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Examiners' Report
June 2019

GCE Chemistry 9CH0 03

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June 2019
Publications Code 9CH0_03_1906_ER

Introduction

This paper tests understanding for all parts of the specification and many of the questions are synoptic in nature as they draw on two or more different topics. There is an emphasis on questions that assess conceptual and theoretical understanding of experimental methods that draw on students' experience of the core practicals. There is a requirement for a minimum of 20% of the marks for mathematics at Level 2 or above.

Successful candidates:

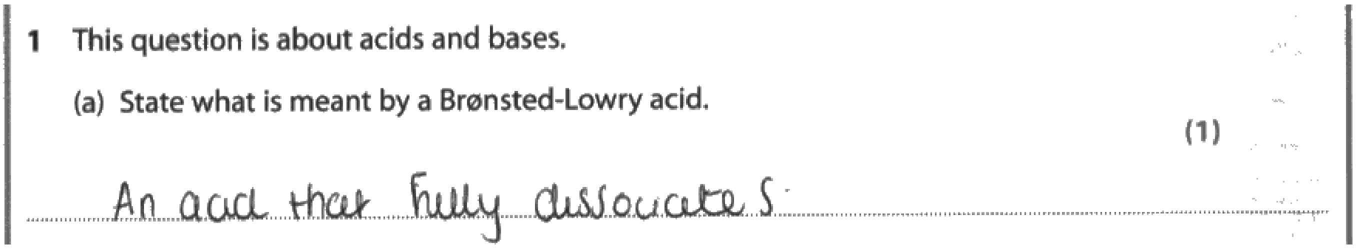
- Read the questions carefully and answered the questions as they were set.
- Had a thorough knowledge and understanding of all the topics in the specification.
- Understood and used correct scientific terminology.
- Could carry out unstructured calculations.
- Could apply their experience of the core practicals to different experiments.

Some answers were of a lower standard. Less successful candidates:

- Did not read the questions carefully and gave answers that were related to the topic being tested but did not answer the question.
- Did not use correct scientific terminology.
- Had large gaps in their knowledge of the specification.
- Were unable to write balanced equations.
- Made slips in writing the names or formulae of organic compounds.

Question 1 (a)

The majority of candidates knew that an acid is a proton donor. A few candidates gave the Lewis acid definition of an electron pair acceptor, which did not receive any credit.



1 This question is about acids and bases.

(a) State what is meant by a Brønsted-Lowry acid.

(1)

An acid that fully dissociates.

ResultsPlus
Examiner Comments

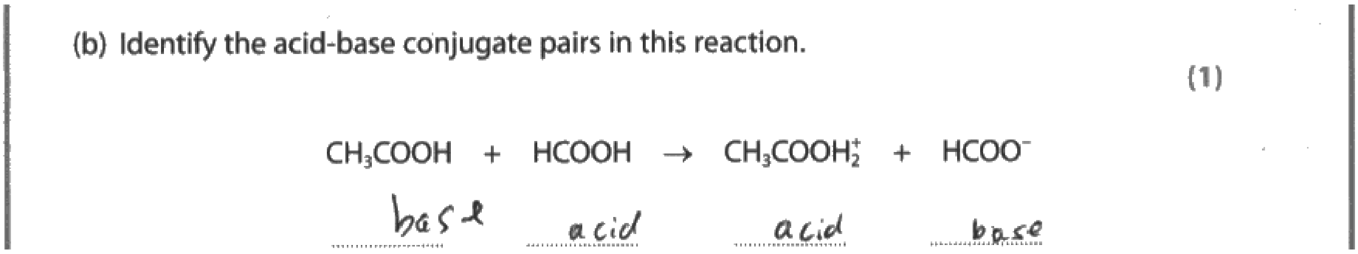
There were some incorrect answers that scored 0, as in this example.

ResultsPlus
Examiner Tip

Learn the simple definitions in the specification.

Question 1 (b)

Although the majority of candidates could identify the acid-base conjugate pairs, there were many who either did not link the correct pairs or thought that ethanoic acid was behaving as an acid in this reaction.



(b) Identify the acid-base conjugate pairs in this reaction.

(1)

$$CH_3COOH + HCOOH \rightarrow CH_3COOH_2^+ + HCOO^-$$

base acid acid base

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Examiner Comments

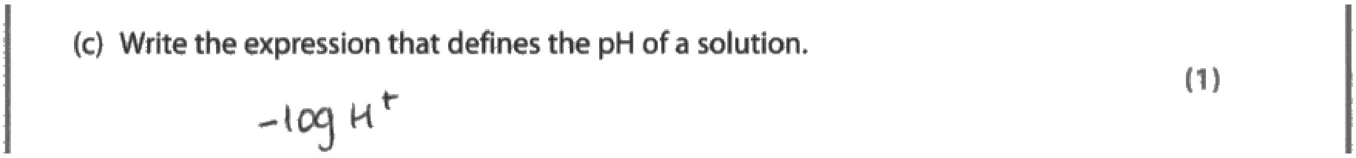
This candidate has correctly identified that ethanoic acid is acting as a base and methanoic acid is acting as an acid. However, they did not receive any credit as they did not link the conjugate pairs using lines, numbers or the word 'conjugate'.

ResultsPlus
Examiner Tip

Learn how to identify acid-base conjugate pairs and how to link them together.

Question 1 (c)

The majority of candidates could write the expression that defines the pH of a solution. Some candidates made small slips, e.g. not using square brackets to represent concentration and some omitted the charge on the hydrogen ions. A few candidates wrote completely incorrect expressions.



(c) Write the expression that defines the pH of a solution.

(1)

$-\log H^+$

ResultsPlus
Examiner Comments

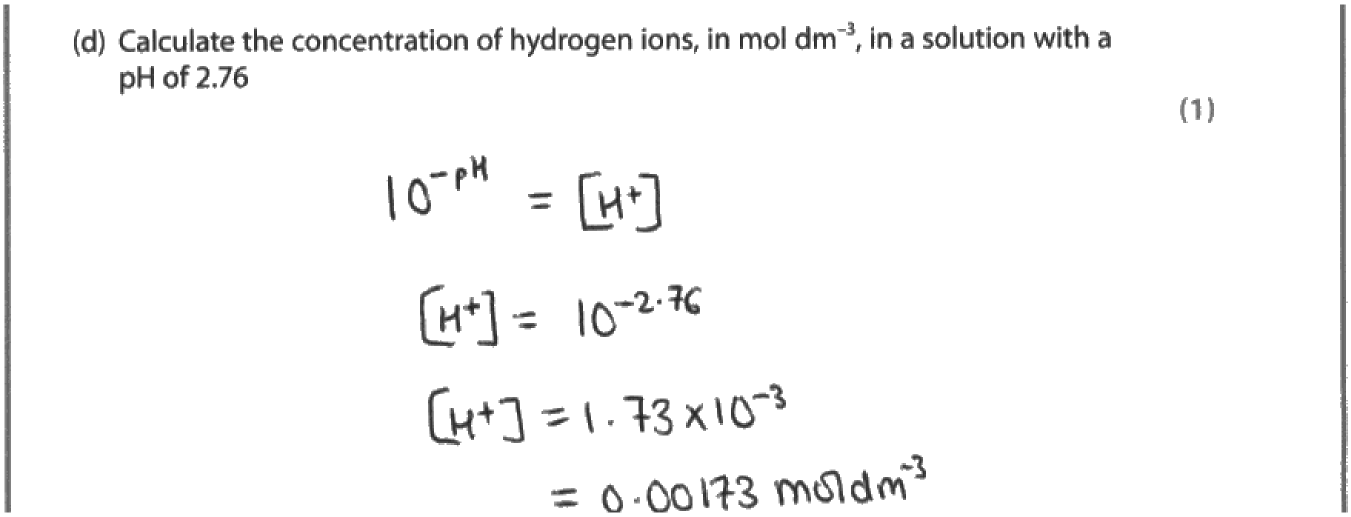
This candidate has an idea about pH but they have omitted the square brackets around the hydrogen ion so, not represented the concentration. This answer scored 0.

ResultsPlus
Examiner Tip

Learn the definitions from the specification.

Question 1 (d)

The majority of candidates could calculate the concentration of hydrogen ions in the solution with a pH of 2.76. A few candidates rounded their answer incorrectly, e.g. they rounded 0.001738 to 0.00173.



(d) Calculate the concentration of hydrogen ions, in mol dm^{-3}, in a solution with a pH of 2.76

(1)

$$10^{-pH} = [H^+]$$

$$[H^+] = 10^{-2.76}$$

$$[H^+] = 1.73 \times 10^{-3}$$

$$= 0.00173 \text{ moldm}^{-3}$$

ResultsPlus
Examiner Comments

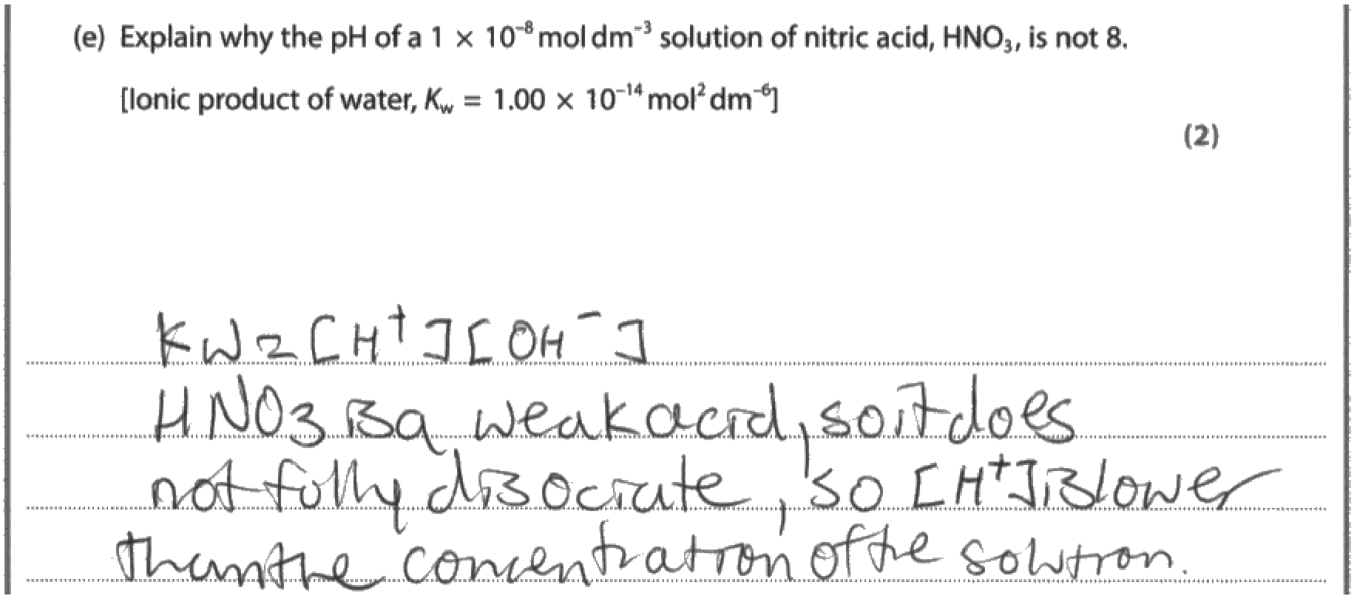
This candidate has shown clear working and carried out the calculation correctly. However, they were not awarded the mark as they rounded their final answer incorrectly.

ResultsPlus
Examiner Tip

In calculations, don't just leave off the final decimal place, check that you have rounded the number correctly.

Question 1 (e)

Many candidates were unable to explain why the pH of the nitric acid is not 8, even though they were given the value of the ionic product of water. Some candidates did realise that the concentration of hydrogen ions from water would be significant at this concentration of acid. A few candidates calculated the pH of the solution as 6.96 and they received both marks. Some candidates thought that nitric acid was a weak acid so the pH would be higher than 8 and some calculated pOH as 6 and thought that would be equivalent to pH.



(e) Explain why the pH of a 1×10^{-8} mol dm^{-3} solution of nitric acid, HNO_3, is not 8.

[Ionic product of water, $K_w = 1.00 \times 10^{-14}$ mol^2 dm^{-6}]

(2)

$Kw = [H^+][OH^-]$

HNO_3 is a weak acid, so it does not fully dissociate, so $[H^+]$ is lower than the concentration of the solution.

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Examiner Comments

This is a common confused answer that scored 0 as it referred to nitric acid as a weak acid. There was no reference to the hydrogen ions from water.

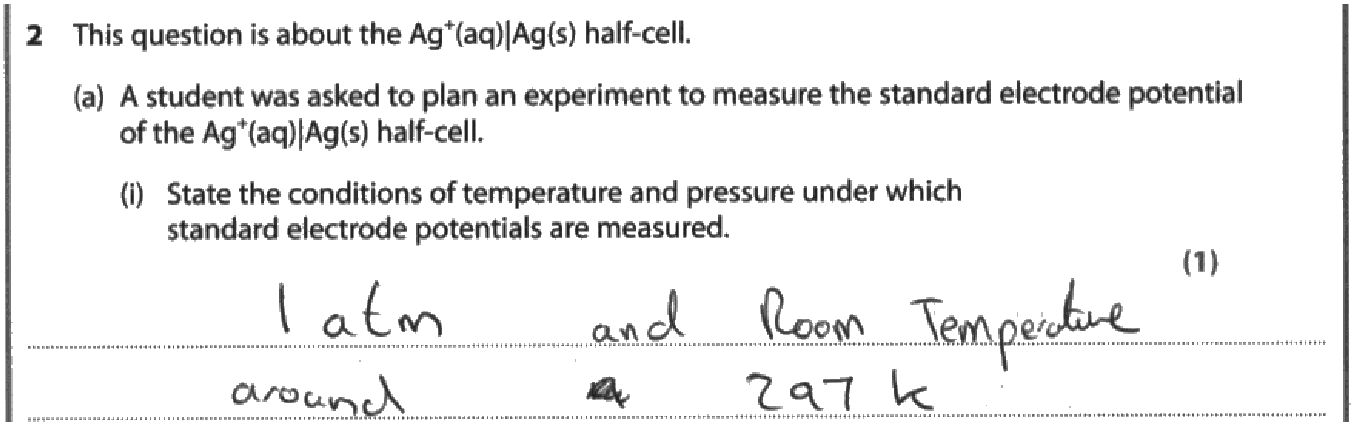
ResultsPlus
Examiner Tip

Learn the common strong acids - hydrochloric acid, nitric acid and sulfuric acid.

If you are given some data e.g. the ionic product of water in this question, you should use it in your answer.

Question 2 (a) (i)

The majority of candidates knew the temperature and pressure needed to measure a standard electrode potential. However, some candidates just referred to 'room temperature' without specifying a value. Some gave incorrect temperatures and pressures, such as 293 K and 100 atmospheres.



2 This question is about the $Ag^+(aq)|Ag(s)$ half-cell.

(a) A student was asked to plan an experiment to measure the standard electrode potential of the $Ag^+(aq)|Ag(s)$ half-cell.

(i) State the conditions of temperature and pressure under which standard electrode potentials are measured.

(1)

1 atm and Room Temperature

around 297 k

ResultsPlus
Examiner Comments

The pressure is correct but the temperature should be 298K. Both correct values were needed for the mark.

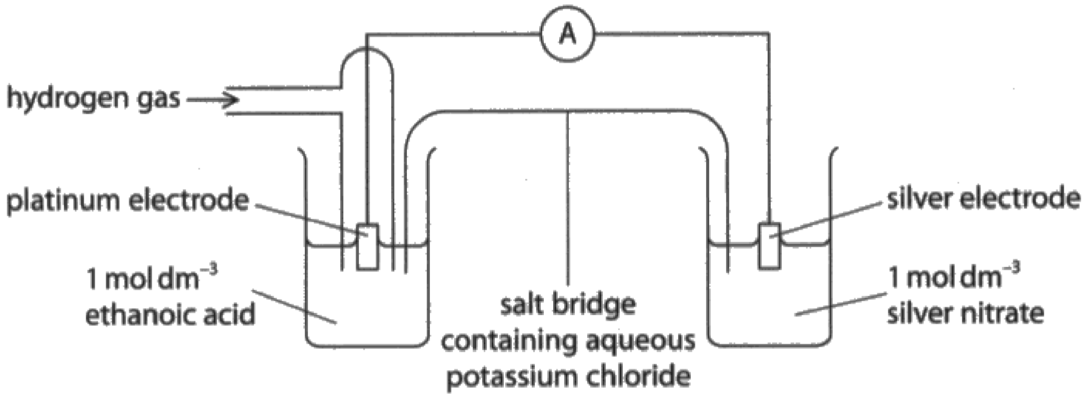
ResultsPlus
Examiner Tip

Learn the values for the temperature and pressure needed to measure a standard electrode potential.

Question 2 (a) (ii)

Many excellent answers scoring 3 marks were seen for this question. Almost all candidates realised the ammeter needed to be replaced with a voltmeter and the majority knew that potassium nitrate was needed in the salt bridge. Some did not realise that there would be a problem with the potassium chloride used in the salt bridge as they did not know that silver chloride would form and this is insoluble. Slightly fewer scored the mark for replacing ethanoic acid. Some candidates just referred to replacing it with a strong acid. If sulfuric acid is used, the concentration would have to be different so that was not given credit. Some candidates thought that there would be a problem with the electrodes not being fully submerged, but that would not affect the measurement of the standard electrode potential.

(ii) The student drew the diagram shown.



Identify **three** mistakes in this diagram and the modifications that should be made to correct them.

(3)

Mistake in diagram	Modification needed to correct mistake
Ammeter is used	It needs to be a voltmeter
Used ethanoic acid (a weak acid)	Needs a strong acid such as sulfuric acid
It has a platinum electrode	Should use platinum foil ~~and~~ instead

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Examiner Comments

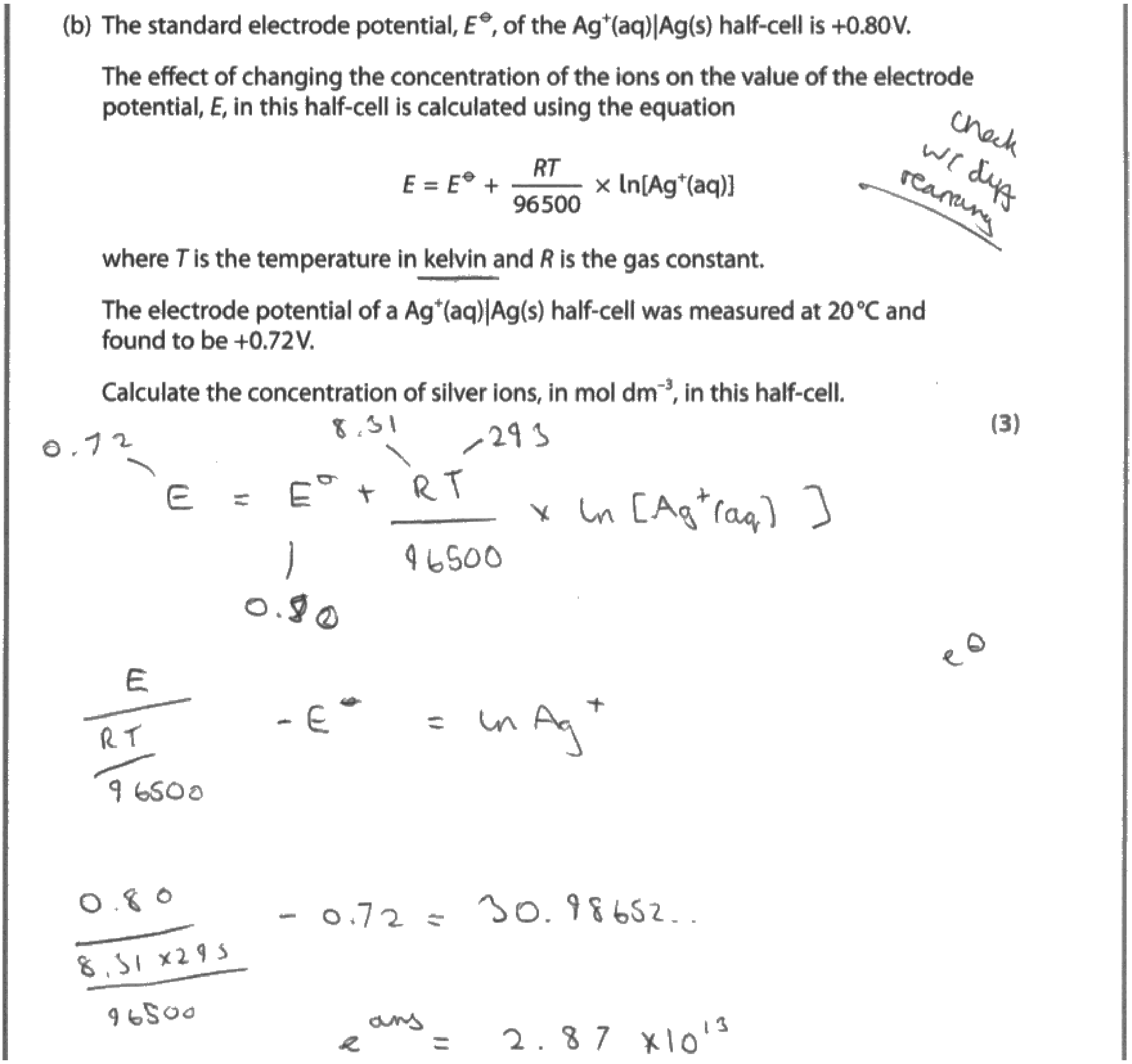
This answer scored 1 mark for replacing the ammeter with a voltmeter. Ethanoic acid does need to be replaced with a strong acid but hydrochloric acid would be a better suggestion as it is also monobasic. If sulfuric acid is used, the concentration would need to be different as it is a dibasic acid. The label to the platinum electrode is not incorrect. A wire or piece of foil could be used.

ResultsPlus
Examiner Tip

Learn the difference between monobasic and dibasic acids.

Question 2 (b)

Candidates are not expected to know the expression to calculate the electrode potential given in the question. However, they should be able to substitute numbers correctly, rearrange an equation and calculate the final answer. Candidates should be familiar with the use of log in relation to ionisation energies and pH and ln in the Arrhenius equation. They may be expected to apply their knowledge of these to other calculations in the examination papers. The majority of candidates could substitute the correct values into the expression. Some could not rearrange the expression correctly but they could still score a transferred error mark for the final answer. Some candidates would benefit from more practice in rearranging equations and in using their calculators to find e^x by using the Shift ln buttons on their calculator. A few candidates confused log and ln and found 10^x.



(b) The standard electrode potential, $E^\ominus$, of the $Ag^+(aq)|Ag(s)$ half-cell is +0.80V.

The effect of changing the concentration of the ions on the value of the electrode potential, E, in this half-cell is calculated using the equation

$$E = E^\ominus + \frac{RT}{96500} \times \ln[Ag^+(aq)]$$

Check w/ diff rearranging

where T is the temperature in kelvin and R is the gas constant.

The electrode potential of a $Ag^+(aq)|Ag(s)$ half-cell was measured at 20 °C and found to be +0.72V.

Calculate the concentration of silver ions, in mol dm^{-3}, in this half-cell.

(3)

$$\overset{0.72}{E} = \underset{0.80}{E^\ominus} + \frac{\overset{8.31}{R}\overset{293}{T}}{96500} \times \ln[Ag^+(aq)]$$

$$\frac{E}{\frac{RT}{96500}} - E^\ominus = \ln Ag^+ \qquad e^\ominus$$

$$\frac{0.80}{\frac{8.31 \times 293}{96500}} - 0.72 = 30.98652..$$

$$e^{ans} = 2.87 \times 10^{13}$$

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Examiner Comments

This candidate has shown all the correct values in the equation. They have rearranged the equation incorrectly but have then used the correct method to calculate the concentration of silver ions correctly so were given a transferred error mark. This answer was awarded 2 marks.

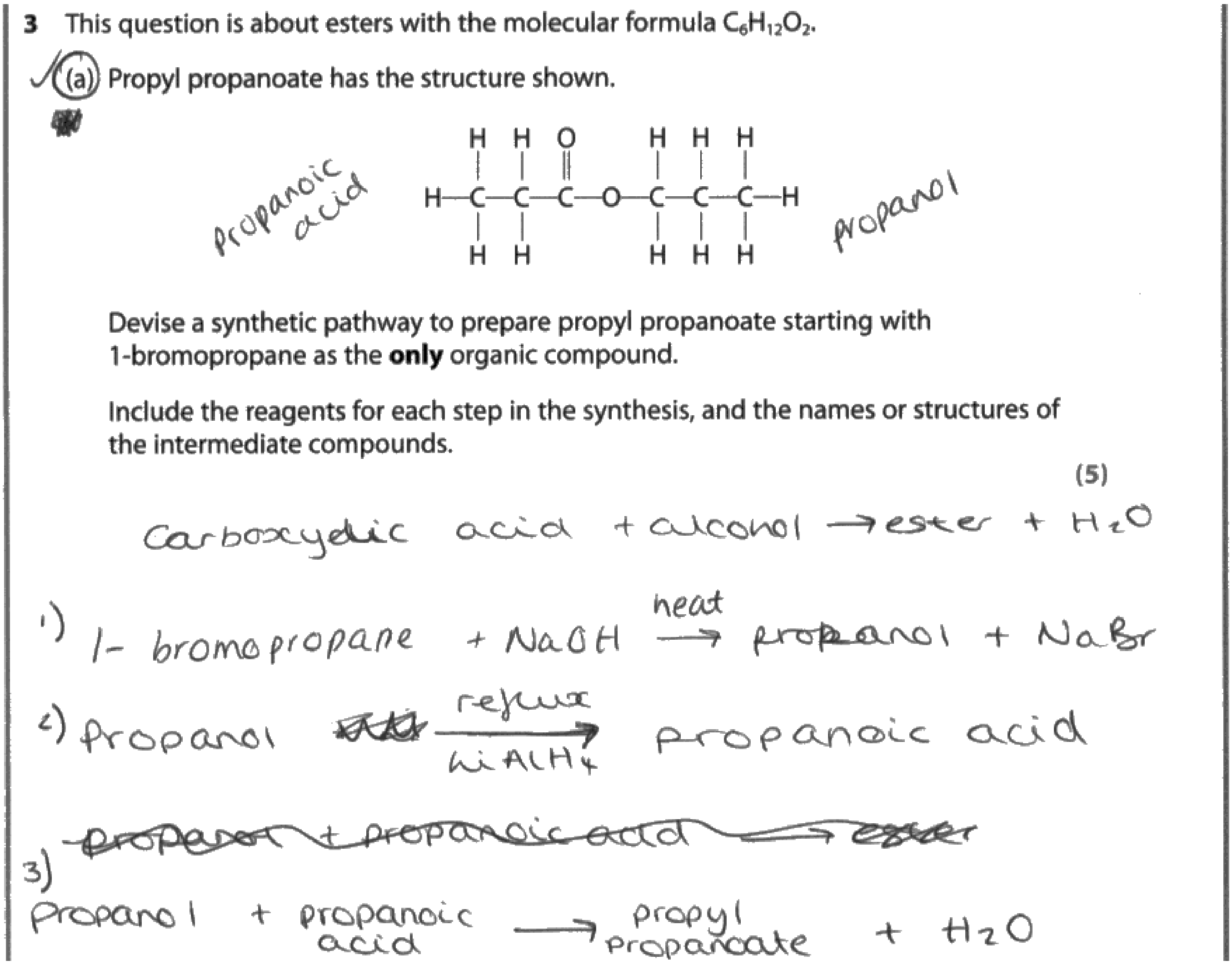
ResultsPlus
Examiner Tip

Revise how to rearrange equations. This is one of the mathematical skills required in the specification.

Show all your working in calculations so that you can be awarded transferred error marks if you do make a mistake.

Question 3 (a)

Many candidates realised that propan-1-ol and propanoic acid or propanoyl chloride react together to form propyl propanoate so they were able to devise a correct synthetic pathway. Some candidates lost a mark for converting 1-bromopropane to propan-1-ol as they used ethanolic potassium hydroxide and this would favour the elimination reaction to form prop-1-ene. Some candidates just referred to propanol instead of stating or showing the position of the OH group. Some candidates were careless when drawing structures and it was not unusual to see hydrogen atoms omitted or the OH group incorrectly attached to a carbon atom through the hydrogen atom. Many candidates who made the ester from propanoic acid and propan-1-ol omitted the acid catalyst and some omitted the acid with the dichromate in the oxidation of propan-1-ol. A small number of candidates used a Grignard reagent but that occurs later in the paper and they are told in the question that it is used to add one or more carbon atoms to the compound.



3 This question is about esters with the molecular formula $C_6H_{12}O_2$.

✓ (a) Propyl propanoate has the structure shown.

Devise a synthetic pathway to prepare propyl propanoate starting with 1-bromopropane as the **only** organic compound.

Include the reagents for each step in the synthesis, and the names or structures of the intermediate compounds.

(5)

Carboxylic acid + alcohol → ester + H_2O

1) 1- bromopropane + NaOH $\xrightarrow{heat}$ propanol + NaBr

2) Propanol $\xrightarrow[LiAlH_4]{reflux}$ propanoic acid

~~propanol + propanoic acid → ester~~

3) Propanol + propanoic acid → propyl propanoate + H_2O

ResultsPlus
Examiner Comments

This response scored 2 marks. It was acceptable to use the names of the reagents and products, but they do need to be correct.

NaOH is the correct reagent in the first step. Propanol on its own without a formula is not acceptable as it does not show the position of the OH group.

The second step is incorrect as $LiAlH_4$ is a reducing agent and an oxidising agent is needed to convert propan-1-ol into propanoic acid. 1 mark was awarded for propanoic acid.

The mark for the esterification in the third step was not awarded as the acid catalyst is missing.

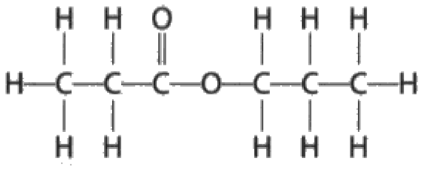
ResultsPlus
Examiner Tip

Do not give ambiguous names such as 'propanol' as you will not receive credit.

Learn the reagents needed for oxidation of alcohols and esterification reactions.

3 This question is about esters with the molecular formula $C_6H_{12}O_2$.

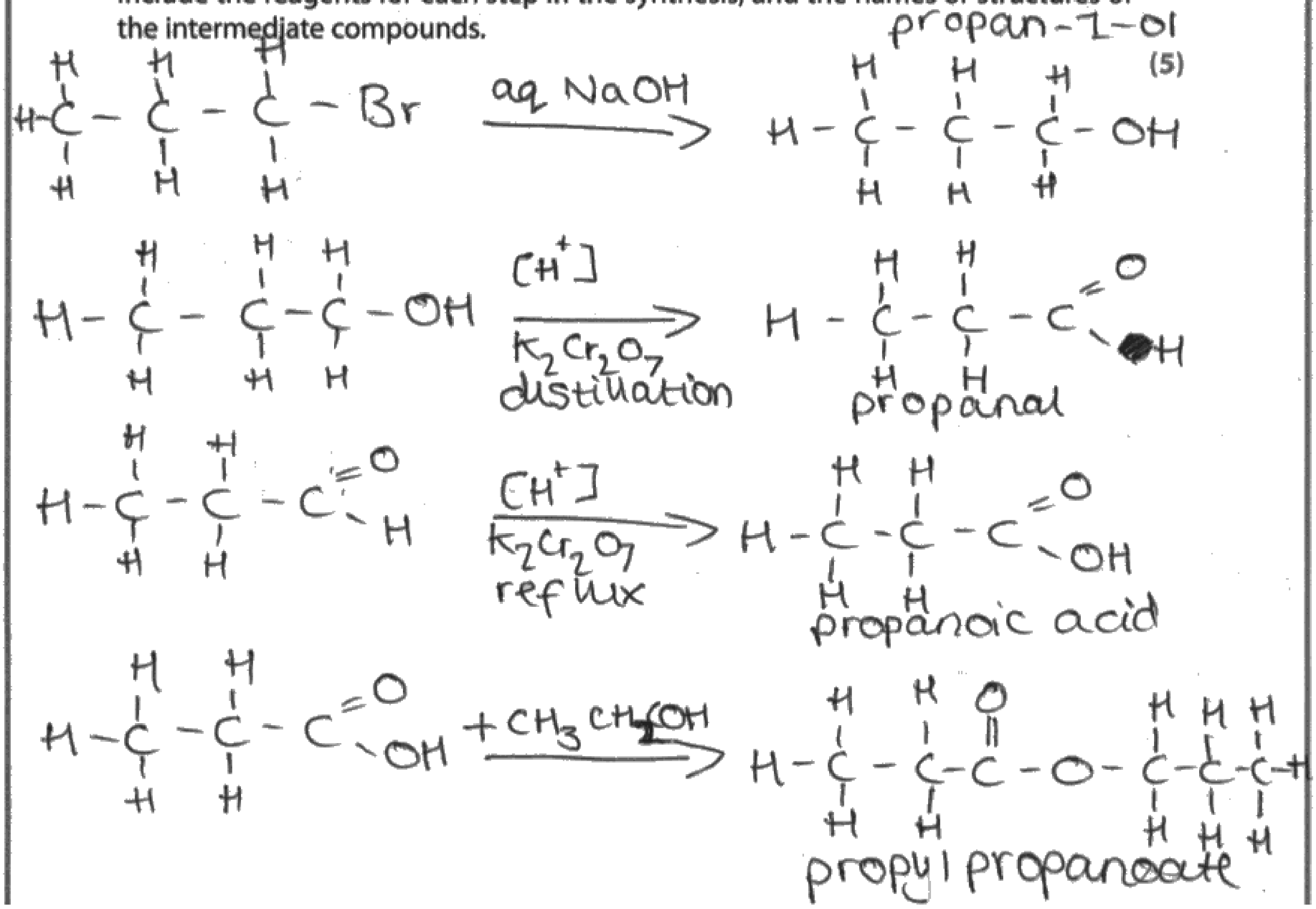
(a) Propyl propanoate has the structure shown.



Devise a synthetic pathway to prepare propyl propanoate starting with 1-bromopropane as the **only** organic compound.

Include the reagents for each step in the synthesis, and the names or structures of the intermediate compounds.

(5)



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Examiner Comments

This response scored 4 marks. The first two steps show correct reagents and products. This candidate has included the formation of propanal, which was not needed in this synthesis. The esterification was not awarded a mark as the acid catalyst is missing and either the formula for propan-1-ol is incorrect or the candidate has used propanal and that is also incorrect.

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Examiner Tip

Set out synthetic pathways clearly, as in this example.

In this question it was not necessary to write balanced equations so showing the formulae of the reactants and products in this way is acceptable.

Check to make sure that you have written the formulae correctly and not left off any hydrogen atoms or connected the OH groups incorrectly. Skeletal formulae can also be used in this type of question.

Question 3 (b)

Many candidates were able to identify the alcohol **B** as butan-2-ol as only a secondary alcohol can be dehydrated to form but-1-ene and but-2-ene. Other explanations were acceptable for the justification of **B** but candidates should be encouraged to give clear and concise reasons for their answers. It is helpful if candidates refer to the carbon atoms in molecules using numbers and remember that a double bond is between a pair of carbon atoms so both need numbering. Fewer were able to draw the structure of the ester produced from ethanoic acid and butan-2-ol and many drew the straight chain ester formed from butan-1-ol. Some candidates lost a mark by omitting one or more hydrogen atoms from their structures.

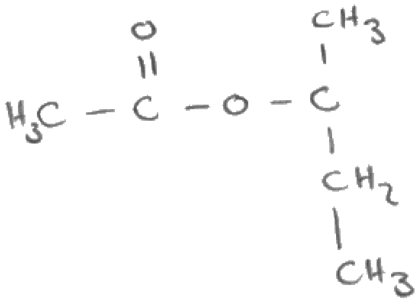
(b) Another ester, **A**, with molecular formula $C_6H_{12}O_2$, was hydrolysed.
It produced ethanoic acid, and an alcohol, **B**, with molecular formula $C_4H_{10}O$.

Alcohol **B** undergoes an elimination reaction to produce a mixture of but-1-ene and but-2-ene.

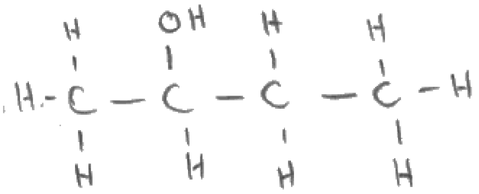
Deduce the structures of **B** and **A**. Justify your structure of **B**.

(3)

Structure A :



Alcohol B



For alcohol B to be able to form but-1-ene and but-2-ene, it must be a secondary alcohol

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Examiner Comments

This response scored 2 marks.

Alcohol **B** is correct and the justification is acceptable. However, this candidate has made a slip and omitted a hydrogen atom from the ester.

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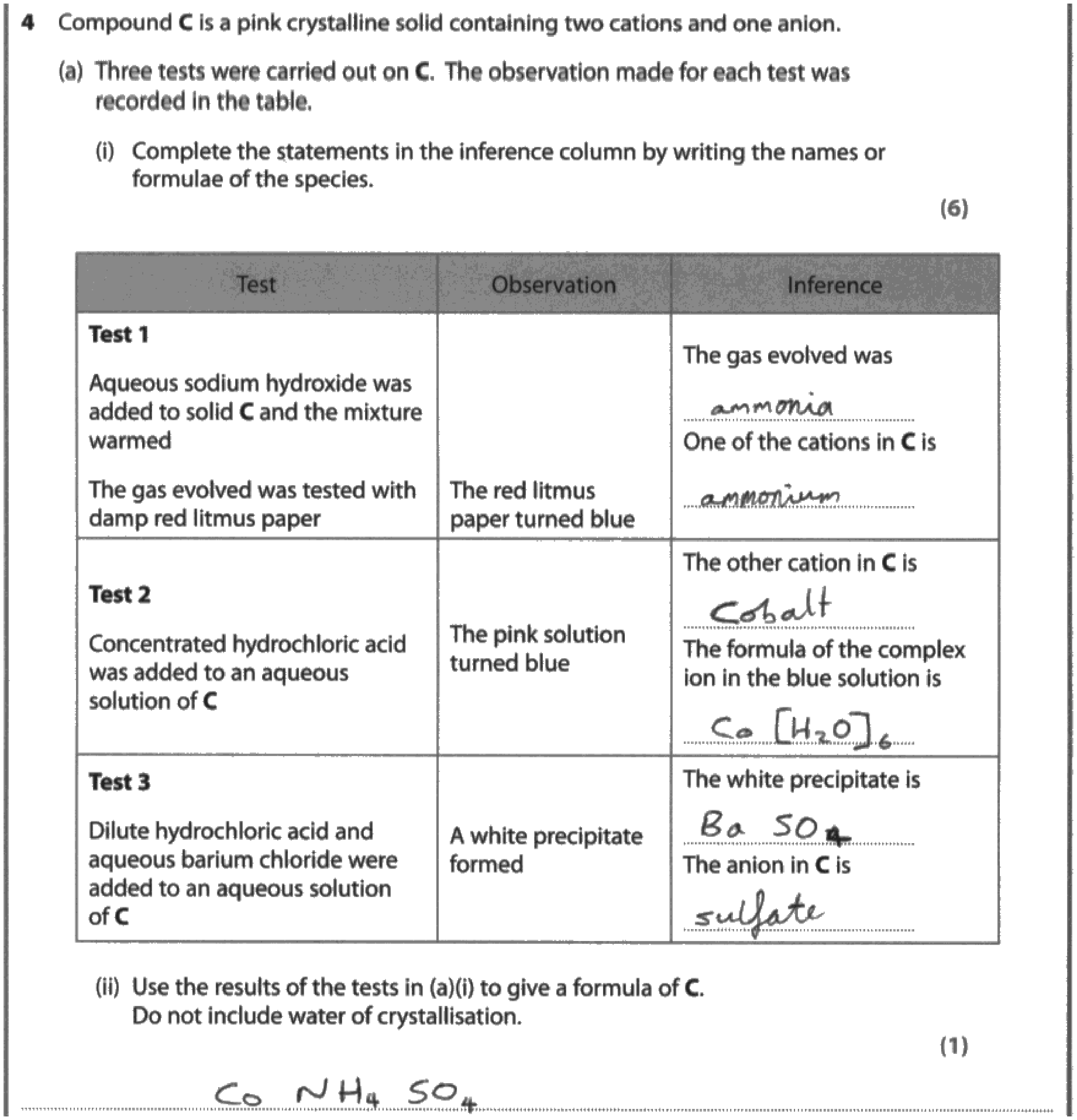
Examiner Tip

Always check your displayed formulae to make sure that you have not omitted any hydrogen atoms. Remember that each carbon atom must have 4 bonds.

Question 4 (a)

Candidates who have carried out tests to identify inorganic substances found this question straightforward. In part (a)(i) the most common error was to omit the oxidation state of cobalt. When a metal ion can have more than one oxidation state, it is important to give the name and oxidation state or the symbol with the charge ie cobalt(II) or Co^{2+}. A number of candidates thought that copper(II) salts changed from pink to blue when concentrated hydrochloric acid is added. This is incorrect, but they were awarded marks for the correct tetrchloro complex of copper(II) and a consequential formula of **C** in (ii). Some candidates were unfamiliar with the tetrachloro complex ion of cobalt(II). Candidates found it much more challenging to combine the formulae of the three ions to give an overall neutral species. They would benefit from more practice in using formulae of double salts.



4 Compound **C** is a pink crystalline solid containing two cations and one anion.

(a) Three tests were carried out on **C**. The observation made for each test was recorded in the table.

(i) Complete the statements in the inference column by writing the names or formulae of the species.

(6)

Test	Observation	Inference
Test 1 Aqueous sodium hydroxide was added to solid **C** and the mixture warmed The gas evolved was tested with damp red litmus paper	The red litmus paper turned blue	The gas evolved was ammonia One of the cations in **C** is ammonium
Test 2 Concentrated hydrochloric acid was added to an aqueous solution of **C**	The pink solution turned blue	The other cation in **C** is Cobalt The formula of the complex ion in the blue solution is $Co[H_2O]_6$
Test 3 Dilute hydrochloric acid and aqueous barium chloride were added to an aqueous solution of **C**	A white precipitate formed	The white precipitate is $Ba\ SO_4$ The anion in **C** is sulfate

(ii) Use the results of the tests in (a)(i) to give a formula of **C**.
Do not include water of crystallisation.

(1)

$Co\ NH_4\ SO_4$

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Examiner Comments

(i) 2 marks were scored for Test 1 and 2 marks for Test 3. Cobalt alone is not sufficient for the cation in **C** as cobalt can have more than one oxidation state. Cobalt(II) or Co^{2+} would score the mark. When concentrated hydrochloric acid is added to an aqueous solution containing cobalt(II) or copper(II) ions, the tetrachloro complex ion is formed.

(ii) This formula is incorrect. The cobalt ion has a charge of +2, the ammonium ion is +1 and sulfate is -2. This suggested formula would have an overall charge of +1.

ResultsPlus

Examiner Tip

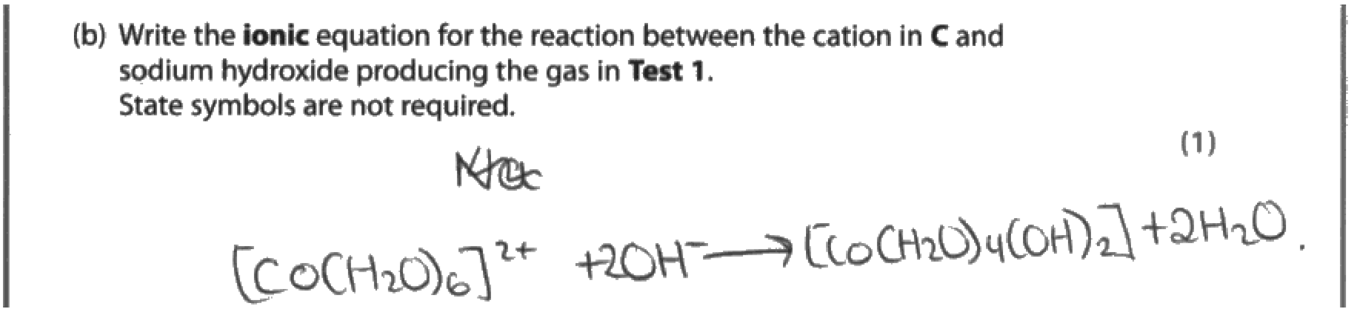
Learn the reactions of transition metal ions from the specification.

Remember to include the oxidation state or charge for the transition metal ions.

Practise writing the formulae of salts containing three ions to produce a neutral species.

Question 4 (b)

Many candidates struggled to write the ionic equation for the reaction between ammonium ions and hydroxide ions to produce ammonia and water. Some candidates did not read the questions and tried to write an equation involving cobalt(II) ions. Many candidates would benefit from more practice in writing ionic equations.



(b) Write the **ionic** equation for the reaction between the cation in **C** and sodium hydroxide producing the gas in **Test 1**.
State symbols are not required.

(1)

[illegible]

$[Co(H_2O)_6]^{2+} + 2OH^- \longrightarrow [Co(H_2O)_4(OH)_2] + 2H_2O$.

ResultsPlus
Examiner Comments

This response scored 0. The question asks for the ionic equation for the reaction to produce the gas in Test 1. The cation in Test 1 is NH_4^+ and the gas produced is ammonia.

ResultsPlus
Examiner Tip

Read the questions carefully and check to make sure that your answer matches the question.

(b) Write the **ionic** equation for the reaction between the cation in **C** and sodium hydroxide producing the gas in **Test 1**.
State symbols are not required.

(1)

$NH_4^+ + OH^- \rightarrow NH_3$

ResultsPlus
Examiner Comments

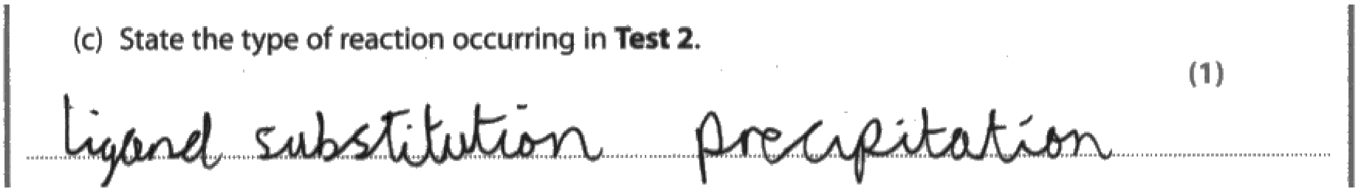
This response scored 0. The candidate has shown the ammonium ions reacting with hydroxide ions to form ammonia but the equation has not been balanced with H_2O.

ResultsPlus
Examiner Tip

When you are asked to write an equation, always check to make sure that you have balanced it correctly. Some equations do need water added as a reactant or product.

Question 4 (c)

The majority of candidates identified the reaction as ligand exchange or ligand substitution.



(c) State the type of reaction occurring in **Test 2.**

(1)

ligand substitution precipitation

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Examiner Comments

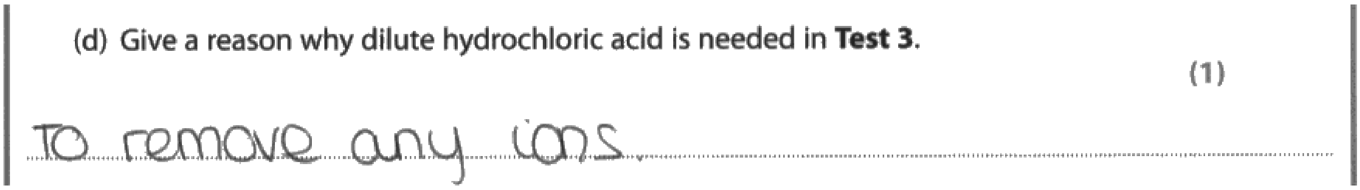
This candidate has given ligand substitution, which is correct. However, they have also written precipitation, which is incorrect so no mark was awarded.

ResultsPlus
Examiner Tip

If you give additional incorrect answers, you will lose the mark for the correct answer.

Question 4 (d)

Candidates who are familiar with the test for sulfate ions knew that hydrochloric acid is needed to prevent other anions, such as carbonate ions, from forming a precipitate with the barium ions. Many vague answers, such as 'to remove impurities' or 'to remove other ions' were seen and these did not receive any credit. Some candidates thought that the acid was a catalyst to speed up the reaction. Some candidates would benefit from a greater understanding of the tests for the ions in the specification.



(d) Give a reason why dilute hydrochloric acid is needed in **Test 3**.

(1)

To remove any ions.

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Examiner Comments

Many vague answers were seen, as in this example, that scored 0.

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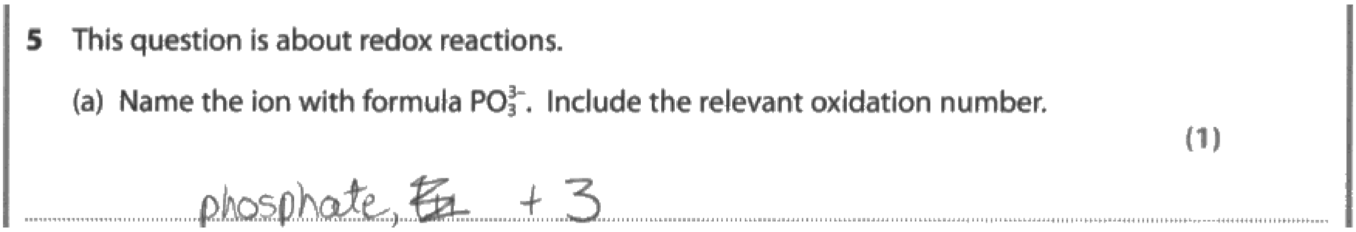
Examiner Tip

Learn the tests for the ions in the specifications and the reasons for adding hydrochloric acid when testing for sulfate ions or nitric acid when testing for halide ions.

Question 5 (a)

Many candidates struggled to give the name of the PO_33- ion. They should know that when there is oxygen in an anion, the name will end in -ate and the oxidation number should be written as Roman numerals in brackets after the name, so phosphate(III) is the best representation. All combinations of names that included phosphorus and oxygen were seen.



5 This question is about redox reactions.

(a) Name the ion with formula PO_3^{3-}. Include the relevant oxidation number.

(1)

phosphate, ~~[illegible]~~ +3

ResultsPlus
Examiner Comments

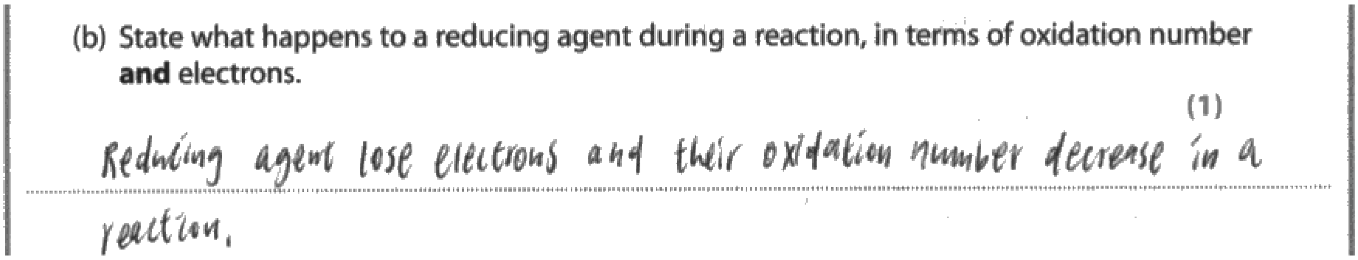
This answer was allowed for 1 mark. However, the oxidation state should be written in Roman numerals in brackets after the name.

ResultsPlus
Examiner Tip

Practise writing the names of anions containing oxygen.

Question 5 (b)

The majority of candidates knew that reducing agents lose electrons and increase in oxidation number. Some candidates thought that reducing agents are reduced themselves so gave the opposite answer and a few gave mixed answers.



(b) State what happens to a reducing agent during a reaction, in terms of oxidation number **and** electrons.

(1)

Reducing agent lose electrons and their oxidation number decrease in a reaction.

ResultsPlus
Examiner Comments

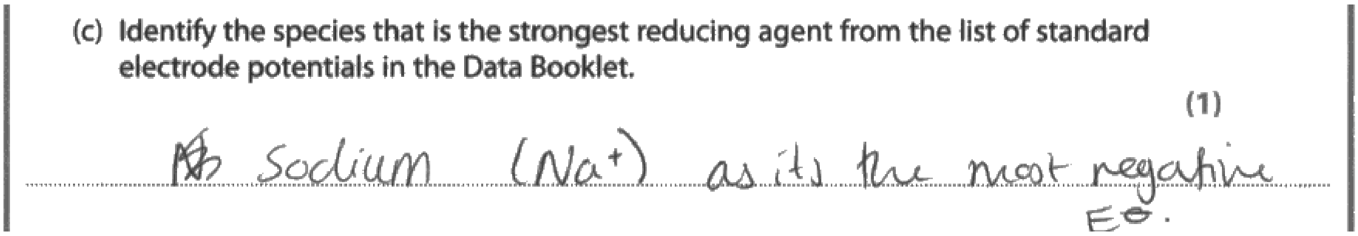
This candidate knows that reducing agents lose electrons as they reduce another substance by giving them electrons but the oxidation number is incorrect. No mark was awarded as both parts of the answer need to be correct.

ResultsPlus
Examiner Tip

Revise what happens to oxidising agents and reducing agents during a reaction, in terms of oxidation number and electrons.

Question 5 (c)

The majority of candidates selected sodium as the strongest reducing agent in the Data Booklet. However, some did not think carefully about what a reducing agent does and wrote Na^+. Others selected hydrogen peroxide but that would be the strongest oxidising agent.



(c) Identify the species that is the strongest reducing agent from the list of standard electrode potentials in the Data Booklet.

(1)

Sodium (Na^+) as its the most negative $E^\ominus$.

ResultsPlus
Examiner Comments

This candidate has stated sodium but given the formula of the sodium ion so scores 0. The high negative value indicates that the half equation takes place in reverse so sodium atoms readily lose electrons to form ions. The atoms, not the ions, are the strongest reducing agents.

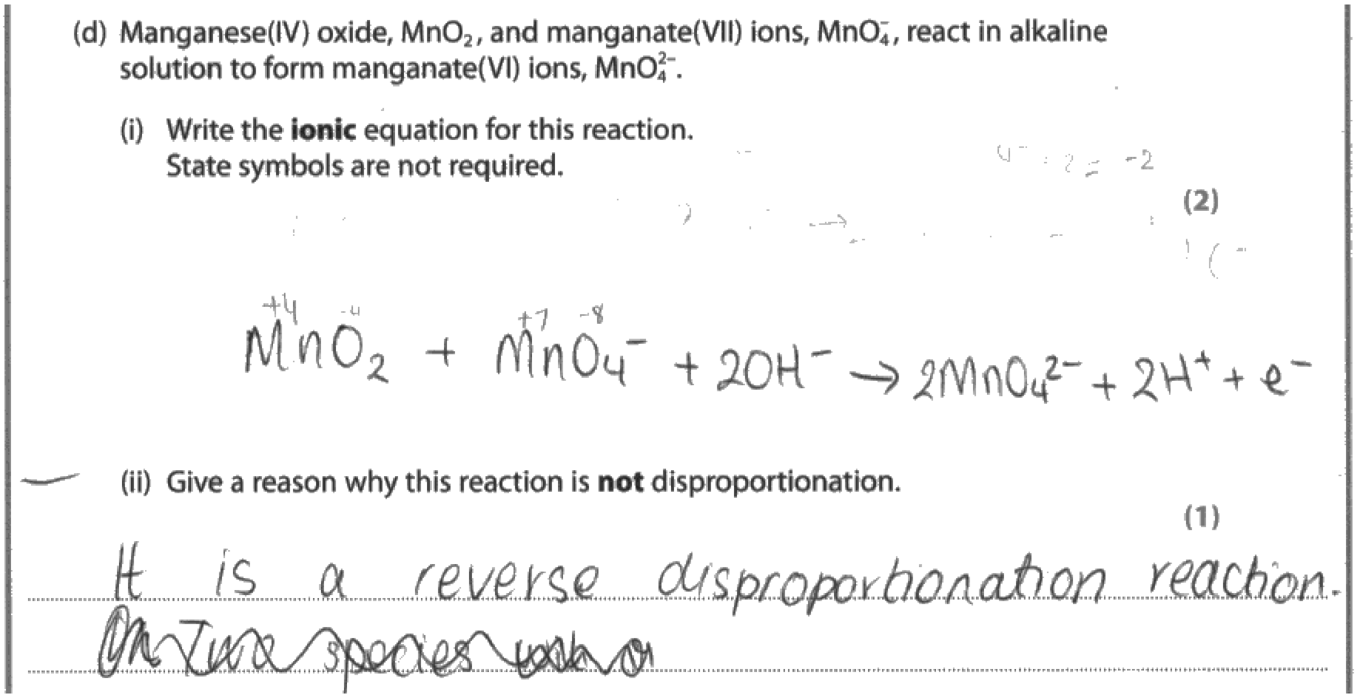
ResultsPlus
Examiner Tip

Learn how to use the half-equations and standard electrode potentials in the Data Booklet.

Question 5 (d)

(i) The majority of candidates struggled to write the ionic equation for the reaction between manganese(IV) oxide, manganate(VII) ions in alkaline solution to produce manganate(VI) ions, even though the formulae for all the manganese species were given in the stem of the question. Candidates did not seem to realise that hydroxide ions are present in an alkaline solution and it was disappointing to see many try to balance equations with H^+ and H_2. H_2O is a much more likely product.

(ii) More candidates were able to explain why the reaction was not disproportionation but there were many vague answers that were not given any credit. A common answer was that 'Mn is not oxidised and reduced' and that was not allowed as it did not state 'in the same species'. Manganese is being oxidised and reduced but it is in two different species. Candidates should think carefully about using the correct terminology as they interchanged terms such as element, ion, atom, molecule and compound without realising their meanings. The term 'species' is very useful in this context.



(d) Manganese(IV) oxide, MnO_2, and manganate(VII) ions, MnO_4^-, react in alkaline solution to form manganate(VI) ions, MnO_4^{2-}.

(i) Write the **ionic** equation for this reaction.
State symbols are not required.

(2)

$$\overset{+4}{Mn}\overset{-4}{O_2} + \overset{+7}{Mn}\overset{-8}{O_4^-} + 2OH^- \rightarrow 2MnO_4^{2-} + 2H^+ + e^-$$

(ii) Give a reason why this reaction is **not** disproportionation.

(1)

It is a reverse disproportionation reaction.

~~On Two species with a~~

ResultsPlus
Examiner Comments

(i) This response scored 1 mark for the manganese species in the correct sides of the equation and the use of OH^- ions. The second mark was not awarded as there should not be any uncancelled electrons in equations and H^+ ions will not be a product in a reaction involving hydroxide ions.

(ii) This is a correct statement but it does not answer the question so scores 0. The candidate could have added that there is not one species that is being oxidised and reduced.

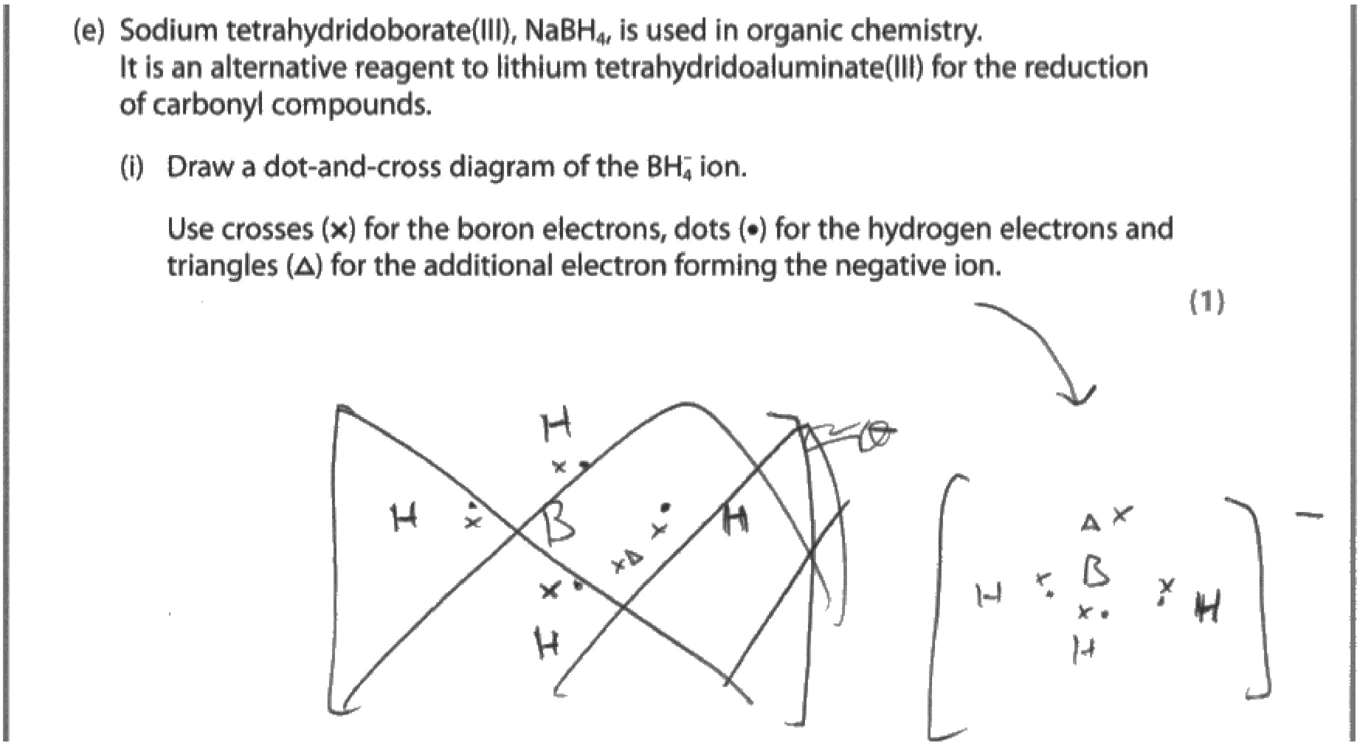
ResultsPlus

Examiner Tip

Practise writing ionic equations for redox reactions and balancing them using H^+, OH^- and / or H_2O as appropriate.

Question 5 (e) (i)

Although many candidates could draw the correct dot-and-cross diagram of the BH_4^- ion, there were many careless errors seen that lost the mark. Common errors included: omitting the negative charge, using incorrect symbols for the electrons, showing four electrons from the boron atom, adding the extra electron to an already full shell containing eight electrons and adding a lone pair of electrons.



(e) Sodium tetrahydridoborate(III), $NaBH_4$, is used in organic chemistry. It is an alternative reagent to lithium tetrahydridoaluminate(III) for the reduction of carbonyl compounds.

(i) Draw a dot-and-cross diagram of the BH_4^- ion.

Use crosses (×) for the boron electrons, dots (•) for the hydrogen electrons and triangles (Δ) for the additional electron forming the negative ion.

(1)

ResultsPlus
Examiner Comments

This candidate has included the negative charge on the ion. However, they have shown 4 electrons from boron, instead of three and only included three hydrogen atoms instead of four so this response scored 0.

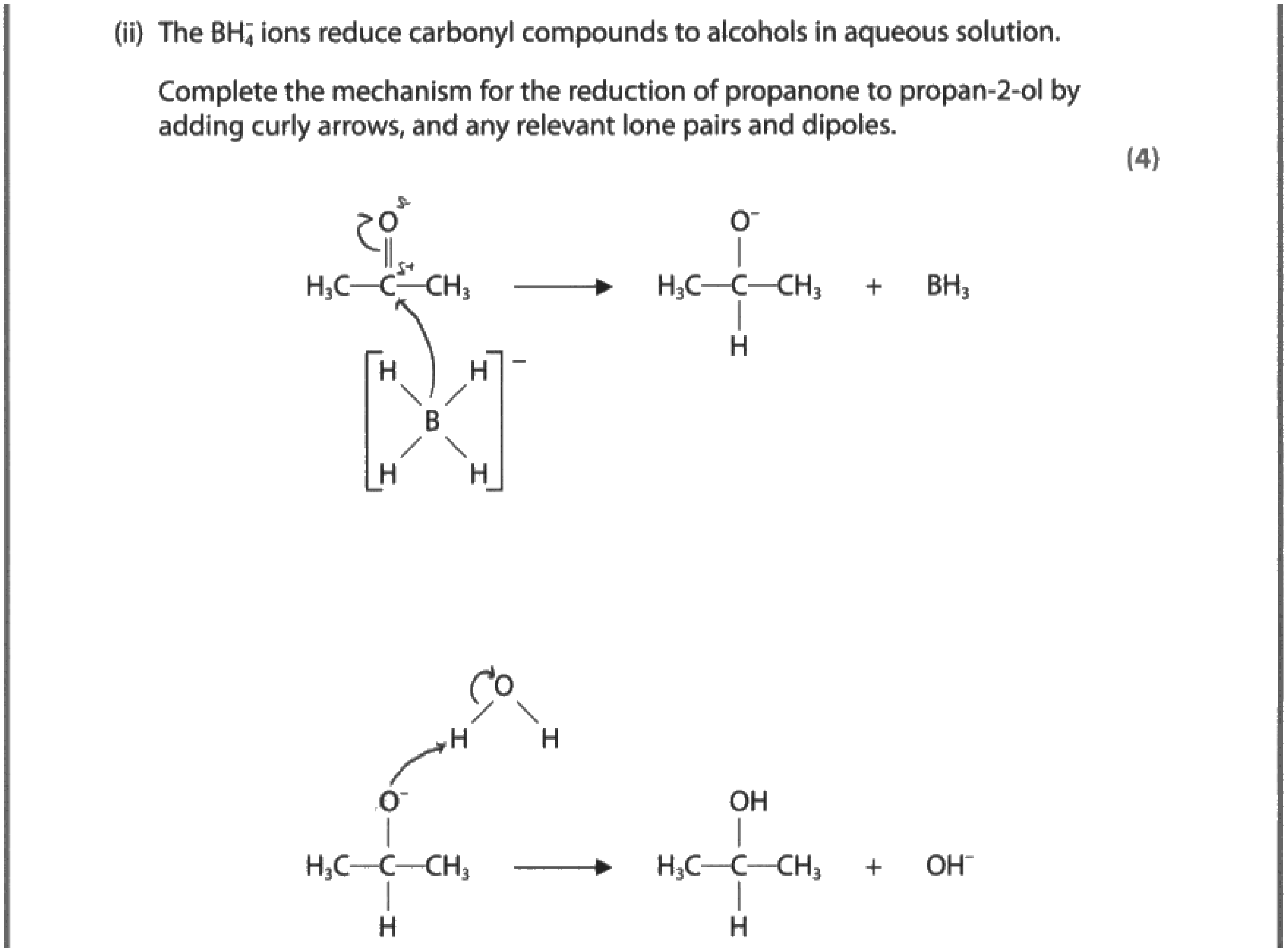
ResultsPlus
Examiner Tip

Read the question carefully and check that your dot-and-cross diagram contains the correct number of atoms.

Use the Periodic Table to work out the number of electrons in the outer shell of an atom.

Question 5 (e) (ii)

Candidates are not expected to know this mechanism for the reduction of propanone to propan-2-ol but they should be able to apply their knowledge of other mechanisms, e.g. the nucleophilic addition of HCN to carbonyl compounds. Candidates should know that oxygen is more electronegative than carbon and hydrogen so should be able to include relevant dipoles. They should also know that oxygen atoms have lone pairs. Some answers seemed to contain a random arrangement of curly arrows, including some with half arrow-heads, that showed those candidates did not understand that a curly arrow represents the movement of a pair of electrons so must start from a bond or a lone pair. Many candidates would benefit from gaining a clear understanding of organic reaction mechanisms, rather than trying to rote learn them.



(ii) The BH_4^- ions reduce carbonyl compounds to alcohols in aqueous solution.

Complete the mechanism for the reduction of propanone to propan-2-ol by adding curly arrows, and any relevant lone pairs and dipoles.

(4)

ResultsPlus
Examiner Comments

The dipole on the C=O bond is correct but the curly arrow has a half arrow-head which represents the movement of a single electron and results in the formation of a free radical. The curly arrow starting from the boron atom is incorrect as curly arrows represent the movement of a pair of electrons so must start from a bond or a lone pair. The lone pair is missing from the O^- ion and the dipole is missing from the O-H bond but 1 mark was allowed for the two curly arrows.

ResultsPlus
Examiner Tip

Don't just learn the organic reaction mechanisms, make sure that you understand what is happening at each stage so that you can apply your knowledge to different reactions.

Question 6 (a) (i)

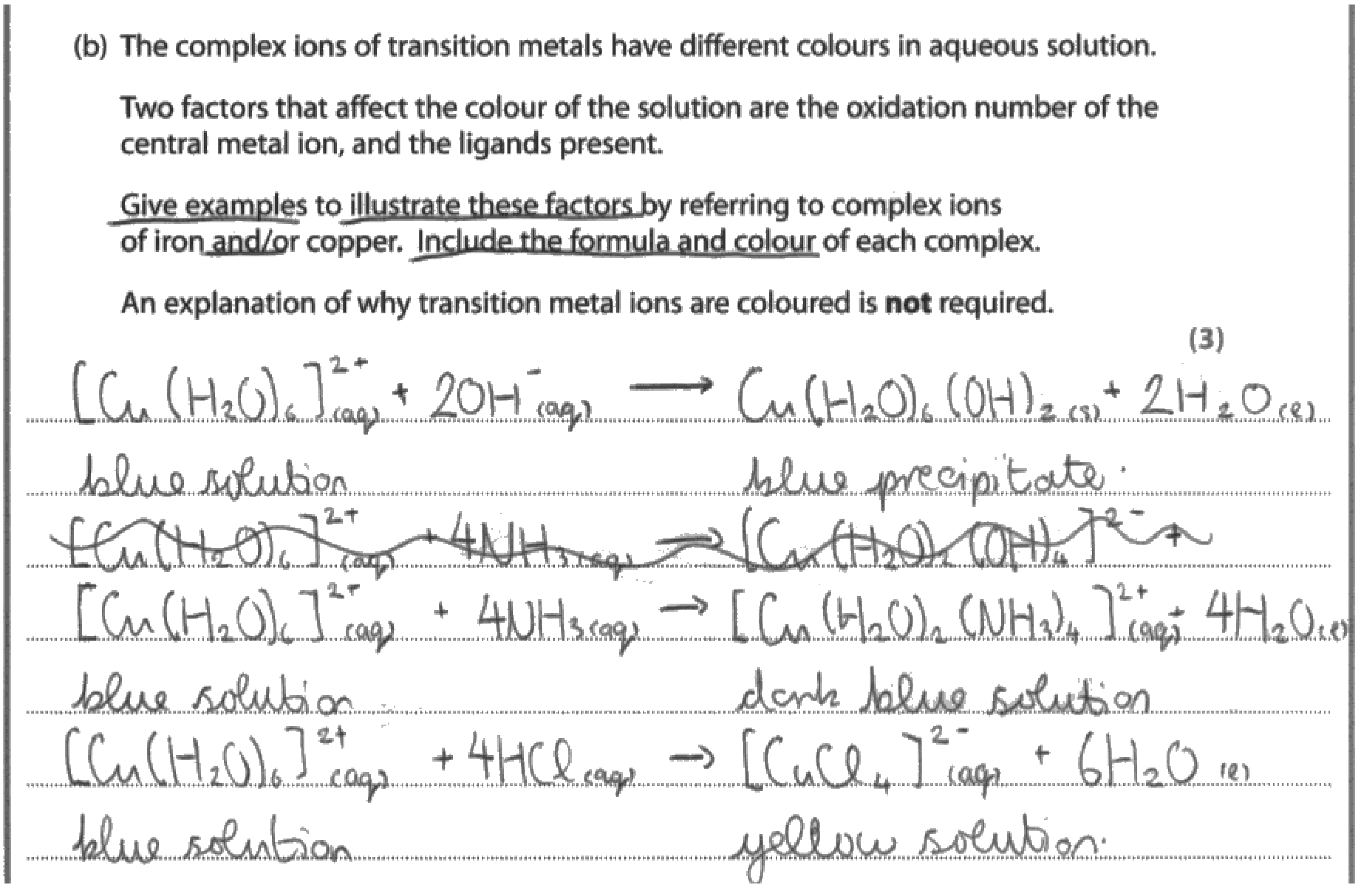
Candidates should know that the coordination number is the number of coordinate (dative covalent) bond around the central ion and not the number of ligands.

Question 6 (a) (ii)

Candidates should know that chloride ions have a negative charge and ethane-1,2-diamine is neutral so the overall charge on the ion can be deduced as +1.

Question 6 (b)

Candidates who were familiar with the complex ions of iron(II), iron(III) and copper(II) and their colours, found this a straightforward question. Some candidates did not read the question and wrote about the colours of the hydroxide precipitates formed by those metals instead of the complex ions asked for in the question. The question asked for the effect of oxidation number and ligands on the colour and a significant number of candidates only answered one of these points. Common errors included: giving incorrect formulae of the complex ions eg $[Cu(NH_3)_6]^{2+}$, incorrect colours eg $[CuCl_4]^{2-}$ as green instead of yellow or giving incorrect complex ions eg $[Fe(NH_3)_6]^{2+}$. Candidates would benefit from carrying out test tube experiments involving the complex ions in the specification and then recording the colours and formulae of these complex ions. A few candidates ignored the instruction to **not** give an explanation of why transition metal ions are coloured.



(b) The complex ions of transition metals have different colours in aqueous solution.

Two factors that affect the colour of the solution are the oxidation number of the central metal ion, and the ligands present.

Give examples to illustrate these factors by referring to complex ions of iron and/or copper. Include the formula and colour of each complex.

An explanation of why transition metal ions are coloured is **not** required.

(3)

$[Cu(H_2O)_6]^{2+}_{(aq)} + 2OH^-_{(aq)} \longrightarrow Cu(H_2O)_6(OH)_{2(s)} + 2H_2O_{(l)}$

blue solution blue precipitate.

~~$[Cu(H_2O)_6]^{2+}_{(aq)} + 4NH_{3(aq)} \rightarrow [Cu(H_2O)_2(OH)_4]^{2-} +$~~

$[Cu(H_2O)_6]^{2+}_{(aq)} + 4NH_{3(aq)} \rightarrow [Cu(H_2O)_2(NH_3)_4]^{2+}_{(aq)} + 4H_2O_{(l)}$

blue solution dark blue solution

$[Cu(H_2O)_6]^{2+}_{(aq)} + 4HCl_{(aq)} \rightarrow [CuCl_4]^{2-}_{(aq)} + 6H_2O_{(l)}$

blue solution yellow solution.

ResultsPlus
Examiner Comments

This answer scored 2 marks.

The candidate has given the correct formulae and colours of three complex ions with different ligands, even though two would have been enough to illustrate the point. The blue precipitate was ignored.

However, they have not given an example to show how the colour is affected by oxidation number. The best example to illustrate that point would be the colours of the Fe^{2+}(aq) and Fe^{3+}(aq) ions.

ResultsPlus
Examiner Tip

Check your work to make sure that you have answered all parts of a question.

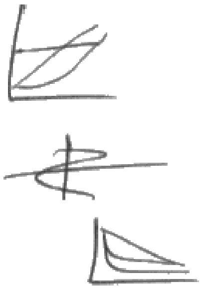
Question 6 (c) (i) - (iii)

Many candidates could draw an acceptable graph for 2 marks in (i), although some omitted units from the axis labels and some started the pressure axis at 0 so their points did not cover at least half of the graph paper. A few candidates reversed the axes and some chose complicated scales that usually meant they plotted one or more points incorrectly.

In (ii), some candidates realised that the graph is a straight line so the rate equation is just rate = k. However, some thought the straight line meant that it was first order as they confused a pressure / time graph with a rate / time graph. A few candidates gave the expression for the equilibrium constant.

Many candidates were able to calculate the gradient of the graph in (iii) and give the corresponding units, although a significant number used mol dm^{-3} s^{-1} as they did not use the units given in the question.

(c) Tungsten wire catalyses the decomposition of ammonia.



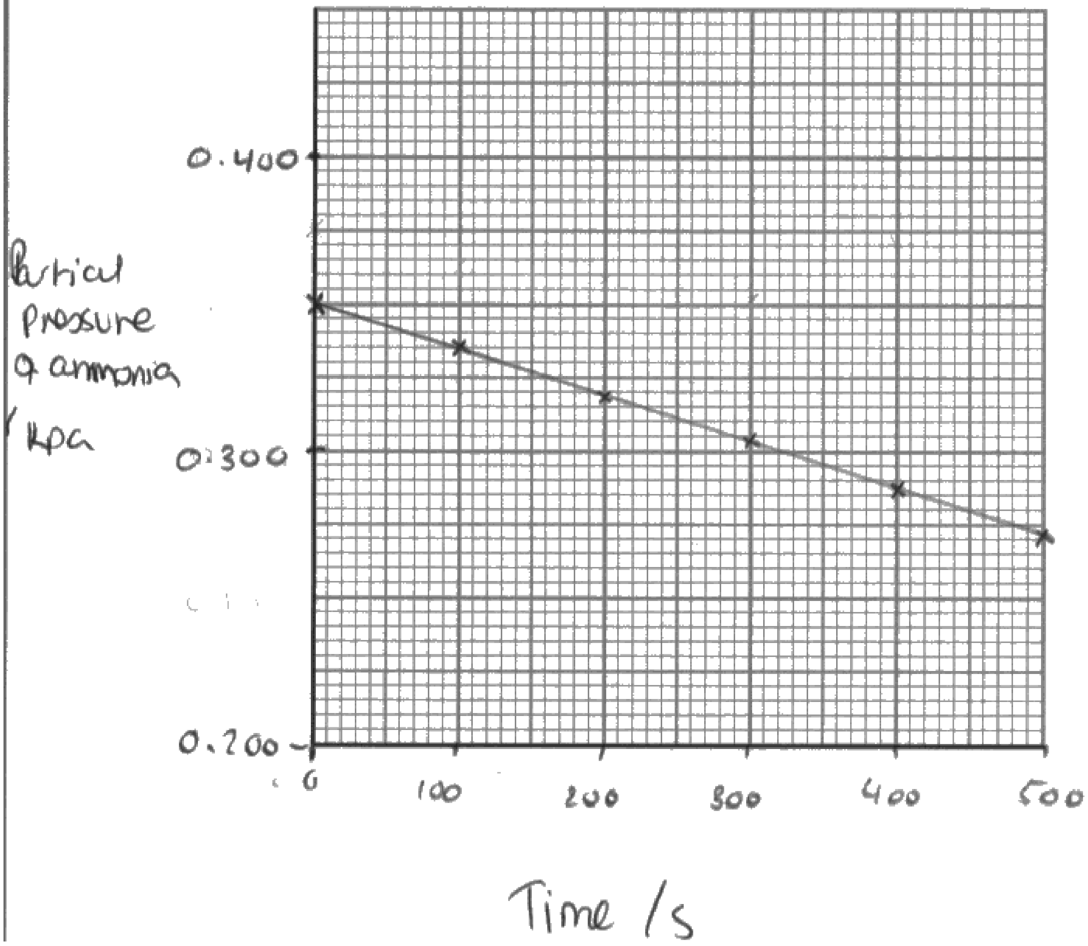
$$2NH_3(g) \rightarrow N_2(g) + 3H_2(g)$$

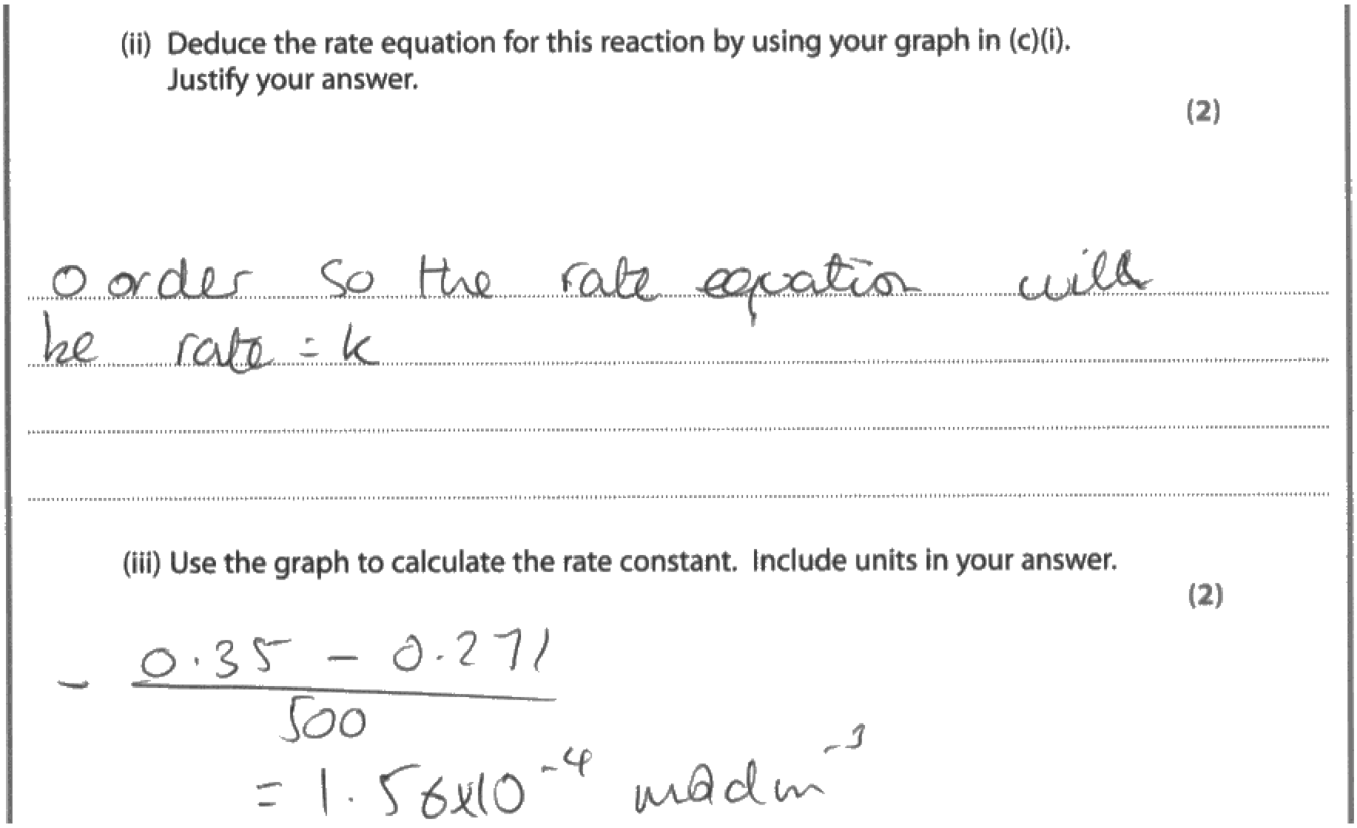
In an experiment, the following results were obtained.

Time /s	Partial pressure of ammonia / kPa
0	0.350
100	0.335
200	0.319
300	0.303
400	0.287
500	0.271

(i) Plot a graph of partial pressure of ammonia against time.

(2)





(ii) Deduce the rate equation for this reaction by using your graph in (c)(i). Justify your answer.

(2)

0 order so the rate equation will be rate = k

(iii) Use the graph to calculate the rate constant. Include units in your answer.

(2)

$$-\frac{0.35 - 0.271}{500}$$

$$= 1.58 \times 10^{-4} \text{ mol dm}^{-3}$$

ResultsPlus

Examiner Comments

(i) The points do not cover at least half of the y axis so only 1 mark was awarded.

(ii) The rate equation is correct for 1 mark but the candidate has not explained why it is 0 order. They could have stated that the rate is independent of the partial pressure of ammonia or just that the graph is a straight line.

(iii) The gradient and value of the rate constant are correct but the units are incorrect. Use the units from the data in the table or on the graph.

ResultsPlus
Examiner Tip

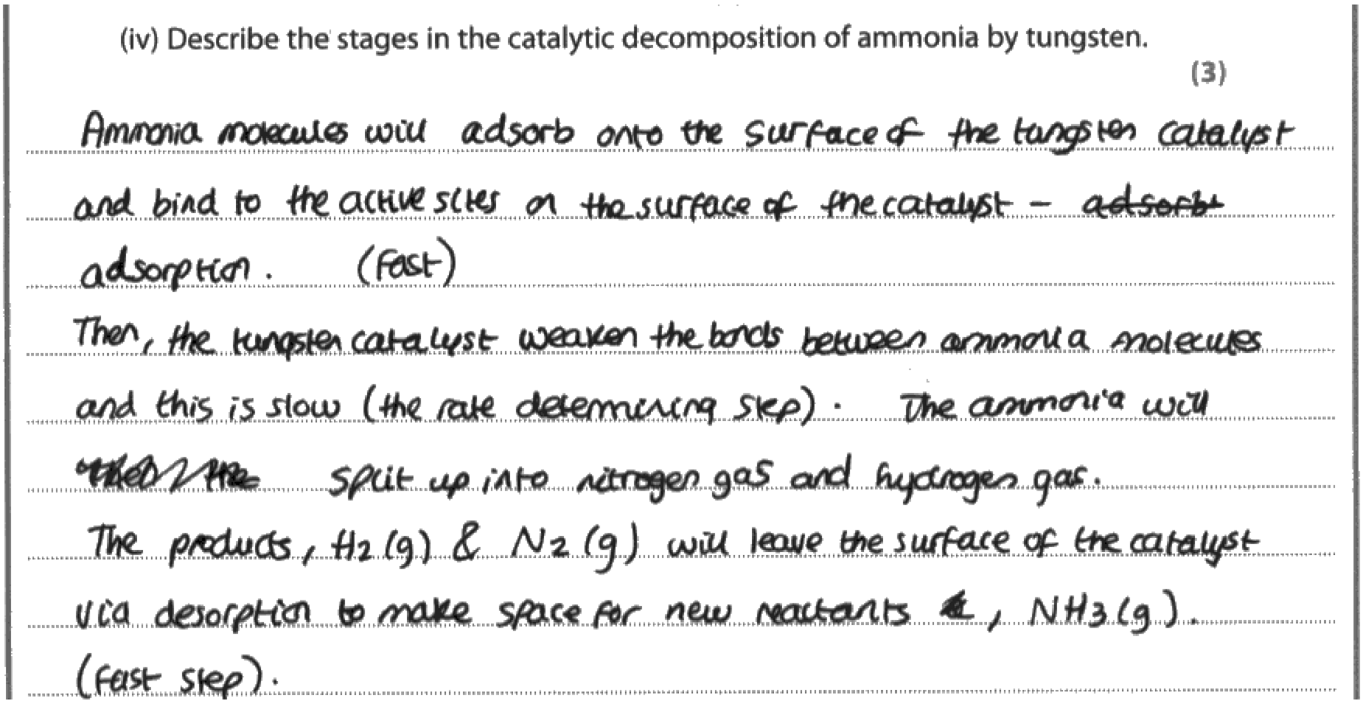
Choose a suitable scale for graphs so that the points cover at least half of both the x and y axes.

Give full reasons for any justifications you are asked for.

Check the units of the data you are given in the question paper.

Question 6 (c) (iv)

The majority of candidates were able to make a good attempt at this question, with many scoring full marks. Some candidates lost a mark by just stating that the ammonia molecules are adsorbed and did not mention the surface of the tungsten and a few thought that ammonia would be desorbed from the catalyst, rather than the products. A few candidates confused heterogeneous and homogeneous catalysts and wrote about the change in oxidation number of tungsten and a few wrote generally about catalysts providing an alternative route with a lower activation energy, but that was not needed here.



(iv) Describe the stages in the catalytic decomposition of ammonia by tungsten.

(3)

Ammonia molecules will adsorb onto the surface of the tungsten catalyst and bind to the active sites on the surface of the catalyst – ~~adsorbt~~ adsorption. (Fast)

Then, the tungsten catalyst weaken the bonds between ammonia molecules and this is slow (the rate determining step). The ammonia will ~~then / the~~ split up into nitrogen gas and hydrogen gas.

The products, $H_2(g)$ & $N_2(g)$ will leave the surface of the catalyst via desorption to make space for new reactants ~~&~~, $NH_3(g)$. (fast step).

ResultsPlus
Examiner Comments

This answer scored 2 marks.

The candidate knows that the ammonia molecules are adsorbed onto the surface of the tungsten and that the products will be absorbed. However, they have written that the catalyst 'weakens the bonds between ammonia molecules' and this is incorrect. There are hydrogen bonds between ammonia molecules but those are not relevant here. It is the covalent bonds **in** the ammonia molecules that are weakened.

ResultsPlus
Examiner Tip

Make sure that you know the difference between forces or bonds **between** molecules (intermolecular) and the bonds **in** a molecule (intramolecular).

Question 7 (a) (i)

Most candidates are familiar with a meniscus on the surface of an aqueous solution and how to read a burette. However, some candidates lost a mark by drawing a straight line or a meniscus curving upwards and others read the burette upwards instead of downwards.

7 A group of students analysed a hydrated salt with the formula $KH_3(C_2O_4)_y.zH_2O$ where **y** and **z** are whole numbers.

The students carried out experiments to determine the values of **y** and **z**.

(a) **Experiment 1** – to determine the value of **y**

One student was provided with a 0.0235 mol dm^{-3} solution of the salt.

25.0 cm^3 portions of the salt solution were acidified with excess dilute sulfuric acid and heated to about 60 °C.

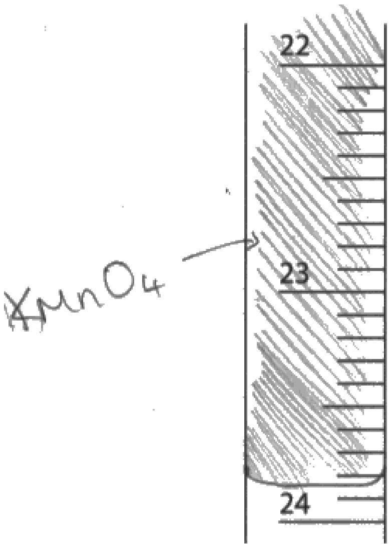
Each portion was titrated with 0.0203 mol dm^{-3} potassium manganate(VII).

The results of four titrations are shown in the table.

Titration number	1	2	3	4
Final burette reading / cm^3	23.85	47.20	24.05	48.10
Initial burette reading / cm^3	0.00	24.00	0.50	25.00
Titre / cm^3	23.85	23.20	23.55	23.10

(i) Complete the diagram to show the final burette reading in **Titration 1**.

(2)



ResultsPlus
Examiner Comments

This answer scored 1 mark.

This candidate has shown the correct shape of meniscus in the correct position in the burette. However, they have lost a mark as they have shaded the solution above the meniscus. The solution did not need to be shaded but if it is shaded, it must be below the meniscus.

ResultsPlus
Examiner Tip

Look carefully at a solution in a burette and make sure that you know how to read the volume correctly.

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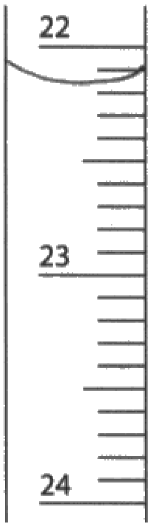
Titre / cm^3	23.85	23.20	23.55	23.10

(i) Complete the diagram to show the final burette reading in **Titration 1**.

(2)



ResultsPlus
Examiner Comments

This answer scored 1 mark for the shape of the meniscus. The bottom of the meniscus is incorrect as the candidate has gone up 0.85 from 23, instead of down.

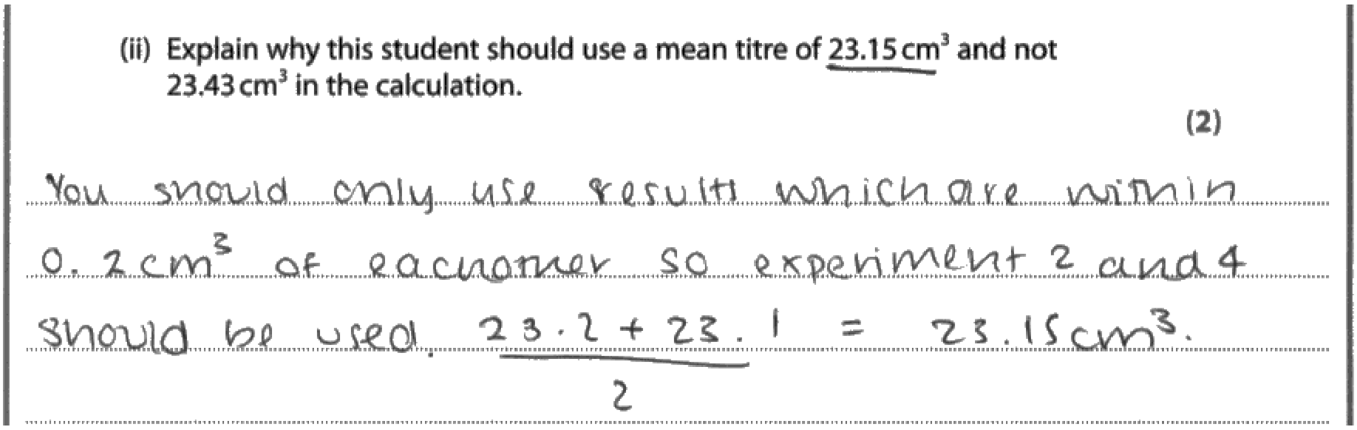
ResultsPlus

Examiner Tip

Learn how to take a burette reading.

Question 7 (a) (ii)

The majority of candidates scored at least 1 mark for this item as they knew that only the concordant titres should be used. A significant number did not explain why 23.43 cm^3 should not be used.



(ii) Explain why this student should use a mean titre of $\underline{23.15\,cm^3}$ and not 23.43 cm^3 in the calculation.

(2)

You should only use results which are within 0.2cm^3 of eachother so experiment 2 and 4 should be used. $\frac{23.2 + 23.1}{2} = 23.15cm^3$.

ResultsPlus

Examiner Comments

This is a clear answer that explains why 23.15 cm^3 should be used as the mean so it scored 1 mark. The candidate should have also explained why 23.43 cm^3 should not be used, e.g. since it includes the non-concordant values.

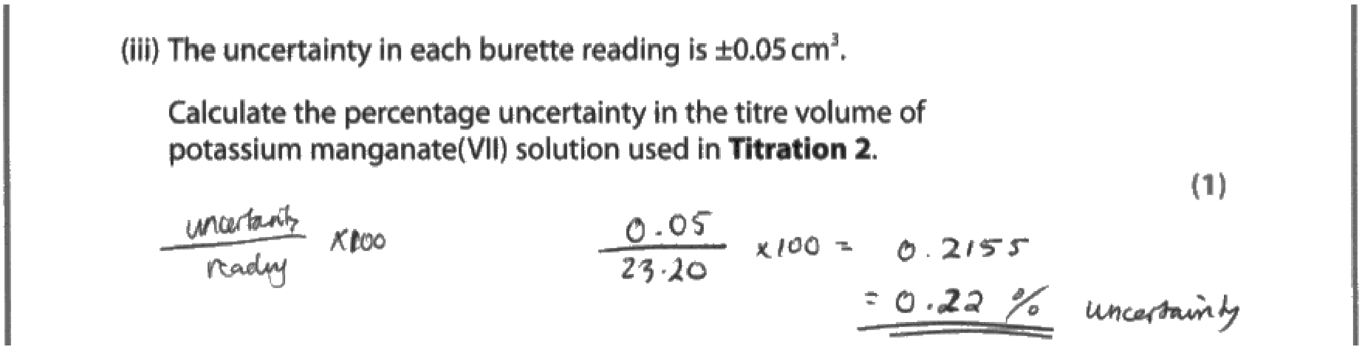
ResultsPlus

Examiner Tip

Check your answers to make sure that you have answered all parts of the question.

Question 7 (a) (iii)

The majority of candidates calculated the percentage uncertainty in the titre volume correctly. Some did not realise that there are two burette readings for each titre, as shown in the results table, so the uncertainty must be multiplied by 2. A few candidates used the wrong data.



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

Calculate the percentage uncertainty in the titre volume of potassium manganate(VII) solution used in **Titration 2**.

(1)

$\frac{\text{uncertainty}}{\text{reading}} \times 100$ $\frac{0.05}{23.20} \times 100 = 0.2155$

$= 0.22\ \%$ uncertainty

ResultsPlus
Examiner Comments

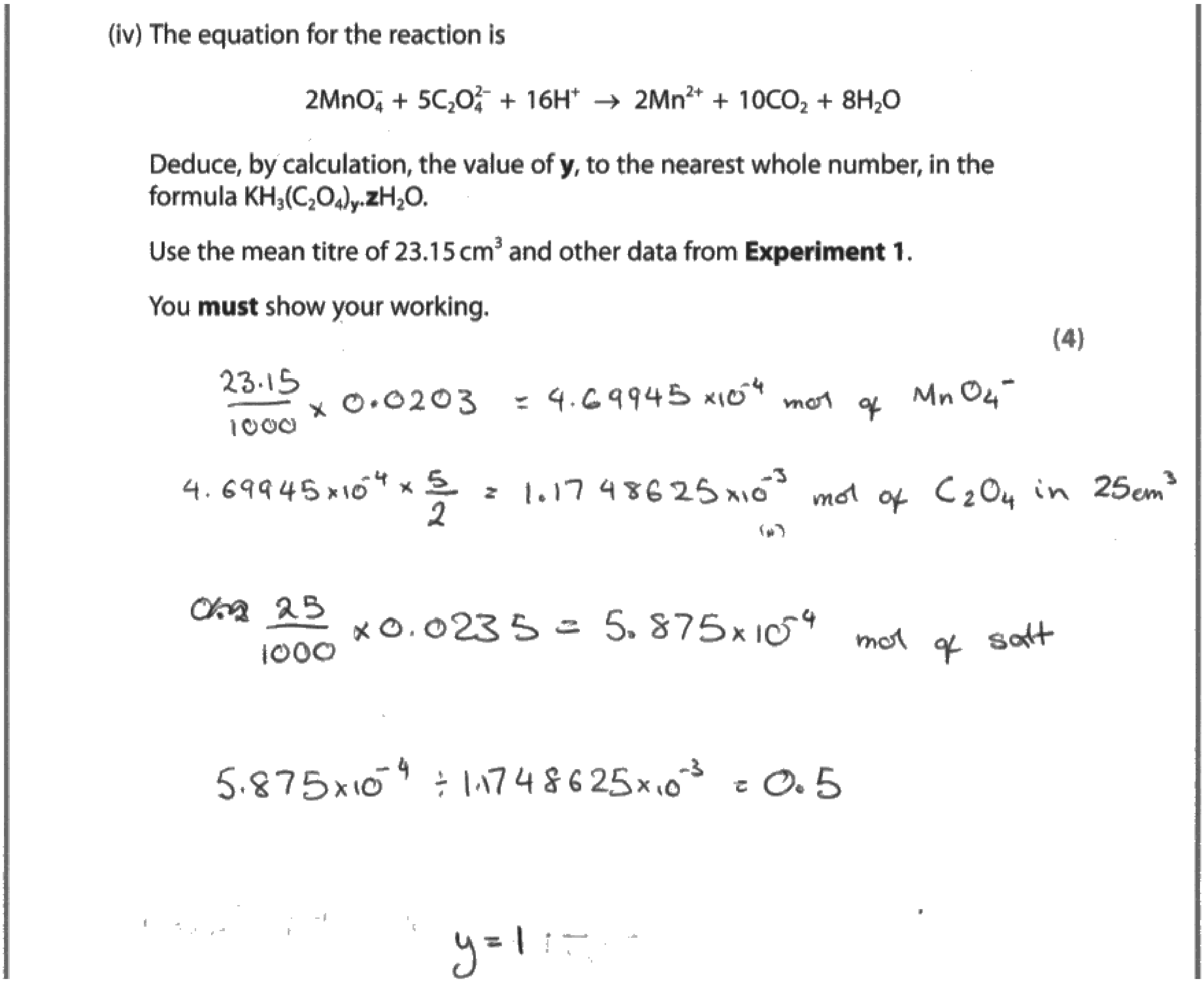
This was a common incorrect answer that scored 0. The candidate just used one burette reading instead of two.

ResultsPlus
Examiner Tip

Remember that you have to take two burette readings to obtain a titre so the uncertainty should be multiplied by 2.

Question 7 (a) (iv) - (bi)

Many candidates were able to calculate the values of *y* and *z* and they set out their working clearly so that it was easy to follow. Many candidates were able to score some of the marks in (a)(iv) for calculating some or all of the numbers of moles of manganate(VII) ions, ethanedioate ions and salt but then they struggled to find the final ratio and value of *y*. Candidates generally found (b)(i) more difficult. They calculated the masses of hydrated salt, anhydrous salt and water but did not go any further. Those who calculated the moles of water scored 1 mark.



(iv) The equation for the reaction is

$$2MnO_4^- + 5C_2O_4^{2-} + 16H^+ \rightarrow 2Mn^{2+} + 10CO_2 + 8H_2O$$

Deduce, by calculation, the value of **y**, to the nearest whole number, in the formula $KH_3(C_2O_4)_\mathbf{y}.\mathbf{z}H_2O$.

Use the mean titre of 23.15 cm³ and other data from **Experiment 1**.

You **must** show your working.

(4)

$\frac{23.15}{1000} \times 0.0203 = 4.69945 \times 10^{-4}$ mol of MnO_4^-

$4.69945 \times 10^{-4} \times \frac{5}{2} = 1.1748625 \times 10^{-3}$ mol of C_2O_4 in 25cm³

$\frac{25}{1000} \times 0.0235 = 5.875 \times 10^{-4}$ mol of salt

$5.875 \times 10^{-4} \div 1.1748625 \times 10^{-3} = 0.5$

$y = 1$

(b) **Experiment 2** – to determine the value of **z**

Another student wrote an account of the method for this experiment.

A crucible was weighed.

A sample of the hydrated salt was added to the crucible and it was reweighed.

The crucible and salt were heated to remove the water of crystallisation and then allowed to cool.

The crucible and contents were weighed again.

Results

Mass of crucible	= 19.56 g
Mass of crucible + $KH_3(C_2O_4)_y.\mathbf{z}H_2O$	= 22.97 g
Mass of crucible + $KH_3(C_2O_4)_y$	= 22.52 g

(i) Deduce, by calculation, the value of **z**, to the nearest whole number, in the formula $KH_3(C_2O_4)_y.\mathbf{z}H_2O$.

You must use the data from **Experiment 2** and your value of **y** in (a)(iv).

You **must** show your working.

(3)

(22.97 − 19.56) − (22.52 − 19.56)

= 0.45 g of water

~~mol = $\frac{0.45}{18}$ = 0.025~~

22.97 − 19.56 = 3.41 g of hydrated crystal

$\frac{0.45}{18} = 0.025$

0.5 ÷ 0.025 = 2

y = 2

ResultsPlus
Examiner Comments

(a)(iv) This answer scored 3 marks for the correct calculation of the moles of manganate(VII) ions, ethanedioate ions and salt. The ratio is the wrong way up so the value of *y* is incorrect.

(b)(i) This answer scored 1 mark for calculating the moles of water. The rest of the calculation is incorrect as 0.5 divided by 0.025 equals 20, not 2.

ResultsPlus
Examiner Tip

Set your work out clearly so that you can be awarded marks for the intermediate steps even if the final answer is incorrect.

If you are given the volume and concentration of a solution, start the calculation by working out the number of moles of solute.

Think carefully about which way to calculate a ratio.

Subtracting masses alone is rarely worth any credit in examinations but you should be able to convert some of them to moles by dividing by the molar mass and then you will receive credit.

Question 7 (b) (ii)

Some candidates gave clear and concise evaluations of the suggestions and how the method could be improved to prevent the errors. Others found it difficult to express their ideas clearly and were contradictory or confused about the effects of the errors on the calculated value of z. Many candidates wrote about the masses of the solids, rather than focussing on z, which is the moles of water. Candidates should clearly structure their answers to questions like this and it is acceptable to use bullet points. The majority of candidates would benefit from much more practice at evaluating results of experiments and suggesting improvements.

(ii) A third student carried out Experiment 2 and calculated a value of **z** that was lower than expected.

This student evaluated the experiment and gave two suggestions for **z** being lower.

Suggestion **1**
"Some of the crystals jumped out of the crucible while it was being heated."

Suggestion **2**
"It was difficult to tell when all the water of crystallisation had been lost."

Evaluate these two suggestions to decide whether they could account for the lower value of **z** obtained from the experimental results.

Include an explanation of the effect each suggestion would have on the calculated value of **z** and how the method could be improved to prevent these errors.

(5)

If some of the crystals jumped out, this would give a lower reading for the mass, thus implying that more water evaporated. If more water evaporated, the value for z would be greater ~~so →~~. Suggestion 1 does not account for the lower value.

Suggestion 2 ~~do~~ may account for a lower value of z, because they may have weighed ~~it before~~ the crucible before ~~the~~ all the water ~~was~~ was lost. This would imply that less water was present in the salt, thus giving a lower value for z.

ResultsPlus
Examiner Comments

This answer scored 3 marks. The candidate has clearly explained the effect of the errors on the mass of water lost and hence the value of *z*. However, there is no mention of how to improve the method to prevent the errors.

ResultsPlus
Examiner Tip

Check your answers carefully to make sure that you have answered all parts of the question.

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Include an explanation of the effect each suggestion would have on the calculated value of **z** and how the method could be improved to prevent these errors.

(5)

Suggestion 1

If some crystals jumped out of the crucible then the mass after heating would be lower therefore the student would have thought more water evaporated than the actual amount. This would lead to the student believing there was a greater mass of water therefore more mols of water so z would be greater. ∴ cannot account for lower z

To prevent crystals jumping out use a crucible with higher walls or a lid.

Suggestion 2

If not all the water of crystallisation was removed since it was hard to tell if it was completely dry then the final mass of the crucible would be ~~les~~ greater therefore the student would believe the mass of water in the hydrated salt is less than it is in reality thus leading to a lower value of z being calculated.

To ensure all water of crystalisation is removed heat to constant mass.

ResultsPlus
Examiner Comments

This is an example of an excellent response that scored 5 marks.

ResultsPlus
Examiner Tip

Set out your answers clearly and logically, as in this example.

Question 8 (a) (i)

Many candidates scored 3 marks for giving clear reasons for each of the Steps **2**, **3** and **4**. However, some gave vague answers that were not worthy of credit. Many missed the fact that the reaction with concentrated sulfuric acid would be exothermic so they just wrote about slowing down the rate of reaction in Step **2**. A common error in Step **3** was to state that anti-bumping granules distribute the heat more evenly instead of providing a surface for small bubbles to form and many candidates thought that they would promote smooth heating instead of smooth boiling. Some candidates lost a mark in Step **4** as they thought that all the reactants and products would escape if it was not heated under reflux, instead of specifying the volatile or organic reactants and products.

8 1-bromobutane can be prepared from butan-1-ol and hydrogen bromide.

$$CH_3CH_2CH_2CH_2OH + HBr \rightarrow CH_3CH_2CH_2CH_2Br + H_2O$$

Hydrogen bromide can be made from sodium bromide and 50% concentrated sulfuric acid.

(a) The steps for the preparation of impure 1-bromobutane are summarised.

Step **1** Dissolve the sodium bromide in distilled water in a pear-shaped flask and then add 20.0 cm^3 of butan-1-ol.

Step **2** Surround the flask with an ice bath to **cool the mixture**, before adding concentrated sulfuric acid drop by drop.

Step **3** Remove the flask from the ice bath and add a few **anti-bumping granules** to the reaction mixture.

Step **4** Set up the apparatus for **heating under reflux**. Heat the mixture in the flask for 30 minutes and then allow the apparatus to cool.

Step **5** Rearrange the apparatus for distillation and heat the mixture until no more 1-bromobutane distils over.

(i) Parts of the method are given in **bold** type in Steps **2**, **3** and **4**.
Give a reason why each of these parts is necessary.

(3)

- It is necessary to cool the mixture so that the ~~1-bromobutane doesn't oxidise~~ butan-1-ol doesn't oxidise any further (e.g. oxidise to form an aldehyde or oxidise further to form a carboxylic ~~ha~~ acid).
- It is necessary to add anti-bumping granules so that smaller bubbles can form on the surface of these to prevent large bubble from forming and to prevent an uneven distribution of heat which would cause the mixture to splutter and escape.
- It is necessary to heat under reflux because complete ~~the~~ oxidation reactions ~~etc~~ and the general reaction can occur quickly and thoroughly without the formation of side / by products which don't contribute towards the formation of the products → ($CH_3CH_2CH_2CH_2Br$ & H_2O).

ResultsPlus
Examiner Comments

This answer scored 1 mark for the use of anti-bumping granules.

This candidate seems to have confused the preparation of 1-bromobutane from butan-1-ol with the oxidation of butan-1-ol to form butanal and butanoic acid so cannot score any marks for Step **2** and Step **4**.

ResultsPlus
Examiner Tip

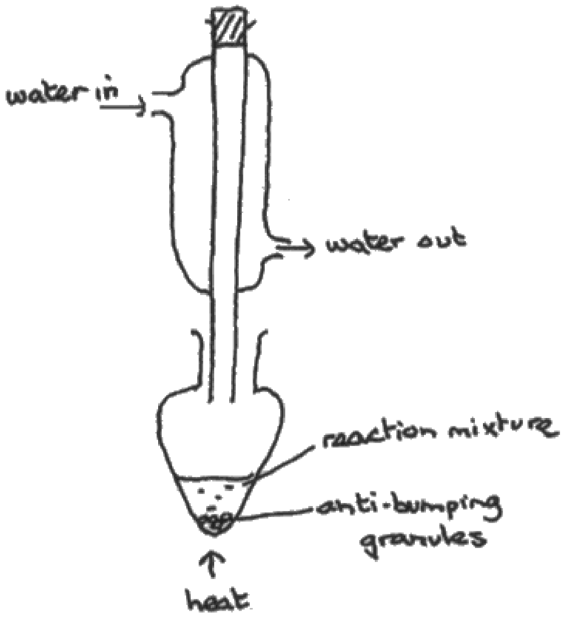
Read the question carefully to make sure that you know which reaction is being described.

Use bullet points to separate out the different points in the answer.

Question 8 (a) (ii)

The majority of candidates could identify at least one error in the diagram and state the effect of the error. Some candidates thought that there should be a stopper in the top of the condenser but that it should have a thermometer in it, so they seemed to be confused between heating under reflux and distillation. A few candidates thought that the arrow and heat was an error as it did not specify the type of heat, but this was not allowed as an incorrect heat source was not given.

(ii) A student drew a diagram of the apparatus used for heating under reflux in Step **4**. There are three errors in the apparatus shown in the diagram.
Assume the apparatus is suitably clamped.



Identify the three errors, including the effect of each error.
3

(3)

• the water must go intothe condenser in the bottom spout, and out of the top. this ensures that effective cooling takes place and that there are no air bubbles

• The top of the pearshaped flask isnt flush with the end of the condenser, products or reactants could escape / evapourate and get lost through this gap.

• A thermometer should be added in the top of the condenser to monitor temperature to ensure the reaction can happen effectively.

ResultsPlus
Examiner Comments

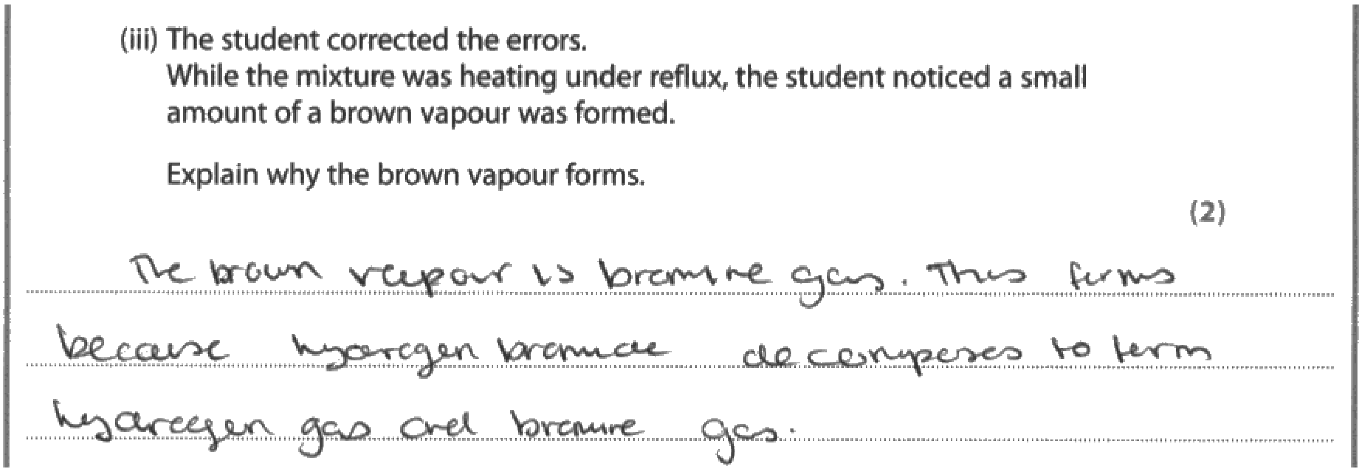
This answer scored 2 marks for the errors related to the condenser and the open flask. A thermometer is not needed for heating under reflux.

ResultsPlus
Examiner Tip

Make sure that you understand the difference between heating under reflux and distillation.

Question 8 (a) (iii)

The majority of candidates realised that the brown vapour is bromine, however, it was not unusual for hydrogen bromide, nitrogen dioxide or sulfur dioxide to be given. Only a minority of candidates worked out that the bromine was produced when concentrated sulfuric acid oxidised the bromide ions.



(iii) The student corrected the errors.

While the mixture was heating under reflux, the student noticed a small amount of a brown vapour was formed.

Explain why the brown vapour forms.

(2)

The brown vapour is bromine gas. This forms because hydrogen bromide decomposes to form hydrogen gas and bromine gas.

ResultsPlus

Examiner Comments

This response scored 1 mark for correctly identifying bromine as the brown vapour. However, hydrogen bromide is oxidised, not decomposed.

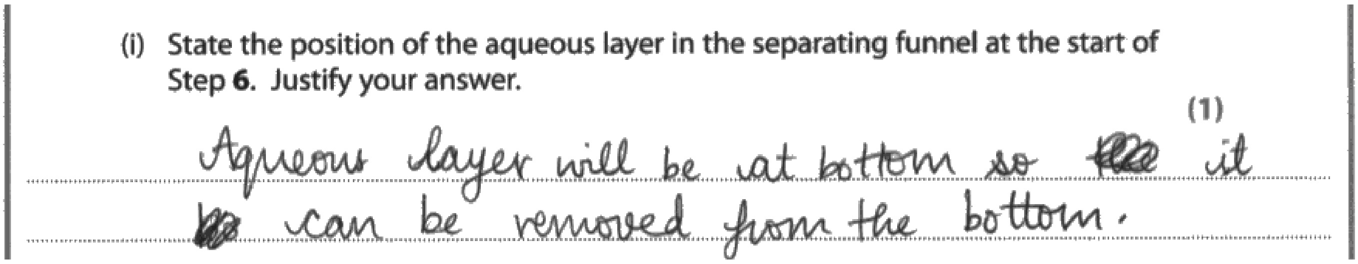
ResultsPlus

Examiner Tip

Use the information in the question to help with your answer. Bromide ions need to lose electrons to form bromine, so this is oxidation.

Question 8 (b) (i)

Many candidates did work out that the aqueous layer would be on the top as it has a lower density. Common errors included: stating that there would be three layers and that water would be in the middle and stating that water must be at the bottom so that it can be removed by opening the tap. Some candidates just stated the position of the aqueous layer and did not justify their answer.



(i) State the position of the aqueous layer in the separating funnel at the start of **Step 6.** Justify your answer.

(1)

Aqueous layer will be at bottom so it can be removed from the bottom.

ResultsPlus
Examiner Comments

This answer scored 0. The candidate has not used the densities given in the question and has just assumed that the aqueous layer will be at the bottom as it is easy to remove by opening the tap.

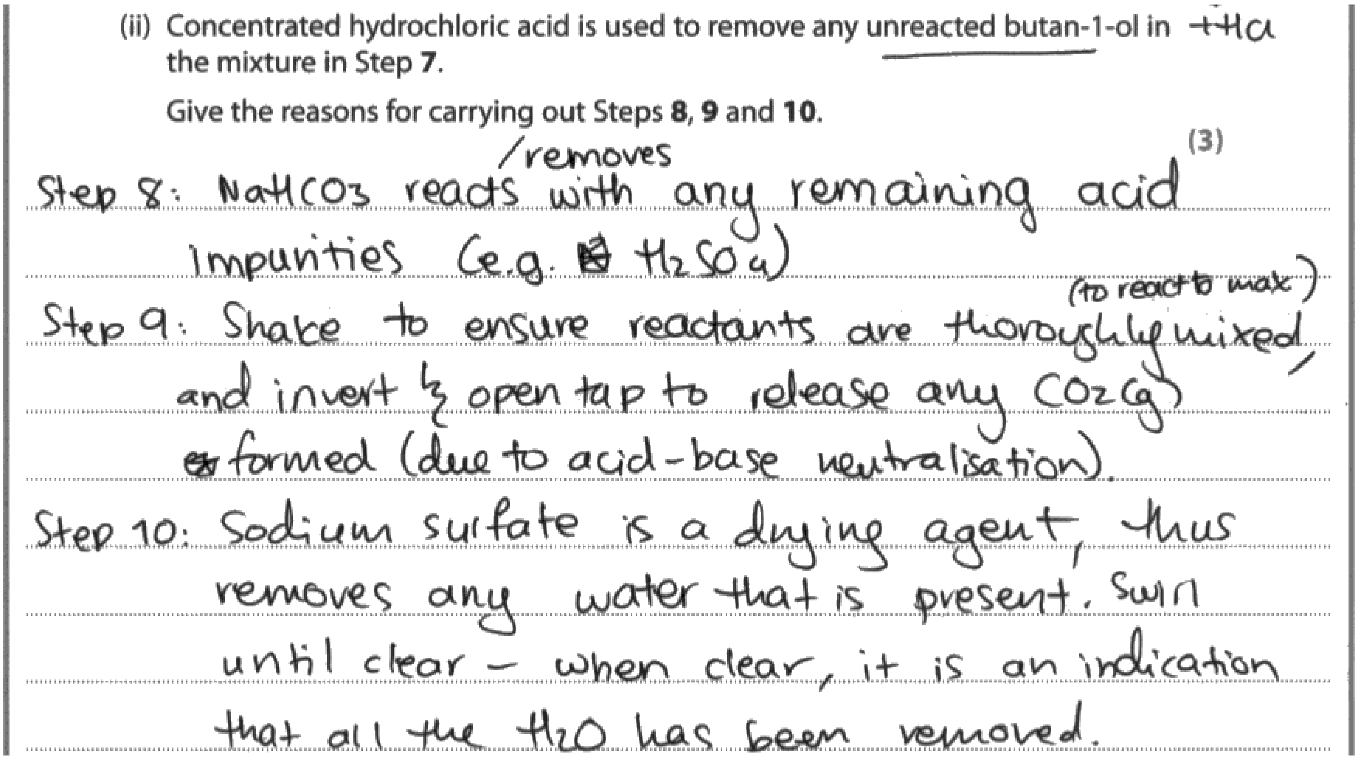
ResultsPlus
Examiner Tip

Use the data given in the question.

When using a separating funnel to purify a liquid, the layer to be discarded could be at the top or the bottom. You need to consider the densities to work out the order of the layers.

Question 8 (b) (ii)

Many candidates are familiar with the purification of an organic liquid and scored 3 marks for this item. Some candidates lost a mark for the use of sodium hydrogencarbonate as they just stated that it removes impurities and did not specify what they are and others stated that it would remove sulfuric acid without realising that would not have distilled over. Some candidates did not score the mark for the use of anhydrous sodium sulfate as they thought it was a dehydrating agent or would react with water, rather than act as a drying agent.



(ii) Concentrated hydrochloric acid is used to remove any unreacted butan-1-ol in +HCl the mixture in Step **7**.

Give the reasons for carrying out Steps **8**, **9** and **10**.

(3)

Step 8: $NaHCO_3$ reacts /removes with any remaining acid impurities (e.g. ~~H~~ H_2SO_4)

Step 9: Shake to ensure reactants are thoroughly mixed (to react to max) / and invert & open tap to release any $CO_2(g)$ ~~e~~ formed (due to acid-base neutralisation).

Step 10: Sodium sulfate is a drying agent, thus removes any water that is present. Swirl until clear – when clear, it is an indication that all the H_2O has been removed.

ResultsPlus
Examiner Comments

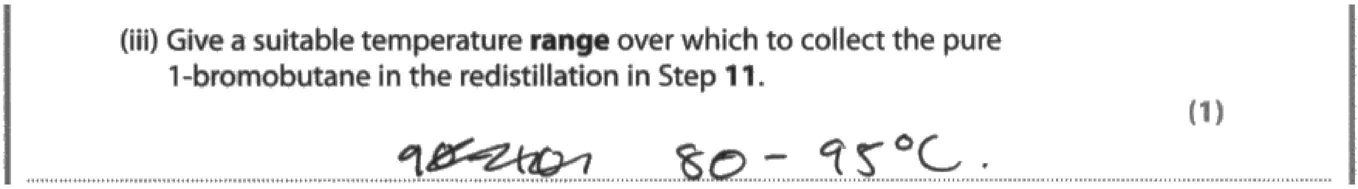
This answer scored 2 marks for Steps **9** and **10**. If they had stopped their answer to Step **8** after 'acid impurities' they would have scored the third mark. However, sulfuric acid is incorrect and negates this mark. There should be no sulfuric acid in the distillate but hydrochloric acid was added in Step **7** and that will react with sodium hydrogencarbonate.

ResultsPlus
Examiner Tip

Read the question carefully and use all the information given.

Question 8 (b) (iii)

Although the majority of candidates suggested a suitable temperature range over which to collect the pure 1-bromobutane, many gave too large a range and some ranges did not include the boiling temperature of 1-bromobutane. A small number of candidates gave a very small range of temperature e.g. 101.5°C to 102.5°C, which would be too difficult to carry out. Two degrees either side of the boiling temperature of the pure substance is a suitable range.



(iii) Give a suitable temperature **range** over which to collect the pure 1-bromobutane in the redistillation in Step **11**.

(1)

~~[illegible]~~ 80 - 95°C .

ResultsPlus
Examiner Comments

This answer scored 0 as the range does not include the boiling temperature of pure 1-bromobutane.

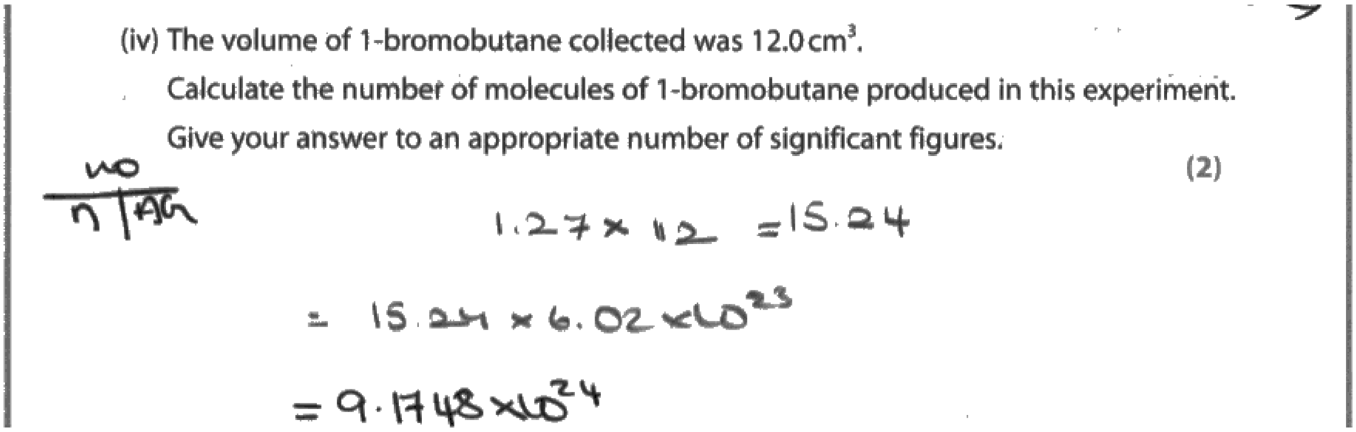
ResultsPlus
Examiner Tip

Use the data given in the question.

The boiling temperature of 1-bromobutane is 102 °C so the most suitable temperature range to collect it in the redistillation is 100 to 104 °C.

Question 8 (b) (iv)

Many candidates struggled to calculate the number of molecules in the sample of 1-bromobutane. Some thought it was a gas, even though the boiling temperature was given, so they divided the volume by the molar gas volume to calculate the number of moles. Others did not use the density and just divided the volume by the molar mass. Some calculated the number of moles but did not then calculate the number of molecules. Candidates should use the Data Booklet to find Avogadro's constant, the gas constant when needed.



(iv) The volume of 1-bromobutane collected was 12.0 cm^3.

Calculate the number of molecules of 1-bromobutane produced in this experiment.

Give your answer to an appropriate number of significant figures.

(2)

$\frac{\text{no}}{n \mid \text{AG}}$

$1.27 \times 12 = 15.24$

$= 15.24 \times 6.02 \times 10^{23}$

$= 9.1748 \times 10^{24}$

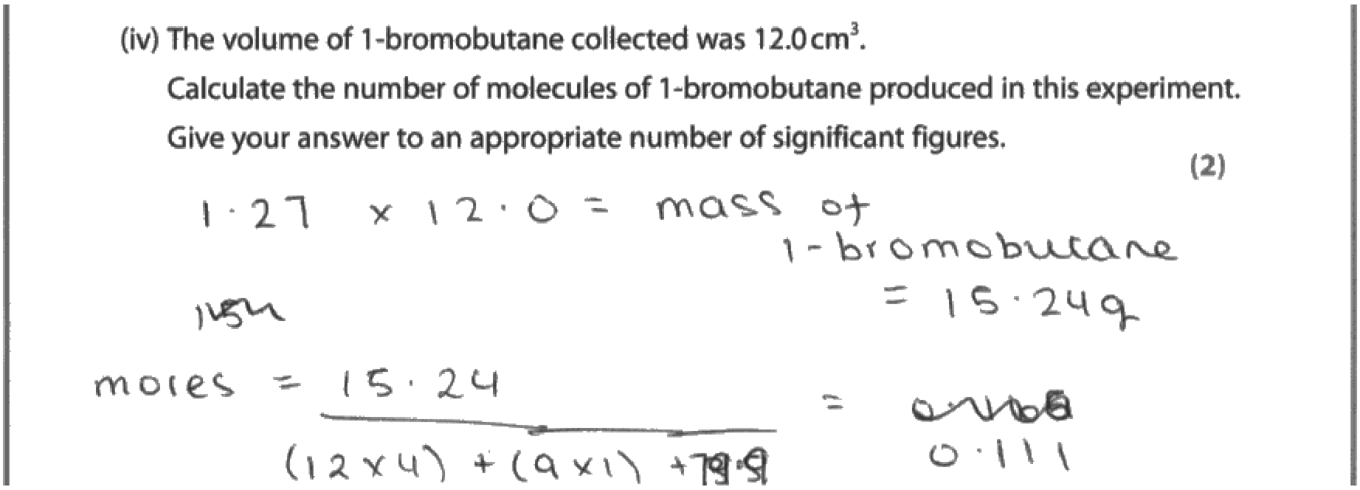
ResultsPlus
Examiner Comments

This answer scored 0.

The candidate has used the density to determine the mass of 1-bromobutane but has not converted it into moles by dividing by the molar mass. There was no transferred error for multiplying the Avogadro constant by the mass.

ResultsPlus
Examiner Tip

Practise determining the number of moles of a liquid using the volume, density and molar mass and vice versa.



(iv) The volume of 1-bromobutane collected was 12.0 cm^3.

Calculate the number of molecules of 1-bromobutane produced in this experiment.

Give your answer to an appropriate number of significant figures.

(2)

$1·27 \times 12·0 =$ mass of 1-bromobutane $= 15·24g$

1154

moles $= \dfrac{15·24}{(12 \times 4) + (9 \times 1) + 79·9} =$ [illegible] 0·111

ResultsPlus
Examiner Comments

This answer scored 1 mark for calculating the number of moles of 1-bromobutane produced. This needs to be multiplied by the Avogadro constant to determine the number of molecules.

ResultsPlus
Examiner Tip

Check your answer to make sure that you have fully answered the question.

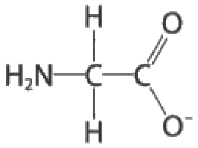
Look up the Avogadro constant in the Data Booklet.

Question 9 (a) (i)

The majority of candidates scored 2 marks for this question. Some candidates thought that the glycinate ion would be chiral and some thought that a racemic mixture would form.

9 Some organic compounds contain metals.

(a) Glycinate ions are formed from the amino acid glycine.



glycinate ion

(i) Explain the effect, if any, of an aqueous solution containing glycinate ions on plane-polarised monochromatic light.

(2)

~~[illegible]~~ The ions formed are usually of a racemic
(no effect)
mixture (as zwitter ions) but when formed as a normal ion, it will rotate ~~it in~~ the plane polarised light in one direction.

ResultsPlus
Examiner Comments

This is an example of an answer that scored 0 as the candidate thought that it could form a racemic mixture so an individual ion would rotate the plane of plane-polarised monochromatic light.

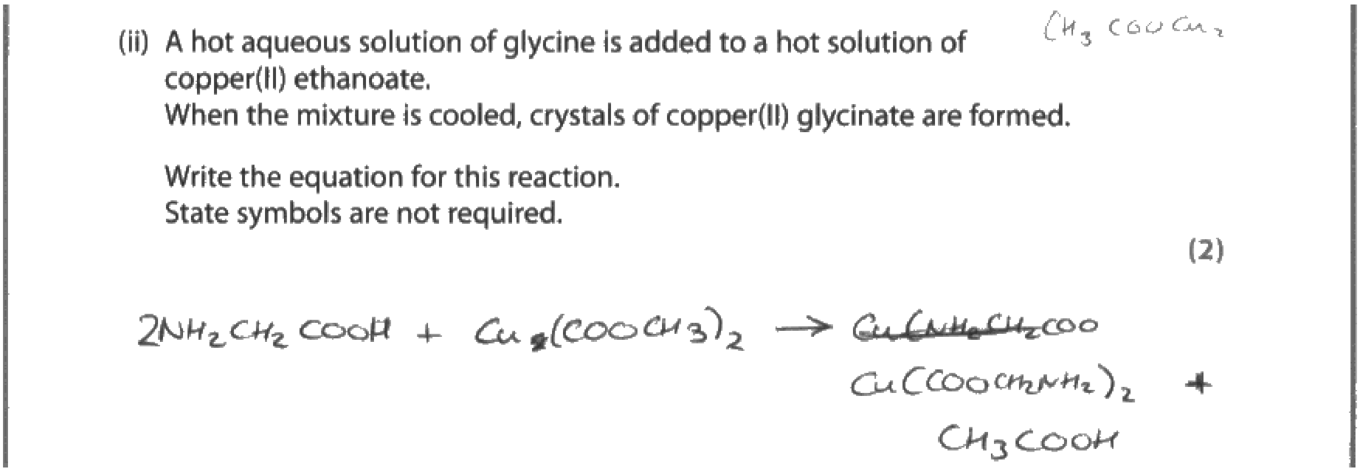
ResultsPlus
Examiner Tip

An organic molecule or ion will only be optically active if it contains a chiral carbon atom
i.e. 4 different atoms or groups attached to a carbon atom.

Be careful with terminology here - it would be incorrect to state that there are 4 different molecules attached to a carbon atom.

Question 9 (a) (ii)

It was disappointing to see that only a minority of candidates could write the correct formula for copper(II) ethanoate or copper(II) glycinate. Most candidates did not realise that as copper has a 2+ charge and the carboxylate ion has a - charge, two carboxylate ions will be needed to balance the charge. Some candidates included the charges and that was acceptable provided **both** charges were given. A significant minority of candidates showed a covalent bond between the copper and oxygen. Candidates would benefit with more practice in writing the formulae of salts of carboxylic acids.



(ii) A hot aqueous solution of glycine is added to a hot solution of copper(II) ethanoate.
When the mixture is cooled, crystals of copper(II) glycinate are formed.

CH_3COOCu_2

Write the equation for this reaction.
State symbols are not required.

(2)

$2NH_2CH_2COOH + Cu(COOCH_3)_2 \rightarrow$ ~~$Cu(NH_2CH_2$~~COO

$Cu(COOCH_2NH_2)_2 + CH_3COOH$

ResultsPlus
Examiner Comments

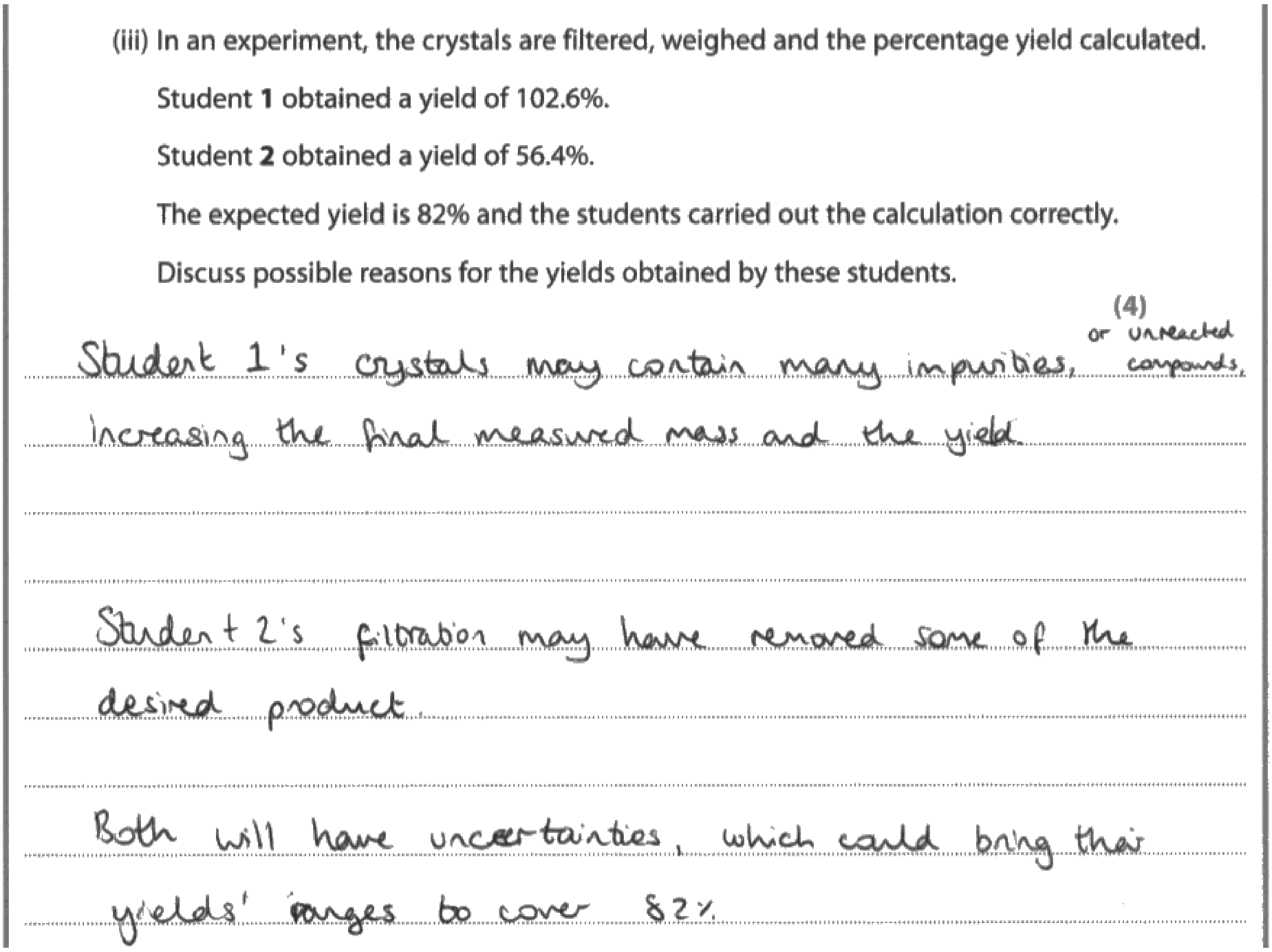
This answer scored 1 mark. It is almost correct but the candidate has not finished balancing the equation with a 2 in front of ethanoic acid.

ResultsPlus
Examiner Tip

Check all equations that you write to make sure that they are balanced.

Question 9 (a) (iii)

Many candidates were able to give several reasons for the differences in yields. The most common answers were that the crystals were still damp causing the higher yield and a specific handling loss, such as during filtration, for the lower yield. A few candidates were confused between water of crystallisation in the crystals and the water left on the crystals. Some candidates did not relate the reasons to the student or the yield and just gave a list of possible reasons and this limited them to a maximum of 1 mark. Some candidates referred to errors in the calculation, even though this was excluded in the question.



(iii) In an experiment, the crystals are filtered, weighed and the percentage yield calculated.

Student **1** obtained a yield of 102.6%.

Student **2** obtained a yield of 56.4%.

The expected yield is 82% and the students carried out the calculation correctly.

Discuss possible reasons for the yields obtained by these students.

(4)

Student 1's crystals may contain many impurities, or unreacted compounds, Increasing the final measured mass and the yield

Student 2's filtration may have removed some of the desired product.

Both will have uncertainties, which could bring their yields' ranges to cover 82%.

ResultsPlus
Examiner Comments

This response scored 2 marks.

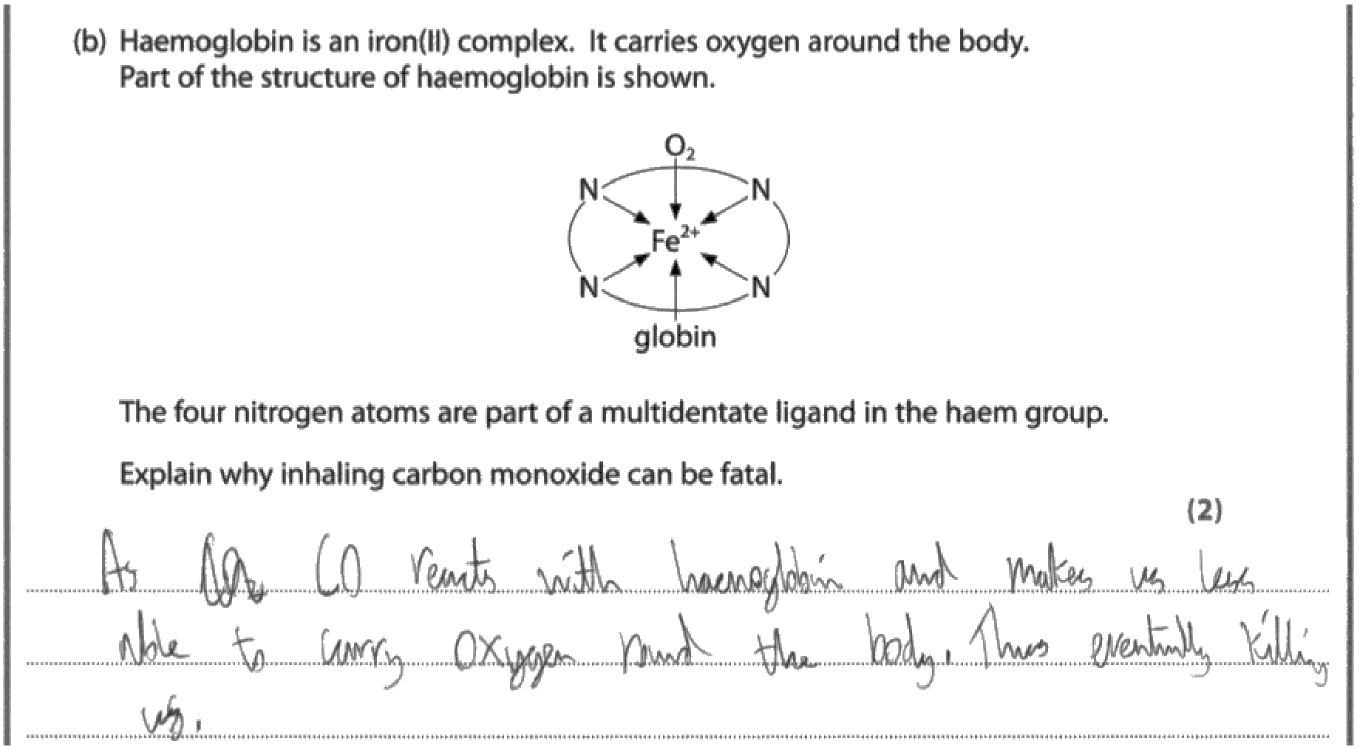
One correct reason is given for each student and the reasons are clearly linked to the students. There are 4 marks for this question so the candidate should have given four reasons.

ResultsPlus
Examiner Tip

Try to relate the detail of your answer to the number of marks allocated. 4 marks means that 4 points are needed to score full marks.

Question 9 (b)

This question is taken directly from the specification so it was surprising that more candidates did not score full marks. Many candidates did not state that carbon monoxide replaces the oxygen molecule in haemoglobin and a few thought that it replaced nitrogen. Many candidates referred to a strong bond between carbon monoxide and haemoglobin but most did not specify the bond to the Fe^{2+} ion in haemoglobin. The majority of candidates were able to score the mark for the effect on the body, although some referred to breathing or suffocation, which are incorrect.



(b) Haemoglobin is an iron(II) complex. It carries oxygen around the body.
Part of the structure of haemoglobin is shown.

The four nitrogen atoms are part of a multidentate ligand in the haem group.

Explain why inhaling carbon monoxide can be fatal.

(2)

As CO reacts with haemoglobin and makes us less able to carry Oxygen round the body. Thus eventually killing us.

ResultsPlus
Examiner Comments

This answer scored 1 mark for haemoglobin being less able to carry oxygen around the body. 'CO reacts with haemoglobin' is not precise enough for the second mark.

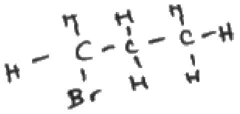
ResultsPlus
Examiner Tip

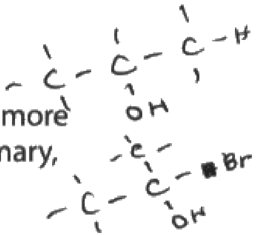
Remember that a carbon monoxide molecule replaces the oxygen molecule in haemoglobin and that carbon monoxide forms a strong bond with the Fe^{2+} ion, not the haemoglobin molecule.

Question 9 (c)

Candidates who had revised Grignard reagents were able to perform well on this question and score high marks. There were many candidates who had not revised Grignard reagents or had just glossed over that section of organic chemistry and they did not perform well on this question. Grignard reagents are an important part of organic chemistry as they are used to add one or more carbon atoms to the carbon chain in synthesis so they should not be omitted. The majority of candidates knew how to prepare the Grignard reagent using magnesium in dry ether. Candidates who wrote generally about methanal being used to form a primary alcohol, ethanal to form a secondary alcohol, a ketone to form a tertiary alcohol and carbon dioxide to form a carboxylic acid received credit. Only those who started with the 1-bromopropane given in the question and gave the specific name or formula of the product could score full marks. Some candidates did not increase the length of the carbon chain following the reaction with a carbonyl compound or carbon dioxide. It was disappointing to see a candidate give a correct name followed by an incorrect formula or vice versa. Many candidates did not mention the need to add a dilute acid to hydrolyse the intermediate and those that did know that acid needs to be used often added it at the same time as dry ether and the carbonyl compound.

*(c) Grignard reagents contain a metal.





Discuss how Grignard reagents are formed and used in adding one or more carbon atoms to the carbon chain in 1-bromopropane to produce primary, secondary and tertiary alcohols and a carboxylic acid.

Include a suitable example for each reaction and give reagents, conditions and products. You may include equations in your answer.

(6)

For $BrCH_2CH_2CH_3$ to form a carboxylic acid, CO_2 is needed to make the final product and CH_2CH_3Br is needed to form the ~~to~~ Grignard reagent:

$$CH_3CH_2Br \xrightarrow{Mg/dry\ ether} \overset{\text{Grignard reagent}}{CH_3CH_2MgBr} \xrightarrow[\text{then } H^+/H_2O]{CO_2} CH_3CH_2COOH$$

For 1° alcohol - $CH_3CH_2CH_2OH$: HCHO is needed:

$$CH_3CH_2Br \xrightarrow{Mg/dry\ ether} CH_3CH_2MgBr \xrightarrow[\text{then } H^+/H_2O]{HCHO} CH_3CH_2CH_2OH$$

For 2° alcohol - $CH_3CH(OH)CH_3$ - the aldehyde CH_3CHO is needed:

$$CH_3Br \xrightarrow{mg/dry\ ether} CH_3MgBr \xrightarrow[\text{then } H^+/H_2O]{CH_3CHO} CH_3CH(OH)CH_3$$

For 3° alcohol: $(CH_3)_3OH$, Ketone CH_3COCH_3

~~CH_3~~

$$CH_3Br \xrightarrow{Mg/dry\ ether} CH_3MgBr \xrightarrow[\text{then } H^+/H_2O]{CH_3COCH_3} \overset{OH}{(CH_3)_3}$$

ResultsPlus
Examiner Comments

This answer scored 4 marks.

Magnesium and dry ether are correct and the candidate has clearly shown that the acid is added after the carbonyl compound or carbon dioxide.

The candidate knows that methanal, ethanal, propanone and carbon dioxide are needed to form the products but they have not used 1-bromopropane as they were told to in the question. Also, the formula for the tertiary alcohol is incorrect as there is a carbon atom missing.

ResultsPlus
Examiner Tip

Read the question carefully and take careful note of any specific examples you have been asked to use.

Check the formulae of organic compounds carefully to make sure that you have not missed out any atoms. Skeletal formulae can be used.

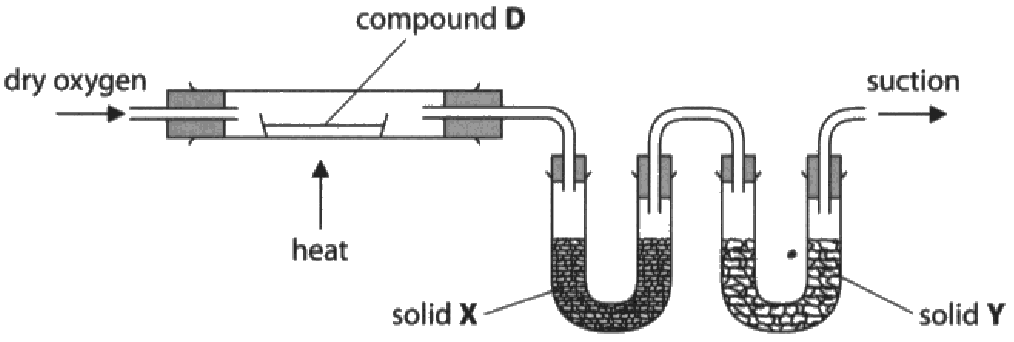
If you give a name and formula of an organic product, make sure that both are correct.

Question 10 (a) (i)

Many candidates scored at least 1 mark for realising that the mass of **X** would increase and the mass of **Y** would not change. Some candidates did not mention that **X** would absorb the extra water and some thought there would be incomplete combustion so the mass of **Y** would decrease.

10 Organic compound **D** contains the elements carbon, hydrogen, oxygen and nitrogen only.

(a) A sample of **D** was burned completely in the apparatus shown.
Solid **X** absorbed the water formed in the combustion.
Solid **Y** absorbed the carbon dioxide.



(i) The masses of solids **X** and **Y** increased during the experiment.

Explain the effect, if any, on the changes in mass of **X** and **Y** if the oxygen gas was not dry.

(3)

~~X would~~. The mass of X would increase as it absorbs water, therefore if the content of water increases the mass of X would also increase. The mass of Y would stay the same because water content has no effect on the amount of CO_2. Or Y would increase in mass ~~[illegible]~~ as more CO_2 ~~[illegible]~~ would dissolve into the water meaning that more ~~[illegible]~~ CO_2 is left to be absorbed into the solid Y.

ResultsPlus
Examiner Comments

This answer scored 1 mark.

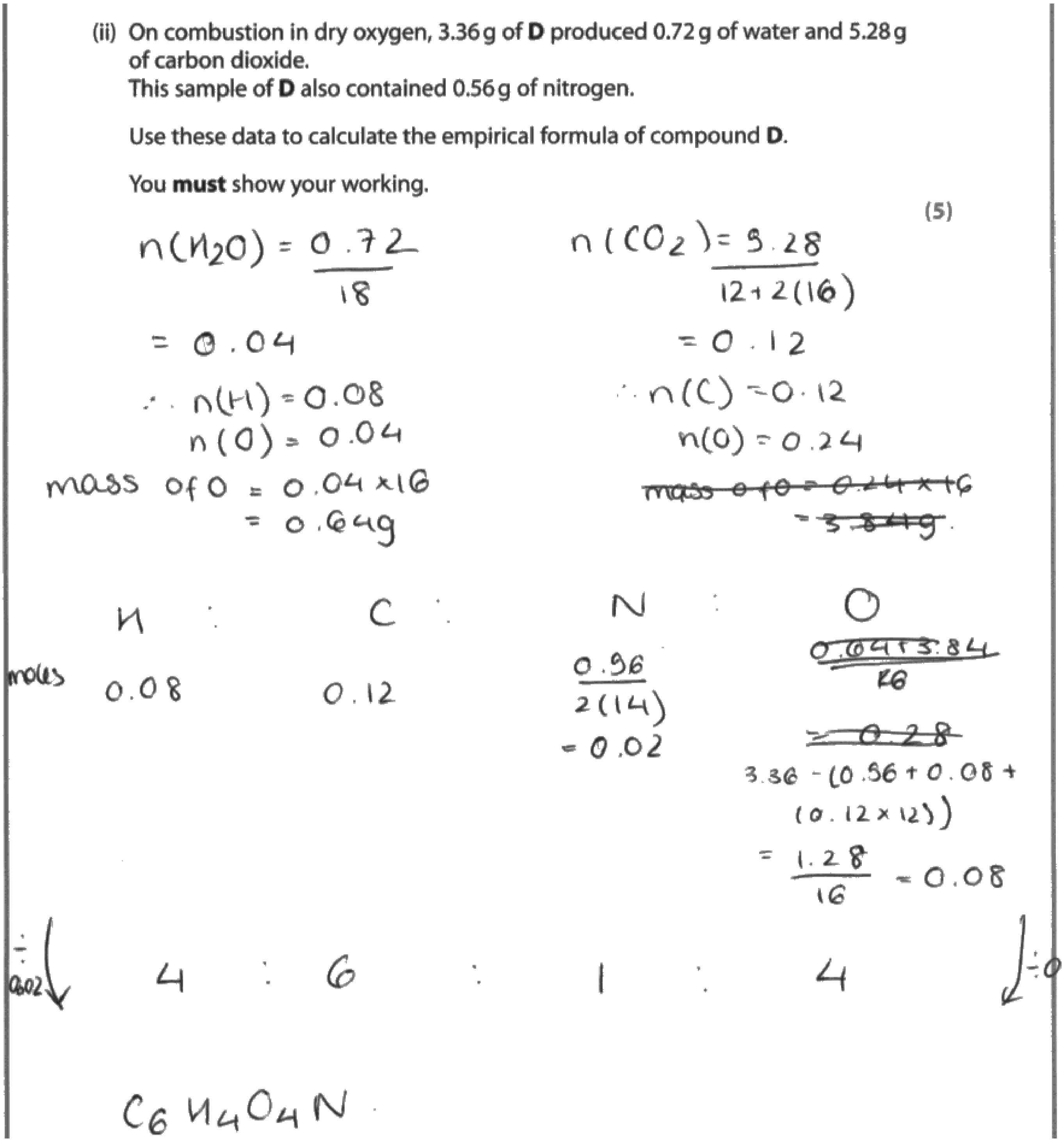
If the candidate had stopped the answer before the 'Or' they would have scored 3 marks. This additional incorrect chemistry negates the marks.

ResultsPlus
Examiner Tip

Try to just answer the question as it is set. If you add additional incorrect chemistry, it will negate the marks for the correct chemistry. If you have written an additional answer, decide which is correct then cross out the incorrect answer to avoid this happening.

Question 10 (a) (ii)

It was encouraging to see many correct answers scoring full marks. Most candidates are setting out their working clearly so that the examiners can easily follow it and award intermediate marks if the final answer is not correct. Some candidates did not realise that water contains two hydrogen atoms so the moles of hydrogen atoms will be twice the moles of water. Some candidates omitted the oxygen from their answer or just tried to work it out from the oxygen atoms in carbon dioxide and water.



(ii) On combustion in dry oxygen, 3.36 g of **D** produced 0.72 g of water and 5.28 g of carbon dioxide.
This sample of **D** also contained 0.56 g of nitrogen.

Use these data to calculate the empirical formula of compound **D**.

You **must** show your working.

(5)

$n(H_2O) = \frac{0.72}{18}$

$= 0.04$

$\therefore n(H) = 0.08$

$n(O) = 0.04$

mass of O $= 0.04 \times 16$

$= 0.64g$

$n(CO_2) = \frac{5.28}{12+2(16)}$

$= 0.12$

$\therefore n(C) = 0.12$

$n(O) = 0.24$

~~mass of O = 0.24 × 16~~

~~= 3.84g~~

	H	C	N	O
moles	0.08	0.12	$\frac{0.56}{2(14)}$ $= 0.02$	~~$\frac{0.64+3.84}{16}$~~ ~~= 0.28~~ $3.36 - (0.56 + 0.08 + (0.12 \times 12))$ $= \frac{1.28}{16} = 0.08$
÷ 0.02	4	6	1	4

$C_6H_4O_4N$

ResultsPlus
Examiner Comments

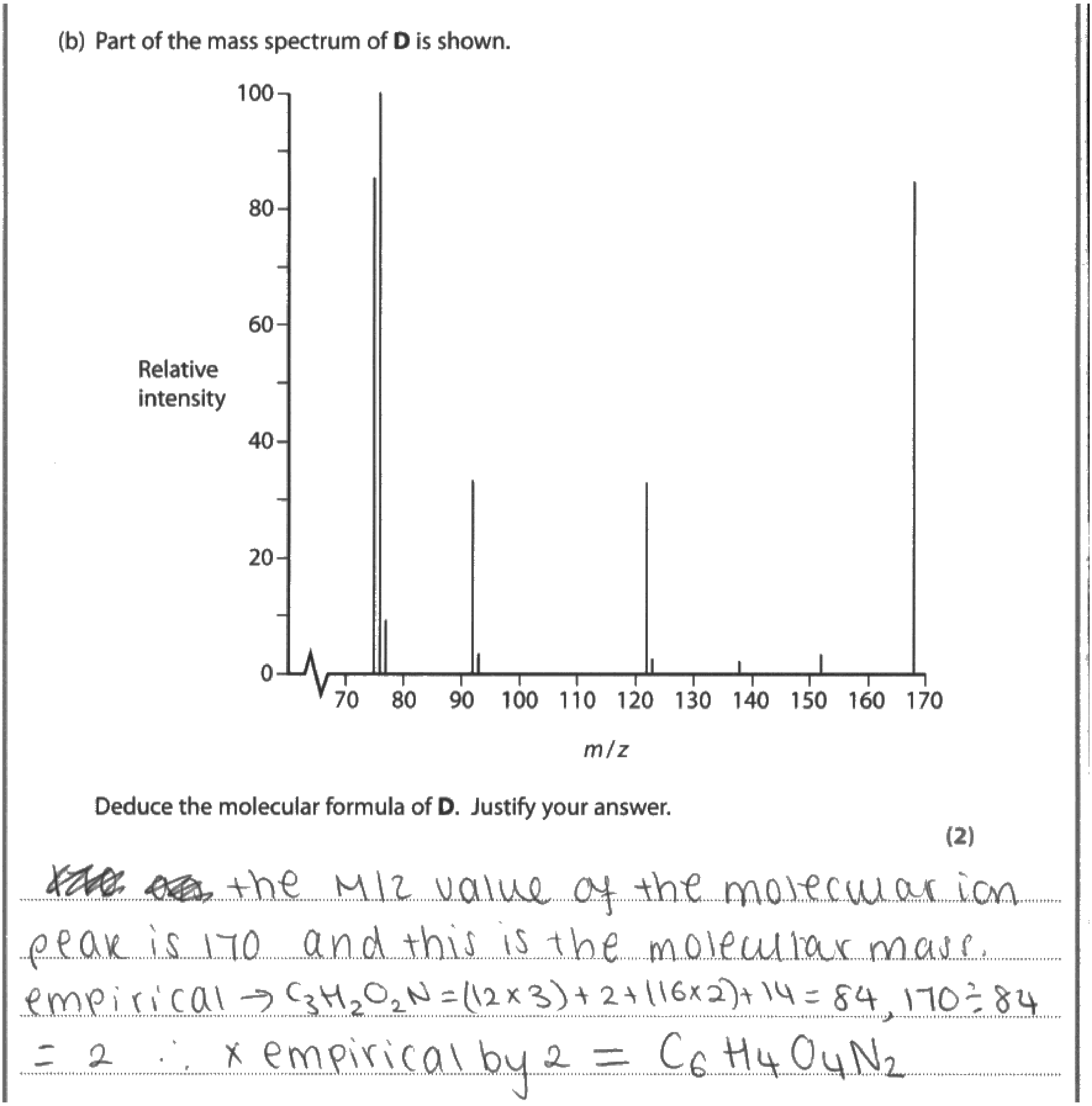
This answer scored 4 marks. The carbon, hydrogen and oxygen are correct but the nitrogen is incorrect as the candidate has calculated the moles of N_2 and not multiplied it by 2 to find the moles of nitrogen atoms.

ResultsPlus
Examiner Tip

Think carefully about whether you should be using molecules or atoms in calculations.

Question 10 (b)

Candidates who looked carefully at the scale on the y axis could work out that the M_r of **D** is 168 and then deduce the molecular formula. Some candidates thought that 168 was the molecular formula.



(b) Part of the mass spectrum of **D** is shown.

Deduce the molecular formula of D. Justify your answer.

(2)

the M/z value of the molecular ion peak is 170 and this is the molecular mass. empirical → $C_3H_2O_2N = (12 \times 3) + 2 + (16 \times 2) + 14 = 84$, $170 \div 84 = 2$ ∴ x empirical by 2 = $C_6H_4O_4N_2$

ResultsPlus
Examiner Comments

This response scored 1 mark for the correct molecular formula.

The candidate has worked out that the M_r of the empirical formula is 84 but has also stated that 170 divided by 84 = 2, which is incorrect. The peak furthest to the right is at 168, not 170.

ResultsPlus
Examiner Tip

Look carefully at the scale on any axis to make sure that you can read it correctly.

Question 10 (c) (i)

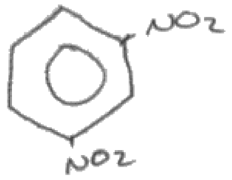
It was surprising that many candidates could not work out that the M_r of benzene = (6 x 12) +(6 x 1) = 78 so a peak at 76 would be caused by $C_6H_4^+$. Some candidates omitted the positive charge on the ion and a few gave a 2+ charge.

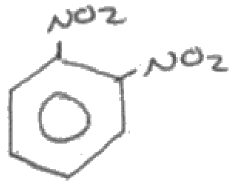
Question 10 (c) (ii) - (iii)

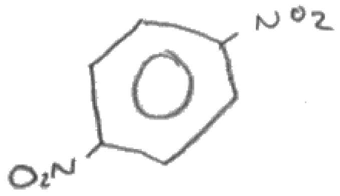
Many candidates gave the three isomers of dinitrobenzene in (c)(ii). Candidates could score the marks for any three disubstituted benzenes to allow for the incorrect molecular formulae they may have given earlier. Many candidates correctly identified **D** and showed the correct carbon environments on the isomers. The most common error was to show three carbon environments on 1,4-dinitrobenzene. Again, transferred error marks were available for any disubstituted benzenes.

(ii) Draw the structures of the **three** possible isomers of **D** containing a benzene ring.

(2)



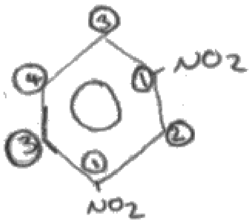




(iii) The ^{13}C NMR spectrum of compound **D** has four peaks.

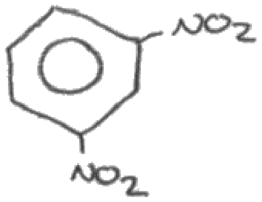
Identify the structure of **D**. Justify your answer by labelling the different carbon environments in **all** the structures drawn in (c)(ii).

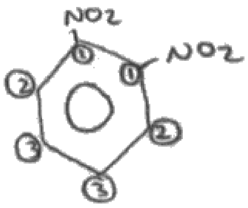
(3)



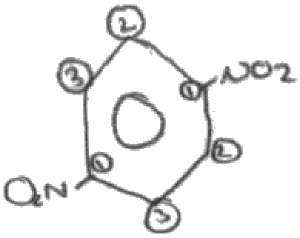
- 4 peaks

D =





-3 peaks



— 3 peaks

ResultsPlus
Examiner Comments

(ii) This scored 2 marks for 3 correct isomers.

(iii) This scored 2 marks for the carbon environments shown correctly on 1,2-dinitrobenzene and 1,3-dinitrobenzene. There are only two different carbon environments on 1,4-dinitrobenzene.

ResultsPlus
Examiner Tip

Set out your answers clearly, as in this example.

There are many different ways to label the carbon environments and this shows one way.

Paper Summary

Based on their performance on this paper, candidates are offered the following advice:

- Read all the information given in the question carefully and use it to help you to answer the question.
- Learn the meaning of the key scientific words in each topic and use them accurately in your answers.
- Look at the number of marks for each part of question and give this number of relevant points in your answer.
- Practise answering the extended writing questions so you understand how to improve your performance by structuring your answer and giving more relevant details.
- Structure other longer answers with bullet points to make them clearer.
- Explain each stage in your working for unstructured calculations.
- Practise writing balanced equations.
- Practise evaluating the results of experiments you have carried out.

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