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Examiners' report

CHEMISTRY A

H432

For first teaching in 2015

H432/01 Summer 2024 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 answers is also provided. The reports will also explain aspects which caused difficulty and why the difficulties arose, whether through a lack of knowledge, poor examination technique, or any other identifiable and explainable reason.

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

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

Paper 1 series overview

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:
• produced clearly structured working for calculations – Questions 16 (a),16 (c) (ii), 18 (a), 19 (a) (iii), 19 (b) (i), 21 (b), 22 (c) • produced clear and concise responses for the two Level of Response questions – Questions 17 (b) and 20 (c) • produced clear and concise responses to describe a polar molecule – Question 18 (b) (ii) • deduced the rate determining step and rate equation – Question 20 (b) • correctly used electrode potentials – Question 21 (d) (ii) • wrote a formula for an unfamiliar complex ion – Question 22 (b) (ii) • deduced the oxidation numbers of an unfamiliar compound • drew an enthalpy profile for an exothermic or endothermic reaction – Question 16 (b) (i) • drew a labelled diagram to measure a standard electrode potential.	• found it difficult to apply what they had learned to unfamiliar situations • produced unstructured responses to Level of Response questions which were lacking in depth or used incorrect terminology – Questions 17 (b) and 20 (c) • did not clearly set out calculations, making it difficult for marks to be given for working – Questions 16 (a), 16 (c) (ii), 18 (a), 19 (a) (iii), 19 (b) (i), 21 (b), 22 (c) • did not give answers to calculations to the specified number of significant figures – Questions 18 (a) (i), 19 (a) (iii), 21 (b) • did not appropriately convert between units for calculations – Question 21 (b) • found it difficult to write a balanced equation, or ionic equations, for reactions with group 2 metal and metal compounds or group 7 redox reactions – Questions 20 (a) (ii), 21 (a) • drew an inaccurate enthalpy profile for an exothermic or endothermic reaction – Question 16 (b) (i) • drew an inaccurate or incomplete labelled diagram to measure a standard electrode potential.

Section A overview

Multiple Choice Questions

Candidates need to make sure their response is clear to the examiner, particularly when changing their response. Candidates who performed well wrote equations or calculation steps next to their responses to aid their choice.

Assessment for learning

There were occasionally some candidates who gave no response to some multiple choice questions. Candidates should be encouraged to provide a response to every multiple choice question as there is no penalty for giving a wrong response.

Question 1

1 Oxygen has the electron configuration $1s^2 2s^2 2p^4$.

How are the electrons in an atom of oxygen arranged in the p-orbitals?

A

↑↑	↑↑	

B

↑↓	↑↓	

C

↑↑	↑	↑

D

↑↓	↑	↑

Your answer ☐ **[1]**

The correct answer was D. Wrong answers were very rarely seen as candidates had secure knowledge of filling orbitals individually before pairing.

Question 2

2 Water has the anomalous properties below.

- Water has relatively high melting and boiling points.
- Ice is less dense than water.

Which statement explains these anomalous properties?

A The covalent bonding within water molecules.

B The hydrogen bonding between water molecules.

C The induced dipole–dipole interactions (London forces) between water molecules.

D The ionic bonding between water molecules.

Your answer ☐ **[1]**

The correct answer was B. Candidates generally understood that these anomalous properties were due to hydrogen bonding. A few selected C, associating the incorrect type of intermolecular force.

Question 3

3 Which chemical process is the most sustainable in terms of the atom economy of the iron produced?

A $Fe_2O_3 + 3CO \rightarrow 2Fe + 3CO_2$

B $Fe_2O_3 + 3H_2 \rightarrow 2Fe + 3H_2O$

C $2Fe_2O_3 \rightarrow 4Fe + 3O_2$

D $2Fe_2O_3 + 3C \rightarrow 4Fe + 3CO_2$

Your answer ☐ **[1]**

The correct answer was C. Candidates should be encouraged to use the space around the question to jot down the equation and perform any calculations. There was evidence of some confusion about atom economy leading to B or D being selected.

Question 4

4 Which compounds of magnesium can be used as 'antacids'?

A Chlorides

B Hydroxides

C Nitrates

D Sulfates

Your answer [ ] **[1]**

The correct answer was B. Most candidates selected this response and understood that hydroxides were needed to neutralise an acid. Incorrect options were also selected in equal measure. It is important that candidates make the link between theory and practical use.

Question 5

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

A The bond enthalpy of the covalent bonds increases.

B The halogens become less electronegative.

C The induced dipole–dipole interactions (London forces) become stronger.

D The reactivity of the halogens decreases.

Your answer [ ] **[1]**

The correct answer was C. This question was answered well, alongside Q2. Candidates should aim to separate explanations regarding chemical and physical properties. B was a common wrong answer and a few candidates suggested that the covalent bonds need to be broken, selecting A.

Question 6

6 Which equation does **not** represent a disproportionation reaction?

A $Cl_2 + H_2O \rightarrow HClO + HCl$

B $Cl_2 + 2NaOH \rightarrow NaClO + NaCl + H_2O$

C $4KClO_3 \rightarrow KCl + 3KClO_4$

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

Your answer [ ] **[1]**

The correct answer was D. This proved a more challenging question. Successful candidates often presented oxidation numbers above the equations to identify the element that was simultaneously oxidised and reduced. Most candidates recognised that A and B could be ruled out, with C being the most common error.

Question 7

7 The equation for the reaction of sulfuric acid with potassium hydroxide is shown below.

$H_2SO_4(aq) + 2KOH(aq) \rightarrow K_2SO_4(aq) + 2H_2O(l)$

$25\,cm^3$ of $1.00\,mol\,dm^{-3}$ H_2SO_4 is reacted with excess KOH.
The energy given out is 2.8 kJ.

What is the enthalpy change of neutralisation, in $kJ\,mol^{-1}$?

A –56

B –70

C –112

D –224

Your answer [ ] **[1]**

The correct answer was A. Some candidates showed full working in the space provided. B and C were common errors. Those who selected C did not take into account the need to half the reaction's enthalpy change to meet the definition requirements of one mole of water.

Question 8

8 Which row in the table explains how a catalyst affects the activation energy (E_a) and the proportion of molecules with energy > E_a?

	How the activation energy changes	**Proportion of molecules with energy > E_a**
A	decreases	decreases
B	decreases	increases
C	increases	decreases
D	increases	increases

Your answer **[1]**

The correct answer was B. Candidates had a good knowledge of the Boltzmann distribution and few incorrect responses were seen.

Question 9

9 A graph of ln(*k*) is plotted against 1 / *T* for a reaction.
(*k* = rate constant, *T* = temperature in K.)

The gradient has the numerical value of –16 000.

What is the activation energy, in $kJ\,mol^{-1}$, for this reaction?

A +1.92

B +133

C +1920

D +133 000

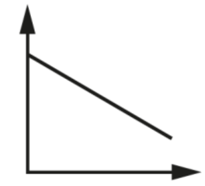
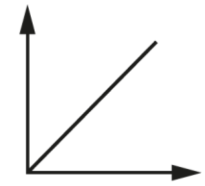
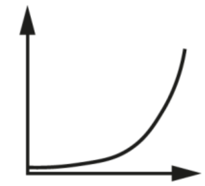
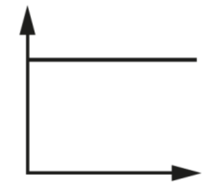
Your answer **[1]**

The correct answer was B. Candidates generally find the use and manipulation of the Arrhenius equation challenging. Focus was need on the unit conversion when using R (**J**$mol^{-1}K^{-1}$) for the gradient and activation energy (**kJ** mol^{-1}). This led to a few candidates selecting D. It is worth reminding candidates that the two forms of this equation are given on the data sheet.

Question 10

10 A reaction is zero order with respect to a reactant.

Which rate–concentration graph for the reactant is the correct shape?

A	
B	
C	
D	

Your answer **[1]**

The correct answer was D. Candidates performed well on this question with incorrect answers rarely seen. A minority of candidates confused rate-concentration graphs with concentration-time graphs.

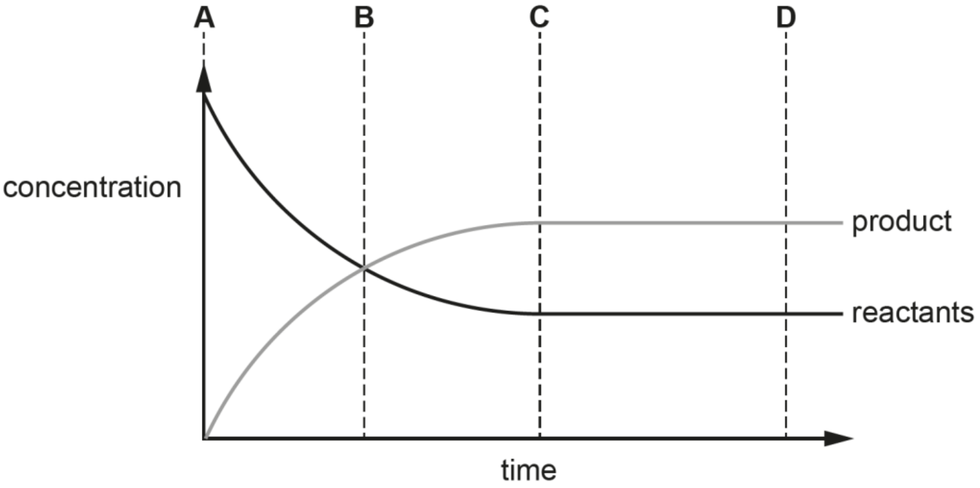
Question 11

11 The reversible reaction between hydrogen and iodine to form hydrogen iodide is

$$H_2(g) + I_2(g) \rightleftharpoons 2HI(g)$$

The graph shows how the concentrations of the reactants and product change as the reaction reaches a dynamic equilibrium.

At which point on the graph is the equilibrium reached?



Your answer [1]

The correct answer was C. This was a well answered question with most candidates gaining the mark. The most common error was B, where reactants and product concentration became equal. It is important that candidates can apply definitions and theory to diagrams.

Misconception

Dynamic equilibrium exists in a closed system when the rate of the forward reaction is equal to the rate of the reverse reaction and the concentrations of reactants and products do not change. It is a misconception that equilibrium is at the point where reactants and product concentration became equal.

Question 12

12 Which solution can be added to $CH_3COOH(aq)$ to make a buffer solution?

A $CH_3COONa(aq)$

B HCOOH(aq)

C $HCl(aq)$

D $NaCl(aq)$

Your answer ☐ **[1]**

The correct answer was A. Formation of a buffer solution can either be from either:

- a weak acid and a salt of the weak acid, e.g. CH3COOH/CH3COONa
- an excess of a weak acid and a strong alkali, e.g. excess CH3COOH/NaOH

A few candidates suggested the other alternatives in equal measure.

Question 13

13 A student analyses a solution of a salt.

The results are shown below.

Test	Observation
Reaction with NaOH(aq)	Green precipitate
Reaction with $Ba(NO_3)_2(aq)$	White precipitate

What is the formula of the salt?

A $CuCl_2$

B $CuSO_4$

C $FeCl_2$

D $FeSO_4$

Your answer ☐ **[1]**

The correct answer was D. Many candidates were able to identify the green precipitate as $Fe(OH)_2$ and the white precipitate as $BaSO_4$. A few candidates suggested C, identifying $BaCl_2$ as the white precipitate, or B, identifying $Cu(OH)_2$ as the green precipitate.

Question 14

14 Chlorine has the electron configuration $[Ne]3s^2 3p^5$.

Which statement(s) about chlorine is/are correct when it reacts in redox reactions?

1 It can gain one electron to form 1– ions.

2 It can lose its $3s^2$ electrons to form 2+ ions.

3 It can lose its $3p^5$ electrons to form 5+ ions.

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 D. Most candidates were able to select this response, but the common error was the selection of A. It is important that candidates can distinguish the difference between oxidation states and charge on the ions. Oxidation state is the measure of the number of electrons that an atom uses to bond with atoms of another element.

Question 15

15 Which statement(s) about elements in the periodic table is/are correct?

1 The position of an element is determined by its relative atomic mass.

2 The elements in a group have similar chemical properties.

3 Transition elements are used as catalysts in the manufacture of chemicals.

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 C. Most candidates chose the correct answer but a few selected A. The position of the element is based on its atomic number.

Section B overview

The section contained questions from all aspects 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 at least three significant figures, unless directed otherwise, in their intermediate calculations to avoid rounding errors in their final answer. Candidates should be advised that well set out calculations, which clearly indicate what each numerical value represents, allows effective error carried forward to be given in the event of an incorrect answer. It is also important that candidates avoid offering several solutions and clearly indicate which one has been used to derive the final answer.

Some candidates were less confident and knowledgeable of questions which covered content traditionally taught earlier on in the A Level course. These were specifically: equations involving group 2 metals and their compounds; group 7; enthalpy profiles; and structure and bonding. There was evidence that candidates wrote far more than was necessary in some responses. Candidates should avoid repeating sentences which often introduce contradictions when expanding on written answers.

Question 16 (a) (i)

16 This question is about energy changes.

Hydrogen peroxide decomposes as shown in **Reaction 16.1**.

$H_2O_2(l) \rightarrow H_2O(l) + \frac{1}{2}O_2(g)$ **Reaction 16.1**

(a) The table shows enthalpy changes of formation and entropies.

	$\Delta H_f^\ominus$ / kJ mol^{-1}	$S^\ominus$ / J K^{-1} mol^{-1}
$H_2O_2(l)$	–188	110
$H_2O(l)$	–286	70.0
$O_2(g)$	0	205

(i) Calculate the free-energy change, ΔG, in kJ mol^{-1}, of **Reaction 16.1** at 25 °C.

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

ΔG = ...kJ mol^{-1} **[4]**

Almost all candidates had a good attempt at this calculation, with many gaining full marks. Most were able to calculate the entropy change. Almost all could reproduce the equation for free energy. Of those who did not get the correct final answer, the most common error was not converting the entropy value into kJ and / or the temperature to K. There were a few candidates who did not manipulate the equation correctly. A few candidates incorrectly calculated ΔS, obtaining the value of 165 J K^{-1} mol^{-1} or ΔH, obtaining -474 kJ mol^{-1}. Candidates were given ECF in these cases.

Question 16 (a) (ii)

(ii) The decomposition of hydrogen peroxide shown in **Reaction 16.1** is feasible.

Suggest why **Reaction 16.1** does **not** take place at 25 °C despite being feasible.

....

....

....

.... **[1]**

Lots of good answers from candidates were seen for this question. A few candidates attempted the explanation via a ΔG / ΔS argument and misinterpreted the comment within the question.

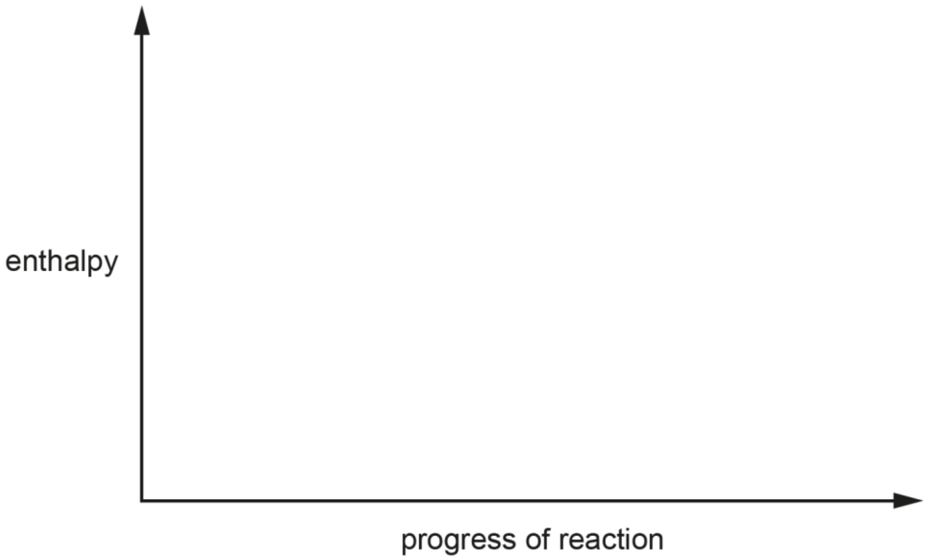
Question 16 (b) (i)

(b) The rate of decomposition of hydrogen peroxide shown in **Reaction 16.1** can be increased by adding a small amount of powdered manganese(IV) oxide, MnO_2.

The MnO_2 acts as a catalyst.

(i) Complete the enthalpy profile diagram for **Reaction 16.1** using formulae for the reactants and products.

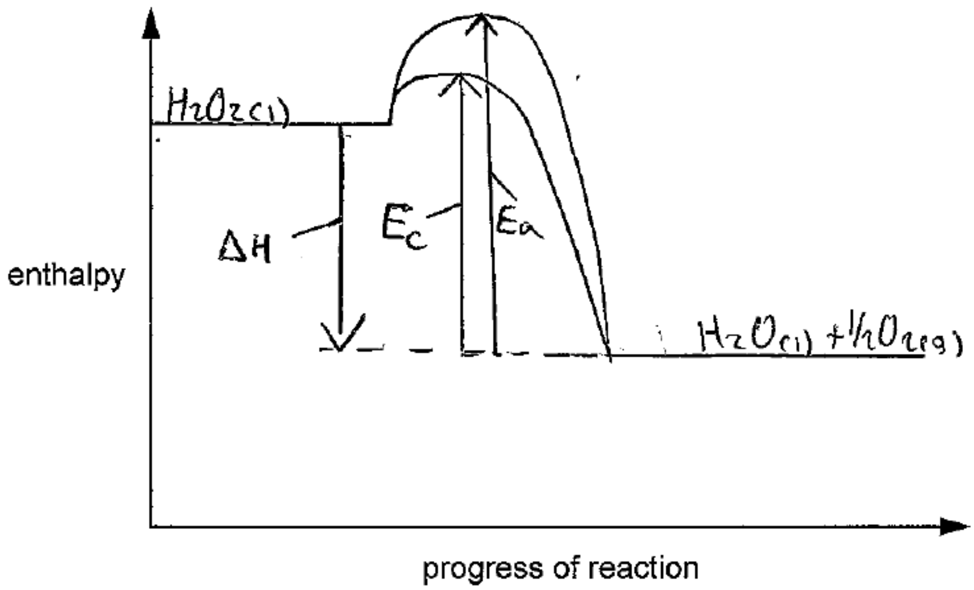
- Use E_a to label the activation energy **without** MnO_2.
- Use E_c to label the activation energy **with** MnO_2.
- Use ΔH to label the enthalpy change of reaction.



[3]

This question proved more difficult for candidates with lots of inaccuracies. The profile was dependent on the calculation for ΔH in Question 16 (a) (i). The arrowhead for ΔH needs to be pointing from the reactants to the products. The activation energies, again, need to start at the reactant line and go to the maximum level of the curve. Those that needed to draw an endothermic profile were far more likely to make an error with the E_a and E_c arrows, often starting from the product line or even from the base line of the graph. A significant number of candidates did not add arrows and instead labelled the curves E_a and E_c. Some candidates drew a Boltzmann distribution curve scoring 0 marks.

Exemplar 1



The candidate has the correct exothermic profile but has the incorrect starting point for the activation energy going from the product line.

Question 16 (b) (ii)

(ii) Explain why MnO_2 is described as a **heterogeneous** catalyst for this reaction.

....

.... **[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 did not mention the catalyst.

Question 16 (b) (iii)

(iii) Mn_3O_4 is a compound in which Mn has two different oxidation states. The two oxidation states are different from the Mn in MnO_2.

Suggest the two oxidation states of manganese in Mn_3O_4.

.... **[1]**

This question proved more challenging for candidates. Candidates stating +4 was the most common error; this is the oxidation state in MnO_2. Some candidates stated fractions, negative values and gave the state symbol instead i.e. solid and liquid.

Question 16 (c) (i)

(c) Manganese(II) oxide, MnO, has a giant ionic lattice structure.

The table shows the enthalpy changes that are needed to determine the lattice enthalpy of MnO.

	enthalpy change / kJ mol^{-1}
atomisation of manganese	+281
atomisation of oxygen	+249
first ionisation energy of manganese	+717
second ionisation energy of manganese	+1509
first electron affinity of oxygen	–141
second electron affinity of oxygen	+798
formation of manganese(II) oxide	−385

(i) Define the term **lattice enthalpy**.

....

....

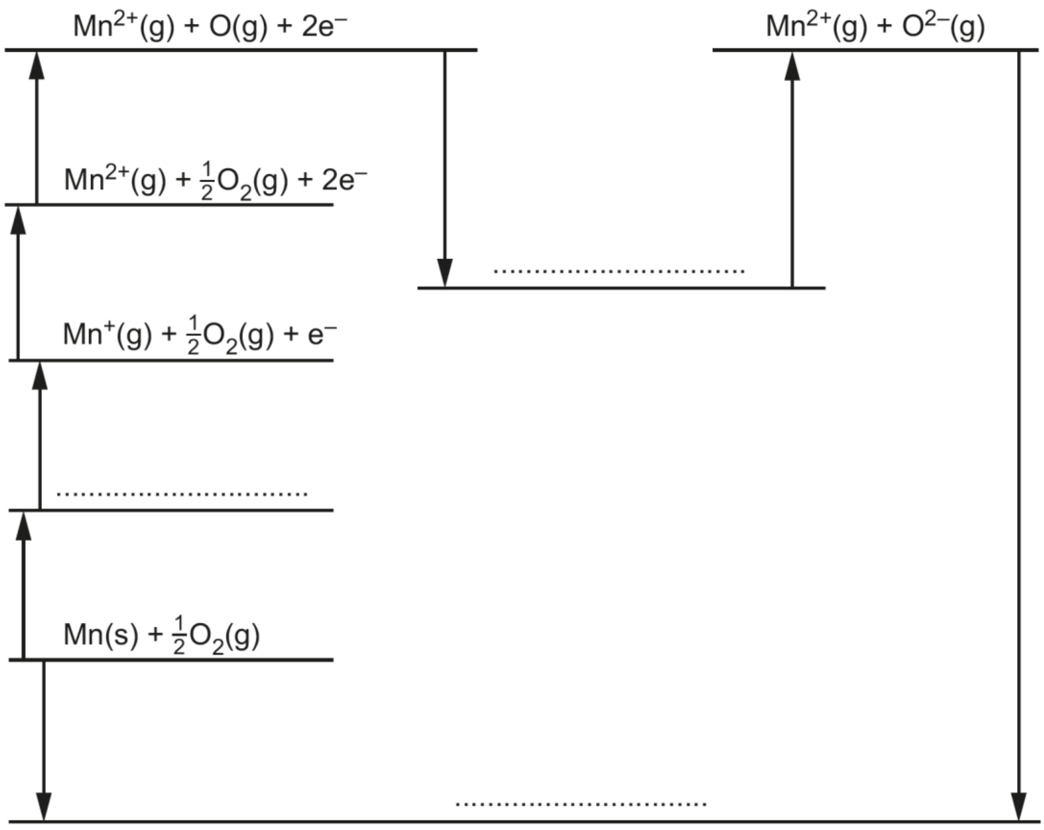
....

.... **[2]**

This question required a standard definition to be recalled. The two components are (a) one mole of an ionic lattice and (b) formed from its gaseous ion. Some candidates produced answers combining all the various definitions, most often 1 mol of gaseous ions. In general, when enthalpy definitions are required, candidates should be mindful of whether energy is given out or taken in. The phrase ‘enthalpy that accompanies’ may be most appropriate when candidates are unsure of the energy change.

Question 16 (c) (ii)

(ii) The diagram shows an incomplete Born-Haber cycle that can be used to determine the lattice enthalpy of MnO.



Complete the diagram by adding the species present on the dotted lines, include state symbols.

[3]

Most candidates scored all three marks. Some candidates wrote illegible state symbols where (g) and (s) were impossible to tell apart, but this was improved on from last year. Also, many candidates choose to write state symbols as a very small sub-script e.g. $Mn_{(s)}$ or $O_{2(g)}$. The convention is to use lower case letters of normal size e.g. Mn(s) or O_2(g). The most common errors were the manganese formula, i.e. MnO_2, and incorrect state symbol with (g) being used. Candidates also missed state symbols in one species, electron on the top left and an incorrect charge on either the Mn or O ions.

Question 16 (c) (iii)

(iii) Calculate the lattice enthalpy of MnO.

lattice enthalpy = ... kJ mol^{-1} **[2]**

The correct answer was seen frequently, along with lots of the common errors listed on the mark scheme. Candidates tended to misjudge the mole ratio and divided +249 by two. Some candidates applied the cycle incorrectly and therefore used the wrong sign for an enthalpy change, leading to them attaining one mark. Candidates should check for transcription errors as -3789 was often written for -3798.

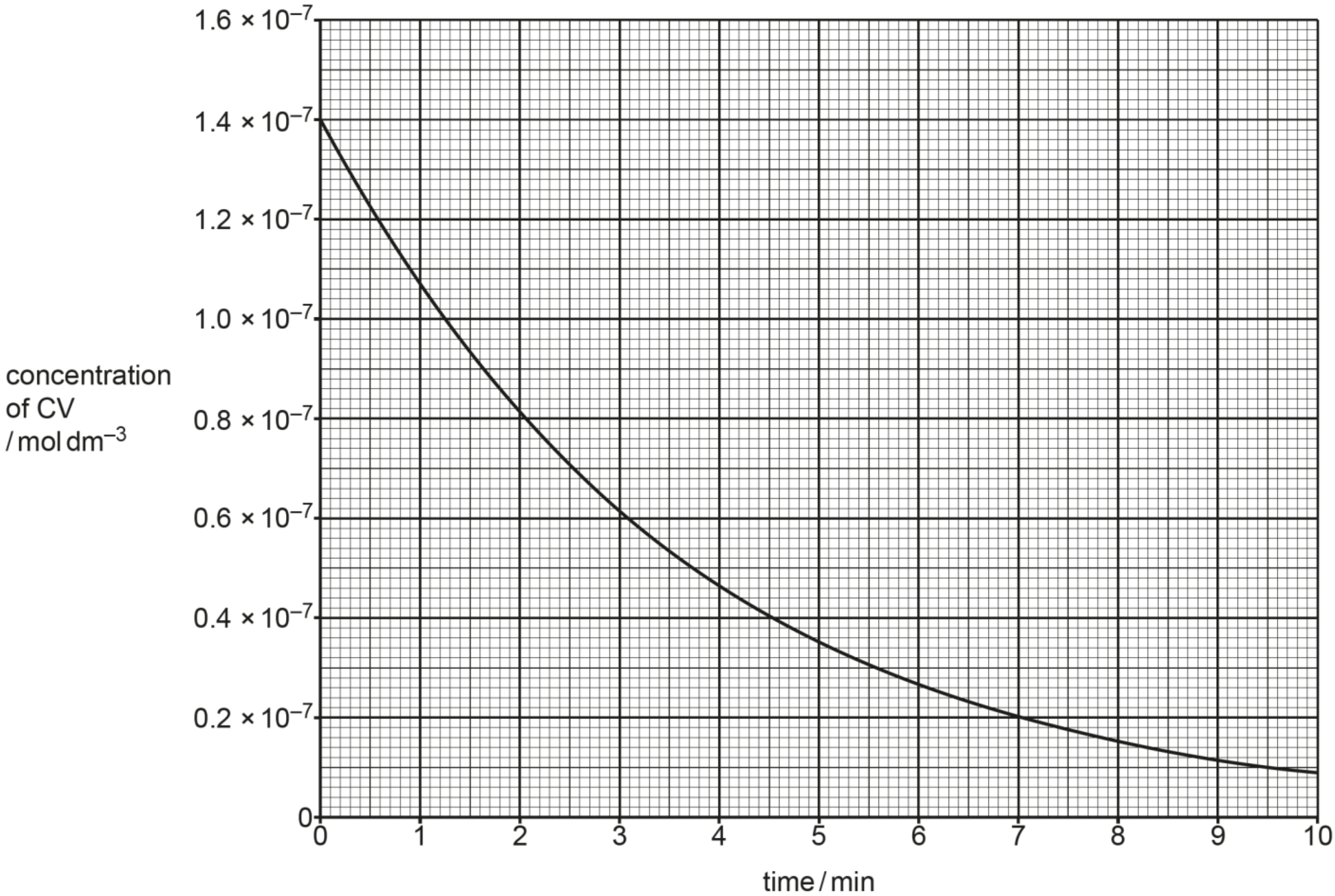
Question 17 (a)

17 Crystal violet (CV) is a purple dye. In the presence of an alkali, CV reacts to form a colourless product.

A student uses a colorimeter to investigate the rate of the reaction between CV and sodium hydroxide, NaOH.

- The student mixes $10.0\,cm^3$ of $2.8 \times 10^{-7}\,mol\,dm^{-3}$ CV with $10.0\,cm^3$ of $0.016\,mol\,dm^{-3}$ NaOH.
- A large excess of NaOH is used, so that the reaction is effectively zero-order with respect to OH^- ions.
- The student places a sample of the reaction mixture in a colorimeter and measures the absorbance over time.

The student uses the absorbance readings to calculate the concentration of CV and plots a graph of concentration of CV against time, as shown below.



(a) Using collision theory, explain why the gradient decreases over time.

....

....

.... **[1]**

This question proved difficult for candidates to explain well. Collision theory linked to rate requires a quantitative approach, e.g. less particles per <u>unit volume</u> and less collisions <u>per unit time</u>. A lot of candidates wrote vague responses about fewer particles so less collisions and did not gain credit.

Misconception

Some candidates described a decrease in energy in the reaction or gave responses related to activation energy for the concentration effect. For example, 'reactants have less kinetic energy' and 'only a certain number of particles which have enough energy above the activation energy…over time energy will decrease and less particles have enough energy'.

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)]

Question 17 (b)*

(b)* Use the graph to determine the order of reaction with respect to CV, the rate of the reaction at three minutes and the rate constant, *k*.

Your answer must show full working on the graph and on the lines below. **[6]**

The first Level of Response question in the paper was answered well with the higher-attaining candidates on the paper scoring full marks.

These students started with a nice clear analysis of the half-life, referring to labelled sections of the graph, then went on to calculate the rate from a well-drawn tangent with correct indices and were careful to write down the correct units. Then used the rate equation to calculate K and get the correct units.

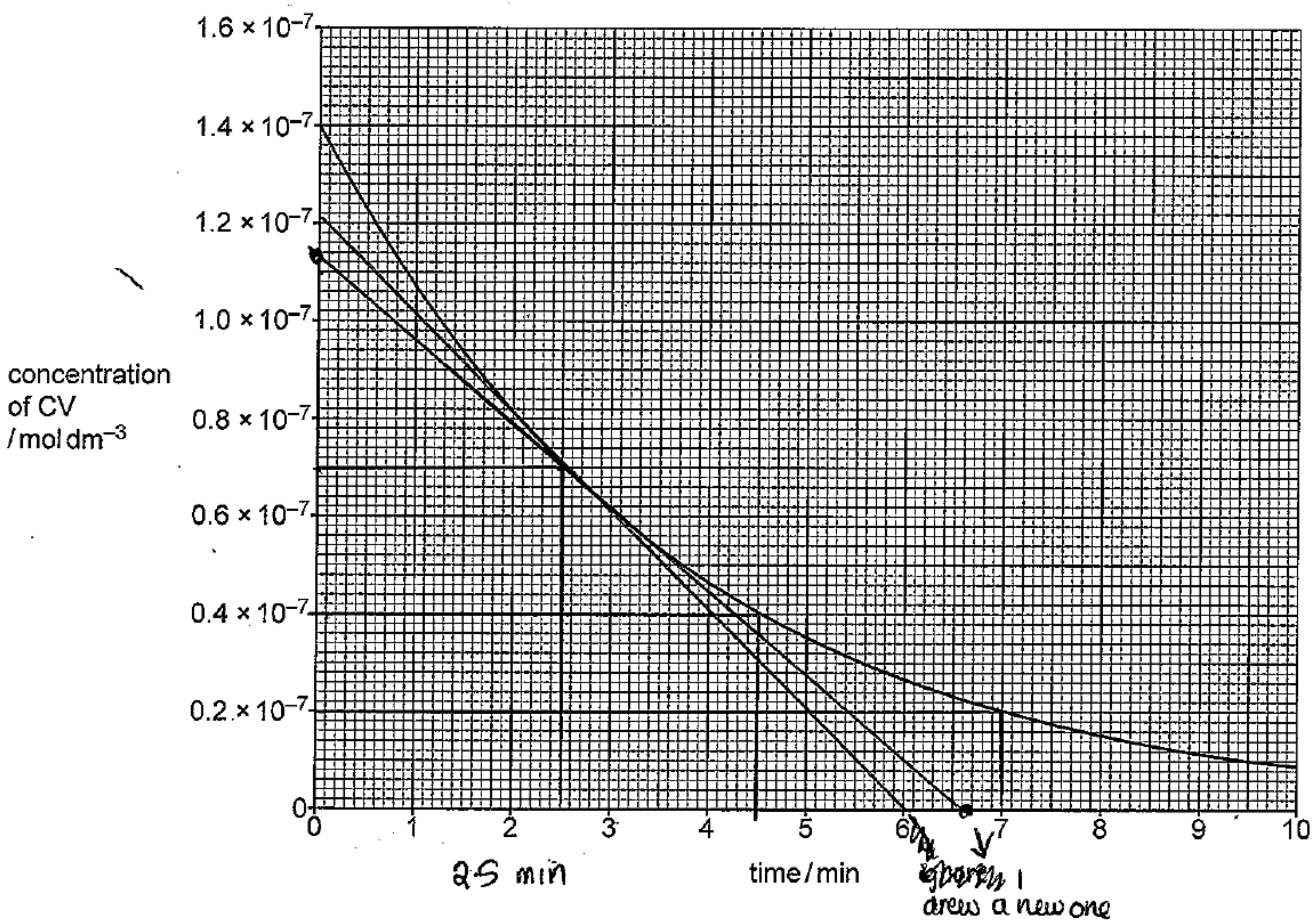
Almost all candidates were able to conclude that it was first order for CV. Most used the half-life approach with others comparing two gradients. Candidates should be advised, especially in LoR questions, that the conclusion needs a clear link to the data.

The gradient at 3 minutes was done well and the candidates used the appropriate scale from the graph in their calculations. Clarity of communication does require indication of what is being calculated and how the numbers were obtained. This would allow an initial rate versus a rate at three minutes to be distinguished. Units were particularly important in this question as some candidates used minutes from the graph while others converted time into seconds. A common error was to state the wrong units or leave them out altogether.

Most candidates used the rate equation to calculate K and get the correct units. A few approached the value by using $k = \frac{\ln 2}{t_{½}}$. Error carried forward was given for those with incorrect half-lives or rate value.

Candidate errors arose from graph readings that caused rate to be wrong, errors in concentrations used in rate or K calculation, and badly drawn tangents causing the rate to be out of tolerance. Some candidates tried to adjust the concentrations as if conducting mole calculations or take the rate from two points on the graph.

Exemplar 2



The order of reaction:

Half life 1.4×10^{-7} to 0.7×10^{-7} = 2.5 min

0.4×10^{-7} to 0.2×10^{-7} = 7 − 4.5 = 2.5 min

So since the half life is constant, the order of the reaction with respect to CV is 1.

Rate constant = $\frac{\ln 2}{2.5 \times 60}$ = k = 4.62×10^{-3} s^{-1} (or 0.277 min^{-1})

Rate of reaction at 3 minutes:

$\frac{\text{change in } y}{\text{change in } x} = \frac{1.14 \times 10^{-7}}{6.6} = 1.72 \times 10^{-8}$ mol dm^{-3} min^{-1}

⇒ 2.88×10^{-10} mol dm^{-3} s^{-1}

The candidate scored Level 3. The graph was clearly used to obtain half-lives and gradients. This was communicated on the answer lines, showing calculations and units.

OCR support

M3 section of the Maths Skills handbook contains useful information on use of graphs in chemistry, including M3.5 on drawing and using the slope of the tangent to a curve as a measure of a rate of change: Teach Cambridge (ocr.org.uk)

Question 18 (a) (i)

18 This question is about two oxides of sulfur: sulfur dioxide, SO_2, and sulfur trioxide, SO_3.

(a) SO_3 decomposes to form SO_2 and O_2, as shown in **Equilibrium 18.1**.

$SO_3(g) \rightleftharpoons SO_2(g) + \frac{1}{2}O_2(g)$ $\Delta H = +99\,kJ\,mol^{-1}$ **Equilibrium 18.1**

(i) 2.25 moles of SO_3 is heated to 550 °C in the presence of a catalyst and the resulting mixture allowed to reach equilibrium.

The equilibrium mixture contains 0.900 mol of SO_2 and the total pressure is 2.80 atm.

Calculate the numerical value for K_p for **Equilibrium 18.1** under these conditions and state the units of K_p.

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

K_p = ...

units .... **[5]**

Candidates tend to find Kp calculations difficult and so a strategy to work their way through them could include:

- Write the Kp expression using the molar ratio given in the question. Care should be taken not to change the molar ratio to help an easier calculation. Square brackets should not be used as these represent concentration.
- Calculation of initial moles present, with careful consideration of the use of appropriate significant figures
- Calculation of the change in moles present
- Deduction of the number of moles present at equilibrium
- Determination of total moles present at equilibrium

These steps are often best completed as RICE tables (Ratio, Initial, Change, Equilibrium) and should look to use the appropriate amount of significant figures to avoid having a rounding error in the final answer.

Misconception

? K_p values are for the equation as stated. Candidates should recognise that changing the stoichiometry of the equation changes the K_p value.

Question 18 (a) (ii)

(ii) The numerical values of K_p for **Equilibrium 18.1** at temperatures T_1 and T_2 are shown below.

Temperature	K_p
T_1	3.3×10^{-5}
T_2	7.7×10^{-2}

Explain why T_2 is a higher temperature than T_1.

....

....

....

....

.... **[2]**

Candidates performed well with this question and many stated that K_p would increase. Some identified the forward reaction as endothermic but did not link this to equilibrium being shifted to the right, thus increasing the ratio within the K_p expression. A few candidates sought to incorrectly explain the effect by using Le Chatelier effect on pressure.

Question 18 (a) (iii)

(iii) Suggest how the value of K_p would change if the reaction was repeated with no catalyst added and the pressure of the system increased.

Tick (✓) one box in each row.

Change	Decrease	No change	Increase
No catalyst			
Increased pressure			

[2]

This proved a challenging question where candidates did not stick to the principle that K_p (or K_a) values only change due to temperature changes. Only a few candidates scored both marks with many having the K_p value changing due to increased pressure.

Question 18 (b) (i)

(b) SO_2 and SO_3 both have molecules with sulfur in the centre and bond angles of approximately 120°.

(i) Explain why the bond angles in SO_3 are 120°.

....

.... **[1]**

Another challenging question, requiring the identification of 3 double bonds (and no lone pair). The most common error was stating that SO_2 has 3 bonding pairs – it doesn't, it has 6 bonding pairs which are arranged as 3 double bonds. They could also state that it has 3 bonding regions.

Question 18 (a) (ii)

(ii) Explain why both SO_2 and SO_3 have polar bonds, but only SO_2 has polar molecules.

....

....

....

....

.... **[2]**

Candidates found this question demanding. Many candidates explained the formation of a polar bond by describing the difference in electronegativity between S and O. Many answers had descriptions about symmetry but explained polarity in terms of polar bonds/charges cancelling instead of dipoles.

A symmetric molecule (all bonds identical and no lone pairs) will not be polar even if individual bonds within the molecular are polar. The individual dipoles on the bonds 'cancel out' due to the symmetrical shape of the molecule. There is no net dipole moment: the molecule is non-polar

Question 19 (a) (i)

19 This question is about acids and bases.

(a) Chloroethanoic acid, $ClCH_2COOH$, is a weak monobasic acid.

(i) Write the expression for the acid dissociation constant, K_a, of $ClCH_2COOH$.

[1]

Most candidates scored the marking point. They realised that the full formulae were needed although some candidates left off the square brackets or used HA or $[H]^2$. Care should be taken in checking the correct amount and location of H in the formula. As an acid dissociates to form a H^+, it is important to acknowledge only one H^+ is dissociated from the correct part of the molecule.

Question 19 (a) (ii)

(ii) The expression for the acid dissociation constant, K_a, of $ClCH_2COOH$ can be simplified to:

$$K_a = \frac{[H^+]^2}{[ClCH_2COOH]}$$ **Expression 19.1**

State one approximation that allows the expression from **(a)(i)** to be simplified to **Expression 19.1**.

....

.... **[1]**

This question required the candidate to understand that the dissociation of water to produce H^+ ions had no effect on the overall $[H^+]$ of the solution, leading to $[H^+] = [A^-]$. This was mostly answered well but some candidates used the idea of $[H^+] = [OH^-]$.

Question 19 (a) (iii)

(iii) A student carries out an experiment to determine the pK_a value of a solution of $ClCH_2COOH$.

- The concentration of $ClCH_2COOH$ is 0.090 mol dm^{-3}.
- The pH of $ClCH_2COOH$ is 1.95.

Use **Expression 19.1** to calculate the pK_a value of $ClCH_2COOH$.

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

pK_a = ... **[3]**

Candidates made good progress with this calculation, many gaining 2 or 3 marks, including error carried forward. Common errors included, in various combinations: using -log[-1.95]; using an incorrect value for the concentration of $ClCH_2COOH$; and using 10^{-Ka}.

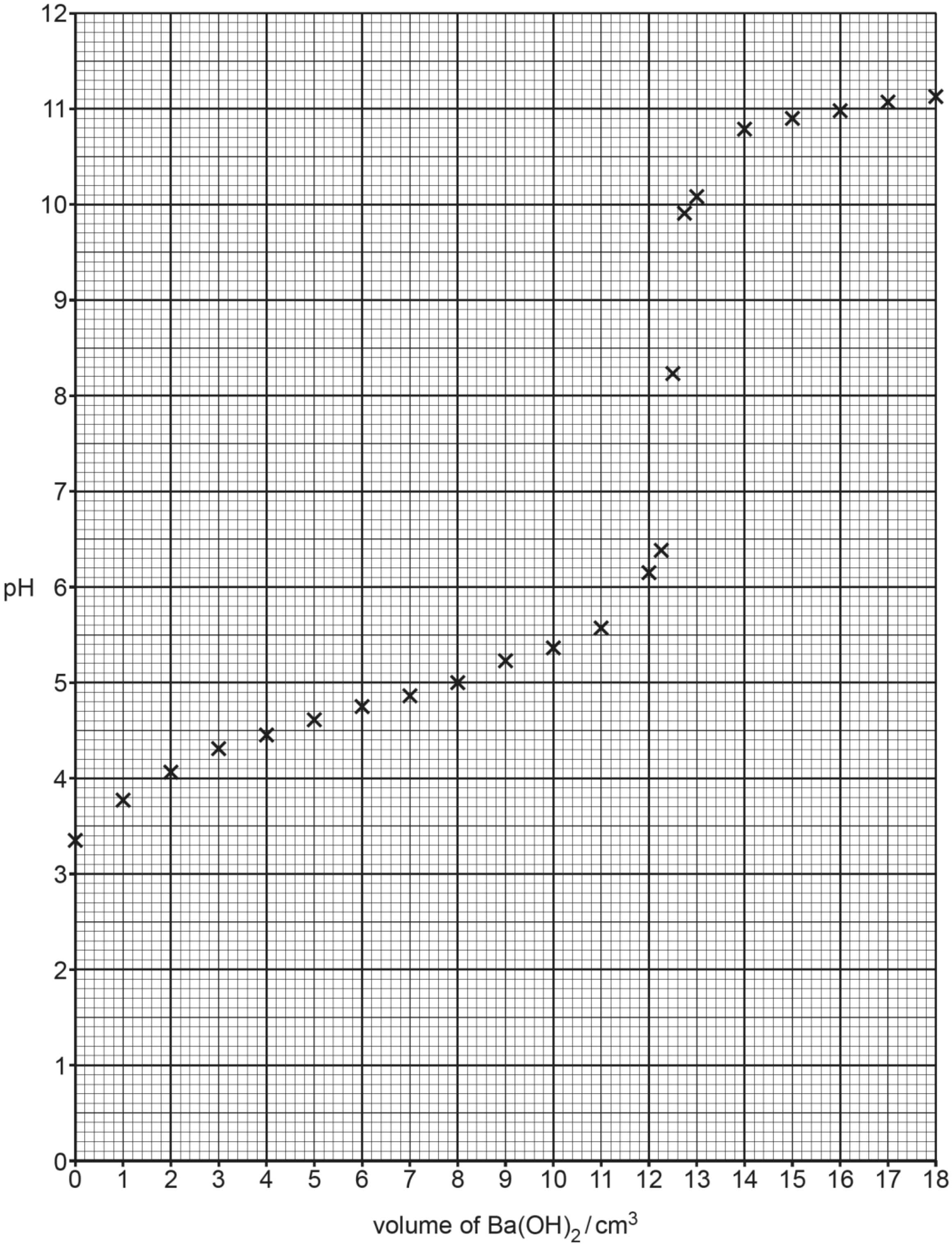
Question 19 (b) (i)

(b) A student titrates a $10.0\,cm^3$ sample of ethanoic acid, CH_3COOH, against an aqueous solution of $0.0560\,mol\,dm^{-3}$ $Ba(OH)_2$.

$$2CH_3COOH + Ba(OH)_2 \rightarrow Ba(CH_3COO)_2 + 2H_2O$$

The student used a pH meter to measure the pH of the mixture after every addition of $Ba(OH)_2$ throughout the titration.

The student's results are shown below.



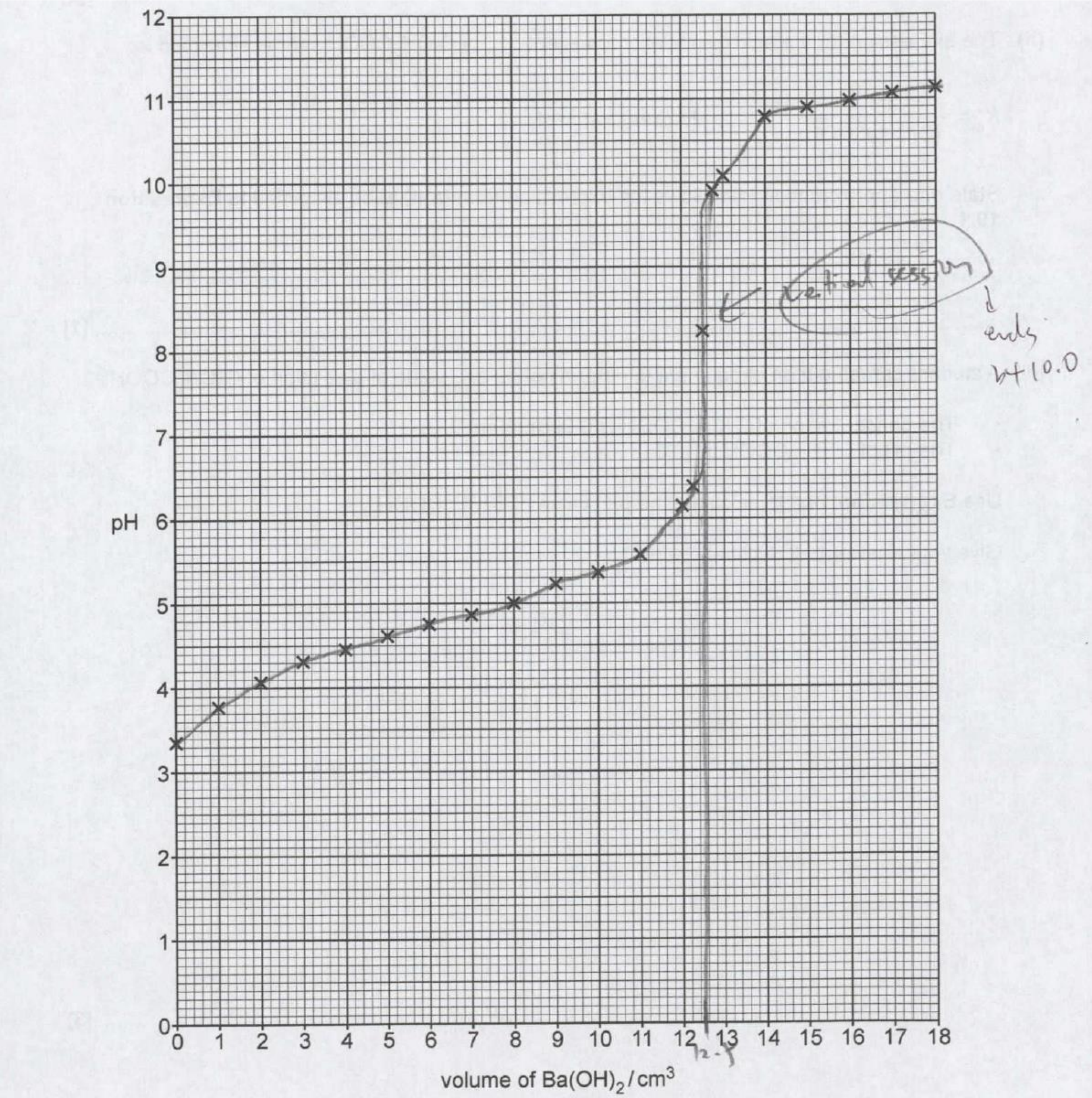
(i) Draw a best-fit curve on the graph and calculate the concentration of the CH_3COOH solution.

CH_3COOH concentration = ... $mol\,dm^{-3}$ **[5]**

Nearly all candidates were able to draw the line of best fit and linked the sharp vertical section of the graph with the volume of $Ba(OH)_2$ needed to neutralise the ethanoic acid. Candidates should aim to produce a smooth line of best fit and avoid 'tram' lines when the pencil is taken off the paper and the curve started again. The line should go through most points.

Some candidates misinterpreted the graph and used values of 8, 12, 12.2, 12.25 and 18. However, the remainder of the calculation was accessible, and most candidates scored well with ECF marks from this point. There was occasional division of 2 for the moles of ethanoic acid and dividing by the original volume of $Ba(OH)_2$ rather than the $10 cm^3$ of ethanoic acid.

Exemplar 3


pH
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
volume of Ba(OH)$_2$ / cm^3
vertical session
ends
at 10.0
12.8

From graph, end point ≈ 12.5 cm^3.
so ≈ 12.5 cm^3 of $Ba(OH)_2$ is added.

n($Ba(OH)_2$) = 0.0560 × $\frac{12.5}{1000}$ = 7.0 × 10^{-4} mol.
(mole of)

n(CH_3COOH) : n($Ba(OH)_2$) = 2 : 1, so
n(CH_3COOH) = 2 × (7.0 × 10^{-4}) = 1.4 × 10^{-3} mol

$\frac{10.0}{1000}$ × (conc. of CH_3COOH) = 1.4 × 10^{-3} mol.
Answer = 0.14 mol dm^{-3}

CH_3COOH concentration = ...0.14........ mol dm^{-3} **[5]**

This candidate scored all available marks. This is a very good example of a candidate displaying their working. The response was well communicated indicating the end point, links were made to what was being calculated and how the next number was obtained.

Question 19 (b) (ii)

(ii) The end point of the titration can also be found by observing the colour change of an indicator.

The pH ranges of some indicators are shown in the table.

Indicator	pH range
Malachite green	0.2 – 1.8
Bromophenol blue	2.8 – 4.6
Phenol red	6.8 – 8.4
Phenolphthalein	8.2 – 10.0

Identify the indicator in the table that would be suitable to observe the end point of the titration between CH_3COOH and $Ba(OH)_2$.

.... **[1]**

Nearly all candidates scored this marking point. Phenol red and Phenolphthalein were good choices of indicator as their colour changed on the sharp vertical section of the graph, depending on how the top end of the line of best fit was drawn. Occasionally malachite green and bromophenol blue were seen.

Question 20 (a) (i)

20 This question is about elements in the periodic table.

(a) Chlorine has many uses.

(i) Chlorine is used to treat water in large-scale water treatment plants.

Suggest why chlorine is added to water in large-scale water treatment plants.

....

.... **[1]**

Candidates performed well on this question with most knowing that Cl_2 kills the bacteria. Some stated that chlorine removed bacteria or purified the water.

Question 20 (a) (ii)

(ii) Sea water contains aqueous bromide ions.

Chlorine is used to extract bromine from sea water.

Construct the ionic equation for this reaction and explain why chlorine is suitable for this extraction of bromine but iodine is **not**.

Equation ....

Explanation ....

....

.... **[2]**

Most students scored the equation mark, although some presented unbalanced equations. Nearly all candidates used the ionic equation.

Explanations were well argued with most candidates using the order of reactivity. A few considered the oxidising power of the halogen. Candidates are advised to ensure that both comparisons are clearly made, and it is obvious which of the two halogens the response is referring to. It is also important that candidates can distinguish between a halogen and a halide. Some candidates explained in terms of electronegativity and displacement.

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)]

Question 20 (b)

(b) Fluorine, F_2, reacts with nitrogen dioxide, NO_2, to form nitryl fluoride, NO_2F, as shown in **Reaction 20.1** below.

$F_2 + 2NO_2 \rightarrow 2NO_2F$ **Reaction 20.1**

The mechanism for this reaction involves two steps. **Step 1** is the 'slow' step and **Step 2** is the 'fast' step.

The equation for **Step 2** is shown below:

$F + NO_2 \rightarrow NO_2F$

Suggest the equation for **Step 1** and the rate equation for **Reaction 20.1**.

Equation for **Step 1**: ....

Rate equation for **Reaction 20.1**: ....
[2]

Candidates found this question more challenging. Many candidates deduced Step 1 and then went on to state the rate equation. A few candidates incorrectly deduced F rather than F_2 and/or obtained a second order for NO_2

Question 20 (c)*

(c)* The table shows the melting points of some of the elements in Period 3 of the periodic table.

Element	**Al**	**Si**	**P_4**	**S_8**
Melting point / °C	660	1410	44	119

Explain the melting points in terms of bonding and structure. **[6]**

Structure and bonding continue to be a difficult concept for many candidates. High-attaining candidates were able to identify why the element had a certain magnitude of melting point. They clearly linked the structure type with the type of bonding. They then described, in detail, the nature of the bond. The strength of force required to break/overcome the bond/London Force was linked to the melting point.

It was very common for 'giant' to be omitted in the name of the lattice, especially in Al. 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 but sometimes not described as being forces between molecules and not linked to the increased number of electrons.

A holistic, rather than a point based, approach is used in marking these responses. This allowed Level 2 to be given when the candidate did not use all of the correct terminology throughout the three structure types.

Several candidates described the varying melting point going across the period as being due to atoms having more electrons in the outer shell and a greater nuclear charge.

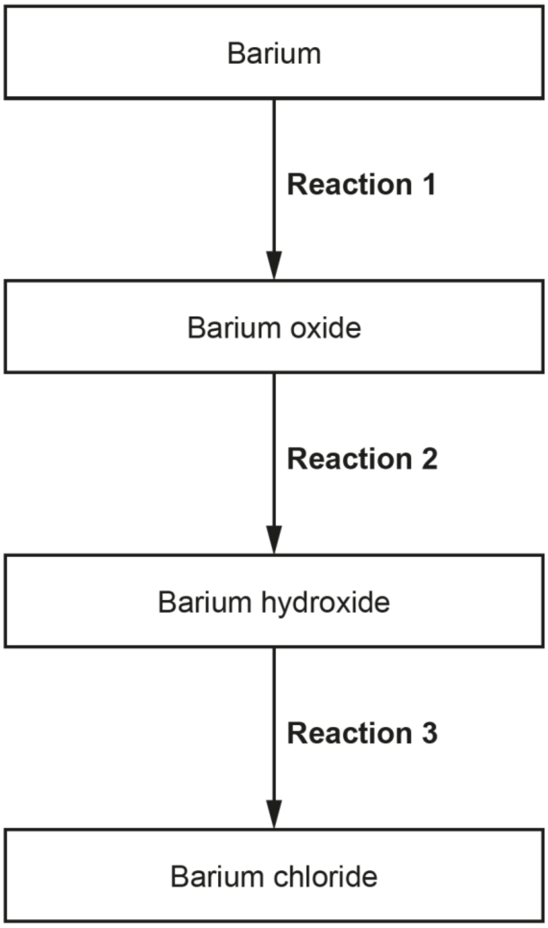
OCR support

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)]

Question 21 (a)

21 This question is about redox reactions and electrode potentials.

(a) The flowchart shows some reactions of barium and its compounds.



- Write balanced equations for **Reaction 1** and **Reaction 2**.
- Identify the type of reaction in **Reaction 3**.

Reaction 1: equation ....

Reaction 2: equation ....

Reaction 3: type of reaction ....
[3]

Some candidates coped well with this question which was based on the AS part of the specification and gained all three marks. Common errors were for unbalanced equations in reaction 1 or adding H_2 to the product of reaction 2. Reaction 3 was often, incorrectly, considered as: redox, halogenation, nucleophilic substitution or a precipitation reaction.

Assessment for learning

Regular practice writing formulae and balancing chemical equations will help to consolidate these concepts, avoiding basic errors such as giving formula of group 2 hydroxide as BaOH.

OCR support

We have produced a topic exploration pack to assist with learning about the reaction of group 2 elements and their compounds: [Teach Cambridge (ocr.org.uk)](https://teach.ocr.org.uk)

Question 21 (b)

(b) Potassium iodate tablets prevent the uptake of radioactive iodine in the human body following a nuclear accident.

The mass of potassium iodate(V), KIO_3, in a tablet can be determined by reaction with an aqueous solution of potassium iodide, KI, in the presence of acid.

$IO_3^- + 5I^- + 6H^+ \rightarrow 3I_2 + 3H_2O$

A chemist finds that two KIO_3 tablets react with exactly 26.2 cm^3 0.150 mol dm^{-3} KI.

Calculate the mass, in mg, of KIO_3 in **one** tablet.

Give your answer to the nearest whole number.

mass KIO_3 = ... mg **[4]**

Although lots of candidates got the correct final answer, almost all achieved some credit from this calculation through error carried forward with marks spread across the available range. Almost all candidates were able to find the number of moles of iodide. A few candidates did not get the molar ratio and/or used the mass of just IO_3^- rather than KIO_3. Some then did not realise the need to half this number to find the mass in 1 tablet, and multiplied by either 10 or 100 in order to convert g to mg.

Assessment for learning

Candidates need to develop their ability to perform calculations that require them to convert between different units, e.g. mg to g. Each step of a calculation should be shown.

Question 21 (c)

(c) Standard electrode potentials are measured by comparison with a reference half-cell.

Draw a labelled diagram to show how the standard electrode potential could be measured for the redox system below.

$Fe^{3+}(aq) + e^- \rightleftharpoons Fe^{2+}(aq)$

Include details of the apparatus, solutions and the standard conditions needed when measuring this standard electrode potential.

Standard conditions ....

....

[4]

Successful candidates drew a complete circuit and voltmeter with the labelled salt bridge dipped into the two solutions. Both cells had Pt as the electrodes. One cell contained 1 $moldm^{-3}$ Fe^{2+} and Fe^{3+} where the other had a delivery mechanism for H_2 (at 1 atm) and H^+ (at 1 mol dm^{-3}). Standard temperature of 298K (or 25ºC) was stated.

Common errors included: not have solutions in the beakers, used Fe or Fe^{2+} electrodes, the hydrogen cell was missing and/or the H_2 with a device for adding it. A few candidates suggested two cells with only Fe^{2+} one side and only Fe^{3+} on the other.

Question 21 (d) (i)

(d) Many electric vehicles are powered by lithium-ion cells.

Hydrogen-oxygen fuel cells can also be used to power vehicles.

Six redox systems are shown in the table. State symbols have been omitted.

Redox system	Half-equation	$E^\ominus$/V
1	$Li^+ + e^- \rightleftharpoons Li$	–3.04
2	$2H_2O + 2e^- \rightleftharpoons H_2 + 2OH^-$	–0.83
3	$2H^+ + 2e^- \rightleftharpoons H_2$	0.00
4	$O_2 + 2H_2O + 4e^- \rightleftharpoons 4OH^-$	+0.40
5	$Li^+ + CoO_2 + e^- \rightleftharpoons LiCoO_2$	+1.16
6	$O_2 + 4H^+ + 4e^- \rightleftharpoons 2H_2O$	+1.23

(i) A lithium-ion cell involves **redox systems 1 and 5**.

Construct the overall cell equation for a lithium-ion cell.

.... **[1]**

Most candidates were successful in constructing this equation. Common errors included the backwards reaction and some with unbalanced Li^+. Candidates should also check their equations, as a few included an erroneous C in the formula e.g. $LiCoCO_2$.

Question 21 (d) (ii)

(ii) Hydrogen-oxygen fuel cells can operate in acidic or in alkaline conditions.

Show that for acidic and alkaline hydrogen–oxygen fuel cells, the standard cell potentials, and the overall cell equations, are the same.

Acidic ....

....

....

....

Alkaline..

....

....

....

[3]

Most candidates were able to successfully show the overall equations were the same. Most combined the two half equations and then cancelled down to give the overall equations. A few candidates chose to describe the redox nature or use the equilibrium shifts scoring the first 2 marks. Some candidates, incorrectly, deduced the equation as $H^+ + OH^- \rightarrow H_2O$. Some candidates gave the 1.23V value without showing any calculation or did not refer to this part of the question at all. This was one of the most common questions where candidates omitted to provide a response on the paper.

Question 22 (a)

22 This question is about transition elements.

(a) Iron is in the d block of the periodic table and contains s, p and d orbitals.

- Draw diagrams to show the shapes of an s orbital and a p orbital.
- Complete the electron configurations of an iron atom and an iron(II) ion.

Shapes

s orbital	**p orbital**

Electron configurations

Iron atom: $1s^2$ ....

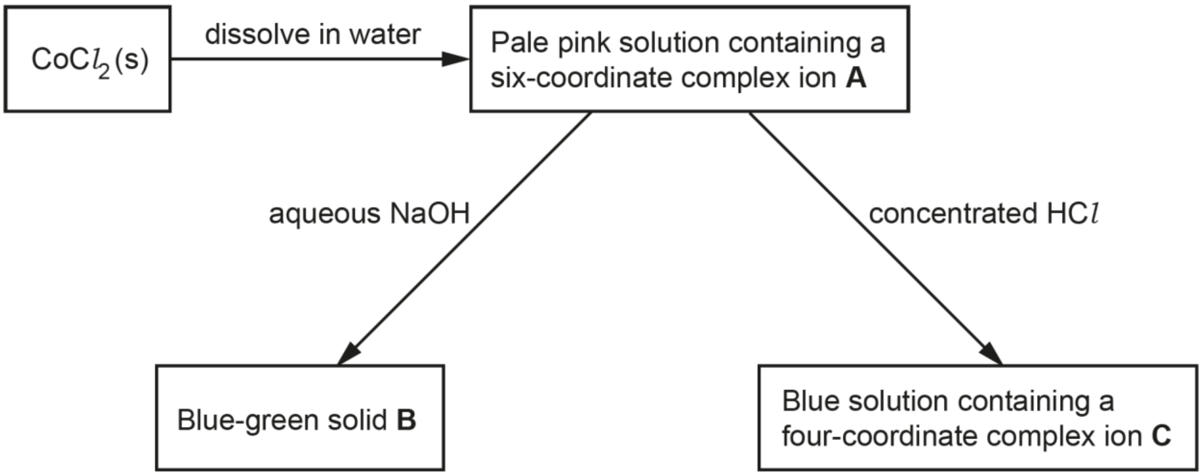
Iron(II) ion $1s^2$ ....

[2]

Many candidates were successful in drawing the orbital shapes. Occasionally candidates linked the question to the formation of a π bond or drew two arrows in a box to represent the electrons. 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 $2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^4\ 4s^2$.

Question 22 (b) (i)

(b) The flowchart shows some reactions of cobalt(II) chloride, $CoCl_2$.



In **A**, **B** and **C**, cobalt has an oxidation number of +2.

(i) Suggest the formulae of **A**, **B** and **C**.

Complex ion **A**: ....

Solid **B**: ....

Complex ion **C**: ....

[3]

Most candidates scored three marks. Some used other transition metal ions such as Cu^{2+} or Mn^{2+} and candidates should be mindful of the information given in the question. Charges were sometimes incorrect, and some responses lacked the square brackets to show the complex.

Question 22 (b) (ii)

(ii) Cobalt (III) forms an octahedral complex ion **D**, which contains both ammonia and chloride ligands.

Complex ion **D** has a molar mass of 197.9 g mol^{-1}.

Determine the formula **and** charge of complex ion **D**.

....

.... **[2]**

Most candidates identified the formula and the charge as 1+. A few candidates stated no charge or 3+. Candidates should consider the use of brackets in the formula, e.g. square brackets to show the complex and curly brackets to show the number of ligands attached. A few candidates used NH_4 rather than NH_3 for the ammonia ligand.

Question 22 (c)

(c) Red blood cells contain haemoglobin which transports oxygen around the body.

For efficient transportation of oxygen, healthy human blood must be maintained at a pH value between 7.35 and 7.45.

Human blood acts as a buffer due to the presence of carbonic acid, H_2CO_3, and hydrogencarbonate, HCO_3^-, ions as shown below.

$H_2CO_3(aq) \rightleftharpoons H^+(aq) + HCO_3^-(aq)$ $K_a = 4.27 \times 10^{-7}\ mol\,dm^{-3}$

- Explain, using ligand substitution, how haemoglobin transports oxygen around the body.
- Determine whether a sample of blood with a $[HCO_3^-] : [H_2CO_3]$ ratio of 8.5:1 is healthy.

....

....

....

....

....

.... **[5]**

The key chemistry that candidates needed to discuss in their response was as follows:

- O_2 molecules forming **coordinate** bonds with and Fe^{2+} ions in haemoglobin. Often candidates omitted the Fe^{2+} and just stated it was to haemoglobin
- O_2 **molecules** being replaced by another **ligand** (e.g. H_2O or CO_2)

The calculation using the $[HCO_3^-] : [H_2CO_3]$ ratio of 8.5 : 1 was well described, although sometimes the final expression of the ratio left ambiguity as it was hard to tell whether the ratio given referred to the $[HCO_3^-] : [H_2CO_3]$ ratio or the $[H_2CO_3] : [HCO_3^-]$ ratio. ECF was given for the $[H^+]$ and then the pH linked to whether the blood was healthy.

A smaller number of candidates approached the question by calculating the ratio of $[HCO_3^-] : [H_2CO_3]$ for both pH 7.35 and pH 7.45 and then compared both ratios to the ratio of 8.5 : 1 for healthy blood. A few candidates attempted the calculation by the weak acid approach using $[H^+]^2$. In this case only the $[H^+]$ was given.

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