ (g)}$ (nearest whole number) ✓	2(AO2.4 x 2)	ALLOW ecf from incorrect number of moles <u>Examiner's Comments</u> A number of candidates lost the second mark for this question due to not converting their answer to the nearest whole number as instructed in the stem of the question. Many candidates correctly calculated that the mass produced would be 26.2g, scoring one mark, but then did not convert to 26g as the nearest whole number value. Other common errors included calculating the Mr value for benzene-1,4-carboxylic acid as 142, or that for compound A as 179, both of which derive from omitting the carbon atoms that form the carbonyl group at either end of each molecule. A candidate who correctly calculated the Mr of benzene-1,4-dicarboxylic acid and hence the number of moles present in 32g scored 1 mark, even if they used 179 for A and gave their final answer to one or more decimal places. Where a candidate had incorrectly calculated the number of moles by using 142, but had then used the correct Mr for A, they could still score 1 mark if they had given their final answer to the nearest whole number. Both of these routes were seen regularly and were marked accordingly to allow candidates to gain some credit for demonstrating what they knew.
			Total	2	

Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
71	*Please refer to the marking instructions on page 4 of this mark scheme for guidance on how to mark this question. Level 3 (5 – 6 marks) Chooses an appropriate acid concentration. AND Gives a detailed description, including some fine detail, of procedure. AND Describes how the result would be calculated. <i>There is a well-developed line of reasoning which is clear and logically structured.</i> Level 2 (3 – 4 marks) Gives most of the key steps in the procedure, may include some fine detail AND describes how the result would be calculated. OR Addresses all three areas but lacks depth in any of them. <i>There is a line of reasoning presented with some structure. The information presented is relevant and supported by some evidence.</i> Level 1 (1 – 2 marks) A basic description of procedure. OR An attempt to describe the choice of acid concentration. OR An attempt to describe how the result would be calculated. <i>There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.</i> 0 marks No response or no response worthy of credit.	6(AO3.4 x 3)(AO3.4 x 3)	Indicative scientific points include: Choice of acid concentration • Calculates conc of $\text{Sr}(\text{OH})_{2(\text{aq})} = 0.08 \text{ mol dm}^{-3}$; • use of reaction stoichiometry 2:1 to determine appropriate concentration of acid to be used (approx. $0.15 - 0.2 \text{ mol dm}^{-3}$) Practical details • pipette $20/25 \text{ cm}^3$ $\text{Sr}(\text{OH})_2/\text{HCl}$ in a suitable flask; • add indicator; (details not required) • place acid/alkali in burette; • titrate until colour change (details not required) • repeat until concordant titres obtained Relevant fine detail • Rinses pipette with solution to be delivered • Rinses burette with solution to be delivered • Performs a rough titration • Add dropwise near to end point Final calculation • Calculates average volume used • Use of equation or mole ratio • Gives example of suitable relationship to calculate actual concentration eg use of $c = n/v$ Examiner's Comments This was the first of the Level of Response questions on this paper. The topic chosen was based around a familiar practical procedure that all students should have carried out as part of the required practical element of the course. Candidates were provided with sufficient information to deduce that a titration was required but

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
					there was sufficient challenge in the task to allow for differentiation between candidates in the responses produced. To access Level 3 a candidate had to use the solubility of the strontium hydroxide given in the question and convert this to a concentration value. Having done this, they needed to write (or use) a balanced symbol equation for the reaction in order to use the stoichiometry to derive an appropriate concentration of hydrochloric acid to use in their titration. They then needed to give details of the procedure they would use to collect the required data. Finally, they needed to give an explanation of how they would use the data to determine the accurate concentration of the saturated strontium hydroxide solution. At Level 2 what was typically seen was a good description of the titrimetric method, including some fine detail, and a description of a workable calculation that would determine a value for the concentration of the strontium hydroxide solution. What was lacking was usually that the candidate had not made use of the solubility data and so had not identified an appropriate concentration of acid to use. At Level 1 the most commonly seen response was a workable description of a titration that gave enough detail to allow for the candidate to collect concordant titres to use in a calculation. The details of the calculation were often omitted, or were very sketchy and showed that the candidate was unsure of how to carry out the required processing. Exemplar 2, a Level one response which scored two marks, illustrates this. Exemplar 2

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
					Using a pipette measure a known volume of 0.1 mol dm⁻³ into a conical flask for example 25 cm³. Fill a beaker with 1 molar hydrochloric acid and add a few drops of indicator to the conical flask. ~~Boil gently~~ Place the conical flask on a water bath under the beaker and slowly add the hydrochloric acid while swirling the flask. Once the colour of the indicator changes ~~add the~~ record the volume of hydrochloric acid used.
			Total	6	
72			FIRST CHECK THE ANSWER ON THE ANSWER LINE If answer = 52 (%) award 3 marks 2.1g of 4-aminophenol produces maximum $2.1 \times \frac{1}{1}$ $\% \text{ yield} = \frac{1}{2}$ = 52(%) (2 sig figs.) ✓	3(AO 2.8 x3)	ALLOW ecf ALLOW 3 or more sf for second mark OR 2.1 g of aminophenol = 0.0193 mols (from 2.1 g/109) 1.5 g of paracetamol = 0.010 mols (from 1.5 g/151) $\% = \frac{0.010}{0.0193}$ An answer of 51% can be achieved by not rounding - lookout <u>Examiner's Comments</u> This question was well answered by a majority of candidates, the most common error being the wrong choice of significant figures. Candidates should make sure they give answers to the number of significant figures specified in the question. In this case, the question asks for the answer to be given to the 'appropriate' number of significant figures – this should be interpreted as the smallest number of significant figures in the data provided for the question (in this case, two).
			Total	3	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
73		i	heating until there is no further change to mass ✓	1 (AO1.1)	Ideas around mass doesn't change / remains constant / to constant mass
		ii	mass of CO₂ lost = 2.09 g so moles of CO₂ = 2.09/44 = 0.0475 ✓ 4.00g of MCO₃ = 0.0475 moles mass of 1 mole = 4.00/0.0477 = 84.2(105..) OR ✓ 1.91 g of MgO = .0475 mol Mass of 1 mol = 40.2 g mass of M = 84.2 – 60 (or 40.2 – 16) = 24.2 so M is magnesium / Mg ✓	3 (AO3.1) (AO3.1) (AO3.2)	Some CORRECT working must be shown to score marks It is possible to answer this question using an algebraic method..... as mols of carbonate and oxide formed are the same $\frac{4.00}{(x + 60)} = \frac{1.91}{(x + 16)}$ giving 2.09x = 50.6 x = 24/Mg ALSO if Mg assumed only the use of 24 gives same number of moles of oxide as carbonate Only scores last mark if method correct
			Total	4	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
74	a		FIRST CHECK ANSWER ON THE ANSWER LINE If answer = $-1520 / -1518 \text{ (kJmol}^{-1}\text{)}$ award 3 marks $q = mc\Delta T = 100 \times 4.18 \times 11.5 = 4807 \text{ (J)} \checkmark$ moles of fuel burnt = $0.19/60 = 0.00317 / 0.00316 \checkmark$ enthalpy change per mole = $4807/0.00317 = -1520 / -1518 \text{ (kJmol}^{-1}\text{)} \checkmark$	3 (AO2.8×3)	ALLOW 2 or more sf, rounding in different steps ALLOW 4.2 negative sign needed for final mark
	b	i	Any two from: incomplete combustion $\checkmark$ evaporation of fuel $\checkmark$ evaporation of water $\checkmark$ non-standard condition $\checkmark$	2 (AO3.3 × 2)	
		ii	Any one from: a top for spirit burner when flame out $\checkmark$ Insulate(d) container $\checkmark$ draft shields $\checkmark$ lid on metal can $\checkmark$	1 (AO3.4)	ALLOW minimising distance between flame and can "lid" alone is enough
			Total	6	
75			A	1 (AO2.8)	
			Total	1	

Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
76	<i>Please refer to the marking instructions on pages 4/5 of this mark scheme for guidance on how to mark this question.</i> Level 3 (5–6 marks) Identifies A as phenol and B as propanone using the evidence from some tests, the mass spectrum for product A and the composition of product B. <i>There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.</i> Level 2 (3–4 marks) Identifies A as a phenol and B as a ketone or C₃H₆O using the evidence from some tests OR the mass spectrum for product A OR the composition of product B. <i>There is a line of reasoning presented with some structure. The information presented is relevant and supported by some evidence.</i> Level 1 (1–2 marks) Identifies A as a phenol OR B as a ketone using the evidence from some tests OR the mass spectrum for product A OR the composition of product B. <i>There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.</i> 0 marks No response or no response worthy of credit	6 (AO3.1 × 3) (AO3.2 × 3)	Indicative scientific points may include: Product A: • Is a phenol • It is weakly acidic, but not strong enough to react with sodium carbonate • Gives the purple colour with FeCl₃ • Mass spectrum shows that the M_r is 94 • Consistent with phenol, C₆H₅OH Product B: • Moles: C 5.175; H 10.3; O 1.735 • Empirical formula is C₃H₆O • Not an acid • Can be reduced to an alcohol so is aldehyde or ketone. • Does not get oxidised by Tollen's reagent so is a ketone. • propanone / CH₃COCH₃.
	Total	6	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
77			FIRST CHECK THE ANSWER ON THE ANSWER LINE If answer = 0.53 award 3 marks Moles of Cl^- ions in 25 cm^3 of the diluted sea water = $0.1 \times 0.0265 (= 2.65 \times 10^{-3})$ ✓ Moles of chloride ions in 20 cm^3 original sea water = $0.1 \times 0.0265 \times 100/25 (=0.0106)$ ✓ Concentration of Cl^- ions in original sea water = $0.1 \times 0.0265 \times 100/25 \times 1000/20 = 0.53 (\text{mol dm}^{-3})$ ✓	3 (AO2.8 × 3)	ALLOW 2 or more significant figures 0.106 scores 2 OR conc Cl^- (in diluted) = $26.5 \times 0.1/25 = 0.106$ ✓✓ conc Cl^- (in undiluted) = $26.5 \times 0.1/25 \times 5 = 0.53$ ✓
			Total	3	
78		i	Equation showing that IO_3^- reacts with Cu ✓ $2\text{IO}_3^- + 12 \text{H}^+ + 5\text{Cu} \rightarrow \text{I}_2 + 6\text{H}_2\text{O} + 5 \text{Cu}^{2+}$ ✓	2 (AO2.8 × 2)	Mark separately Second mark can be scored for reverse equation. ALLOW equilibrium sign IGNORE state symbols
		ii	Pt / graphite electrode ✓ IO_3^- and I_2 and H^+ in solution ✓	2 (AO3.3 × 2)	<u>Examiner's Comments</u> This theme was continued in 2(d)(ii) where most candidates correctly stated that the standard cell should contain a platinum (or graphite) electrode, but then did not include any H^+ ions in the solution which they should have been able to identify from the information provided in table 2.2.
		iii	FIRST CHECK THE ANSWER ON ANSWER LINE If answer = 0.4 (mol dm^{-3}) award 3 marks $[\text{I}_2] = 0.04$ ✓ $\sqrt{0.04} = 0.2$ ✓ $[\text{IO}_3^-] = 0.4 (\text{mol dm}^{-3})$ ✓	3 (AO2.8 × 3)	0.28.... (omission of factors of 2) scores 1 mark 0.56 and 0.2 score 2 marks ALLOW ecf from any statement that begins "$[\text{I}_2] =$"
			Total	7	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
79	a	i	(C=C) decolorises bromine water ✓ (COOH / acid) will fizz with carbonate / appropriate colour with (named) indicator ✓	2 (AO1.2 × 2)	ALLOW gas produced turns limewater cloudy(AW) if carbonate test used Examiner's Comments In part (i) and (ii) most candidates scored 3 or 4 marks, usually missing the final conversion from amount of NaOH to volume of NaOH by failing to include the reaction stoichiometry in their calculation.
		ii	FIRST CHECK THE ANSWER ON ANSWER LINE If answer = 5 (cm³) award 3 marks conc maleic acid = (2.32/116) OR 0.02 (mol dm ⁻³) ✓ amt NaOH = 2 × 250 × 0.02/1000 OR 0.01 (mol) ✓ vol NaOH = 1000 × 0.01/2 = 5	3 (AO2.4 × 3)	2.5 scores 2 marks ALLOW ecf Allow wrong answers (after ecf) to 2 or more sig figs.
	b	i	CHO ✓	1 (AO1.2)	ALLOW elements in any order
		ii	Z ✓ butenedioic acid ✓	2 (AO1.1 × 2)	ALLOW 'butendioic acid'
	c	i	Atom economies (98/170) = 58% AND (98/222) = 44% ✓ Identifies butane / reaction 1 should be used because it has the larger atom economy / produces less waste ✓	2 (AO2.6) (AO3.1)	ALLOW 0.58 AND 0.44 Examiner's Comments Parts(i) and (ii) were well answered by most candidates, although (iii) saw marks being lost for use of an inappropriate number of significant figures in the final answer.
		ii	Benzene toxic / more expensive / butane more available from cracking / doesn't produce CO ₂ (ORA for reaction 2)✓	1 (AO3.1)	ALLOW ecf from (i) eg butane more flammable

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		iii	FIRST CHECK THE ANSWER ON ANSWER LINE If answer = 61 (kg) award 2 marks amt butane = $15000/24 = 625 \text{ mol}$ ✓ mass maleic anh = $625 \times 98/1000 = 61(\text{kg})$ (2sf) ✓	2 (AO2.8 × 2)	61.3 or 61.2 score 1 Correct use of gas equation can score both marks
			Total	13	
80	a	i	solvent for ester/(organic) product formed ✓	1 (AO2.3)	
		ii	Removes / neutralises acid (impurity) ✓	1 (AO1.2)	ALLOW reacts with acid
		iii	removes water / dries/dehydrates the mixture ✓	1 (AO1.2)	
		iv	(about) boiling point of ester / cyclohexane boils off before ester ✓	1 (AO2.7)	So methyl benzoate is the only product / substance collected.. ALLOW only pure product.
	b		FIRST CHECK ANSWER ON THE ANSWER LINE If answer = 61(%) award 4 marks 8.0g of benzoic acid is $8.00/122 = 0.066\text{moles}$ ✓ 100% conversion gives $0.066 \times 136 = 8.976\text{g}$ ✓ % yield is $5.46/8.92 \times 100 = 61.2 / 60.8$ ✓ two sf = 61(%) ✓	4 (AO2.6 × 2)(AO2.8 × 2)	ecf on values actual values depend on when rounding done OR mol ester = $5.46/136 = 0.04$ OR % = $0.04 \times 100 / 0.066 = 60.6$
			Total	8	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
81			FIRST CHECK THE ANSWER ON THE ANSWER LINE If answer = 4×10^{19} award 3 marks Unit conversion $5/1000 = 5 \times 10^{-3} \text{ g / cm}^3$ AND Mole conversion $5 \times 10^{-3}/79.9 = 6.258 \times 10^{-5} \text{ moles } \checkmark$ Multiplication by $N_A \checkmark$ $= 4 \times 10^{19} \checkmark$	3 (AO2.2 × 3)	3.7625... to 2 or more sf scores 2 marks. ALLOW evaluation of any expression to 1 sf for MP3
			Total	3	