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AS LEVEL

Examiners' report

CHEMISTRY A

H032
For first teaching in 2015

H032/01 Summer 2019 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 exam paper can be downloaded from OCR.

Paper 1 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. 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 did the following:	***Candidates who did less well on this paper generally did the following:***
• Demonstrated knowledge and understanding for the filling of orbitals and sub-shells: 21(c); drawing 'dot and cross' diagrams for ionic compounds: 21(d)(i). • Produced clear and concise responses for explanations of chemical knowledge and understanding, e.g. use of Le Chatelier's principle to explain how changing conditions affect the direction of equilibrium shift: 24(b). • Performed calculations using Hess' Law: 24(b)(ii). • Applied knowledge and understanding of radical substitution: 25(b)(i).	• Found it difficult to apply what they had learnt in situations that are unfamiliar. • Produced responses that lacked depth and were often rambling and peripheral to what had been asked, sometimes providing an explanation for a different model entirely; e.g. boiling point trend of halogens: 23(a); ion tests: 23(b). • Did not clearly set out unstructured calculations, e.g. titration calculation: 22(b), percentage uncertainties: 22(c), K_c calculation: 24(a)(ii) and Hess' Law calculation: 24(b)(ii), unstructured molecular formula determination: 25(b)(iii). • Use of significant figures: 22(b) and standard form: 24(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.

Note

From this series students have been provided with a fixed number of answer lines and an additional answer space. The additional answer space will be clearly labelled as additional, and is only to be used when required. Teachers are encouraged to keep reminding students about the importance of conciseness in their answers. Please follow this link to our SIU (https://www.ocr.org.uk/administration/support-and-tools/siu/alevel-science-538595/)

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.

Question 2

2 Which molecule contains the largest bond angle?

A C_2H_4

B H_2O

C NH_3

D CH_4

Your answer ☐ **[1]**

This part discriminated well, with most able candidates selecting the correct answer of A. A sizeable number selected B, accompanied by a diagram of an H_2O molecule with a 180° bond angle, presumably by ignoring the lone pairs. C_2H_4 was often shown with a bond angle of 109.5°, presumably as the C=C bond had not been identified, giving a bond angle of 120°.

Question 4

4 Which chemical process is the most sustainable in terms of the atom economy of the organic product?

A $CO_2 + 3H_2 \rightarrow CH_3OH + H_2O$

B $CH_3CH_2OH + NaCl + H_2SO_4 \rightarrow CH_3CH_2Cl + NaHSO_4 + H_2O$

C $CH_3CH_2Br + NaOH \rightarrow CH_3CH_2OH + NaBr$

D $CH_3CH_2CH_2CH_2OH \rightarrow CH_3CH_2CH{=}CH_2 + H_2O$

Your answer ☐ **[1]**

This part discriminated extremely well. Many scripts showed clear working of the atom economy of each process, the usual result being the correct response of D. Candidates choosing an incorrect process (usually A), often showed no working suggesting the response was a guess. The advice here is obviously to work through calculations before choosing the answer.

Question 5

5 8.0 dm^3 of NO is mixed with 6.0 dm^3 of O_2 at room temperature and pressure (RTP).
The reaction below takes place until one of the reactants is used up.

$$2NO(g) + O_2(g) \rightarrow 2NO_2(g)$$

What is the volume of the mixture at RTP after the reaction has taken place?

A 8.0 dm^3

B 10.0 dm^3

C 12.0 dm^3

D 14.0 dm^3

Your answer ☐ **[1]**

This question proved to be the most difficult of the multiple-choice questions. Candidates clearly did not use the clue in the question: 'until one of the reactants is used up'. Many then responded with C, the volume of NO_2 formed from complete reaction of 6 dm^3 of O_2. D was another common error, which is simply the sum of the volumes of NO and O_2 provided in the question. The correct answer of B required candidate to identify that NO is in excess, reacting with 4 dm^3 of the O_2 to form 8 dm^3 NO_2 and leaving behind 2 dm^3 of O_2, and contributing to a total volume of 10 dm^3 of gas.

Question 6

6 What is the volume of 0.0100 mol of N_2 at 350 °C and 200 kPa?

A 145 cm^3

B 259 cm^3

C 145 dm^3

D 259 dm^3

Your answer ☐ **[1]**

After the difficulties with Question 6, most candidates were able to use the ideal gas equation (annotated on many scripts) to obtain either 259 cm^3 or 259 dm^3. The correct value of B (259 cm^3) revealed the difficulties of unit conversions experienced by many candidates.

Question 9

9 Which reaction shows chlorine only being oxidised?

A $Cl_2 + H_2O \rightarrow HCl + HClO$

B $2ClO_2 + 2NaOH \rightarrow NaClO_2 + NaClO_3 + H_2O$

C $4KClO_3 \rightarrow 3KClO_4 + KCl$

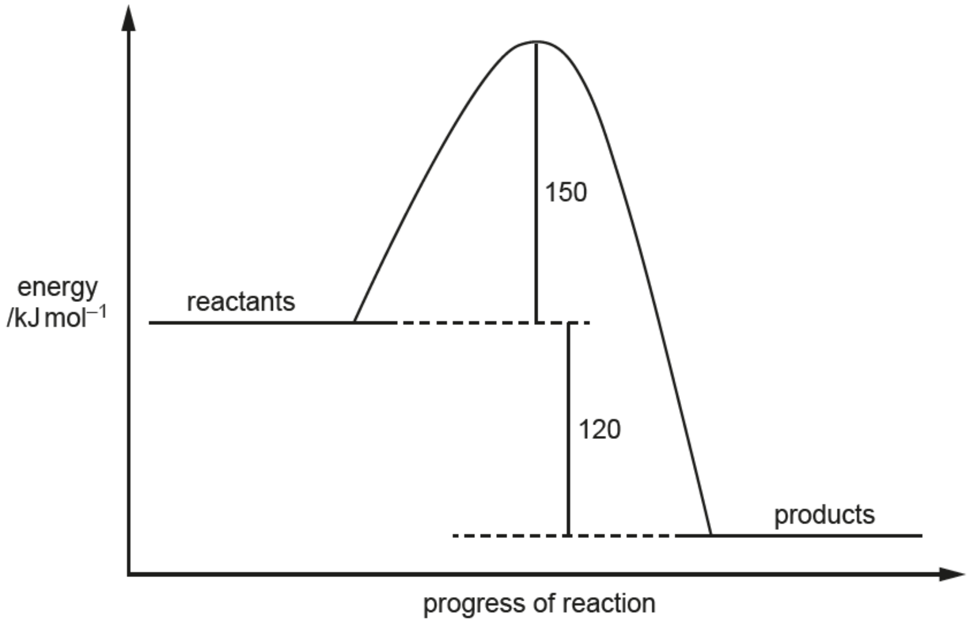
D $MnO_2 + 4HCl \rightarrow MnCl_2 + Cl_2 + 2H_2O$

Your answer ☐ **[1]**

Despite most scripts being covered with annotations of oxidation numbers, only about half of all candidates obtained the correct answer of D.. Option B was the most common incorrect response, followed by option C. The annotations on these scripts often showed incorrect assignments of oxidation numbers.

Question 10

10 A reversible reaction has the enthalpy profile diagram shown below.



Which statement about this reaction is correct?

A The activation energy of the forward reaction is 120 kJ mol^{-1}.

B The activation energy of the reverse reaction is 270 kJ mol^{-1}.

C The enthalpy change of the forward reaction is −30 kJ mol^{-1}.

D The reverse reaction is exothermic.

Your answer ☐ **[1]**

This part discriminated extremely well. Most candidates correctly identified option B but a sizeable number of less able candidates chose the different options in almost equal amounts. It was difficult to recognise where candidates were having problems and the incorrect responses were probably mainly guesses.

Question 11

11 Hydrogen and chlorine react as shown below.

$H_2(g) + Cl_2(g) \rightarrow 2HCl(g)$ $\Delta H^\ominus = -184.6\,kJ\,mol^{-1}$

Which statement about this reaction is correct?

A Less energy is released on bond making than is taken in during bond breaking.

B The enthalpy change for the reverse equation is $+184.6\,kJ\,mol^{-1}$.

C The enthalpy change of formation of $HCl(g)$ is $-184.6\,kJ\,mol^{-1}$.

D The temperature decreases during the reaction.

Your answer ☐ **[1]**

Many candidates found this question difficult with less than half choosing the correct option of B. Options A and C proved to be the main discriminators in almost equal amounts. Although first encountered at GCSE level, energies associated with bond breaking and bond making continue to cause candidates problems at AS and A Level. The discriminator C would have been chosen by candidates who did not recognise that –184.6 kJ is released when 2 mol HCl is formed and that the enthalpy change of formation would be half this value.

Question 12

12 What is the **main** reason for the increase in reaction rate with increasing temperature?

A The activation energy decreases.

B The activation energy increases.

C More molecules have an energy greater than the activation energy.

D The molecules collide more frequently.

Your answer ☐ **[1]**

The role of activation energy in the rate of a reaction with increasing temperature was well-known and most candidates chose the correct option C. From the annotations on candidate scripts, many had ruled out options A and B entirely. D was anticipated as being the main distractor and this proved to be the case. Activation energy has a much greater effect than increasing collision frequency.

Question 14

14 What is the best description for the bonding between the carbon atoms in an ethene molecule?

A One σ-bond and one π-bond

B One π-bond

C Two σ-bonds

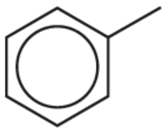
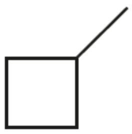
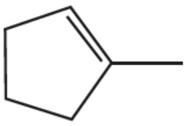
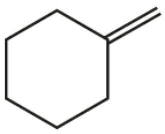
D Two π-bonds

Your answer **[1]**

Candidates answered this question well with over two-thirds choosing the correct option A. Option D was the most common incorrect response suggesting that candidates are uncertain about the nature of a C=C double bond.

Question 15

15 Which compound is unsaturated, alicyclic and contains an alkyl group?

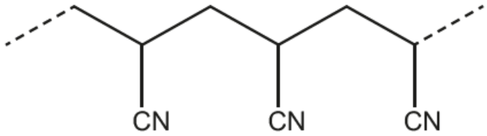
A	
B	
C	
D	

Your answer **[1]**

Unsaturated, alicyclic and alkyl are all terms that are introduced in AS Chemistry and about two-thirds of candidates recognised that option C met the three criteria. From the annotations on scripts, most candidates ruled out the saturated option B. A sizeable number of candidates selected either the aromatic option A, or structure D which does not possess an alkyl group. It is important that candidates learn the terms introduced in the specification Section 4.1.1, Basic concepts in organic chemistry.

Question 17

17 A section of a polymer is shown below.



Which monomer could form this polymer?

A $CH_3CH(OH)CN$

B $HOCH_2CH_2CN$

C $H_2C{=}CHCN$

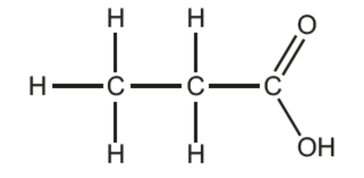
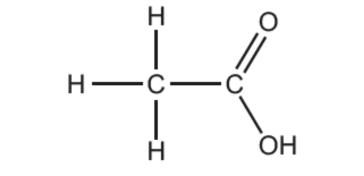
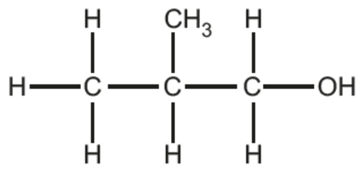
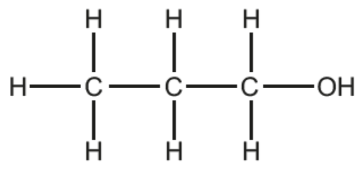
D NCCH=CHCN

Your answer ☐ **[1]**

This part discriminated well. Although most candidates did select C as the correct structure, many were diverted into selecting option D, the other alternative containing a double C=C bond. In identifying a monomer for an addition polymer, candidates are advised to identify the repeat unit and then to replace the single C–C bond with a double bond to give the monomer.

Question 18

18 Which compound is **not** likely to have a fragment ion at $m/z = 43$ in its mass spectrum?

A	
B	
C	
D	

Your answer ☐ **[1]**

Candidates found this part difficult. Less than half the candidates selected the correct option A, with 'B' being the main distractor. From annotations on scripts, successful candidates often drew rings around parts of the structures which helps in identifying parts of a structure that might fragment.

Question 19

19 Which statement about infrared radiation is **not** correct?

A The energy from IR radiation causes some covalent bonds to vibrate more.

B Absorption of IR radiation by some atmospheric gases is linked by some scientists to global warming.

C IR radiation is used to monitor gases causing air pollution.

D The action of IR radiation on CFCs in the upper atmosphere leads to the formation of chlorine radicals.

Your answer ☐ **[1]**

Less than half the candidates correctly chose option D. This part discriminated well, with less able candidates selecting the incorrect A and C in similar amounts. A small number of candidates selected B.

Question 20

20 An unknown compound produces the infrared spectrum below.

Item removed due to third party restrictions

Which compound could have produced the infrared spectrum?

Item removed due to third party restrictions

Your answer ☐ **[1]**

Able candidates selected option B, identifying that the O–H peak matches an alcohol rather than carboxylic acid from the wavenumbers. Many candidates opted for option A, the carboxylic acid, which would have a much broader O–H peak with slightly lower wavenumber range. Annotations were common on the spectrum and a sizeable number labelled the C–H peak with O–H, a clear misconception which was also mentioned in the report for H032/01 from June 2018.

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)

21 This question is about atomic structure and the compounds of calcium, nitrogen and oxygen.

(a) Most elements contain different isotopes.

State **two** differences between isotopes of the same element.

....

....

.... **[1]**

Candidates needed to state two differences for 1 mark. Most candidates selected 'different numbers of neutrons' but this was often followed up by different 'relative atomic mass', the weighted mean of different isotopes, rather than 'different mass' for a single isotope. This suggested that many candidates may not have understood the meaning of 'relative' in 'relative atomic mass'.

Misconception	When discussing the mass of individual isotopes, 'mass' or 'mass number' should be used. The relative atomic mass is the weighted average mass of all of the isotopes of an element, and is consequently the incorrect term to use in this context.

Question 21 (b)

(b) Complete the table for an atom and an ion of two different elements.

Element	**Mass number**	**Protons**	**Neutrons**	**Electrons**	**Charge**
....	....	26	28	....	0
....	80	....	....	36	2−

[2]

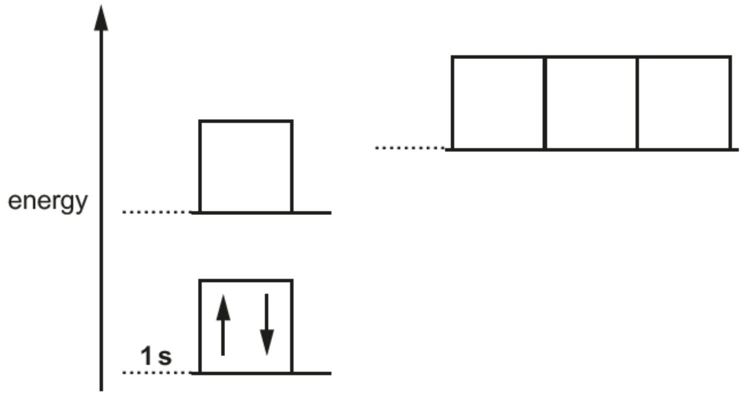
Candidates answered this question reasonably well but many selected incorrect elements despite having identified the correct mass number and numbers of protons, neutrons and electrons. A common error was a mass number of 55.8 for Fe, clearly a confusion between the mass number of an isotope and relative atomic mass (see also comments for 21(a)). Mn was also a common error for the first element, presumably by matching the mass number of 54 with the relative atomic mass of Mn (54.9).

Question 21 (c)

(c) Electrons occupy orbitals which are arranged in energy levels.

In the diagram below, each box represents an orbital and each electron is shown as an arrow.

Label the sub-shells and add arrows to show how electrons occupy orbitals in an atom of **oxygen**.



[2]

Most candidates added arrows correctly to the boxes but the sub-shell labels were sometimes omitted. Lower attaining candidates sometimes paired electrons, rather than showing them singly or showed six electrons in the 2p sub-shell. This suggested either a lack of understanding or failure to read the question.

Question 21 (d) (i)

(d) Calcium reacts with nitrogen to form calcium nitride, Ca_3N_2, which is an ionic compound.

(i) Construct a 'dot-and-cross' diagram for Ca_3N_2.

Show outer electrons only and the charges on each ion.

[2]

Most candidates showed a correct, clear 'dot and cross' diagram. Lower attaining candidates sometimes used wrong charges, not enough ions or an incorrect number of electrons on N. Covalently-bonded molecules were seen, but rarely.

Question 21 (d) (ii)

(ii) Calcium nitride reacts with water to form a solution containing two alkaline compounds.

Write an equation for this reaction.

.... **[2]**

Exemplar 1

(ii) Calcium nitride reacts with water to form a solution containing two alkaline compounds.

Write an equation for this reaction.

$Ca_3N_2 + 3H_2O \longrightarrow 2NH_3 + 3CaO$ **[2]**

Exemplar 2

(ii) Calcium nitride reacts with water to form a solution containing two alkaline compounds.

Write an equation for this reaction.

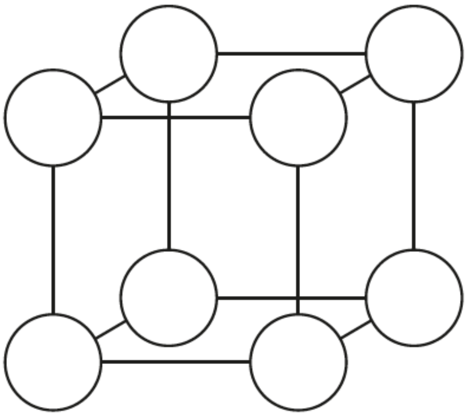
$Ca(NO_3)_2 + H_2O \longrightarrow Ca(OH)_2 + 2HNO_3$ **[2]**

Most candidates were given 1 of the 2 available marks for showing the formula of one correct product, $Ca(OH)_2$ or NH_3. The best answers identified both products and were then able to balance the equation. Common errors included 'CaO' as a product and incorrect compounds of nitrogen (see the two responses above). This part discriminated very well.

Question 21 (d) (iii)

(iii) Calcium reacts with oxygen to form a compound which has a giant ionic lattice structure. The diagram shows ions as circles in part of the lattice.

Complete the diagram by showing the symbols of the ions, including charges.



[2]

Most candidates completed the diagram with correct Ca^{2+} and O^{2-} ions, shown alternately. Many different errors were seen for which 1 of the 2 marks could sometimes be given, e.g. 2+ and 2–, or Ca and O shown alternately. Some candidates used incorrect ions, with N^{3-} the most common as a carry-over from 21d(i) and (ii). Some candidates completed each face of the structure with the same ion, rather than different ions alternately.

Question 21 (d) (iv)

(iv) Nitrogen forms an oxide with the formula N_2O. A molecule of N_2O is linear and has a nitrogen atom in the centre.

Draw a 'dot-and-cross' diagram for an N_2O molecule.

Show outer electrons only.

[2]

N_2O is a very unfamiliar molecule for candidates and they found this 'dot and cross' diagram far more difficult than diagram for Ca_3N_2 in 21(d)(i). Information in the question clearly stated that a nitrogen atom is in the centre but many diagrams were drawn with the O atom at the centre. It was also fairly common to see NO_2 rather than N_2O. Candidates found the bonding of the O atom to the central N atom easier than the double or dative covalent bond between the two N atoms. Many candidates included lone pairs on the central N atom despite this resulting in a non-linear molecule. (The question states that the molecule is non-linear). It was common to see an expanded octet with 10 electrons being involved with the central N atom (a triple and double bond). If correct, this was given, reflecting a candidate's knowledge at this stage of the course. Candidates are advised to take great care in showing clear symbols for electrons (dots and crosses or other symbols). Parts of the diagram where a dot and a cross cannot be distinguished cannot be credited. This part discriminated extremely well.

Question 22 (a) (i)

22 A student carries out a titration to determine the concentration of some hydrochloric acid.

The student titrates the hydrochloric acid against a standard solution of sodium carbonate, Na_2CO_3. The equation is shown below.

$Na_2CO_3(aq) + 2HCl(aq) \rightarrow 2NaCl(aq) + H_2O(l) + CO_2(g)$

- The student prepares 0.150 mol dm^{-3} Na_2CO_3 in a 250.0 cm^3 volumetric flask.
- The hydrochloric acid is added to a 50.0 cm^3 burette.
- The student pipettes the $Na_2CO_3(aq)$ using a 25.0 cm^3 pipette.

(a) The student's burette readings are shown in the table.
The rough titre has been omitted.

(i) Complete the table by adding the titres to the table.

Final reading / cm^3	24.60	48.45	34.30
Initial reading / cm^3	0.40	24.60	10.00
Titre / cm^3	....	....	....

[1]

Most candidates added correct titres for the three titrations. However, an error made by a quarter of candidates was to omit the zero as the second decimal place in the first and third titres. This should have been usual practice from candidate experience of practical work and has also been highlighted as a common error in previous exam series.

Question 22 (a) (ii)

(ii) Calculate the mean titre of HCl, to the nearest 0.05 cm^3, that the student should use for analysing the results.

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

Most candidates identified that the first and third titres were concordant and calculated the mean titre that should be used as 24.25 cm^3. About a third of candidates calculated the mean of all 3 titres as 24.10 or 24.12 cm^3. Normal practice in titrations would be to select the closest titres.

i	**OCR support**	The Practical Skills handbook contains guidance on correct practice for recording titration results and calculating average titre values in Appendix 4: Measurements, which can be shared with students: https://www.ocr.org.uk/Images/208932-chemistry-practical-skills-handbook.pdf.

Question 22 (b)

(b) Calculate the concentration, in mol dm^{-3}, of the hydrochloric acid.

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

concentration of HCl = ... mol dm^{-3} **[3]**

Exemplar 3

(b) Calculate the concentration, in mol dm^{-3}, of the hydrochloric acid.

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

mol = $\frac{m}{Mr}$

mol = conc x vol

Na_2CO_3

$0.180 \text{ moldm}^{-3} \times \frac{25}{1000} = 3.75 \times 10^{-3}$ mol

$Na_2CO_3 + 2HCl$

1 : 2

3.75×10^{-3} mol $\times 2 = 7.5 \times 10^{-3}$ mol of HCl

7.5×10^{-3} mol $\div \frac{24.25}{1000} = 0.30928$ moldm^{-3}

concentration of HCl = 0.309 mol dm^{-3} **[3]**

Many candidates were able to calculate the amount of Na_2CO_3 in the titration as 0.00375 mol although a common error was to calculate the amount of Na_2CO_3 in the 250 cm^3 volumetric flask as 0.0375 mol. Most candidates were credited for the amount of HCl: twice their calculated amount of Na_2CO_3. Candidates then need to scale up this value by 1000/mean titre to obtain the concentration as 0.309 mol dm^{-3}, and to quote the answer to 3 significant figures. Many candidates scaled up using 50.0, the burette volume, rather than their mean titre, resulting in a concentration 0.15 or 1.5 mol dm^{-3}. A significant number also rounded their value to 2 rather than 3 significant figures.

Candidates are advised to show clear working so that credit can be given for such responses by applying error carried forward. The working shown in this response is clear. Many candidates working was more jumbled, with unreferenced numbers common.

Question 22 (c)

(c) In the titrations, the student measured volumes with a pipette and a burette.

- The pipette had an uncertainty of ±0.04 cm^3 in the volume measured.
- The burette had an uncertainty of ±0.05 cm^3 in the volume measured.

Determine whether the volume measured by the pipette or the volume measured by the burette has the greater percentage uncertainty.

[2]

The calculations here should have reflected practical work carried out by candidates. Candidates were expected to realise that the pipette volume involves one measurement requiring the uncertainty of ±0.04 provided being used. As the volume measured by a burette uses two measurements, the uncertainty of ±0.05 must then be doubled to obtain the percentage uncertainty. It was very common for the burette value to be obtained using 0.05 rather than the doubled 0.10; some candidates doubled both uncertainties. Another common error was to use the volume of the burette of 50 cm^3 rather than the volume of solution measured in the burette.

i	**OCR support**	The Practical Skills handbook contains guidance on calculating uncertainties in Appendix 4: Measurements, which can be shared with students: https://www.ocr.org.uk/Images/208932-chemistry-practical-skills-handbook.pdf.

Question 23 (a)

23 This question is about halogens and halides.

(a) The boiling points of the halogens are shown in the table.

Halogen	Boiling point / K
fluorine	85
chlorine	239
bromine	332
iodine	457
astatine	503

Explain the trend in boiling points of the halogens.

.... **[3]**

Exemplar 4

Explain the trend in boiling points of the halogens.

Down group ~~2~~7 the boiling point of the halogens increase, this is because down group 7 the amount of electrons increase which makes the induced dipole-dipole forces stronger and so more energy is required to overcome them.

[3]

This question discriminated well. Candidates were expected to link increasing boiling point down the group with the increasing number of electrons and stronger induced dipole–dipole forces or London forces between molecules that must be broken. To be given all 3 marks, candidates needed to show that intermolecular forces (or forces between molecules) are broken during boiling. This mark proved to be the most difficult. The response shows a typical response that did not include intermolecular forces.

Lower attaining candidates often let themselves down by being unable to construct a well-reasoned, relevant response. Many discussed nuclear charge, shielding, atomic radius and the ease of losing or gaining an electron to produce a valid explanation for ionisation energy or electron gain trend but not for different boiling points. The contrast in the clarity of low- and high-attaining candidate responses was particularly pronounced for this question.

Question 23 (b)

(b) You are supplied with a sample of ammonium bromide.

Describe simple tests that would identify the cation and anion present in ammonium bromide.

Include reagents, expected observations and relevant equations.

....

....

....

....

....

.... **[5]**

This question was best discriminator of the paper and rewarded the well-prepared candidates who were competent in writing equations. Most candidates were given the 2 marks for the bromide test with silver nitrate and the related equation (usually shown ionically). Many found the test for the ammonium ion more challenging to describe. The alkaline nature of ammonia was well-known and the indicator colour change to blue was often seen. Many candidates omitted the NaOH reagent and tested the compound with indicator, thinking that the ammonium ion itself is alkaline. Few candidates were able to write the equation for the ammonium test. Lower attaining students often outlined electrolysis as a test and many candidates wrote about the carbonate and sulfate tests prior to the halide test.

Question 24 (a) (i)

24 This question is about ammonia, NH_3.

(a) In industry, ammonia is made from nitrogen and hydrogen. This is a reversible reaction, as shown in **equilibrium 24.1** below.

$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$ $\Delta H = -92\,kJ\,mol^{-1}$ **Equilibrium 24.1**

(i) Explain how le Chatelier's principle can be used to predict the conditions of temperature and pressure for a maximum **equilibrium** yield of ammonia.

....

....

....

....

....

.... **[4]**

This question was answered well with many candidates being given all 4 marks. Most candidates identified that there are fewer gaseous moles of products and that an increase the pressure will shift the equilibrium position to the right. Although the exothermic nature of the forward reaction was usually identified, candidates sometimes muddled the temperature conditions required, with 'higher temperature' being seen often instead of 'low temperature'. Lower attaining candidates often seemed to confuse equilibrium (in this question) with rates.

Question 24 (a) (ii)

(ii) Using certain conditions, **equilibrium 24.1** has the equilibrium concentrations in the table.

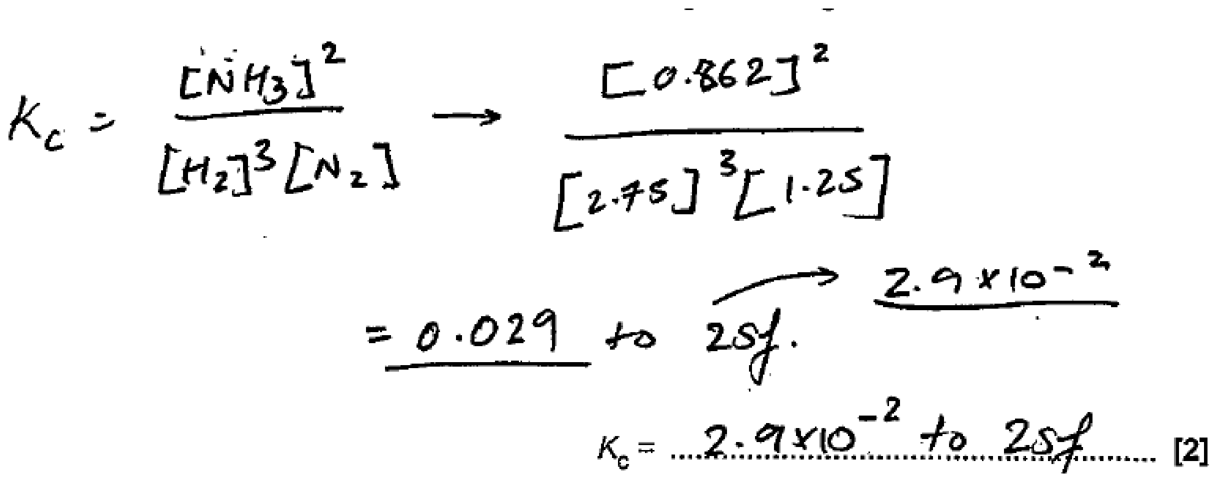
Substance	Equilibrium concentration / $mol\,dm^{-3}$
$N_2(g)$	1.25
$H_2(g)$	2.75
$NH_3(g)$	0.862

Calculate the numerical value for K_c for **equilibrium 24.1** under these conditions.

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

K_c = ... **[2]**

Exemplar 5



This part discriminated well. Most candidates were able to write the correct expression for K_c as the starting point of the calculation. Candidates often got into a muddle in calculating K_c, perhaps due to issues inputting the calculation into their calculators. The question asked for 'an appropriate number of significant figures and in standard form'. As the provided data was all to 3 significant figures, this also indicates the required number of significant figures in the answer. A calculated value to 2 significant figures was often seen (see the response); also 0.0286 rather than the standard form: 2.86×10^{-2}. Some responses showed K_c inverted or added, rather than multiplying the two reactants in the denominator. Other candidates wrote the correct equilibrium expression but were then used 2.75^2, rather than 2.75^3, to obtain the standard form answer of 7.786×10^{-2} or 0.0786 with no standard form. Candidates are advised to check back through calculations to see if they have made any such errors.

Question 24 (b) (i)

(b) Ammonia is used to make nitric acid. The first stage of the reaction is shown below.

$4NH_3(g) + 5O_2(g) \rightarrow 4NO(g) + 6H_2O(g)$ $\Delta H = -908\,kJ\,mol^{-1}$

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

Substance	**$\Delta_f H^\ominus$ / kJ mol^{-1}**
$NH_3(g)$	−46
$O_2(g)$	0
$H_2O(g)$	−242

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

Temperature ....

Pressure ....

[1]

Only just over half of the candidates were able to quote standard conditions for enthalpy measurements. Errors included an incorrect temperature, often 273 and 293 K, or incorrect pressure (e.g. 1000 kPa, 100 atm). Candidates are reminded that 'room temperature' is not a standard temperature – a specific figure must be stated.

Question 24 (b) (ii)

(ii) Calculate the standard enthalpy change of formation for NO(g).

Give your answer to a **whole number**.

$\Delta_f H^\ominus$ for NO(g) = ... $kJ\,mol^{-1}$ **[3]**

Exemplar 6

Give your answer to a **whole number**. P–R = -908 kJ

$NH_3 \times 4 = (-46 \times 4) = -184$

P = -908 + (-184)

P = -1092

6 x -242 = -1482

H_2O + NO = -1092

NO = -1092 - (-1452)

NO = 360

$\Delta_f H^\ominus$ for NO(g) = ...360.......... $kJ\,mol^{-1}$ **[3]**

Most candidates were able to make some progress with the enthalpy calculation. Most recognised that the provided $\Delta_f H$ values had to be multiplied by the balancing numbers in the equation. Correct processing of these values with ΔH for the reaction discriminated well between candidates. The response shows a response that was given 2 out of the 3 available marks. The candidate has correctly calculated +360 kJ mol^{-1} from their enthalpy cycle but has not realised that this value is for 4 mol NH_3 and must be divided by 4 to obtain the enthalpy change of formation of 1 mol of NH_3. It was impressive that the correct answer of +90 kJ mol^{-1} was achieved by about one-third of candidates.

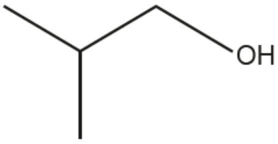
Question 25 (a) (i), (ii) and (iii)

25 This question is about alcohols and alkanes.

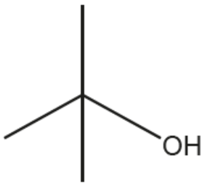
(a) Three alcohols **A**, **B** and **C** are structural isomers of $C_4H_{10}O$.

Each alcohol is refluxed with acidified dichromate(VI), $H^+/Cr_2O_7^{2-}$.

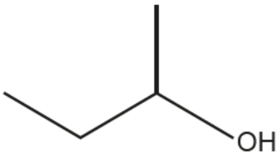
(i) Draw the structures for the organic products.
If there is no reaction, write '**NONE**'.



A →



B →



C →

[3]

(ii) Write the systematic name for alcohol **C**.

.... **[1]**

(iii) Complete the equation below for the complete combustion of alcohol **A**.

$C_4H_{10}O$ .... → .... **[1]**

Part 25(a)(i) discriminated extremely well and rewarded well-prepared candidates. Most candidates recognised that B is a tertiary alcohol and will not react with acidified dichromate. The structure from A was often shown as an aldehyde rather than a carboxylic acid. It was also common for candidates to replace the OH group of A with the carboxyl COOH group, gaining a carbon atom in the chain in the process. The ketone oxidation product from C proved to be easier.

Part 25(a)(ii) proved to be difficult. Candidates need to be careful in identifying the longest carbon chain to derive the stem of an organic name. Many candidates thought that alcohol C was a branched propanol, with 1-methylpropan-1-ol being seen very often instead of the correct name of butan-2-ol.

In part 25(a)(iii), less than half the candidates wrote a correctly-balanced equation for this reaction. Although $4CO_2$ and $5H_2O$ were usually seen for the products, oxygen was usually seen as $6½O_2$, rather than $6O_2$. Candidates need to look very closely at the formula of the organic compound so that the O in $C_4H_{10}O$ is accounted for in the balancing.

Question 25 (b) (i)

(b) Under suitable conditions, butane, C_4H_{10}, reacts with chlorine by radical substitution. A mixture of organic compounds is formed, including C_4H_9Cl, and compounds **D** and **E**.

(i) Complete the table below to show the mechanism for the initiation and propagation stages of the reaction of C_4H_{10} with chlorine to form C_4H_9Cl.

In your equations, use molecular formulae and 'dots' (•) with any radicals.

Initiation	Equation .... Conditions ....
Propagation	.... → .... → ....

[3]

Many candidates scored all 3 marks for this part, showing that most had thoroughly learnt the mechanism for radical substitution. The equation and conditions for the initiation step were well-known but the equations for the propagation steps often included errors. It was common for dots to be omitted for some radicals and C_4H_9Cl•, rather than C_4H_9•, was often shown for one of the products in the first propagation stage. H• was then shown as the other product.

Question 25 (b) (ii)

(ii) Organic compound **D** is formed by substitution of **all** the H atoms in butane by Cl atoms.

Write the equation for the formation of compound **D** from butane.

Use molecular formulae.

.... **[1]**

Only the highest attaining candidates were able to write the correct equation. Although most candidates did identify the organic product as C_4Cl_{10}, the other product was usually seen as $5H_2$ rather than $10HCl$.

Question 25 (b) (iii)

(iii) Organic compound **E** is formed by the substitution of **some** of the H atoms in butane by C*l* atoms.

A chemist found that 0.636 g of compound **E** has a volume of 78.0 cm^3.
Under the conditions used, the molar gas volume is 32.5 $dm^3 mol^{-1}$.

Determine the molecular formula of compound **E**.

molecular formula = ... **[3]**

This question discriminated very well. It was encouraging to see the number of candidates who used 32.5 $dm^3 mol^{-1}$ as the molar gas volume under the experimental conditions to obtain 2.40×10^{-3} mol of gas. Many though used 24.0 $dm^3 mol^{-1}$ for RTP and obtained 3.25×10^{-3} mol. Error carried forward allowed such candidates to still secure the final 2 of the 3 marks available.

Lower attaining candidates were unsure where to start and tried to do anything with the number provided. The result was often n unusable number.

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