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Examiners' report

CHEMISTRY A

H032
For first teaching in 2015

H032/01 Summer 2018 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. 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 can be downloaded from OCR.

Paper H032/01 series overview

H032/01 is one of the two examination components for the new revised 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. Learners 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 did the following:

- Performed calculations following the required rubric (e.g. clear working, units, significant figures), e.g. relative atomic mass: 21(a)(ii), stoichiometry: 22(a)(ii), ideal gas equation: 22(a)(ii) and energy change using $mc\Delta T$: 23(a)(i).
- Produced clear and concise responses for explanations of chemical knowledge and understanding, e.g. Boltzmann distribution: 23b.
- Drew an organic mechanism with clear curly arrows, lone pairs and charges: 25(b)(i).
- Constructed reasoned explanations of supplied data, e.g. boiling points of hydrocarbon isomers: 24(a).
- Applied knowledge and understanding to questions set in a novel context, e.g. multiple chlorination of an alkane 25(b).

Candidates who did less well on this paper generally did the following:

- Found it difficult to apply what they had learnt to unfamiliar situations.
- Produced responses that lacked depth and were often rambling and peripheral to what had been asked, sometimes simply repeating information provided. e.g. 24(a)
- Showed poor setting out of unstructured calculations, e.g. ideal gas equation: 22(a)(ii); unstructured enthalpy change: 23(a)(ii).
- Showed poor presentation, e.g. Boltzmann distribution: 23b.
- Drew organic structures with basic errors, such as five-bonded carbon atoms: 25(a)(i).
- Found it difficult to apply what they had learnt in practical situations, e.g. 22(a)(iii); 23(a)(ii).

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.

Section A overview

Question 1

1 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 Na**X**

B Na$\mathbf{X}_2$

C Na_2**X**

D $Na_2\mathbf{X}_3$

Your answer [1]

Nearly all candidates responded with the correct response of C.

Question 2

2 What is the number of oxygen atoms in 88.0 g of CO_2?

A 3.01×10^{23}

B 1.20×10^{24}

C 2.41×10^{24}

D 4.82×10^{24}

Your answer [1]

Candidates found this question difficult with comparatively few obtaining the correct response of C. Many candidates selected B instead, the number of CO_2 or O_2 molecules, and not the number of O atoms. Good advice is to read the question carefully and to underline any key features.

Question 3

3 A compound has the composition by mass:

H, 5.00%; N, 35.00%; O, 60.00%.

Which compound has this composition?

A HNO_3

B NH_4NO_3

C HNO_2

D NH_2OH

Your answer ☐ **[1]**

Nearly all candidates responded with the correct response of B.

Question 4

4 Sodium reacts with water as shown below.

$$2Na(s) + 2H_2O(l) \rightarrow 2NaOH(aq) + H_2(g)$$

Which mass of sodium reacts with water to produce 960 cm^3 of hydrogen gas at RTP?

A 0.46 g

B 0.92 g

C 1.84 g

D 3.68 g

Your answer ☐ **[1]**

This part discriminated well, with most able candidates selecting the correct answer of C. A sizeable number selected B, presumably by not considering the 2:1 stoichiometric ratio in the equation.

Question 5

5 Which equation does **not** represent a neutralisation reaction?

A $Zn + 2HCl \rightarrow ZnCl_2 + H_2$

B $2NH_3 + H_2SO_4 \rightarrow (NH_4)_2SO_4$

C $Na_2CO_3 + 2CH_3COOH \rightarrow 2CH_3COONa + CO_2 + H_2O$

D $CuO + 2HNO_3 \rightarrow Cu(NO_3)_2 + H_2O$

Your answer [1]

Candidates found this part difficult with many selecting B, the equation that looked a little different, rather than the correct answer of A (a redox equation). This suggests that many candidates are unaware of the role of ammonia as a base.

Question 6

6 What is the oxidation number of Fe in K_2FeO_4?

A +4

B +5

C +6

D +7

Your answer [1]

Nearly all candidates responded with the correct response of C. Candidates seem to have a very good understanding of applying oxidation number rules.

Question 7

7 Which reaction shows oxidation of sulfur?

A $2HBr + H_2SO_4 \rightarrow SO_2 + 2H_2O + Br_2$

B $SO_2 + 2NaOH \rightarrow Na_2SO_3 + H_2O$

C $8HI + H_2SO_4 \rightarrow 4I_2 + H_2S + 4H_2O$

D $H_2S + Cl_2 \rightarrow 2HCl + S$

Your answer [1]

Candidates needed to do a lot of work to solve this problem and most wrote oxidation numbers around the equations. This systematic process allowed most candidates to find that D is the only option in which sulfur is oxidised.

Question 8

8 What determines the order of elements in the Periodic Table?

A first ionisation energy

B number of electrons in the outer shell

C number of protons in the nucleus

D relative atomic mass

Your answer [ ] **[1]**

Most candidates correctly selected C (number of protons) but a sizeable number selected D (relative atomic mass) or B (number of electrons) instead.

Question 9

9 The first five successive ionisation energies of an element **Y** are shown below.

1st	2nd	3rd	4th	5th
496	4563	6913	9544	13352

What is the formula of a chloride of **Y**?

A YCl

B YCl_2

C YCl_3

D YCl_4

Your answer [ ] **[1]**

Success depended on identifying the group of Y and working out the formula of the chloride. Most candidates recognised the large increase between 1st and 2nd ionisation energies, leading to the conclusion that Y is in Group 1 and the correct formula is YCl (A).

Question 10

10 Which element has induced dipole–dipole interactions (London forces) in its solid lattice?

A boron

B magnesium

C silicon

D sulfur

Your answer [ ] **[1]**

As is often the case, candidates find structure and bonding difficult. Many candidates selected silicon (C) instead of the correct response of sulfur (D).

Question 11

11 The equation for the reaction of aluminium sulfide, Al_2S_3, with oxygen is shown below.

$$2Al_2S_3(s) + 9O_2(g) \rightarrow 2Al_2O_3(s) + 6SO_2(g)$$

The table shows standard enthalpy changes of formation, $\Delta_f H^\ominus$.

Substance	Al_2S_3(s)	O_2(g)	Al_2O_3(s)	SO_2(g)
$\Delta_f H^\ominus$ / kJ mol^{-1}	−723.8	0	−1675.7	−296.8

What is the standard enthalpy change of combustion of Al_2S_3(s), in kJ mol^{-1}?

A −3684.6

B −1842.3

C +1842.3

D +3684.6

Your answer [ ] **[1]**

This question proved to be the most difficult of the multiple-choice questions. Most candidates constructed a correct energy cycle using the provided equation. This gave an energy change of –3684.6 kJ mol^{-1} (A). The question asks for the enthalpy change of combustion for Al_2S_3, which is half this value (option B). As with question 2, candidates are advised to read the question carefully.

Question 12

12 A student carried out an experiment to measure the enthalpy change of combustion of methanol.

The energy from the combustion of methanol was used to heat a beaker containing water.

The student's calculated enthalpy change of combustion was **more** exothermic than the value in data books.

Which error could have caused this difference?

A Some methanol had evaporated from the wick before the final weighing.

B In the calculation, the student used the molar mass of ethanol instead of methanol.

C There was incomplete combustion.

D The water boiled for 5 minutes before the final temperature was taken.

Your answer ☐ **[1]**

Candidates find questions based on practical procedures difficult and this question proved to be no exception. A similar number of candidates selected each option, suggesting that most guessed. The correct option is B.

Question 13

13 The reversible reaction below is at equilibrium.

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

Which changes in pressure and temperature would shift the equilibrium position towards the products?

	Pressure	**Temperature**
A	Decrease	Decrease
B	Decrease	Increase
C	Increase	Decrease
D	Increase	Increase

Your answer ☐ **[1]**

This question was a good discriminator with well-prepared candidates usually selecting the correct option of C. Incorrect responses were reasonably evenly split across the other options, suggesting guesses and poor preparation.

Question 14

14 The reversible reaction below is at equilibrium.

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$$

What is the expression for K_c?

A $\dfrac{[N_2(g)]\,[H_2(g)]^3}{[NH_3(g)]^2}$

B $\dfrac{[NH_3(g)]^2}{[N_2(g)]\,[H_2(g)]^3}$

C $\dfrac{[N_2(g)] + 3[H_2(g)]}{2[NH_3(g)]}$

D $\dfrac{2[NH_3(g)]}{[N_2(g)] + 3[H_2(g)]}$

Your answer [1]

Most candidates responded with the correct response of B. The most common incorrect response was the inverse expression shown in A.

Question 15

15 1 mol of a compound reacts with 8 mol O_2 for complete combustion.

What is the formula of the compound?

A C_4H_8

B C_4H_9OH

C $C_5H_{11}OH$

D C_5H_{12}

Your answer [1]

Most candidates selected A or D, with D being the correct option. Presumably, A was chosen by halving the '8' in C_4H_8 without considering that each H_2O molecule contains two H atoms. The successful answer of D usually resulted from the candidate constructing equations.

Question 16

16 How many structural isomers of $C_6H_{14}O$ are tertiary alcohols?

A 1

B 2

C 3

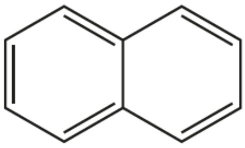
D 4

Your answer [ ] **[1]**

The responses showed a reasonably even split across all options with relatively few correct responses of C. A good route to success here is to draw out the possibilities.

Question 17

17 The structure of naphthalene is shown below.



What is the molecular formula of naphthalene?

A $C_{10}H_8$

B $C_{10}H_{10}$

C $C_{12}H_{10}$

D $C_{12}H_{12}$

Your answer [ ] **[1]**

Many candidates added H atoms to the structure to aid their choice. Most candidates selected the correct response of A, with a sizeable number selecting B (by adding two H atoms where the two rings join).

Question 18

18 A student reacts pent-2-ene with bromine in the laboratory.

Which compound is formed?

A 1,1-dibromopentane

B 1,2-dibromopentane

C 2,2-dibromopentane

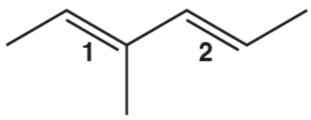
D 2,3-dibromopentane

Your answer [1]

Most candidates chose the correct option of D but a sizeable number chose B and C, the other options containing a '2' in their names. The best strategy here is to draw out the carbon skeleton of pent-2-ene from which it is clear that bromine atoms must be added at carbon positions 2 and 3.

Question 19

19 The molecule below has two double bonds, labelled **1** and **2**.



The arrangement around each double bond can be identified as *E* or *Z*.

Which row in the table is correct for double bond **1** and double bond **2**?

	Double bond 1	Double bond 2
A	*E*	*Z*
B	*Z*	*E*
C	*E*	*E*
D	*Z*	*Z*

Your answer [1]

This was a difficult question but higher ability candidates selected the correct option of C. The main discriminator was B, which identifies the 1 double bond as *Z*. CIP analysis is required to show that the double bond is *E*. This is a good 'hard' example for illustrating *E*/*Z* isomerism.

Question 20

20 Which alcohol is likely to have a fragment ion at m/z = 31 in its mass spectrum?

A $CH_3CH_2CH(OH)CH_3$

B $CH_3CH_2CH_2C(OH)(CH_3)_2$

C $CH_3CH(OH)CH_2CH_2CH_3$

D $(CH_3)_2CHCH_2OH$

Your answer ☐ **[1]**

Overall, candidates answered this question well with many selecting the correct response of D. From scripts, successful candidates drew vertical lines to isolate likely fragments.

Section B Overview

Question 21(a)(i)

21 This question is about elements from the p-block of the periodic table.

(a) Silicon exists as a mixture of three isotopes, ^{28}Si, ^{29}Si and ^{30}Si.

(i) Complete the table to show the atomic structure of ^{30}Si.

	Protons	Neutrons	Electrons
^{30}Si	....	....	....

[1]

This question was an easy starter to the paper with most candidates producing the correct answer.

Question 21(a)(ii)

(ii) A sample of silicon is analysed by mass spectrometry.

The mass spectrum shows peaks with the relative abundances below.

- ^{28}Si 92.23%
- ^{29}Si 4.68%
- ^{30}Si 3.09%

Calculate the relative atomic mass of silicon in the sample.

Give your answer to **two** decimal places.

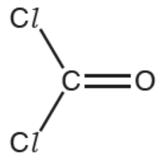
relative atomic mass = ... **[2]**

Almost all candidates followed a well-learnt procedure to complete the calculation. Despite being in the rubric to the question, some candidates did not give an answer to two decimal places. Others made a rounding error in reducing 28.1086 to two decimal places, with 28.10 and 28.12 being common errors.

Question 21(b)(i)

(b) Phosgene, $COCl_2$, exists as simple molecules.

The displayed formula of a phosgene molecule is shown below.



(i) Draw a '*dot-and-cross*' diagram of a phosgene molecule.

Show outer electrons only.

[1]

Most candidates attempted a dot-and-cross diagram of a $COCl_2$ molecule, with ionic representations being rare. Candidates should take care to include any lone pairs in their diagrams. Omission of the O and Cl lone pairs was the most common error.

Question 21(b)(ii)

(ii) Name the shape of a phosgene molecule and explain why it has this shape.

Name of shape ....

Explanation ....

....

....

.... **[3]**

This question discriminated well. Most candidates recognised that a $COCl_2$ molecule has a trigonal planar shape. The best answers explained this shape in terms of the three electron regions around the central C atom and their repulsion.

Question 21(c)

(c) Why are silicon, carbon, oxygen and chlorine all classified as p-block elements?

....

.... **[1]**

Candidates were expected to identify that a p-block element has its highest energy electron(s), or outer electrons, in a p orbital or sub-shell. Lower ability candidates often omitted 'electrons' in their responses and just repeated the information in the question.

Question 22(a)(i)

22 This question is about compounds of magnesium and phosphorus.

(a) A student plans to prepare magnesium phosphate using the redox reaction of magnesium with phosphoric acid, H_3PO_4.

$$3Mg(s) + 2H_3PO_4(aq) \rightarrow Mg_3(PO_4)_2(s) + 3H_2(g)$$

(i) In terms of the number of electrons transferred, explain whether magnesium is being oxidised or reduced.

....

.... **[1]**

Despite the question clearly asking for a response in terms of the number of electrons transferred, most candidates answered in terms of oxidation number changes. Candidates are recommended to read the question and to answer in terms of its requirements. Underlining 'number of electrons' may have helped candidates to answer the question that had been set.

Question 22(a)(ii)

(ii) The student plans to add magnesium to 50.0 cm^3 of 1.24 mol dm^{-3} H_3PO_4.

Calculate the mass of magnesium that the student should add to react exactly with the phosphoric acid.

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

mass of Mg = ... g **[3]**

Most candidates are competent at answering questions based on the mole.

Almost all candidates were able to calculate the amount of H_3PO_4 as 0.062 mol. Candidates then needed to use the 2:3 mole stoichiometric ratio to show that 0.093 mol of Mg reacts, which has a mass of 2.26 g to the required 3 significant figures. The commonest errors were use of the inverse 3:2 ratio to obtain 1.00 g Mg, or to omit the ratio to obtain 1.51 g Mg, as shown in the exemplar. Candidates are advised to show clear working so that credit can be awarded for such responses by applying error carried forward.

Exemplar 1

(ii) The student plans to add magnesium to 50.0 cm^3 of 1.24 mol dm^{-3} H_3PO_4.

Calculate the mass of magnesium that the student should add to react exactly with the phosphoric acid.

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

$n = cV$

$50 cm^3 = 0.05 dm^3$

$1.24 \times 0.05 = 0.062$ mol

$0.062 \times 24.3 = 1.5066$ g

$M = n \times mr$

mass of Mg = 1.51 g **[3]**

Question 22(a)(iii)

(iii) How could the student obtain a sample of magnesium phosphate after reacting magnesium with phosphoric acid?

....

....

....

.... **[2]**

Candidates often struggle with questions based on practical work. There were many random responses to this question, with relatively few candidates identifying that solid magnesium phosphate could be obtained by filtration, followed by drying.

Question 22(a)(iv)

(iv) Magnesium phosphate can also be prepared by reacting phosphoric acid with a compound of magnesium.

Choose a suitable magnesium compound for this preparation and write the equation for the reaction.

Formula of compound ....

Equation .... **[2]**

Candidates were expected to identify a suitable reagent for this reaction, with most choosing magnesium oxide, hydroxide or carbonate. Credit was also given for using a soluble magnesium salt such as its sulfate, chloride or nitrate. The correct equation often followed, but errors sometimes appeared in the form of incorrect formulae, such as MgOH for magnesium hydroxide. The exemplar shows a good clear response, using MgO as the reagent.

Exemplar 2

(iv) Magnesium phosphate can also be prepared by reacting phosphoric acid with a compound of magnesium.

Choose a suitable magnesium compound for this preparation and write the equation for the reaction.

Formula of compound MgO ✓

Equation $3MgO + 2H_3PO_4 \rightarrow Mg_3(PO_4)_2 + 3H_2O$ ✓ **[2]**

Question 22(b)(i)

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

$$4H_3PO_3(s) \rightarrow PH_3(g) + 3H_3PO_4(s)$$

(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]**

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 m^3. 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 phosphine, obtaining a volume of 1258 cm^3. 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 cm^3

Exemplar 3

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

$$4H_3PO_3(s) \rightarrow PH_3(g) + 3H_3PO_4(s)$$

(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.

$PV = nRT$

P → 100, V → dm^3, n → mol^{-1}, R → 8.314, T → 200 + 273

$200 + 273 = 473$

$100 \times V = (3.2 \times 10^{-2}) \times 8.314 \times 473$

$100 \times V = 125.840704$

$V = 1.25840704$

$= 1.26\ dm^3 \times 1000$

~~(1262.80)~~

$= 1258.41\ cm^3$

volume of PH_3 = ~~1226~~ 1258.41 cm^3 **[4]**

Question 22(b)(ii)

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

Construct an equation for this reaction.

.... **[1]**

Most candidates were able to write a correctly balanced equation for this reaction.

Question 23(a)(i)

23 This question is about energy changes and rate of reaction.

(a) Magnesium reacts with aqueous silver nitrate, $AgNO_3(aq)$, as in **equation 23.1**.

$$Mg(s) + 2AgNO_3(aq) \rightarrow 2Ag(s) + Mg(NO_3)_2(aq) \qquad \textbf{Equation 23.1}$$

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

- The student adds $25.0\,cm^3$ of $0.512\,mol\,dm^{-3}$ $AgNO_3$ to a polystyrene cup.
- The student measures the temperature of the solution.
- The student adds a small spatula measure of magnesium powder, stirs the mixture and records the maximum temperature.

Temperature readings

Initial temperature	= 19.5 °C
Maximum temperature	= 47.5 °C

(i) Calculate $\Delta_r H$, in $kJ\,mol^{-1}$, for the reaction shown in **equation 23.1**.

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

Assume that the density and specific heat capacity, *c*, of the solution are the same as for water and that all the aqueous silver nitrate has reacted.

$\Delta_r H$ = ... $kJ\,mol^{-1}$ **[4]**

Candidates are well-versed with the relationship $q = mc\Delta T$ and most were able to calculate that 2.926 kJ of energy was released in this reaction. It was also common to see the amount of $AgNO_3$ correctly calculated as 1.28×10^{-3} mol. Candidates were expected to determine the amount of energy released from 1 mol $AgNO_3$ as 229 kJ and finally to multiply this value by 2 for the molar quantities in the equation to match the 'enthalpy change of reaction'. It was common to see –229 given as the final answer but this was rarely multiplied by 2. The question also required the final answer to be given to an appropriate number of significant figures. Many candidates seemed to be unaware that this reflects the least significant figure provided in the data, in this case 3 significant figures. The exemplar shows a typical response for 3 of the available 4 marks. Many omitted the negative sign in their ΔH value to consider the exothermicity of the reaction. Candidates are also advised to only round at the end of a multi-step calculation. Rounding of intermediate values introduces rounding errors in the final answer.

Answer = –457 kJ mol^{-1}

Exemplar 4

(i) Calculate $\Delta_r H$, in kJ mol^{-1}, for the reaction shown in **equation 23.1**.

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

Assume that the density and specific heat capacity, *c*, of the solution are the same as for water and that all the aqueous silver nitrate has reacted.

c = 4.18 ~~density = 1.00 g dm^3~~ Q = mcΔT

ΔT = density = 1.00 g cm^3

Q = 25 × 4.18 × 28 ~~n = $\frac{M}{Mr}$~~ n = cV

Q = 2926 J

Q = 2.926 kJ

n = $\frac{25}{1000}$ × 0.512

n = 0.0128

$\frac{2.926}{0.0128}$ = ~~228.60~~ 228.59375

$\Delta_r H$ = ...229...... kJ mol^{-1} **[4]**

Question 23(a)(ii)

(ii) At the end of the experiment, the student adds a few drops of aqueous sodium chloride to the reaction mixture in the polystyrene cup to test whether all the aqueous silver nitrate has reacted.

Explain how the results would show whether all the aqueous silver nitrate has reacted. Include an equation with state symbols in your answer.

....

....

....

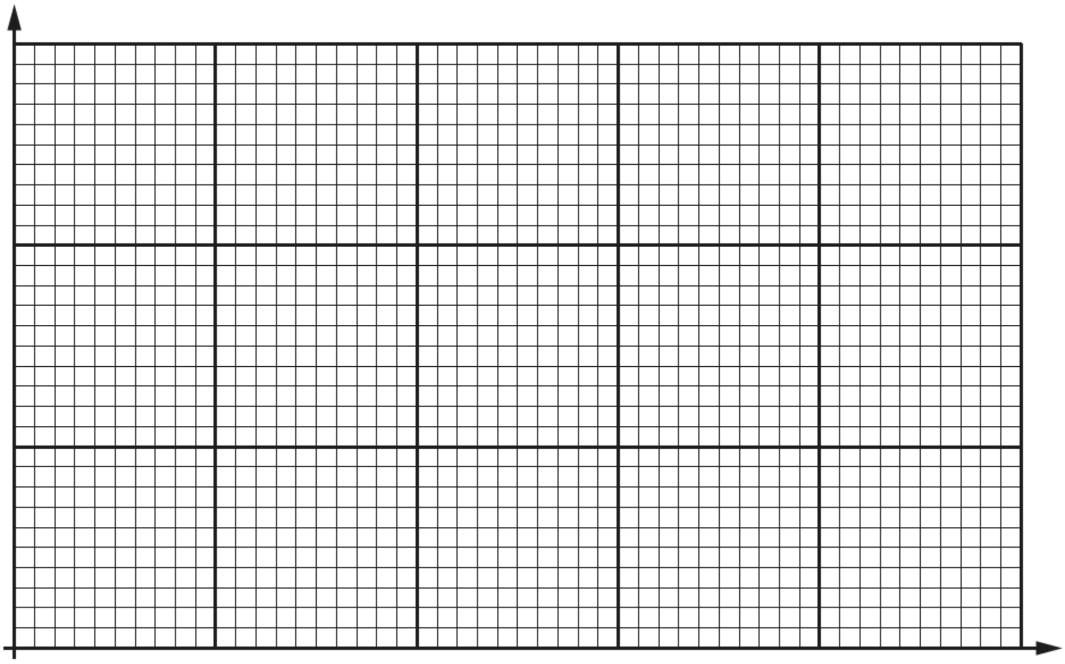
.... **[2]**

Most candidates recognised that silver nitrate and chloride ions react together to form a white precipitate, but many did not make the link between this observation and whether any silver nitrate was left unreacted. Many candidates did not give a correct equation, with missing or incorrect state symbols being common. This question discriminated extremely well.

Question 23(b)

(b) Using the Boltzmann distribution model, explain how the rate of a reaction is affected by temperature.

You are provided with the axes below, which should be labelled.



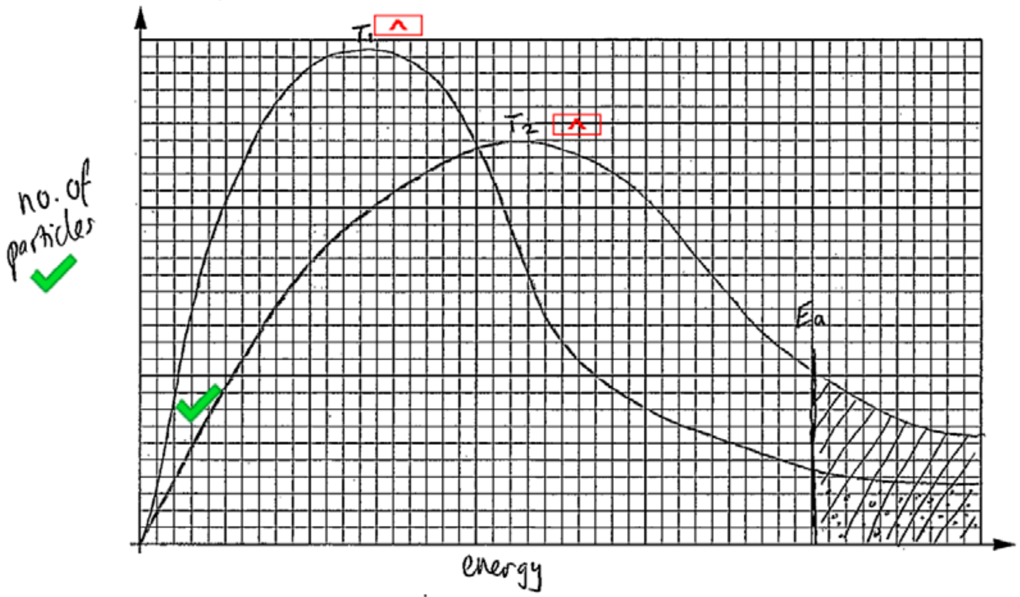
[4]

Overall, this question was answered well. Most candidates showed two Boltzmann distribution curves at different temperatures. Labelling of the axes was usually correct, although the labels were sometimes seen the wrong way around. Most candidates were aware that more molecules possessed the required activation energy at a higher temperature, although lower ability candidates discussed frequency of collisions instead. Strangely, many good responses were spoilt by not labelling which of the two curves was at higher temperature. This is shown in the otherwise excellent response in the exemplar.

Exemplar 5

(b) Using the Boltzmann distribution model, explain how the rate of a reaction is affected by temperature.

You are provided with the axes below, which should be labelled.



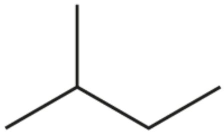
The increase in temperature shifts the curve to the right allowing more particles to have ~~the~~ energy above the activation energy shown by greater area over Ea under Curve T_2 than under curve T_1

[4]

Question 24(a)

24 This question is about saturated hydrocarbons.

(a) 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]**

This question discriminated well and resulted in a full range of marks. Most candidates were aware that structural isomers have different structural formulae 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 C_5H_{12}. 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.

Question 24(b)(i)

(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]**

Most candidates identified this reaction as radical substitution.

Question 24(b)(ii)

(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]

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.

Question 24(b)(iii)

(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.

Compound D

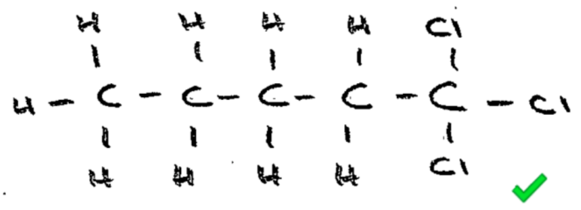
Equation .... **[2]**

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.



Compound D

Equation $C_5H_{12(g)} + 3Cl_{2(g)} \rightarrow C_5H_9Cl_{3(l)} + 3HCl_{(g)}$ **[2]**

Question 25(a)(i)

25 This question is about reactions involving alcohols.

(a) Three reactions of an alcohol **E** are shown in **Fig. 25.1**.

(i) Complete **Fig. 25.1** to show the structures of the organic products formed in the reactions.

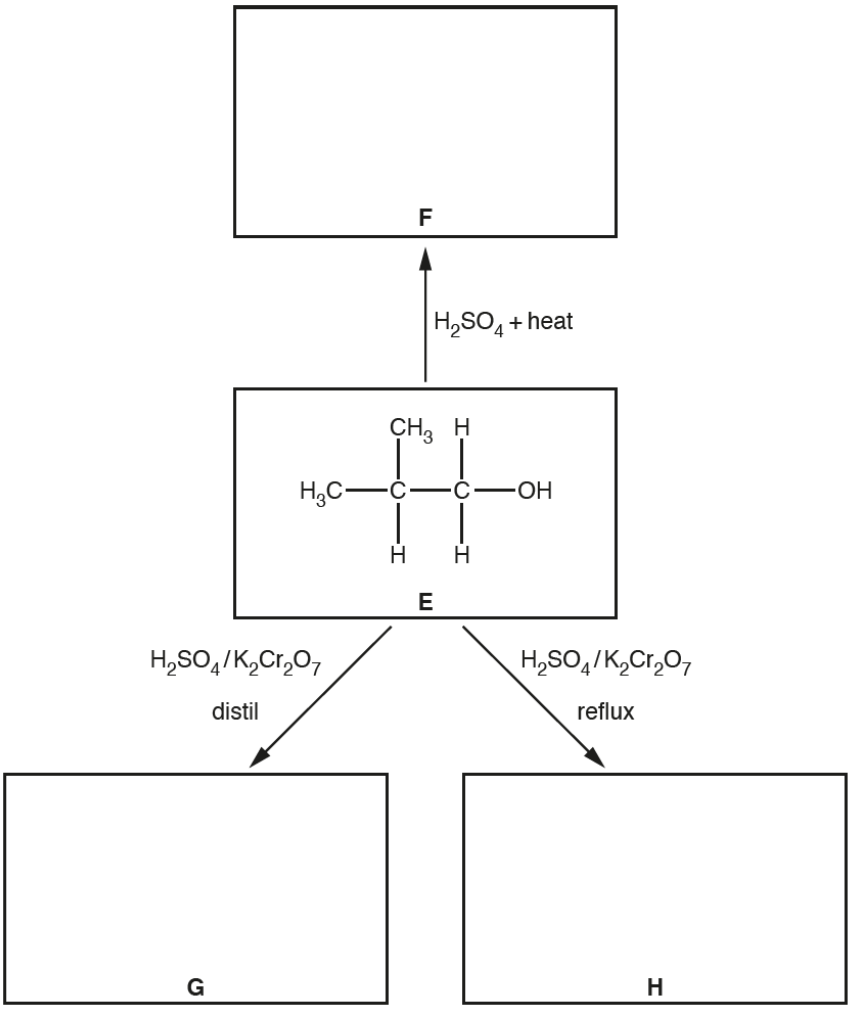


Fig. 25.1

[3]

(ii) What is the systematic name of alcohol **E**?

.... **[1]**

Part (i) discriminated extremely well and rewarded the well-prepared candidate. Compound F proved to be the most difficult option, with a large variety of responses, many appearing to be guesses. Candidates were much more successful with compounds **G** and **H**, although these were sometimes shown in reverse order. A significant number of candidates drew structures containing C=C or C=O bonds in which the carbon atom had five bonds. Candidates should check drawing of organic structures carefully to ensure that all carbon atoms have four bonds.

There were some good responses for part (ii), with many clearly shown and correct systematic names.

Question 25(b)(i)

(b) An alcohol can be prepared by hydrolysing the haloalkane $C_2H_5CHBrCH_3$ with aqueous sodium hydroxide.

(i) Outline the mechanism for this reaction.

Show curly arrows and relevant dipoles.

[3]

As with 25(a)(i), this question rewarded the well-prepared candidate. The large number of proposed mechanisms showed little resemblance to the accepted mechanism for nucleophilic substitution. Mechanisms were often seen showing curly arrows going in the wrong direction and between the wrong bonds and atoms, charges and dipoles were often incorrect, and partial changes used where full charges were required.

Two exemplars are shown. The first exemplar shows clear curly arrows, the role of the lone pair and all charges correct. The second exemplar shows a typical muddled response. Although the curly arrow from the hydroxide ion has been accurately drawn, the hydroxide ion has a partial charge rather than a – charge. There is also no curly arrow showing breaking of the C–Br bond. The only mark available is for the correct organic product and a Br^- ion.

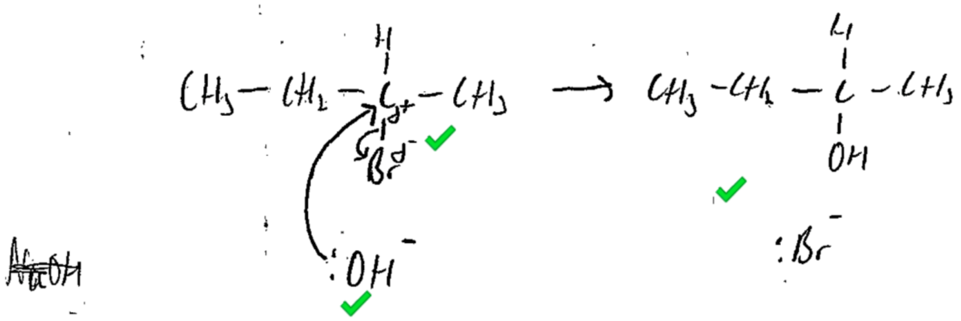
Some mechanisms were so poor that it was impossible to credit many candidates with any marks. Writing mechanisms is an important skill in organic chemistry and it is recommended that candidates learn and practice their writing.

Exemplar 7

(b) An alcohol can be prepared by hydrolysing the haloalkane $C_2H_5CHBrCH_3$ with aqueous sodium hydroxide.

(i) Outline the mechanism for this reaction.

Show curly arrows and relevant dipoles.



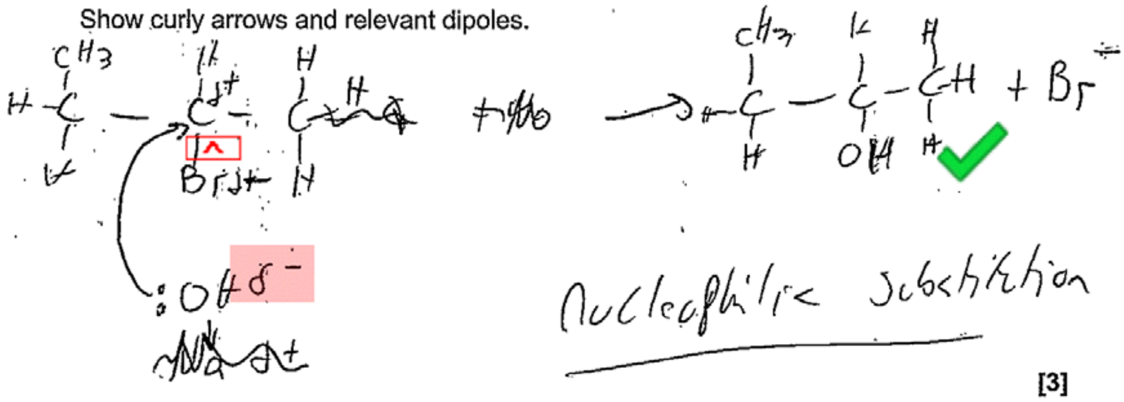
[3]

Exemplar 8

(b) An alcohol can be prepared by hydrolysing the haloalkane $C_2H_5CHBrCH_3$ with aqueous sodium hydroxide.

(i) Outline the mechanism for this reaction.

Show curly arrows and relevant dipoles.



[3]

Question 25(b)(ii)

(ii) The infrared (IR) spectrum for $C_2H_5CHBrCH_3$ is shown in **Fig. 25.2**.
The C–Br bond absorption is labelled.

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Fig. 25.2

Outline how IR spectroscopy could be used to show that the bromoalkane functional group has reacted and that the alcohol functional group has formed.

....

....

....

.... **[2]**

This part discriminated very well with able candidates identifying that the absorption for the C–Br bond would disappear, with a new peak appearing for the alcohol O–H bond. A significant number of candidates did not seem to understand what was required, with many interpreting the spectrum as that of the alcohol, rather than predicting how the spectrum would change during the reaction. A common error was to interpret the absorption for a C–H bond at ~3000 cm^{-1} as that of an O–H bond.

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