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Examiners' report

AS LEVEL

CHEMISTRY A

OCR Level 3 Advanced Subsidiary GCE in Chemistry A

H032

For first teaching in 2015

H032/02 Summer 2025 series

Version 1

Contents

Introduction

Our examiners' reports are produced to offer constructive feedback on candidates' performance in the examinations. They provide useful guidance for future candidates.

The reports will include a general commentary on candidates' performance, identify technical aspects examined in the questions and highlight good performance and where performance could be improved. A selection of candidate responses is also provided. The reports will also explain aspects which caused difficulty and why the difficulties arose, whether through a lack of knowledge, poor examination technique, or any other identifiable and explainable reason.

Where overall performance on a question/question part was considered good, with no particular areas to highlight, these questions have not been included in the report.

A full copy of the question paper and the mark scheme can be downloaded from Teach Cambridge.

Paper 2 series overview

This paper is one of the two examination components for the AS Level examination for GCE Chemistry A.

This synoptic 'Depth in Chemistry' paper links together content from all 4 modules and is worth 70 marks. There are a range of question styles, including short response (structured questions, problem solving, calculations, practical) and extended response questions, including those marked using level of response mark schemes.

Candidates who did well on this paper generally:	Candidates who did less well on this paper generally:
• gave clear and concise responses – keeping within the space provided. This was especially evident in the LOR Questions 2 (a) (ii) and 5 (c) as well as Question 4(a) comparing boiling points. • demonstrated a good understanding of the fundamentals of chemistry studied in the course, making correct use of terminology in their responses, e.g. Question 4 (d) (ii) definition of homolytic fusion and Question 6 (a) (ii) M+1 peak. • performed longer calculations showing detailed working for each step and in a logical order, e.g. Question 1 (c) (i) Enthalpy of neutralisation and Question 3 (a) (iii) titration calculation. • made a good attempt at more tricky calculations not seen previously, e.g. Question 4 (b) (ii) mass of CO2 produced and Question 4 (b) (iv) estimating Enthalpy of combustion. • showed a clear understanding of practical work, e.g. Question 1 (c) (ii) impact of changing concentration/volume and Question 2 (b) (ii) reasons for lower gas volume.	• wrote overly long responses which often resulted in contradictions. • did not proofread their responses, checking for any errors in the wording or possible contradictions. • did not use the correct number of significant figures and were not able to convert units correctly, e.g. volumes from dm3 to cm3, masses from g to mg. • did not use the correct terminology in their response, e.g. not able to name 'separating funnel' or use term 'distillation' in Question 2 (a) (ii) and gave a confused explanation of homolytic fission in Question 4 (d) (ii). • did not answer the question asked, e.g. missing state symbols in Question 2 (a) (i), using structural formula rather than molecular/skeletal in Question 4 (c) and Question 4 (d) (i), not using different symbols for each element in dot-and-cross diagram in Question 5 (a) (i).

Question 1 (a)

1 A student is investigating the enthalpy change of neutralisation for a strong acid and a strong alkali.

(a) Explain what is meant by an **alkali**.

....

.... **[1]**

Most correctly related an alkali to the "release of OH^- ions". Responses which did not score a mark usually stated that the "pH is greater than 7" or an alkali is "a proton acceptor" or gave simple explanations such as a "soluble base" or "neutralises an acid".

Question 1 (b)

(b) Write the ionic equation for the neutralisation reaction between an acid and an alkali.

.... **[1]**

Most candidates were able to write the ionic equation. Common incorrect responses included giving the full equation, word equation or using the spectator ions i.e. Na+ + Cl^- → NaCl

Question 1 (c) (i)

(c) The student mixes $40.0\,cm^3$ of $1.40\,mol\,dm^{-3}$ HCl and $40.0\,cm^3$ of $1.40\,mol\,dm^{-3}$ NaOH.

The temperature rises by 9.40 °C

(i) Calculate the enthalpy change of neutralisation, in $kJ\,mol^{-1}$.

Give your answer to **3** significant figures.

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

Enthalpy change of neutralisation = ... $kJ\,mol^{-1}$ **[4]**

Many well-structured calculations were seen, even if all the marks weren't achieved. Almost all candidates calculated the number of moles involved.

For those candidates' hat didn't get full marks, it was often caused by using an incorrect mass in Q = mcΔT. Some tried to calculate the mass of NaOH and HCl (from moles and M_r values) while others didn't add the total volumes together i.e. used 40 g rather than 80 g.

Some used moles × 2 i.e. 0.112 rather than per mole of water formed.

One of the most common errors was the omission of the negative sign for the final enthalpy change. Some put a positive charge instead. Some lost a mark for the incorrect significant figures.

Question 1 (c) (ii)

(ii) The student repeats the experiment using the same volume and concentration of NaOH but using 20.0 cm^3 of 2.80 mol dm^{-3} HCl instead of 40.0 cm^3 of 1.40 mol dm^{-3} HCl.

The temperature rise is greater than 9.4 °C.

Explain why.

....

....

....

....

....

....

.... **[2]**

Many candidates found this question challenging.

Some managed to recognise the idea that the moles remained the same. Fewer recognised that the enthalpy change stayed the same while the mass/volume decreased. A minority combined both ideas together.

Many gave responses in terms of increasing concentration increases rate, attributing a higher temperature to more collisions.

Misconception

?

Candidates struggled to understand the difference between the rate of reaction and the enthalpy change, often indicating that more collisions would result in more energy being released. Make sure that candidates know that overall energy change depends on the net difference in bond energies between reactants and products per mole. While an increase in concentration can lead to a faster rate of reaction, it will not change the enthalpy change of the reaction.

We have some useful resources to support this:

Topic Exploration Pack: Kinetics and Catalysis

https://teachcambridge.org/item/9fbefaed-4ade-4f22-95ec-3defcfef5a46

Delivery guide (H032) Enthalpy changes

https://teachcambridge.org/item/6f16de69-f654-407c-b513-3ed7902ef9ce

Question 2 (a) (i)

2 This question is about reactions of some Group 2 elements and their compounds.

(a) The table below shows the first and second ionisation energies of magnesium and calcium.

Group 2 element	1st Ionisation energy / $kJ\,mol^{-1}$	2nd Ionisation energy / $kJ\,mol^{-1}$
Mg	738	1451
Ca	590	1145

(i) Write an equation to represent the **second** ionisation energy of calcium.

Include state symbols.

.... **[1]**

More than half of the candidates gave the correct equation. However, many lost the mark for missing or incorrect state symbols. In some responses it was hard to differentiate between (g) and (s) – candidates need to make sure their handwriting is clear so credit can be given. Some other errors that were seen included: losing 2 electrons, incorrect charges, gaining electrons or using Mg rather than Ca.

Question 2 (a) (ii)*

(ii)* Magnesium and calcium differ in their reactivity.

Give a balanced equation for the reaction of **calcium** with water and describe what would be observed. Explain why this is a redox reaction.

Explain the difference in reactivity of magnesium and calcium.

....

....

....

....

....

.... **[6]**

Many candidates scored highly on this level of response question, answering all three parts. Generally, candidates found it easier to explain the difference in reactivity between Mg and Ca than the other parts of the question. Some lacked clarity in their responses, describing a decreased "electrostatic attraction" without reference to the nucleus and/or outer electrons. Some muddled the order of reactivity describing the gain of electrons. A few candidates described a general trend down the group without linking to the position of Mg and Ca in the group.

A number of candidates had an incorrect equation forming CaO rather than hydroxide and occasional errors in the formula, e.g. CaOH or balancing of the equation were seen. Most gave at least one correct observation. Some candidates suggested that bubbles would be seen but did not have hydrogen produced in their equation.

Most candidates were able to recognise that redox meant that oxidation and reduction took place. However, some were not clear here, e.g. "it is redox as calcium is oxidised". Most understood that to explain why this was a redox reaction they needed to give oxidation number changes and/or number of electrons lost or gained. Some errors were seen in assigning oxidation numbers such as H in water, which was given as +2, rather than +1 for each atom. Lower-attaining candidates often suggested that oxygen was reduced.

Candidates should be aware that they do not need to fill the answer space provided. Often longer responses introduce contradictions in responses.

Exemplar 1

Explain the difference in reactivity of magnesium and calcium.

$Ca + 2H_2O \rightarrow Ca(OH)_2 + H_2$

observation: effervescence due to H_2 gas produced; this reaction is redox because calcium is oxidised ~~to~~ from an oxidation state of 0 to a state of +2; hydrogen is reduced from +1 to 0.

calcium is more reactive than magnesium (as shown by its' lower ionisation energies) because it has more electron shells. the electrons in Ca's outer shell receive more shielding from inner electron shells than in Mg, reducing the attractive force from the nucleus on electrons of Ca. thus, less energy is required to remove an electron from calcium's outer shell and so it is more reactive.

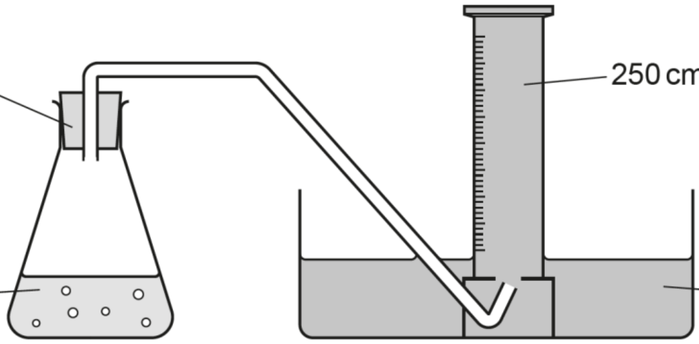
An excellent response which achieved Level 3 and gained all 6 marks.

Question 2 (b) (i)

(b) A student adds 1.51 g of barium carbonate, $BaCO_3$ (molar mass 197.3 g mol^{-1}), to an excess of dilute nitric acid. The equation is shown below.

$BaCO_3(s) + 2HNO_3(aq) \rightarrow Ba(NO_3)_2(aq) + H_2O(l) + CO_2(g)$

The student uses the following apparatus.



(i) Calculate the volume, in cm^3, of gas the student expects to be produced at room temperature and pressure (RTP).

Give your answer to **3** significant figures.

Volume of gas .... cm^3 **[2]**

Most were able to correctly calculate the number of moles with the molar mass given in the question. Many were then able to use the molar gas volume at RTP, given on the data sheet, to find the volume of gas. The most common errors seen here were an incorrect number of significant figures, not converting to cm^3 but leaving as dm^3, and some multiplied by 2. A few candidates attempted to use the ideal gas equation here and if this was done correctly marks were credited.

Question 2 (b) (ii)

(ii) The volume of gas collected is less than the calculated volume.

Suggest **two** reasons for this difference.

1 ....

....

2 ....

.... **[2]**

A very challenging question with most candidates failing to score any marks. Only a few correctly suggested the gas dissolving in water or the use of non-standard conditions. Most correct responses were for gas lost while replacing the stopper. Most mentioned loss of gas but didn't link to the procedure to say how it was lost.

Lots of candidates suggested that the reaction was incomplete despite being told the acid is in excess in the question. Candidates should consider that if a reagent is in excess, the reaction is expected to go to completion.

Many suggested faults with setting up apparatus – possibly from personal experience. We wanted them to consider the limitations should this be set up without 'human' errors. A lot of candidates discussed the various leaks in the apparatus as the sources of gas loss. Some made reference to gas present in the tubing already not understanding that it would push through and displace gas to fill the measuring cylinder, with equivalent amount being left in tubing at the end.

OCR support

We provide support to help students prepare for questions based on the practical work they have carried out. Each of our suggested practicals has extension questions which can be used to explore practical work in more detail and evaluate different procedures.

This question links well with PAG 1.1: https://teachcambridge.org/item/b9be7815-8c49-4fd6-b0eb-8f476393c653

Question 2 (b) (iii)

(iii) Suggest **one** way in which the student could modify the apparatus to produce a volume closer to the calculated volume.

....

.... **[1]**

Around half of the candidates gained a mark for this question. Many suggested the use of "gas syringe" but from their response in (i) it was clear that a significant number didn't understand how this would improve the experiment. Lower-attaining candidates sometimes couldn't give the correct name for a gas syringe suggesting "gas volume measurer" or "gas tube" instead.

Some other incorrect responses included:

- Improve resolution on measuring cylinder
- Use a larger mass of $BaCO_3$
- Leave reaction for longer
- Heat to a constant mass
- Make sure delivery tube is further in the measuring cylinder
- Make sure connections are airtight

Question 3 (a) (i)

3 Malic acid tablets are sold as a health supplement.

A student carries out a titration to determine the mass of malic acid, $C_4H_6O_5$, in **one** tablet.

The student follows the method below:

Step 1 Crush **three** tablets, transfer the powder into a beaker and dissolve in distilled water.

Step 2 Transfer the solution into a 250.0 cm^3 volumetric flask and make up to the mark with distilled water.

Step 3 Pipette 25.0 cm^3 of the solution from **Step 2** into a conical flask and add a few drops of indicator.

Step 4 Titrate this solution with 0.0800 mol dm^{-3} sodium hydroxide, NaOH, in the burette.

The equation for the neutralisation reaction is:

$C_4H_6O_5 + 2NaOH \rightarrow C_4H_4O_5Na_2 + 2H_2O$

(a) The student takes burette readings to the nearest 0.05 cm^3.

The student's readings are shown in the table.

The rough titre has been omitted.

(i) Complete the table below.

Titration	1	2	3
Final reading / cm^3	23.60	46.70	25.65
Initial reading / cm^3	0.30	23.65	2.50
Titre / cm^3	....	....	....

[1]

Very few lost this mark and when they did it was usually for the giving the first titre to only 1 decimal place. Occasionally arithmetic errors were seen.

Question 3 (a) (ii)

(ii) Calculate the mean titre of NaOH that the student should use to analyse the results.

Mean titre = ... cm^3 **[1]**

Most scored here. A minority used all three titres for the mean and even fewer used 23.30 in the calculation with either of the other two values.

Question 3 (a) (iii)

(iii) Calculate the mass, in mg, of malic acid in **one** tablet.

Assume that malic acid (molar mass 134.0 g mol^{-1}) is the only acid in the tablets.

Give your answer to **3** significant figures.

Mass of malic acid .... mg **[5]**

Many responses were well constructed and showed most of the stages. This made it much easier to award error carried forward (ECF) marks if a correct response was not obtained. Around a quarter of candidates were able to score all 5 marks. Almost all candidates scored the first 2 marks.

However, it was sometimes hard to follow the steps a candidate had taken to obtaining a final response, due to:

- Steps not being labelled
- Steps merging into one another (all equalling each other despite different processes)
- Competing alternative methods described without crossing through incorrect working.

Many candidates did not gain marks for unit conversions i.e. not converting volumes from cm^3 to dm^3 and incorrectly converting g to mg. Some did not gain marks for missing the × 10 step. Lower-attaining candidates often didn't use the titre value obtained in (ii) but used 25 cm^3 instead, muddling which volume value should be attributed to which reactant.

Maths Skills for AS Chemistry

It is important for candidates to have the opportunity to develop their maths skills as part of the course. Particular attention should be paid as to how to:

- Setting out the working for calculations
- Keeping the full value of any step in their calculator to use in the next step
- Common unit conversions, e.g. dm^3 to cm^3
- Giving the final answer to an appropriate number of significant figures or that asked for in the question
- Checking their working for any errors

Some support can be found in our Maths Skills Handbook:

https://www.ocr.org.uk/Images/295468-chemistry-mathematical-skills-handbook.pdf

This article from the RSC contains some useful resources:

https://edu.rsc.org/resources/maths-skills-for-chemistry/4013899.article

Question 3 (b)

(b) Another student carries out the same experiment.

Instead of rinsing the burette used in **Step 4** with 0.0800 mol dm^{-3} NaOH, the student rinses with water before filling it up with 0.0800 mol dm^{-3} NaOH.

State and explain how this error would affect the titre.

....

....

....

.... **[2]**

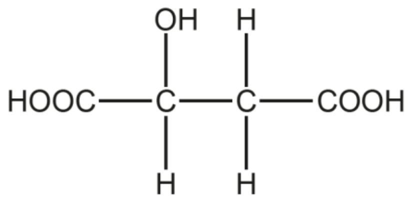
Around half of the candidates scored both marks, understanding the impact on the titre of rinsing the burette with water. It was essential for candidates to refer to the "titre" and not just the volume in their response.

Some understood that the NaOH would be more dilute but then suggested it would give a smaller titre or didn't give impact on the titre value at all. Some suggested that the water provided OH^- ions thus decreasing the amount of NaOH required to neutralise.

A few gave non-committal responses such as "Water would alter the concentration of NaOH, so you wouldn't get an accurate titre" so scored 0 marks.

Question 3 (c)

(c) The structure of malic acid is shown below.



When malic acid is heated with an acid catalyst, a mixture of *cis* and *trans* stereoisomers is produced.

Draw the structures of the *cis* and *trans* isomers.

cis	*trans*

[2]

Approximately half of the candidates did not score any marks for this question. Many left the OH group on the alkenes formed i.e. removed H_2 rather than H_2O. Some attempted to draw cis/trans isomers with structures with no C=C in them. Some drew any alkene, e.g. but-2-ene, to show cis/trans, but this was not given here. Common reasons for scoring 1 mark included the isomers being the wrong way round or poor connectivity to -COOH groups.

Question 4 (a)

4 The alkanes belong to a homologous series of hydrocarbons.

Table 4.1 shows information about some straight chain alkanes.

Table 4.1

Alkane	**Molecular formula**	**Boiling point /°C**	**Enthalpy change of combustion / kJ mol^{-1}**
Propane	C_3H_8	–42	–2219
Butane	C_4H_{10}	0	To estimate in part **(b)(iv)**
Pentane	C_5H_{12}	36	–3509
Hexane	C_6H_{14}	69	–4163

(a) State and explain the trend in boiling points of the straight chain alkanes in **Table 4.1.**

....

....

....

....

....

.... **[4]**

Many candidates were able to score all 4 marks. More successful responses were clear and concise, covering all the detail required in much less space that provided here (see exemplar).

Less successful responses often scored a mark for the correct trend but stated that this was due to more (covalent) bonds needing to be broken. Some were able to give well-rehearsed explanations for the difference in boiling point but lost the trend mark as state change by the position in the table only, e.g. "as you go down the table, the boiling point increases".

A few muddled different types of intermolecular forces, suggesting that H-bonds were present. There was evidence that some held the misconception that a C-H-bond constitutes a H-bond.

Explanations were sometimes missing the 'contact' between molecules or alternatively an increase in the number of electrons. Some did not gain marks as their responses were not comparative, e.g. "has surface contact so can form London forces" or" requires a lot of energy to break London forces". It was fairly common to see "more energy to break the bonds" which was not given as it needed to be clear that it was the intermolecular/London forces which are broken.

Some referred to enthalpy of combustion data which was not asked about in the question. Some responses had lots of repetition i.e. explained why longer chains had a high boiling point, then repeated the same but for the reverse argument for smaller chains.

Exemplar 2

• the boiling point increases as chain length increases, due to more points of contact between molecules, so more london forces which require more energy to overcome.

•

Vs

↑ more points of contact

A clear and concise response which scores all 4 marks. The diagrams at the bottom confirm that this candidate has understood the concepts completely.

Question 4 (b) (i)

(b) When alkanes undergo complete combustion carbon dioxide and water are produced.

(i) Write the balanced equation for the complete combustion of **one** mole of pentane.

.... **[1]**

The majority gave a correctly balanced equation here. The most common error was an incorrect number of oxygen molecules. A few candidates gave the equation for propane rather than pentane.

Question 4 (b) (ii)

(ii) Use the information in **Table 4.1** to calculate the mass of carbon dioxide formed when 1.00 kJ of energy is released during the complete combustion of pentane.

Mass of carbon dioxide ....g **[2]**

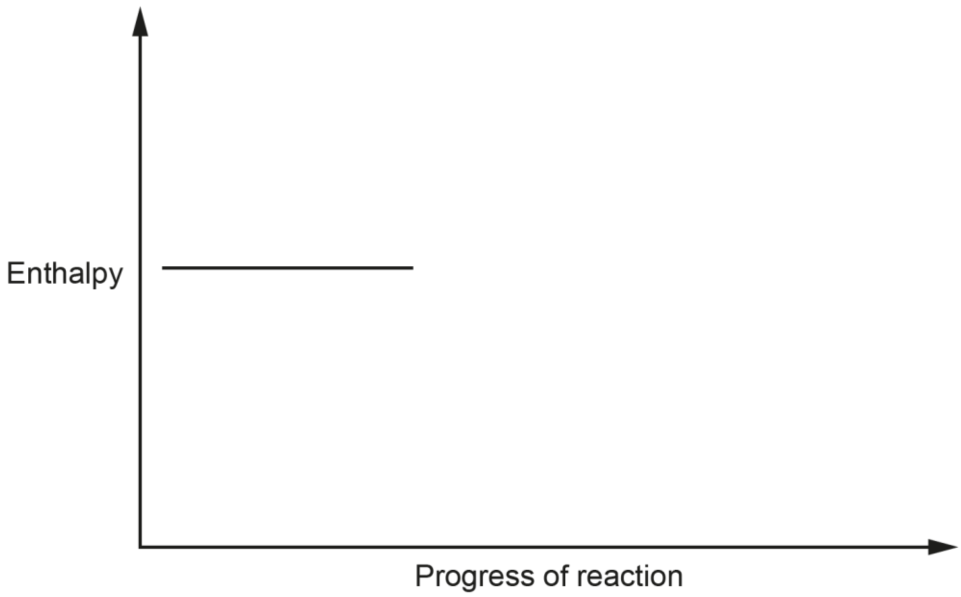
Many found this unfamiliar calculation quite tricky. Some tried to use the equation q = mcΔT to try to find a mass. Others tried a Hess cycle. Some multiplied by the M_r for pentane rather than carbon dioxide. A common error was to use 1000 J in the calculation, despite the enthalpy change being given in kJ mol^{-1}, giving a final answer of 62.7g.

Question 4 (b) (iii)

(iii) Complete the enthalpy profile diagram for the complete combustion of pentane.

On your diagram:

- Label the enthalpy change as ΔH.
- Include the formulae of the reactants and products.
- Label the activation energy as *E*a.



[2]

Most candidates were able to score 2 marks here for this familiar question. However, marks were lost for the following errors:

- Double headed arrows or arrow wrong way round for ΔH or missing arrow heads
- Arrow for E_a not extending to the maximum
- Missing formula for reactants and products
- −ΔH label
- E_a arrow drawn from products up to maximum

A few drew an endothermic profile diagram limiting their mark to 1.

Question 4 (b) (iv)

(iv) Use the data in **Table 4.1** to estimate a value for the enthalpy change of combustion of butane.

Give your answer to **2** significant figures.

Estimated enthalpy change of combustion of butane ....kJ mol^{-1} **[1]**

Many struggled to give the correct response here. They were expected to find the mid-point between the values given for propane and pentane. (The difference between pentane and hexane could also be used.) They then needed to give the value to 2 significant figures. Candidates were generally confident at giving final answers to 3 significant figures but struggled here when asked for only 2. A significant number also forgot to include the – sign.

Question 4 (c)

(c) Besides pentane, there are two other structural isomers of C_5H_{12}.

Draw the **skeletal** formulae of these two other structural isomers and state the systematic name of each.

	Isomer 1	**Isomer 2**
Skeletal formula		
Systematic name		

[2]

Most candidates scored both marks here. Some lost a mark due to slips in naming, e.g. missing 'di' from dimethylpropane or incorrect numbering, e.g. 2-dimethylpropane, 2,3-dimethylpropane. Some used structural formula rather than skeletal. Common incorrect structures included cyclopentane, 1- or 2-ethylpropane or 1,2-dimethylpropane (not realising that these are 2-methylbutane) or 6 C structures with addition of a methyl group to pentane.

Question 4 (d) (i)

(d) In the presence of ultraviolet radiation, propane reacts with bromine to form a mixture of products.

Two of these products are structural isomers of C_3H_7Br.

(i) Write an equation, using molecular formulae, for the formation of C_3H_7Br from propane.

.... **[1]**

Generally well known, with most recognising that HBr is formed as a product.

Incorrect responses sometimes had 2 Br instead of Br_2 or included other radicals in their response.

Some candidates confused propane and pentane, despite being given them in the table. Some started with a longer C chain, breaking the chain and substituting with Br to give bromopropane as state in the question, e.g. $C_4H_{10} + Br_2 \rightarrow C_3H_7Br + CH_3Br$.

Some used structural formulae rather than the molecular formula which was asked for.

Question 4 (d) (ii)

(ii) The first step in the mechanism of the reaction is the homolytic fission of a Br–Br bond.

Explain what is meant by **homolytic fission**.

....

.... **[1]**

Candidates struggled to give a full explanation here. They needed to say what fission is and explain homolytic. Many said "bond breaking to form radicals" without explaining what radicals are or what happens to electrons from the bond. Many referred to elements rather than atoms in their response, e.g. "covalent bond is broken so that each element gets 1 electron". It was evident that some had attempted to learn a definition but didn't really understand what it meant, e.g. "each of the bonding atoms takes one of the electron pairs." The description of what happened to electrons from the bond was often too vague, e.g." electrons are shared evenly between atoms."

Question 4 (d) (iii)

(iii) Complete the equations for the propagation steps in the mechanism.

Use molecular formulae for organic species and dots (•) for unpaired electrons on radicals.

C_3H_8 + Br• → .... + ...

.... + ... → C_3H_7Br + ...

[2]

Most scored both marks here. The most common error involved substituting the Br in the first step – this lost both marks. Very few candidates scored 1 mark; this was usually for a correct first step but then re-acting the C_3H_7 radical with either 2 Br or HBr in second step.

Candidates must check that equations balance in terms of atoms.

Candidates should also understand that hydrogen radicals are highly reactive and are therefore unlikely to exist under standard conditions.

Question 4 (d) (iv)

(iv) Explain why two structural isomers of C_3H_7Br are formed.

....

....

.... **[1]**

This question was a slightly different way of asking why a number of different products are formed in radical reactions. However here candidates needed to recognise that it would be due to substitution at different positions along the chain. Common incorrect response included "multiple termination products" or "further substitution". It was also evident in some responses that candidates had muddled this with nucleophilic substitution and described the "stability of the carbocation intermediate". Some just stated the two different structural isomers that would be formed but didn't gain the mark as needed to say how they are formed.

Question 5 (a) (i)

5 This question is about haloalkanes.

(a) Chloromethane, CH_3Cl is a covalent molecule.

(i) Draw a 'dot-and-cross' diagram for CH_3Cl.

Show outer electrons only.

Use a different symbol for the electrons of each element.

[1]

Many candidates lost the mark here for omitting to add lone pairs on chlorine. Some lost the mark as they didn't use three different symbols for electrons on each of the elements, making it unclear which electrons were associated with each element.

Question 5 (a) (ii)

(ii) Name the shape of the chloromethane molecule and predict the value of the H–C–Cl bond angle.

Name of shape...

Bond angle ....

[2]

Most scored both marks here, as they were able to use the 'dot-and-cross' diagram drawn in (i). Some struggled with recalling the bond angle.

A few "trigonal planar" and "120" responses were seen perhaps confusing themselves with the next part of the question.

Question 5 (b)

(b) Chloroethene, $H_2C{=}CHCl$, is a covalent molecule with a double bond.

The bond angles in $H_2C{=}CHCl$ are different from those in CH_3Cl.

Predict the H–C–Cl bond angle in $H_2C{=}CHCl$ and explain why it is different from the H–C–Cl bond angle in CH_3Cl.

Bond angle ....

Explanation ....

....

....

....

.... **[3]**

A range of marks is scored on this question with most scoring at least 1 mark for the correct bond angle. A larger range of bond angles were allowed here to account for the impact of the double bond. Candidates were not expected to account for the additional repulsion from the double bond but should be able to use electron pair repulsion theory to predict and explain.

Many candidates found the explanation challenging, with a significant number not making any comparison between chloroethene with chloromethane as required in the question.

As seen in previous years, a mark was available for stating that "electron pairs repel" but this was often omitted despite being the main principle that determines molecular shapes. Many candidates felt like they needed to discuss lone pairs – in some cases saying they were present and therefore caused more repulsion. Candidates need to be reminded to focus only on the electron pairs around the central atom. Discussion of regions or areas of electron density or the number of bonded atoms was not enough to gain credit here.

Misconception

Many students think that molecular shapes are determined solely by lone pairs or by repulsion between bonded atoms. The principle behind molecular shapes is called electron pair repulsion theory because it is based on repulsion between electron pairs, which may be bonded pairs or lone pairs, but **not** atoms.

Question 5 (c)*

(c)* 2-Chlorobutane, $CH_3CH_2CHClCH_3$, is an organic liquid with a boiling point of 70 °C.

A student prepares 2-chlorobutane from butan-2-ol, $CH_3CH_2CHOHCH_3$, as shown in the equation below.

$$CH_3CH_2CHOHCH_3 + NaCl + H_2SO_4 \rightarrow CH_3CH_2CHClCH_3 + NaHSO_4 + H_2O$$

The student's method is outlined below.

- Add 9.25 g $CH_3CH_2CHOHCH_3$ to an excess of NaCl(aq) in a pear-shaped flask.
- Add an excess of concentrated sulfuric acid.
- Heat the flask under reflux for about 45 minutes.

The student obtains a reaction mixture containing an organic layer (density = 0.87 g cm^{-3}) and an aqueous layer (density = 1.00 g cm^{-3}).

After purification, the percentage yield of $CH_3CH_2CHClCH_3$ is 65.0 %.

Describe how the student could obtain a pure, dry sample of $CH_3CH_2CHClCH_3$ from the reaction mixture and explain the reason for carrying out each purification step.

Calculate the mass of pure $CH_3CH_2CHClCH_3$ that would be expected from this preparation.

.... **[6]**

Many understood the necessary steps to purify a liquid and were confident with the calculation. Most knew at least one or two purification steps and could explain their purpose.

Reasons marks were lost included:

- Not remembering the correct name for equipment i.e. separating funnel
- Getting the layers the wrong way round despite being given density information
- Unclear which layer an anhydrous salt was added to for drying
- Using an inappropriate salt for dry step, e.g. Na_2CO_3 or $MgCO_3$
- Slips in calculations, e.g. incorrect M_r values, yield inverted or not accounted for

- Thinking a solid would be formed
- Describing reflux (including drawing apparatus)
- Saying to distil at a specific boiling point but not stating the actual value (given in the question)

As with all calculations, it is important to set out working clearly as it helps to avoid slips. Remind candidates of the importance of checking their M_r values – many made slips here. Candidates should also avoid rounding intermediate values and consider the number of significant figures used for the final response. Some rounded intermediate values to less than 3 significant figures but gave a final response to 4 or more.

Exemplar 3

Calculate the mass of pure $CH_3CH_2CHClCH_3$ that would be expected from this preparation.

To obtain a pure, dry sample of $CH_3CH_2CHClCH_3$, first use a separating funnel to separate aqueous layer from organic layer. Since the organic layer has a lower density than the aqueous layer, the organic layer will be collected from the top of the separating funnel. Next, use anhydrous salt $MgSO_4$ to dry organic layer 2-chlorobutane. Finally, redistill to purify the product 2-chlorobutane and collect fraction distilling at 70°C.

n butan-2-ol $= \frac{9.25}{15+14+13+17+15} = 0.125$ mol

n 2-chlorobutane $= 0.125$ mol

Since % yield is 65.0%, n 2-chlorobutane $= \frac{65}{100} \times 0.125$

$= 0.08125$ mol

mass obtained $= 0.08125 \times (15+14+13+35.5+15)$

$= 7.5156$ g

$= 7.52$ g (to 3sf)

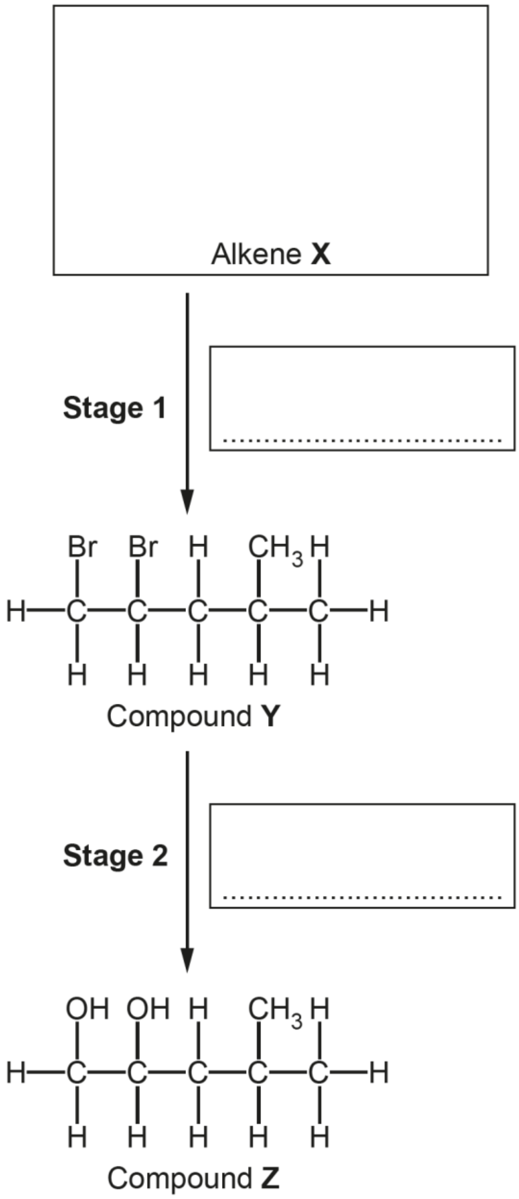
The response scored Level 3 and gained all 6 marks. All three purification steps are given in the correct order and explained. The calculation for mass is set out clearly and the final mass is given to 3 significant figures.

Question 5 (d) (i)

(d) Haloalkanes are important intermediates in organic synthesis.

A student plans a two-stage synthesis to prepare compound **Z** from a hydrocarbon alkene **X**.

(i) Draw the structure of the hydrocarbon alkene **X** in the box and write down the reagents for each stage on the dotted lines.



[3]

Candidates need to be reminded to check structures carefully – common errors included additional H atoms around C=C or missing the $-CH_3$ group. Some used $-C_4H_9$ rather than writing out the complete structure; unfortunately, this is ambiguous so didn't score the mark. Lower-attaining candidates sometimes gave an alkane rather than an alkene, reacting with Br_2 in presence of UV. Many had the correct reagents but added additional incorrect reagents resulting in loss of the mark, e.g. the addition of H_2SO_4 as a catalyst alongside NaOH for stage 2.

Question 5 (d) (ii)

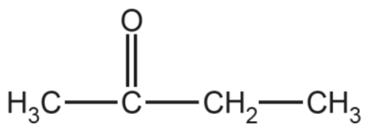
(ii) State the name of the mechanism of the reaction in **Stage 2**.

.... **[1]**

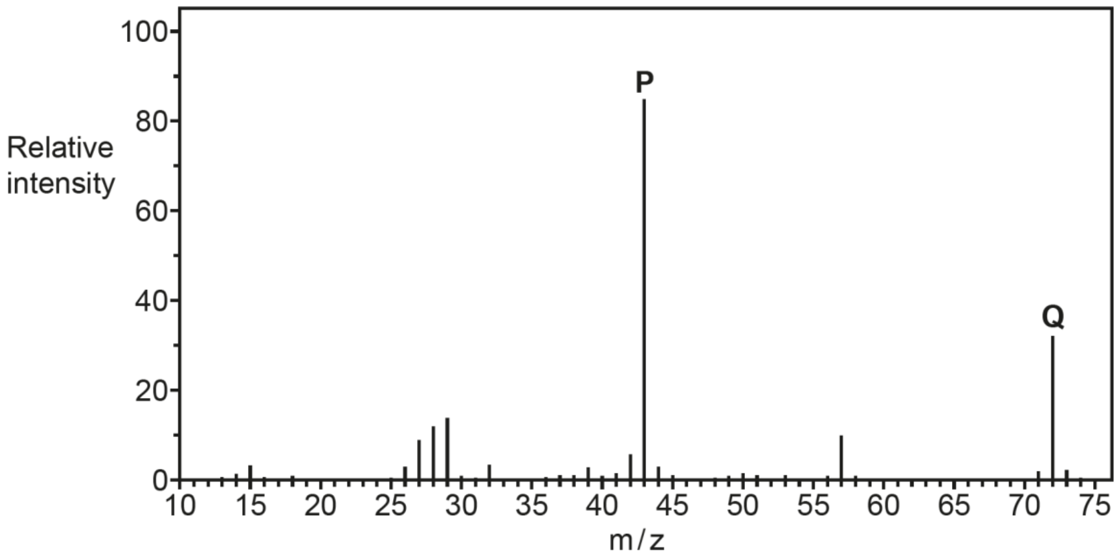
Most candidates were able to correctly state the mechanism. Most common incorrect responses included hydrolysis, hydration or electrophilic substitution.

Question 6 (a) (i)

6 Compound **A** is a ketone. It has the following structure.



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



(i) Draw structures for the ions responsible for peak **P** and peak **Q**.

ion responsible for peak **P**

ion responsible for peak **Q**

[2]

Most candidates only scored 1 mark as they omitted the charges, despite being asked in the question for the structures of ions. Some gave charge on the fragment P but not on the molecular ion Q.

Some also gave ions that would have the correct mass but don't exist in this molecule, e.g. P $CH_2CH_2CH_3^+$. A few gave molecular formulas rather than structures.

Question 6 (a) (ii)

(ii) Explain why there is a small peak at m/z = 73

....

.... **[1]**

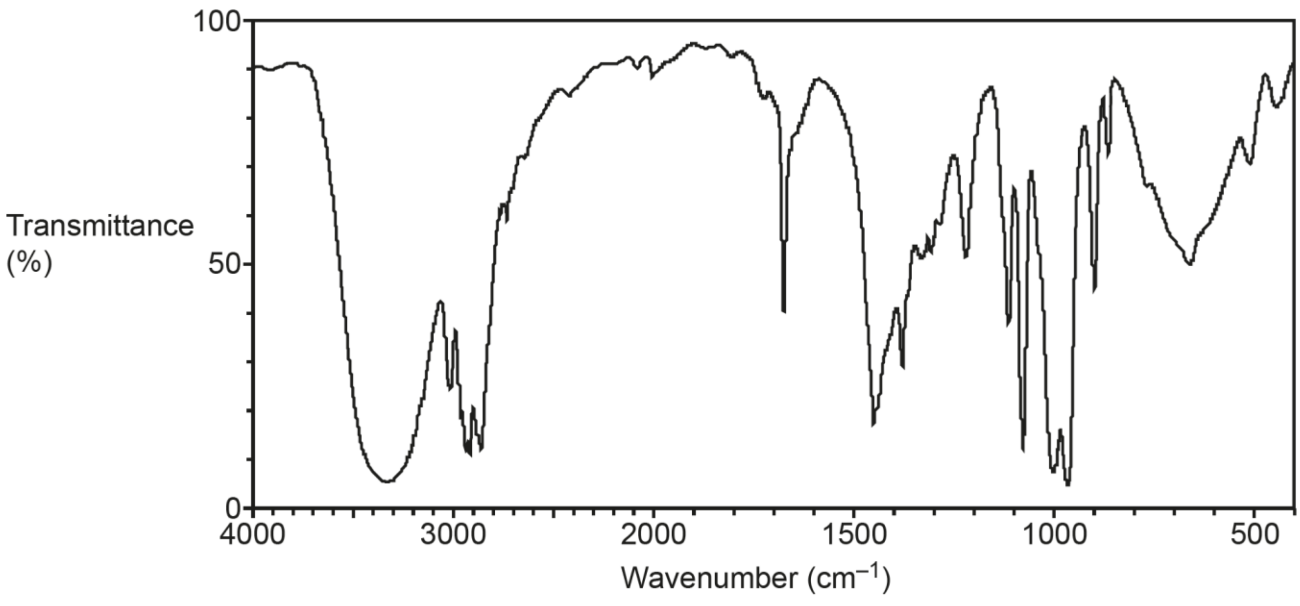
Many recognised it as the M+1 peak but did not explain why it is there. Some suggested the addition of a H to the molecular ion.

Some suggested it was due to different isotopes but did not specify for C-13. Other isomers, e.g. H-2, exist in such small natural abundance they would not be detectable. Lower-attaining candidates that struggled with (i) often thought that it was the M+ peak and so gave the M_r of the compound.

Question 6 (b) (i)

(b) Compound **B** is a non-cyclic structural isomer of Compound **A**.

The infrared spectrum of Compound **B** is shown below.



(i) State the effect infrared radiation has on covalent bonds.

....

.... **[1]**

The majority of candidates said infrared radiation caused the bonds to vibrate. This was not sufficient for the mark as the bonds would already be vibrating – but IR causes them to vibrate more. A significant number thought that IR would cause the bonds to break.

Question 6 (b) (ii)

(ii) Identify **two** functional groups which are likely to be present in Compound **B** but are not present in Compound **A**.

Explain your answers.

Functional group ....

....

....

Explanation ....

....

.... **[2]**

Candidates must take care to name functional groups rather than just bonds as O-H bonds are found in both carboxylic acids and alcohols, C=C are found in alkenes and arenes. Many candidates thought that there was a carboxylic acid present in B, not realising this would then have too many O atoms to be a structural isomer. Similarly, some identified a halogen.

Candidates must be clear about the IR peaks identified ensuring they give precise values within the range identified on the data sheet. Many candidates still confuse O-H in a carboxylic acid, which gives a much broader peak that merges into the C-H stretch, and O-H in alcohol, still broad but distinct from C-H.

OCR support

Candidates are often confused about how IR works. Our delivery guide for identifying unknowns contains information on IR including how it works and the use of a simple spring model to help explain. There is also a link to a TES resource with a bank of real IR spectra which clearly shows difference between O-H in an alcohol and O-H in a carboxylic acid.

Delivery Guide (H032): Identifying Unknowns

https://teachcambridge.org/item/9698f11f-a6d4-45a6-9f3d-de025f7bd434

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