

OCR A-LEVEL CHEMISTRY A • H432

CHEMISTRY



EXAM QUESTION PACK

2.1.1-2.1.2 ATOMS, COMPOUNDS, MOLECULES AND EQUATIONS

SCORE

/345

PERCENTAGE

%

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- 1 A salt used as a fertiliser has the empirical formula $\text{H}_4\text{N}_2\text{O}_3$.

Suggest the formulae of the ions present in this salt.

-----[2]

- 2 A chemist carries out reactions of barium and barium nitride, Ba_3N_2 .

Reaction 1 Barium is reacted with water.

Reaction 2 Barium nitride is reacted with water, forming an alkaline solution and an alkaline gas.

Reaction 3 Barium is reacted with an excess of oxygen at 500°C , forming barium peroxide, BaO_2 .

- (i) Write equations for **Reaction 1** and **Reaction 2**.

Ignore state symbols.

Reaction 1: -----

Reaction 2: -----

[3]

- (ii) Predict the structure and bonding of Ba_3N_2 .

-----[1]

- (iii) BaO_2 formed in **Reaction 3** contains barium and peroxide ions.

The peroxide ion has the structure $[\text{O}-\text{O}]^{2-}$.

Suggest a '*dot-and-cross*' diagram for BaO_2 .

Show outer shell electrons only.

[1]

3 This question is about compounds of Group 3 elements.

Aluminium will combine directly with fluorine.

Write the equation for the reaction between aluminium and fluorine.

-----[1]

4 A molecule of an alkane has 24 carbon atoms.

State the empirical formulae of this alkane.

[1]

5(a) Chromite is the main ore of chromium. The chromium-containing compound in chromite is $\text{Fe}(\text{CrO}_2)_2$. The percentage of chromium in a sample of chromite can be determined using the method below.

Step 1

A 5.25 g sample of chromite ore is heated with sodium peroxide, Na_2O_2 .



Water is added to the resulting mixture.

Na_2CrO_4 dissolves in the water forming a solution containing CrO_4^{2-} ions.

Step 2

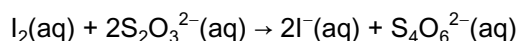
The mixture from **Step 1** is filtered and the filtrate is made up to 1.00 dm^3 in a volumetric flask.

A 25.0 cm^3 sample of this alkaline solution is pipetted into a conical flask and an excess of aqueous potassium iodide is added.

- A redox reaction takes place between I^- ions, CrO_4^{2-} ions and H_2O .
- In this reaction 1 mol CrO_4^{2-} forms 1.5 mol I_2 .

Step 3

The resulting mixture is titrated with $0.100 \text{ mol dm}^{-3}$ sodium thiosulfate, $\text{Na}_2\text{S}_2\text{O}_3(\text{aq})$ to estimate the I_2 present:



The average titre of $\text{Na}_2\text{S}_2\text{O}_3(\text{aq})$ is 25.5 cm^3 .

In **Step 1** Na_2O and NaFeO_2 react with water forming an alkaline solution containing a brown precipitate. This is **not** a redox reaction.

Write equations for:

- the reaction of Na_2O with water
- the reaction of NaFeO_2 with water.

----- [2]

- (b) Determine the percentage, by mass, of chromium in the ore.

Give your answer to **one** decimal place.

[6]

(c) This part refers to **Step 2** of the method.

In the redox reaction between I^- ions, CrO_4^{2-} ions and H_2O :

- CrO_4^{2-} ions, are reduced to chromium(III) ions, Cr^{3+}
- I^- ions are oxidised to iodine, I_2
- Construct an overall equation for the redox reaction and write half equations for the oxidation and reduction.

Overall equation:

Half equations:

[3]

6 What is the formula of chromium(III) sulfate?

- A Cr_3SO_4
- B $\text{Cr}(\text{SO}_4)_3$
- C $\text{Cr}_2(\text{SO}_4)_3$
- D Cr_3SO_3

Your answer

[1]

7 Bromine and mercury react with many elements and compounds.

Predict the formula of the compound formed when bromine reacts with aluminium.

[1]

- 8 A student carries out the following experiment to investigate the reaction between hexane and chlorine. The chlorine is made by reaction of aqueous sodium chlorate(I) with dilute hydrochloric acid.

Procedure	Observations
1 cm ³ of hexane is mixed with 1 cm ³ dilute aqueous sodium chlorate(I) in a test-tube.	The mixture forms two colourless layers.
1 cm ³ dilute hydrochloric acid is slowly added to the mixture.	The acid mixes with the lower layer, which turns a pale green colour.
The tube is then stoppered and shaken.	The pale green colour moves to the upper layer, leaving the lower layer colourless.
The tube is placed under a bright light and shaken at regular intervals for about 10 minutes. The stopper is loosened regularly to release any pressure.	The pale green colour slowly disappears leaving two colourless layers after about 10 minutes.

- (i) The reaction between aqueous sodium chlorate(I) and dilute hydrochloric acid produces aqueous sodium chloride as well as chlorine.

Suggest an equation for this reaction.

-----[2]

- (ii) Outline a simple practical test that would confirm the presence of chloride ions in the lower layer, and give the expected result.

test: -----

result: -----

-----[2]

- (iii) Name the apparatus that could be used to separate the two liquid layers present at the end of the experiment.

-----[1]

9 Haloalkanes can undergo hydrolysis.

A student carries out an experiment to find the relative rate of hydrolysis of 1-chloropropane, $\text{C}_3\text{H}_7\text{Cl}$, 1-bromopropane, $\text{C}_3\text{H}_7\text{Br}$, and 1-iodopropane, $\text{C}_3\text{H}_7\text{I}$.

The student adds 2 cm^3 of ethanol to 2 cm^3 of aqueous silver nitrate to three test tubes labelled A, B and C.

The student adds 5 drops of a different haloalkane to each test-tube in rapid succession and shakes each tube. The student measures the time for a precipitate to form in each test-tube.

The results are shown below.

Test tube	Haloalkane	Time taken for reaction to take place
A	$\text{C}_3\text{H}_7\text{Cl}$	about half an hour
B	$\text{C}_3\text{H}_7\text{Br}$	a few minutes
C	$\text{C}_3\text{H}_7\text{I}$	a few seconds

- (i) Write an ionic equation involving aqueous silver nitrate for formation of **one** of the precipitates.

-----[1]

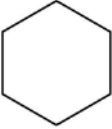
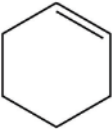
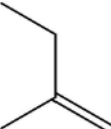
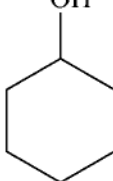
- (ii) What do the experimental results tell you about the carbon–halogen bond enthalpies?

-----[1]

- (iii) How could the student modify their experiment so that it could be completed in less time?

-----[1]

10(a) The organic compounds in the table below can be termed, aliphatic, alicyclic or aromatic.

E 	F 	G 
H 	I 	J 

Identify, using letters E, F, G, H, I, J, the compound(s) which are the following types.

Each response may contain more than one letter.

aliphatic _____

alicyclic _____

aromatic _____

[3]

(b) Compound I has one alkyl group.

What is the general formula of alkyl groups?

_____ [1]

(c) Compound H can be prepared in an elimination reaction by heating compound J with an acid catalyst.

A student carries out this preparation using 7.65 g of compound J.

The student obtains 2.05 g of compound H.

(i) Write an equation for this reaction, using molecular formulae.

Calculate the percentage yield of compound H.

Give your answer to **one** decimal place.

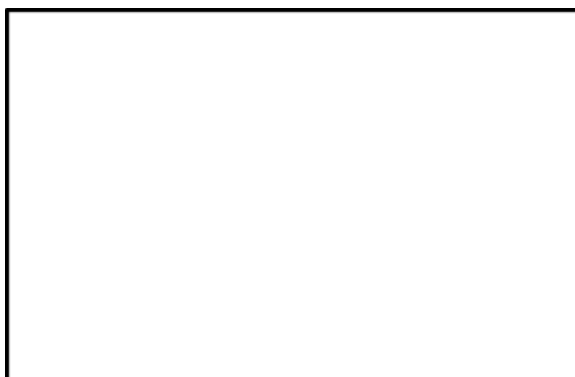
percentage yield = _____ % [4]

- (ii) Describe a simple test that the student could carry out to confirm the presence of the functional group in compound H.

Draw the structure of the organic product from the test.

test: _____

organic product =



[2]

A student carries out an experiment to determine the enthalpy change for a neutralisation reaction.

The student measures out 35.0 cm^3 of 2.40 mol dm^{-3} KOH and 35.0 cm^3 of 1.20 mol dm^{-3} H_2SO_4 .
The temperature of each solution is 19.5°C .

The student mixes the solutions. The KOH is all neutralised and the maximum temperature reached is 36.0°C .

(i) Write the overall equation for the reaction that takes place.

[1]

(ii) Calculate the enthalpy change for the reaction between 1 mol KOH and 1 mol HCl.

Assume that the density of the mixture is 1.00 g cm^{-3} and that the specific heat capacity for the solution is the same as for water.

$\Delta H =$ _____ kJ [3]

(iii) Explain, why the answer to (ii) is the enthalpy change of neutralisation.

----- [1]

(iv) In this experiment, the student uses a thermometer with an uncertainty of $\pm 0.5^\circ\text{C}$ in each reading.

Calculate the percentage uncertainty in the temperature rise.

percentage uncertainty = _____ % [1]

- (i) Hydrazine, N_2H_4 , is used as a rocket fuel. Hydrazine can be prepared from the reaction of ammonia with sodium chlorate(I). There are two other products in the reaction.

Write an equation for this reaction.

[1]

- (ii) Using the electron pair repulsion theory, draw a 3-D diagram of a molecule of hydrazine.

Predict the H–N–H bond angle around each nitrogen atom.

H–N–H bond angle: _____ [2]

- 13 Two elements, **A** and **B**, react to form an ionic compound with the formula A_2B_3 . In this compound, **A** and **B** both have the electron configuration $1s^2 2s^2 2p^6 3s^2 3p^6$.

Deduce possible identities of the ions in A_2B_3 .

A:

B:

[2]

- 14 Bromine is a reactive element. It combines with other non-metals to form covalent compounds. Phosphorus tribromide, PBr_3 , and iodine monobromide, IBr , are examples of covalent compounds used in organic synthesis.

PBr_3 can be prepared by heating bromine with phosphorus, P_4 .

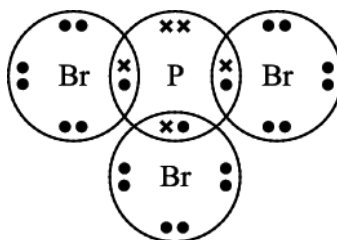
- (i) Write an equation for this reaction.

----- [1]

- (ii) How many molecules are present in 1.3535 g of PBr_3 ?

number of molecules = ----- [3]

- (iii) The 'dot-and-cross' diagram of a molecule of PBr_3 is given below.



Name the shape of this molecule and explain why the molecule has this shape.

name: -----

explanation: -----

[3]

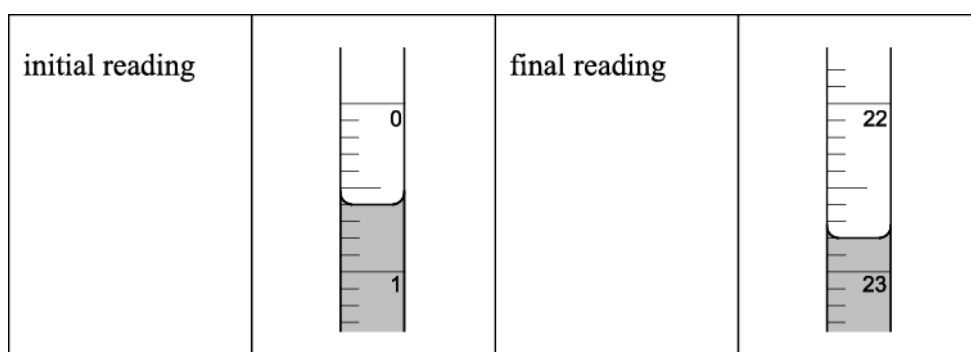
15(a) A student carries out an experiment to identify an unknown carbonate.

- The student weighs a sample of the solid carbonate in a weighing bottle.
- The student tips the carbonate into a beaker and weighs the empty weighing bottle.
- The student prepares a 250.0 cm^3 solution of the carbonate.
- The student carries out a titration using 25.0 cm^3 of this solution measured using a pipette with 0.100 mol dm^{-3} hydrochloric acid in the burette.

The student carries out the final part of the experiment by adding 0.100 mol dm^{-3} hydrochloric acid to a burette and performing a titration using a 25.0 cm^3 sample of the aqueous carbonate.

The student reads the burette to the nearest 0.05 cm^3 .

The diagrams below show the initial burette reading and the final burette reading.



(i) Record the student's readings and the titre.

[1]

(ii) Describe what the student should do next to obtain reliable results for the titration.

----- [1]

(b) The equation below represents the reaction between the carbonate and hydrochloric acid.



(i) Calculate the amount, in mol, of M_2CO_3 used in the titration.

$$n(\text{M}_2\text{CO}_3) = \text{----- mol [2]}$$

(ii) The student's mass readings are recorded below.

Mass of weighing bottle + carbonate / g	14.92
Mass of weighing bottle / g	13.34

Use the student's results to identify the carbonate, M_2CO_3 .

Show **all** your working.

[4]

16(a) This question looks at groups in the periodic table.

Calcium and strontium are Group 2 metals. They both react with water.

A chemist reacts 0.200 g of strontium with 250 cm³ water, leaving a colourless solution containing strontium ions. The volume remains at 250 cm³.

(i) Write an equation for the reaction between strontium and water.

Include state symbols.

----- [1]

(ii) Calculate the concentration, in mol dm⁻³, of strontium ions in the resulting solution.

concentration of strontium ions = _____ mol dm⁻³ [2]

(iii) A student plans to carry out this experiment using 0.200 g of calcium instead of 0.200 g of strontium.

Predict the difference, if any, between the volume of gas produced by calcium and strontium.

Explain your reasoning and include a calculation in your answer.

----- [3]

(b) Ionisation energies can provide evidence for electron structure.

Write an equation for the first ionisation energy of chlorine.

Include state symbols.

-----[1]

(c) The following data shows the first eight successive ionisation energies of an element.

Ionisation energy	1st	2nd	3rd	4th	5th	6th	7th	8th
Energy / kJ mol^{-1}	590	1145	4912	6474	8144	10 496	12 320	14 207

In which group of the periodic table would this element be found?

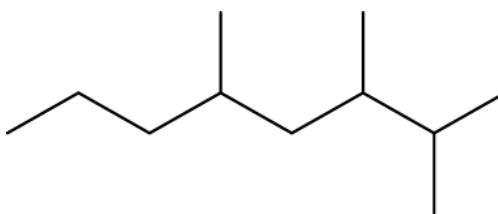
Use the data to justify your choice.

group:

justification:

-----[2]

17(a) Hydrocarbon D is a structural isomer of $C_{11}H_{24}$ used in aviation fuel.

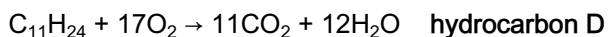


hydrocarbon D

Name hydrocarbon D.

-----[1]

(b) When used in a jet engine, hydrocarbon D undergoes complete combustion as shown in the equation below:



(i) During a typical flight in the upper atmosphere:

- the aircraft burns 80.4 tonnes of hydrocarbon D
- the temperature outside the aircraft is $-55\text{ }^{\circ}\text{C}$
- the pressure is 26.5 kPa

Calculate the volume, in m^3 , of CO_2 released during a typical aircraft flight.

Give your answer in **standard form** and to **three** significant figures.

volume of CO_2 = _____ m^3 [5]

(ii) Exhaust gases from an aircraft engine contain nitrogen monoxide.

Write an equation for the formation of nitrogen monoxide in an aircraft engine.

----- [1]

18 A redox reaction takes place when copper metal is heated with concentrated sulfuric acid. A blue solution forms and 95.0 cm^3 of a colourless gas is collected, measured at RTP. The gas has a mass of 254 mg.

(i) Write the electron configuration, in terms of sub-shells, for a copper atom.

-----[1]

(ii) Suggest the identity of the colourless gas and write an equation for the reaction taking place.

State symbols are **not** required in the equation.

Show your working for calculations.

gas: -----

equation: -----

[4]

19(a) Ethers are a homologous series of organic compounds containing the R–O–R functional group.

The structures and names of two ethers are shown in Fig. 4.1.

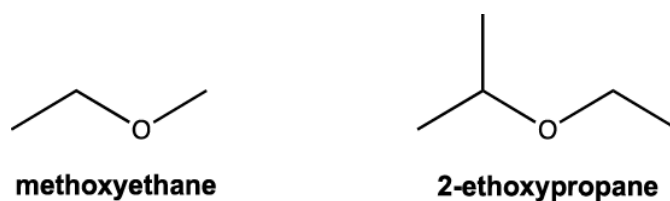


Fig. 4.1

Draw the **skeletal** formula of the ether, 2-ethoxy-3-methylbutane.

[1]

(b) Ethers can be prepared by nucleophilic substitution of haloalkanes with alkoxide ions, RO^- .

(i) Alkoxide ions can be prepared by reacting sodium with an alcohol. A gas is also formed.

Write an equation for the formation of methoxide ions from sodium and an alcohol.

-----[1]

(ii) Methoxyethane, shown in Fig. 4.1, can be prepared by reacting bromoethane, $\text{CH}_3\text{CH}_2\text{Br}$, with methoxide ions, CH_3O^- .

Suggest the mechanism for the nucleophilic substitution of $\text{CH}_3\text{CH}_2\text{Br}$ with CH_3O^- .

Show curly arrows, charges, relevant dipoles, and products.

[3]

(iii) In this mechanism, explain how CH_3O^- ions have acted as a nucleophile.

State the type of bond fission that takes place.

-----[1]

(c) 2-Ethoxypropane, shown in Fig. 4.1, is analysed by ^1H NMR spectroscopy.

Complete the table to predict the ^1H NMR spectrum of 2-ethoxypropane.

You may **not** need to use all the rows.

Chemical shift, δ/ppm	Relative peak area	Splitting pattern

[4]

(d) In organic reactions, alkoxide ions can also act as a base.

The diagram below shows an incomplete mechanism for the reaction of a diester with methoxide ions, CH_3O^- (**Step 1**), followed by reaction of the intermediate with bromoethane (**Step 2**).

- (i) For **Step 1**, add curly arrows to show how CH_3O^- reacts with the diester to form the intermediate.
In the box, draw the structure of the organic product formed in **Step 2**.



[3]

- (ii) Explain how CH_3O^- ions have acted as a base in this mechanism.

----- [1]

N_2O is a useful anaesthetic and NO has been linked to the depletion of ozone in the stratosphere.

The standard enthalpy changes of formation of N_2O and NO are given in the table.

Compound	$\Delta_f H^\ominus / \text{kJ mol}^{-1}$
$\text{N}_2\text{O (g)}$	+ 82.0
NO (g)	+ 90.2

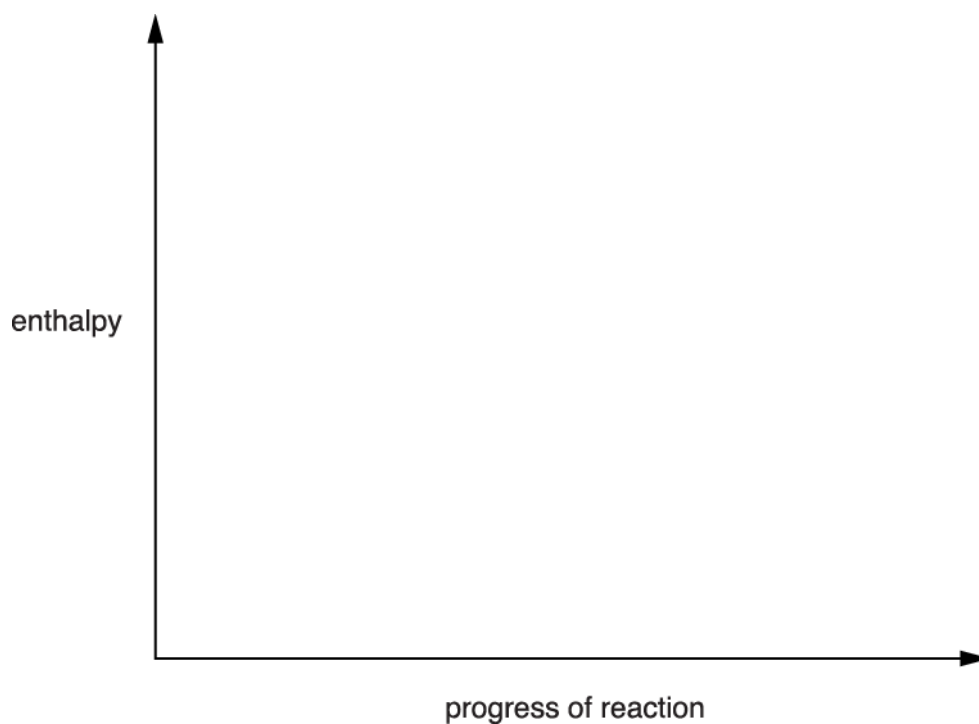
- (i) Explain, in terms of bond breaking and bond making, why the enthalpy change of formation of NO is endothermic.

----- [1]

- (ii) Draw a fully labelled enthalpy profile diagram to represent the enthalpy change of formation of N_2O .

The formulae, with state symbols, of the reactants and products should be included as part of the diagram.

You are **not** expected to show the activation energy for the reaction.



The student is provided with the following solutions:

- bromine water
- aqueous iodine
- aqueous barium chloride
- aqueous magnesium bromide
- aqueous calcium iodide.

Chlorine gas and chlorine water are **not** available.

The student carries out the **minimum** number of test-tube experiments using these solutions in the presence of cyclohexane (an organic solvent).

- State the solutions that need to be added together in order to prove the trend in reactivity of the halogens, using the **minimum** number of test-tube experiments.
- Describe the colour seen in the organic solvent at the end of each test-tube experiment.
- Write an ionic equation for **one** reaction that takes place.

22(a) Gallium, atomic number 31, is in Period 4 of the Periodic Table. Gallium is a Group 3 element.

Predict the formula of a gallium ion.

-----[1]

(b) Fluorine forms several compounds with sulfur and with oxygen.

(i) Give the **formula** and the **name** of the compound formed between fluorine and sulfur which has octahedral molecules.

Formula -----

Name -----

[1]

(ii) Fluorine reacts with aqueous sodium hydroxide to form the oxide F_2O .

Two other products are also formed. One product is an ionic compound with a relative formula mass of 42.0.

Construct a balanced equation for this reaction.

-----[2]

23(a) Zinc carbonate, ZnCO_3 , reacts with dilute hydrochloric acid.

A student reacts a sample of ZnCO_3 with an excess of dilute hydrochloric acid in a test-tube.

(i) Describe what the student would see during this reaction.

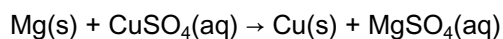
----- [1]

(ii) Write the equation for the reaction between ZnCO_3 and dilute hydrochloric acid.

----- [1]

(b) Magnesium will undergo redox reactions with aqueous salts of less reactive metals.

(i) A student reacts magnesium with aqueous copper(II) sulfate.



Explain, in terms of **numbers** of electron transferred, the redox processes taking place in this reaction.

----- [2]

(ii) The student also noticed that the magnesium started fizzing.

The student thought the fizzing was due to the magnesium reacting with water in the mixture.

Write the equation for the reaction of magnesium with water.

Include state symbols.

----- [2]

(c) Compounds of calcium have many uses.

(i) Identify a compound of calcium that could be used to convert a soil pH from 5.8 to 7.5.

-----[1]

(ii) Calcium phosphide, Ca_3P_2 , is an ionic compound used in rat poison.

Calcium phosphide can be prepared by reacting calcium metal with phosphorus, P_4 .

Write the equation for the reaction of calcium with phosphorus to form calcium phosphide.

-----[1]

(iii) Draw a 'dot-and-cross' diagram to show the bonding in calcium phosphide, Ca_3P_2 .

Show outer electrons only.

[2]

24 Stearic acid, oleic acid and linoleic acid are examples of naturally occurring fatty acids.

Traditional name	Structure	Systematic name
Stearic acid	$\text{C}_{17}\text{H}_{35}\text{COOH}$	Octadecanoic acid
Oleic acid	$\text{C}_{17}\text{H}_{33}\text{COOH}$	Octadec-9-enoic acid
Linoleic acid	$\text{C}_{17}\text{H}_{31}\text{COOH}$	Octadeca-9,12-dienoic acid

Sodium stearate is the salt formed when stearic acid reacts with sodium hydroxide solution.

Write an equation for the formation of sodium stearate.

-----[1]

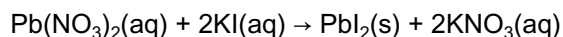
25 What is the formula of ammonium sulfide?

- A NH_4S
- B NH_4SO_4
- C $(\text{NH}_4)_2\text{S}$
- D $(\text{NH}_4)_2\text{SO}_4$

Your answer

[1]

26(a) Aqueous lead(II) nitrate, $\text{Pb}(\text{NO}_3)_2(\text{aq})$, and aqueous potassium iodide, $\text{KI}(\text{aq})$, react together.
The equation is shown below.



A student carries out an experiment to determine the enthalpy change of reaction, $\Delta_r H$, of this reaction.

The student follows the method outlined below.

- Add 50.0 cm^3 of 1.50 mol dm^{-3} $\text{Pb}(\text{NO}_3)_2(\text{aq})$ to a polystyrene cup.
- Measure out 50.0 cm^3 of a solution of $\text{KI}(\text{aq})$, which is in excess.
- Measure the temperature of both solutions.
- Add the $\text{KI}(\text{aq})$ to the polystyrene cup, stir the mixture and record the maximum temperature.

Temperature readings

Initial temperature of both solutions = 19.5°C

Maximum temperature of mixture = 30.0°C

Calculate $\Delta_r H$, in kJ mol^{-1} , for the reaction shown in the equation above.

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

Assume that the density of all solutions and specific heat capacity, c , of the reaction mixture is the same as for water.

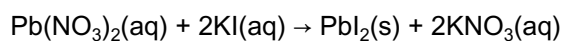
$\Delta_r H =$ _____ kJ mol^{-1} [4]

(b) Write an ionic equation for the reaction that the student carries out.

Include state symbols.

----- [1]

- (c) The 50.0 cm^3 of KI(aq) used in the experiment contains 10% more KI than is needed to react with 50.0 cm^3 of $1.50 \text{ mol dm}^{-3} \text{ Pb(NO}_3)_2\text{(aq)}$.



Calculate the concentration, in mol dm^{-3} , of KI that the student used.

concentration of KI = _____ mol dm^{-3} [2]

27(a) Hydrated copper(II) methanoate, $\text{Cu}(\text{HCOO})_2 \cdot x\text{H}_2\text{O}$, is a copper salt.

A student carries out the procedure below to prepare $\text{Cu}(\text{HCOO})_2 \cdot x\text{H}_2\text{O}$ and to determine the value of x in its formula.

Step 1

The student prepares $\text{Cu}(\text{HCOO})_2 \cdot x\text{H}_2\text{O}$ by reacting a copper compound with aqueous methanoic acid to form $\text{Cu}(\text{HCOO})_2(\text{aq})$ and allowing the solvent to evaporate.

Step 2

The student dissolves 2.226 g of $\text{Cu}(\text{HCOO})_2 \cdot x\text{H}_2\text{O}$ in water and makes up the solution to 250.0 cm^3 .

Step 3

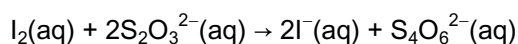
Using a pipette, the student adds 25.0 cm^3 of this solution to a conical flask followed by an excess of $\text{KI}(\text{aq})$.

The $\text{Cu}^{2+}(\text{aq})$ ions react to form a precipitate of copper(I) iodide and $\text{I}_2(\text{aq})$.

In this reaction, 2 mol Cu^{2+} form 1 mol I_2 .

Step 4

The student titrates the iodine in the resulting mixture with $0.0420 \text{ mol dm}^{-3} \text{Na}_2\text{S}_2\text{O}_3(\text{aq})$.



23.5 cm^3 $0.0420 \text{ mol dm}^{-3} \text{Na}_2\text{S}_2\text{O}_3(\text{aq})$ is required to reach the end point.

Complete the electron configuration of copper in

$\text{Cu}(\text{HCOO})_2 \cdot x\text{H}_2\text{O}$: $1s^2$ _____

copper(I) iodide: $1s^2$ _____ [2]

- (b) Choose a suitable copper compound for **step 1**, and write the full equation for the reaction that would take place to form $\text{Cu}(\text{HCOO})_2(\text{aq})$.

State symbols are **not** required.

----- [1]

- (c) Write an ionic equation, including state symbols, for the reaction in **step 3**.

----- [1]

(d) In **step 4**, the student adds a solution to observe the end point accurately.

Name the solution and state the colour change at the end point.

Solution added: _____

Colour change: _____ [2]

(e) Determine the value of x in $\text{Cu}(\text{HCOO})_2 \cdot x\text{H}_2\text{O}$.

Show your working.

28(a) This question is about reactions of sulfur compounds.

A student neutralises aqueous sulfuric acid, $\text{H}_2\text{SO}_4(\text{aq})$, with aqueous sodium hydroxide, $\text{NaOH}(\text{aq})$, to determine the enthalpy change of neutralisation, $\Delta_{\text{neut}}H$.

- (i) Define the term *enthalpy change of neutralisation* and write the ionic equation for the this change. Include state symbols.

----- [2]

- (ii) Write a full equation for the complete neutralisation of H_2SO_4 with $\text{NaOH}(\text{aq})$.
State symbols are **not** required.

----- [1]

- (iii) In their experiment, the student follows the method below.

- Add 50.0 cm^3 of 1.50 mol dm^{-3} $\text{NaOH}(\text{aq})$ to a polystyrene cup.
- Measure out 25.0 cm^3 of 1.50 mol dm^{-3} $\text{H}_2\text{SO}_4(\text{aq})$.
- Measure the initial temperature of both solutions.
- Add the $\text{H}_2\text{SO}_4(\text{aq})$ to the $\text{NaOH}(\text{aq})$ in the polystyrene cup, stir the mixture, and record the maximum temperature reached.

Results

Initial temperature of both solutions	22.0 °C
Maximum temperature of mixture	35.5 °C

Calculate $\Delta_{\text{neut}}H$, in kJ mol^{-1} .

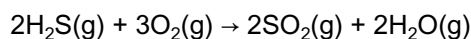
Assume that the density and specific heat capacity of all solutions are the same as for water.

$$\Delta_{\text{neut}}H = \text{-----} \text{ kJ mol}^{-1} \text{ [3]}$$

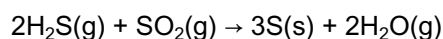
- (b) Much of the sulfur required for production of sulfuric acid is obtained from sulfur impurities in natural gas, such as hydrogen sulfide, H_2S .

The H_2S is converted into sulfur in two steps.

Step 1: Some of the H_2S is reacted with oxygen to form sulfur dioxide, SO_2 .



Step 2: The remaining H_2S is reacted with the SO_2 to produce sulfur.



- (i) Construct the overall equation for the two steps above.

-----[1]

- (ii) A natural gas supply contains 16.0% H_2S by volume.

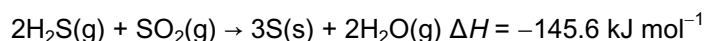
The $\text{H}_2\text{S}(\text{g})$ in $1.50 \times 10^8 \text{ dm}^3$ of this natural gas supply, measured at RTP, is processed into sulfur with an overall percentage yield of 95.0%.

Calculate the mass of sulfur, in g, obtained from $1.50 \times 10^8 \text{ dm}^3$ of natural gas supply.

Give your answer to **three** significant figures and in standard form.

mass of sulfur = ----- g [3]

- (c) The enthalpy change for the equation in **step 2** is shown below.



Standard entropies, S , and enthalpy changes of formation, $\Delta_f H$, are given in the table.

Substance	H ₂ S(g)	SO ₂ (g)	S(s)	H ₂ O(g)
$S / \text{J mol}^{-1} \text{K}^{-1}$	205.7	248.1	31.8	188.7
$\Delta_f H / \text{kJ mol}^{-1}$	-20.6		0	-241.8

- (i) Calculate ΔG at 25 °C, and explain whether the reaction in **step 2** is feasible at 25 °C.

Calculate the temperature, in K, at which the feasibility changes.

Show your working and explain your reasoning.

[5]

- (ii) Calculate $\Delta_f H$ for SO₂(g).

$\Delta_f H$ for SO₂(g) = _____ kJ mol⁻¹ [2]

29 The use of some haloalkanes, such as chlorotrifluoromethane, has been banned as they form $\text{C}/\bullet$ radicals which break down ozone.

(i) Construct an equation to show the formation of $\text{C}/\bullet$ radicals from chlorotrifluoromethane.

-----[1]

(ii) Ozone is broken down by $\text{C}/\bullet$ radicals in a two-step process.

Write the equations for the two steps and the overall equation for this process.

Step 1 -----

Step 2 -----

Overall equation ----- [3]

(iii) A research chemist found that 1.00 g of $\text{C}/\bullet$ radicals can breakdown 135 kg of O_3 .

Calculate the number of O_3 molecules removed by one $\text{C}/\bullet$ radical.

Give your answer in **standard form** and to **three** significant figures.

number of O₃ molecules = _____ [3]

30(a) A student was provided with five compounds: an aldehyde, a ketone, a carboxylic acid and two esters. The student decides to identify the type of compound by carrying out some chemical tests.

Suggest chemical tests to identify the carboxylic acid and aldehyde.

For each test, include essential reagent(s), observation(s) and a balanced equation.

In your equations, use 'R' for the alkyl group.

(i) Test for carboxylic acid.

Reagent(s) _____

Observation(s) _____

Equation

[2]

(ii) Test for aldehyde.

Reagent(s) _____

Observation(s) _____

Equation

[2]

- (b) Suggest a chemical test to distinguish the ketone from the two esters.

Reagent(s) _____

Observation(s) _____

-----[1]

- (c) The student wants to confirm that the other two compounds are esters. Unfortunately there is no direct test for an ester group.

The esters are $\text{CH}_3\text{COOC}(\text{CH}_3)_3$ and $(\text{CH}_3)_3\text{CCOOCH}_3$.

The student plans the following:

- hydrolyse the two esters using aqueous sodium hydroxide.
- separate the hydrolysis products.
- carry out tests on the hydrolysis products.

- (i) Write an equation for the hydrolysis of one of the two esters with aqueous sodium hydroxide.

Show the structures for the organic compounds.

[2]

- (ii) Suggest a chemical test on the hydrolysis products that would allow the two esters to be identified.

Write an equation for one reaction that takes place.

Show the structures for the organic compounds.

Reagent(s) _____

Observation(s) _____

[2]

- (iii) The student thought that NMR spectroscopy could be used to identify the two esters without the need to carry out chemical tests.

The esters are $\text{CH}_3\text{COOC}(\text{CH}_3)_3$ and $(\text{CH}_3)_3\text{CCOOCH}_3$.

Explain whether the student is correct for ^{13}C and ^1H NMR spectroscopy. Your answer should also clearly state any differences between the spectra of the two esters.

[3]

(d) The ketone and aldehyde provided to the student both contain five carbon atoms.

The ^1H NMR spectrum of the aldehyde contains two singlet peaks only: a large peak at $\delta = 1.2$ ppm and smaller peak at $\delta = 9.6$ ppm.

Suggest **all** possible structures for the ketone and identify the aldehyde.

Show **all** your reasoning.

[5]

31 Which calcium compound contains the **greatest** percentage by mass of calcium?

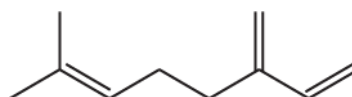
- A calcium carbonate
B calcium nitrate
C calcium hydroxide
D calcium sulfate

Your answer

10

[1]

32 Myrcene, C₁₀H₁₆, is a naturally occurring hydrocarbon containing more than one carbon-carbon double bond.



myrcene

- (i) Reaction of 204 mg of myrcene with hydrogen gas produces a saturated alkane.

Calculate the volume of hydrogen gas, in cm³ and measured at RTP, needed for this reaction.

Show your working.

volume = _____ cm³ [2]

- (ii) β -Carotene is a naturally occurring unsaturated hydrocarbon found in carrots.

A β -carotene molecule contains 40 carbon atoms, has two rings, and a branched chain.

0.0200 mol of β -carotene reacts with 5.28 dm³ of hydrogen gas to form a saturated hydrocarbon.

Using molecular formulae, construct a balanced equation for this reaction.

Include relevant calculations and reasoning.

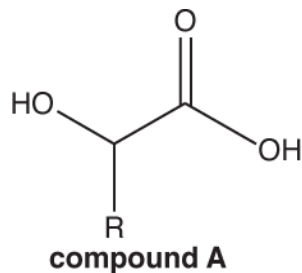
Equation _____ [4]

33(a) This question is about alcohols.

Construct an equation for the complete combustion of an unsaturated alcohol with 5 carbon atoms.

-----[1]

35 The structural formula of compound **A** is shown below.



Two reactions of compound **A** are carried out.

Suggest an equation for each reaction and state the type of reaction.

In your equations, draw structures for organic compounds.

You can use R for the alkyl group.

- (i) Magnesium ribbon is added to a solution of compound **A**.
Gas bubbles are seen and the magnesium slowly dissolves.

Equation

Type of reaction ----- [3]

- (ii) Compound **A** is heated with a few drops of concentrated sulfuric acid as a catalyst.
A cyclic 'dimer' of compound **A** forms.

Equation

Type of reaction ----- [3]

36 Barium nitride is formed when barium is heated with nitrogen.

(i) Complete the electron configuration of a nitride ion.

1s² -----[1]

(ii) Solid barium nitride is reacted with water, forming an alkaline solution **A** and an alkaline gas **B**.

Identify **A** and **B**.

Write an equation, including state symbols, for the reaction.

A -----

B -----

-----[4]

37 2-chloropropene can be polymerised to form poly(2-chloropropene).

(i) Write a balanced equation for the formation of this polymer.

The equation should include the structure of the repeat unit of the polymer.

[2]

(ii) After their useful life, waste polymers can be disposed of by combustion.

State **one** particular problem with disposal of poly(2-chloropropene) by combustion.

----- [1]

38 Fig. 22.1 shows first ionisation energies for elements across Period 3.

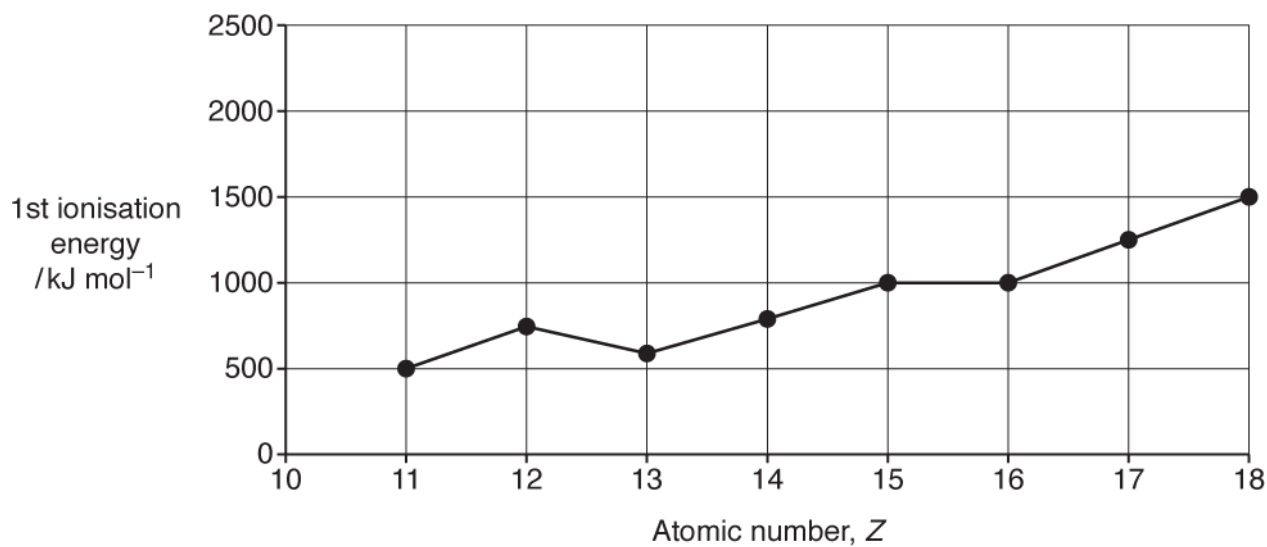


Fig. 22.1

- (i) Add a point to Fig. 22.1 for the first ionisation energy of the element with $Z = 10$.

[1]

- (ii) Estimate the energy required to form **one** $\text{Na}^+(\text{g})$ ion from one $\text{Na}(\text{g})$ atom.
Give your answer in kJ, in standard form, and to **two** significant figures.

energy = _____ kJ [1]

(iii) Explain why the first ionisation energies in Fig. 22.1 show a general increase across Period 3 (Na–Ar).

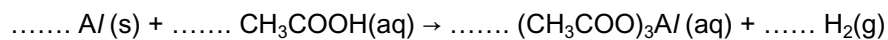
[3]

(iv) Explain why the general increase in first ionisation energies across Period 3 is **not** followed for Mg ($Z = 12$) to Al ($Z = 13$).

[2]

- (i) The unbalanced equation for the reaction is shown below.

Balance the equation.



[1]

- (ii) This reaction is a redox reaction.

Deduce which element has been oxidised and which element has been reduced, and state the changes in oxidation number.

Element oxidised: _____ oxidation number change: from _____ to _____

Element reduced: _____ oxidation number change: from _____ to _____

[2]

40 Selenium is in the same group of the periodic table as sulfur.

(i) Complete the full electron configuration of a selenium atom.

$1s^2$ [1]

(ii) Sodium selenide reacts with hydrochloric acid to form a toxic gas, **B**, with a relative molecular mass of 81.0.

Identify gas **B** and write an equation for this reaction.

Gas B

Equation [2]

41 'Enthalpy change of vaporisation' is the enthalpy change when one mole of a substance changes from a liquid to a gas at its boiling point.

(i) Write an equation, including state symbols, to represent the enthalpy change of vaporisation of bromine.

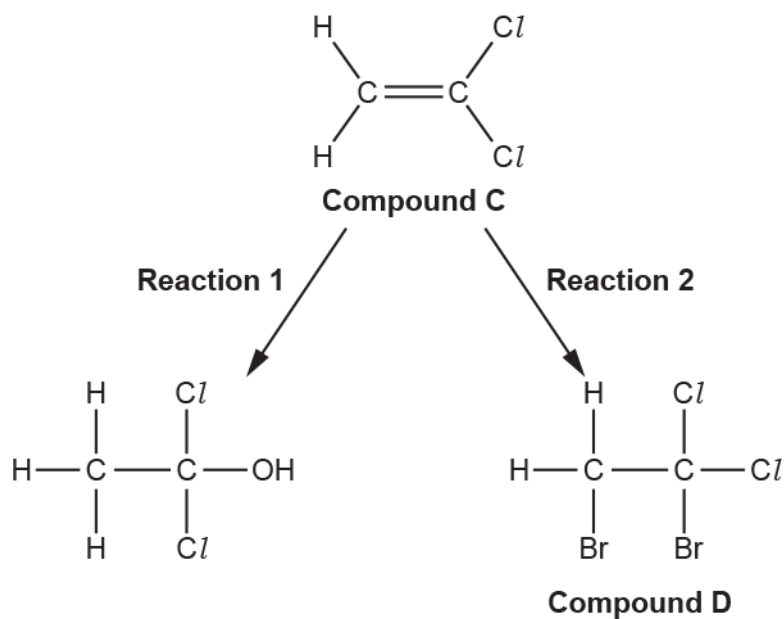
-----[1]

(ii) Suggest whether the enthalpy change of vaporisation of bromine is exothermic or endothermic.

Explain your answer.

-----[1]

42(a) Two reactions of compound **C** are shown in the flowchart below.



State the reagents and conditions for **reaction 1**.

.....

..... [1]

(b) In **reaction 2**, compound **C** reacts with bromine to form compound **D**.

(i) Give the systematic name of compound **D**.

-----[1]

(ii) Outline the mechanism for **reaction 2**.

Include curly arrows, charges and relevant dipoles.

[3]

(c) Compound **C** forms an addition polymer **E**.

(i) Write a balanced equation for this reaction.

Show displayed formulae.

[2]

(ii) State **one** advantage and **one** disadvantage of using combustion as a method for the disposal of waste polymer **E**.

Advantage -----

Disadvantage -----

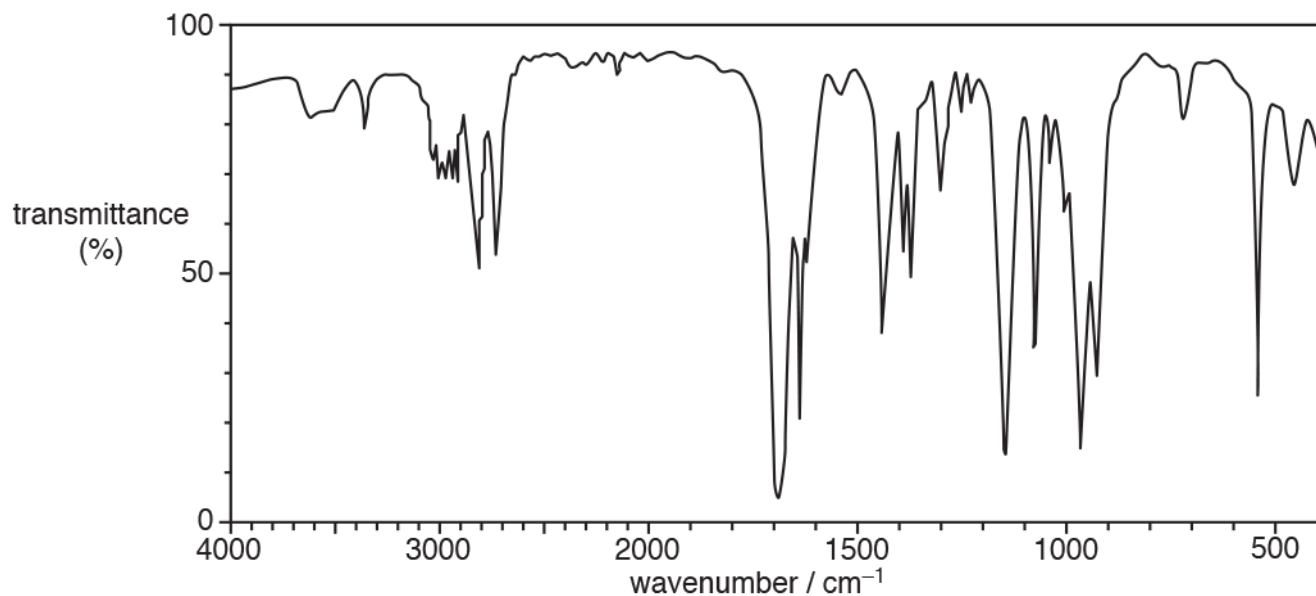
[2]

43 * Compound **F** is a *trans* stereoisomer which is a useful intermediate in organic synthesis.

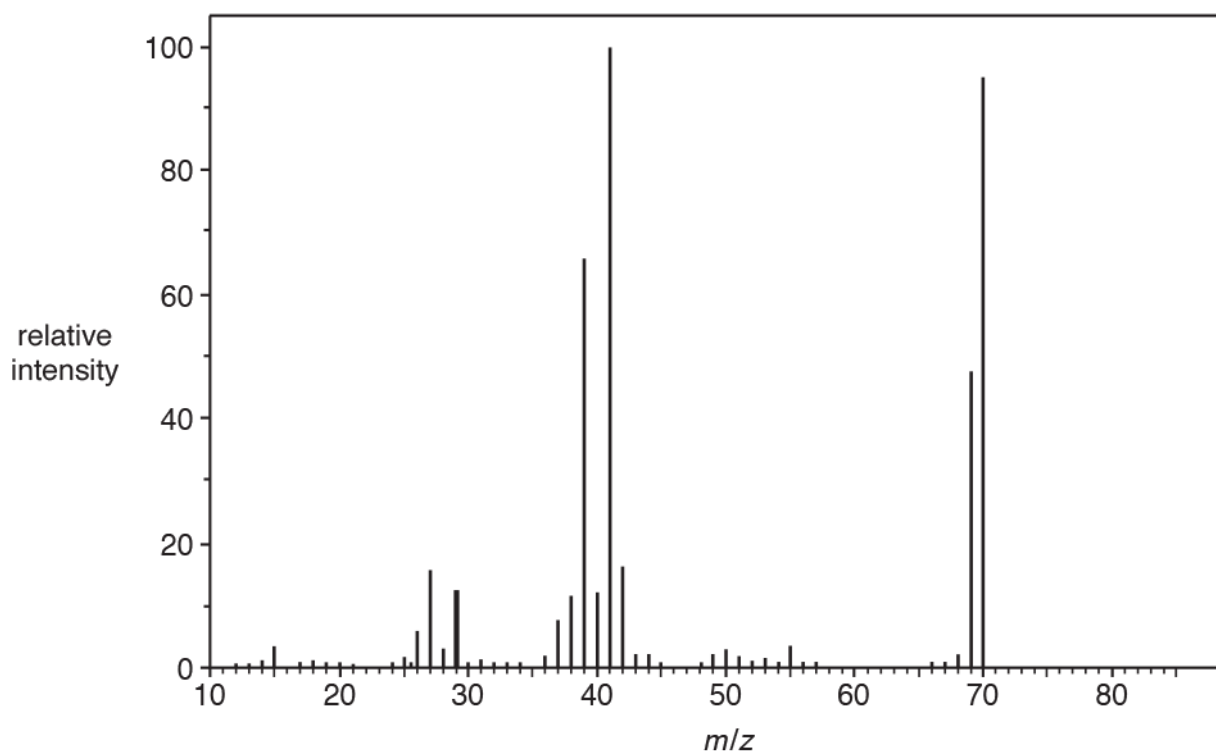
The results of elemental and spectral analysis of compound **F** are shown below.

Percentage composition by mass: C, 68.6 %; H, 8.6 %; O, 22.8 %.

Infrared spectrum



Mass spectrum



In the mass spectrum, the peak with the greatest relative intensity is caused by the loss of a functional group from the molecular ion of compound F.

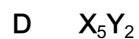
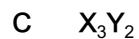
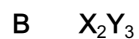
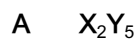
Determine the structure of compound F.

Explain your reasoning and show your working.

[6]

44 In the Periodic Table, element X is in Group 2 and element Y is in Group 15 (5).

What is the likely formula of an ionic compound of X and Y?



Your answer

[1]

45 Which statement about ammonium carbonate is **not** correct?

A It reacts with $Ba(NO_3)_2(aq)$ to form a white precipitate.

B It effervesces with dilute nitric acid.

C It release an alkaline gas with warm $NaOH(aq)$.

D It has the formula NH_4CO_3 .

Your answer

[1]

Reaction 1: Aqueous copper(II) sulfate reacts with excess aqueous ammonia in a ligand substitution reaction. A deep-blue solution is formed, containing an octahedral complex ion, **C**, which is a trans isomer.

Reaction 2: Copper(I) oxide reacts with hot dilute sulfuric acid in a disproportionation reaction. A blue solution, **D**, and a brown solid, **E** are formed.

Reaction 3: Copper(II) oxide reacts with warm dilute nitric acid in a neutralisation reaction, to form a blue solution. Unreacted copper(II) oxide is filtered off, and the solution is left overnight in an evaporating basin.

A hydrated salt, F, crystallises, with the percentage composition by mass:

Cu, 26.29%; H, 2.48%; N, 11.59%; O, 59.63%.

Identify **C–F** by formulae or structures, as appropriate.

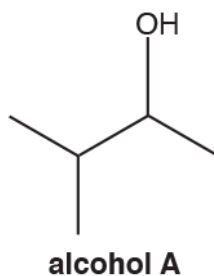
Include equations, any changes in oxidation number, and working.

[6]

[illegible]

47(a) This question is about reactions of organic compounds containing carbon, hydrogen and oxygen.

A chemist investigates two reactions of alcohol **A**, shown below.



(i) What is the systematic name of alcohol **A**?

-----[1]

(ii) What is the structural formula of alcohol **A**?

-----[1]

(iii) The chemist heats alcohol **A** with an acid catalyst to form a mixture containing **two** alkenes.

Draw the structures of the **two** alkenes formed in this reaction.

--	--

[2]

(iv) The chemist heats alcohol **A** with sodium chloride and sulfuric acid.

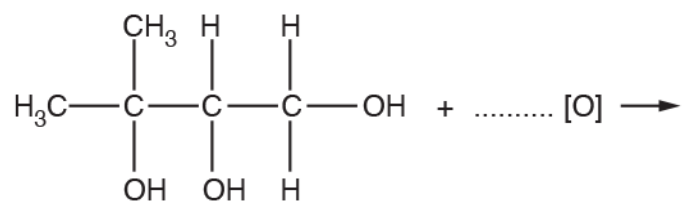
Construct a balanced equation for this reaction.

Show structures for the organic compounds in your equation.

[2]

- (b) Compound **B**, shown below, is refluxed with excess acidified potassium dichromate(VI) to form a single organic product.

Complete the equation for this reaction.



compound B

[2]

48(a) The relative molecular masses and boiling points of some fuels are shown in Table 22.1.

Fuel	Relative molecular mass	Boiling point / °C
hexane	86	69
pentan-1-ol	88	138
heptane	100	98

Table 22.1

Write an equation for the incomplete combustion of heptane.

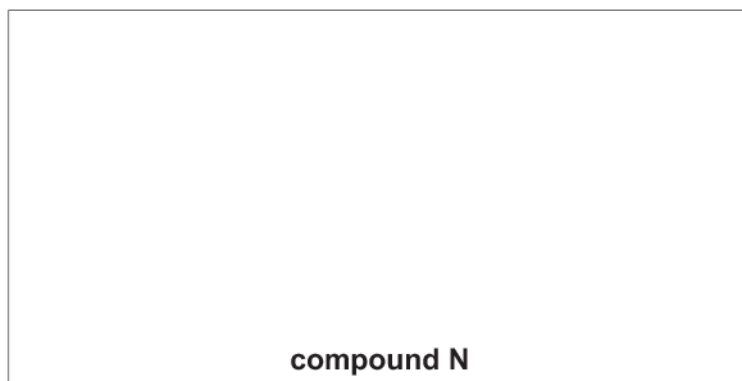
-----[1]

(b) Fuel additives are often used to improve the combustion of a fuel.

(i) Compound N is a fuel additive containing carbon, hydrogen and oxygen only.

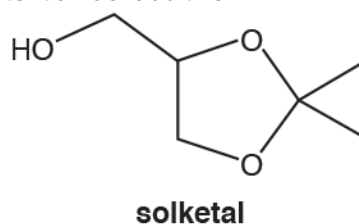
Complete combustion of 1.71 g of compound N produces 2.97 g of CO₂ and 1.62 g of H₂O. The relative molecular mass of compound N is 76.0.

Calculate the molecular formula of N and suggest a possible structure for the compound.



[5]

(ii) Solketal has been investigated as a potential fuel additive.



Solketal is synthesised from propane-1,2,3-triol and a carbonyl compound.

Construct a balanced equation for this synthesis.

Show structures for the organic compounds in your equation.

[2]

- 49 Succinic acid $(\text{CH}_2\text{COOH})_2$ is esterified by ethanol, $\text{C}_2\text{H}_5\text{OH}$, in the presence of an acid catalyst to form an equilibrium mixture.

Succinic acid is esterified by ethanol, $\text{C}_2\text{H}_5\text{OH}$, in the presence of an acid catalyst to form an equilibrium mixture.

The equilibrium constant, K_c , for this equilibrium can be calculated using the amounts, in moles, of the components in the equilibrium mixture, using **expression 5.1**.

$$K_c = \frac{n((\text{CH}_2\text{COOC}_2\text{H}_5)_2) \times n(\text{H}_2\text{O})^2}{n((\text{CH}_2\text{COOH})_2) \times n(\text{C}_2\text{H}_5\text{OH})^2} \quad \text{Expression 5.1}$$

A student carries out an experiment to determine the value of K_c for this equilibrium.

- The student mixes together 0.0500 mol of succinic acid and 0.150 mol of ethanol, with a small amount of an acid catalyst.
- The mixture is allowed to reach equilibrium.
- The student determines that 0.0200 mol of succinic acid are present in the equilibrium mixture.

(i) Which technique could be used to determine the equilibrium amount of succinic acid?

----- [1]

(ii) Write the equation for the equilibrium reaction that takes place.

----- [1]

(iii) Draw the skeletal formula of the ester present in the equilibrium mixture.

[1]

(iv) K_c is the equilibrium constant in terms of equilibrium concentrations.

Why can **expression 5.1** be used to calculate K_c for this equilibrium?

----- [1]

(v) Calculate the value of K_c for this reaction.

Show your working.

$K_c =$ ----- [3]

50 The electron configuration of element X is: $1s^2 2s^2 2p^6 3s^2 3p^4$

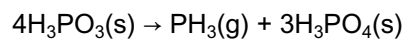
What is the formula of a compound formed when sodium reacts with element X?

- A NaX
- B NaX_2
- C Na_2X
- D Na_2X_3

Your answer

[1]

51 Phosphine, PH_3 , is a gas formed by heating phosphorous acid, H_3PO_3 , in the absence of air.



(i) 3.20×10^{-2} mol of H_3PO_3 is completely decomposed by this reaction.

Calculate the volume of phosphine gas formed, in cm^3 , at 100 kPa pressure and 200 °C.

volume of PH_3 = _____ cm^3 [4]

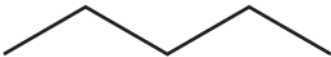
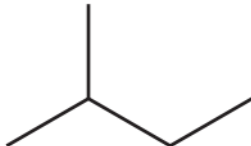
(ii) When exposed to air, phosphine spontaneously ignites, forming P_4O_{10} and water.

Construct an equation for this reaction.

-----[1]

Compounds **A**, **B** and **C** are saturated hydrocarbons.

The structures and boiling points of **A**, **B** and **C** are shown below.

	Isomer	Boiling point / °C
A		36
B		28
C		9

- Use the structures to explain what is meant by the term structural isomer.
- Explain the trend in boiling points shown by **A**, **B** and **C** in the table.

[5]

(b) Compounds **A**, **B** and **C** all react with chlorine in the presence of ultraviolet radiation to form organic compounds with the formula $C_5H_{11}Cl$.

(i) Name the mechanism for this reaction.

----- [1]

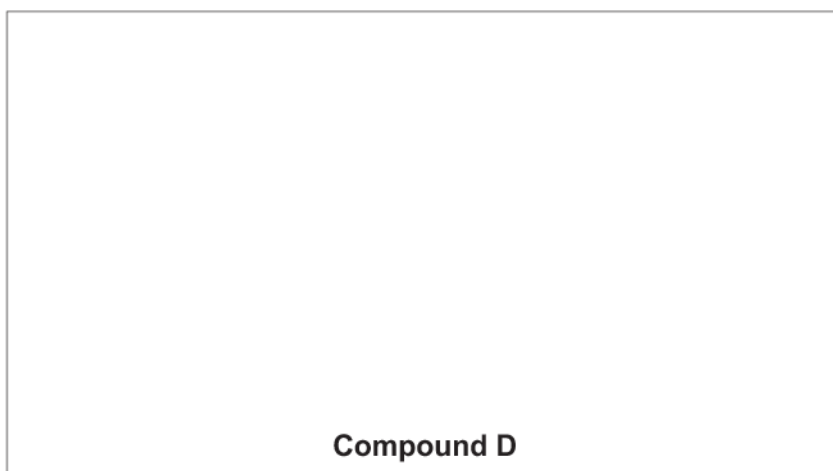
(ii) Complete the table to show the number of structural isomers of $C_5H_{11}Cl$ that could be formed from the reaction of chlorine with **A** and **B**.

	A	B
Number of structural isomers		

[2]

(iii) The reaction of compound **A** with excess chlorine forms a compound **D**, which has a molar mass of 175.5 g mol^{-1} .

Draw a possible structure for compound **D** and write the equation for its formation from compound **A**. Use molecular formulae in the equation.



Equation ----- [2]

53 This question is about some elements in Period 4 of the periodic table.

The Period 4 element selenium is in the same group of the periodic table as oxygen.

Selenium and oxygen both form compounds with hydrogen with the formulae H_2Se and H_2O respectively.

- (i) H_2Se can be prepared by reacting aluminium selenide, Al_2Se_3 , with water.
Aluminium hydroxide and hydrogen selenide are formed.

Write the equation for this reaction.

[1]

- (ii) The boiling points of H_2O and H_2Se are shown below.

Compound	Boiling point / °C
H_2O	100
H_2Se	-41

Explain why H_2O has a higher boiling point than H_2Se .

[3]

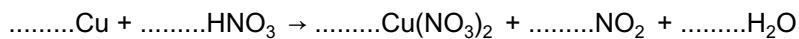
54 What is the formula of silver carbonate?

- A AgCO_3
B $\text{Ag}(\text{CO}_3)_2$
C Ag_2CO_3
D Ag_3CO^3

Your answer

[1]

55 The unbalanced equation for the reaction of copper with concentrated nitric acid is shown below.



What is the number of moles of HNO_3 that react with 1 mole of Cu?

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

Your answer

[1]

56 Which statement(s) for Group 2 elements is/are correct?

- 1 The 2nd ionisation energy of magnesium is greater than the 2nd ionisation energy of calcium.
- 2 A strontium ion, Sr^{2+} , contains a total of 6 electrons in s orbitals.
- 3 The equation for the reaction of barium with water is:
 $2\text{Ba} + 2\text{H}_2\text{O} \rightarrow 2\text{BaOH} + \text{H}_2$.

- A 1, 2 and 3
- B Only 1 and 2
- C Only 2 and 3
- D Only 1

Your answer

[1]

- 57 In the laboratory, acid spills can be cleaned up and made safe by spreading anhydrous sodium carbonate over the spill to neutralise the acid.

A student accidentally spills 50.0 cm^3 of $2.00\text{ mol dm}^{-3}\text{ HCl (aq)}$ on the bench.

What is the minimum mass of anhydrous sodium carbonate required to neutralise the acid?

- A 4.15 g
B 5.30 g
C 8.30 g
D 10.6 g

Your answer

[1]

- 58 This question is about compounds of bromine.

Bromine reacts with phosphorus, P_4 , to form phosphorus tribromide, PBr_3 .

- (i) Complete the electron configuration of a bromine atom.

$1s^2$ ----- [1]

- (ii) Write the equation for the reaction of phosphorus with bromine.

----- [1]

A student adds a solution of bromine in an organic solvent to two test tubes.

The student adds aqueous sodium chloride to one test tube, and aqueous sodium iodide to the other test tube.

The student shakes the mixtures, allows them to settle, and records the colour of the organic layer in each mixture.

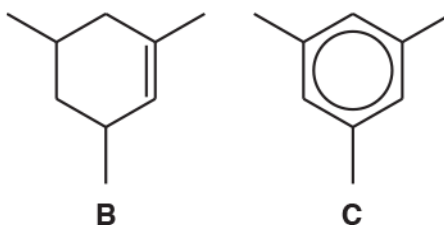
Sodium halide	Colour of organic layer
Sodium chloride	orange
Sodium iodide	violet

Explain how the student's results provide evidence for the trend in reactivity of the halogens down group 17(7) and write an ionic equation for any reaction that takes place.

Use your chemical knowledge to explain the trend in reactivity.

[5]

60 Compounds **B** and **C**, shown below, are unsaturated hydrocarbons containing nine carbon atoms.



Compound **C** can be prepared by 'trimerisation' of propanone using concentrated sulfuric acid as a catalyst.

Suggest an equation for this reaction, using **molecular formulae**.

-----[3]-----

61 Alcohols can be used to prepare organic compounds with different functional groups.

$\text{HO}(\text{CH}_2)_4\text{OH}$ can be oxidised to form $\text{HOOC}(\text{CH}_2)_2\text{COOH}$.

(i) State the reagents and conditions and write an equation for this oxidation.

In the equation, use [O] for the oxidising agent.

Reagents and conditions:

Equation:

[3]

(ii) $\text{HOOC}(\text{CH}_2)_2\text{COOH}$ is soluble in water.

Explain, using a labelled diagram, why $\text{HOOC}(\text{CH}_2)_2\text{COOH}$ is soluble in water.

[2]

62 This question is about organic chemistry.

The amino acid Z-H₂NCH=CHCOOH can react to form a cyclic compound with the molecular formula C₃H₃NO and one other product.

Complete the equation for this reaction.



[2]

63 This question is about barium hydroxide.

A student plans to prepare a solution of $\text{Ba}(\text{OH})_2$ from barium by two different reaction routes.

Outline 2 reaction routes for preparing a solution of $\text{Ba}(\text{OH})_2$ from barium in the laboratory.

Include relevant equations.

[4]

The student analyses metal **M** using a 'back-titration' technique:

- The metal is reacted with excess acid.
- The resulting solution is titrated to determine the amount of acid remaining after the reaction.

Stage 1

The student adds 100 cm³ of 2.10 mol dm⁻³ HCl(aq) to 6.90 g of **M**.

An excess of HCl(aq) has been used to ensure that all of metal **M** reacts.

A redox reaction occurs, forming a solution containing **M** in the +2 oxidation state.

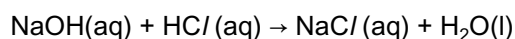
Stage 2

The resulting solution from **Stage 1** is made up to 250.0 cm³ with distilled water.

Stage 3

A 25.00 cm³ sample of the diluted solution from **Stage 2** is titrated with 0.320 mol dm⁻³ NaOH(aq).

The NaOH(aq) reacts with excess HCl(aq) that remains in **Stage 1**:



The student repeats the titration to obtain concordant titres.

Titration results (The trial titre has been omitted.)

The burette readings have been recorded to the nearest 0.05 cm³.

	1	2	3
Final reading / cm ³	27.80	37.55	32.20
Initial reading / cm ³	0.50	10.00	5.00

- (i) In **Stage 1**, a redox reaction takes place between **M** and HCl(aq), forming hydrogen and a solution containing **M** in the +2 oxidation state.

Write an overall equation, with state symbols, for this reaction. Write half-equations for the oxidation and reduction processes.

Overall equation _____

Oxidation half-equation _____

Reduction half-equation _____

[3]

(ii) In **Stage 1**, suggest **two** observations that would confirm that all of metal **M** has reacted.

1 _____

2 _____

[2]

(iii) In **Stage 3**, write the ionic equation for the reaction taking place in the titration.

_____ [1]

(iv) Metal **M** can be identified following the steps below.

1. The amount, in mol, of excess $\text{HCl}(\text{aq})$ that remains after the reaction of **M** with $\text{HCl}(\text{aq})$.
2. The amount, in mol, of $\text{HCl}(\text{aq})$ that reacted with **M**.
3. The identity of metal **M**.

Analyse the results to identify metal **M**.

Metal M = ... [6]

A student carries out test tube reactions on aqueous solutions of **B** and **C**.

The observations of the student's tests are shown below.

	Test	B(aq)	C(aq)
1	NH ₃ (aq) added dropwise	green precipitate D	grey-green precipitate E
	excess NH ₃ (aq) added	no further change	purple solution F
2	HNO ₃ (aq)	no change	no change
	followed by Ba(NO ₃) ₂ (aq)	white precipitate G	no change
3	HNO ₃ (aq)	no change	no change
	followed by AgNO ₃ (aq)	no change	white precipitate H

Analyse the results to identify **B** to **H**, and construct ionic equations for the formation of products **D** to **H**.

[6]

66 Alcohols can be used to prepare organic compounds with different functional groups.

$\text{HOOC}(\text{CH}_2)_2\text{COOH}$ and $\text{HO}(\text{CH}_2)_4\text{OH}$ react together to form polymer E.

(i) Draw **one** repeat unit of polymer E.

The functional groups should be clearly displayed.

[2]

(ii) Governments are encouraging the development of biodegradable polymers to reduce dependency on persistent plastic waste derived from fossil fuels.

Polymer E is a biodegradable polymer.

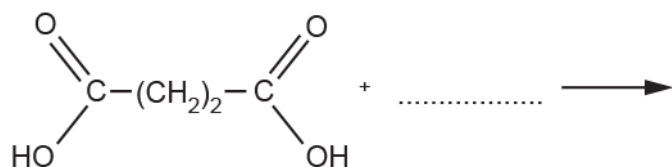
Suggest why polymer E is able to biodegrade.

[1]

(iii) A large yield of polymer E can be obtained by reacting a diacyl dichloride with $\text{HO}(\text{CH}_2)_4\text{OH}$.

The diacyl dichloride is prepared from $\text{HOOC}(\text{CH}_2)_2\text{COOH}$.

Complete the equation for the formation of a diacyl dichloride from $\text{HOOC}(\text{CH}_2)_2\text{COOH}$.



[3]

END OF QUESTION PAPER

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
1			NH_4^+ ✓ NO_3^- ✓	2	Mark incorrect ions first Examiner's Comments This question proved more difficult than intended. The specification indicates the polyatomic ions which the candidates are expected to know the formulae of and it was little surprising that many candidates could not make the leap from the empirical formula given to the possible ions present. Weak answers came from candidates who took their lead from the empirical formula $\text{H}_4\text{N}_2\text{O}_3$ to suggest that the ions were H^+ and N_2O^- . Among stronger candidates it was more common to identify NO_3^- than NH_4^+ , although it remained rare to see both correct ions given.
			Total	2	
2		i	Reaction 1: $\text{Ba} + 2\text{H}_2\text{O} \rightarrow \text{Ba}(\text{OH})_2 + \text{H}_2$ ✓ Reaction 2: $\text{Ba}_3\text{N}_2 + 6\text{H}_2\text{O} \rightarrow 3\text{Ba}(\text{OH})_2 + 2\text{NH}_3$ Correct products ✓ Balancing ✓	3	Ignore state symbols Examiner's Comments Both equations were relatively challenging. Reaction 1 was a direct question about reactions of Group 2 elements. Reaction 2 demanded a higher level of application based upon information given. Many identified the alkaline gas as NH_3 , but then incorrectly assumed that the alkaline solution was BaO instead of $\text{Ba}(\text{OH})_2$. Weaker candidates suggested equations with hypothetical species that could not have borne any relation to formulae that they might have encountered before.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		ii	Giant ionic (lattice) ✓	1	ALLOW 'Giant lattice with ionic bonds' ALLOW 'Giant ionic bonds' DO NOT ALLOW 'atoms or molecules or dipoles' Examiner's Comments This question was relatively well answered, although some candidates did negate the mark by referring to molecules of Ba₃N₂ either directly or by indirect reference to intermolecular forces.
		iii	$\left[\begin{array}{c} \text{x x} \\ \text{x Ba x} \\ \text{x x} \end{array} \right]^{2+} \left[\begin{array}{cc} \bullet\bullet & \bullet\bullet \\ \text{x O} & \bullet\bullet \text{ O x} \\ \bullet\bullet & \bullet\bullet \end{array} \right]^{2-}$ OR $\left[\begin{array}{c} \text{x x} \\ \text{x Ba x} \\ \text{x x} \end{array} \right]^{2+} \left[\begin{array}{cc} \bullet\bullet & \text{O O} \\ \text{x O} & \bullet\bullet \text{ O x} \\ \bullet\bullet & \text{O O} \end{array} \right]^{2-}$ OR $\left[\begin{array}{c} \text{x x} \\ \text{x Ba x} \\ \text{x x} \end{array} \right]^{2+} \left[\begin{array}{cc} \bullet\bullet & \text{O O} \\ \text{x O} & \bullet\bullet \text{ O O} \\ \bullet\bullet & \text{O O} \end{array} \right]^{2-}$ OR $\left[\begin{array}{c} \text{x x} \\ \text{x Ba x} \\ \text{x x} \end{array} \right]^{2+} \left[\begin{array}{cc} \bullet\bullet & \bullet\bullet \\ \text{x O} & \bullet\bullet \text{ O} \\ \bullet\bullet & \bullet\bullet \end{array} \right]^{2-}$	1	Ba must have a 2+ charge Ba can be with or without octet. IGNORE lack of charge on O₂²⁻ ion O₂²⁻ ion to have 12 electrons belonging to O atoms + 2 other electrons of another symbol. The 2 other electrons must match Ba if Ba has an octet. If O electrons are shown as 6 of one symbol and 6 of another, each O must have six electrons of the same symbol

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
					ALLOW $\left[\begin{array}{ccc} & \times \times & \\ \times & \text{Ba} & \times \\ & \times \times & \end{array} \right]^{2+} \left[\begin{array}{ccc} \bullet \bullet & & \bullet \bullet \\ \bullet \times & \times & \bullet \times \\ \bullet \bullet & & \bullet \bullet \end{array} \right]^{2-}$ OR $\left[\begin{array}{ccc} & \times \times & \\ \times & \text{Ba} & \times \\ & \times \times & \end{array} \right]^{2+} \left[\begin{array}{ccc} \bullet \bullet & & \bullet \bullet \\ \bullet \times & \times & \bullet \times \\ \bullet \bullet & & \bullet \bullet \end{array} \right]^{2-}$ Examiner's Comments This question was designed to be difficult, but many candidates rose to the challenge. Weaker candidates simply drew a 'dot-and-cross' diagram for BaO₂ in which they treated each oxygen species as an oxide ion each having a single negative charge. Many stronger candidates did realise from the structure given in the question that there was only a single bond between the two oxygen atoms, as was clear from their suggested diagram. Only the stronger candidates managed to incorporate correctly the electrons from barium, to arrive at a correct version of the bonding of BaO₂.
			Total	5	
3			2Al + 3F ₂ → 2AlF ₃ ✓	1	ALLOW multiples IGNORE state symbols Examiner's Comments Although the formula of AlF₃ was not given, this question was well answered. When the mark was not awarded it was rarely because of errors in the formula for AlF₃, but more in the ratio of the reactants or in fluorine not being given as diatomic. Occasionally, the symbol for fluorine was given as Fl.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
			Total	1	
4			C ₁₂ H ₂₅ ✓	1	IGNORE C₂₄H₅₀ Examiner's Comments The majority of candidates were able to deduce the correct empirical formula of the alkane.
			Total	1	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
5	a		Equations can be in either order $\text{Na}_2\text{O} + \text{H}_2\text{O} \rightarrow 2\text{NaOH}$ ✓ $\text{NaFeO}_2 + 2\text{H}_2\text{O} \rightarrow \text{Fe}(\text{OH})_3 + \text{NaOH}$ ✓	2	ALLOW multiples throughout IGNORE state symbols ALLOW $\text{Na}_2\text{O} + \text{H}_2\text{O} \rightarrow 2\text{Na}^+ + 2\text{OH}^-$ DO NOT ALLOW equations with uncanceled species. e.g. $\text{Na}_2\text{O} + 2\text{H}_2\text{O} \rightarrow 2\text{NaOH} + \text{H}_2\text{O}$ ALLOW $2\text{NaFeO}_2 + \text{H}_2\text{O} \rightarrow \text{Fe}_2\text{O}_3 + 2\text{NaOH}$ OR $2\text{NaFeO}_2 + \text{H}_2\text{O} \rightarrow \text{Fe}_2\text{O}_3 + 2\text{Na}^+ + 2\text{OH}^-$ Examiner's Comments The information needed to write the equation was within the information provided for step 1 and the stem. Candidates were much more successful with the first than the second equation. The clue that an alkaline solution had been formed should have helped with the identification of NaOH as a product of both reactions. The brown precipitate provided a clue that $\text{Fe}(\text{OH})_3$ had been formed although the examiners also credited an equation producing Fe_2O_3.
	b		FIRST, CHECK THE ANSWER ON ANSWER LINE IF answer = 33.7%, award 6 marks. IF there is an alternative answer, check to see if there is any ECF credit possible using working below ----- amount $\text{S}_2\text{O}_3^{2-}$ used = $0.1000 \times \frac{25.50}{1000}$ = 2.550×10^{-3} (mol) ? amount I_2 = $2.550 \times 10^{-3} \div 2$ 1.275×10^{-3} (mol) ✓ amount CrO_4^{2-} $\frac{2}{3} \times 1.275 \times 10^{-3}$ OR $1.275 \times 10^{-3} \div 1.5$ = $8.5(00) \times 10^{-4}$ (mol) ✓ amount CrO_4^{2-} in original 1000 cm^3 = $40 \times 8.5(00) \times 10^{-4}$ = $3.4(00) \times 10^{-2} \text{ mol}$ ✓	6	FULL ANNOTATIONS MUST BE USED IF a step is omitted but subsequent step subsumes previous, then award mark for any missed step Working: at least 3 SF throughout until final % mark BUT ignore trailing zeroes, ie for 0.490 allow 0.49 ----- ECF answer above $\div 2$ ECF answer above $\div 1.5$ ECF answer above $\times 40$

Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
	Mass of Cr / Cr³⁺ in ore = $52.0 \times 3.4(00) \times 10^{-2}$ g 1.768 g ✓ Percentage Cr in ore = $\frac{1.768}{5.25} \times 100$ = 33.7% ✓ MUST be to one decimal place (in the question)		ECF answer above $\times 52.0$ IMPORTANT: The last two marks are ONLY available by using 52.0 for Cr ----- Common ECFs: 0.8% $\times 40$ missing 5 marks (scaling error) 0.84% $\times 40$ missing 4 marks (scaling error and 2 DP) 33.68% 5 marks (2 DP) 16.8% 5 marks (divide Cr somewhere by 2) 144.9%; 72.5% 4 marks (Final 2 marks unavailable) Use of $M(\text{Fe}(\text{CrO}_2)_2) = 223.8$ instead of $M(\text{Cr})$. Examiner's Comments Many candidates were on firm territory with a redox titration problem. The majority went through a well-rehearsed sequence of steps to obtain four marks for reaching the amount of CrO_4^{2-} ions in the original solution. Sometimes, candidates used the 1:1.5 molar ratio for $\text{CrO}_4^{2-} : \text{I}_2$ the wrong way around to obtain 1.9125×10^{-3} rather than 8.50×10^{-4} mol CrO_4^{2-}. More candidates had problems in scaling up by 40 to obtain the original amount of CrO_4^{2-} as 3.40×10^{-2} mol. Strangely many used a factor of 4 instead. The last two marks proved to be more elusive, with many candidates calculating the percentage of $\text{Fe}(\text{CrO}_2)_2$ rather than Cr in the sample of chromite. The responses seen show just how far candidates have travelled since early structured titration calculations for AS to complex unstructured calculations at the end of the A-level course. Answer: 33.7%

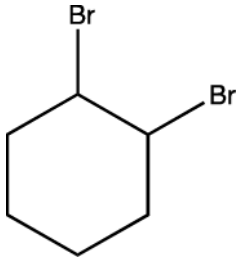
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
	c		<i>Overall:</i> $\text{CrO}_4^{2-} + 3\text{I}^- + 4\text{H}_2\text{O} \rightarrow \text{Cr}^{3+} + 1\frac{1}{2}\text{I}_2 + 8\text{OH}^-$ ✓ CrO <i>Half equations:</i> $\text{CrO}_4^{2-} + 4\text{H}_2\text{O} + 3\text{e}^- \rightarrow \text{Cr}^{3+} + 8\text{OH}^-$ ✓ CrO $2\text{I}^- \rightarrow \text{I}_2 + 2\text{e}^-$ ✓	3	ALLOW multiples and equilibrium signs throughout IGNORE state symbols throughout e.g. $2\text{CrO}_4^{2-} + 6\text{I}^- + 8\text{H}_2\text{O} \rightarrow 2\text{Cr}^{3+} + 3\text{I}_2 + 16\text{OH}^-$ ALLOW equation using H^+. i.e. $\text{CrO}_4^{2-} + 3\text{I}^- + 8\text{H}^+ \rightarrow \text{Cr}^{3+} + 1\frac{1}{2}\text{I}_2 + 4\text{H}_2\text{O}$ OR $2\text{CrO}_4^{2-} + 6\text{I}^- + 16\text{H}^+ \rightarrow 2\text{Cr}^{3+} + 3\text{I}_2 + 8\text{H}_2\text{O}$ ALLOW CrO_4^{2-} half equation using H^+. i.e. $\text{CrO}_4^{2-} + 8\text{H}^+ + 3\text{e}^- \rightarrow \text{Cr}^{3+} + 4\text{H}_2\text{O}$ Examiner's Comments This part required candidates to construct three equations for an unfamiliar reaction. The examiners allowed equations using H^+ rather than OH^-. It was then possible to credit many candidates with the full three marks with many excellent responses seen. Predictably the equations involving CrO_4^{2-} were more difficult but even some weaker candidates were able to construct an equation for the oxidation of iodide ions. The very best candidates did manage to construct the equations in alkaline conditions.
			Total	11	
6			C	1	
			Total	1	
7			A/Br ₃	1	
			Total	1	

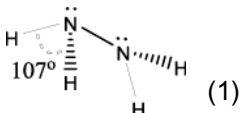
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
8		i	$\text{NaClO} + 2\text{HCl} \rightarrow \text{NaCl} + \text{Cl}_2 + \text{H}_2\text{O}$ correct formulae of reactants, NaCl and chlorine (1) water and balancing (1)	2	allow $\text{NaClO}_3 + 6\text{HCl} \rightarrow \text{NaCl} + 3\text{Cl}_2 + 3\text{H}_2\text{O}$ for 1 mark
		ii	Test: add (a few drops of aqueous) silver nitrate (1) Result: white ppt (1)	2	ignore addition of dilute nitric acid before the AgNO_3 ignore redissolving in excess NH_3 or darkening of the ppt
		iii	separating funnel (1)	1	allow dropping pipette
			Total	5	
9		i	$\text{Ag}^+ + \text{Cl}^- \rightarrow \text{AgCl}$ OR $\text{Ag}^+ + \text{Br}^- \rightarrow \text{AgBr}$ OR $\text{Ag}^+ + \text{I}^- \rightarrow \text{AgI}$	1	
		ii	Bond enthalpy decreases $\text{C}-\text{Cl} > \text{C}-\text{Br} > \text{C}-\text{I}$	1	allow chlorine–carbon bonds are strongest.
		iii	Heat the test tubes in a water bath.	1	
			Total	3	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
10	a		Aliphatic = E, H, I, J (1) Alicyclic = E, H, J (1) Aromatic = F, G (1)	3	
	b		C_nH_{2n+1}	1	do not allow C_nH_{2n+1}
	c	i	<i>Equation:</i> $C_6H_{12}O \rightarrow C_6H_{10} + H_2O$ (1) <i>Calculation:</i> FIRST CHECK THE ANSWER ON THE ANSWER LINE IF answer = 32.7 (%) award 3 marks theoretical yield = $7.65 / 100 = 0.0765$ (mol) (1) actual yield = $2.05 / 82 = 0.025$ (mol) (1) % yield = $(0.025 / 0.0765) \times 100\% = 32.7(\%)$ (1)	4	ignore state symbols allow $C_6H_{11}OH$ for $C_6H_{12}O$ If there is an alternative answer, check to see if there is any ECF credit possible using working below % yield must be to 1 dp allow theoretical and actual yield calculated in mass theoretical yield = $0.0765 \times 82 = 6.273$ g % yield = $(2.05 / 6.273) = 32.7(\%)$ allow ecf from calculated actual and theoretical yields
		ii	bromine water is decolourised (1)  (1)	2	allow bromine water turns colourless ignore 'goes clear' allow correct structural OR displayed OR skeletal formula OR mixture of the above
			Total	10	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
11		i	$\text{H}_2\text{SO}_4 + 2\text{NaOH} \rightarrow \text{Na}_2\text{SO}_4 + 2\text{H}_2\text{O}$ (1)	1	allow multiples
		ii	<i>Energy (into water) mark</i> $70.0 \times 4.18 \times 16.5 = 4827.9$ (J) or 4.8279 (kJ) (1) <i>amount of substance mark</i> $n(\text{H}_2\text{O}) = \frac{35.0}{1000} \times 2.40 = 0.084(0)$ (mol) <i>$\Delta_{\text{neut}}H$ mark</i> $(-4.8279 / 0.084(0)) =$ $(-57.475 \text{ OR } (-57.48 \text{ OR } (-57.5$ (1) Correctly rounded to at least 3 significant figures	3	allow rounding to 4828 OR 4830 allow amount of substance mark to be based upon either HCl or NaOH allow ecf for <u>Energy (into water) mark</u> <u>Amount of substance mark</u>
		iii	1 mole of water had been formed (1)	1	
		iv	$\frac{2 \times 0.5}{16.5} \times 100 = 6\%$ (1)	1	
			Total	6	
12		i	$2\text{NH}_3 + \text{NaOC}/ \rightarrow \text{N}_2\text{H}_4 + \text{NaC}/ + \text{H}_2\text{O}$	1	
		ii	 Bond angle 107° (1)	2	diagram must attempt to show geometry around the nitrogen atom to be pyramidal. allow $106-108^\circ$
			Total	3	
13			A: Sc^{3+} B: S^{2-}	2	
			Total	2	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
14		i	$P_4 + 6Br_2 \rightarrow 4PBr_3$	1	ignore state symbols
		ii	FIRST CHECK THE ANSWER ON THE ANSWER LINE If answer = 3.01×10^{21} award 3 marks $M_r(PBr_3) = 270.7 \text{ (g mol}^{-1}\text{)} \text{ (1)}$ $n(PBr_3) = 1.3535 / 270.7 = 5.000 \times 10^{-3} \text{ mol (1)}$ number of molecules = $5.000 \times 10^{-3} \times 6.02 \times 10^{23} = 3.01 \times 10^{21} \text{ molecules (1)}$	3	If there is an alternative answer, check to see if there is any ecf credit possible using working below. allow in working shown as $28.1 + 35.5 \times 4$ allow ecf from incorrect molar mass of PBr_3 allow 0.005(00) (mol) for two marks allow ecf for incorrect amount of PBr_3 allow calculator value or rounding to 3 significant figures or more but ignore 'trailing' zeroes, e.g. 0.200 allowed as 0.2 do not allow any marks for: $1.3535 \times 6.02 \times 10^{23} = 8.15 \times 10^{23}$
		iii	Pyramidal (1) (because there are) 3 bonded pairs and 1 lone pair (around the central phosphorus atom) (1) and electron pairs repel each other as far apart as possible so will take on a tetrahedral arrangement (giving a pyramidal shape overall) (1)	3	
			Total	7	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
15	a	i	Initial reading = 0.60 (cm ³) Final reading = 22.80 (cm ³) Titre = 22.20 cm ³ Initial and final values recorded to two decimal places AND titre recorded to the nearest 0.05 cm ³ with correct units	1	
		ii	Suggests repeating the titration to obtain consistent / concordant results (those that agree to within 0.1 cm ³) AND calculating the mean titre	1	
	b	i	$n(\text{HCl}) = (0.100)(\text{answer to (c)(i)}/1000) = 0.00222 \text{ (mol) (1)}$ $n(\text{M}_2\text{CO}_3) = 0.00222/2 = 0.00111 \text{ (mol) (1)}$	2	allow ecf from (b)(i)
		ii	$n(\text{M}_2\text{CO}_3) \text{ in total} = 0.00111 \times 10 = 0.0111 \text{ mol (1)}$ Molar mass = $1.58/0.0111 = 142.3 \text{ g mol}^{-1}$ (1) Mass of M = $(142.3 - 60)/2 = 41.15$ (= K) (1) K_2CO_3 (1)	4	Note: molar mass is between K_2CO_3 (138.2) and SrCO_3 (147.6); only possible match for a Group 1 carbonate is K_2CO_3 .
			Total	8	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
16	a	i	$\text{Sr(s)} + 2\text{H}_2\text{O(l)} \rightarrow \text{Sr(OH)}_2\text{(aq)} + \text{H}_2\text{(g)}$ Note: all state symbols required	1	allow multiples
		ii	$n(\text{Sr}) = n(\text{Sr}^{2+}) = 0.200 / 87.6 = 2.28 \times 10^{-3}$ (1) $[\text{Sr}^{2+}] = 2.28 \times 10^{-3} \times 1000 / 250 = 9.13 \times 10^{-3} \text{ (mol dm}^{-3}\text{)}$ (1)	2	allow ecf
		iii	Greater volume with Ca AND larger amount / more moles of Ca OR A_r Ca is smaller (1) $n(\text{Ca}) = 0.200/40.1 = 0.005(0) \text{ (mol)}$ (1) volume H_2 with Sr = 55 cm^3 AND volume with Ca = 120 cm^3 OR 65 cm^3 more H_2 with Ca (1)	3	ora allow values up to calculator values allow volumes $\pm 1 \text{ cm}^3$
	b		$\text{Cl(g)} \rightarrow \text{Cl}^{\cdot-} \text{(g)} + \text{e}^-$ Correct species, balanced AND correct state symbols	1	allow $\text{Cl(g)} - \text{e}^- \rightarrow \text{Cl}^{\cdot-} \text{(g)}$ ignore state symbols after electron
	c		Group: 2 (1) Justification: Large increase between 2nd and 3rd ionisation energy values. (1)	2	allow alkaline earth No ecf for justification (dependent on correct group)
			Total	9	

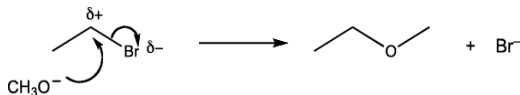
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
17	a		2,3,5-trimethyloctane	1	This is the only acceptable response
	b	i	FIRST CHECK THE ANSWER ON THE ANSWER LINE IF answer = 3.88×10^5 (m³) award all five marks <i>Calculating moles of C₁₁H₂₄</i> (moles = $\frac{80.4 \times 10^6}{156}$) = 515385 <i>Use of stoichiometry to calculate moles of CO₂</i> (11 × 515385) = 5669231 <i>Rearranging ideal gas equation to make V subject AND conversion to Pa and K</i> $V = \frac{nRT}{P} = \frac{5669231 \times 8.314 \times 218}{26.5 \times 10^3}$ 3.88×10^5 (m³) Correct answer correctly rounded Given in standard form AND to 3SF	5	Allow any correctly rounded value from 515000 to calculator value of 515384.6154 Allow any correctly rounded value from 5670000 to calculator value of 5669230.769 ALLOW ECF from incorrect moles, pressure or temperature (in K). Common incorrect answers are shown below Award 4 marks for 3.88×10^{-1} (using 80.4 g in moles calculation) 3.88×10^8 (using 26.5 Pa as pressure) 3.52×10^4 (using moles C₁₁H₂₄ as moles of CO₂) DO NOT ALLOW marking points 3, 4, and 5 for responses which have a negative value for volume of CO₂ (temperature not converted to K). i.e. max 2
		ii	N ₂ + O ₂ → 2NO	1	ALLOW multiples
			Total	7	

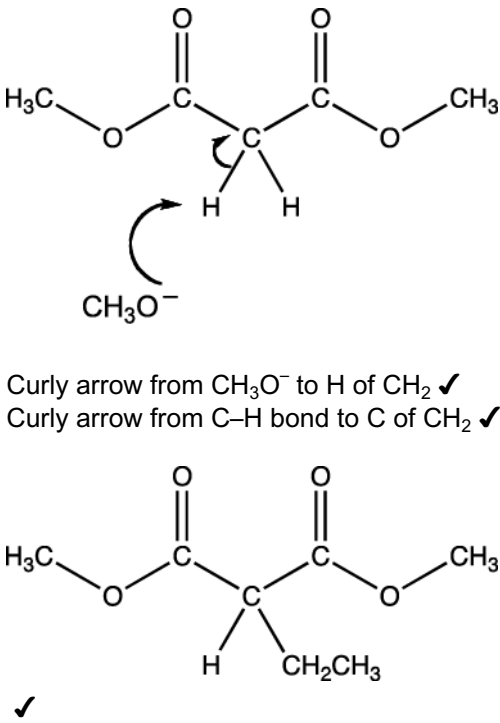
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
18		i	$1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^1$ ✓	1	ALLOW upper case S, P and D and subscripts, e.g. 3S₂3P₆3D₁₀ ALLOW 4s¹ before 3d¹⁰ DO NOT ALLOW [Ar] as shorthand for $1s^2 2s^2 2p^6 3s^2 3p^6$, i.e. DO NOT ALLOW [Ar]3d⁸ Look carefully at $1s^2 2s^2 2p^6 3s^2 3p^6$ – there may be a mistake
		ii	$n = \frac{95.0}{24000} = 3.96 \times 10^{-3} \text{ (mol)}$ ✓ <i>Calculation of M</i> $M = \frac{m}{n} = \frac{254 \times 10^{-3}}{3.96 \times 10^{-3}} = 64.2 \text{ OR } 64.1 \text{ (g mol}^{-1}\text{)}$ ✓ <i>Gas:</i> sulfur dioxide OR SO ₂ ✓ <i>Equation</i> $\text{Cu} + 2\text{H}_2\text{SO}_4 \rightarrow \text{CuSO}_4 + \text{SO}_2 + 2\text{H}_2\text{O}$ ✓	4	IF there is an alternative answer, check to see if there is any ECF credit possible using working below Unrounded values give 64.2; Rounded to 3 SF gives 64.1 ALLOW $\text{Cu} + 2\text{H}^+ + \text{H}_2\text{SO}_4 \rightarrow \text{Cu}^{2+} + \text{SO}_2 + 2\text{H}_2\text{O}$
			Total	5	

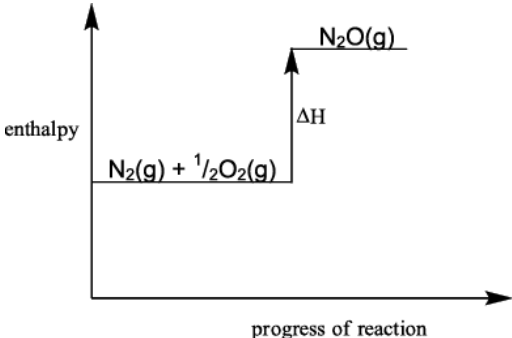
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance																				
19	a		✓	1																					
	b	i	$2\text{Na} + 2\text{CH}_3\text{OH} \rightarrow 2\text{Na}^+ + 2\text{CH}_3\text{O}^- + \text{H}_2$ ✓	1	ALLOW $2\text{Na} + 2\text{CH}_3\text{OH} \rightarrow 2\text{CH}_3\text{ONa} + \text{H}_2$																				
		ii	 Curly arrow from CH_3O^- to carbon atom of C-Br bond ✓ Dipole shown on C-Br bond, $\text{C}^{\delta+}$ and $\text{Br}^{\delta-}$ AND curly arrow from C-Br bond to the Br atom ✓ Products of reaction (must not be ambiguous) ✓	3	ALLOW correct structural OR skeletal OR displayed formula OR mixture of the above as long as non-ambiguous. The curly arrow must start from O atom of CH_3O^- AND must start either from a lone pair or from the negative charge. No need to show lone pair if curly arrow comes from negative charge. ALLOW $\text{S}_{\text{N}}1$ Dipole shown on C-Br bond, $\text{C}^{\delta+}$ and $\text{Br}^{\delta-}$, and curly arrow from C-Br bond to the Br atom. Correct carbocation drawn. AND curly arrow from CH_3O^- to carbocation. The curly arrow must start from the oxygen atom of the CH_3O^-, and must start either from a lone pair or from the negative charge.																				
		iii	CH_3O^- donates an electron pair AND heterolytic fission ✓	1	ASSUME 'it' refers to CH_3O^-																				
	c		<table><tr><th>Chemical shift, δ/ppm</th><th>Relative peak area</th><th>Splitting pattern</th><th></th></tr><tr><td>0.5–1.9</td><td>3</td><td>Triplet</td><td>✓</td></tr><tr><td>3.0–4.3</td><td>2</td><td>Quartet</td><td>✓</td></tr><tr><td>0.5–1.9</td><td>6</td><td>Doublet</td><td>✓</td></tr><tr><td>3.0–4.3</td><td>1</td><td>Heptet</td><td>✓</td></tr></table>	Chemical shift, δ/ppm	Relative peak area	Splitting pattern		0.5–1.9	3	Triplet	✓	3.0–4.3	2	Quartet	✓	0.5–1.9	6	Doublet	✓	3.0–4.3	1	Heptet	✓	4	ALLOW δ values ± 0.2 ppm, as a range or a value within the range ALLOW multiplet for heptet
Chemical shift, δ/ppm	Relative peak area	Splitting pattern																							
0.5–1.9	3	Triplet	✓																						
3.0–4.3	2	Quartet	✓																						
0.5–1.9	6	Doublet	✓																						
3.0–4.3	1	Heptet	✓																						

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
	d	i	 Curly arrow from CH_3O^- to H of CH_2 ✓ Curly arrow from C-H bond to C of CH_2 ✓	3	The curly arrow must start from O atom of CH_3O^- AND must start either from a lone pair or from the negative charge. No need to show lone pair if curly arrow comes from negative charge. ALLOW any unambiguous structure, skeletal, displayed, structural or combination.
		ii	CH_3O^- accepted a proton ✓	1	ASSUME 'it' refers to CH_3O^-
			Total	14	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
20		i	More energy is required for bond breaking than is released by bond making ✓	1	Examiner's Comments The poor quality of answers observed surprised the Examiners as this question had featured a number of times on legacy papers which would have been used in Centres to prepare candidates for this examination. Many candidates were not able to explain that bond breaking requires energy whereas bond making produces energy. For the reaction to be endothermic more energy is required to break bonds than is evolved when bonds are formed. In their answers candidates frequently stated that both processes required energy or that more bonds were broken than were formed.
		ii	Enthalpy profile diagram • ΔH labelled OR 82 on vertical arrow • Products above reactants (either chemical symbols or the words products and reactants) • Arrow upwards ✓ Formulae AND state symbols $\text{N}_2(\text{g}) + \frac{1}{2}\text{O}_2(\text{g}) \rightarrow \text{N}_2\text{O}(\text{g})$ ✓	2	 IGNORE activation energy DO NOT ALLOW multiples of equation: 1 mole of N_2O is formed Examiner's Comments Half of the candidates scored zero for this question, many failing to label the enthalpy change or to show this as an arrow pointing upwards. Although the question stated that the activation energy was not required, candidates frequently included it in their diagrams and then labelled it ΔH. Many Candidates did not write the formula of the reactants or products and those who did multiplied the species by two so as the diagram did not represent the enthalpy of formation.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
			Total	3	

Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
21	<i>M1 Mixing of first pair of solutions</i> Adding (aqueous) barium chloride to bromine (water) OR $\text{BaCl}_2 + \text{Br}_2$ <i>M2 Mixing of second pair of solutions</i> Adding (aqueous) calcium iodide to bromine (water) OR $\text{CaI}_2 + \text{Br}_2$ OR Adding aqueous magnesium bromide to aqueous iodine OR $\text{MgBr}_2 + \text{I}_2$ <i>M3 Colours in cyclohexane</i> Colour for M1 is orange OR yellow AND Colour for M2 is purple OR violet OR mauve OR pink OR lilac <i>M4 Ionic equation mark</i> $\text{Br}_2 + 2\text{I}_- \rightarrow \text{I}_2 + 2\text{Br}_-$ <i>M5 Use of M1 and one of M2 as only two experiments</i>	5	For M1 and M2 ALLOW any halide for the named halides in the question eg 'potassium chloride' for barium chloride 'potassium bromide' for barium chloride 'potassium iodide' for calcium iodide DO NOT ALLOW 'barium chloride/BaCl' 'calcium iodide/CaI' 'magnesium bromide/MgBr' as the halide DO NOT ALLOW 'bromide' for 'bromine' OR 'iodide' for 'iodine' M1 can be seen anywhere M2 could be awarded from a correct ionic equation in M4 M2 can be seen anywhere If both M2 tests and M1 are given, this will nullify M5 M3 is given for the correct resultant colour of pairs of solution given in M1 and M2. If both possible pairs of solutions in M2 are given, both colours must be correct. IGNORE colours of other combinations of solutions IGNORE colours in the aqueous layer if stated DO NOT ALLOW other colours for M1 and M2 (eg iodine is brown) M4 can be awarded anywhere M4 also scores M2 if not already awarded ALLOW multiples IGNORE state symbols IGNORE $\text{I}_2 + 2\text{Br}_- \rightarrow \text{I}_2 + 2\text{Br}_-$ IGNORE $\text{Br}_2 + 2\text{Cl}_- \rightarrow \text{Br}_2 + 2\text{Cl}_-$ DO NOT ALLOW other ionic equations DO NOT ALLOW if more than two experiment are attempted even if pointless eg 'barium chloride + calcium iodide' Place the 'tick' for M5 against the sub-total mark, [5], at the bottom right hand side of the answer space Examiner's Comments Able candidates were able to provide full answers involving only two reactions, one ionic equation and correct colours of

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
					products in succinct form. Some candidates answered the question correctly then ignored the instruction to keep the number of reactions to a minimum and gave an unnecessary third confirmatory reaction. This question distinguished well for many weaker candidates were unable to produce chemically coherent responses. Suggestions for 'impossible' reactions such as adding magnesium bromide to calcium iodide were frequently seen from such candidates.
			Total	5	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
22	a		Ga^{3+} ✓	1	Examiner's Comments The formula, Ga^{3+}, was almost universally known.
	b	i	SF_6 AND Sulfur(VI) fluoride OR Sulfur hexafluoride ✓	1	IGNORE sulfur fluoride Examiner's Comments Nearly all candidates knew the formula of the molecule in question but some of these were less secure when it came to the name. Sulfur(IV) fluoride being the most common error.
		ii	$2\text{F}_2 + 2\text{NaOH} \rightarrow \text{F}_2\text{O} + 2\text{NaF} + \text{H}_2\text{O}$ M1 F_2O AND NaF ✓ M2 Rest of equation (including balance) ✓	2	ALLOW multiples IGNORE state symbol ALLOW OF_2 for F_2O AND FNa for NaF ALLOW both marks for alternative equations which have both F_2O and NaF AND three products Eg $3\text{F}_2 + 2\text{NaOH} \rightarrow 2\text{F}_2\text{O} + 2\text{NaF} + \text{H}_2$ Eg $2\text{F}_2 + \text{NaOH} \rightarrow \text{F}_2\text{O} + \text{NaF} + \text{HF}$ Examiner's Comments Even weaker candidates coped well with the construction of this difficult equation. (Once again suggesting that having covered the A2 part of the specification, this had given candidates the experience that the normal AS candidate would not have met.)
			Total	4	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
23	a	i	Effervescence OR fizzing OR bubbling OR gas produced AND The solid OR zinc carbonate would dissolve OR disappear ✓	1	ALLOW 'carbon dioxide produced' DO NOT ALLOW incorrectly named gas eg H ₂ Examiner's Comments Most candidates realised that effervescence and dissolving would be seen.
		ii	$\text{ZnCO}_3 + 2\text{HCl} \rightarrow \text{ZnCl}_2 + \text{CO}_2 + \text{H}_2\text{O}$ ✓	1	ALLOW multiples IGNORE state symbols Examiner's Comments Nearly all candidates were able to write the equation successfully – including those who had omitted effervescence in (i).

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
	b	i	Magnesium (atoms) has been oxidised AND Because it has lost two electrons ✓ Copper (ions) has been reduced AND Because it has gained two electrons ✓	2	IGNORE use of oxidation numbers if electron gain/loss is mentioned. Electrons gain/loss could be in half equations In the absence of text look for evidence on the equation ALLOW 'donated' for 'lost' Assume 'Cu' refers to copper in 'CuSO₄' ALLOW one mark two electrons gained and lost for each species but oxidation/reduction is incorrect or is omitted ALLOW one mark for correct oxidation and reduction if electron transfer is omitted and correct changes of oxidation state are shown (ie Mg 0 --> (+)2 AND Cu (+)2 to 0) ALLOW 'two' electrons transferred from magnesium to copper Examiner's Comments This type of question in the past has proved difficult but the current cohort found little difficulty. By far, the most common error was to use changes in oxidation numbers as the basis of the redox rather than using the number of electrons gained and lost for the explanation of the redox process.
		ii	$\text{Mg(s)} + 2\text{H}_2\text{O(l)} \rightarrow \text{Mg(OH)}_2\text{(aq)} + \text{H}_2\text{(g)}$ Correct reactants and products ✓ Balance and state symbols ✓	2	ALLOW multiples ALLOW $\text{Mg(OH)}_2\text{(s)}$ ALLOW $\text{Mg(s)} + \text{H}_2\text{O(g)}$ OR $\text{H}_2\text{O(l)}$ MgO(s) + $\text{H}_2\text{(g)}$ including state symbols for one mark Examiner's Comments The equation for the reaction between magnesium and water was well known – but many erroneously assumed MgO was formed.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
	c	i	Ca(OH) ₂ OR Calcium hydroxide OR CaO OR Calcium oxide ✓ □	1	ALLOW Calcium carbonate OR CaCO ₃ Examiner's Comments The unusual equation involving P ₄ molecules was answered well. Weaker candidates assumed that phosphorus was monatomic and consequentially lost credit.
		ii	6Ca + P ₄ □ 2Ca ₃ P ₂ ✓	1	ALLOW multiples IGNORE state symbols Examiner's Comments This potentially difficult dot-and-cross diagram of the ions present was done well by candidates.
		iii	$3x \begin{bmatrix} & xx & \\ x & Ca & x \\ x & & x \\ & xx & \end{bmatrix}^{2+} \quad 2x \begin{bmatrix} \bullet \bullet \bullet & & \\ \bullet & P & \bullet \\ x & & x \\ \bullet & & \bullet \end{bmatrix}^{3-}$ Ca with 8 (or no) electrons AND phosphide ion with dot-and-cross outermost octet ✓ Three Ca ions AND two phosphide ions with correct charges ✓	2	For first mark: If 8 electrons are shown on the cation then the extra electron in the anion must match the symbol chosen for the electrons in the cation. IGNORE inner shells IGNORE circles ALLOW one mark if both electron arrangements and charges are correct but only one of each ion is drawn. ALLOW (brackets not required) 3[Ca²⁺] 3[Ca]²⁺ [Ca²⁺]₃ 2[P³⁻] 2[P]³⁻ [P³⁻]₂ DO NOT ALLOW [Ca₃]²⁺ [3Ca]²⁺ [Ca]³²⁺ [P₂]³⁻ [2P]³⁻ [P]₂
			Total	10	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
24			$\text{C}_{17}\text{H}_{35}\text{COOH} + \text{NaOH}$ $\rightarrow \text{C}_{17}\text{H}_{35}\text{COO}^-\text{Na}^+ + \text{H}_2\text{O} \checkmark$	1	ALLOW $\text{C}_{17}\text{H}_{35}\text{COONa}$ IGNORE state symbols Examiner's Comments Very well answered. Most candidates could write the correct equation.
			Total	1	
25			C	1	Examiner's Comments Distractor D was a common incorrect answer.
			Total	1	

Mark Scheme

Question		Answer/Indicative content	Marks	Guidance
26	a	FIRST, CHECK THE ANSWER ON ANSWER LINE IF $\Delta_r H = -58.5 \text{ (kJ mol}^{-1}\text{)}$ award 4 marks <i>Energy released in J OR kJ</i> $= 100.0 \times 4.18 \times 10.5 = 4389 \text{ (J) OR } 4.389 \text{ (kJ) } \checkmark$ <i>Correctly calculates $n(\text{Pb}(\text{NO}_3)_2)$</i> $= 1.50 \times \frac{50}{1000} = 0.075(0) \text{ (mol) } \checkmark$ ΔH value in J OR kJ Answer MUST divide energy by $n(\text{Pb}(\text{NO}_3)_2)$ $(-) \frac{4389}{0.0750} \text{ OR } (-)58520 \text{ (J)}$ OR $(-) \frac{4.389}{0.0750} \text{ OR } (-)58.52 \text{ (kJ) } \checkmark$ <i>(Sign ignored and/or more than 3 SF)</i> Correct $\Delta_r H$ in kJ AND – sign AND 3 SF $= -58.5 \text{ (kJ mol}^{-1}\text{)} \checkmark$	4	FULL ANNOTATIONS MUST BE USED ----- ALLOW 4390 J; 4.39 kJ DO NOT ALLOW less than 3 SF IGNORE units <i>i.e. ALLOW correctly calculated number in J OR kJ</i> ALLOW ECF from $n(\text{Pb}(\text{NO}_3)_2)$ AND/OR Energy ALLOW 58500 (from 4390) IGNORE absence of – sign and 3 SF requirement Final mark requires – sign, kJ AND 3 SF Note: From 4390 J, $\Delta_r H = -58.5 \text{ (kJ mol}^{-1}\text{)}$ (SAME) ----- Common error –29.3 3 marks (50 g instead of 100 g in $mc\Delta T$) <u>Examiner's Comments</u> Although similar in style to unstructured direct enthalpy calculations on the legacy specification, this question was harder for two reasons. Firstly, two volumes of 50 cm³ had to be added together to generate m as 100 g for $mc\Delta T$. Secondly, candidates were asked to quote their final answer to an ‘appropriate’ number of significant figures. This will be the least accurate measurement (to 3 significant figures in this example). Many incorrect answers used <i>m</i> as 50 g or

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
					quoted a final numerical value to more than 3 significant figures. Even after obtaining a correct final value for ΔH, this was often not given a negative sign to indicate the exothermic change. It is important for candidates to show clear working so that markers can see what is intended and able to apply credit using error carried forward. Answer: $\Delta H = -58.5 \text{ kJ mol}^{-1}$
	b		$\text{Pb}^{2+}(\text{aq}) + 2\text{I}^{-}(\text{aq}) \rightarrow \text{PbI}_2(\text{s}) \checkmark$ State symbols required	1	ALLOW $\text{Pb}^{+2}(\text{aq})$ IGNORE spectator ions, $\text{K}^{+}(\text{aq})$ and $2\text{NO}_3^{-}(\text{aq})$ on both sides <u>Examiner's Comments</u> Only the best candidates were able to construct the required equation. Even when written correctly, state symbols (asked for in the question) were often omitted or shown incorrectly. Although very similar to the ionic equation for formation of silver halides, this equation was beyond most candidates at this stage of their chemistry studies.

Mark Scheme

Question		Answer/Indicative content	Marks	Guidance
	c	FIRST, CHECK ANSWER ON ANSWER LINE IF [KI(aq)] rounds to 3.3 mol dm⁻³ e.g. 3.30, 3.33, 3.3 recurring ----- Method 1 [KI(aq)] for complete reaction $= 2 \times 0.0750 = 0.150 \text{ mol} \times \frac{1000}{50} = 3 \text{ (mol dm}^{-3}\text{)} \checkmark$ 10% greater gives $3 \times 1.1 = 3.3(0) \checkmark$ OR----- Method 2 $n(\text{KI(aq)})$ required = $2.2 \times 0.0750 = 0.165 \text{ mol} \checkmark$ $[\text{KI(aq)}] = 0.165 \times \frac{1000}{50} = 3.3(0) \text{ (mol dm}^{-3}\text{)} \checkmark$	2	ALLOW ECF from incorrect $n(\text{Pb(NO}_3)_2)$ from 24(a) BUT if (a) is incorrect but 0.0750 used here, treat as a fresh start and IGNORE response from 24(a) ALLOW 2 marks for 3.3/3.3 recurring <i>Attempt at increasing concentration by 10%</i> $= 2 \times 0.0750 = 0.150 \text{ mol} \times \frac{1000}{45} = 3.33 \text{ (mol dm}^{-3}\text{)}$ ALLOW ECF from incorrect $n(\text{KI})$ <u>Common errors</u> 3 1 mark (Correct for KI with no extra 10%) 1.6 1 mark (no factor of 2 used for KI) 5 2.7 1 mark (10% less rather than 10% more) 2.7 1 mark (10% increase in volume: 55 3/2. cm³) 72 <u>Examiner's Comments</u> This part was well attempted with many candidates able to score at least one of the two marks. Errors related to use of an incorrect mole ratio, applying 10% incorrectly, or ignoring 10% altogether. Answer: 3.30 mol dm⁻³
		Total	7	

Mark Scheme

Question		Answer/Indicative content	Marks	Guidance
27	a	Cu^{2+}: $(1s^2) 2s^2 2p^6 3s^2 3p^6 3d^9$ ✓ Cu^+: $(1s^2) 2s^2 2p^6 3s^2 3p^6 3d^{10}$ ✓	2	IGNORE repeated $1s^2$ after $1s^2$ prompt on answer line ALLOW $4s^0$, either before or after 3d ALLOW upper case D, etc and subscripts, e.g.....$3S_2 3P^6$ DO NOT ALLOW [Ar] as shorthand for $1s^2 2s^2 2p^6 3s^2 3p^6$ Examiner's Comments The responses seen were very mixed. Able candidates scored the two marks easily but many errors were seen, particularly by removal of 3d electrons rather than 4s electrons from copper atoms to give the electron configurations of the ions (especially for Cu^+ in CuI).
	b	IGNORE any charges shown within formulae (treat as rough working) $\text{CuCO}_3 + 2\text{HCOOH} \rightarrow \text{Cu}(\text{HCOO})_2 + \text{H}_2\text{O} + \text{CO}_2$ OR $\text{CuO} + 2\text{HCOOH} \rightarrow \text{Cu}(\text{HCOO})_2 + \text{H}_2\text{O}$ OR $\text{Cu}(\text{OH})_2 + 2\text{HCOOH} \rightarrow \text{Cu}(\text{HCOO})_2 + 2\text{H}_2\text{O}$ ✓	1	IGNORE state symbols In formula of HCOOH / HCOO, ALLOW H, C and O in ANY order ALLOW H_2CO_3 for H_2O and CO_2 in carbonate equation ALLOW $(\text{HCOO})_2\text{Cu}$ for $\text{Cu}(\text{HCOO})_2$ DO NOT ALLOW equation with CuSO_4 Examiner's Comments Most candidates attempted an equation using CuO, $\text{Cu}(\text{OH})_2$ or CuCO_3. Marks were then sometimes lost by not balancing the equation. It was not uncommon to see equations using CuSO_4 or CuCl_2 as reactant and consequently this mark was often not awarded.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
	c		$2\text{Cu}^{2+} + 4\text{I}^{-} \rightarrow 2\text{CuI}(\text{s}) + \text{I}_2$ ✓ State symbol for CuI(s) ONLY required	1	ALLOW multiples, e.g. $\text{Cu}^{2+} + 2\text{I}^{-} \rightarrow \text{CuI}(\text{s}) + \frac{1}{2}\text{I}_2$ IGNORE other state symbols, even if incorrect Examiner's Comments This equation proved to be much more difficult than in 8(b), with only the best candidates producing a correctly balanced equation. As with 4(c) and 7(b)(iii), equations were often unbalanced in terms of charge and oxidation number.
	d		Starch ✓ Blue / black to colourless / white ✓ MARK INDEPENDENTLY	2	IGNORE 'brown' in composite colour with blue or black, i.e. ALLOW blue / brown to colourless ALLOW black / brown to colourless DO NOT ALLOW just 'it turns colourless / is decoloured' <i>Initial colour required</i> IGNORE clear for colourless Examiner's Comments Most candidates seemed unaware that starch is used to identify the end point in iodine–thiosulfate titrations. Even when starch was given, the colour change was often incorrect. Random responses were seen to this part, e.g. methyl orange, phenolphthalein, potassium manganate and sodium thiosulfate.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
	e		WORKING REQUIRED Correct answer: $x = 4$ required evidence of working ----- $n(\text{S}_2\text{O}_3^{2-}) \text{ OR } n(\text{Cu}^{2+}) = \frac{0.0420 \times 23.5}{1000} = 9.87 \times 10^{-4} \text{ (mol) } \checkmark$ In 250.0 cm^3 solution, $n(\text{Cu}^{2+}) = 9.87 \times 10^{-3} \text{ (mol) } \checkmark$ $M(\text{Cu}(\text{HCOO})_2 \cdot 4\text{H}_2\text{O}) = \frac{2.226}{9.87 \times 10^{-3}} = 225.5 \text{ (g mol}^{-1}\text{) } \checkmark$ $x(\text{H}_2\text{O})$ has mass of $225.5 - M(\text{Cu}(\text{HCOO})_2)$ $= 225.5 - 153.5$ $= 72(.0) \checkmark$ $x = \frac{72(.0)}{18(.0)} = 4$ WHOLE NUMBER needed AND evidence of working $\checkmark$	5	FULL ANNOTATIONS MUST BE USED ----- At least 3 SF required throughout <i>Alternative approach for final 3 marks based on mass:</i> mass $\text{Cu}(\text{HCOO})_2 = 9.87 \times 10^{-3} \times 153.5 = 1.515 \text{ g } \checkmark$ $n(\text{H}_2\text{O}) = \frac{2.226 - 1.515}{18(.0)} = \frac{0.711}{18(.0)} = 0.0395 \text{ (mol) } \checkmark$ $x = \frac{0.0395}{9.87 \times 10^{-3}} = 4 \checkmark$ ALLOW $\text{Cu}(\text{HCOO})_2 \cdot 4\text{H}_2\text{O}$ ----- COMMON ERRORS for 4 marks $x = 117$ (calc 116.78) <i>Use of 9.87×10^{-4} (no scaling $\times 10$) $\rightarrow M = 2255.319$</i> $x = 17$ (calc 16.53) 4 marks <i>Use of 4.935×10^{-4} (Use of $0.5 \times 9.87 \times 10^{-3}$)</i> Check $n(\text{Cu}^{2+})$ for other ECFs Check for ECFs from incorrect $M(\text{anhydr salt})$ Actual = 153.5 Examiner's Comments Many candidates were on firm territory with a redox titration problem. The majority went through a well-rehearsed sequence of steps to obtain all five marks for showing that x was 4. Where '4' had not been obtained, marks could still be awarded for intermediate working if correct. Answer: $x = 4$
			Total	11	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
28	a	i	(enthalpy change for) the formation of 1 mole H₂O from reaction of an acid/H⁺ with an alkali/base/OH⁻ ✓ H⁺(aq) + OH⁻(aq) → H₂O(l) ✓	2	ALLOW (enthalpy change for) the reaction of 1 mol H⁺ with 1 mol of OH⁻ ALLOW formation of 1 mol of water from neutralisation If no definition in words, award 1st mark if 1 mol is written under species in the equation, in line with marking criteria DO NOT ALLOW formation of 1 mol H₂O from 1 mole of acid and/or 1 mol of alkali DO NOT ALLOW formation of 1 mol H₂O from an acid and its conjugate base
		ii	2NaOH + H ₂ SO ₄ → Na ₂ SO ₄ + 2H ₂ O ✓	1	IGNORE state symbols (even if wrong) <i>not required</i>

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		iii	FIRST, CHECK THE ANSWER ON ANSWER LINE IF answer = -56.43 OR -56.4 (kJ mol^{-1}) award 3 marks ----- Energy change energy change = $75.0 \times 4.18 \times 13.5$ $= 4232.25$ (J) OR 4.23225 (kJ) ✓ Moles $n(\text{NaOH}) = 1.5(0) \times \frac{50.0}{1000} = 0.075(0)$ (mol) OR $n(\text{H}_2\text{SO}_4) = 1.5(0) \times \frac{25.0}{1000} = 0.0375(0)$ (mol) OR $n(\text{H}_2\text{O})$ formed $= 0.075(0)$ (mol) ✓ $\Delta_{\text{neut}}H = -\frac{4.23225}{0.075} = -56.43$ OR -56.4 (kJ mol^{-1}) ✓ – sign required	3	FULL ANNOTATIONS MUST BE USED ----- IF there is an alternative answer, check to see if there is any ECF credit possible using working below ----- IGNORE any sign shown ALLOW 4230 (J) AND 4.23 (kJ) up to calculator value correctly rounded ALLOW ECF from <u>calculated energy change</u> <u>calculated moles H_2O</u> ALLOW 3 significant figures up to calculator value correctly rounded
	b	i	$2\text{H}_2\text{S}(\text{g}) + \text{O}_2(\text{g}) \rightarrow 2\text{S}(\text{s}) + 2\text{H}_2\text{O}(\text{g})$ ✓	1	ALLOW multiples, e.g. $6\text{H}_2\text{S}(\text{g}) + 3\text{O}_2(\text{g}) \rightarrow 6\text{S}(\text{s}) + 6\text{H}_2\text{O}(\text{g})$

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		ii	FIRST, CHECK THE ANSWER ON ANSWER LINE IF answer = 3.05×10^7 (g) award 3 marks ----- volume of H_2S $= 1.50 \times 10^8 \times 16(0)/100 = 2.4(0) \times 10^7$ dm^3 of H_2S ✓ $n(\text{H}_2\text{S}) (= n(\text{S}))$ $2.4(0) \times 10^7 / 24.0 \text{ mol} = 1(00) \times 10^6$ mol ✓ Mass S = $1(00) \times 10^6 \times 95(0)/100 \times 32.1$ $= 3.05 \times 10^7$ (g) ✓	3	ALLOW ECF from incorrect volume of H_2S 3 SF AND standard form required
	c	i	FIRST, CHECK FOR A VALUE OF ΔG. IF answer = $-89.96(34)$ (kJ mol^{-1}) award 3 marks ----- ΔS calculation (2 marks) $\Delta S = (3 \times 31.8) + (2 \times 188.7) - [(2 \times 205.7) + (248.1)]$ OR $\Delta S = 472.8 - 659.5$ ✓ $\Delta S = -186.7 \text{ J mol}^{-1} \text{ K}^{-1}$ OR $-0.1867 \text{ kJ mol}^{-1} \text{ K}^{-1}$ ✓ ΔG calculation (1 mark) $\Delta G = \Delta H - T \Delta S = -145.6 - (298 \times -0.1867)$ $= -89.96(34) (\text{kJ mol}^{-1})$ ✓ Comment (1 mark) – sign shows the (forward) reaction is feasible ✓ Temperature at which feasibility changes (1 mark) $T = \frac{\Delta H}{\Delta S} = \frac{-145.6}{-0.1867} = 780 \text{ K}$ AND comment that ΔG OR $\Delta H - T \Delta S = 0$ ✓	5	ALLOW (-) 187 OR 0.187 ALLOW ECF from incorrect ΔH ALLOW –90 up to calculator value of –89.9634 correctly rounded ORA for comment about – sign required for feasibility

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		ii	FIRST, CHECK THE ANSWER ON ANSWER LINE IF answer = $-296.8 \text{ (kJ mol}^{-1}\text{)}$ award 2 marks ----- Correct expression $-145.6 = (2 \times -241.8) - (2 \times -20.6 + \Delta_f H(\text{SO}_2)) \checkmark$ Calculation of $\Delta_f H(\text{SO}_2)$ formation $\Delta_f H(\text{SO}_2) = (2 \times -241.8) - (2 \times -20.6) + 145.6$ $= -296.8 \text{ (kJ mol}^{-1}\text{)} \checkmark$	2	ALLOW ECF ALLOW 1 mark for (+)296.8 Subtraction the wrong way around
			Total	17	
29		i	$\text{CF}_3\text{Cl} \rightarrow \text{CF}_3\cdot + \text{Cl}\cdot \checkmark$	1	Note: dots are required
		ii	Step 1: $\text{C}\cdot + \text{O}_3 \rightarrow \text{C/O}\cdot + \text{O}_2 \checkmark$ Step 2: $\text{C/O}\cdot + \text{O} \rightarrow \text{C}\cdot + \text{O}_2 \checkmark$ Overall equation: $\text{O}_3 + \text{O} \rightarrow 2\text{O}_2 \checkmark$	3	ALLOW one mark for both correct symbol equations in propagation steps with (any or all) dots missing or extra dots. e.g. $\text{C}\cdot + \text{O}_3\cdot \rightarrow \text{C/O} + \text{O}_2$ $\text{C/O}\cdot + \text{O}\cdot \rightarrow \text{C/} + \text{O}_2\cdot$
		iii	FIRST CHECK THE ANSWER ON THE ANSWER LINE IF answer = 9.98×10^4 award 3 marks $n(\text{C}\cdot) = \frac{1}{35.5} = 0.02817 \text{ (mol)} \checkmark$ $n(\text{O}_3) = \frac{135000}{48} = 2812.5 \text{ (mol)} \checkmark$ $n(\text{C}\cdot) : n(\text{O}_3) = \frac{2812.5}{0.02817} = 9.98 \times 10^4 \checkmark$ Must be in standard form AND to 3SF	3	If there is an alternative answer, check to see if there is any ECF credit possible ALLOW 0.0282 up to calculator value of 0.02816901408 correctly rounded to 3 or more sig. fig. ALLOW 3SF: 2810 up to calculator value of 2812.5 correctly rounded Note: use of 0.0282 mol $\text{C}\cdot$ gives 9.97×10^4
			Total	7	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
30	a	i	Reagent and observation sodium carbonate AND Fizzing/effervescence/bubbling ✓ Equation Correctly balanced equation ✓ e.g. $2\text{RCOOH} + \text{Na}_2\text{CO}_3 \rightarrow 2\text{RCOONa} + \text{CO}_2 + \text{H}_2\text{O}$	2	Note: both reagent and observation are required for first mark ALLOW name or formula for any suitable carbonate e.g. NaHCO_3, potassium carbonate etc. ALLOW reagent from equation if not stated elsewhere
		ii	Reagent and observation Tollens' (reagent) AND Silver (mirror) ✓ Equation $\text{RCHO} + [\text{O}] \rightarrow \text{RCOOH}$ ✓	2	Note: both reagent and observation are required for first mark ALLOW ammoniacal silver nitrate OR Ag^+/NH_3 ALLOW $\text{H}^+/\text{Cr}_2\text{O}_7^{2-}$ OR acidified (potassium/sodium) dichromate AND Orange to green (<i>this would identify the aldehyde from the carboxylic acid, ketone and esters</i>)
	b		2,4-dinitrophenylhydrazine AND Orange/yellow/red precipitate ✓	1	ALLOW errors in spelling ALLOW 2,4(-)DNP OR 2,4(-)DNPH ALLOW Brady's reagent or Brady's Test ALLOW solid OR crystals OR ppt as alternatives for precipitate
	c	i	$\text{CH}_3\text{COOC}(\text{CH}_3)_3 + \text{NaOH} \rightarrow \text{CH}_3\text{COONa} + (\text{CH}_3)_3\text{COH}$ CH_3COONa ✓ Rest of equation correct ✓ OR $(\text{CH}_3)_3\text{CCOOCH}_3 + \text{NaOH} \rightarrow (\text{CH}_3)_3\text{CCOONa} + \text{CH}_3\text{OH}$ $(\text{CH}_3)_3\text{CCOONa}$ ✓ Rest of equation correct ✓	2	Note: the hydrolysis of either ester may be given ALLOW any combination of skeletal OR structural OR displayed formula as long as unambiguous DO NOT ALLOW molecular formulae of products (<i>question requires structures of products to be shown</i>)

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		ii	Reagent and observation $\text{H}^+/\text{Cr}_2\text{O}_7^{2-}$ OR acidified (potassium/sodium) dichromate AND Orange to green (with CH_3OH) ✓ Equation $\text{CH}_3\text{OH} + [\text{O}] \rightarrow \text{HCHO} + \text{H}_2\text{O}$ OR $\text{CH}_3\text{OH} + 2[\text{O}] \rightarrow \text{HCOOH} + \text{H}_2\text{O}$ ✓	2	ALLOW any combination of skeletal OR structural OR displayed formula as long as unambiguous DO NOT ALLOW molecular formulae <i>(question requires structures of organic compounds to be shown)</i>
		iii	^{13}C NMR (1 mark) (It is) not possible to identify (the esters) with ^{13}C NMR AND (both) spectra would contain four peaks (with similar chemical shifts) ✓ ^1H NMR (2 marks) (It is) possible to identify (the esters) with ^1H NMR (^1H NMR spectrum of) $\text{CH}_3\text{COOC}(\text{CH}_3)_3$ has a singlet/peak between 2.0–3.0 (ppm) (^1H NMR spectrum of) $(\text{CH}_3)_3\text{CCOOCH}_3$ has a singlet/peak between 3.0–4.3 (ppm) All three correct statements ✓✓ Any two correct statements ✓	3	ALLOW 'same number of peaks' in place of 'four peaks' ALLOW any value or range of values within 2.0–3.0 ALLOW any value or range of values within 3.0–4.3

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
	d		<u>Possible structures for ketone (2 marks)</u> $\begin{array}{c} \text{O} \\ \\ \text{CH}_3 - \text{C} - \text{CH}_2\text{CH}_2\text{CH}_3 \end{array}$ $\begin{array}{c} \text{O} \\ \\ \text{CH}_3\text{CH}_2 - \text{C} - \text{CH}_2\text{CH}_3 \end{array}$ $\begin{array}{c} \text{O} \\ \\ \text{CH}_3 - \text{C} - \text{CH} - \text{CH}_3 \\ \\ \text{CH}_3 \end{array}$ All three correct ✓✓ Any two correct ✓ <u>Aldehyde (3 marks)</u> Peak at (δ) 1.2 shows HC–R AND No H on adjacent C atom as peak is singlet ✓ Peak at (δ) 9.6 shows H–C=O AND No H on adjacent C atom as peak is singlet ✓ $\begin{array}{c} \text{CH}_3 \quad \text{O} \\ \quad \\ \text{H}_3\text{C} - \text{C} - \text{C} - \text{H} \\ \\ \text{CH}_3 \end{array}$ OR (2,2-)dimethylpropanal ✓	5	ALLOW any combination of skeletal OR structural OR displayed formula as long as unambiguous IGNORE names of ketones
			Total	17	
31			C	1	
			Total	1	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
32		i	$n(\text{myrcene}) = \frac{204 \times 10^{-3}}{136.0} = 1.5(0) \times 10^{-3} \text{ (mol)} \checkmark$ $\text{Volume of H}_2 = 3 \times 1.5(0) \times 10^{-3} \times 24000 = 108 \text{ (cm}^3\text{)} \checkmark$	2	Correct working required for the first marking point. ALLOW ECF from incorrect moles of myrcene i.e. $n(\text{myrcene}) \times 3 \times 24000$ Common incorrect answers 108000 cm³ = 1 mark (not converted to g) 12cm³ = 1 mark (divided by 3) 36 cm³ = 1 mark (not multiplied by 3) IGNORE Calculations based on $pV = nRT$ Examiner Comments The best answers first converted 204 mg into g and then divided this value by the molar mass of myrcene. Candidates then linked this to presence of three double bonds and calculated correctly the moles of hydrogen required to produce the saturated alkene. Finally the moles were multiplied by 24000 cm³ to provide an answer in cm³. Candidates who worked in mg could not access the first mark however the subsequent mark was awarded as error carried forward. Answer = 108 cm³

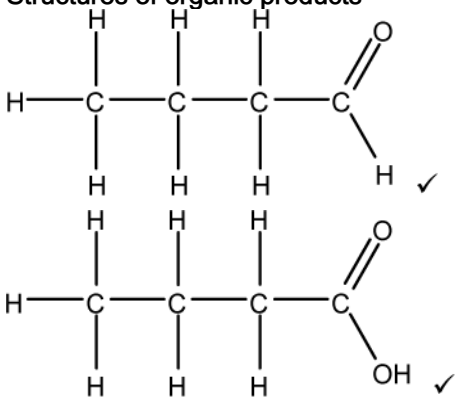
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		ii	Amount of hydrogen $n(\text{H}_2) = \frac{5.28}{24.0} = 0.22(0) \text{ (mol)} \quad \checkmark$ Number of double bonds $= \frac{0.220}{0.0200} = 11 \quad \checkmark$ Formula of saturated product $\text{C}_{40}\text{H}_{78}$ Equation $\text{C}_{40}\text{H}_{56} + 11\text{H}_2 \longrightarrow \text{C}_{40}\text{H}_{78} \quad \checkmark$	4	ALLOW Evidence of $n(\text{H}_2) = \frac{5.28}{24.0}$ if 0.22 is not seen Evidence for 11 double bonds could come from 11H_2 in equation Formula could be shown as the product of an equation ALLOW ECF from $\text{C}_{40}\text{H}_{82}$ and $\text{C}_{40}\text{H}_{80}$ only i.e. $\text{C}_{40}\text{H}_{60} + 11\text{H}_2 \longrightarrow \text{C}_{40}\text{H}_{82}$ $\text{C}_{40}\text{H}_{58} + 11\text{H}_2 \longrightarrow \text{C}_{40}\text{H}_{80}$ Examiner Comments The most common score on this question was two, with candidates being able to calculate the moles of hydrogen gas and relate this to the replacement of eleven double bonds. Frequently candidates calculated the formula of the saturated hydrocarbon to be $\text{C}_{40}\text{H}_{82}$ by applying the general formula $\text{C}_n\text{H}_{2n+2}$ to a compound containing 40 carbon atoms. The best Candidates were able to adjust this formula to account for the presence of the two rings and were then able to write the correct equation for the hydrogenation
			Total	6	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
33	a		$\text{C}_5\text{H}_{10}\text{O} + 7\text{O}_2 \longrightarrow 5\text{CO}_2 + 5\text{H}_2\text{O} \checkmark$	1	ALLOW multiples e.g. $2\text{C}_5\text{H}_{10}\text{O} + 14\text{O}_2 \longrightarrow 10\text{CO}_2 + 10\text{H}_2\text{O}$ ALLOW any equation involving an unsaturated alcohol with correct balancing e.g. $\text{C}_5\text{H}_8\text{O} + 6.5\text{O}_2 \longrightarrow 5\text{CO}_2 + 4\text{H}_2\text{O}$ $\text{C}_5\text{H}_6\text{O} + 6\text{O}_2 \longrightarrow 5\text{CO}_2 + 3\text{H}_2\text{O}$ $\text{C}_5\text{H}_4\text{O} + 5.5\text{O}_2 \longrightarrow 5\text{CO}_2 + 2\text{H}_2\text{O}$ $\text{C}_5\text{H}_2\text{O} + 5\text{O}_2 \longrightarrow 5\text{CO}_2 + \text{H}_2\text{O}$ IGNORE state symbols Examiner Comments The more able candidates were able to balance this combustion equation. Those who failed to be awarded the mark either used the molecular formula of a saturated alcohol or did not consider the presence of the oxygen atom in the alcohol when balancing the equation.

Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
b	Structures of organic products  Equations $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{OH} + [\text{O}] \longrightarrow \text{CH}_3\text{CH}_2\text{CH}_2\text{CHO} + \text{H}_2\text{O} \quad \checkmark$ $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{OH} + 2[\text{O}] \longrightarrow \text{CH}_3\text{CH}_2\text{CH}_2\text{COOH} + \text{H}_2\text{O} \quad \checkmark$ Reaction conditions Distillation to produce aldehyde/$\text{CH}_3\text{CH}_2\text{CH}_2\text{CHO}$ AND Reflux to produce carboxylic acid/$\text{CH}_3\text{CH}_2\text{CH}_2\text{COOH}$ $\checkmark$	5	ANNOTATE WITH TICKS AND CROSSES Use of any primary alcohol containing 3, 5 or more carbons can be awarded up to 4 marks. ALLOW any combination of skeletal OR structural OR displayed formula as long as unambiguous IGNORE names DO NOT ALLOW $\text{CH}_3\text{CH}_2\text{CH}_2\text{COH}$ for the structure of the aldehyde. ALLOW $\text{CH}_3\text{CH}_2\text{CH}_2\text{CO}_2\text{H}$ for the structure of the carboxylic acid. ALLOW marks for structures from equations as long as unambiguous. ALLOW molecular formulae in equations e.g. $\text{C}_4\text{H}_{10}\text{O} + [\text{O}] \longrightarrow \text{C}_4\text{H}_8\text{O} + \text{H}_2\text{O}$ $\text{C}_4\text{H}_{10}\text{O} + 2[\text{O}] \longrightarrow \text{C}_4\text{H}_8\text{O}_2 + \text{H}_2\text{O}$ $\text{C}_4\text{H}_9\text{OH} + [\text{O}] \longrightarrow \text{C}_3\text{H}_7\text{CHO} + \text{H}_2\text{O}$ $\text{C}_4\text{H}_9\text{OH} + 2[\text{O}] \longrightarrow \text{C}_3\text{H}_7\text{CO}_2\text{H} + \text{H}_2\text{O}$ IGNORE incorrect structures in equations i.e. $\text{C}_4\text{H}_{10}\text{O} + [\text{O}] \longrightarrow \text{C}_3\text{H}_7\text{COH} + \text{H}_2\text{O}$ scores equation mark Conditions must be linked to aldehyde/carboxylic acid or correct products. Conditions may be written above arrow of equation. Examiner Comments A very well answered question. Candidates had obviously been well prepared as even the weakest candidates gained a number of marks here. The most common mark lost was a failure to include H_2O in the balanced equations. In the preparation of the carboxylic acid, a number of Candidates balanced the equation with $2\text{H}_2\text{O}$.
	Total	6	

Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
34	ALLOW equilibrium sign in equations provided reactants on left Reaction of H₂O₂ with MnO₂: $\text{H}_2\text{O}_2 + \text{MnO}_2 + 2\text{H}^+ \rightarrow \text{O}_2 + \text{Mn}^{2+} + 2\text{H}_2\text{O}$ ✓ Reaction of H₂O₂ with Mn²⁺: $\text{H}_2\text{O}_2 + \text{Mn}^{2+} \rightarrow \text{MnO}_2 + 2\text{H}^+$ ✓ Use of <i>E</i> data Use of <i>E</i> data to support equation(s) above or half direction of provided half equations (one including MnO₂) ✓ <i>Also look for evidence around half equations</i> MnO₂ regenerated / reformed ✓ <i>Must be linked to an equation showing MnO₂ as reactant and an equation showing MnO₂ as product</i>	4	ALLOW correct multiples IGNORE state symbols ----- ALLOW uncanceled H₂O and H⁺ $\text{H}_2\text{O}_2 + \text{MnO}_2 + 4\text{H}^+ \rightarrow \text{O}_2 + \text{Mn}^{2+} + 2\text{H}_2\text{O} + 2\text{H}^+$ $\text{H}_2\text{O}_2 + \text{Mn}^{2+} + 2\text{H}_2\text{O} + 2\text{H}^+ \rightarrow \text{MnO}_2 + 4\text{H}^+ + 2\text{H}_2\text{O}$ <i>Examples</i> • More negative <i>E</i> moves to left ORA • Reduction half equation to the right ORA • Most positive <i>E</i> is reduced ORA • Calculated <i>E</i> cell = +0.81 V (<i>from top 2</i>) OR +0.27 V (<i>from bottom 2</i>) ALLOW combining of equations above to show that MnO₂ is used and reformed Examiner's Comment: Many candidates found this part challenging and there was a wide variety of answers and marks awarded. There were two equations to construct showing how MnO₂, and Mn²⁺ react with H₂O₂. Many combined the two equations involving H₂O₂ to obtain the overall equation for the decomposition of H₂O₂ which was given at the top of the paper. Of the equations seen, many had species uncanceled. Many candidates only tackled one of the equations. Candidates were expected to provide evidence for their equations based on the electrode potentials provided. Use of this data was patchy and only the best candidates linked the relative <i>E</i> values to the direction of movement or redox details.

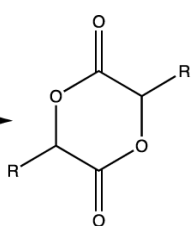
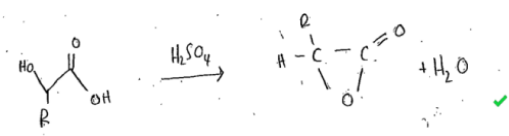
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
					A significant number gave cell potentials. Regeneration of MnO_2 was well understood but often just stated with no reference to the equations. This part discriminated very well.
			Total	4	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
35		i	<i>Equation</i> $2\text{HOCH(R)COOH} + \text{Mg} \rightarrow (\text{HOCH(R)COO})_2\text{Mg} + \text{H}_2$ Organic product ✓ Balance ✓ <i>Type of reaction</i> Redox ✓	3	ALLOW correct structural OR skeletal OR displayed formula OR mixture of the above as long as non- ambiguous ALLOW $2\text{HOCH(R)COOH} + \text{Mg} \rightarrow 2\text{HOCH(R)COO}^- + \text{Mg}^{2+} + \text{H}_2$ ALLOW multiples IGNORE poor connectivity to OH groups <i>Given in question</i> Examiner's Comment: Candidates found this part difficult and the problem presented many opportunities for errors. Many candidates tried to show charges for the salt formed but often the 2+ charge was missing on Mg^{2+} or Mg^+ was shown. The balanced equation required a balancing 2 before compound A but this was often omitted. Candidates using skeletal formulae fared better than attempts to show structural formulae such as HOCHRCOOH, with many omitting the H atom from CHR. Few candidates identified the reaction as redox, with many giving neutralisation instead.

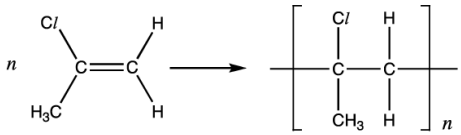
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		ii	Equation $2\text{HOCH(R)COOH} \longrightarrow \text{Cyclic dimer} + 2\text{H}_2\text{O}$  Organic product ✓ Balance ✓ Type of reaction Condensation OR esterification ✓	3	ALLOW correct structural OR skeletal OR displayed formula OR mixture of the above as long as non-ambiguous ALLOW 1 mark of the 2 equation marks for formation of '3 ring' with balanced equation:  ALLOW condensation polymerisation ALLOW addition-elimination IGNORE elimination IGNORE dehydration Examiner's Comment: As with 4(b)(ii), candidates found this question difficult. It was not often that the dimer was seen but, when it was, the structure was usually correct. Balancing required 2H₂O and the balancing 2 was often omitted. In contrast with 4(b)(i), many more candidates identified the type of reaction, here condensation or esterification.
			Total	6	

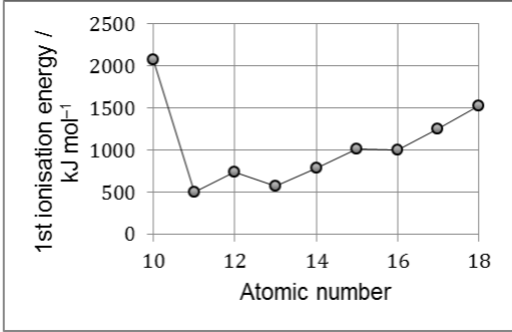
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
36		i	$(1s^2) 2s^2 2p^6$ ✓	1	IGNORE $1s^2$ seen twice ALLOW upper case letters AND subscripts Examiner's Comments Many incorrect answers but I am happy to report that the use of incorrect notation, mentioned in last year's report, was not an issue in the 2017 paper.
		ii	<i>Products of reaction</i> A = Barium hydroxide / $Ba(OH)_2$ ✓ B = Ammonia / NH_3 ✓ <i>Formula for barium nitride</i> Ba_3N_2 ✓ <i>Balanced equation AND state symbols</i> $Ba_3N_2(s) + 6H_2O(l) \rightarrow 3Ba(OH)_2(aq) + 2NH_3(g)$ ✓ State symbols are required	4	ANNOTATE ANSWER WITH TICKS AND CROSSES ETC ALLOW one mark for correct products incorrectly labelled Formulae must be correct No ECF from any incorrect formula ALLOW multiples Correct equation with state symbols scores 4 marks Examiner's Comment: This question discriminated well and only the most able candidates were able to score full marks with a correctly balanced equation including state symbols. Weaker candidates were able to pick up some marks for identifying barium hydroxide or ammonia, although barium oxide and nitrogen were not uncommon. Some failed to score the more accessible marks because they used an incorrect formula instead of writing the name of the product.
			Total	5	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
37		i	 Correct repeat unit (<i>n</i> and brackets not required) ✓ Equation balanced with <i>n</i> ✓ TAKE CARE of '<i>n</i>' position on both sides of equation.	2	For monomer, ALLOW correct molecular OR structural OR displayed OR skeletal formula OR mixture of the above (as long as unambiguous) For repeat unit, DO NOT ALLOW molecular formula NOTE: 'side bonds' ARE required on either side of repeat unit from C atoms ALLOW section of polymer containing more than one repeat unit NO ECF from incorrect repeat unit Examiner's Comments The majority of candidates correctly drew the repeat unit but only a few wrote a full equation, balanced with <i>n</i>. The most common error was omission of the '<i>n</i>' before the monomer. Candidates are reminded of the importance of balancing equations.
		ii	Formation of HCl/hydrochloric acid/ OR chlorine ✓	1	ALLOW Cl or Cl₂ for chlorine IGNORE toxic waste products <i>Response must reflect chlorine in some way</i> Examiner's Comments Most candidates realised that the combustion would produce toxic/harmful gases, but the majority either incorrectly identified the problem gas as CO₂/CO or did not identify the gas at all. Others referred to ozone damage and global warming. Good responses referred to the formation of chlorine compounds such as hydrogen chloride.
			Total	3	

Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
38	i  Ne (Z = 10) shown higher than 1500 (i.e. > Ar) ✓	1	Look carefully for small dots on the y axis IGNORE no straight line from Ne (10) to Na (11) Examiner's Comments This part was poorly attempted with only the most able candidates adding a point on the graph above 1500.
	ii $\frac{500}{6.02 \times 10^{23}} = 8.3 \times 10^{-22} \text{ (kJ) } \checkmark$ Answer MUST be to 2 SF AND in standard form.	1	ALLOW use of IEs close to 500 giving a range: $8.0 \times 10^{-22} - 8.6 \times 10^{-22}$ i.e. $8.3 \pm 0.3 \times 10^{-22}$ Examiner's Comments Very few candidates realised the need to use the Avogadro constant, with most candidates responded with 500, or 5.00×10^{-2} in standard form, the energy for one mole. Many candidates did not seem to know the meaning of standard form and there was some confusion between significant figures and decimal places, all basic mathematical concepts and requirements for Chemistry AS. Answer: $= 8.3 \times 10^{-22} \text{ kJ}$

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		iii	<i>Nuclear charge</i> number of protons/proton number increases OR greater nuclear charge ✓ <i>Distance/shielding</i> (Outer) electrons are in the same shell OR (Outer) electrons experience the same/similar shielding OR Atomic radius decreases ✓ <i>Attraction</i> Greater nuclear attraction (on outer electrons) OR (out) electrons are attracted more strongly (to the nucleus) ✓	3	FULL ANNOTATIONS WITH TICKS, CROSSES, CON, etc MUST BE USED Comparison should be used for each mark IGNORE atomic number increases IGNORE nucleus gets bigger IGNORE 'effective nuclear charge increases' IGNORE same sub-shell OR same orbital IGNORE 'there is shielding' ALLOW 'greater repulsion from inner shells' ALLOW 'pull' for 'attraction' IGNORE just 'greater attraction' OR greater force IGNORE 'held' for attracted, <i>e.g. IGNORE 'held' more strongly</i> Examiner's Comments This part was answered well, with many stock answers seen in terms of atomic size, nuclear charge and attraction. Weaker candidates often produced long responses that lacked focus, which often obtained fewer marks than short concise answers.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		iv	Sub-shells Mg electron is removed from (3)s AND Al electron is removed from (3)p ✓ Energy levels Al electron has a higher energy OR (3)p has higher energy than (3)s ✓	2	IGNORE number before s and p <i>e.g. ALLOW (2)s and (2)p</i> ALLOW response implying that orbitals/sub-shell changes from s to p IGNORE comments about distance from nucleus IGNORE 'less energy to remove' DO NOT ALLOW unpaired electron removed more easily (ORA) Examiner's Comments Few candidates answered this part well. Candidates were expected to realise that Mg loses an electron from an s orbital, whereas Al loses an electron from a higher energy p orbital. There were few clear answers and many candidates were distracted by paired and unpaired electrons or distance from the nucleus. Few candidates responded in terms of the difference in energy between the s and p orbitals.
			Total	7	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
39		i	$2 \text{ Al(s)} + 6 \text{ CH}_3\text{COOH(aq)} \rightarrow 2 \text{ (CH}_3\text{COO)}_3\text{Al(aq)} + 3 \text{ H}_2\text{(g)}$ ✓	1	ALLOW multiples, e.g. $\text{Al(s)} + 3 \text{ CH}_3\text{COOH(aq)} \rightarrow \text{(CH}_3\text{COO)}_3\text{Al(aq)} + 1\frac{1}{2} \text{ H}_2\text{(g)}$ Examiner's Comments The majority of candidates were able to balance this equation using whole numbers or half multiples. Where there was an error, it was invariably for the balancing number of H₂.
		ii	Element oxidised: aluminium/Al 0 to +3 ✓ Element reduced: hydrogen/H +1 to 0 ✓	2	ALLOW 3+ for +3 and 1+ for +1 ALLOW H₂ for hydrogen ALLOW 1 mark for elements AND all oxidation numbers correct, but H in oxidised line and Al in reduced line '+' is required in +3 and +1 oxidation numbers IGNORE numbers around equation (<i>treat as rough working</i>) Examiner's Comments This question was not answered as well as expected. It was pleasing to see that almost all candidates recognised the importance of writing oxidation numbers correctly including a '+' or '-' sign where needed. Common mistakes included giving the total contribution from an element as opposed to the oxidation state of each atom of the element.
			Total	3	

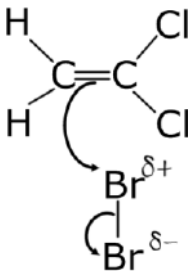
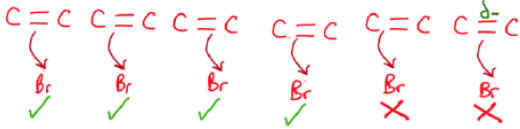
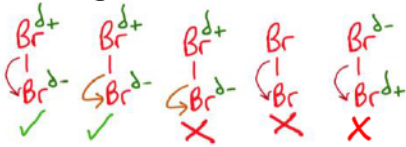
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
40		i	$(1s^2) 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 4p^4$ ✓ Look carefully at $(1s^2) 2s^2 2p^6 3s^2 3p^6$ – there may be a mistake	1	ALLOW subscripts ALLOW in any order i.e. $3d^{10}$ after $4s^2$ or after $4p^4$ ALLOW upper case D, etc and subscripts, e.g. 3S₂3P⁶ DO NOT ALLOW [Ar] as shorthand for $1s^2 2s^2 2p^6 3s^2 3p^6$ <u>Examiner's Comments</u> Most candidates answered this correctly. The most common error seen was $4p^6$ instead of $4p^4$
		ii	Gas B H_2Se / Hydrogen selenide / Selenium hydride ✓ Equation $Na_2Se + 2HCl \rightarrow 2NaCl + H_2Se$ All formulae and balancing ✓	2	ALLOW SeH_2 ALLOW correct multiples IGNORE STATE SYMBOLS DO NOT ALLOW H_2S for gas B BUT ALLOW ECF from H_2S for equation: $Na_2S + 2HCl \rightarrow 2NaCl + H_2S$ <u>Examiner's Comments</u> The majority of candidates obtained 1 or 2 marks on this question. The most common errors seen were identifying the gas as H_2S or incorrect balancing.
			Total	3	

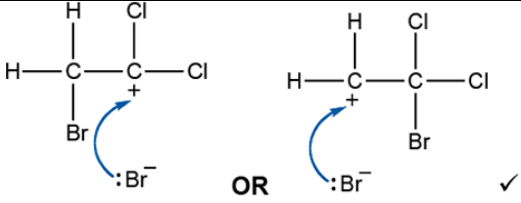
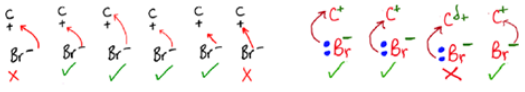
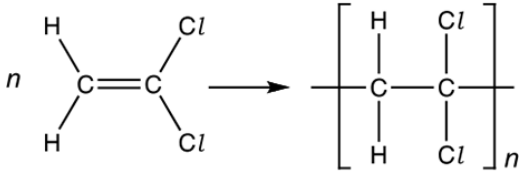
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
41		i	$\text{Br}_2(\text{l}) \rightarrow \text{Br}_2(\text{g})$ ✓	1	<u>Examiner's Comments</u> A good attempt by many candidates but some lost marks by having the wrong state of bromine, even though the question stated it was a liquid changing to a gas. Many added water or oxygen, some confused the equation with bond enthalpy and answers such as $\text{Br}_{2(\text{l})} \rightarrow 2\text{Br}_{(\text{g})}$ were commonly seen.
		ii	Endothermic AND Energy required to overcome induced dipole–dipole forces/London forces ✓	1	Mark independently of 3 (d) (i) ALLOW endo to break intermolecular forces/bonds ALLOW bonds between molecules DO NOT ALLOW van der Waals' forces <u>Examiner's Comments</u> The majority of candidates answered this question incorrectly. Only 10% of candidates mentioned intermolecular/London forces. Most stated 'exothermic' or described breaking covalent bonds.
			Total	2	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
42	a		steam AND Acid/H ⁺ (catalyst) ✓	1	Examiner's Comments Many candidates knew the answer to this question but forgot that water must be in the gaseous state. There were numerous responses stating nickel as the catalyst, but most knew that an acid catalyst was required.
	b	i	1,2-dibromo-1,1-dichloroethane✓	1	Examiner's Comments This question was generally well answered, although some candidates made careless mistakes such as not writing -di or writing 1,2-dibromo-1-dichloroethane
		ii	 1st curly arrow (from ANY alkene) Curly arrow from double bond to Br of Br-Br ✓ DO NOT ALLOW partial charge on C=C 2nd curly arrow Correct dipole on Br Br AND curly arrow for breaking of Br-Br bond ✓ 3rd curly arrow Correct carbocation with + charge on C with 3 bonds AND curly arrow from Br⁻ to C⁺ of carbocation ✓ DO NOT ALLOW δ^+ on C of carbocation	3	ANNOTATE ANSWER WITH TICKS AND CROSSES ETC For curly arrows, ALLOW straight or snake-like arrows and small gaps (see examples): 1st curly arrow must • go to a Br atom of Br-Br • AND • start from, OR be traced back to any point across width of C=C  2nd curly arrow must • start from, OR be traced back to, any part of $\delta^+ \text{Br} - \delta^- \text{Br}$ bond • AND go to δ^-  3rd curly arrow must • go to the C⁺ of carbocation • AND • start from, OR be traced back to any point across width of lone pair on :Br⁻

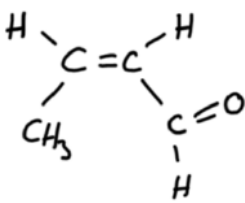
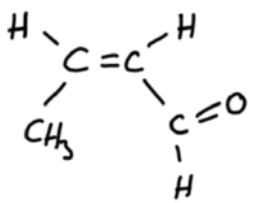
Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
	 <i>i.e. ALLOW carbonium + on either C atom</i> DO NOT ALLOW half headed or double headed arrows but allow ECF if seen more than once		OR start from – charge on Br[–] ion  (Lone pair NOT needed if curly arrow shown from – charge on Br[–]) <u>Examiner's Comments</u> Many candidates gained all three marks on this question and the diagrams were clear and easy to read. Lower ability candidates had incorrect dipoles or curly arrows that could not be traced back to the correct origin. Candidates should be encouraged to consider what the arrows mean rather than memorising mechanisms with no understanding.
c i	 Correct polymer with side links and brackets ✓ Equation balanced with <i>n</i> ✓ TAKE CARE of '<i>n</i>' position on both sides of equation.	2	For repeat unit, - displayed formula required 'side bonds' required on either side of repeat unit from C atoms ALLOW section containing more than one repeat unit DO NOT ALLOW ECF from incorrect repeat unit <i>n</i> on LHS at any height to the left of the formula <i>n</i> on RHS must be subscript <u>Examiner's Comments</u> Most candidates correctly drew the repeat unit and were credited with one mark, but many placed the <i>n</i> position in the wrong place on the left-hand side of the equation or forgot to write it in at all.

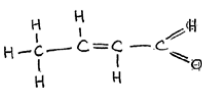
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		ii	Advantage (1 mark) Energy production / (energy) used to produce electricity ✓ Disadvantage (1 mark) Formation of HCl/products of combustion cause acid rain OR Formation of CO₂/gases that cause global warming / greenhouse gases OR Formation of CO ✓	2	ALLOW reduced use of fossil fuels ALLOW less landfill / less harm to wildlife ALLOW chlorine/Cl OR Cl₂ ALLOW toxic/poisonous waste products <u>Examiner's Comments</u> With all the media interest in plastic pollution this question was answered well, although many gave the answer 'quick and efficient' as an advantage which was not credited. Candidates should beware of vague statements such as these. Many wrote 'harmful' instead of toxic, or 'bad for the environment' instead of being specific about the environmental issue.
			Total	9	

Mark Scheme

Question		Answer/Indicative content	Marks	Guidance																				
43		<i>Please refer to the marking instructions on page 5 of the mark scheme for guidance on how to mark this question.</i> Level 3 (5-6 marks) A comprehensive description including most of the evidence to justify the correct structure of F (accept <i>cis</i> or <i>trans</i>). <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) The candidate attempts all three scientific points, but explanations are incomplete. OR Explains two scientific points thoroughly with few omissions. AND an attempt at a feasible structure based on deduction from correct molecular formula <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) The correct empirical formula AND a simple description based on at least one of the main scientific points. OR The candidate explains one scientific point thoroughly with few omissions. <i>There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.</i> 0 No response or no response worthy marks of credit.	6	LOOK AT THE SPECTRA for labelled peaks Indicative scientific points may include: <u>Empirical formula</u> - empirical formula = C₄H₆O <table><tr><th>element</th><th>% mass</th><th>Ar</th><th>moles</th><th>ratio</th></tr><tr><td>C</td><td>68.6</td><td>12</td><td>5.72</td><td>4</td></tr><tr><td>H</td><td>8.6</td><td>1</td><td>8.60</td><td>6</td></tr><tr><td>O</td><td>22.8</td><td>16</td><td>1.43</td><td>1</td></tr></table> <u>IR and spectra and molecular formula</u> - infrared absorption; 1630–1820 cm^{–1}, due to C=O (aldehyde/ketone/carbonyl group) - molar mass = 70 g mol^{–1} (mass spectrum molecular ion peak <i>m/z</i> = 70) - molecular formula = C₄H₆O <u>Functional groups, structure and stereochemistry</u> - alkene / C=C - aldehyde / –CHO (C₃H₅⁺ fragment) - mass spectrum; peak at 41 due to C₃H₅⁺ (loss of CHO) <i>E/Z</i> or <i>cis-trans</i> isomer: <i>E/Z</i> or <i>cis-trans</i> isomer:  <i>cis</i>  <i>trans (correct structure)</i> <u>Examiner's Comments</u> This question was a good discriminator. Most candidates were able to deduce the empirical formula and the C=O peak on the IR spectrum. However, many mistook the C-H peaks around 3000 cm^{–1} for an	element	% mass	Ar	moles	ratio	C	68.6	12	5.72	4	H	8.6	1	8.60	6	O	22.8	16	1.43	1
element	% mass	Ar	moles	ratio																				
C	68.6	12	5.72	4																				
H	8.6	1	8.60	6																				
O	22.8	16	1.43	1																				

Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
			alcohol O-H peak or assumed from the empirical formula that it was an alcohol so made the spectra 'fit' their hypothesis. At AS, the exposure of candidates to IR and MS spectra is not as comprehensive as in the second year of A Level and this was evident. There was very little annotation of the spectra and candidates should be encouraged to do this as it is helpful to them in their deductions (and to the examiners for crediting marks). Analysis of the IR spectrum was much more detailed than the mass spectrum. Most candidates just referred to the molecular ion peak and made no attempt, or an incorrect attempt, at discerning the peak at 41. Those that did quickly realised what the structure was and gained 5 or 6 marks. Some candidates, despite ascertaining that a <i>trans</i> stereoisomer should be drawn, drew the <i>cis</i> version instead. Exemplar 5 In the mass spectrum, the peak with the greatest relative intensity is caused by the loss of a functional group from the molecular ion of compound F. Determine the structure of compound F. Explain your reasoning and show your working. $C : H : O = 68.6 : 8.6 : 22.8$ $= 12 : 1 : 16$ $= 5.716 : 8.6 : 1.425$ $= 4.011 : 6.03 : 1$ Empirical formula of compound F is C_4H_6O. The M^+ peak on mass spectrum is at an m/z value of 70, so the molecular mass of compound F is 70 g mol^{-1}. So the molecular formula of compound F is C_4H_6O. The infrared spectrum shows an absorbance peak at in the range $1630-1820 \text{ cm}^{-1}$, indicating the presence of a $C=O$ bond. There is no absorbance peak in the range $2500-3300 \text{ cm}^{-1}$ so there is no O-H bond, so compound F is not a carboxylic acid. Compound F is not a carbonyl compound. The mass spectrum shows a fragmentation peak at 41 m/z, indicating the presence of a CH_2CHCH^+ fragment from the loss of 10 a CHO functional group. Compound F is an aldehyde. It is a <i>trans</i> stereoisomer, so the hydrogens attached to the carbons on the double bond are opposite each other. 
			This candidate has very logically worked through all the information provided and has come up with the correct structure from the deductions.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
					Exemplar 6 Explain your reasoning and show your working. $ \begin{array}{ccc} \text{C} & \text{H} & \text{O} \\ 68.6 & 8.6 & 22.8 \\ \hline 2 & 1 & 16 \end{array} $ $= 9.76 : 8.6 : 1.425$ $= 4.0 : 6.0 : 1$ empirical formula = $\text{C}_4\text{H}_6\text{O}$ $\text{Mr} : (12 \times 4) + (6 \times 1) + (16) = 70$ F.m.r. = 70 $\rightarrow$ molecular formula = $\text{C}_4\text{H}_6\text{O}$ Peak at $2.9^{\circ} \rightarrow \text{CH}_2=\text{CH}$ } mass spectrum. Peak at $4.1 \rightarrow \text{H}_2\text{C}=\text{CHCH}_2\text{S}$ IR Spectrum $\rightarrow$ Peak at $1630\text{--}1820$ indicates the presence of a $\text{C}=\text{O}$ group $\rightarrow$ Peak at $1620 \rightarrow 1630$ indicates the presence of a $\text{C}=\text{C}$ group. Structure = Like most candidates, the crucial information about F being a <i>trans</i> isomer was not picked up so they drew the double bond in the wrong place.
			Total	6	
44			C	1 (AO 1.2)	Examiner's Comments Nearly all candidates were able to determine the most likely formula.
			Total	1	
45			D	1 (AO 2.3)	Examiner's Comments Most candidates knew that the formula given in D was incorrect.
			Total	1	

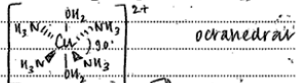
Mark Scheme

Question	Answer/Indicative content	Marks	Guidance																					
46	Please refer to the marking instructions on page 5 of this mark scheme for guidance on how to mark this question. Level 3 (5–6 marks) All three reactions are covered in detail with C, D, E and F identified with clear explanations. <i>There is a well-developed line of reasoning which is clear and logically structured with clear chemical communication and few omissions. The information presented is relevant and substantiated.</i> Level 2 (3–4 marks) All three reactions are covered but explanations may be incomplete OR Two reactions are explained in detail. <i>There is an attempt at a logical structure with a line of reasoning. The information is relevant e.g. formulae may contain missing brackets or numbers and supported by some evidence.</i> Level 1 (1–2 marks) Make two simple explanations from any one reaction. OR Makes one simple explanation from each of two reactions <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 worthy of credit.	6	Indicative scientific points may include: REACTION 1 (CuSO₄/NH₃) <i>Product</i> C : [Cu(NH₃)₄(H₂O)₂]²⁺ <i>Equation</i> [Cu(H₂O)₆]²⁺ + 4NH₃ → [Cu(NH₃)₄(H₂O)₂]²⁺ + 4H₂O <i>Structure of trans stereoisomer</i> Correct connectivity REACTION 2 (Cu₂O/H₂SO₄) <i>Products</i> D : CuSO₄ OR [Cu(H₂O)₆]²⁺ E: Cu <i>Equation</i> Cu₂O + H₂SO₄ → CuSO₄ + Cu + H₂O <i>Oxidation numbers</i> Cu(+1) → Cu(+2) + Cu(0) REACTION 3 (CuO/HNO₃) <i>Equation</i> CuO + 2HNO₃ → Cu(NO₃)₂ + H₂O <i>Molar ratios</i> <table><tr><td>Cu</td><td>:</td><td>H</td><td>:</td><td>N</td><td>:</td><td>O</td></tr><tr><td>26.29</td><td>:</td><td>2.49</td><td>:</td><td>11.59</td><td>:</td><td>59.63</td></tr><tr><td>63.5</td><td>:</td><td>1.0</td><td>:</td><td>14.0</td><td>:</td><td>16.0</td></tr></table> <i>Formula of F</i> CuH₆N₂O₉ F: Cu(NO₃)₂•3H₂O (OR Cu(NO₃)₂(H₂O)₃) Further guidance on use of wedges - Must contain 2 ‘out wedges’, 2 ‘in wedges’ and 2 lines in plane of paper OR 4 lines, 1 ‘out wedge’ and 1 ‘in wedge’: - For bond into paper, ALLOW: ALLOW following geometry:	Cu	:	H	:	N	:	O	26.29	:	2.49	:	11.59	:	59.63	63.5	:	1.0	:	14.0	:	16.0
Cu	:	H	:	N	:	O																		
26.29	:	2.49	:	11.59	:	59.63																		
63.5	:	1.0	:	14.0	:	16.0																		

Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
			<u>Examiner's Comments</u> Many candidates had a stab at identifying C–F but neglected to include equations for the three reactions described or to show relevant working. Most candidates recognised C as the ammoniacal copper(II) ion but the formula was frequently incorrect and correct attempts at a ligand substitution equation from $[\text{Cu}(\text{H}_2\text{O})_6]^{2+}$ was rarely seen. Diagrams showing the <i>trans</i> isomer were attempted but often of poor quality due to incorrect linking. Candidates recognised D as being CuSO_4 but often did not identify E as Cu due to a lack of familiarity with this common disproportionation reaction. $\text{Cu}(\text{OH})_2(\text{s})$ was a common incorrect identification of E. Only the best responses described the oxidation number changes which made this a disproportionation reaction. F was identified by a percentage by mass calculation to determine an empirical formula and then by deduction to produce $\text{Cu}(\text{NO}_3)_2 \cdot 3\text{H}_2\text{O}$. Having done this, many candidates did not give the relatively simple equation for reaction 3 between copper(II) oxide and dilute nitric acid.

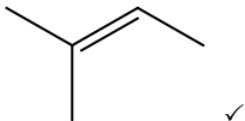
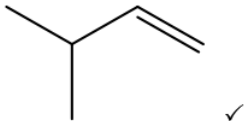
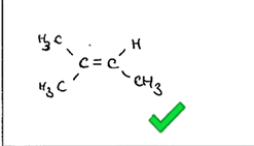
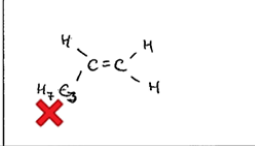
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance																				
					Exemplar 2 (d)* Three different reactions of copper compounds are described below. Reaction 1: Aqueous copper(II) sulfate reacts with excess aqueous ammonia in a ligand substitution reaction. A deep-blue solution is formed, containing an octahedral complex ion, G, which is a <i>trans</i> isomer. $\Rightarrow 100$ Reaction 2: Copper(I) oxide reacts with hot dilute sulfuric acid in a disproportionation reaction. A blue solution, D, and a brown solid, E are formed. Reaction 3: Copper(II) oxide reacts with warm dilute nitric acid in a neutralisation reaction, to form a blue solution. Unreacted copper(II) oxide is filtered off, and the solution is left overnight in an evaporating basin. A hydrated salt, F, crystallises, with the percentage composition by mass: Cu, 26.29%; H, 2.48%; N, 11.59%; O, 59.63%. Identify C-F by formulae or structures, as appropriate. Include equations, any changes in oxidation number, and working. [6] ① $[Cu(H_2O)_6]^{2+} + 4NH_3 \rightarrow [Cu(NH_3)_4(H_2O)_2]^{2+} + 4H_2O$  This is the <i>trans</i> isomer [C] because the H_2O ligands are 180° apart. ② $Cu_2O + H_2SO_4(aq) \rightarrow Cu_2O + CuSO_4(aq) + H_2O(l)$ brown solid blue solution [E] [D] [NOTE] ③ $CuO + 2HNO_3(aq) \rightarrow Cu(NO_3)_2(aq) + H_2O(l)$ <table><thead><tr><th></th><th>Cu</th><th>H</th><th>N</th><th>O</th></tr></thead><tbody><tr><td>mass</td><td>26.29</td><td>2.48</td><td>11.59</td><td>59.63</td></tr><tr><td>rfm</td><td>63.5</td><td>1</td><td>14</td><td>16</td></tr><tr><td>mol</td><td>0.414</td><td>2.48</td><td>0.828</td><td>3.73</td></tr></tbody></table> Additional answer space if required. $1 : 6 : 2 : 9$ $\Rightarrow CuH_6N_2O_9$ A hydrated salt is made up of an anhydrous salt with water of crystallisation. $Cu(NO_3)_2 \cdot 3H_2O$ [F] and molecular. $\Rightarrow$ This fits the empirical formula. NOTE: ② The oxidation number of Cu goes from +1 to 0 in Cu_2O, and from +1 to +2 in $CuSO_4(aq)$. Cu is reduced to form Cu and oxidised to form Cu^{2+} in $CuSO_4$. This exemplifies how considered structuring of candidate responses can enhance their clarity. The clear labelling of C-F in the response, along with numbering which corresponds to the reactions in the question stem, make the candidate's line of reasoning easy to follow. The underlining and annotations in the question stem show good practice in picking out and interpreting key information.		Cu	H	N	O	mass	26.29	2.48	11.59	59.63	rfm	63.5	1	14	16	mol	0.414	2.48	0.828	3.73
	Cu	H	N	O																					
mass	26.29	2.48	11.59	59.63																					
rfm	63.5	1	14	16																					
mol	0.414	2.48	0.828	3.73																					
			Total	6																					

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47	a	i	3-methylbutan-2-ol ✓	1	IGNORE lack of hyphens or addition of commas ALLOW 3-methylbutane-2-ol DO NOT ALLOW 2-methylbutan-3-ol OR 3-methylbut-2-ol OR 3-methbutan-2-ol OR 3-methybutan-2-ol OR 3-methlybutan-2-ol <u>Examiner's Comments</u> The majority of candidates were able to correctly name alcohol A as 3-methylbutan-2-ol. A significant number of responses used incorrect numbering and suggested 2-methylbutan-3-ol as the name.
		ii	(CH ₃) ₂ CHCHOHCH ₃ ✓	1	ALLOW brackets around OH e.g. (CH₃)₂CHCH(OH)CH₃ ALLOW any unambiguous structural formula e.g. CH₃CH(CH₃)CHOHCH₃ CH₃CH(CH₃)CH(CH₃)OH <u>Examiner's Comments</u> Most candidates were able to show a correct structural formula of alcohol A.

Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
iii	One mark for each correct structure.  	2	ALLOW any combination of skeletal OR structural OR displayed formula as long as unambiguous ALLOW in either order <u>Examiner's Comments</u> Many candidates correctly identified the two alkenes formed as 2-methylbut-2-ene and 3-methylbut-1-ene. Stronger responses used skeletal formula to show the structures clearly. Some candidates preferred to use chemical symbols to represent the atoms present and although this approach is valid, lower ability responses did not show sufficient detail as demonstrated in Exemplar 1. Exemplar 1   In this response the alkene 2-methylbut-2-ene has been correctly identified and one mark credited. However, the attempt to show 3-methylbut-1-ene does not score. This is because C_3H_7 has been used instead of $CH(CH_3)_2$. Candidates should be encouraged to show every carbon atom when drawing a structure as the use of ambiguous formulae is not sufficient to gain credit.

Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
iv	$\text{2-methylbutan-2-ol} + \text{NaCl} + \text{H}_2\text{SO}_4 \rightarrow \text{2-chloro-2-methylbutane} + \text{NaHSO}_4 + \text{H}_2\text{O}$ Correct haloalkane ✓ Correctly balanced equation ✓	2	ALLOW any combination of skeletal OR structural OR displayed formula as long as unambiguous ALLOW H^+ for H_2SO_4 ALLOW equations forming Na_2SO_4 $2 \text{ 2-methylbutan-2-ol} + 2\text{NaCl} + \text{H}_2\text{SO}_4 \rightarrow 2 \text{ 2-chloro-2-methylbutane} + \text{Na}_2\text{SO}_4 + 2\text{H}_2\text{O}$ ALLOW equations with HCl $\text{2-methylbutan-2-ol} + \text{HCl} \rightarrow \text{2-chloro-2-methylbutane} + \text{H}_2\text{O}$ DO NOT ALLOW equations that form NaOH <u>Examiner's Comments</u> This question proved difficult for candidates. Although many candidates were able to identify the correct organic product, only the higher ability candidates were able to construct an appropriate balanced equation. A common error was to omit the role of the acid; this is shown in Exemplar 2 below. Lower ability candidates appeared not to recognise this reaction and suggested an alkoxide salt, rather than a haloalkane as the organic product. Exemplar 2 $\text{2-methylbutan-2-ol} + \text{NaCl} \rightarrow \text{2-chloro-2-methylbutane} + \text{NaOH}$ This type of response was seen frequently by examiners. The candidate has drawn the correct structure of the haloalkane formed and scores the first mark. However, the response fails to recognise that the reaction occurs under acidic conditions and omits the sulfuric acid from the equation.

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	b		$ \begin{array}{c} \text{CH}_3 \quad \text{H} \quad \text{H} \\ \quad \quad \\ \text{H}_3\text{C}-\text{C}-\text{C}-\text{C}-\text{OH} \\ \quad \quad \\ \text{OH} \quad \text{OH} \quad \text{H} \end{array} + 3 [\text{O}] \rightarrow \begin{array}{c} \text{CH}_3 \\ \\ \text{H}_3\text{C}-\text{C}-\text{C}-\text{C}=\text{O} \\ \quad \quad \\ \text{OH} \quad \text{O} \quad \text{OH} \end{array} + 2\text{H}_2\text{O} $ Correct organic product ✓ Rest of equation ✓	2	ALLOW any combination of skeletal OR structural OR displayed formula as long as unambiguous ALLOW any vertical bond to the tertiary OH group e.g. ALLOW $ \begin{array}{c} \text{CH}_3 \\ \\ \text{H}_3\text{C}-\text{C}- \\ \\ \text{OH} \end{array} \quad \text{OR} \quad \begin{array}{c} \text{CH}_3 \\ \\ \text{H}_3\text{C}-\text{C}- \\ \\ \text{OH} \end{array} $ <u>Examiner's Comments</u> This question required candidates to apply their knowledge of the oxidation of alcohols to complete the equation for the complete oxidation of compound B. This question discriminated well. Many candidates correctly identified the organic product but only the higher ability candidates could complete the equation. A common error was to omit water as a product of the reaction.
			Total	8	

Mark Scheme

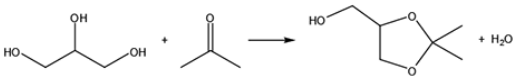
Question			Answer/Indicative content	Marks	Guidance
48	a		$\text{C}_7\text{H}_{16} + 7\frac{1}{2}\text{O}_2 \rightarrow 7\text{CO} + 8\text{H}_2\text{O}$ OR $\text{C}_7\text{H}_{16} + 4\text{O}_2 \rightarrow 7\text{C} + 8\text{H}_2\text{O} \checkmark$	1	ALLOW multiples IGNORE state symbols ALLOW equations for incomplete combustion that give CO and/or C with CO_2 e.g $\text{C}_7\text{H}_{16} + 9\text{O}_2 \rightarrow 4\text{CO} + 3\text{CO}_2 + 8\text{H}_2\text{O}$ $\text{C}_7\text{H}_{16} + 6\text{O}_2 \rightarrow 4\text{CO} + 3\text{C} + 8\text{H}_2\text{O}$ <u>Examiner's Comments</u> The majority of candidates were able to provide a correct equation for the incomplete combustion of heptane.
	b	i	$n(\text{CO}_2) = 2.97/44 = 0.0675 \text{ (mol)} \checkmark$ $n(\text{H}_2\text{O}) = 1.62/18 = 0.0900 \text{ (mol)} \checkmark$ Ratio of C : H 3 : 8 $\checkmark$ Molecular formula $\text{C}_3\text{H}_8\text{O}_2 \checkmark$ Structure any correct structure of $\text{C}_3\text{H}_8\text{O}_2 \checkmark$ e.g. $\begin{array}{ccccc} & \text{H} & & \text{H} & & \text{H} \\ & & & & & \\ \text{HO} & - \text{C} & - & \text{C} & - & \text{C} & - \text{OH} \\ & & & & & \\ & \text{H} & & \text{H} & & \text{H} \end{array}$ OR $\begin{array}{ccccc} & \text{H} & & \text{H} & & \text{H} \\ & & & & & \\ \text{H} & - \text{C} & - \text{O} & - \text{C} & - \text{O} & - \text{C} & - \text{H} \\ & & & & & \\ & \text{H} & & \text{H} & & \text{H} \end{array}$ etc	5	Consult your team leader if an alternative creditworthy approach is seen IGNORE ratio of CO_2 to H_2O is 3:4 ALLOW this mark from the correct molecular formula OR a correct structure if not shown in working DO NOT ALLOW an incorrect molecular formula Mark independently from molecular formula but structure MUST contain 3C, 8H and 2O ALLOW any combination of skeletal OR structural OR displayed formula as long as unambiguous ALLOW any vertical bond to the OH group e.g. ALLOW $\begin{array}{c} \\ \text{OH} \end{array}$ OR $\begin{array}{c} \\ \text{HO} \end{array}$ DO NOT ALLOW OH-

Mark Scheme

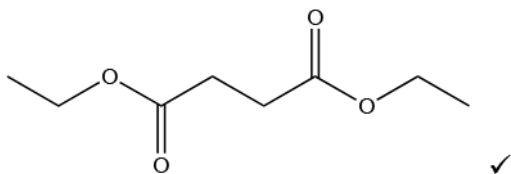
Question	Answer/Indicative content	Marks	Guidance
			Examiner's Comments The majority of candidates approached this problem by initially calculating the number of moles of CO₂ and H₂O produced. Many candidates were able to process these amounts to deduce the molecular formula for N, as shown in Exemplar 11. Alternate approaches were seen, but with much less frequency. Exemplar 11 $2.57g \div (12 + 32) = 0.0675 \text{ mol CO}_2$ $1.62g \div (2 + 16) = 0.09 \text{ mol H}_2\text{O}$ $1.7g \div (76) = 0.0225 \text{ mol N}$ $0.0675 \div 0.0225 = 3$ $0.09 \div 0.0225 = 4$ $N + xO_2 \rightarrow 3CO_2 + 4H_2O$ $\downarrow \quad \downarrow$ $3C \quad 8H$ $3(12) + 8 = 44 \quad 76 - 44 = 32$ $N = C_3H_8O_2$ $\frac{32}{16} = 2 O$ $\begin{array}{c} H & H & H \\ & & \\ HO-C & -C & -C-OH \\ & & \\ H & \text{A} & H \end{array}$ compound N

[5]

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Question			Answer/Indicative content	Marks	Guidance
					This response is logically presented with clear working demonstrating the candidate's approach. In the first part the candidate determines the amount, in moles, of carbon dioxide and water produced. This response uses the number of moles of N to deduce the molar ratio of CO₂ to H₂O. Other candidates obtained this by dividing the moles of carbon dioxide by the moles of water. The candidate uses a balanced equation to deduce the molar ratio of C to H in N; this is an excellent strategy that is worth highlighting to future candidates. The working on the right hand side shows how the amount of O in compound N is determined. It is a shame that the structure suggested has one H atom missing, as this omission has prevented full marks from being credited. Candidates are encouraged to check structures carefully to ensure that all atoms are drawn with the correct number of bonds.
		ii	 Carbonyl compound identified as propanone ✓ Rest of equation ✓	2	ALLOW any combination of skeletal OR structural OR displayed formula as long as unambiguous <u>Examiner's Comments</u> Many candidates found this demanding question very difficult. Some were able to deduce that propanone was the carbonyl compound in the reaction. Only the most able recognised that water was a by-product of this reaction.
			Total	8	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
49		i	Titration ✓	1	IGNORE type of titration <u>Examiner's Comments</u> Candidates found this part difficult and only higher ability candidates identified that a titration could easily determine the concentration of succinic acid. The answers seen covered most of the techniques encountered in the course. Candidates should consider the information provided in a practical context to arrive at an informed response rather than what sometimes seemed to be a guess.
		ii	$(\text{CH}_2\text{COOH})_2 + 2\text{C}_2\text{H}_5\text{OH} \rightleftharpoons (\text{CH}_2\text{COOC}_2\text{H}_5)_2 + 2\text{H}_2\text{O} \checkmark$	1	ALLOW → instead of $\rightleftharpoons$ sign ALLOW molecular formulae or hybrid formulae <i>Structures provided on QP</i> e.g. $\text{C}_4\text{H}_6\text{O}_4 + 2\text{C}_2\text{H}_6\text{O} \rightleftharpoons \text{C}_8\text{H}_{14}\text{O}_4 + 2\text{H}_2\text{O}$ <u>Examiner's Comments</u> Candidates were required to derive the equation from which the supplied K_c expression had been written. Overall, this part was answered well but some candidates struggled with the brackets or used CH_2COOH_2 for succinic acid.
		iii		1	IGNORE displayed formulae <u>Examiner's Comments</u> This part discriminated extremely well with many candidates finding it difficult to convert the bracketed structural formula into a skeletal formula. Common errors were drawing of the mono-ester or omitting a carbon atom in the centre of the structure. Even when incorrect, most attempted answers were skeletal formulae.

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Question			Answer/Indicative content	Marks	Guidance
		iv	Volume cancels OR Same number of moles on each side of equation ✓	1	ALLOW units cancel ALLOW (sum of) balancing numbers/coefficients on each side of equation are the same OR same number of (moles of) reactants and products IGNORE volume is the same; K_c has no units <u>Examiner's Comments</u> Many candidates did not seem to realise that the supplied equation used moles, not concentrations. Those who did often stated that the mole representation could be used because the volume was the same for all. Of those who went on to state that the volume would cancel, only a few explained why that was true in this particular case. This challenging part discriminated very well. The best responses showed the units as n/V in the expression and showed that the volumes cancel.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		v	Moles of equilibrium products 1 mark $n(\text{CH}_2\text{COOC}_2\text{H}_5)_2 = 0.0300 \text{ (mol)}$ AND $n(\text{H}_2\text{O}) = 0.0600 \text{ (mol) } \checkmark$ Moles of $\text{C}_2\text{H}_5\text{OH}$ 1 mark $n(\text{C}_2\text{H}_5\text{OH}) = 0.150 - 0.060 = 0.0900 \text{ (mol) } \checkmark$ K_c calculated 1 mark $= \frac{0.03 \times 0.06^2}{0.02 \times 0.09^2} = 0.667 \text{ OR } 0.67 \checkmark$ NOTE: 0.02 must be used for $n(\text{succinic acid})$	3	ALLOW ECF ALLOW 0.66, 0.666, etc. (2 SF and more) <i>Treated as meaning 0.6 recurring</i> ALLOW 2/3 IGNORE any units <u>Examiner's Comments</u> Overall, this part discriminated well with many candidates obtaining the correct answer of 0.67. Common errors included a one significant figure answer of 0.6 or 0.7 and 0.375, by using 0.12 mol instead of 0.09 mol for the moles of ethanol. Many successful answers were well-presented and included a table of initial and final values. This gave a systematic way of deriving the equilibrium moles.
			Total	7	
50			C	1	<u>Examiner's Comments</u> Nearly all candidates responded with the correct response of C.
			Total	1	

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Question	Answer/Indicative content	Marks	Guidance
51	FIRST CHECK ANSWER ON THE ANSWER LINE IF answer = 315 (cm³) award 4 marks Amount of PH₃ $n(\text{PH}_3) = \frac{3.20 \times 10^{-2}}{4}$ OR $8(.00) \times 10^{-3} \text{ (mol) } \checkmark$ Unit conversions $p \text{ conversion} \rightarrow \text{Pa} = 100 \times 10^3 \text{ (Pa)}$ AND $T \text{ conversion} \rightarrow \text{K} = 473 \text{ (K) } \checkmark$ Evidence of use of rearranged gas equation OR $V = \frac{nRT}{p}$ OR $V = \frac{8(.00) \times 10^{-3} \times 8.314 \times 473}{100 \times 10^3}$ OR $V = 3.15 \times 10^{-4} \checkmark$ <i>Calculator:</i> $= 3.1460176 \times 10^{-4}$ V conversion of m³ → cm³ ✓ $V = 3.15 \times 10^{-4} \times 10^6 = 315 \text{ cm}^3 \checkmark$ <i>Calculator from unrounded cm³:</i> 314.60176 cm³ Requires 3 OR MORE SF, correctly rounded ALLOW use of R = 8.31 → 314.4504 → 314 to 3SF	4	If there is an alternative answer, check to see if there is any ECF credit possible ALLOW ECF throughout Common Errors (3 marks) <i>Use of $n(\text{H}_3\text{PO}_4) = 3.20 \times 10^{-2}$ (Very common)</i> $V = \frac{3.2(0) \times 10^{-2} \times 8.314 \times 473}{100 \times 10^3} \times 10^6$ $= 1258.40704 \text{ cm}^3 \text{ (1260 to 3 SF)}$ No temperature conversion from °C to K $V = \frac{8(.00) \times 10^{-3} \times 8.314 \times 200}{100 \times 10^3} \times 10^6$ $= 133 \text{ cm}^3$ No p conversion from kPa to Pa $V = \frac{8(.00) \times 10^{-3} \times 8.314 \times 473}{100} \times 10^6$ $= 315000 \text{ cm}^3$ No volume conversion from m³ to cm³ $V = 3.15 \times 10^{-4}$ IGNORE use of 24/24000 for molar volume e.g. $3.2(0) \times 10^{-3} \times 24000 = 768$ scores zero $8(.00) \times 10^{-3} \times 24000 = 292$ scores 1st mark only Examiner's Comments Almost all candidates realised that the calculation required the ideal gas equation. Most candidates correctly rearranged the equation and used the data from the question to obtain a value for the volume of phosphine. The most common errors were with conversion of units into Pa and m³. It is recommended that candidates learn how to carry out these conversions. In their calculations, many candidates used the amount of phosphoric acid, 3.20×10^{-3} mol, rather than 8.00×10^{-3} mol of

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Question			Answer/Indicative content	Marks	Guidance
					phosphine, obtaining a volume of 1258 cm³. Error carried forward ensured that 3 of the available 4 marks could be credited, provided that the working was clear. The exemplar shows such a response. Answer = 315 cm³ Exemplar 3 (b) Phosphine, PH₃, is a gas formed by heating phosphorous acid, H₃PO₃, in the absence of air. $4\text{H}_3\text{PO}_3(\text{s}) \rightarrow \text{PH}_3(\text{g}) + 3\text{H}_3\text{PO}_4(\text{s})$ (i) 3.20 × 10⁻² mol of H₃PO₃ is completely decomposed by this reaction. Calculate the volume of phosphine gas formed, in cm³, at 100 kPa pressure and 200 °C. <i>Handwritten working:</i> $P V = n R T$ 100 kPa 100 dm³ 3.20 × 10⁻² mol 8.314 J K⁻¹ mol⁻¹ 200 + 273 = 473 K $100 \times V = (3.2 \times 10^{-2}) \times 8.314 \times 473$ $100 \times V = 125.840704$ $V = 1.25840704$ $= 1.26 \text{ dm}^3 \times 1000$ $= 1258.41 \text{ cm}^3$ volume of PH₃ = 1258.41 cm³ [4]
		ii	4PH ₃ + 8O ₂ → P ₄ O ₁₀ + 6H ₂ O ✓	1	ALLOW multiples Examiner's Comments Most candidates were able to write a correctly balanced equation for this reaction.
			Total	5	

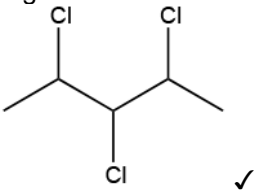
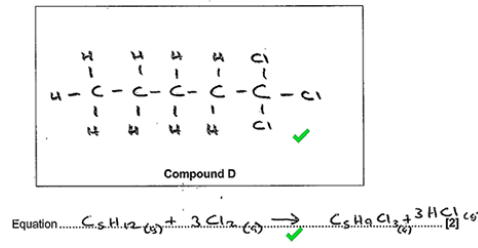
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
52	a		Structural isomers: 1 mark Different structural formulae AND same molecular formula ✓ Common molecular formula: 1 mark C_5H_{12} for all 3 hydrocarbons ✓ Boiling point and branching: 1 mark Boiling point decreases with more branching OR more methyl/alkyl groups/side chains OR shorter carbon chain ✓ Branching and London forces: 1 mark <i>Could be seen anywhere within response</i> More branching gives less (surface) contact AND fewer/weaker London forces ✓ Energy and intermolecular forces: 1 mark Less energy to break London forces/intermolecular forces/intermolecular bonds/ ✓	5	For 'structural': ALLOW different structure OR different displayed/ skeletal formula DO NOT ALLOW any reference to spatial/space/3D Same formula is not sufficient (no 'molecular') Different arrangement of atoms is not sufficient (no 'structure'/'structural') ALLOW 5 carbons and 12 hydrogens ALLOW for 2 marks: Different structural formulae AND same molecular formula ✓ of C_5H_{12} ✓ Comparisons needed throughout ORA throughout ALLOW comparison between any alcohols, e.g. A is least branched and has highest b pt C is most branched and has lowest b pt ALLOW induced dipole(–dipole) interactions IGNORE van der Waals'/vdw forces ALLOW SA for surface area ALLOW 'harder to overcome' intermolecular forces ALLOW more energy to separate the molecules IGNORE just 'bonds' <i>intermolecular/London forces required</i> Examiner's Comments This question discriminated well and resulted in a full range of marks. Most candidates were aware that structural isomers have different structural formulae

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Question			Answer/Indicative content	Marks	Guidance				
					but the same molecular formulae. It was common though for candidates to refer to different arrangements of atoms in space, clearly confusing with stereoisomerism. The best candidates used the structures (as in the question) to show that the common molecular formula was C5H12. Candidates were expected to link the amount of surface contact between molecules with induced dipole–dipole forces or London forces. ‘Contact’ or the name of the intermolecular forces was often omitted. Finally, candidates were expected to link the amount of branching to the strength of the intermolecular forces and the energy needed to change state. Lower ability candidates often let themselves down by being unable to construct a well-reasoned response. There was often a gulf between the clear responses of able candidates and those of lower ability candidates.				
	b	i	Radical substitution ✓	1	ALLOW Free radical substitution <u>Examiner’s Comments</u> Most candidates identified this reaction as radical substitution.				
		ii	<table><tr><td>A</td><td>B</td></tr><tr><td>3 ✓</td><td>2 ✓</td></tr></table>	A	B	3 ✓	2 ✓	2	<u>Examiner’s Comments</u> Most candidates achieved at least one mark, particularly for isomer A. Successful candidates often drew structures of the isomers alongside the table to help with their response.
A	B								
3 ✓	2 ✓								

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Question	Answer/Indicative content	Marks	Guidance
iii	Structure of D Structure of a trichloro isomer of A, e.g.  ALLOW any trichloro isomer of A CHECK carefully Equation $C_5H_{12} + 3Cl_2 \rightarrow C_5H_9Cl_3 + 3HCl$ ✓ Molecular formulae required NO ECF from incorrect structure of D	2	ALLOW correct structural OR displayed OR skeletal formula OR mixture of the above (as long as unambiguous) IGNORE molecular formula ALLOW multiples, e.g. $2C_5H_{12} + 6Cl_2 \rightarrow 2C_5H_9Cl_3 + 6HCl$ Examiner's Comments Many candidates correctly drew the structure of compound D but comparatively few were able to construct a correct equation. For this equation, candidates needed to apply their knowledge and understanding of monosubstitution of alkanes to substitution of three H atoms by three Cl atoms. This task proved to be one of the most difficult questions on this paper. The exemplar shows an excellent response. The candidate has drawn a trisubstituted structure that fits the molar mass of 175.5 g mol^{-1} and a correct equation for its formation. Many attempts at this equation showed H_2 as the second product rather than HCl. Exemplar 6 (iii) The reaction of compound A with excess chlorine forms a compound D, which has a molar mass of 175.5 g mol^{-1}. Draw a possible structure for compound D and write the equation for its formation from compound A. Use molecular formulae in the equation. 

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Question			Answer/Indicative content	Marks	Guidance
			Total	10	
53		i	$\text{Al}_2\text{Se}_3 + 6\text{H}_2\text{O} \rightarrow 2\text{Al}(\text{OH})_3 + 3\text{H}_2\text{Se}$	1 (AO2.6×1)	Examiner's Comments This was dependent on candidates' ability to give correct formula of aluminium hydroxide, $\text{Al}(\text{OH})_3$. Writing correct formulae is an important skill in chemistry, which should be practised regularly in different topics to help candidates master the skill.
		ii	H_2O has hydrogen/H-bonds (between molecules) ✓ H_2Se has induced dipole(-dipole) interactions OR London forces ✓ H-bonds are stronger (than other intermolecular forces) OR more energy needed to overcome H-bonds ✓	3 (AO1.1×2) (AO2.1×1)	ALLOW permanent dipole-dipole interactions Examiner's Comments Most candidates were able to recognise that water had the higher boiling point due to hydrogen bonding. However, it was evident in a number of responses that they were unclear that this is an example of an intermolecular force and doesn't just refer to the covalent bond formed between O and H. Most avoided discussing the intermolecular forces present in H_2Se even although both London forces and permanent dipole-dipole interactions were accepted as they may not have come across this specific example and had not been given electronegativity data.
			Total	4	
54			C	1 (AO1.2)	Examiner's Comments Candidates are expected to know the charges on silver and carbonate ions. However, a number of candidates responded with A: AgCO_3 , rather than C: Ag_2CO_3 .
			Total	1	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
55			C	1 (AO1.2)	ALLOW 4 <u>Examiner's Comments</u> Candidates found this question difficult, with the nitric acid N atoms being split between two products, $\text{Cu}(\text{NO}_3)_2$ and NO_2. B proved to be the biggest distractor from the correct response of C, probably the result of miscounting the N atoms.
			Total	1	
56			D	1 (AO 1.2)	ALLOW 1 in the answer box
			Total	1	
57			B	1 (AO 2.8)	<u>Examiner's Comments</u> This was a challenging question, the correct answer being B. Candidates had to know the correct formula for sodium carbonate in order to deduce the 2:1 molar ratio of HCl to Na_2CO_3 and to calculate its Mr (106). Option D was arrived at by assuming the molar ratio was 1:1, option A by incorrectly thinking the formula was NaCO_3, and option C by making both of these mistakes.
			Total	1	

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58		i	$(1s^2)2s^22p^63s^23p^63d^{10}4s^24p^5$ ✓ Look carefully at $1s^22s^22p^63s^23p^6$ – there may be a mistake	1 (AO1.2)	ALLOW 3d after $4s^2$, e.g. $1s^22s^22p^63s^23p^64s^23d^{10}4p^5$ ALLOW upper case D, etc and subscripts, e.g. 4S ₂ D ₁ DO NOT ALLOW [Ar] as shorthand for $1s^22s^22p^63s^23p^6$ IGNORE $1s_2$ repeated <u>Examiner's Comments</u> Candidates answered this part well, showing good knowledge and understanding of electron configuration. When incorrect, it was usually errors with the number of electrons in the 3d and 4p subshells.
		ii	$P_4 + 6Br_2 \rightarrow 4PBr_3$ ✓	2 (AO2.4)	ALLOW multiples <u>Examiner's Comments</u> Most candidates were able to construct a correct balanced equation for this unfamiliar equation. The commonest error was use of Br instead of Br ₂ in the equation.
			Total	2	

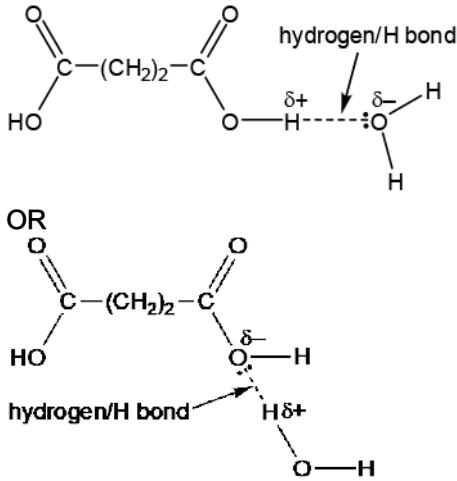
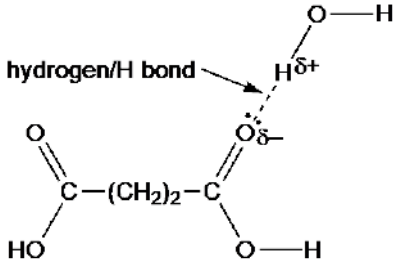
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Question	Answer/Indicative content	Marks	Guidance
59	Interpretation of Results Orange contains bromine AND no reaction AND violet contains iodine ✓ Ionic equation $\text{Br}_2 + 2\text{I}^- \rightarrow 2\text{Br}^- + \text{I}_2$ ✓ Reactivity (down the group) Reactivity decreases AND oxidising power decreases OR gains electrons less easily OR forms negative ion/1- ion less easily OR less energy released when electron gained ✓ OR more negative electron affinity Size/shells/shielding (down the group) Greater atomic radius OR more shells OR more shielding ✓ Attraction (down the group) Less nuclear attraction down the group ✓	5 (AO 2.3×1) (AO 2.6×1) (AO 1.1×3)	Results can be interpreted anywhere in answer. ALLOW multiples, e.g. $\frac{1}{2}\text{Br}_2 + \text{I}^- \rightarrow \text{Br}^- + \frac{1}{2}\text{I}_2$ IGNORE other halogen/halide equations IGNORE state symbols ALLOW ORA DO NOT ALLOW idea of losing electrons/ionisation energy IGNORE chlorine is the most electronegative IGNORE explanations in terms of displacement <u>Examiner's Comments</u> This question required the candidate to explain the reactivity of the halogens given experimental observations. Higher-attaining candidates were able to explain the observations with ionic equations and explain the reactivity in terms of gaining electrons. Some candidates did not associate the colour with the halogen and linked it with the halide ion, but then did explain the trend in reactivity due to the ability to gain electrons. Lower-attaining candidates explained the reaction in terms of displacement (which was ignored) and they did not proceed with ionic equations or describe the ability to gain electrons. Misconception Some candidates linked the ability to gain electrons to ionisation energy rather than electron affinity. The colour of the organic layer was also associated with the halide ion rather than the halogen.

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					 OCR support Further guidance can be found in the AS Level delivery guide 'Theme: Patterns' (Group 2 and Group 17): https://www.ocr.org.uk/Images/231740-patterns.pdf
			Total	5	
60			$3\text{C}_3\text{H}_6\text{O} \rightarrow \text{C}_9\text{H}_{12} + 3\text{H}_2\text{O}$ molecular formulae of $\text{C}_3\text{H}_6\text{O}$ AND C_9H_{12} ✓ H_2O as by-product ✓ correct balanced equation ✓	3 (AO2.6) (AO2.5) (AO2.6)	
			Total	2	

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Question			Answer/Indicative content	Marks	Guidance
61		i	Reagents $\text{K}_2\text{Cr}_2\text{O}_7$ AND acid AND reflux ✓ Equation $\text{HO}(\text{CH}_2)_4\text{OH} + 4[\text{O}] \rightarrow$ $\text{HOOC}(\text{CH}_2)_2\text{COOH} + 2\text{H}_2\text{O}$ [O] AND H_2O ✓ Correctly balanced equation ✓	3 (AO1.1) (AO2.5) (AO2.6)	ALLOW $\text{Na}_2\text{Cr}_2\text{O}_7$ OR $\text{Cr}_2\text{O}_7^{2-}$ ALLOW H_2SO_4 OR HCl OR H^+ ALLOW words. e.g. 'acidified dichromate' ALLOW a small slip in formula for dichromate e.g. KCr_2O_7, <u>Examiner's Comments</u> Many candidates did not correctly balance this equation or missed water as a product entirely.
		ii	 Diagram showing correct dipole charges on each end of one hydrogen bond between a water molecule and a diacid ✓ Hydrogen bond between one lone pair on O atom in one of the molecules and the H atom of another AND Hydrogen bonding stated or labelled on diagram	2 (AO2.1×2)	ALLOW any combination of skeletal OR structural OR displayed formula as long as unambiguous DO NOT ALLOW δ^+ on H atoms of CH_2 group ALLOW H-bond for hydrogen bond ALLOW H bond between $\text{C}=\text{O}$ and H_2O, i.e.  IF diagram is not labelled, ALLOW hydrogen bond/H bond from text <u>Examiner's Comments</u> Candidates who answered this question well had clear, labelled diagrams. Too often, labels, dipoles and lone pairs were missing.
Total				5	

Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
62	Organic product and water marked independently. <i>1st mark</i> correct organic product OR water IGNORE balancing numbers <i>2nd mark</i> BOTH products AND correctly balanced.	2 (AO 3.2)	ALLOW any combination of skeletal OR structural OR displayed formula as long as unambiguous ALLOW NOTE: For ECF, any structure must have correct number of bonds to C, H, O and N DO NOT ALLOW structure of dimer <i>Question states molecular formula = C₃H₃NO</i> <u>Examiner's Comments</u> Candidates were supplied with information about an unfamiliar reaction of an amino acid and asked to predict a possible equation. Many candidates suggested H₂O as one product, being the difference in the formula of the amino acid and the C₃H₃NO cyclic organic product. Any cyclic structure of C₃H₃NO that met the bonding rules for C, H, N and O was credited. Examples included a 4-membered ring lactam and substituted cyclopropenes. A significant number of candidates showed an equation for the reaction of two molecules of the amino acid to form 2 H₂O and a cyclic dipeptide. Although chemically feasible, the dipeptide could not be credited because the molecular formula was C₃H₃NO in the question. This error could have been avoided if the information in the question had been used.
	Total	2	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
63			Route 1 <i>Reactant:</i> Add water (to Ba) OR H₂O in equation ✓ <i>Balanced equation:</i> $\text{Ba} + 2\text{H}_2\text{O} \rightarrow \text{Ba}(\text{OH})_2 + \text{H}_2$ ✓ Route 2 <i>Balanced equation with O₂</i> $2\text{Ba} + \text{O}_2 \rightarrow 2\text{BaO}$ ✓ <i>Balanced equation with H₂O</i> $\text{BaO} + \text{H}_2\text{O} \rightarrow \text{Ba}(\text{OH})_2$ ✓	4 (AO3.3) (AO2.6) (AO3.3) (AO3.3)	ALLOW multiples in equations Balanced equation automatically collects 2 marks for Route 1 ALLOW 1 mark for BOTH reactants in route 2: i.e. React with O₂ AND then with H₂O NOTE 3 correct balanced equations → 4 marks <u>Examiner's Comments</u> Many candidates were able to calculate the amount of HNO₃ in the titration as 4.28×10^{-3} mol. Most candidates were credited for the amount of Ba(OH)₂ as 2.14×10^{-3} mol, half the calculated amount of HNO₃. Candidates then need to scale up this value by 1000/25 to obtain the concentration as $0.0856 \text{ mol dm}^{-3}$. All intermediate calculations gave values to 3 significant figures. Discrimination was extremely good, but about a third of candidates did not receive any marks. Candidates should be encouraged to practise stock titration calculations as part of their preparation for the examinations. Candidates should show clear working so that credit can be given for such responses by applying error carried forward. Many candidates produced largely unreferenced numbers.
			Total	4	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
64		i	Overall equation AND state symbols: $M(s) + 2HCl(aq) \rightarrow MCl_2(aq) + H_2(g)$ ✓ STATE SYMBOLS required in overall equation ONLY Half equations: Oxidation $M \rightarrow M^{2+} + 2e^-$ ✓ Reduction $2H^+ + 2e^- \rightarrow H_2$ OR $H^+ + e^- \rightarrow \frac{1}{2}H_2$ ✓	3 (AO 2.6×3)	All 3 marks are independent. IGNORE charges/oxidation numbers shown around overall equation. <i>Treat as rough working</i> ALLOW overall equation shown with some or all ions that are present e.g. (with state symbols) $M + 2H^+ \rightarrow M^{2+} + H_2$ $M + 2HCl \rightarrow M^{2+} + 2Cl^- + H_2$ $M + 2H^+ + 2Cl^- \rightarrow M^{2+} + 2Cl^- + H_2$ In half equations, IGNORE state symbols even is wrong BUT half equations MUST only have species that change. For charges on half equations, ALLOW M^{+2} for M^{2+} OR H^{+1} for H^+ ALLOW $M - 2e^- \rightarrow M^{2+}$ If BOTH half equations are correct but shown with oxidation and reduction the wrong way around, award 1 mark from the 2 marks for half equations Examiner's Comments This question required candidates to write an overall equation and half equations for oxidation and reduction. Many candidates made errors within one or more equations. The overall equation was often written without state symbols, despite the question instruction 'with state symbols'. The oxidation half equation was more likely to be correct than the reduction half equation, which often used Cl instead of H^+. When H^+ was used, the half equation was often unbalanced or electrons had been omitted. It is recommended that candidates carefully use the chemical information in the question.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		ii	Bubbles/effervescence/fizzing stops ✓ M/metal/solid has disappeared/dissolved ✓	2 (AO 3.3×2)	Responses must imply that all fizzing has stopped and that all the solid has dissolved i.e. 'metal disappears' is not quite enough. 'All the metal disappears' is enough IGNORE constant mass IGNORE no increase in temperature <u>Examiner's Comments</u> Most candidates identified that all the metal would have reacted when it had all disappeared and that gas bubbles from the reaction would have stopped. Some responses did not emphasise that these observations would have stopped and this prevented credit being given.
		iii	$\text{H}^+ + \text{OH}^- \rightarrow \text{H}_2\text{O}$ ✓	1 (AO 2.5)	ALLOW multiples e.g. $2\text{H}^+ + 2\text{OH}^- \rightarrow 2\text{H}_2\text{O}$ IGNORE state symbols, even if wrong <u>Examiner's Comments</u> The ionic equation for neutralisation of an acid with an alkali was well known and this question was answered correctly by most candidates.

Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
iv	Mean titre 1 mark $= \frac{(27.30 + 27.20)}{2} = 27.25 \text{ (cm}^3\text{)} \checkmark$ Analysis of results 5 marks $n(\text{NaOH}) = 27.25 \times \frac{0.320}{1000} = 8.72 \times 10^{-3} \text{ (mol)} \checkmark$ $n(\text{HCl}) \text{ in } 25.0 \text{ cm}^3 = n(\text{NaOH})$ $n(\text{HCl}) \text{ in } 250 \text{ cm}^3$ $= 8.72 \times 10^{-3} \times 10 = 8.72 \times 10^{-2} \text{ (mol)} \checkmark$ $n(\text{HCl}) \text{ that reacted with M}$ $= 0.210 - 8.72 \times 10^{-2} = 0.1228 \text{ (mol)} \checkmark$ $n(\text{M}) \text{ that reacted} = \frac{0.1228}{2} = 0.0614 \text{ (mol)} \checkmark$ $A_r \text{ of M} = \frac{6.90}{0.0614} = 112.4 \text{ AND M} = \text{cadmium/Cd} \checkmark$ COMMON ERRORS: Mean of 27.35 (use of all 3 titres) $\rightarrow 8.752 \times 10^{-3} \rightarrow 8.752 \times 10^{-2} \rightarrow 0.12248$ $\rightarrow 0.06124 \rightarrow 112.7 \text{ AND Cd: } 5 \text{ marks}$ No $\div 2$ to obtain $n(\text{M})$ $\rightarrow 56.2 \text{ AND Fe (from 27.25)} \quad 5 \text{ marks}$ $\rightarrow 56.3 \text{ AND Fe (from 27.35)} \quad 4 \text{ marks}$ No subtraction from 0.210 $A_r \text{ of M} = \frac{6.90}{0.0614} = 112.4 \text{ AND M} = \text{cadmium/Cd} \checkmark$ $\rightarrow 158.2 \text{ to } 158.3 \text{ AND Tb} \quad 5 \text{ marks}$ No $\times 10$ to obtain $n(\text{HCl})$ in 250 cm^3 5 marks $0.210 - 8.72 \times 10^{-3} = 0.20128 \text{ OR } 0.201$ $n(\text{M}) = 0.20128/2 = 0.10064$ $A_r = 6.90/0.10064 = 68.56 \rightarrow \text{Zn}$ No $\times 10$ and no $\div 2$ 4 marks $0.210 - 8.72 \times 10^{-3} = 0.20128$ $A_r = 6.9/0.20128 = 34.28 \rightarrow \text{Ca}$ Omitting initial titration calculation Zero marks $0.210/2 = 0.105 \rightarrow 6.9/0.105 = 65.71 \rightarrow \text{Zn}$	6 (AO 2.8×5) (AO 3.2)	FULL ANNOTATIONS MUST BE USED Common error: Incorrect mean from all 3 titres = 27.35 cm^3 Use ECF throughout Intermediate values for working to at least 3 SF. TAKE CARE: Value written down may be truncated calculator value. Depending on rounding, either can be credited. ALLOW 0.123 (mol) i.e. 3SF ALLOW 0.0615 (mol) IF 0.1228 rounded to 0.123 ALLOW 112.2 from 0.0615 AND Cd ALLOW A_r to nearest whole number ALLOW ECF for metal closest to calculated A_r DO NOT ALLOW Ga OR Sc (Form 3+ ions only) Examiner's Comments Candidates were presented with information about a back titration, a technique that they would be unlikely to have encountered during their course. The question stem to (iv) suggested a three-step strategy. Many candidates followed this guidance and were credited with many of the available marks. Marks were given for a correct method (by error carried forward) even if there was an error or omission in the multi-step calculation. This emphasises the importance of clear working. Most candidates determined the correct mean titre of 27.25 cm^3. A few candidates

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
					did take the mean of all three titres rather than the closest. Most calculated that 8.72×10^{-3} mol of NaOH reacted with the same number of moles of HCl in the titration and then scaled up the HCl by a factor of 10 to 8.72×10^{-2} mol in the 250 cm³ volumetric flask. These steps are standard for many titration calculations and gave a route to three of the six available marks. The more difficult back titration steps then followed and the higher-attaining candidates recognised the need to subtract this amount of HCl from the original amount of HCl used to react with metal M. These candidates then divide this value by two to find the moles of M that reacted (from the 1 : 2 stoichiometry of M : HCl). The correct calculation then gave a relative atomic mass of M as 112 and its identity as cadmium. It was common for candidates to omit the division by two and to arrive at a relative atomic mass of 56 for iron. The mark scheme shows the variety of metals that candidates identified from their calculations, the errors made, and the error carried forward marks that resulted. Many lower-attaining candidates did not follow the 3 steps in the stem, using only the original amount of HCl and ignoring the titration. This approach was not credited with marks. A large range of marks was seen, and the question discriminated extremely well.
			Total	12	

Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
65	<i>Refer to marking instructions on page 5 of mark scheme for guidance on marking this question.</i> Level 3 (5–6 marks) All three tests are covered in detail, with at least six of B to H identified correctly and equations mostly correct. <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) All three tests are covered with at least four of B to H identified correctly. Some attempt at writing equations, but with several omissions or incorrect formulae. <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) Only two tests covered with at least two of B to H identified correctly, and little attempt at writing equations. <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>	6 (AO 3.3×3) (AO 3.4×3)	Indicative scientific points may include: Identification of unknowns Can be identified within labelled equation. B is FeSO_4 OR Iron(II) sulfate • Test 1: Fe^{2+} present • Test 2: SO_4^{2-} present D is $\text{Fe}(\text{OH})_2$ OR $[\text{Fe}(\text{H}_2\text{O})_4(\text{OH})_2]$ OR iron(II) hydroxide G is BaSO_4 OR barium sulfate C is CrCl_3 OR chromium(III) chloride • Test 1: Cr^{3+} present • Test 3: Cl^- present E is $\text{Cr}(\text{OH})_3$ OR $[\text{Cr}(\text{H}_2\text{O})_3(\text{OH})_3]$ OR chromium(III) hydroxide F is $[\text{Cr}(\text{NH}_3)_6]^{3+}$ H is silver chloride OR AgCl Equations D: $[\text{Fe}(\text{H}_2\text{O})_6]^{2+} + 2\text{OH}^- \rightarrow \text{Fe}(\text{OH})_2 + 6\text{H}_2\text{O}$ OR $\text{Fe}^{2+} + 2\text{OH}^- \rightarrow \text{Fe}(\text{OH})_2$ OR $[\text{Fe}(\text{H}_2\text{O})_6]^{2+} + 2\text{OH}^- \rightarrow [\text{Fe}(\text{H}_2\text{O})_4(\text{OH})_2] + 2\text{H}_2\text{O}$ OR $[\text{Fe}(\text{H}_2\text{O})_6]^{2+} + 2\text{NH}_3 \rightarrow [\text{Fe}(\text{H}_2\text{O})_4(\text{OH})_2] + 2\text{NH}_4^+$ OR $[\text{Fe}(\text{H}_2\text{O})_6]^{2+} + 2\text{NH}_3 \rightarrow \text{Fe}(\text{OH})_2 + 4\text{H}_2\text{O} + 2\text{NH}_4^+$ E: $[\text{Cr}(\text{H}_2\text{O})_6]^{3+} + 3\text{OH}^- \rightarrow \text{Cr}(\text{OH})_3 + 6\text{H}_2\text{O}$ OR $\text{Cr}^{3+} + 3\text{OH}^- \rightarrow \text{Cr}(\text{OH})_3$ OR $[\text{Cr}(\text{H}_2\text{O})_6]^{3+} + 3\text{OH}^- \rightarrow [\text{Cr}(\text{H}_2\text{O})_3(\text{OH})_3] + 3\text{H}_2\text{O}$ OR $[\text{Cr}(\text{H}_2\text{O})_6]^{3+} + 3\text{NH}_3 \rightarrow [\text{Cr}(\text{H}_2\text{O})_3(\text{OH})_3] + 3\text{NH}_4^+$ OR $[\text{Cr}(\text{H}_2\text{O})_6]^{3+} + 3\text{NH}_3 \rightarrow \text{Cr}(\text{OH})_3 + 3\text{H}_2\text{O} + 3\text{NH}_4^+$ F: $[\text{Cr}(\text{H}_2\text{O})_6]^{3+} + 6\text{NH}_3 \rightarrow [\text{Cr}(\text{NH}_3)_6]^{3+} + 6\text{H}_2\text{O}$ OR $\text{Cr}(\text{OH})_3 + 6\text{NH}_3 \rightarrow [\text{Cr}(\text{NH}_3)_6]^{3+} + 3\text{OH}^-$ OR $[\text{Cr}(\text{H}_2\text{O})_3(\text{OH})_3] + 6\text{NH}_3 \rightarrow [\text{Cr}(\text{NH}_3)_6]^{3+} + 3\text{H}_2\text{O} + 3\text{OH}^-$

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
					G: $\text{Ba}^{2+} + \text{SO}_4^{2-} \rightarrow \text{BaSO}_4$ H: $\text{Ag}^+ + \text{Cl}^- \rightarrow \text{AgCl}$
			Total	6	
66		i	$\text{-----}\overset{\text{O}}{\parallel}\text{C}-(\text{CH}_2)_2-\overset{\text{O}}{\parallel}\text{C}-\text{O}-(\text{CH}_2)_4-\text{O}\text{-----}$ Ester link (must be displayed) ✓ Rest of structure ✓	2 (AO1.2) (AO2.5)	ALLOW the 'O' or C=O at either end, e.g. $\text{---O---}\overset{\text{O}}{\parallel}\text{C}-(\text{CH}_2)_2-\overset{\text{O}}{\parallel}\text{C}-\text{O}-(\text{CH}_2)_4\text{---}$ $\text{---}(\text{CH}_2)_2-\overset{\text{O}}{\parallel}\text{C}-\text{O}-(\text{CH}_2)_4-\text{O}-\overset{\text{O}}{\parallel}\text{C}\text{---}$ IGNORE brackets IGNORE n End bonds' MUST be shown (solid or dotted) DO NOT ALLOW more than one repeat unit
		ii	the ester/ ester bond/ ester group /polyester can be broken down ✓ OR It can be hydrolysed ✓	1 (AO3.2)	IGNORE references to photodegradable 'Bond breaks' is not sufficient – no reference to ester bond
		iii	$\begin{array}{c} \text{O} & & \text{O} \\ \parallel & & \parallel \\ \text{HO}-\text{C} & (\text{CH}_2)_2 & \text{C}-\text{OH} \end{array} + 2 \text{SOCl}_2 \longrightarrow \begin{array}{c} \text{O} & & \text{O} \\ \parallel & & \parallel \\ \text{Cl}-\text{C} & (\text{CH}_2)_2 & \text{C}-\text{Cl} \end{array} + 2 \text{SO}_2 + 2 \text{HCl}$ SOCl_2 in equation ✓ Structure of diacyl dichloride ✓ Complete balanced equation ✓	3 (AO1.1) (AO1.2) (AO2.6)	ALLOW alternative approach using PCl_5 or PCl_3
			Total	6	