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Examiners' report

A LEVEL

CHEMISTRY A

OCR Level 3 Advanced GCE in Chemistry A

H432

For first teaching in 2015

H432/01 Summer 2025 series

Version 1

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Contents

Introduction

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

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

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

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

Paper 1 series overview

H432/01 is the first of the three examination components for GCE Chemistry A. This component is focused on physical and inorganic chemistry and brings together topics from modules 3 and 5 of the specification, including relevant practical techniques. In this paper and H432/02 there is more of an emphasis on knowledge and understanding of the assessment outcomes from the specification, as compared to H432/03 which involves more application of knowledge. The paper consists of two sections, comprised of multiple-choice questions and a mixture of short and long response questions respectively.

Candidates who did well on this paper generally:	Candidates who did less well on this paper generally:
• correct trend on the melting point across period 3 – Question 16 (a) (i) • gave a correct explanation of melting points in terms of structure and bonding – Question 16 (a) (ii) • gave correct observations of colour changes and ionic equation for reactions of group 7 elements – Question 16 (c) • gave the correct shapes and explanations for three different molecules – Question 16 (d) • explained a change in a K_p value due to equilibrium shift and resulting temperature change – Question 17 (c) (iii) • was able to explain pH in terms of both $[H^+]$ and dissociation – Question 19 (b) (i) • could calculate the mass needed for a buffer and give a full description of the action of a buffer – Question 19 (c) • gave correct equations and explanations in terms of e^e values and equilibrium shifts – Question 20 (b) • could fully define a monodentate ligand – Question 21 (b) • could correctly draw a geometric isomer and identify as cis/trans – Question 21 (c) • could explain a titre difference from understanding a novel titration – Question 21 (d) (ii).	• found it difficult to apply what they had learned to unfamiliar situations – Question 21 (d) (ii) • did not clearly set out calculations or give answers to calculations to the specified number of significant figures – Question 17 (a) (ii), 17 (a) (iv), 17 (b), 18 (c) (ii), 19 (a), 21 (d) (i) • were less able to identify shapes, and explain the reasons, for three different molecules – Question 16 (d) • were given some credit for deduction of rate equation and k value – this may have been scored via ecf – Question 18 (b) • were given some credit in identifying oxidation numbers for a disproportionation reaction – Question 19 (b) (ii) • were unable to calculate the mass needed to produce a buffer or describe the action of a buffer – Question 19 (c) • drew an inaccurate or incomplete labelled diagram to measure a standard electrode potential – Question 20 (a) (i) • were able to write electron configurations for transition metals but often unable to write electron configurations for the ion – Question 21 (a) • were able to correctly calculate an empirical formula but not identify coordination number or number of ligands – Question 21 (c).

Section A overview

Candidates needed to make sure their response is clear to the examiner. Well written letters are required, and the candidate should cross-out and rewrite the letter if they need to change their response. Candidates who performed well wrote working next to their responses to aid their choice.

Assessment for learning

There were occasionally some candidates who left some multiple-choice question answers blank. Candidates should provide a response to every multiple-choice question. There is no penalty for giving a wrong response.

Question 1

1 The table shows the number of protons and neutrons in four different atoms.

Atom	Number of protons	Number of neutrons
W	17	18
X	18	18
Y	19	18
Z	18	19

Which two atoms are isotopes of the same element?

A **W** and **X**

B **X** and **Y**

C **X** and **Z**

D **Y** and **Z**

Your answer ☐ **[1]**

The correct answer was C. Incorrect answers were rarely seen as candidates had a secure knowledge of isotopes.

Question 2

2 11.895 g of hydrated cobalt(II) chloride, $CoCl_2 \cdot xH_2O$, is heated to remove the water of crystallisation.

After heating to constant mass, the mass of the anhydrous salt was 6.495 g.

What is the value of **x**?

A 3

B 5

C 6

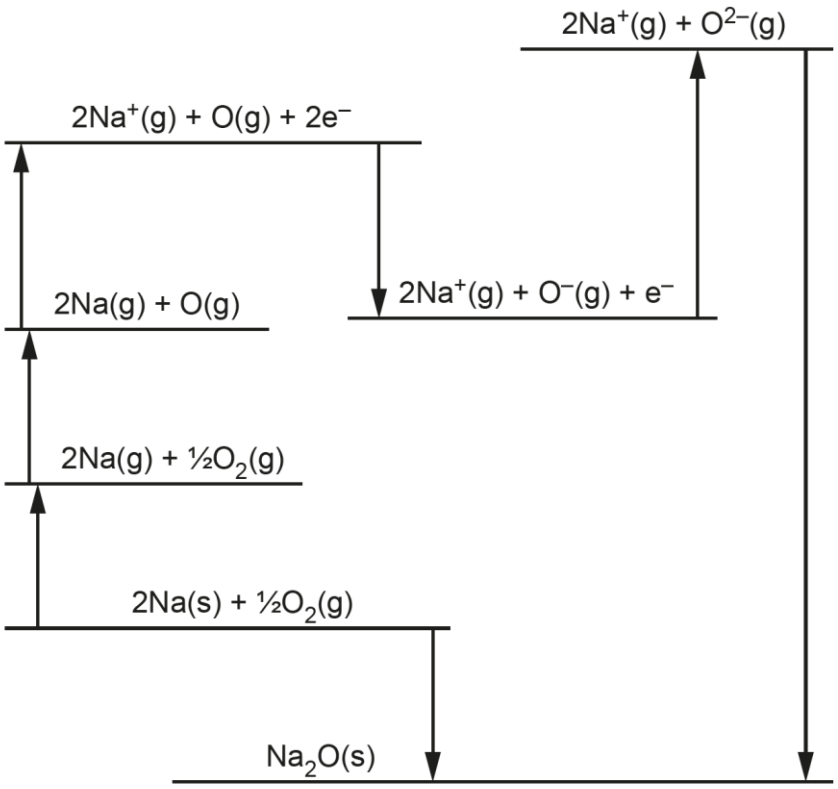
D 7

Your answer ☐ **[1]**

The correct answer was C. Candidates generally were able to complete this calculation to obtain the value for **x** by finding the molar ratio. A few candidates selected A from an incorrect calculation of the number of moles.

Question 3

3 The diagram shows the Born-Haber cycle for sodium oxide, Na_2O.



Why is the value for the second electron affinity of oxygen positive?

A An electron is added to a high energy orbital.

B An electron is added to a negative ion.

C An electron is removed from a gaseous atom.

D An electron is removed from a positive ion.

Your answer ☐ **[1]**

The correct answer was B. Most candidates were able to link the energy required to the repulsion between the negative charges. A few candidates suggested A and C. These candidates did not understand why the 2nd electron affinity is endothermic or that an electron was being added to form the O^{2-} ion.

Question 4

4 What volume, in cm^3, of 0.250 mol dm^{-3} barium hydroxide solution is required to exactly neutralise 25.0 cm^3 of 0.115 mol dm^{-3} hydrochloric acid?

$Ba(OH)_2(aq) + 2HCl(aq) \rightarrow BaCl_2(aq) + 2H_2O(l)$

A 5.75

B 11.50

C 23.00

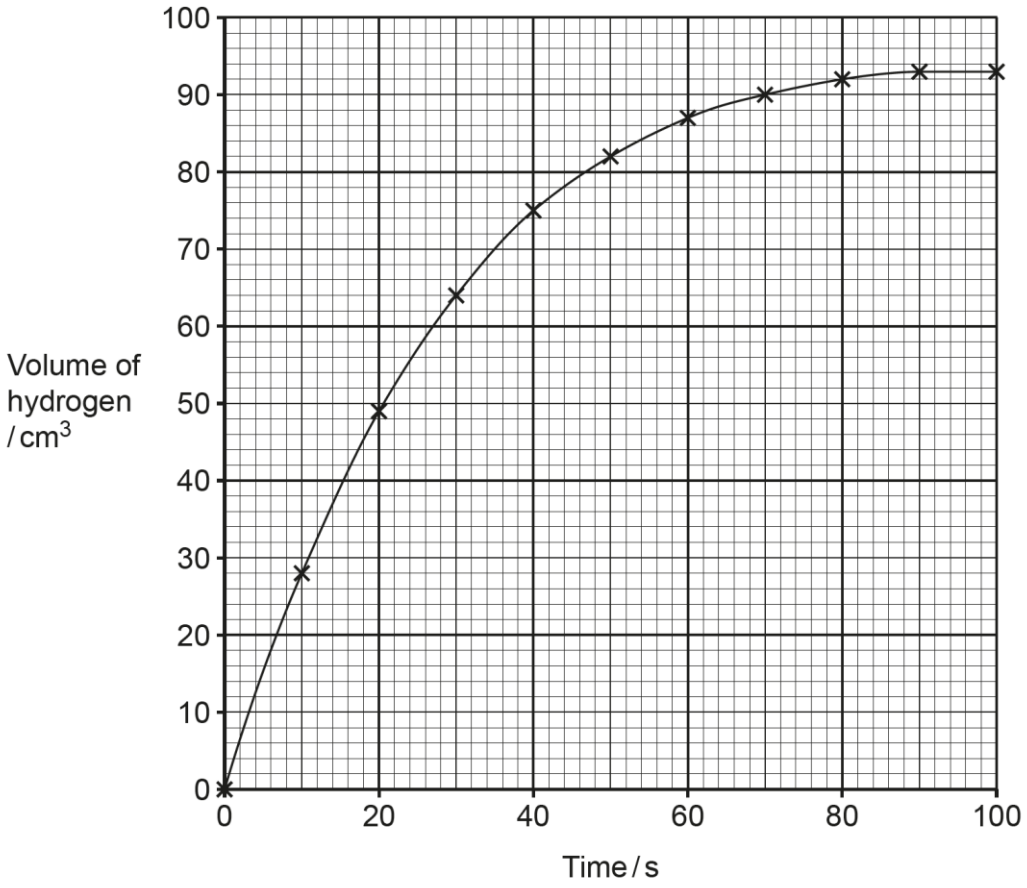
D 54.35

Your answer ☐ **[1]**

The correct answer was A. Most students were able to complete this titration calculation. B was a common incorrect answer seen as candidates did not consider the stoichiometry in the equation.

Question 5

5 The graph shows the volume of hydrogen released over time in a chemical reaction.



What is the rate of reaction, in $cm^3 s^{-1}$, at 30 seconds?

A 0.8

B 1.2

C 2.1

D 2.4

Your answer ☐ **[1]**

The correct answer was B. Candidates had to draw the tangent and calculate the gradient at 30 seconds. The answer should then be selected from the closest value to take the inaccuracy of the tangent into consideration. The most common incorrect answer was C, where candidates incorrectly calculated an average rate for the first 30 seconds.

Question 6

6 Methane reacts with oxygen as shown in the equation:

$CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(g)$ $\Delta_r H = -730\,kJ\,mol^{-1}$

The table shows some bond enthalpies.

Bond	O–H	O=O	C=O
Bond enthalpy / kJ mol^{-1}	+464	+498	+805

What is the bond enthalpy, in kJ mol^{-1}, of the C–H bond in methane?

A +109

B +367

C +435

D +568

Your answer ☐ **[1]**

The correct answer was C. This question was well answered by most candidates. Candidates should be encouraged to use the space around the question to jot down the equation and perform any calculations. Those who obtained an incorrect answer did not consider the number of moles of bonds broken or made and used wrong signs.

Question 7

7 The table below shows the boiling points of some hydrogen halides.

Hydrogen halide	Boiling point/K
HC*l*	188
HBr	206
HI	238

What is the best explanation for the trend in boiling points from HC*l* to HI?

A The strength of the covalent bonds increases.

B The strength of the hydrogen bonds increases.

C The strength of the induced dipole–dipole interactions (London forces) increases.

D The strength of the permanent dipole–dipole interactions increases.

Your answer ☐ **[1]**

The correct answer was C. Candidates generally understood the intermolecular nature of this trend was due to London forces. The most common incorrect answer was D. It is important to make sure that candidates can appreciate that London forces can be more significant/stronger, as the molecule increases in size, compared to other intermolecular forces.

Question 8

8 The burette readings from an experiment are shown:

Final reading / cm^3	29.35
Initial reading / cm^3	2.60

The burette has an uncertainty of $\pm 0.05\,cm^3$.

What is the percentage uncertainty of the titre?

A 0.17%

B 0.19%

C 0.34%

D 0.37%

Your answer ☐ **[1]**

The correct answer was D. This was another well answered question with most of the candidates being given the mark. The idea that the titre reading comes from a subtraction and hence two errors are introduced was better understood than in previous series. Common errors were from not multiplying uncertainty by 2 (response A) and use of the final volume (response B).

Question 9

9 Hydrogen reacts with iodine monochloride, ICl, as shown in the equation:

$H_2 + 2ICl \rightarrow 2HCl + I_2$

The mechanism for the reaction is:

$H_2 + ICl \rightarrow HCl + HI$ slow step

$HI + ICl \rightarrow HCl + I_2$ fast step

What is the rate equation for the reaction between H_2 and ICl?

A rate = $k[HI]\,[ICl]$

B rate = $k[H_2]\,[ICl]$

C rate = $k[H_2]\,[ICl]^2$

D rate = $k[H_2]\,[HI]\,[ICl]^2$

Your answer ☐ **[1]**

The correct answer was B. This question proved slightly more challenging, but a significant number of candidates selected this response. The most common incorrect answer was C due to, presumably, basing their reasoning on the stoichiometric equation rather than the mechanism.

Question 10

10 The overall equation for a hydrogen–oxygen fuel cell is:

$H_2(g) + \frac{1}{2}O_2(g) \rightarrow H_2O(l)$

The half-equation at the negative electrode is:

$H_2(g) + 2OH^-(aq) \rightarrow 2H_2O(l) + 2e^-$

What is the half-equation at the positive electrode?

A $\frac{1}{2}O_2(g) + H_2(g) \rightarrow 2H_2O(l) + 2e^-$

B $\frac{1}{2}O_2(g) + H_2O(l) \rightarrow 2OH^-(aq) + 2e^-$

C $\frac{1}{2}O_2(g) + H_2O(l) + 2e^- \rightarrow 2OH^-(aq)$

D $O_2(g) + 2OH^-(aq) + H_2(g) + 2e^- \rightarrow 2H_2O(l)$

Your answer ☐ **[1]**

The correct answer was C. This question was slightly more challenging for some candidates who often selected B due to incorrectly observing where the electrons were placed.

Question 11

11 Two redox systems are shown below.

$Mg^{2+}(aq) + 2e^- \rightleftharpoons Mg(s)$ $E^e = -2.37\,V$

$Pb^{2+}(aq) + 2e^- \rightleftharpoons Pb(s)$ $E^e = -0.13\,V$

Which species is the strongest reducing agent?

A $Mg^{2+}(aq)$

B Mg(s)

C $Pb^{2+}(aq)$

D Pb(s)

Your answer ☐ **[1]**

The correct answer was B. This was often the most challenging question for candidates. Redox and electrode potentials continue to be a higher-level concept. The terms reducing 'agent' and the species being reduced can often be confused. A good number of candidates did not reverse the more negative equilibrium system before they chose their answer.

Question 12

12 The rate constant, k, for a first order reaction is $6.19 \times 10^{-3} s^{-1}$.

What is the half-life, in s, for the reaction?

A 4.29×10^{-3}

B 49

C 112

D 323

Your answer ☐ **[1]**

The correct answer was C. A good number of candidates chose this response as they were able to recall the mathematical relationship between k and half-life i.e. $k = \ln 2 / t_{1/2}$. The most common incorrect answer was A.

Question 13

13 A mixture of ethanoic acid and ethanol is left to reach equilibrium.

A student determines the amount of ethanoic acid remaining in the equilibrium mixture by titrating the mixture with a solution of sodium hydroxide.

Which row of the table shows a suitable indicator for the titration?

	pH range of the indicator
A	1.2 – 2.8
B	4.8 – 6.0
C	9.4 –10.6
D	12.0 –13.4

Your answer ☐ **[1]**

The correct answer was C. Only some of the candidates selected this response, showing good knowledge of a choice of indicator from a weak acid – strong base titration. B was the most common incorrect response, presumably due to considering the pH of a weak acid.

Question 14

14 Barium is in Group 2 of the periodic table.

Which statement(s) about barium is / are correct?

1 Its outer shell electrons are in an s-orbital.

2 It reacts more vigorously with water than magnesium.

3 It has a higher first ionisation energy than magnesium.

A 1, 2 and 3

B Only 1 and 2

C Only 2 and 3

D Only 1

Your answer ☐ **[1]**

The correct answer was B. Most candidates were able to select this response, showing a good knowledge of group 2 chemistry. Some candidates did not successfully recall the trend in reactivity and/or ionisation energy and selected A or D.

Question 15

15 Chromium forms the complex ions $[Cr(NH_3)_6]^{3+}$ and $[Cr(OH)_6]^{3-}$.

Which statement(s) about the complexes is / are correct?

1 Chromium is in the same oxidation state in each complex ion.

2 The complex ions are different colours.

3 The complex ions have different coordination numbers.

A 1, 2 and 3

B Only 1 and 2

C Only 2 and 3

D Only 1

Your answer ☐ **[1]**

The correct answer was B. Most candidates chose the correct answer but a few selected C or D as they were unsuccessful in assigning oxidation numbers or coordination numbers to the given complex ion.

Section B overview

The section contained questions from all aspects of modules 1, 2, 3 and 5 of the specification. Candidates found many of the questions, including those with an extended response nature, relatively straightforward and the majority managed to cope with the mathematical content.

As a rule, candidates should aim to use unrounded calculator values in their intermediate calculations to avoid rounding errors in their final answer. Candidates should be reminded to present their numerical working clearly. They should also be advised to avoid leaving two different solution approaches without crossing one of them out. If they need to restart an answer, they would be well advised to make use of additional space as necessary rather than trying to write their answers in the margins with the order of steps difficult to follow. In more complicated calculations, where multiple different chemical species and quantities are involved, using appropriate symbols and subscripts/descriptors in brackets, as well as units, helps appropriately identify numbers provided as amounts in moles/concentrations/masses.

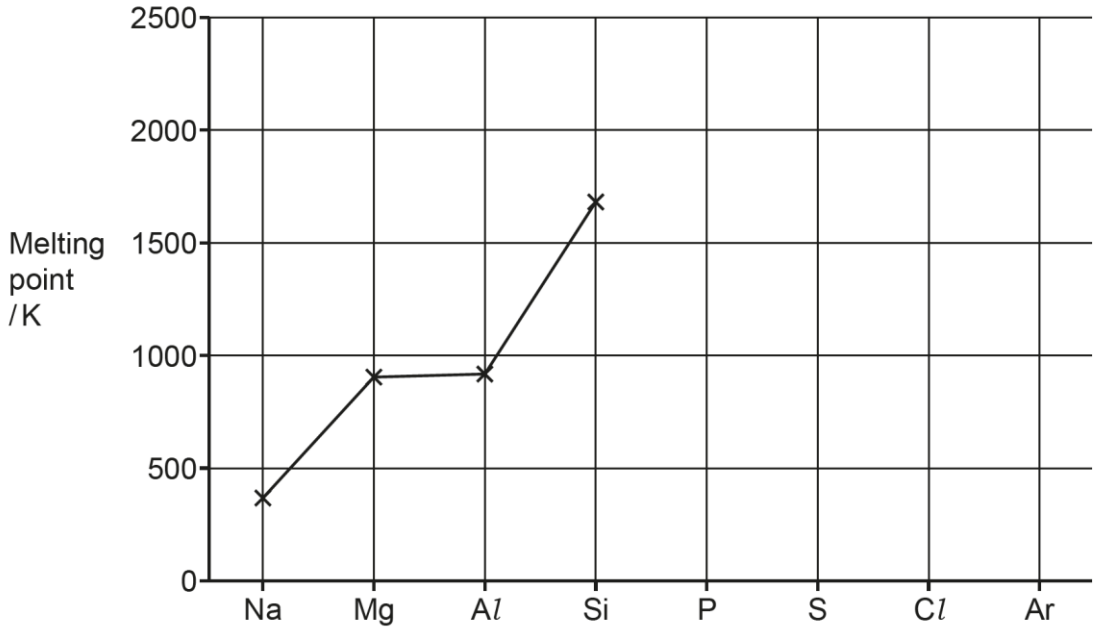
Some candidates were less confident and knowledgeable of content shared with the AS specification and traditionally taught earlier on in the course. These were specifically: structure and bonding, reaction rates and redox reactions of the halogens.

Candidates wrote far more than was necessary in some responses. Candidates should avoid repeating sentences which often introduce contradictions at the end of the response when expanding on written answers. Where candidates make use of additional space, it would be worth reminding them to write down the full question part: in many cases where questions had a number, part and subpart, the part or subpart was missing (or incorrect).

Question 16 (a) (i)

16 This question is about trends in the periodic table.

(a) The graph shows the melting points for Period 3 elements from sodium to silicon.



(i) Complete the graph to show approximate melting points for P, S, C*l* and Ar. **[2]**

This question required the candidates to know the trend in melting points across period 3. This question proved difficult for candidates with few being given both marks. Many candidates did not recognise Mg as a metal with a higher melting point than the non-metals and continued the trend upwards above Si. The candidates may be aware that Ar and Cl_2 are gases at room temperature, but they didn't relate this into the concept of melting points. Some candidates plotted points lower than Mg in a straight line on a downward trajectory. Sulfur, with a higher melting point than phosphorus, appears to be not well-known.

One misconception seemed to be confusing this with a graph for ionisation energy, maybe by using the first ionisation energy data given on the next page.

Question 16 (a) (ii)

(ii) Explain why silicon has a higher melting point than aluminium.

Use ideas about structure and bonding in your answer.

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..... **[3]**

This question required the comparison of structure and bonding. The structure and bonding topic continues to be a difficult one for many candidates. Candidates who did well on this paper were able to identify why each of the elements had a certain magnitude of melting point. They clearly linked the structure type with the type of bonding. They then described the strength of force and gave a detailed description of the bond that was being broken.

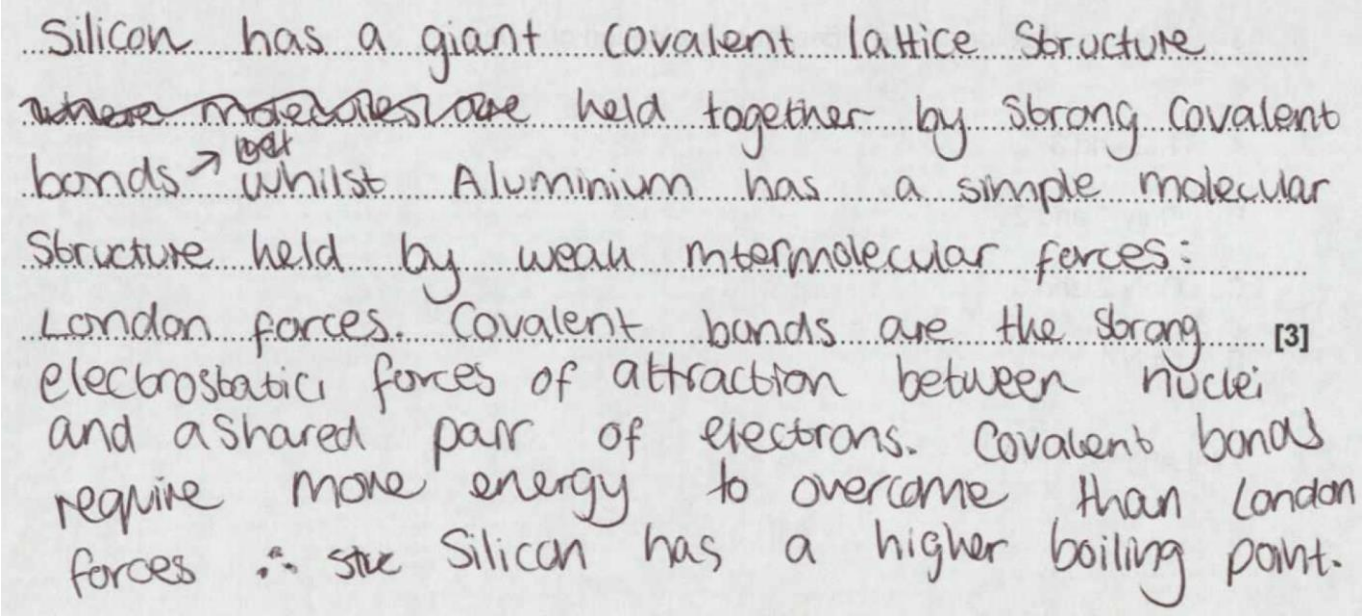
It was very common for 'giant' to be omitted in the name of the lattice for aluminium. Candidates find it particularly challenging to associate the correct terminology with the correct structure, often describing intermolecular forces in giant covalent explanations or use of molecules in giant metallic explanations. London forces were mentioned widely and described when comparing the strength of the bonding and this also appeared after a well written answer causing a CON for the last marking point.

Less successful candidates gave an answer that appeared to confuse the melting point with ionisation energy and described number of electrons, shielding and nuclear attraction.

OCR support

Our bonding delivery guide provides details of common misconceptions students hold relating to this topic, and also includes resources and guidance that can help overcome them: Teach Cambridge (ocr.org.uk)

Exemplar 1


Silicon has a giant covalent lattice structure ~~where molecules are~~ held together by strong covalent bonds → but whilst Aluminium has a simple molecular structure held by weak intermolecular forces: London forces. Covalent bonds are the strong [3] electrostatic forces of attraction between nuclei and a shared pair of electrons. Covalent bonds require more energy to overcome than London forces ∴ the Silicon has a higher boiling point.

The candidate correctly identified silicon as having a giant covalent structure but misidentified aluminium as having a simple molecular structure. This resulted in in incorrect bonding being compared for the final marking point.

Question 16 (b) (i)

(b) The table shows the first ionisation energies for the elements in Period 3.

Element	Na	Mg	A*l*	Si	P	S	C*l*	Ar
First ionisation energy / kJ mol^{-1}	496	738	578	789	1012	1000	1251	1521

(i) Write an equation to represent the first ionisation energy of sulfur. Include state symbols.

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

Most candidates were given this mark. However, there were multiple errors made which included the wrong element, missing or incorrect state symbols, and the formation of a negatively charged ion.

Misconceptions included that a non-metal would form a negative ion, and the sulfur existed as S_8 rather than an atom.

Candidates are advised to make sure that state symbols are clearly written and the (s) and (g) can be easily distinguished by the reader. The convention is to use lower case letters of normal size, e.g. S(s) or S(g).

Question 16 (b) (ii)

(ii) The table shows that there is a general increase in first ionisation energies across Period 3, but that this trend is **not** followed by phosphorus to sulfur.

Explain why the first ionisation energy of sulfur is **lower** than the first ionisation energy of phosphorus.

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

Most candidates were able to explain the lower first ionisation energy in sulfur. The description of the pairing of electrons for sulfur was better for those who used the orbital diagram with electrons clearly paired. Imprecise language was the most common cause of the mark not being given, e.g. 'sulfur has four electrons in the subshell' or incorrectly stating within the orbital. Less successful candidates approached this by explaining in terms of atomic radius, nuclear charge and nuclear attraction which demonstrated that they were not aware of the exceptions to the general trend.

Question 16 (c)

(c) A student adds an aqueous solution of bromine, $Br_2(aq)$, to two test tubes.

The student adds aqueous sodium iodide, NaI(aq), to the $Br_2(aq)$ in one test tube, and aqueous sodium chloride, NaCl(aq), to the $Br_2(aq)$ in the other test tube.

Complete the table to show the student's observations.

Write ionic equation(s) for any reaction(s) that take place.

Solutions	Observations
$Br_2(aq)$ + NaI(aq)	....
$Br_2(aq)$ + NaCl(aq)	....

Ionic equation(s) .....

.....

..... **[3]**

This question required the candidates to know the observations of the reactions of group 7 and to recognise a change in colour to show the evidence of a chemical reaction. This question proved difficult for candidates with few being given all three marks. Colours were not well-known with I_2 in aqueous solution often described as purple. Other incorrect answers included no colours stated, effervescence and descriptions of the formation of the halide precipitates. Several candidates gave an equation instead of an observation. The PAGs – section 1.2.1 (d) mentions accurate use of terminology to describe change instead of just final colours.

A good number of candidates were able to provide the correct ionic equation, although several incorrectly included Na in their equations or wrote half equations. Occasionally candidates wrote more than one incorrect equation, often forming Cl_2.

OCR support

We have produced a teacher and delivery guide to assist with learning about the reaction of group 7 elements and their compounds: Teach Cambridge (ocr.org.uk)

OCR support

Links to the legacy coursework tasks and PAG practice question sets can be found on Teach Cambridge.

Exam hints for students can be found on the OCR website.

Question 16 (d)*

(d)* The hydrides of silicon, phosphorus and sulfur have simple molecular structures, but their molecules have different shapes.

Explain why molecules of SiH_4, PH_3 and H_2S have different shapes.

Your answer should include 'dot-and-cross' diagrams (outer shells only), the names of the shapes and an explanation of why the bond angles are different.

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..... **[6]**

The first level of response question in the paper was answered well. Almost all candidates were able to draw correct dot cross diagrams. Many candidates scored Level 3 with correct shapes, bond angles and gave good explanations of the electron pair repulsion. The mark scheme allowed for the taught bond angle values and the true bond angle values of these molecules which followed the same trend.

Level 2 candidates often had an incorrect shape of either PH_3 or H_2S. The tetrahedral shape for SiH_4 was almost always correct but less successful candidates suggested trigonal planar or bipyramidal for PH_3 and linear for H_2S. Bond angles were often correct with some candidates linking the incorrect angle to their incorrect shape.

Explanations were well described but some candidates were not clear about electron pairs repelling but described atoms or bonds repelling. Some candidates explained the bond angle in terms of being reduced by 2.5° without referencing electron pair repulsion

Most candidates were able to access Level 1 often by having the correct dot cross diagrams.

Question 17 (a) (i)

17 This question is about carbon monoxide and carbon as reducing agents in industry.

(a) Iron(III) oxide, Fe_2O_3, can be reduced by carbon monoxide to form iron.

$Fe_2O_3(s) + 3CO(g) \rightleftharpoons 2Fe(s) + 3CO_2(g)$ **Equilibrium 17.1**

Some standard enthalpy change of formation, $\Delta_f H^\ominus$, and standard entropy, $S^\ominus$, values are shown in the table.

Substance	**$Fe_2O_3(s)$**	**CO(g)**	**Fe(s)**	**$CO_2(g)$**
$\Delta_f H^\ominus$ / kJ mol^{-1}	–824	–111	0	–394
$S^\ominus$ / J K^{-1} mol^{-1}	87	198	To calculate in part **(a)(iv)**	214

(i) Explain why the standard enthalpy change of formation of Fe has a value of 0 kJ mol^{-1}.

.....

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

Most candidates were able to identify that Fe is already in its elemental state and the enthalpy change of formation would, therefore, be 0 kJ mol^{-1}.

Less successful candidates described iron as being in its natural state or an atom and thus didn't have a formation enthalpy.

Question 17 (a) (ii)

(ii) Calculate the enthalpy change, $\Delta_r H$, for the forward reaction in **Equilibrium 17.1**.

ΔH = ... $kJ\,mol^{-1}$ **[2]**

Many candidates were given both marks with the correct answer of -25 kJ mol^{-1}. The best responses showed clear working using a Hess's law cycle.

Common errors of +25 and not using the correct multiples were seen from a few candidates.

Question 17 (a) (iii)

(iii) Explain why the standard entropy of CO_2 is greater than the standard entropy of Fe_2O_3.

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

Many candidates were given both marks with a clear description of the difference in states and a good explanation describing the increase in disorder within a gaseous system. A few candidates linked the standard entropy to the increase in moles (from one mole of Fe_2O_3 to three moles of CO_2), showing a misunderstanding between 'entropy change of reaction' and 'standard entropy'. Occasionally the candidate did not state that Fe was a solid.

Question 17 (a) (iv)

(iv) The standard entropy change, $\Delta S^{\ominus}$, for the forward reaction in **Equilibrium 17.1** has a value of $+15\,J\,K^{-1}\,mol^{-1}$.

Use data from the table to calculate the standard entropy, $S^{\ominus}$, of Fe.

$S^{\ominus}$ = ... $J\,K^{-1}\,mol^{-1}$ **[2]**

Many candidates were given both marks with the correct answer of 27 J K^{-1} mol^{-1}. Common errors saw some candidates quoting +12 from reversing the subtraction and 54 through not dividing by 2.

Question 17 (b)

(b) Carbon can also reduce $Fe_2O_3(s)$ to iron as shown in **Equilibrium 17.2**.

$Fe_2O_3(s) + 3C(g) \rightleftharpoons 3CO(g) + 2Fe(s)$ **Equilibrium 17.2**

$\Delta H = +491\,kJ\,mol^{-1}$

$\Delta S = +543\,J\,K^{-1}\,mol^{-1}$

The forward reaction is only feasible at high temperatures.

- Show that the forward reaction is **not** feasible at 100 °C.
- Calculate the minimum temperature, in K, for the forward reaction to be feasible.

Give the minimum temperature to the nearest whole number.

T = ... K **[3]**

Many candidates scored all three marks. They correctly calculated ΔG, made a feasibility statement and calculated the minimum temperature or 904K or 905K. The alternative methods found in the MS guidance were rarely seen. Nearly all candidates remembered to convert the units which is typically a common error.

Less successful candidates missed the unit conversion (i.e. J K^{-1} mol^{-1} to kJ K^{-1} mol^{-1} for entropy or kJ mol^{-1} to J mol^{-1} for enthalpy) or incorrect temperature used (e.g. 298 K). Sometimes there was a lack of a clear feasibility statement.

Question 17 (c) (i)

(c) Steam can be reduced by carbon monoxide in a reversible reaction.

$H_2O(g) + CO(g) \rightleftharpoons H_2(g) + CO_2(g)$ **Equilibrium 17.3**

$\Delta H = -39.9\,kJ\,mol^{-1}$

At 700 K the value of K_p is 8.13.

(i) Explain why K_p for **Equilibrium 17.3** has no units.

.....

.....

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

This question was well answered by many candidates. There was a clear description of units cancelling, although some did correctly compare the molar ratios. Some candidates showed this in a clearly written equation. Less successful candidates were not given the mark due unclear terminology or explanation. The question was to explain K_p so the units would need to be a pressure unit rather than concentration (as in a K_c expression).

Question 17 (c) (ii)

(ii) An equal number of moles of steam and carbon monoxide are left at 700 K in a sealed container until equilibrium is reached.

At equilibrium, both H_2 and CO_2 have a partial pressure of 211 kPa.

Calculate the partial pressures of H_2O and CO at equilibrium.

Partial pressure of H_2O = ... kPa

Partial pressure of CO = ... kPa

[3]

This question required the calculation of two partial pressures. This question proved to be a challenge for most students.

Common errors were to divide the 5476 by 2 instead of using the square root. Many were given a mark for recognising that the partial pressures needed to be the same. A common error was 602 from the incorrect rearrangement of the K_p expression and some candidates used the value for R (8.31) rather than 8.13 in the Kp expression. Less successful candidates attempted, unsuccessfully, to use an ICE table to work out the moles of everything at equilibrium.

Question 17 (c) (iii)

(iii) At a second temperature the value of K_p for **Equilibrium 17.3** is 129.

Explain whether the second temperature is higher or lower than 700 K.

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.....

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

This question required the candidate to link the change in K_p value to the change in temperature. The question was answered well by many candidates. Most identified it was lower and exothermic, but not all went on to say that equilibrium shifted. A few candidates mixed up their lefts and rights and could be advised to use the terms products side and reactant side, as identified by the written equation.

Misconceptions included that a higher T was because K_p is higher and that 'K_p shifted to the right' rather than the equilibrium.

Question 18 (a) (i)

18 Nitrogen monoxide, NO, reacts with oxygen to form nitrogen dioxide, NO_2.

$2NO(g) + O_2(g) \rightarrow 2NO_2(g)$ **Reaction 18.1**

(a) The rate of reaction increases in the presence of a heterogeneous platinum catalyst.

(i) Explain why platinum is an example of a *heterogeneous* catalyst for **Reaction 18.1**.

.....

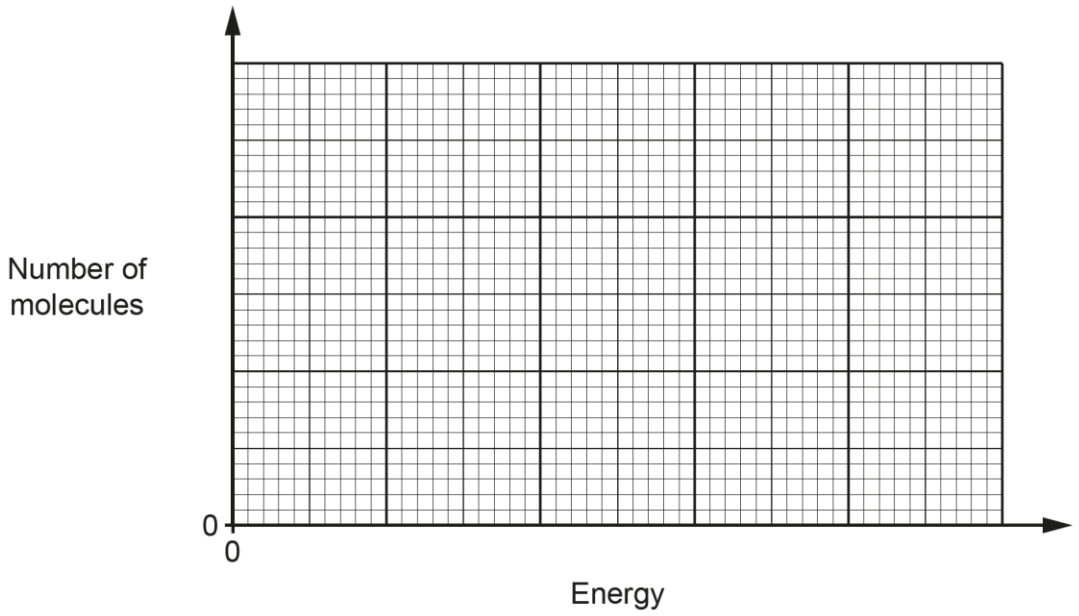
..... **[1]**

This was a well answered question. A few candidates, incorrectly, suggested that it was heterogeneous due to the reactants and products being in different states, and didn't mention the catalyst or suggested the catalyst was in *same* state.

Question 18 (a) (ii)

(ii) Explain how the platinum catalyst increases the rate of reaction.

Include a labelled sketch of the Boltzmann distribution on the grid.



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

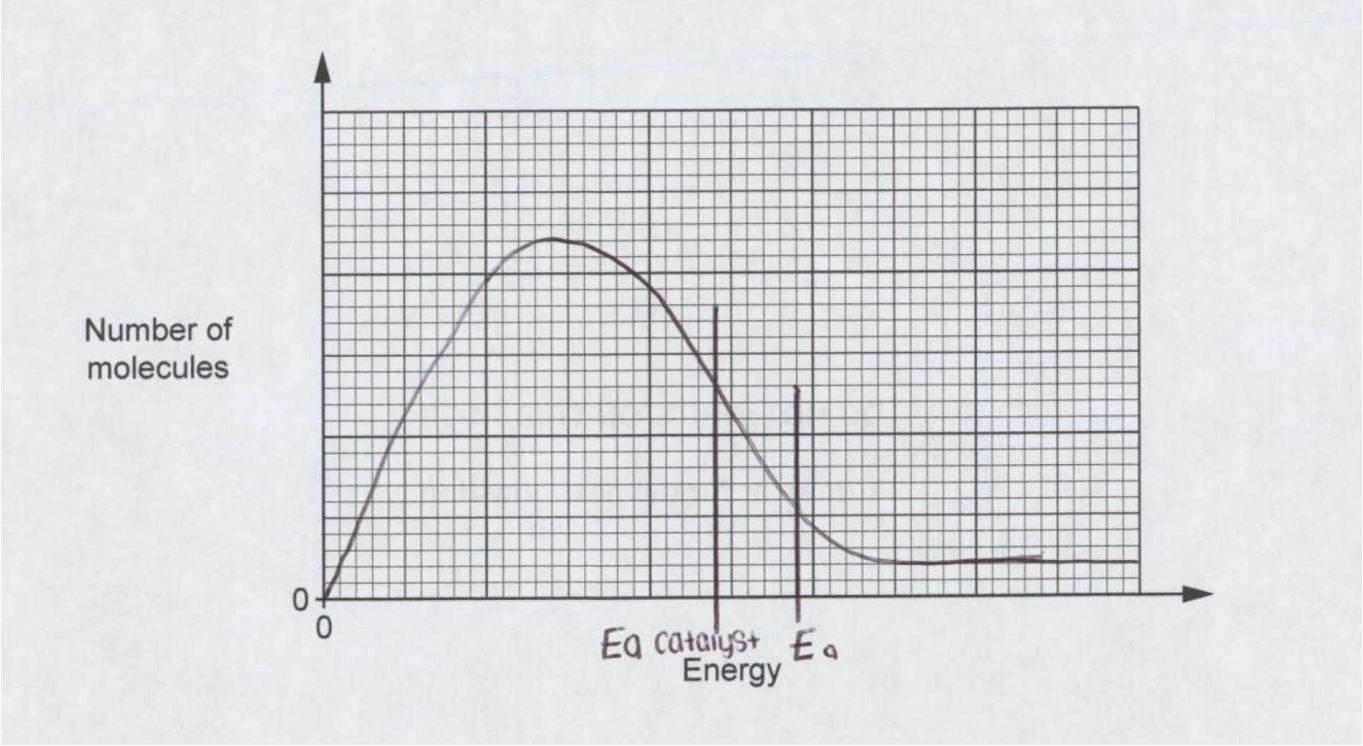
Many candidates gave a good Boltzmann distribution graph, even though a few did not start at the origin, and some were horizontal on the far right-hand side, much above the 0 line. The quality of the Boltzmann distribution could be improved by the candidates, although marks were given. Occasionally candidates drew multiple lines, presumably addressing a change of temperature.

This question proved difficult for some candidates to explain well. Collision theory linked to catalyst requires the link between number of particles having energy ≥ the activation energy. A lot of candidates wrote vague responses, often confusing or mixing temperature and concentration effects and did not gain credit.

Misconception

We have produced a delivery guide on rates with some useful resources to help consolidate ideas and avoid misconceptions such as these: Teach Cambridge (ocr.org.uk)

Exemplar 2



The candidate drew a curve clearly starting at 0,0 but then drew a horizontal line above 0 on the right-hand side. This line would never approach 0 and has a constant number of molecules with the increasing energy and so was not given credit.

Question 18 (a) (iii)

(iii) In industry, catalysts have great economic importance and benefits for increased sustainability.

Explain how the use of catalysts is beneficial to the environment.

.....

.....

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

Most responses were excellent, with many candidates mentioning more than one of the marking criteria. A typical response would be 'lower temperatures can be used, decreasing use of (fossil) fuels, and reducing CO_2 / greenhouse gas emissions.' Some responses instead mentioned that catalysts can be reused. The most common incorrect response was to say fewer toxic products were released or similar.

Question 18 (b)

(b) The following data was obtained in a series of experiments on the rate of the reaction for **Reaction 18.1** at a constant temperature.

Experiment	$[NO]$ / mol dm^{-3}	$[O_2]$ / mol dm^{-3}	rate / mol dm^{-3} s^{-1}
1	0.040	0.035	7.45×10^{-4}
2	0.040	0.070	1.49×10^{-3}
3	0.060	0.035	1.68×10^{-3}

Determine the orders with respect to NO and O_2. Explain your reasoning.

Determine the rate equation and calculate the rate constant, *k*, including units.

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k =..... units .....

[5]

Lots of candidates were given 5 marks. They were able to use the experimental evidence to deduce the orders, write a rate equation and calculate k. The best candidates listed their reasoning for the orders rather than writing in large paragraphs of prose which sometimes got confused and led to contradictions. A good proportion of candidates recognised that 2.25 was 1.5^2, although a few thought that the 2nd order with respect to NO was a result of '2.25 being approximately 2 times 1.5'. Less successful candidates assumed that if they couldn't identify what the relationship was between the concentration and the rate, that meant it was zero order. Less successful candidates were also unsuccessful in working out the units. A few candidates omitted k in their rate equations or didn't write a rate equation. Many candidates were given marks as ECF from incorrect orders.

Question 18 (c) (i)

(c) The rate constant varies with temperature, according to the Arrhenius equation.

A technician determines the activation energy for **Reaction 18.1** by determining the rate constant, k, at different temperatures.

The table shows the technician's results.

Temperature / K	$\frac{1}{T}$ / K^{-1}	k	ln k
1500	6.7×10^{-4}	1.81×10^{3}	7.50
1750	5.7×10^{-4}	8.51×10^{4}	.....
2000	5.0×10^{-4}	2.79×10^{5}	12.5
2250	4.4×10^{-4}	1.47×10^{6}	14.2
2500	4.0×10^{-4}	5.70×10^{6}	15.6

(i) Complete the table by adding the missing value of ln k. **[1]**

Excellent responses were seen with either 11.35 or 11.4 given. A few candidates suggested 10.4 or 11.40. This could have been from completing Question 18 (c) (ii) first and then choosing the value for part (c) (i) based on their line of best fit (e.g. 10.40).

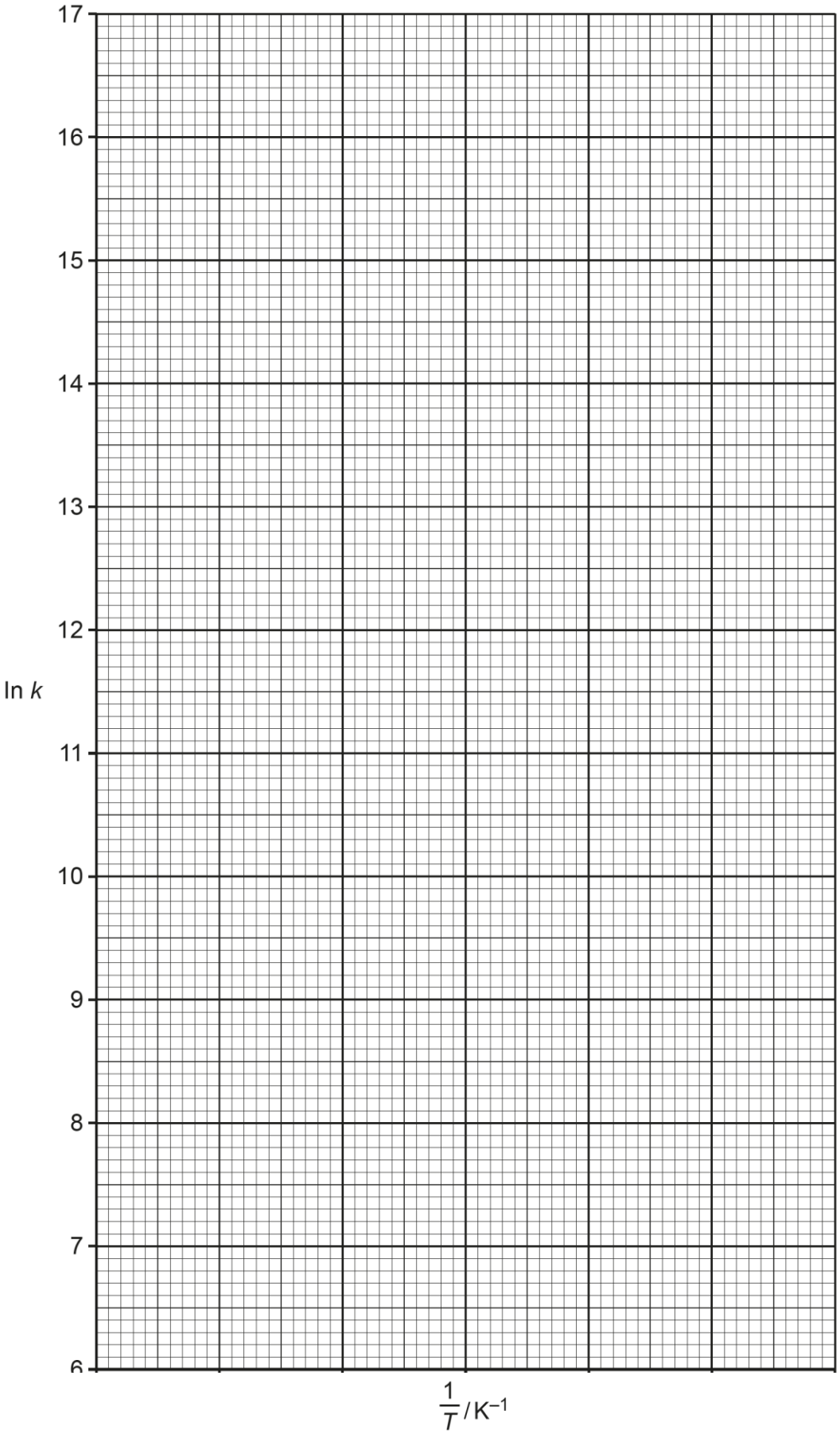
Question 18 (c) (ii)

(ii) Plot a graph of ln k against $\frac{1}{T}$ on the grid opposite.

Use your graph to calculate the value of the activation energy, E_a, in kJ mol^{-1}.

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

E_a = ... kJ mol^{-1} **[4]**



Nearly all candidates were able to draw the line of best fit and linked the equation of a straight line to the equation. A few candidates drew a curve, and some included the anomalous result.

Gradients were calculated with accuracy with a few candidates calculating the gradient using an inverted formula. A few didn't notice the x-axis didn't go to 0, so used Δx in their gradient at -7×10^{-4} and ended up with a gradient of about -12800 and E_a of 110 as ECF.

Most candidates knew to multiply by R but a few incorrectly divided by R. Some candidates didn't give to 2 SF and / or convert to kJ and gave a negative value.

A few candidates tried to substitute values into lnk = - Ea/RT + lnA, rather than use the graph. Many realised that they didn't have a y-intercept and then calculated the gradient. Those that were able to complete the maths calculated the correct answer within the range.

Question 19 (a)

19 This question is about monobasic acids and buffer solutions.

(a) Nitric acid, HNO_3, is a strong monobasic acid.

Calculate the pH of 0.150 mol dm^{-3} HNO_3.

Give your answer to **2** decimal places.

pH = ... **[1]**

Most candidates were successful in calculating pH. A few candidates gave the pH value to 1 or 3 decimal places, and few quoted 13.18 as if HNO_3 were an alkali.

Question 19 (b) (i)

(b)

(i) Nitrous acid, HNO_2, is a weak monobasic acid.

Predict whether the pH of 0.150 mol dm^{-3} HNO_2 is higher, lower or the same as the pH of 0.150 mol dm^{-3} nitric acid, HNO_3.

Explain your answer.

Prediction .....

Explanation .....

.....

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

This question required that the candidate understood that pH was a function of both the dissociation and concentration of H^+ for a weak acid. This did prove more challenging and often was not explained well. Less successful candidates often quoted a lower pH, explained that it didn't fully dissociate (rather than partially dissociate) or didn't link the *number* of H^+ ions to a *concentration*.

Question 19 (b) (ii)

(ii) When heated, aqueous HNO_2 disproportionates. The equation is shown below.

$3HNO_2(aq) \rightarrow HNO_3(aq) + 2NO(g) + H_2O(l)$

- What is meant by **disproportionation**?
- Use oxidation numbers to show that disproportionation has taken place.

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..... **[3]**

This was generally a well answered question from most candidates. The definition requires the use of 'element' rather than the more general term 'species'. Candidates often went on to identify N as the element. Less successful candidates identified H or O from the redox change. A misconception for a few was that an 'atom' was disproportionated without realising this would be impossible. Oxidation numbers were mostly correct and correct oxidation and reduction identified, either by naming compounds in the answer space or labelling them in the equation. Candidates would be advised to make sure that there is a clear link between the oxidation number and the element that it refers to.

Question 19 (c)*

(c)* A student plans to prepare a buffer solution with a pH of 4.85 using propanoic acid, CH_3CH_2COOH, and sodium propanoate, CH_3CH_2COONa.

K_a for $CH_3CH_2COOH = 1.32 \times 10^{-5}\,mol\,dm^{-3}$.

The student mixes $125\,cm^3$ of $0.180\,mol\,dm^{-3}$ $CH_3CH_2COOH(aq)$ with a calculated mass of $CH_3CH_2COONa(s)$. The student assumes that the volume of the solution does not change.

- Calculate the mass of CH_3CH_2COONa needed to make $125\,cm^3$ of a buffer solution with a pH of 4.85.
- Explain why this solution resists changes in pH when a small amount of alkali is added.

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..... **[6]**

This was our second Level of Response question which proved more challenging for candidates. Only a few candidates scored full marks. Candidates are reminded to structure their answers and make sure they answer all points in the question.

Candidates often find pH of buffer solution calculations difficult to process. The most difficult part in this calculation was the concentration of the salt. The majority that calculated salt concentration were able to calculate the mass. We should encourage the candidates to always write the units when calculating any quantity as concentration and moles were often confused within the calculation.

Some candidates were given Level 2 for converting what they thought was the salt concentration into a value for the mass of salt needed, using a correct method. Less successful candidates calculated the correct $[H^+]$ but then used a weak acid calculation approach. A few responses attempted to use the Henderson-Hasselbalch approach, but most were unsuccessful due to the mathematical inaccuracies.

The buffer action description proved to be a more challenging part to the question. Some candidates wrote a clear and concise description, linked to a written equilibrium equation, of the reaction of an alkali and the resulting equilibrium shift. Level 2 candidates often described an equilibrium shift of a non-existent equilibrium equation.

Level 1 candidates were often only able to calculate $[H^+]$ and tried to explain the action of a buffer.

Question 20 (a) (i)

20 Standard electrode potentials for seven redox systems are shown in the table below.

Redox system	Half-equation	$E^{\ominus}$/V
1	$V^{2+}(aq) + 2e^- \rightleftharpoons V(s)$	–1.18
2	$Zn^{2+}(aq) + 2e^- \rightleftharpoons Zn(s)$	–0.76
3	$Co^{2+}(aq) + 2e^- \rightleftharpoons Co(s)$	–0.28
4	$V^{3+}(aq) + e^- \rightleftharpoons V^{2+}(aq)$	–0.26
5	$2H^+(aq) + VO^{2+}(aq) + e^- \rightleftharpoons V^{3+}(aq) + H_2O(l)$	+0.34
6	$Ag^+(aq) + e^- \rightleftharpoons Ag(s)$	+0.80
7	$2H^+(aq) + VO_2^+(aq) + e^- \rightleftharpoons VO^{2+}(aq) + H_2O(l)$	+1.00

(a)
(i) A student sets up a standard cell based on redox systems **2** and **4**.

Draw a labelled diagram to show how this cell could be set up to measure its standard cell potential.

Include the conditions required to measure the standard cell potential.

standard conditions .....

.....

..... **[4]**

Candidates made good progress and produced good diagrams with many given 4 marks. More candidates appreciated how the vanadium half-cell was set up than in previous series.

Common errors were to miss the labelling of the salt bridge or to quote an incorrect temperature, e.g. 273K or 293K. Occasionally a hydrogen electrode was drawn, or V was used instead of Pt. Some candidates put H^+ in with their V^{2+} /V^{3+}.

Question 20 (a) (ii)

(ii) Calculate the standard cell potential of this cell.

standard cell potential = ... V **[1]**

Almost all candidates calculated the standard cell potential correctly. Common errors were -0.5V or -1.02V

Question 20 (b)

(b) A student predicts that cobalt metal will reduce acidified VO^{2+} ions to form V^{2+} ions in two stages.

Explain why this two-stage reduction should happen in terms of electrode potentials and equilibria shifts.

Include overall equations for the predicted reactions.

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.....

..... **[4]**

This question required the candidates to explain the two step reduction of VO^{2+}. The question was only answered well by a few candidates and electrode potentials continues to be a conceptually difficult topic. Choosing the correct systems was difficult for most candidates. Some used the Zn system, perhaps because of the diagram and others joined systems: 4+5, 1 and 7.

Writing the two equations proved challenging. Equations were often unbalanced, written the wrong way round or missing the second reduction step completely. There was evidence of confusion between VO^{2+} and VO_2^+.

When comparing electrode potentials, candidates should avoid the use of higher/lower are these phrases are ambiguous due to the negative signs involved. Phrases such as more negative/less positive removes this ambiguity. Candidates are advised to read the instructions contained within the equation and to use or comment on all the data presented.

Equilibrium shifts were often stated as shifting left/right without making it clear to which equilibrium the candidate was referring to. Often only one equilibrium shift was mentioned.

Candidates should be reminded to use lower case for the second letter in a chemical symbol. CO was often written for Co. While this was accepted for this question, clearly there is a significant chemical difference between these.

Question 21 (a) (i)

21 This question is about reactions of compounds of iron and copper.

(a)
(i) Complete the electron configuration of

an Fe atom: $1s^2$ .....

a Cu^{2+} ion: $1s^2$ .....

[2]

Most candidates were successful in writing the electron configuration for Fe. Many candidates did not realise that when transition metal ions are formed, the first electrons removed from atoms are the 4s electrons and so wrote $2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^7\ 4s^2$. Others, incorrectly suggested, $4s^1$ or $4d^7$.

Question 21 (a) (ii)

(ii) Solutions of iron(II) sulfate, $FeSO_4$, and copper(II) sulfate, $CuSO_4$, can be distinguished by adding aqueous sodium hydroxide.

Describe what would be observed when NaOH(aq) is added to each solution.

Observation with $FeSO_4$(aq) .....

Observation with $CuSO_4$(aq) .....

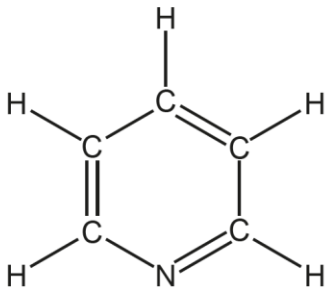
[2]

Most candidates were able to identity the correct colour and followed this by describing a precipitate or solid. A few candidates missed the observation of the precipitate. Incorrect colours suggested were yellow, cream and brown. The latter was perhaps as a confusion with the Fe^{3+} ion.

Question 21 (b) (i)

(b) The cyclic organic compound pyridine, C_5H_5N, can act as a monodentate ligand.

The structure of pyridine is shown below.



(i) What is meant by a **monodentate ligand**?

.....

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

The term 'monodentate ligand' was well-known by most candidates. A few candidates didn't describe the electron pair being donated or forming a coordinate bond. Both these parts were required to be given the mark.

Question 21 (b) (ii)

(ii) An iron(II) complex contains two different ligands: C_5H_5N, and Cl^-.

The complex has a molar mass of 442.8 g mol^{-1} and the following percentage composition by mass:

Fe, 12.6%; C, 54.3%; H, 4.5%; N, 12.6%; Cl, 16.0%

Determine the empirical formula of the iron(II) complex.

Deduce the number of C_5H_5N ligands in the complex and the coordination number of the iron(II) ion.

Empirical formula of iron(II) complex .....

Number of C_5H_5N ligands .....

Coordination number of iron(II) ion .....

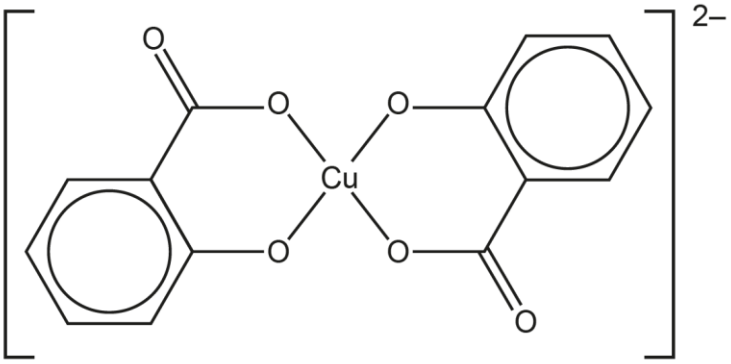
[4]

Most candidates were given full marks. They successfully calculated the empirical formula but a few then grouped the ligands together giving a molecular formula, e.g. $Fe(C_5H_5N_4)Cl_2$. Most candidates then continued and found the number of ligands and coordination number. Occasionally coordination number was mixed up with the charge on the ion.

Question 21 (c)

(c) Aqueous copper(II) sulfate reacts with salicylic acid to form a complex ion which has two stereoisomers.

One isomer of the complex ion is shown:



Draw the other stereoisomer of the complex.

Identify the type of stereoisomerism shown by the complexes.

Type of stereoisomerism ..... **[2]**

This question required the candidates to identify the isomerism in an unfamiliar complex. This question was one of the more demanding ideas on the paper. A few candidates successfully drew the cis isomer and identified the type as cis/trans isomerism. Many candidates suggested, incorrectly, that the isomerisation was optical. A few did draw the cis complex ion but then identified the isomerism as optical.

Question 21 (d) (i)

(d) **Mixture A** is a mixture of copper(II) sulfate crystals, $CuSO_4 \cdot 5H_2O$ and iron(II) sulfate crystals, $FeSO_4 \cdot 7H_2O$.

A student carries out a titration to determine the percentage by mass of $CuSO_4 \cdot 5H_2O$ in **Mixture A**.

The student uses the following method.

Step 1 Dissolve 9.51 g of **Mixture A** in water and make up the solution to 250.0 cm^3 in a volumetric flask.

Step 2 Pipette 25.0 cm^3 of the solution from **Step 1** into a conical flask and add an excess of aqueous potassium iodide, KI(aq).

The copper(II) ions react with iodide ions to form a precipitate of copper(I) iodide and a solution of iodine.

$2Cu^{2+}(aq) + 4I^-(aq) \rightarrow 2CuI(s) + I_2(aq)$

Step 3 Titrate the contents of the conical flask from **Step 2** with 0.0800 mol dm^{-3} sodium thiosulfate, $Na_2S_2O_3$, using starch as the indicator.

$I_2(aq) + 2S_2O_3^{2-}(aq) \rightarrow 2I^-(aq) + S_4O_6^{2-}(aq)$

Step 4 Repeat **Step 2** and **Step 3** to obtain concordant titres and calculate the mean titre.

Results

Mean titre = 31.15 cm^3

(i) Calculate the percentage by mass of $CuSO_4 \cdot 5H_2O$ in **Mixture A**.

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

Percentage of $CuSO_4 \cdot 5H_2O$ in **Mixture A** = ... % **[5]**

This calculation was answered well by many candidates. It is good to see that the level of communication throughout the multistep calculations is improving compared to previous series, although some candidates are still writing numbers with no indication as to what the number relates to. Annotation allows ECF to be given to a correct method, despite an incorrect value being given during the process. This also, more importantly, allows to candidate to remain focused on what is being calculated.

The key steps were:

- Calculating the number of moles of $S_2O_3^{2-}$
- Using the molar ratio to link to the number of moles of Cu^{2+}
- Calculating the number of moles in the original volume

Calculating the mass by multiplying the moles of Cu^{2+} by the RFM of the hydrated copper sulfate.

- Calculating the percentage in the mixture

Common errors were that candidates:

- Forgot to use the ratio within the equation.
- Forgot to x 10 to calculate the moles in the original sample.
- Used the incorrect RFM of copper sulfate or a combined RFM of the two salts $CuSO_4.5H_2O$ and $FeSO_4.7H_2O$.
- Divided the total mass of both salts (9.51) by the number of moles of $CuSO_4$ to get a combined M_r.

Exemplar 3

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

$n(S_2O_3^{2-}) = cV$

$= 0.08 \times 0.03115$

$= 2.492 \times 10^{-3}$ mol

$n(I_2) = \frac{1}{2} \times n(S_2O_3^{2-})$ due to 1:2 molar ratio

$= 1.246 \times 10^{-3}$ mol

$n(Cu^{2+}) = 2 \times n(I_2)$ due to 2:1 molar ratio

$= 2.492 \times 10^{-3}$ mol in 25 cm^3

$n(Cu^{2+})_{250} = 2.492 \times 10^{-3} \times \frac{250}{25}$

$= 0.02492$ mol in 250 cm^3

$n(CuSO_4 \cdot 5H_2O) = n(Cu^{2+})$

$= 0.02492$ mol

Mr $(CuSO_4 \cdot 5H_2O) = 249.6$

$m(CuSO_4 \cdot 5H_2O) = n \times Mr$

$= 6.22$ g (3sf)

% mass $= \frac{6.22}{9.51} \times 100$

$= 65.4\%$ (3sf)

Percentage of $CuSO_4 \cdot 5H_2O$ in **Mixture A** = 65.4 % **[5]**

The candidate has produced a correct and fully annotated calculation. This clarity allows the candidate to remain focused on each calculation step. Any miscalculation could then easily gain ECF through a clear method.

Question 21 (d) (ii)

(ii) The student repeats their method, but after carrying out **Step 1** they leave the solution exposed to the air for a few days.
Some of the iron(II) sulfate is oxidised to iron(III) sulfate.

The student then continues with **Step 2**, **Step 3** and **Step 4** of the method.

This mean titre is greater than 31.15 cm^3.

Suggest why this mean titre is greater than 31.15 cm^3.

.....

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

Candidates found this question quite challenging, with only a few giving a correct explanation.

A common incorrect theme among less successful candidates was to consider that since it was a titration, then it must be a neutralisation reaction. Common errors involved the suggesting that evaporation of the water concentrating the copper solution, a bigger RFM, and confusion between SO_4^{2-} and $S_2O_3^{2-}$. A fair number of candidates did not attempt this question.

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