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AS LEVEL

Examiners' report

CHEMISTRY A

H032

For first teaching in 2015

H032/01 Summer 2023 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 OCR.

Paper 1 series overview

H032/01 is one of the two examination components for the current AS Level examination for GCE Chemistry A.

H032/01 is worth 70 marks, is split into two sections and assesses content from all teaching modules, 1 to 4. Candidates answer all questions.

- **Section A** comprises 20 multiple-choice questions that assess many different areas of the specification. This section of the paper is worth 20 marks.
- **Section B** includes short answer question styles (structured questions, problem solving, calculations, practical) and extended response questions. This section of the paper is worth 50 marks.

Candidates who did well on this paper generally:	Candidates who did less well on this paper generally:
• showed knowledge of key chemical concepts such dot-and-cross diagrams: 21(a)(ii); molecular shapes: 21(b)(i)(ii); construction of balanced equations: 22(b)(i)(ii), 23(a)(i) • produced clear and concise responses for explanations of chemical knowledge and understanding, e.g. use of Le Chatelier's Principle to determine the effects of physical changes on the position of equilibrium: 24(b); explanation for the different boiling points of alkanes: 25(a) • performed calculations proficiently and clearly, e.g. titration calculations: 22(c); indirect determination of enthalpy changes using Hess' Law: 23(b)(i): K_c from provided data: 24(c)(i) • showed organic structures using different unambiguous formula (skeletal, structural and displayed) • displayed good knowledge and understanding of important organic reactions: 25(b), 26.	• found it difficult to apply what they had learnt in situations that are unfamiliar • produced responses that lacked depth and were often rambling, e.g. when describing the effects of physical changes on the position of equilibrium using Le Chatelier's Principle: 24(b) • did not clearly set out unstructured calculations, e.g. Titration calculation: 22(c)(iv); Hess' Law calculation: 23(b)(i) and Equilibrium constant calculation: 24(c)(i) • did not use significant figures appropriately: 24(c)(i) • used organic structures that are unclear or unambiguous, including the same molecular formula for different isomers • displayed gaps in their basic chemical knowledge, e.g. writing of simple formulae: 22(b)(i), standard conditions: 23(b)(i); homogeneous equilibrium: 24(a).

There was no evidence that any time constraints had led to a candidate underperforming or of scripts where there were no responses to many questions.

Note

Candidates have been provided with a fixed number of answer lines and an extra answer space. The extra answer space will be clearly labelled as extra and is only to be used when required. Teachers are encouraged to keep reminding students about the importance of conciseness in their responses.

Section A overview

Section A comprises 20 multiple-choice questions that assess many different areas of the specification. This section of the paper is worth 20 marks.

Most questions performed well and provided a range of scores. Question 11 was very rarely scored, but apart from that there was good range of marks.

Candidates should take note of the following general points.

1. Candidates must write the letter for their choice clearly. It is sometimes very difficult to decipher a letter, particularly between a B and a D. If the letter cannot be definitively identified by the marker, no mark can be given.
2. If a candidate changes their mind, they should cross out the letter and write the replacement alongside. It does not matter if the chosen letter is outside of the box, as long as it is clear. Attempts at changing a letter often result in illegibility, with no mark being given.
3. Finally, candidates should never leave a multiple-choice question with no letter. A guess may turn out to be correct. A 'no response' can only result in no mark.

Question 1

1 Which statement explains the trend in boiling points down the halogens group?

A Covalent bonds become stronger.

B Induced dipole–dipole interactions (London forces) become stronger.

C Ionic bonds become stronger.

D Permanent dipole–dipole interactions become stronger.

Your answer ☐ **[1]**

Almost all candidates selected the correct response of B. The main distractor proved to be D, the other type of dipole–dipole interaction.

Question 2

2 A hydrocarbon contains 85.71% carbon by mass.

What is the empirical formula of the hydrocarbon?

A CH

B CH_2

C CH_4

D C_2H_4

Your answer ☐ **[1]**

Most candidates are well drilled in the calculation of an empirical formula from percentage compositions and most selected the correct response of B. Option D proved to the main distractor, presumably due to confusion between the terms empirical and molecular formula.

Question 3

3 Hydrogen can be prepared industrially by the reaction of methane with steam.
The equation is shown below.

$$CH_4(g) + 2H_2O(g) \rightarrow 4H_2(g) + CO_2(g)$$

What is the atom economy of hydrogen for this process?

A 3.8%

B 4.3%

C 15.4%

D 17.4%

Your answer ☐ **[1]**

Most candidates selected the correct response of C but some chose D, the result of dividing 8 (for $4H_2$) by 44 (for CO_2) instead of dividing by their sum (8 + 44 = 52). Overall, candidates showed a good understanding of the term 'atom economy'.

Question 4

4 How many p-orbitals are occupied by electrons in a sulfur atom?

A 2

B 4

C 6

D 10

Your answer [1]

Candidates found this question more difficult than Questions 1–3. The question discriminated well. Most candidates showed the electron configuration in their working. A and D were the main distractors. Rather than the number of p-**orbitals** occupied, option A (2) is the number of p sub-shells (2p and 3p) and D (10) is the total number of p electrons (6 + 4). The errors may be the result of candidates not understanding the meaning of orbital and sub-shell or perhaps not reading the question closely enough. Underlining 'p-orbitals' may have helped candidates.

Question 5

5 Which substance has the lowest oxidation number for sulfur?

A Na_2SO_4

B S_8

C SF_2

D SO_2

Your answer [1]

Most candidates corrected selected option B. Many candidates wrote their oxidation numbers by each response with most identifying the oxidation number of S in S_8 as being 0. The main distractors were A and C. Annotations showed that many assignments of oxidation number had the wrong sign. For example, assigning S as –2 for S (SF_2) would result in C being chosen. This suggests that some candidates have an insufficient understanding of the rules for assigning oxidation numbers.

Question 6

6 Successive ionisation energies, in kJ mol^{-1}, of an element in Period 3 of the periodic table are shown below.

1st	2nd	3rd	4th	5th	6th	7th	8th	9th
578	1817	2745	11578	14831	18378	23296	27460	31862

What is the formula of the oxide of the Period 3 element?

A Na_2O

B MgO

C Al_2O_3

D SiO_2

Your answer [ ] **[1]**

Most candidate chose the correct response of C. From the annotations on the scripts, most candidates identified the largest jump between the 3rd and 4th ionisation energies. Option D proved to be the main distractor. Having identified the correct large jump, a significant number of candidates chose the group at the end of the jump (Group 4) rather than the group at the start of the jump (Group 3). This suggests a misconception.

Question 7

7 How many oxygen atoms are in 120.2 g of SiO_2?

A 3.01×10^{23}

B 1.20×10^{24}

C 2.41×10^{24}

D 3.61×10^{24}

Your answer [ ] **[1]**

Candidates found this question more demanding than Questions 1–6 with only about half the candidates correctly choosing option C. Most candidates showed working on their scripts with B being the common distractor, the result of working out the moles of SiO_2 as 120.2/60.1 = 2, and then multiplying the Avogadro Constant by 2, rather than first doubling 2 to take into account the two O atoms in SiO_2.

Question 8

8 Magnesium nitrate, $Mg(NO_3)_2$, decomposes when heated:

$$Mg(NO_3)_2(s) \rightarrow MgO(s) + 2NO_2(g) + \tfrac{1}{2}O_2(g)$$

0.00250 mol of $Mg(NO_3)_2$ is decomposed.

What is the volume of gas produced, measured at RTP?

A 30 cm^3

B 60 cm^3

C 120 cm^3

D 150 cm^3

Your answer ☐ **[1]**

Candidates found this question demanding. It showed very good discrimination between abilities with most able candidates choosing the correct option D. Option C was chosen by many, the result of working out the moles of $NO_2(g)$ without adding the moles of O_2. Care is needed when reading the question which asked for 'volume of gas', rather than 'volume of $NO_2(g)$.

Despite the question stating the volume has been measured at RTP, some candidates chose to use the Ideal Gas Equation instead of the simplified molar volume of 24 $dm^3\ mol^{-1}$ at RTP. This approach could still lead to success but would have wasted significant time.

Question 9

9 Zinc reacts with aqueous silver nitrate, as shown in the equation:

$Zn(s) + 2AgNO_3(aq) \rightarrow 2Ag(s) + Zn(NO_3)_2(aq)$

0.10 g of zinc is added to 15 cm^3 of 0.25 mol dm^{-3} aqueous silver nitrate.

What is the mass of silver metal that would be formed?

A 0.16 g

B 0.20 g

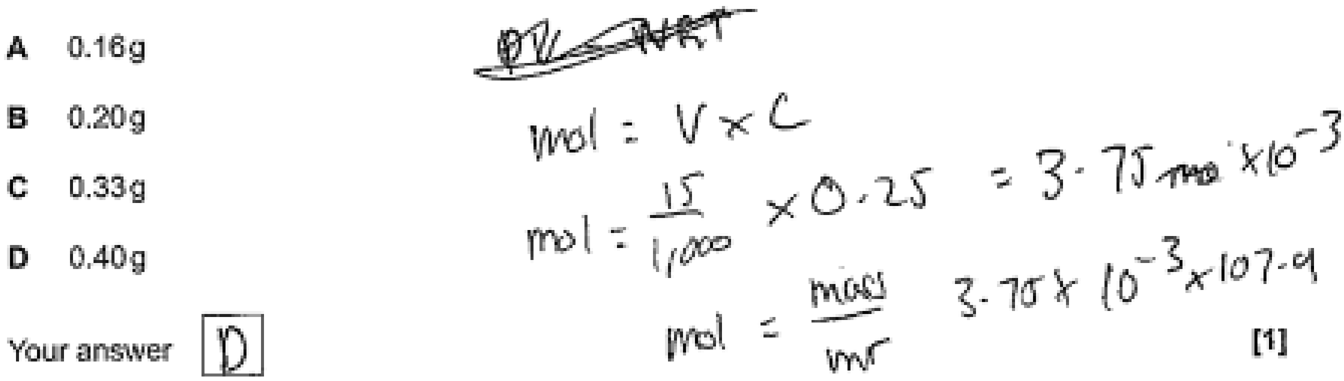
C 0.33 g

D 0.40 g

Your answer ☐ **[1]**

Candidates found this question very difficult with less than half successfully choosing option C. Many candidates chose option D, as shown in Exemplar 1.

Exemplar 1


A 0.16g

B 0.20g

C 0.33g

D 0.40g

Your answer D

mol = V × C

mol = $\frac{15}{1,000}$ × 0.25 = 3.75 × 10^{-3}

mol = $\frac{mass}{mr}$ 3.75 × 10^{-3} × 107.9

[1]

This candidate's working is clear and would have been correct had $AgNO_3$ have been the limiting factor. Calculating the moles of Zn shows that this is the limiting factor, producing 0.33 g of Ag for option C.

Question 10

10 15.00 cm^3 of 18.0 mol dm^{-3} concentrated hydrochloric acid is diluted with water to prepare 250 cm^3 of dilute hydrochloric acid.

What is the concentration, in mol dm^{-3}, of the dilute hydrochloric acid?

A 0.0675

B 0.270

C 0.300

D 1.08

Your answer ☐ **[1]**

Most higher attaining candidates chose the correct option of D. From candidate annotations, most calculated the moles of HCl as 0.27 mol. This directly gave the common distractor of B, the result of not taking into account the volume of 250 cm^3. Successful candidates multiplied 0.27 by 4 (or divided by 0.250) to get the correct response of 1.08 mol dm^{-3} (D).

Question 11

11 The standard enthalpy change of formation of water is –286 kJ mol^{-1}.

Which statement or equation is correct?

A $H_2(g) + ½O_2(g) \rightarrow H_2O(l)$ $\Delta H^\ominus = -143$ kJ mol^{-1}

B $2H_2(g) + O_2(g) \rightarrow 2H_2O(l)$ $\Delta H^\ominus = -286$ kJ mol^{-1}

C The O–H bond enthalpy is –143 kJ mol^{-1}.

D The standard enthalpy change of combustion of hydrogen is –286 kJ mol^{-1}.

Your answer ☐ **[1]**

This question proved to be very difficult with only the highest attaining candidates obtaining the correct response of D. Options A and C were the main distractors but there didn't seem to be any clear pattern. The many candidates could not identify the correct response suggests that candidates have difficulty in understanding the real meaning of these enthalpy terms.

Question 12

12 Which statement about energy changes is correct?

A Combustion of an alkane is endothermic.

B In an exothermic reaction, more energy is needed to break bonds than is given out when bonds are made.

C The activation energy is a negative value.

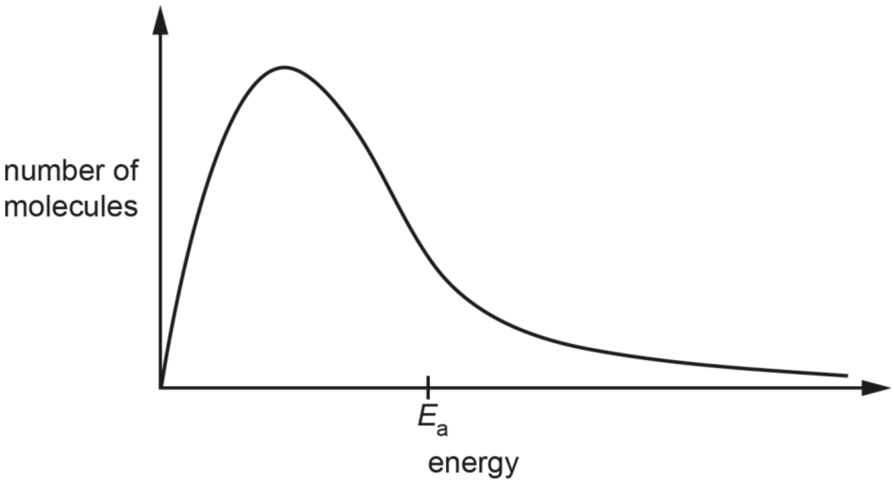
D The enthalpy change for the condensation of a gas to a liquid is a negative value.

Your answer ☐ **[1]**

The theme of problems with enthalpy terms continued with Question 12, with only about half of the candidates choosing the correct option D.

Question 13

13 The Boltzmann distribution showing the activation energy, E_a, for an uncatalysed reaction is shown below.



What is the difference for the **catalysed** reaction?

A The activation energy shifts to the left.

B The activation energy shifts to the right.

C The curve flattens.

D The curve shifts to the right.

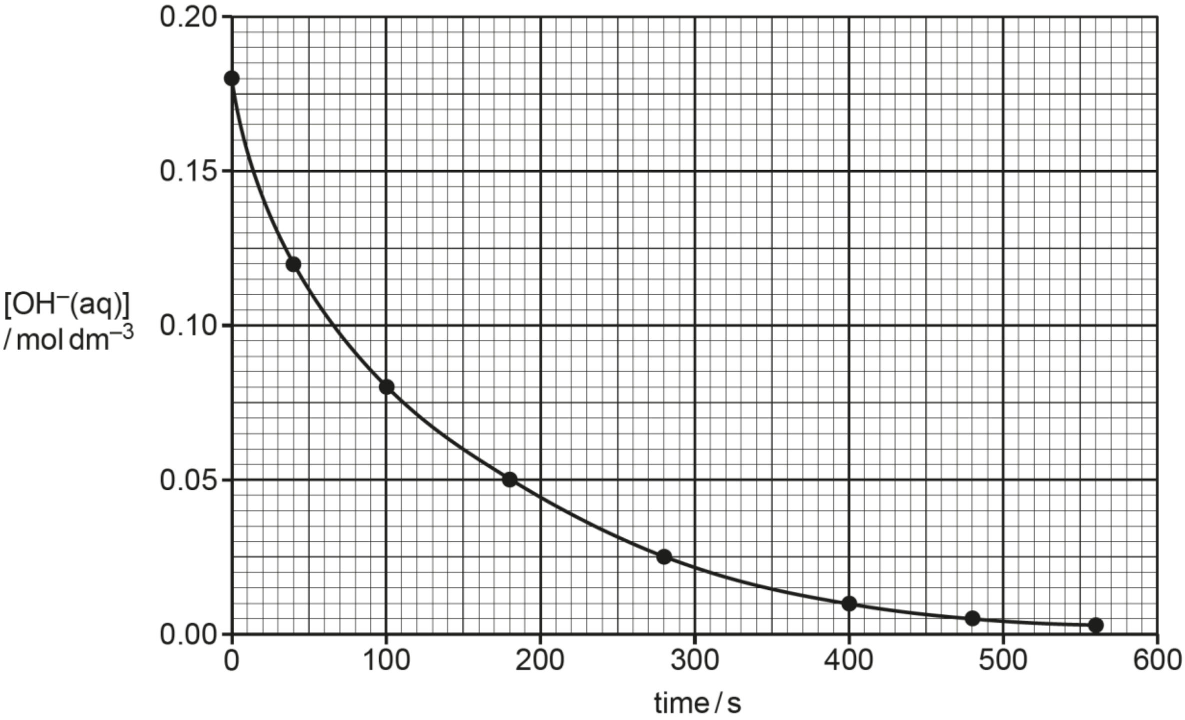
Your answer ☐ **[1]**

The behaviour of the Boltzmann distribution under different conditions is well known with most candidates making the correct choice of A.

Question 14

14 A student measures how the OH^- concentration changes over time for a reaction.

The student plots the graph below.



What is the rate of reaction, in $mol\,dm^{-3}\,s^{-1}$, at 200 s?

A 2.2×10^{-4}

B 2.8×10^{-4}

C 1.8×10^{-3}

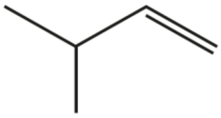
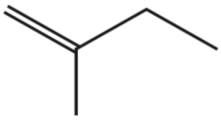
D 4.4×10^{-2}

Your answer ☐ **[1]**

This question discriminated well, rewarding those candidates with a good understanding of the link between concentration, time and rate. Many candidates drew a tangent to the curve at 200 s, measuring its gradient to get the correct choice of B. Common errors focused on reading of the concentration at 200 s. This was then either matched to option D directly or divided by 200 to give option A.

Question 15

15 Which formula does **not** represent 3-methylbut-1-ene?

A	$CH_3CHCH_3CHCH_2$
B	$CH_2CHCH(CH_3)_2$
C	
D	

Your answer ☐ **[1]**

Most candidates showed a good understanding of organic nomenclature to obtain the correct option of D. Candidates who drew out the structures for options A and B were able to easily eliminate them. Those trying to interpret the A and B options without drawing out the structures were often less successful.

Question 16

16 How many structural isomers have the molecular formula C_4H_9Cl?

A 2

B 3

C 4

D 5

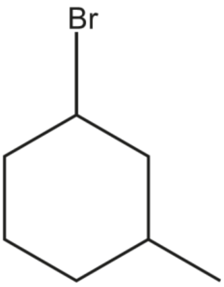
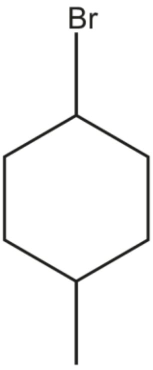
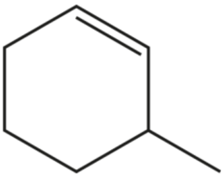
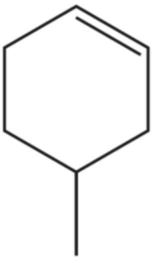
Your answer ☐ **[1]**

As with Question 15, the strategy of drawing out structures was more likely to lead to success with the correct option of C. Despite this, less than half of candidates obtained the correct response with many missing one of the isomers and opting for option B.

Question 17

17 3-Methylcyclohexanol is reacted with NaBr and H_2SO_4.

What is the organic product?

A	
B	
C	
D	

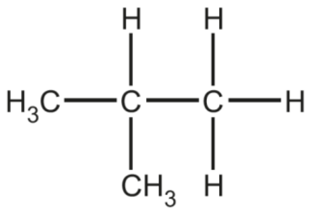
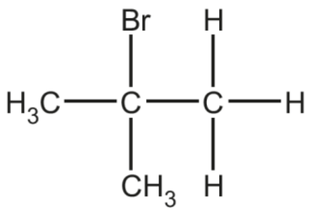
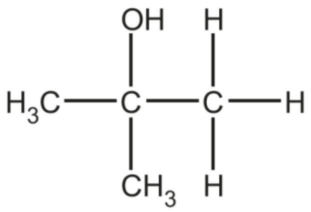
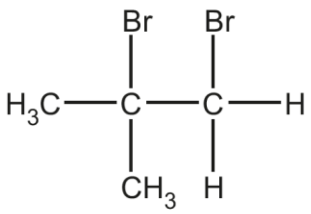
Your answer [ ] **[1]**

Candidates had more success with this question with most obtaining the correct option, A.

Question 18

18 A student has planned the two-stage synthesis shown below.

Which compound could be the intermediate for this synthesis?

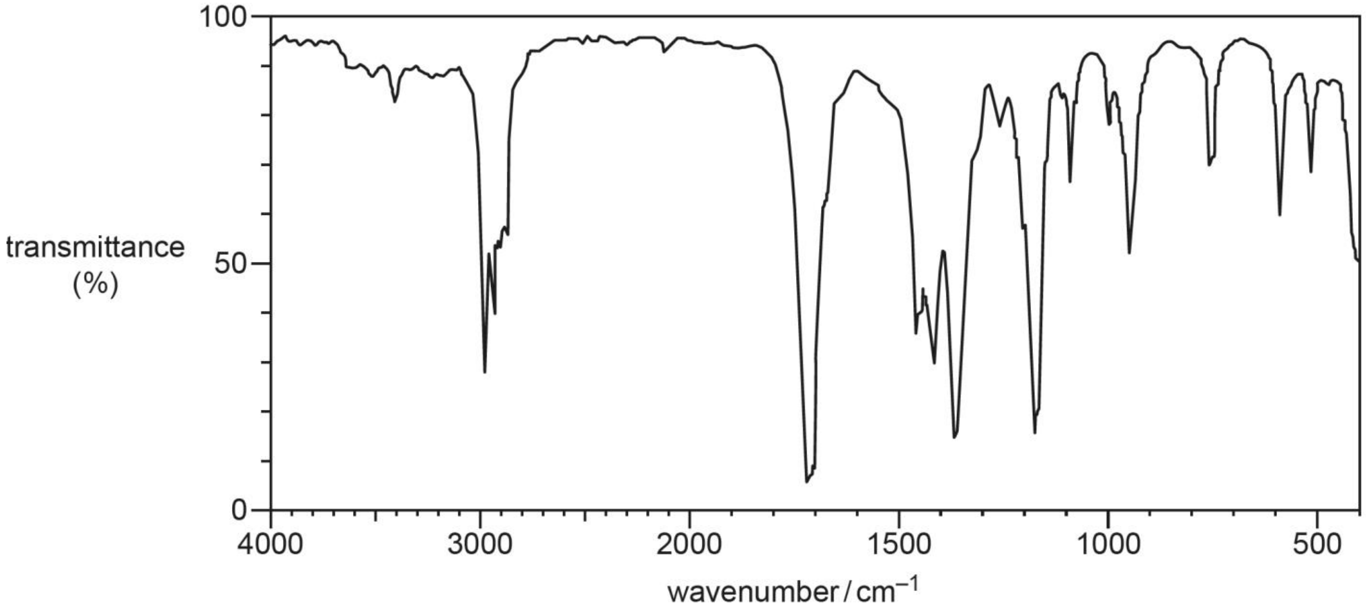
A	
B	
C	
D	

Your answer **[1]**

Candidates find it difficult to identify an intermediate within a synthesis and less than half selected the correct option, D.

Question 19

19 An organic compound produces the infrared spectrum below.



Which compound could have produced this IR spectrum?

A $CH_3CH_2CH{=}CH_2$

B $CH_3CHOHCH_2CH_3$

C $CH_3CH_2COCH_3$

D $(CH_3)_2CHCOOH$

Your answer ☐ **[1]**

Less than half the candidates interpreted which compound could have produced the IR spectrum. Many wrote the functional groups present alongside each option and all four options were seen in the responses. It was expected that the presence of a C=O absorption at 1700 cm^{-1} would have led to A and B to be eliminated. Some thought that the peak at 3000 cm^{-1} was for the carboxylic acid O–H which diverted some away from the correct option, C.

Question 20

20 Pentan-2-ol and pentan-3-ol are structural isomers with the molecular formula $C_5H_{12}O$ and M_r = 88.

The isomers can be distinguished from the fragment ions in their mass spectra.

Which fragment ion would you expect to be present in only **one** of these isomers?

A *m*/*z* = 29

B *m*/*z* = 45

C *m*/*z* = 59

D *m*/*z* = 73

Your answer ☐ **[1]**

Candidates found this question a little easier and, as with previous organic questions, the best route to success was to draw out the structures of the organic isomers. For mass spectrum fragmentation, this ensures that the molecules can visually be split up into possible fragments. So well over half the candidates correctly identified the possible fragments and the correct option, B.

Section B overview

Section B includes short answer question styles (structured questions, problem solving, calculations, practical) and extended response questions. This section of the paper is worth 50 marks.

Question 21 (a) (i)

21 This question is about NF_3 and BF_3 molecules.

(a) NF_3 and BF_3 contain covalent bonds.

(i) What is meant by a **covalent bond**?

.... **[1]**

Most candidates correctly described a covalent bond as a shared pair of electrons. Where this mark was dropped, it was usually because of the omission of 'pair' or 'shared', e.g. 'shared electrons'.

Question 21 (a) (ii)

(ii) Draw 'dot-and-cross' diagrams for NF_3 and BF_3.

Show outer electrons only.

NF_3	BF_3

[2]

The 'dot-and-cross' diagrams were usually correct. Errors were commonly the result of missing a lone pair of electrons from one or more fluorine atoms.

BF_3 was the more challenging diagram suggesting that some candidates were unfamiliar with molecules with less than an octet in their outer shell. Some candidates used two electrons from one of the fluorine atoms to show a double bond around the central B atom to complete the octet.

Question 21 (b) (i)

(b) Molecules of NF_3 and BF_3 have different shapes and bond angles.

(i) Predict the different shapes of, and bond angles in, NF_3 and BF_3 molecules.

	Bond angle	**Name of shape**
NF_3		
BF_3		

[2]

This bond angles and shapes rewarded the well-prepared candidates, with many being given both available marks. The commonest error was NH_3 shown with a tetrahedral shape and a bond angle of 109.5º. This part discriminated very well.

Question 21 (b) (ii)

(ii) Explain why NF_3 and BF_3 molecules have different shapes and bond angles.

....

....

....

....

....

....

.... **[2]**

Most students had the right idea here, but some lacked the detail for the marks. Some discussed repulsion in general terms, without referring the number of electron pairs. This question discriminated very well.

Misconception

Many students can describe electron pair repulsion theory but many think that molecular shapes are determined by lone pairs, with bonded pairs often being ignored. Others seem to believe that lone pairs repel atoms. In this question, explanations sometimes claimed that NF_3 and BF_3 molecules have different shapes because a NF_3 molecule has a lone pair, resulting in no credit.

Question 22 (a)

22 This question is about reactions involving acids.

(a) Hydrochloric acid and nitric acid are classified as strong acids.

What is meant by a **strong** acid?

....

.... **[1]**

Most candidates knew that a strong acid completely dissociates. Only the lower-attaining candidates responded in terms of a low pH.

Question 22 (b) (i)

(b) Write equations for the reactions below. State symbols are **not** required.

(i) The reaction of copper(II) oxide with dilute hydrochloric acid.

.... **[1]**

This question required candidates to recognise the reaction as being 'acid–base' and to interpret a formula from a name containing a Roman numeral. Candidates identifying the formula of copper(II) oxide as CuO were normally able to complete the equation. A reasonably large number identified the copper compounds as CuO_2 and $CuCl$. Overall, most candidates produced a correct equation.

Question 22 (b) (ii)

(ii) The reaction of ammonium carbonate with dilute nitric acid.

.... **[2]**

This item was much more demanding than the equation in 22(b)(i) and was often answered incorrectly. Most were unable to work out the formula of the two ammonium compounds, with NH_3 often shown instead of NH_4. A mark was available for 4 of the 5 formulae being correct but comparatively few were able to construct the correct balanced equation. Candidates are expected to know the formula and charge of ammonium and carbonate ions and the common acids (sulfuric, hydrochloric and nitric) and these are clearly listed in the specification.

Question 22 (c) (i)

(c) A student carries out an investigation to identify an unknown Group 1 metal **M**.

- The student reacts 2.62 g of the Group 1 metal, **M**, with water.
  A solution of the alkali, **M**OH(aq), is formed.
- The student makes this solution of **M**OH(aq) up to 250.0 cm^3 with water.
- The student pipettes 25.0 cm^3 of this **M**OH(aq) solution into a conical flask.
- The student titrates this 25.0 cm^3 volume of **M**OH(aq) with 0.165 mol dm^{-3} $H_2SO_4(aq)$.

The equation is shown below.

$$2\mathbf{M}OH(aq) + H_2SO_4(aq) \rightarrow \mathbf{M}_2SO_4(aq) + 2H_2O(l)$$

(i) Name the type of flask that the student should use to make up the 250.0 cm^3 solution of **M**OH(aq).

.... flask **[1]**

Most candidates recognised that a volumetric flask is used to accurately prepare volumes of solutions. A common error was a conical flask, perhaps by not reading the information clearly and giving the name of the flask used in the titration itself.

Question 22 (c) (ii)

(ii) 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.

Complete the table below.

Final reading / cm^3	20.25	40.85	25.85
Initial reading / cm^3	0.00	20.25	5.50
Titre / cm^3	....	....	....

[1]

Most candidates were able to work out these simple subtractions. Candidates were told that the titration readings were read to the nearest $0.05\ cm^3$, requiring titres to be shown to two decimal places, which includes a '0'. The middle titre is therefore $20.60\ cm^3$ and not $20.6\ cm^3$, which continues to be the commonest error seen.

Question 22 (c) (iii)

(iii) Calculate the mean titre of H_2SO_4, to the nearest $0.05\,cm^3$, that the student should use to analyse the results.

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

Candidates are expected to use only concordant titres when working out the mean titre and the middle titre of $20.60\ cm^3$ should be rejected. Most candidates did this to produce $20.30\ cm^3$ as their mean titre. Predictably, the commonest error was to use all three titres to produce the incorrect mean of $20.40\ cm^3$.

Question 22 (c) (iv)

(iv) Calculate the amount, in mol, of **M**OH in 25.0 cm^3 of solution and determine the identity of the Group 1 metal **M**.

metal **M** = ... **[4]**

Many candidates followed a well drilled method to identify the unknown metal M as potassium:

- Moles of H_2SO_4 in the mean titre
- Moles of KOH in 25 cm^3
- Scaling $\times$10 for moles of KOH in 250 cm^3
- Molar mass of the metal as 39.11 and identified as K.

A number of candidates omitted the scaling stage to obtain a molar mass of 391.1. By ECF, the 'correct' identity would be caesium or francium. Some candidates then 'fiddled' their response, dividing by 10 to 'identify' the metal as K. This incorrect approach was not credited.

Exemplar 2

n(MOH) : 2 : 1 = 3.3495 × 10^{-3} / 2 = ~~3.37~~ 6.699×10^{-3}

25cm³ n(MOH) : ×10 = 6.699×10^{-2} mol 250cm³

Mr(MOH) = $\frac{m}{n}$ = 2.62/6.699×10^{-3} = 39.11

Mr(M) = 39.11 − 17 = 22.11 g/mol

M = Na

metal **M** = ...Na...................................... **[4]**

A common error, illustrated in Exemplar 2, was for candidates to calculate 39.11 but to think that this was the mass of MOH and not M. They then subtracted 17 (for OH) from 39.11 to obtain a response of 22.11 and identified M as sodium instead of potassium.

This error probably stems from candidates either not reading the question closely enough or confusion about the mole concept.

Question 23 (a) (i)

23 This question is about enthalpy changes.

(a) In a petrol engine, alkanes undergo combustion.

(i) Heptane is one of the alkanes in petrol.

Write the equation for the complete combustion of heptane.

State symbols are **not** required.

.... **[2]**

Most candidates were able to construct a balanced equation for the combustion of heptane. Most were aware that CO_2 and H_2O would be the products although some generated CO, C_6H_{12} or unusual compounds such as $C_7H_{14}O$. The hardest part was the formula of heptane itself with use of hexane instead being a common error; candidates who made this error were given 1 mark, provided that their equation was balanced.

Question 23 (a) (ii)

(ii) In a petrol engine, polluting gases such as CO and NO are formed. These are mostly removed before being emitted from the exhaust.

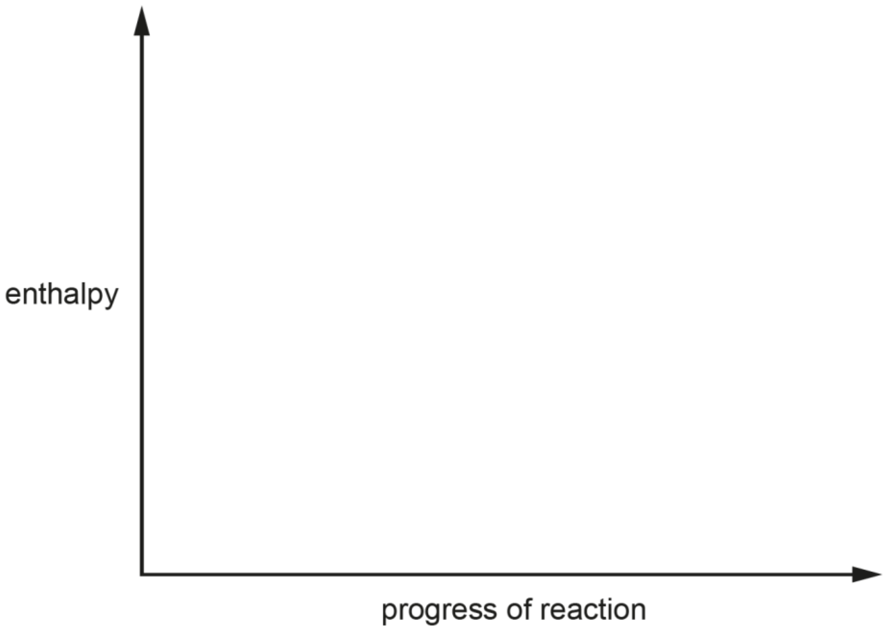
The equation for the removal of CO and NO is shown below.

$2CO(g) + 2NO(g) \rightarrow 2CO_2(g) + N_2(g) \quad \Delta H = -746\,kJ\,mol^{-1}$

Complete the enthalpy profile diagram in **Fig. 23.1** for this reaction.

On your diagram:
- Label the enthalpy change of reaction, ΔH.
- Include the formulae of the reactants and products.
- Label the activation energy, E_a.

Fig. 23.1



[2]

Most candidates obtained 1 or 2 of the available marks, the commonest errors being use of a double-headed arrow for ΔH or a $-\Delta H$ label.

Some candidates showed endothermic profiles and these could create issues with positioning of the ΔH and E_a arrows.

Generally, positioning of ΔH and E_a arrows was imprecise and candidates are advised to start and finish the positions of their arrows accurately. The mark scheme did allow for some leeway but positioning of arrows could generally be improved.

Question 23 (a) (iii)

(iii) CO and NO are removed by use of a catalyst.

Explain the role of the catalyst.

Refer to your enthalpy profile diagram in **Fig. 23.1** in your answer.

....

....

....

.... **[2]**

Almost all candidates knew that a catalyst lowered activation energy and most were aware that an alternative pathway was made possible by a catalyst.

Question 23 (b) (i)

(b) Iron(III) oxide reacts with carbon monoxide as shown:

$Fe_2O_3(s) + 3CO(g) \rightarrow 2Fe(s) + 3CO_2(g) \quad \Delta H = -25\,kJ\,mol^{-1}$

Standard enthalpy changes of formation, $\Delta_f H^{\ominus}$, are given in the table.

Substance	**$\Delta_f H^{\ominus}$ / kJ mol^{-1}**
$Fe_2O_3(s)$	–824
$CO(g)$	–111

(i) State the conditions of temperature and pressure for standard enthalpy changes.

Temperature ....

Pressure .... **[1]**

Only just over a half of candidates obtained this mark with one of the conditions being incorrect, usually as 273 K or 100 Pa.

It is important that candidates learn these standard conditions.

Question 23 (b) (ii)

(ii) Calculate the standard enthalpy change of formation for $CO_2(g)$.

$\Delta_f H^{\ominus}(CO_2(g))$ = ... $kJ\,mol^{-1}$ **[3]**

This question discriminated extremely well with many obtaining the correct enthalpy change of –394 $kJ\,mol^{-1}$ for 3 marks.

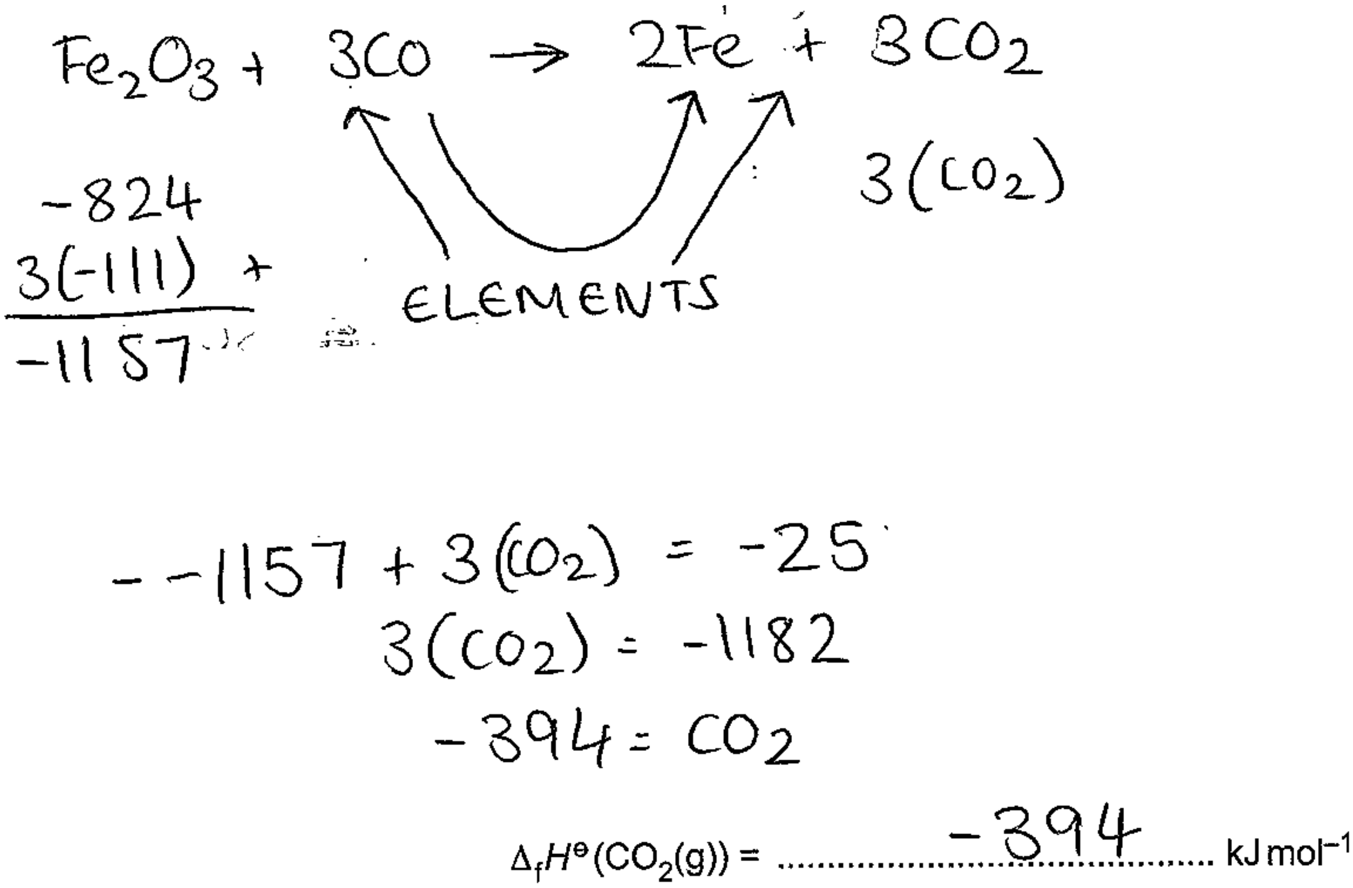
There were 3 stages to the calculating:

- Use of –824 and 3 × –111 to obtain –1157
- Correct incorporation of –25 to obtain –1182
- Division by 3 for 1 mole of CO_2 to obtain –394 $kJ\,mol^{-1}$

Weak candidates usually gained the first marking point but did not get any further. Incorrect signs were common as was not dividing by 3 for the final marking point.

The mark scheme allowed ECF to be applied, provided that there was some correct method in the response.

Exemplar 3



Exemplar 3 is shown to illustrate a clear response, showing clearly all stages in the calculation.

Unfortunately, many responses were very difficult to follow, often shown as numbers almost placed at random in the answer space. This makes it very difficult to identify any logic and to apply ECF. Exemplar 3 serves as a model, clear response, showing what is possible.

Question 24 (a)

24 The reaction between sulfur dioxide, $SO_2(g)$ and oxygen, $O_2(g)$, to form sulfur trioxide, $SO_3(g)$, is a key step in the industrial manufacture of sulfuric acid.

This is a reversible reaction, shown in **Equilibrium 24.1**:

$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$ $\Delta H = -197\,kJ\,mol^{-1}$ **Equilibrium 24.1**

(a) Why is **Equilibrium 24.1** a homogeneous equilibrium?

....

.... **[1]**

Only about half the candidates obtained this mark suggesting that this term had not been recalled by many. A common error stated that the catalyst and reactants were in the same state. Responses from lower-attaining candidates sometimes had the appearance of guesses.

Question 24 (b)

(b) Le Chatelier's principle can be used to predict how different conditions affect the equilibrium position in **Equilibrium 24.1**.

Explain how changing pressure, temperature and using a catalyst affect the equilibrium yield of SO_3.

In your answer, use le Chatelier's principle and other chemical concepts, where appropriate.

....

....

....

....

....

.... **[5]**

This long-answer question was approached very well and there were some excellent and concise answers.

Only the less successful responses did not identify the main trends.

Marks were often lost for responses in general terms, rather than related to the scenario in the question. For example, some candidates stated that the equilibrium would shift in the direction with fewer moles, without stating what that direction was for this equilibrium.

Some candidates contradicted themselves due to a lack of fully understanding how Le Chatelier's Principle should be applied. It was also common to see lengthy responses in which candidates discussed the effect of rate and compromise (not asked for in this question) and then confused equilibrium yield with overall yield.

Question 24 (c) (i)

(c) A mixture of SO_2(g) and O_2(g) is allowed to reach equilibrium at a constant temperature.

The equilibrium concentrations are shown in the table.

Substance	**Equilibrium concentration / mol dm^{-3}**
SO_2(g)	3.0×10^{-3}
O_2(g)	3.5×10^{-3}
SO_3(g)	5.0×10^{-2}

(i) Write the expression for K_c and calculate the numerical value for K_c in **Equilibrium 24.1** at this constant temperature.

Give your answer to an **appropriate** number of significant figures and in **standard form**.

K_c = ... dm^3 mol^{-1} **[2]**

The K_c expression was written well by many inverted the expression or added rather than multiplying the values. Indices were usually included.

Many candidates gave responses to more than 2 significant figures (2SF) and some did not give the response in standard form.

Candidates should be made aware that the term in the question of 'most appropriate' means that the final response should be shown to the least number of significant figures in the supplied data. In this scenario, all values were provided to 2SF and so the final response should also be expressed to 2SF.

OCR support

The Mathematical Skills Handbook provides guidance on the use of significant figures which can be shared with students.

Question 24 (c) (ii)

(ii) In the industrial production of SO_3, an excess of O_2(g) is used rather than a 2:1 proportion of SO_2(g) to O_2(g) which would match the stochiometry in **Equilibrium 24.1**.

Suggest, in terms of equilibrium, why an excess of O_2(g) is used industrially.

....

....

.... **[1]**

Few candidates successfully answered this difficult application question.

Some candidates considered ensuring complete combustion, or not wasting reactants, or various environmental reasons.

The question did supply a hint: 'in terms of equilibrium' but this was ignored by most candidates. The idea of equilibrium shift to the right was essential.

Question 25 (a)

25 This question is about hydrocarbons.

(a) The boiling points of 2 hydrocarbons are shown below.

Hydrocarbon	Boiling point / °C
butane	0
pentane	36

Explain the difference in the boiling points of butane and pentane.

....

....

....

....

.... **[2]**

Most candidates were given 1 or 2 marks, with some omitting the idea of surface area or surface contact. Most candidates identified London forces or induced dipole interactions as the relevant intermolecular force. A few candidates gave a general comment in terms of 'intermolecular' forces without specifying the type of intermolecular forces.

There has been a general improvement in candidate responses to this type of question with fewer candidates than in previous exams suggesting the breaking of hydrogen bonds or covalent bonds.

Question 25 (b)

(b) Butane reacts with bromine by radical substitution to form a mixture of organic products.

The reaction needs UV radiation for the initiation stage.

Write equations for the propagation stage that follows to form 2-bromobutane.

Use skeletal formulae and 'dots' (•) to show the position of any radicals.

Propagation	→ →

[2]

This question discriminated very well at the top end of the ability range, but many ignored the instruction to use skeletal formula and obtained no marks as a result.

Of those that did use skeletal formula, many placed the dot on the wrong carbon atom or produced 1-brombutane, rather than 2-bromobutane, stated in the question. A mark was still available by ECF for misplaced or absent dots or formation of 1-brombutane with dots.

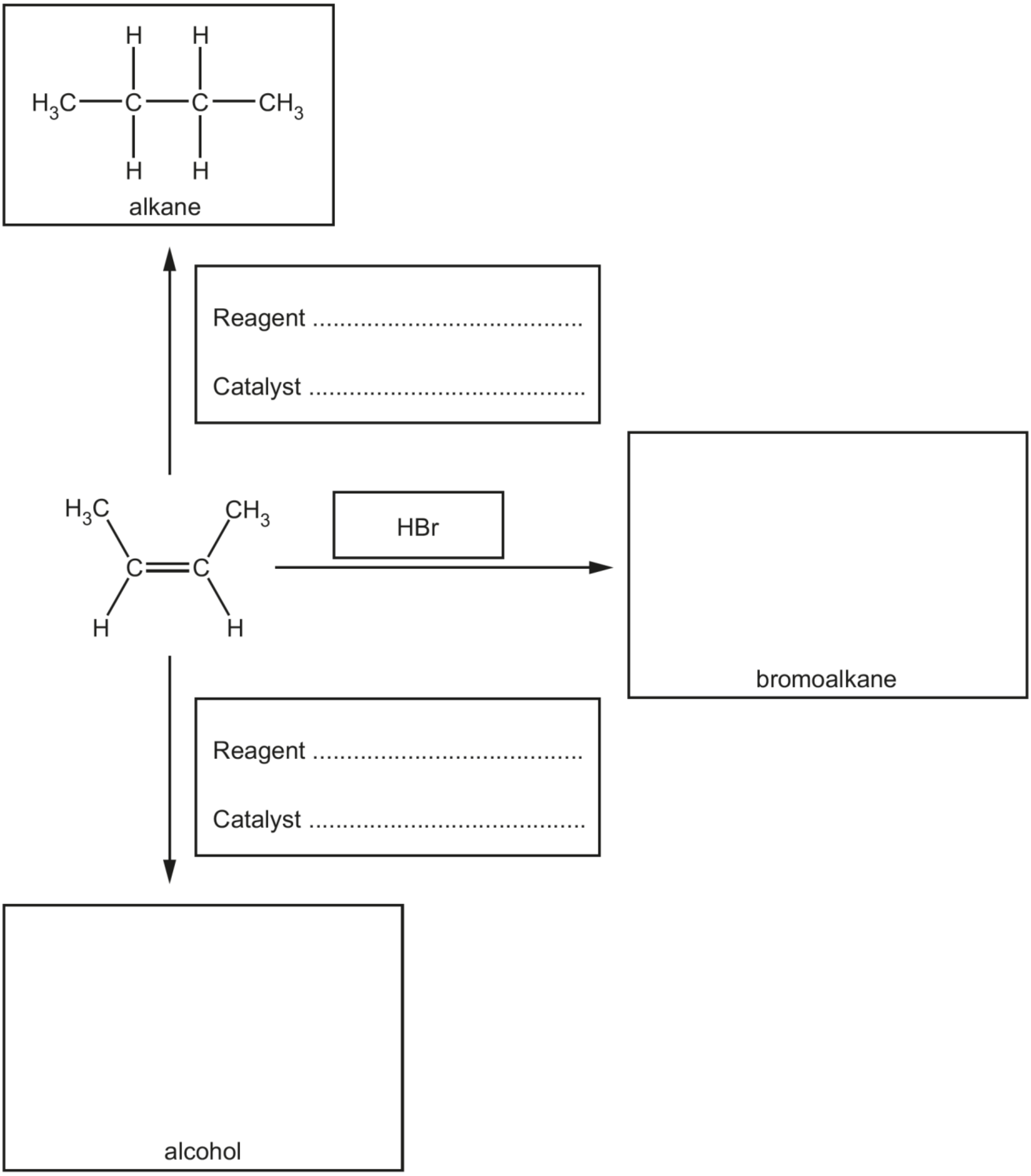
This question was aimed to be demanding and so it proved to be.

Question 25 (c)

(c) Alkenes are used in organic synthesis.

Three reactions of an alkene are shown in the flowchart.

Complete the flowchart to show the missing reagents, catalysts and the structures of organic products.



[4]

Most candidates drew correct structures for the bromoalkane and alcohol molecules, although some added Br and/or OH groups on the terminal carbon atoms. Some added two Br or OH groups.

The reagents and catalysts caused the main problems, with a wide variety of incorrect responses. For the hydrogenation step, nickel was often omitted and H_2SO_4 or $K_2Cr_2O_7$ were common incorrect reagents. For the hydration step, water/H_2O was often seen as the reagent rather than steam or $H_2O(g)$. It was also common to see water stated as the reagent, without a (g) state symbol to infer that it is steam.

Overall, this question discriminated very well with most candidates gaining at least 2 of the available 4 marks.

Question 26

26 This question is about the oxidation of two alcohols that are structural isomers of C_3H_8O.

Compare the oxidation of these two structural isomers using different reaction conditions.

For each reaction include:

- the reaction conditions
- the functional group of any organic product
- a balanced equation.

In your equations, use [O] to represent the oxidising agent and show any organic compounds as structures.

....

....

....

....

....

.... **[5]**

There were some excellent responses to this question which discriminated extremely well. Unfortunately, there were a significant number of incorrect responses and some less successful candidates had clearly struggled to recall and apply this important material. The identification of the isomers was usually correct, as was the identification of the oxidation products from the primary and secondary alcohols, and the conditions required to produce the organic products. The equation proved to be the hardest requirement with the H_2O by-product often being omitted or H_2 shown instead.

A general point applies to organic structures. Some candidates did not show the structures of the isomers and attempted this question using the molecular formula of C_3H_8O supplied in the question for both alcohol isomers and no structural formulae. It was then impossible to know which isomer was being reacted and this could cost the candidate a significant number of marks. It is essential in organic chemistry to use unambiguous formulae which can be any combination of skeletal, structural or displayed. Unless a question specifies that a molecular formula is required, candidates should assume that an unambiguous formula is required.

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