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Examiners' report

CHEMISTRY A

H432

For first teaching in 2015

H432/03 Summer 2024 series

Version 1

Contents

Introduction

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

The reports will include a general commentary on candidates' performance, identify technical aspects examined in the questions and highlight good performance and where performance could be improved. A selection of candidate 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 3 series overview

H432/03 is one of three examination components for GCE Chemistry A. This largely synoptic component links together different areas of chemistry within different contexts, some practical, some familiar and some novel. To do well on this paper, candidates need to be comfortable applying their knowledge and understanding to unfamiliar contexts and be familiar with a range of practical techniques.

H432/03 is much more application based than the other two A Level Chemistry components, H432/01 and H432/02, which have a greater emphasis on knowledge and understanding of the assessment outcomes from the specification. H432/03 also contains more questions set in a practical context than H432/01 and H432/02.

Candidates who did well on this paper generally:	Candidates who did less well on this paper generally:
• displayed knowledge and understanding of important chemistry concepts, e.g. ○ Question 2 (c): predictions based on a complex organic structure, e.g. molecular formula and chirality ○ Questions 3 (a) (i) and (ii): ligands and drawing 3D structures for complex ions of transition metals ○ Question 5 (a): R_f values • performed standard calculations following a set method, e.g. ○ Questions 1 (a) – (c): pH calculations ○ Question 2 (a) (ii): calculation of an unknown bond enthalpy from provided bond enthalpies and an enthalpy change ○ Questions 3 (b) (ii) - (iv): analysis of titration results • understood analysis of chemical tests ○ Question 5 (b) (ii): interpretation of organic tests to suggest possible structures for unknown organic compounds.	• found it difficult to apply knowledge and understanding to unfamiliar situations, e.g. ○ Question 4 (b) (i), (ii) and 4 (c) (i): writing equations for unfamiliar reactions using provided information ○ Question 2 (a) (iii), 2 (b) (ii) and Question 4 (c) (iv): did not use provided information and clues within the questions • found it challenging to structure their responses to calculations, sometimes with unlabelled numbers scattered across the page, e.g. ○ Question 3 (b) (iv): Unstructured titration calculation • showed a lack of knowledge and understanding of common chemical formulae and determination of oxidation number: Question 4 (b) (ii) and 4 (c) (i).

Question 1 (a)

1 This question is about acids, bases and salts.

(a) What is the pH of 1.00 dm^3 of 0.400 mol dm^{-3} of $NaOH(aq)$ at 298 K?

pH = ... **[2]**

Questions 1 (a), 1 (b) and 1 (c) required candidates to calculate the pH of a base, a diluted strong acid and a buffer solution. These different types of pH calculation form the basis of acid-base chemistry, all requiring the relationship pH = $-\log[H^+]$ at some stage. Most candidates showed competency in their pH calculations. A number of candidates often did not appreciate the type of pH calculation required.

Question 1(a) was a standard pH calculation of a strong base and this was an easy start to the paper. Most candidates used K_w and the concentration of NaOH to determine the H^+ concentration of 2.5×10^{-14} mol dm^{-3}, from which the pH of 13.60 can be calculated using pH = $-\log[H^+]$.

Some candidates first determined pOH as 0.40, and the pH using 14.00 – 0.40. This approach is based on sound chemistry and is acceptable.

Several candidates often calculated the pH as –log 0.4 = 0.4 and gave this as their answer. NaOH is a common alkali and cannot have a pH <7 and this should have triggered that the candidate had made an error.

Question 1 (b)

(b) Water is added to 10.0 cm^3 of 0.750 mol dm^{-3} $HCl(aq)$ to produce 100 cm^3 of diluted $HCl(aq)$.

What is the pH of the diluted $HCl(aq)$?

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

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

This question was answered well although nearly a half of candidates made errors. The initial solution had been diluted by 10 times and its concentration had been reduced from 0.750 to 0.0750 mol dm^{-3}. From here pH = –log[H$^+$] gives the correct answer of 1.12 to 2 decimal places, required by the question. Candidates found Question 1 (b) more difficult than 1 (a) or 1 (c).

There seemed to be little pattern in candidate errors, the dilution being the difficult part of the question. Some did not dilute the initial concentration of 0.750 mol dm^{-3}, giving 2.12. Others divided 0.750 by 2 instead of 10 or introduced 90 into the calculation as 90 cm^3 of water would have been added. The most disappointing error was for a correct calculation to be displayed using the wrong number of decimal places. Two decimal places should be the norm for pH, reflecting the accuracy of most pH meters.

Question 1 (c)

(c) A solution has concentrations of 0.300 mol dm^{-3} $CH_3COOH(aq)$ and 0.100 mol dm^{-3} $CH_3COONa(aq)$.

K_a for CH_3COOH = 1.75×10^{-5} mol dm^{-3} at 298 K.

What is the pH of the solution at 298 K?

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

pH = ... **[2]**

This question was a standard calculation for the pH of a buffer solution and most candidates correctly identified the mixture as being a buffer.

Most candidates used the expression for K_a and the concentrations of the weak acid and its salt to determine the H$^+$ concentration of 5.25×10^{-5} mol dm^{-3}. From here, the pH of 4.28 can easily be calculated.

A common error was for the concentrations of the weak acid and its salt to be substituted into the K_a expression the wrong way round, producing an answer of 5.23. As there was only one error, this answer was given 1 mark with error carried forward (ECF). A few candidates first subtracted 0.1 from 0.3, using concentration values of 0.2 and 0.1 instead of 0.3 and 0.1. This gave an answer of 4.46 which was also given 1 mark.

The substantial number of less successful responses fell into the trap of using the pH method for calculating the pH of a weak acid rather than a buffer, squaring the H$^+$ concentration. This was the wrong method to apply for a pH buffer calculation and was not given any marks.

Question 1 (d)

(d) A student is provided with hydrated copper(II) nitrate, $Cu(NO_3)_2{\bullet}3H_2O$.

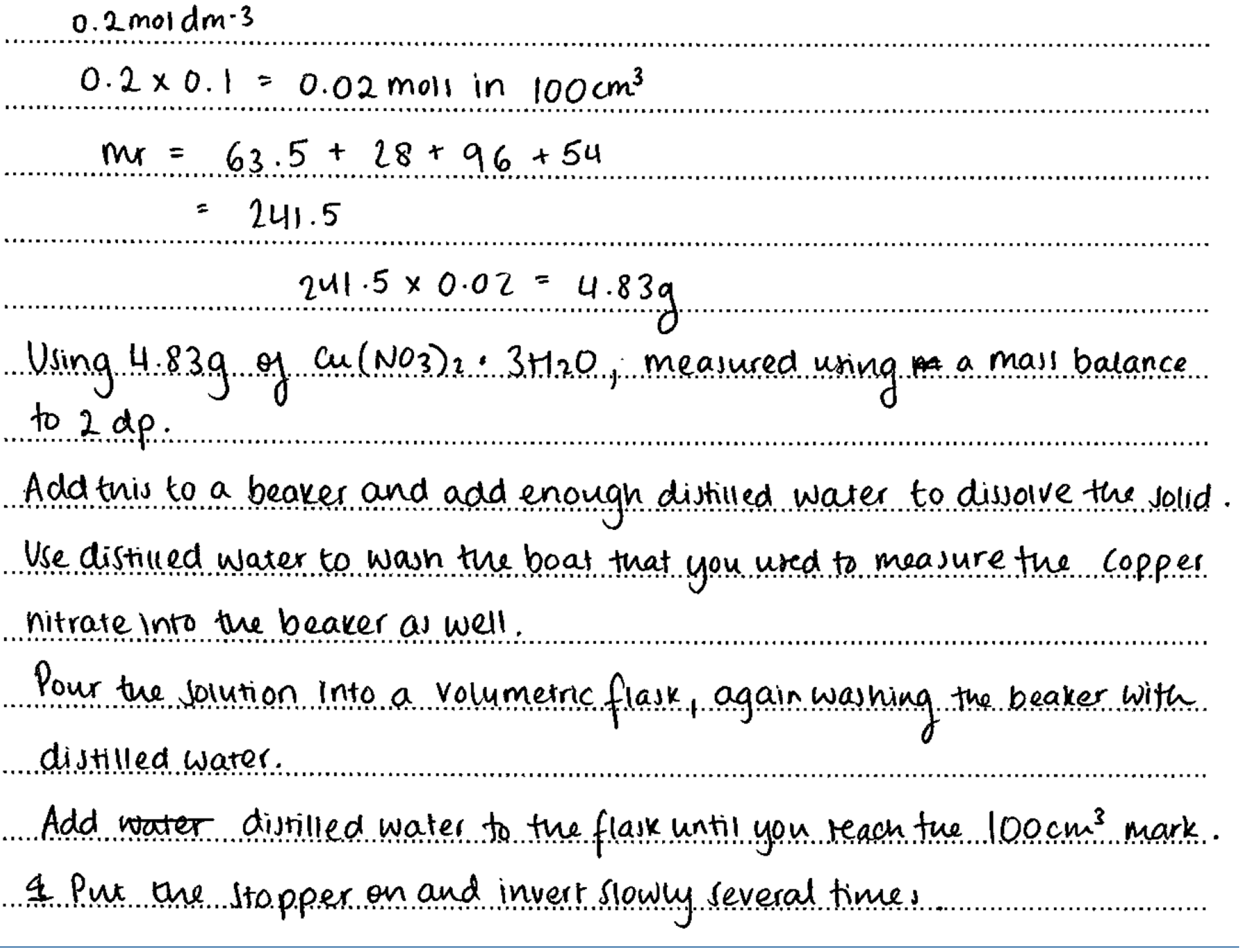
The student needs to prepare a standard solution of $Cu(NO_3)_2{\bullet}3H_2O$ with a concentration of 0.200 mol dm^{-3}. The student has access to usual laboratory apparatus and equipment.

Describe how the student would prepare 100.0 cm^3 of this solution, giving quantities, apparatus and method.

[5]

This question differentiated between candidates extremely well. See Exemplar 1 below.

Exemplar 1



0.2 mol dm^{-3}

$0.2 \times 0.1 = 0.02$ mols in 100cm^3

Mr = 63.5 + 28 + 96 + 54

= 241.5

$241.5 \times 0.02 = 4.83$g

Using 4.83g of $Cu(NO_3)_2 \cdot 3H_2O$, measured using ~~m~~ a mass balance to 2 dp.

Add this to a beaker and add enough distilled water to dissolve the solid. Use distilled water to wash the boat that you used to measure the copper nitrate into the beaker as well.

Pour the solution into a volumetric flask, again washing the beaker with distilled water.

Add ~~water~~ distilled water to the flask until you reach the 100cm^3 mark.

~~4~~ Put the stopper on and invert slowly several times.

Exemplar 1 has been included to demonstrate a superb response. The comments that follow highlight some of the issues encountered in the responses. Unfortunately, nearly a quarter of candidates could not be given any marks at all for their responses. To improve, it is worth studying Exemplar 1.

The candidate has communicated the key steps required to prepare the standard solution:

- Calculation of the mass of hydrated copper(II) nitrate required.
- Dissolving the hydrated copper(II) nitrate in water in a suitable container (a beaker).
- Transferring the solid to a 100 cm^3 volumetric flask, washing the beaker with water and transferring the washings also to the volumetric flask.
- Making the solution up to the 100 cm^3 mark in the volumetric flask and inverting the flask to mix the contents thoroughly.

Issues with responses which arose by not reading the question closely enough:

- Omitting to calculate the mass of hydrated copper(II) nitrate required.
- Calculating the mass of anhydrous copper(II) nitrate instead of the hydrated salt.
- Dissolving in 100 cm^3 of water and then adding more water for rinsing.
- Not rinsing out the original container at all.
- Making the solution up in the volumetric flask.
- Using of a 250 cm^3 volumetric flask for preparing 100 cm^3 of solution.
- Omitting the inversion stage.
- Answering a different question, e.g. how to carry out a titration, how to determine an enthalpy change, how to work out the number of waters of crystallisation by heating in a crucible.

Question 2 (a) (i)

2 This question is about different areas of chemistry.

(a) Hydrogen gas is manufactured by the chemical industry from the reversible reaction of methane and steam, shown below.

$CH_4(g) + H_2O(g) \rightleftharpoons 3H_2(g) + CO(g)$ $\Delta H = +195\,kJ\,mol^{-1}$

Average bond enthalpies are shown in the table.

Bond	H–H	O–H	C≡O
Average bond enthalpy / kJ mol^{-1}	+436	+464	+1077

(i) Why do all average bond enthalpies have a positive value?

....

.... **[1]**

Most candidates were aware that a bond enthalpy is a measure of the energy to break bonds. Most went on to link the positive sign to an endothermic reaction which requires energy.

Some candidates linked bond enthalpies to bond formation instead. A significant number of responses described an endothermic reaction, instead of bond enthalpy, in terms of the energy required to break bonds being greater than the energy to make bonds. This was the answer to a different question and could not be given marks.

Question 2 (a) (ii)

(ii) Determine the C–H bond enthalpy, in kJ mol^{-1}, using the information above.

C–H bond enthalpy = ... kJ mol^{-1} **[3]**

This question differentiated well, with about half the candidates obtaining the correct bond enthalpy of +413 kJ mol^{-1}. With ECF, few candidates scored 0 marks.

Most candidates calculated the energy involved in making 3 H–H bonds and 1 C≡O bond as 2385 kJ mol^{-1}. This value had to be incorporated with the energy associated with breaking bonds and the enthalpy change of –195 kJ mol^{-1}. It was this step where problems arose. There were many errors with signs and the lowest attaining candidates sometimes omitted the enthalpy change completely in their calculation. The commonest error of 315.5 kJ mol^{-1} was the result of using the wrong sign for the enthalpy change. With ECF, this was still given 2 of the 3 available marks.

Question 2 (a) (iii)

(iii) Hydrogen gas is being considered as a household fuel to replace methane.

The enthalpy change of formation, $\Delta_f H$, for $H_2O(l)$ is $-285.8\,\text{kJ}\,\text{mol}^{-1}$.

Determine the energy released when $60.0\,\text{m}^3$ of hydrogen is used as a household fuel at RTP.

Give your answer to **3** significant figures and in **standard form**.

energy released = ... kJ **[2]**

Unlike the standard bond enthalpy calculation in Question 2 (a) (ii), this question required candidates to apply their understanding of enthalpy changes to a new context relevant to energy. Candidates also had to interconvert units and provide an answer to 3 significant figures in standard form. Apart from the chemistry, there were various mathematical skills to use.

Candidates found this question much more demanding than Question 2 (a) (ii), with only just over a half gaining marks.

The first step involved working out that the number of moles of hydrogen gas in 60 m^3 at RTP is 2500 mol. Candidates then had to apply their understanding of $\Delta_f H$ to calculate the energy as 7.15×10^5 kJ.

Common mistakes included:

- multiplying 60 m^3 by the enthalpy change of 285.8 kJ mol^{-1} (omitting to calculate the moles of H_2 – a lack of understanding)
- using more than 3 significant figures, e.g. 7.145 instead of 7.15
- making an error with powers of 10 in the mole calculation (usually by not converting 60 m^3 into 60,000 dm^3, leading to 2.5 moles).

This type of question looks simple but makes for an excellent way of developing application and mathematical skills.

Question 2 (b) (i)

(b) Compound **A** is a chloride of a Period 3 element.

A student carries out the 2 steps below to find the formula of compound **A**.

Step 1 The student adds 5.00×10^{-4} mol of compound **A** to water.
A colourless solution is formed.

Step 2 The colourless solution reacts with exactly $60.0\,\text{cm}^3$ of $2.50 \times 10^{-2}\,\text{mol dm}^{-3}$ $AgNO_3(aq)$ to form a white precipitate.

(i) Write an ionic equation, with state symbols, for the reaction in **Step 2**.

.... **[1]**

Candidates were required to write a straightforward ionic equation that they would have encountered many times during the A Level Chemistry course. It was surprising that only just over half the candidates produced an equation that could be given.

Common errors included the following.

- Omission of state symbols or incorrect state symbols, especially (aq) in $AgCl(s)$.
- Inclusion of nitrate ions or use of $AgNO_3$ instead of Ag^+.
- An equation using Cl_2 and forming $AgCl_2$.

Some candidates used the ideal gas equation to determine the moles of hydrogen, choosing suitable values for temperature and pressure. This approach was allowed, although the exercise would have wasted candidate time compared to the much simpler division by 24 for using RTP, which is stated in the question.

Question 2 (b) (ii)

(ii) Determine the formula of compound **A**.

formula of **A** = ... **[3]**

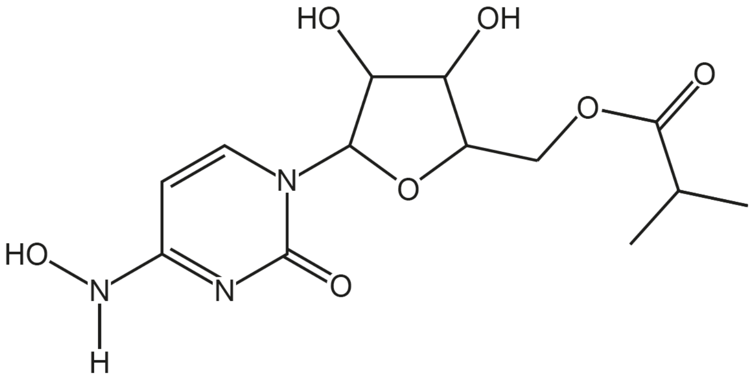
Most candidates determined the moles of $AgNO_3$ and hence Ag^+ as 1.50×10^{-3} mol. This was given 1 mark, but candidates then needed to use this amount to predict the identity of compound **A**. Most candidates could not see the way forward and many received only 1 mark. Many candidates had worked out 'something' from the supplied data, without knowing where this initial step would take them.

Candidates needed to spot that the ratio of the element : C*l* in compound **A** was $5 \times 10^{-4} : 1.50 \times 10^{-3}$ or 1 : 3. The correct formula of $AlCl_3$ then follows. $MgCl_2$ was a common error obtained by subtracting 5×10^{-4} from 1.50×10^{-3} to obtain a 1 : 2 ratio.

This question would be a good exercise for improving the application skills of candidates.

Question 2 (c) (i)

(c) Compound **B**, shown below, is an antiviral medicine.



compound B

(i) What is the molecular formula of compound **B**?

.... **[1]**

Most candidates made a good attempt at working out the molecular formula of the structure as being $C_{13}H_{19}N_3O_7$. N and O were usually correct with mistakes most common with carbon (especially 12) and hydrogen (especially 17–20).

Question 2 (c) (ii)

(ii) How many chiral carbon atoms are there in one molecule of compound **B**?

.... **[1]**

This question was answered well with the correct answer of 4 being seen on most scripts, reflecting good understanding of chiral carbon centres.

The commonest incorrect response was 5, presumably by including the C atom on the bottom right of the structure within the –**C**H(CH_3)$_2$ group.

Question 2 (c) (iii)

(iii) A research chemist synthesises two related compounds, compound **C** and compound **D**, from compound **B**.

- In compound **C**, the N atoms in compound **B** had been replaced by P atoms.
- In compound **D**, the O atoms in compound **B** had been replaced by S atoms.

What is the difference between the relative molecular masses of compound **C** and compound **D**?

difference = ... **[2]**

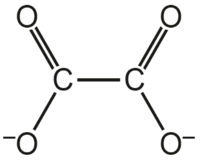
This question was answered extremely well with about three-quarters of candidates securing both marks. Most candidates calculated the molecular masses of compounds **C** and **D** as 380 and 441.7 respectively, to obtain a difference of 61.7. Some candidates adopted a simpler different approach which gives the same correct answer, working out the difference between the masses of nitrogen and phosphorus (for **C**) and oxygen and sulfur (for **D**).

ECF was applied to any incorrect molecular formulae from Question 2 (c) (i) from which both marks could be obtained.

Question 3 (a) (i)

3 This question is about compounds and ions of iron(II) and iron(III) that contain ethanedioate ions, $C_2O_4^{2-}$.

(a) The $C_2O_4^{2-}$ ion, shown below, is an example of a bidentate ligand.



(i) Explain what is meant by the term **bidentate ligand**.

....

....

....

.... **[2]**

The term 'bidentate ligand' was well-known with most candidates gaining some credit.

A mark was sometimes not given if 'lone pairs' had been omitted. A significant number of candidates just wrote 'a pair of electrons', which could have been a bonded pair.

Question 3 (a) (ii)

(ii) A complex ion **E** contains three $C_2O_4^{2-}$ ions bonded to an iron(III) ion in an octahedral shape.

Complex ion **E** exists as a mixture of two optical isomers.

Draw 3D diagrams to show the structures of the optical isomers of **E**.

Include any overall charge.

[3]

The diagrams and 3^- charge were usually correct. The standard of 3D diagrams has improved over the years with most candidates using the wedges requirements outlined in the mark scheme.

Some candidates often did not use wedges and their diagrams were not given marks.

It should be noted that 'impossible' 3D diagrams showing wedges in unrealistic positions were also not given marks. Examples are shown in the published mark scheme.

Question 3 (b) (i)

(b) A student plans an investigation to find the number of waters of crystallisation, **x**, in a sample of hydrated iron(II) ethanedioate, $FeC_2O_4 \bullet \mathbf{x}H_2O$.

The student decides to carry out a redox titration between solutions of iron(II) ethanedioate and potassium manganate(VII) in acidic conditions.

(i) In the titration, both iron(II) ions and ethanedioate, $C_2O_4^{2-}$, ions are oxidised.

Construct half-equations for the oxidation of iron(II) and ethanedioate ions.

Oxidation of iron(II) ions

....

Oxidation of ethanedioate ions

.... **[2]**

Most candidates were given a mark for one of their half-equations.

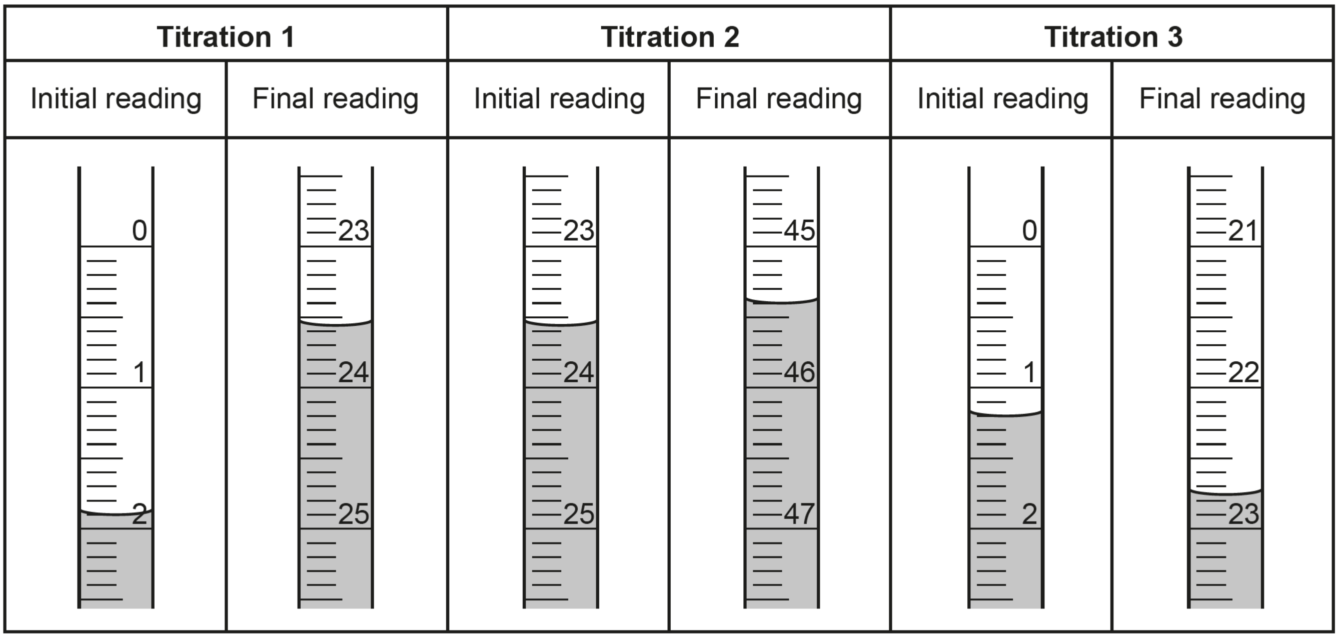
The half-equation for the oxidation of iron(II) ions was correct more often than that for ethanedioate ions. Strangely, a significant number of half-equations started with Fe metal instead of Fe^{2+} ions. The mark scheme allowed for variations in the oxidation of ethanedioate ions, with several alternative equations being given from the correct equation forming CO_2 receiving a mark.

Question 3 (b) (ii)

(ii) The student prepares a 250.0 cm^3 solution of iron(II) ethanedioate by dissolving 1.295 g of $FeC_2O_4\bullet\mathbf{x}H_2O$, in dilute sulfuric acid.

The student titrates 25.0 cm^3 samples of this solution with 0.0200 mol dm^{-3} $KMnO_4$ in the burette. The student carries out a trial, followed by three further titrations.

The diagrams show the initial burette readings and the final burette readings for the student's three further titrations.



All burette readings are measured to the nearest 0.05 cm^3.

Complete the titration table.

	1	2	3
Final reading / cm^3			
Initial reading / cm^3			
Titre / cm^3			

[3]

Most candidates were given all 3 marks for their titration tables. One mark was allocated to the readings, the other 2 for the correct titres.

Candidates are expected to record burette readings to 2 decimal places with the last figure being 0 or 5, reflecting the accuracy of the burette, which is stated in the question. Two issues were seen:

- Some candidates ignored the terminal 0 in their readings, e.g. 1.9 for 1.90 cm^3.
- A small number of candidates recorded the initial and final readings the wrong way round despite these terms being used above each burette diagram.

Titres were usually correct.

Question 3 (b) (iii)

(iii) The uncertainty in each burette reading is ±0.05 cm^3.

Calculate the percentage uncertainty for the titre in **Titration 1**.

percentage uncertainty = ... % **[1]**

Candidates are much better at calculating percentage uncertainties than in previous series.

Almost all candidates realised that the uncertainty in the titre resulted from two readings and that the overall uncertainty in the titre would be $2 \times 0.05 = 0.1$ cm^3, resulting in a percentage uncertainty of 0.46%. Comparatively few candidates ignored the '2' and gave 0.23% as their answer.

Some candidates worked out the percentage uncertainty from the mean titre but this was still given marks.

Question 3 (b) (iv)*

(iv)* In the titration, 5 mol of iron(II) ethanedioate reacts with 3 mol of manganate(VII) ions.

Analyse the student's results to find the number of waters of crystallisation, **x**, in the hydrated iron(II) ethanedioate, FeC_2O_4•**x**H_2O. **[6]**

This unstructured titration problem was assessed by Level of Response (LOR).

Candidates answered this stock titration calculation well. The key stages are listed below:

1. Determination of the mean titre from the two closest titres in the candidate's response to Question 3 (b) (ii). If the titres were correct, this would be 21.60 cm^3, the mean of 21.55 cm^3 and 21.65 cm^3.
2. Calculation of the number of moles of MnO_4^- as 4.32×10^{-4} mol.
3. Calculation of the number of moles of FeC_2O_4 in 25 cm^3 as $5/3 \times 4.32 \times 10^{-4} = 7.20 \times 10^{-4}$ mol. Scaling up this number of moles by 10 for the moles in 250 cm^3 as 7.20×10^{-3} mol.
4. Determination of the number of waters of crystallisation.

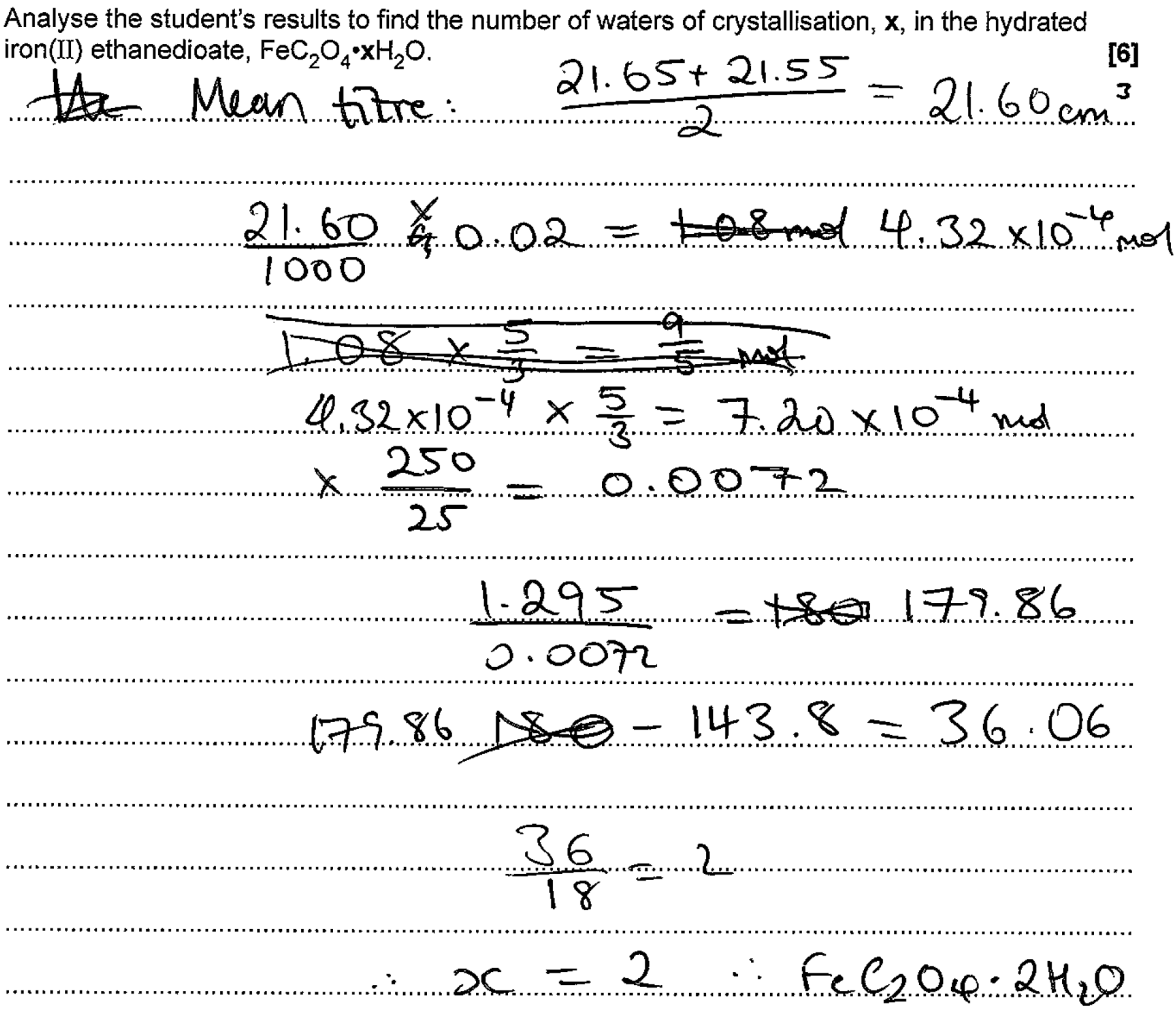
Most candidates completed Stages 1 and 2 correctly, securing a minimum of a Level 1 response.

A significant number of candidates then completed Stage 3, with most including scaling by 10 to secure a minimum of Level 2.

Many of these candidates compared the moles of FeC_2O_4 to the mass of FeC_2O_4•**x**H_2O used to determine the value of **x** as 2. Such candidates would have reached Level 3.

The communication strand of the LOR mark was determined by the clarity of the response, particularly whether the numbers in the calculation had been labelled. Unfortunately, many 'correct' responses had not done this. Over half the candidates were given 5 or 6 marks for this stock calculation.

Exemplar 2



Analyse the student's results to find the number of waters of crystallisation, **x**, in the hydrated iron(II) ethanedioate, $FeC_2O_4{\cdot}xH_2O$. **[6]**

~~the~~ Mean titre: $\frac{21.65+21.55}{2} = 21.60\,cm^3$

$\frac{21.60}{1000} \times 0.02 = \cancel{1.08\,mol}\ 4.32\times10^{-4}\,mol$

$\cancel{1.08 \times \frac{5}{3} = \frac{9}{5}\,mol}$

$4.32\times10^{-4} \times \frac{5}{3} = 7.20\times10^{-4}\,mol$

$\times \frac{250}{25} = 0.0072$

$\frac{1.295}{0.0072} = \cancel{180}\ 179.86$

$179.86\ \cancel{180} - 143.8 = 36.06$

$\frac{36}{18} = 2$

$\therefore x = 2 \quad \therefore FeC_2O_4{\cdot}2H_2O$

This exemplar demonstrates the hazards of not communicating well.

The candidate has followed the four stages described above and the chemistry behind the titration analysis is correct. However, the response is mostly a page of numbers, with no explanation about what the numbers mean.

The response is clearly at Level 3 but it is impossible to credit the communication strand, receiving a total of 5 marks.

Question 4 (a) (i)

4 This question is about the chemistry of compounds containing phosphorus.

(a) Phosphorus forms several acids including H_3PO_4 and H_3PO_3.

H_3PO_4 is a tribasic acid. The equilibria for the dissociations are shown below.

1 $H_3PO_4 \rightleftharpoons H^+ + H_2PO_4^-$

2 $H_2PO_4^- \rightleftharpoons H^+ + HPO_4^{2-}$

3 $HPO_4^{2-} \rightleftharpoons H^+ + PO_4^{3-}$

(i) During the equilibria, $H_2PO_4^-$ behaves both as an acid and as a base.

Explain this statement, using the equilibria **1**, **2** and **3**, as required.

....

....

....

.... **[2]**

Candidates were expected to link proton-transfer behaviour in acids and bases to the provided equilibria. The question differentiated between candidates well.

Some candidates just stated that an acid is a proton donor and a base a proton acceptor without referring to the provided equilibria. This was the answer to a much simpler question and could not be given marks.

The best responses demonstrated excellent understanding within the context of the equilibria. Such candidates clearly explained how $H_2PO_4^-$ behaves as an acid in the forward reaction of Equilibrium 2 and as a base in the reverse reaction of Equilibrium 1.

Question 4 (a) (ii)

(ii) In a H_3PO_3 molecule, the O atoms are covalently bonded to the P atom. The H atoms are bonded to the O atoms.

Draw the structure of a H_3PO_3 molecule, showing all the bonds.

On your diagram, add the values for the O–P–O and P–O–H bond angles.

[3]

Most candidates used the information in the question to draw a correct displayed formula of H_3PO_3. Another acceptable approach was to show a 'dot-and-cross' diagram.

Candidates usually chose 104.5º for the P–O–H bond angles although a significant number suggested 180º. The O–P–O bond angle proved to be more difficult. Many suggested 120º by ignoring the lone pair of electrons on the P atom. The shape was analogous with NH_3 giving a bond angle of 107º.

Overall, candidates answered this question well. Candidates are advised to assess the number of bonded pairs and lone pairs around each atom when suggesting bond angles. This would have reduced the number of incorrect bond angles such as 180º for P–O–H and 120º for O–P–O.

Question 4 (a) (iii)

(iii) The systematic name of H_3PO_4 is phosphoric(V) acid.

What is the systematic name of H_3PO_3?

.... **[1]**

Most candidates wrote the correct systematic name of phosphorus(III) acid and the clue given in the question for the name of H_3PO_4 should have helped.

Common errors included phosphorus(IV) acid, the same as for H_3PO_4, and the (III) oxidation number being placed after 'acid' in the name. The commonest error though, was hydrogen phosphate.

Candidates are advised to use any information provided in the question, which often contains clues. This certainly would have prevented hydrogen phosphate as a response.

Question 4 (b) (i)

(b) Phosphine, PH_3, is a poisonous gas.

(i) Phosphine reacts with oxygen gas to form phosphorus(V) oxide and water.

Write the equation for this reaction.

.... **[1]**

Candidates found this question quite challenging, with only about one-third writing a correct equation. The question gave the reactants and products with only the formula of phosphorus(V) oxide having to be worked out.

The actual reaction does produce P_4O_{10} but P_2O_5 was shown in almost all equations, and this was acceptable.

Various incorrect formulae were seen for phosphorus(V) oxide including PO, PO_2, P_5O, HPO, etc. Unfortunately a significant number of candidates could not balance the equation, despite using correct formulae.

Question 4 (b) (ii)

(ii) Aqueous silver nitrate, $AgNO_3$, is reduced by PH_3.
The unbalanced equation is shown below.

Balance the equation and use oxidation numbers to explain why this is a redox reaction.

.... $AgNO_3$ + ... PH_3 + ... H_2O → .... Ag + ... H_3PO_3 + ... HNO_3

Explanation ....

....

....

....

.... **[3]**

This question generated a wide range of responses, testing many important chemical skills.

Candidates often used oxidation numbers correctly to show that silver is reduced and phosphorus oxidised, with silver being the easier. Hydrogen was sometimes incorrectly chosen for oxidation.

The oxidation number change of +1 to 0 for silver was usually correct although +9 and +11 were common errors for silver in $AgNO_3$, presumably by choosing the oxidation number of nitrogen as –3 or –5.

Candidates usually recognised that phosphorus started with an oxidation number of –3 but the oxidation number of +5 was a common error in H_3PO_3.

Balancing the equation was the most difficult part of this question with numbers being added almost at random. It is easier to balance equations for redox reactions by balancing the oxidation number changes first.

Assessment for learning

Ag^+ and NO_3^- are among the common ions that students should know (see also Question 4 (c) (i)).

For a NO_3^- ion to have a charge of 1–, the oxidation number of nitrogen must be +5. By choosing –5, the charge on NO_3 would be –11 and silver would have an oxidation number of +11. This is completely unrealistic and should be rejected as it points to a serious error.

The specification states the following:

2.1.5 (a) *rules for assigning and calculating oxidation number for atoms in elements, compounds and ions.*

This section will have been studied at the start of the two-year course and forms part of the backbone of chemical literacy.

For success in chemistry, the ions should be learnt and the rules for assigning oxidation numbers need to be mastered.

Question 4 (c) (i)

(c) When phosphorus(V) chloride, PCl_5, and ammonium chloride are heated together, the compound $P_3N_3Cl_6$ is formed, together with HCl gas.

$P_3N_3Cl_6$ has a cyclic structure, like the Kekulé structure of benzene.

(i) Write an equation for the reaction of PCl_5 and ammonium chloride to form $P_3N_3Cl_6$.

.... **[1]**

This question again required candidates to construct an equation. Candidates were provided with the formula of all species reactants and products except for that of ammonium chloride.

Candidates are expected to know that the ammonium ion is NH_4^+ but many incorrect equations showed NH_3Cl. About half the candidates were able to construct a correctly balanced equation with the '12' balancing number for HCl being the hardest part. This links back to the 'assessment for learning' callout added to Question 4 (b) (ii) in this report.

As with other questions requiring equations to be written, this question differentiated very well. Writing formulae and balancing equations are fundamentals for mastering chemistry and candidates are advised to practise these skills throughout the course.

Assessment for learning

The specification states the following.

Formulae and equations

2.1.2(a) *the writing of formulae of ionic compounds from ionic charges, including:*

- ***(i)*** *prediction of ionic charge from the position of an element in the periodic table*
- ***(ii)*** *recall of the names and formulae for the following ions:* NO_3^-, CO_3^{2-}, SO_4^{2-}, OH^-, NH_4^+, Zn^{2+} *and* Ag^+

This section will be studied at the start of the two-year course and form the backbone for chemical literacy. For success in chemistry, the common ions should be learnt.

Question 4 (c) (ii)

(ii) Calculate the percentage by mass of P in $P_3N_3Cl_6$.

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

percentage by mass of P = ... % **[2]**

In contrast to equation writing, candidates found this simple calculation far easier with the majority obtaining both marks for 26.72.

Common incorrect percentages were 26.7 (wrong number of decimal places) and 8.91 (using 31 rather than 3 × 31 for the numerator).

Question 4 (c) (iii)

(iii) Suggest **one** example of evidence that could show that $P_3N_3Cl_6$ has a Kekulé structure rather than a delocalised structure.

....

....

.... **[1]**

About half the candidates suggested a range of creditworthy responses with 'different bond lengths' and 'decolorises bromine' being the most common.

Question 4 (c) (iv)

(iv) In a molecule of $P_3N_3Cl_6$ all the N and Cl atoms are bonded to P atoms.

Suggest a possible structure for a molecule of $P_3N_3Cl_6$.

[2]

This was another question where valuable information: '*all N and Cl atoms are bonded to P atoms*' had been provided.

Many of the structures seen ignored this information with chlorine often been shown bonded to a nitrogen atom. Nitrogen atoms were often shown with 1 bond only and chlorine atoms in the ring structure with 2 or more bonds.

Most structures contained 6 or 3-membered rings.

This was a difficult question, requiring candidates to use the supplied information to come up with realistic structures that met chemical bonding rules. Only about a quarter of candidates could be given any mark.

The Kekulé theme in Questions 4 (c) (i) - (iv) should have prompted candidates that a Kekulé structure was likely here. Several other structures were allowed providing that they met normal chemistry bonding rules.

Question 5 (a) (i)

5 This question is about the analysis of organic compounds.

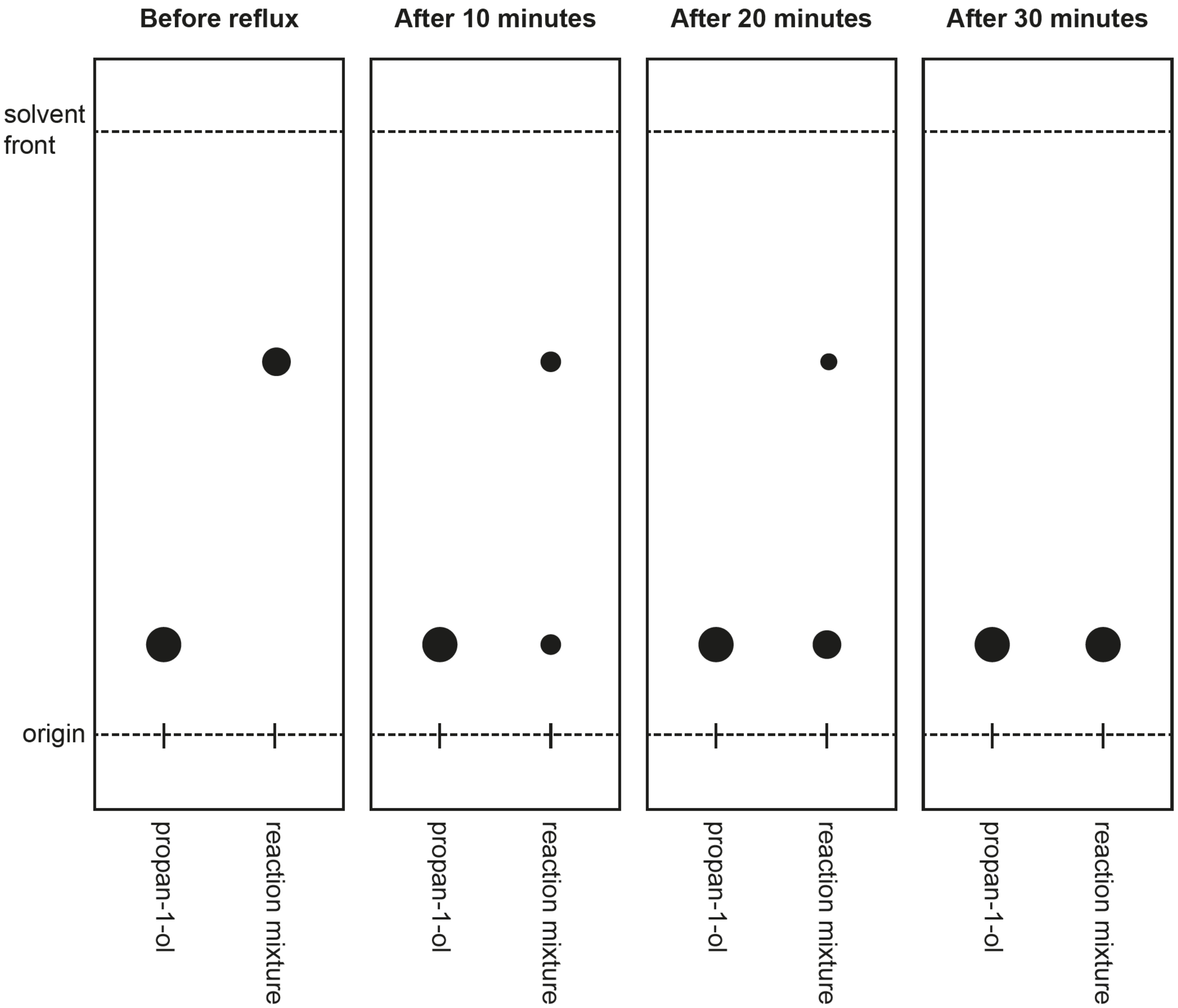
(a) A student investigates the alkaline hydrolysis of 1-bromopropane as outlined below.

Step 1 The student adds 1-bromopropane to an excess of aqueous potassium hydroxide, KOH(aq), in a pear-shaped flask.

Step 2 A TLC chromatogram is run using propan-1-ol and the reaction mixture.

Step 3 The reaction mixture is refluxed.
A TLC chromatogram of the reaction mixture is run every 10 minutes.

The TLC chromatograms are shown below.



(i) Determine the R_f value of propan-1-ol.

Show your working.

R_f = ... **[1]**

Candidates are well versed with calculating an R_f value, with nearly all candidates obtaining a value in the acceptable range of 0.12–0.18.

Question 5 (a) (ii)

(ii) Write an equation for the alkaline hydrolysis of 1-bromopropane.

Show structures of organic compounds.

[1]

This question was answered well by candidates, with most showing correct structures for the organic reactant and its product, propan-1-ol, and skeletal formulae mostly used.

The question asked for an equation for alkaline hydrolysis and candidates were expected to use an alkali. Acceptable answers would include NaOH/KOH and NaBr/KBr, or OH^- and Br^-. Equations including H_2O and HBr were not given a mark, a common error for alkaline hydrolysis.

Question 5 (a) (iii)

(iii) A student investigates the alkaline hydrolysis of 1-chloropropane using the same method as for 1-bromopropane.

Predict, with reasons, how the appearance of the reaction mixture in the chromatogram produced after 20 minutes would be different when 1-chloropropane is used instead of 1-bromopropane.

Suggest why propan-1-ol is run alongside the reaction mixture.

....

....

....

....

....

.... **[3]**

This novel question assessed whether candidates realised why chemists used TLC when carrying out organic reactions.

A good response would identify the following key features after 20 minutes:

- The C–C*l* bond energy is greater than C–Br and so the reaction would be slower.
- The haloalkane spot would be larger and the propan-1-ol spot smaller.
- The propan-1-ol is spotted on the chromatogram to monitor the progress of the reaction.

The question differentiated very well between candidates, but many did not seem to know where to start with many candidates not scoring any marks. This suggested that candidates recognised chromatography as a technique but did not appreciate its relevance in organic chemistry. Some candidates referred to pigments, recalling their early chromatography experiments in finding the colours in ink.

Question 5 (b) (i)

(b) Compounds **F**, **G**, **H** and **I** are structural isomers.

A student carries out test-tube tests on the compounds.
The student records the observations after carrying out each test.
These are shown in **Table 5.1.**

In **Table 5.1**, 2,4-dintrophenylhydrazine has been abbreviated to 2,4-DNP.

Table 5.1

Compound	**Test**			
	2,4-DNP	**Acidified dichromate(VI) reflux**	**Bromine water**	**Tollens' reagent**
F	Orange solution	Green solution	Colourless solution	Colourless solution
G	Orange solution	Green solution	Orange solution	Colourless solution
H	Orange precipitate	Orange solution	Orange solution	Colourless solution
I	Orange precipitate	Green solution	Orange solution	Silver mirror

(i) Write the formula of the species causing the colours after refluxing with acidified dichromate(VI).

Green solution ....

Orange solution ....

[2]

Although high attaining candidates responded with the formulae of chromium-containing species, it was common to see organic compounds being suggested. Consequently, a large proportion of candidates did not score either of the 2 marks. Many candidates seem to expect to only give organic species in their responses on this paper and would benefit from understanding that inorganic species may also need to be provided.

Question 5 (b) (ii)*

(ii)* The student is provided with further information about compounds **F–I**.

- They all have the molecular formula $C_5H_{10}O$.
- One of the compounds is alicyclic.
- The other compounds are unbranched.

Use this further information and the student's observations in **Table 5.1** to answer the following.

- How do the observations provide evidence for the possible functional groups in compounds **F–I**?
- Suggest a possible structure for each of the compounds **F–I**.

Show your reasoning. **[6]**

This Level of Response question was answered well with many candidates identifying compounds **F–I** correctly to reach Level 3. Structures were usually shown skeletally and this practice is to be recommended. Not only is it far quicker and clearer, it eliminates writing every atom in a displayed or structural formula. Some candidates were not given marks for missing hydrogen atoms or for 'sticks' being shown. In these structures, the chemical meaning of a stick is a terminal CH_3 group.

Candidates were also asked to show how the results of the chemical tests helped the identification of the unknown compounds and this formed the basis of the communication strand of the LOR mark. Candidates answered this part of the analysis extremely well and most were given marks for their good communication skills.

This question differentiated very well between well-prepared and less confident candidates. The latter often did not know how the results of these organic tests can be used to identify the functional groups present. It was common for such candidates to identify only one of the four compounds, scoring within Level 1 only.

OCR support

To better prepare candidates, we recommend using either the digital multiple choice quizzes on Teach Cambridge or creating targeted practise materials using ExamBuilder. If you are unsure of how to access these or ways to make the most of them, get in touch via science@ocr.org.uk.

Exemplar 3

Show your reasoning. **[6]**

F and G form orange solutions with 2,4-DNP so are not ketones/alhehydes

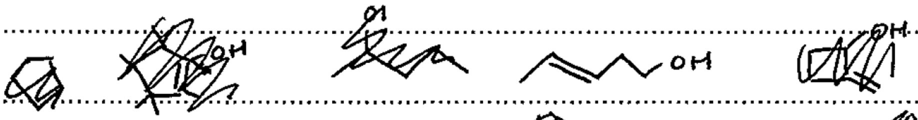
H and I are ketones / aldehydes because they form an orange precipitate

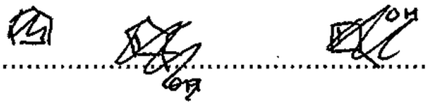
F, G and I are all primary or secondary alcohols because they turn green with $K_2Cr_2O_7 / H_2SO_4$.

F is an alkene because it forms a colourless solution with bromine water

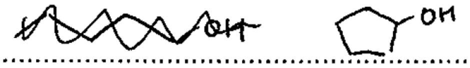
I is an aldehyde because it forms a silver mirror with tollen's reagent.

F :

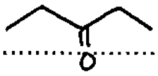




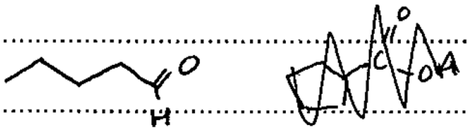
G :



H :



I :



This exemplar is concise and very clear. The candidate has clearly linked the result of each test to the functional groups that must be present.

The candidate has drawn skeletal formulae and clearly has experimented with many possible structures before deciding on which must be correct. Notice that the candidate has crossed out the structures that they have rejected. This is an important exam technique – if two structures are drawn, with one correct and the other incorrect, the correct structure cannot be given marks.

The response is clearly at Level 3 for the four correct structures and the good communication ensures that the communication strand can be given. This response received all 6 marks.

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