Paper Reference(s) 9CH0/03

Pearson Edexcel Level 3 GCE

Chemistry
Advanced
Paper 3: General and Practical Principles in Chemistry

Wednesday 19 June 2019 – Morning

Time: 2 hours 30 minutes plus your additional time allowance

INSTRUCTIONS TO CANDIDATES

Write your centre number, candidate number, surname, other names and your signature in the boxes below. Check that you have the correct question paper.

Centre No.							
Candidate No.							
Surname							
Other names							
Signature							
Paper Reference	9	C	H	0	/	0	3

- Use BLACK ink or BLACK ball-point pen.
- Answer ALL questions.
- Answer the questions in the spaces provided – there may be more space than you need.

MATERIALS REQUIRED FOR EXAMINATION
Scientific calculator, Data Booklet, ruler

ITEMS INCLUDED WITH QUESTION PAPERS
Periodic Table
Separate sheet for use with question 6(c)(i)

INFORMATION FOR CANDIDATES
- The total mark for this paper is 120.
- The marks for EACH question are shown in brackets – use this as a guide as to how much time to spend on each question.
- For the question marked with an ASTERISK (*), marks will be awarded for your ability to structure your answer logically showing the points that you make are related or follow on from each other where appropriate.
- A Periodic Table is provided.

(Instructions continue on next page)

ADVICE TO CANDIDATES

- Read each question carefully before you start to answer it.
- Show all your working in calculations and include units where appropriate.
- Check your answers if you have time at the end.

(Turn over)

Answer ALL questions.

Write your answers in the spaces provided.

1 This question is about acids and bases.

(a) State what is meant by a Brønsted-Lowry acid. (1 mark)

_____

(b) Identify the acid-base conjugate pairs in this reaction. (1 mark)

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

_____ _____ _____ _____

(Question continues on next page)

(c) Write the expression that defines the pH of a solution. (1 mark)

(d) Calculate the concentration of hydrogen ions, in mol dm^{-3}, in a solution with a pH of 2·76 (1 mark)

(Continue your answer on next page)

(Question continues on next page)

(e) Explain why the pH of a $1 \times 10^{-8}\,mol\,dm^{-3}$ solution of nitric acid, HNO_3, is not 8. (2 marks)

[Ionic product of water, $K_w = 1{\cdot}00 \times 10^{-14}\,mol^2\,dm^{-6}$]

(Continue your answer on next page)

(TOTAL FOR QUESTION 1 = 6 MARKS)

(Questions continue on next page)

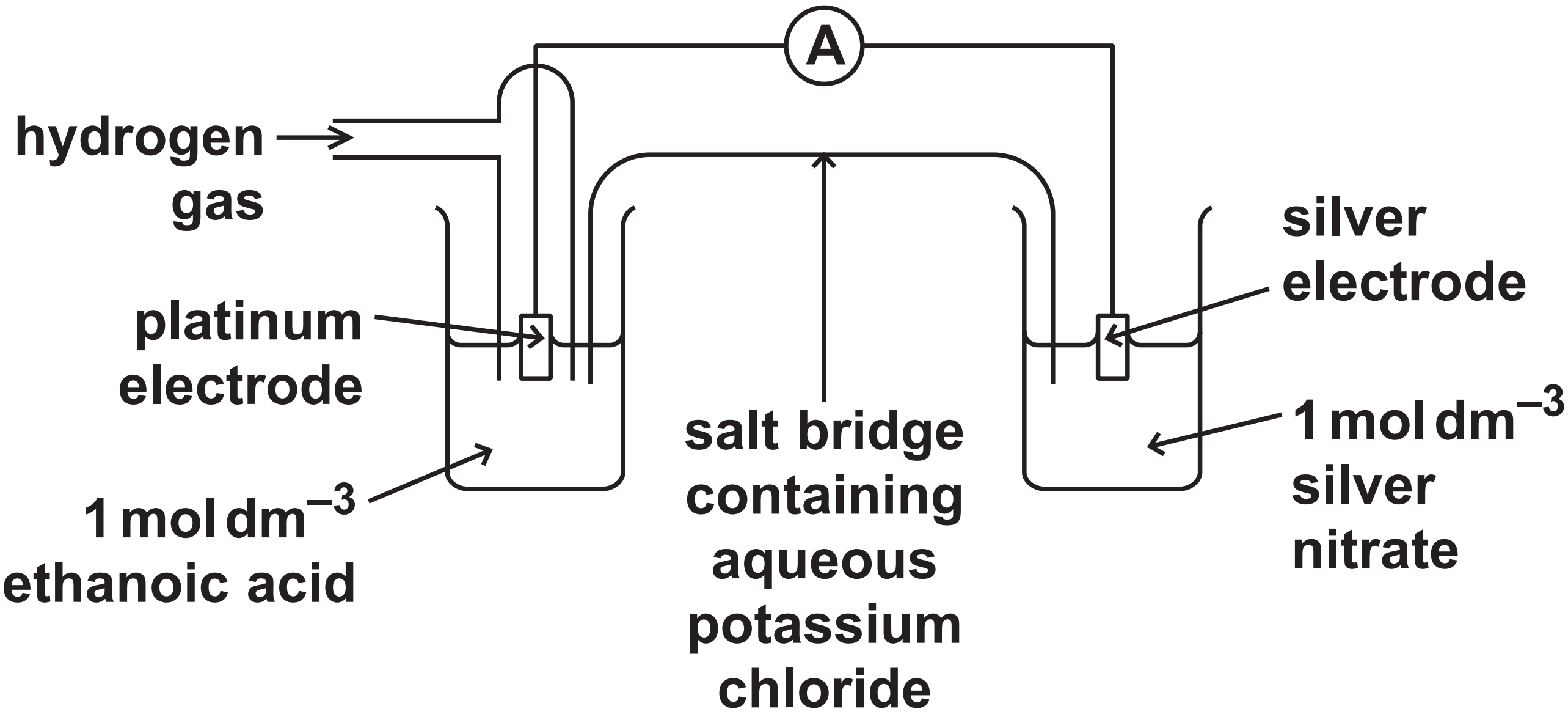
2 This question is about the $Ag^+(aq)|Ag(s)$ half-cell.

(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 mark)

(Question continues on next page)

(ii) The student drew the diagram shown.



(Question continues on next page)

11

Identify THREE mistakes in the diagram on page 10 and the modifications that should be made to correct them. (3 marks)

Mistake in diagram	Modification needed to correct mistake

(Question continues on next page)

(b) The standard electrode potential, $E^{\ominus}$, of the $Ag^{+}(aq)|Ag(s)$ half-cell is +0·80 V.

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

$$E = E^{\ominus} + \frac{RT}{96\,500} \times \ln[Ag^{+}(aq)]$$

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 +0·72 V.

(Question continues on next page)

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

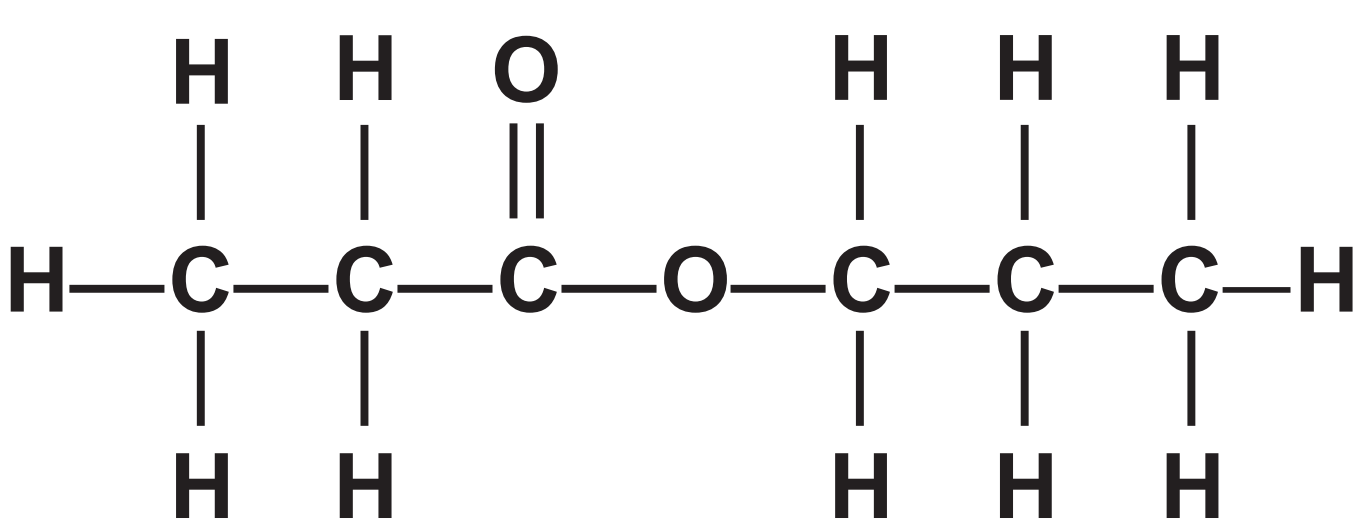
(Continue your answer on next page)

(TOTAL FOR QUESTION 2 = 7 MARKS)

(Questions continue on next page)

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 marks)

(Begin your answer on next page)

(Continue your answer on next page)

(Question continues on next page)

(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 marks)

(Continue your answer on next page)

(Continue your answer on next page)

(Continue your answer on next page)

(TOTAL FOR QUESTION 3 = 8 MARKS)

(Questions continue on next page)

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 on pages 23 to 25.

(i) Complete the statements in the inference column by writing the names or formulae of the species. (6 marks)

(Question continues on next page)

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** _____ _____ **One of the cations in C is** _____ _____

(Continues on next page)

TEST 2 **Concentrated hydrochloric acid was added to an aqueous solution of C**	**The pink solution turned blue**	**The other cation in C is** _____ _____ **The formula of the complex ion in the blue solution is** _____ _____

(Continues on next page)

(Turn over)

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** _____ _____ **The anion in C is** _____ _____

(Question continues on next page)

(Turn over)

(ii) Use the results of the tests in (a)(i) to give a formula of C. Do not include water of crystallisation. (1 mark)

(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 mark)

(Question continues on next page)

(c) State the type of reaction occurring in TEST 2. (1 mark)

(d) Give a reason why dilute hydrochloric acid is needed in TEST 3. (1 mark)

(TOTAL FOR QUESTION 4 = 10 MARKS)

(Questions continue on next page)

5 This question is about redox reactions.

(a) Name the ion with formula PO_3^{3-}. Include the relevant oxidation number. (1 mark)

(b) State what happens to a reducing agent during a reaction, in terms of oxidation number AND electrons. (1 mark)

(Question continues on next page)

(c) Identify the species that is the strongest reducing agent from the list of standard electrode potentials in the Data Booklet. (1 mark)

(Question continues on next page)

(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 marks)

(Question continues on next page)

(ii) Give a reason why this reaction is NOT disproportionation. (1 mark)

(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) On page 32 draw a dot-and-cross diagram of the BH_4^- ion.

(Question continues on next page)

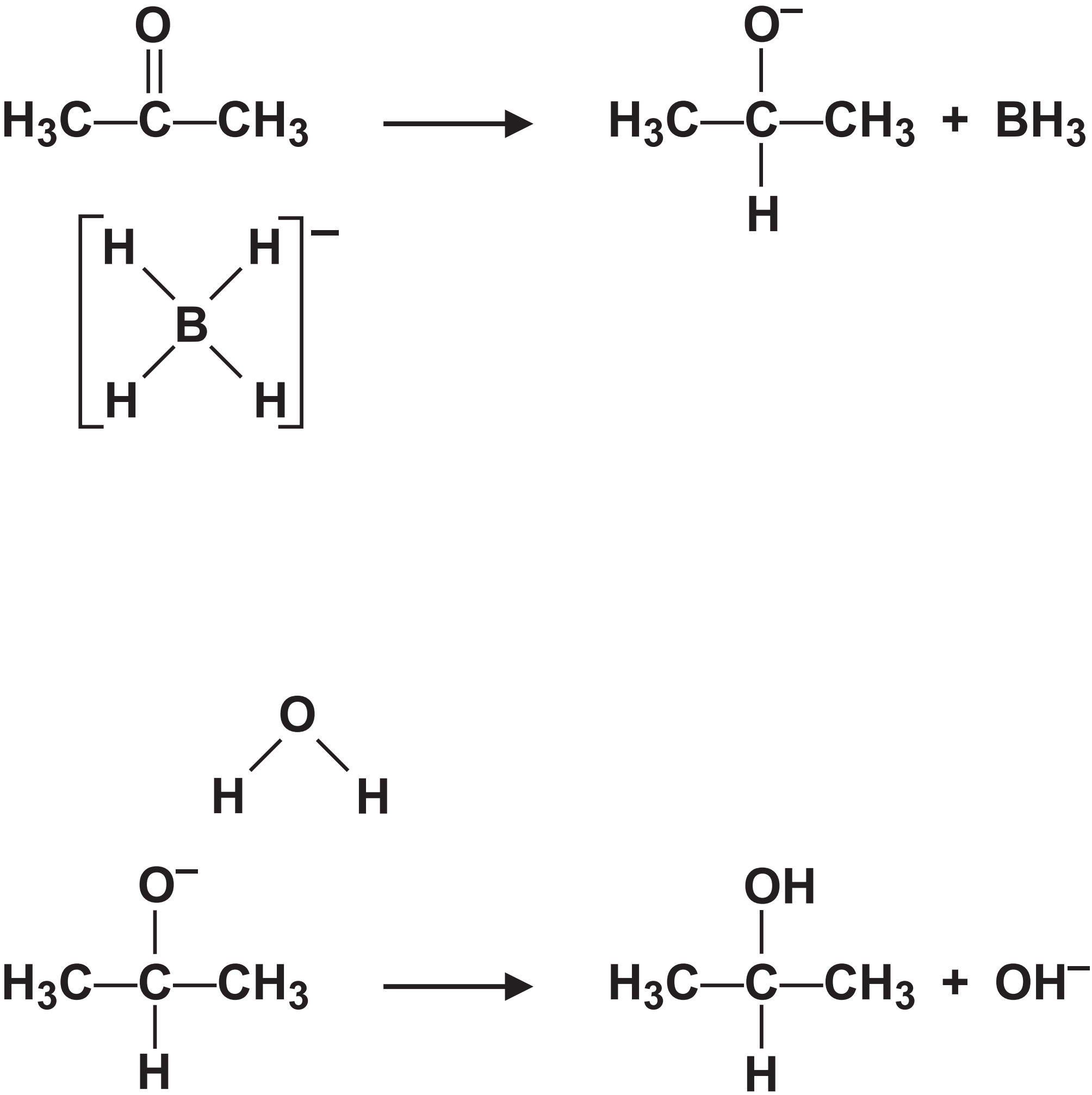
Use crosses (✕) for the boron electrons, dots (●) for the hydrogen electrons and triangles (△) for the additional electron forming the negative ion. (1 mark)

(Question continues on next page)

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

On page 34 complete the mechanism for the reduction of propanone to propan-2-ol by adding curly arrows, and any relevant lone pairs and dipoles. (4 marks)

(Question continues on next page)

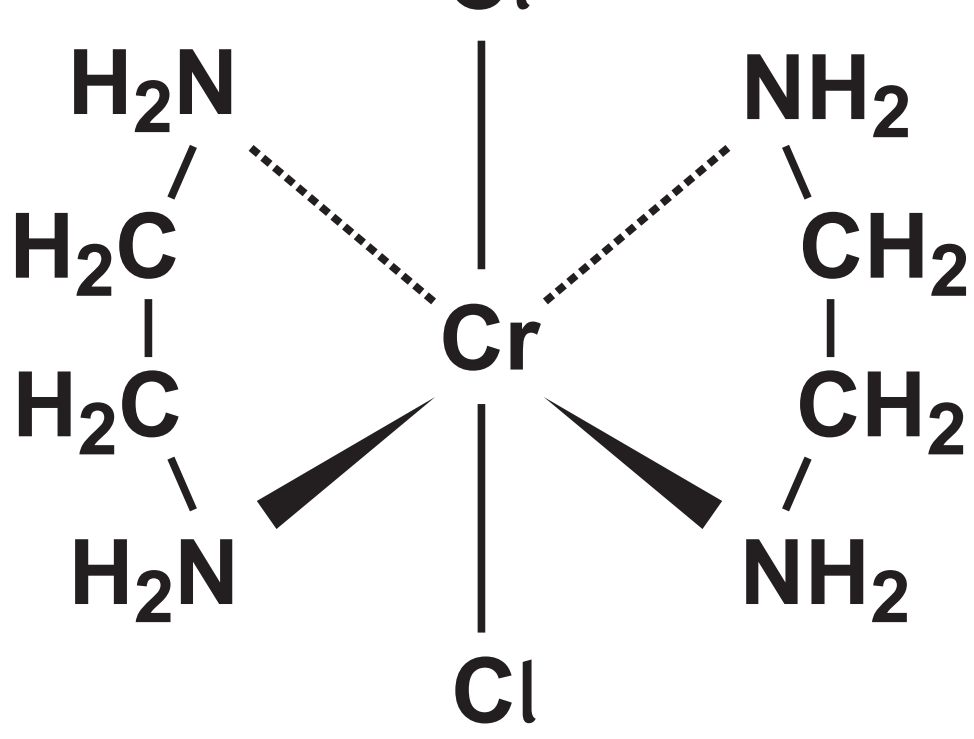


(TOTAL FOR QUESTION 5 = 11 MARKS)

(Questions continue on next page)

6 This question is about transition metals and their ions.

(a) The SHAPE of a complex ion formed from Cr^{3+} ions is shown.



(i) State the coordination number of Cr^{3+} in this complex ion. (1 mark)

(ii) State the overall charge on this complex ion. (1 mark)

(Question continues on next page)

(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 marks)

(Continue your answer on next page)

(Question continues on next page)

(c) Tungsten wire catalyses the decomposition of ammonia.

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

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) On the separate sheet provided plot a graph of partial pressure of ammonia against time. (2 marks)

(Question continues on next page)

(ii) Deduce the rate equation for this reaction by using your graph in (c)(i). Justify your answer. (2 marks)

(Question continues on next page)

(iii) Use the graph to calculate the rate constant. Include units in your answer. (2 marks)

(Question continues on next page)

(iv) Describe the stages in the catalytic decomposition of ammonia by tungsten. (3 marks)

(Continue your answer on next page)

(TOTAL FOR QUESTION 6 = 14 MARKS)

(Questions continue on next page)

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 $0{\cdot}0235\,mol\,dm^{-3}$ solution of the salt.

$25{\cdot}0\,cm^3$ portions of the salt solution were acidified with excess dilute sulfuric acid and heated to about 60 °C.

Each portion was titrated with $0{\cdot}0203\,mol\,dm^{-3}$ potassium manganate(VII).

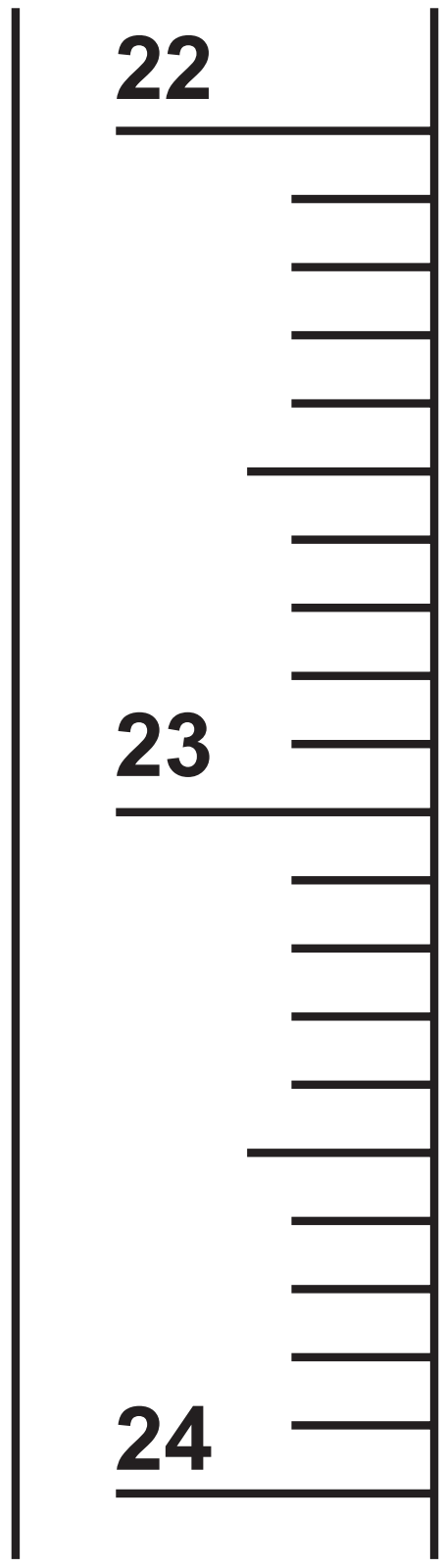
(Question continues on next page)

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

(Question continues on next page)

(i) Complete the diagram to show the final burette reading in TITRATION 1. (2 marks)



(Question continues on next page)

(ii) Explain why this student should use a mean titre of 23·15 cm^3 and not 23·43 cm^3 in the calculation. (2 marks)

(Question continues on next page)

(iii) The uncertainty in each burette reading is $\pm 0 \cdot 05\,cm^3$.

Calculate the percentage uncertainty in the titre volume of potassium manganate(VII) solution used in TITRATION 2. (1 mark)

(Question continues on next page)

(iv) The equation for the reaction is

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

Deduce, by calculation, the value of y, to the nearest whole number, in the formula $KH_3(C_2O_4)_y.zH_2O$.

Use the mean titre of $23{\cdot}15\,cm^3$ and other data from EXPERIMENT 1.

You MUST show your working.
(4 marks)

(Continue your answer on next page)

(Continue your answer on next page)

(Question continues on next page)

(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 + $KH_3(C_2O_4)_y.zH_2O$	= 22·97 g
Mass of crucible + $KH_3(C_2O_4)_y$	= 22·52 g

(Question continues on next page)

(i) Deduce, by calculation, the value of z, to the nearest whole number, in the formula $KH_3(C_2O_4)_y.zH_2O$.

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

You MUST show your working.
(3 marks)

(Continue your answer on next page)

(Question continues on next page)

(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.

(Question continues on next page)

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 marks)

(Continue your answer on next page)

(Continue your answer on next page)

(TOTAL FOR QUESTION 7 = 17 MARKS)

(Questions continue on next page)

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

$$CH_3CH_2CH_2CH_2OH + HBr \longrightarrow CH_3CH_2CH_2CH_2Br + H_2O$$

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.

(Question continues on next page)

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.

(Question continues on next page)

(i) Parts of the method are given in capitalised type in Steps 2, 3 and 4.

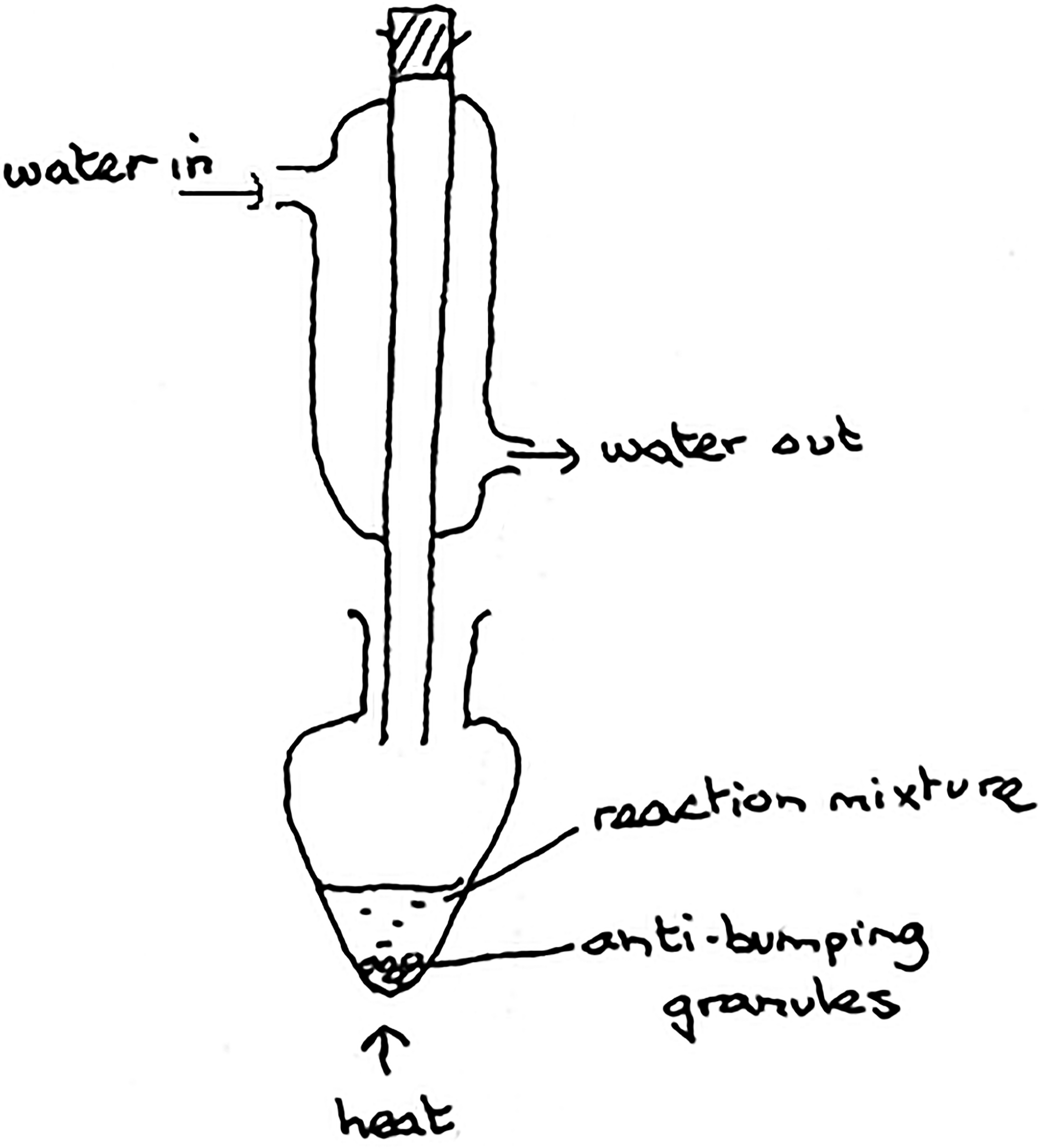
Give a reason why each of these parts is necessary. (3 marks)

(Continue your answer on next page)

(Question continues on next page)

(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 on page 63. Assume the apparatus is suitably clamped.

(Question continues on next page)



(Question continues on next page)

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

(Continue your answer on next page)

(Turn over)

(Question continues on next page)

(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 marks)

(Question continues on next page)

(b) The distillate collected in Step 5 is a mixture consisting of two layers. There is an aqueous layer and a layer containing impure 1-bromobutane.

Data

Densities:

water	$1{\cdot}00\ g\ cm^{-3}$
butan-1-ol	$0{\cdot}81\ g\ cm^{-3}$
1-bromobutane	$1{\cdot}27\ g\ cm^{-3}$

Boiling temperature of 1-bromobutane = 102 °C

The steps for the purification of the 1-bromobutane are summarised.

(Question continues on next page)

Step 6 Transfer the mixture from Step 5 to a separating funnel and remove the aqueous layer.

Step 7 Wash the impure 1-bromobutane with concentrated hydrochloric acid in the separating funnel. Remove the aqueous layer.

Step 8 Add aqueous sodium hydrogencarbonate to the impure 1-bromobutane in the separating funnel.

Step 9 Shake the mixture in the separating funnel and, from time to time, invert the funnel and open the tap.

(Question continues on next page)

Step 10 Collect the 1-bromobutane layer from Step 9 in a small conical flask. Add anhydrous sodium sulfate and swirl the flask until the liquid becomes clear.

Step 11 Decant the 1-bromobutane into a clean pear-shaped flask and redistil it. Measure the volume of 1-bromobutane produced.

(Question continues on next page)

(i) State the position of the aqueous layer in the separating funnel at the start of Step 6. Justify your answer. (1 mark)

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

Give the reasons for carrying out Steps 8, 9 and 10. (3 marks)

(Continue your answer on next page)

(Question continues on next page)

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

(Question continues on next page)

(iv) The volume of 1-bromobutane collected was 12·0 cm^3.

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

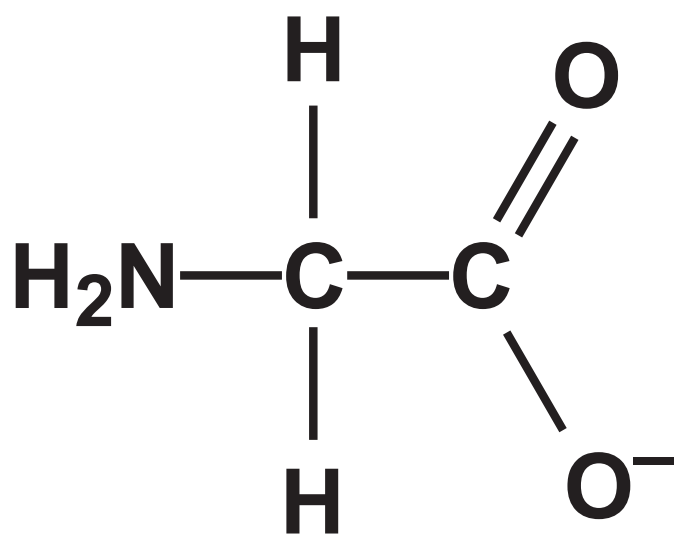
Give your answer to an appropriate number of significant figures. (2 marks)

(TOTAL FOR QUESTION 8 = 15 MARKS)

(Questions continue on next page)

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 marks)

(Continue your answer on next page)

(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.

On page 76 write the equation for this reaction.
State symbols are not required.
(2 marks)

(Write your answer on next page)

(Question continues on next page)

(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%.

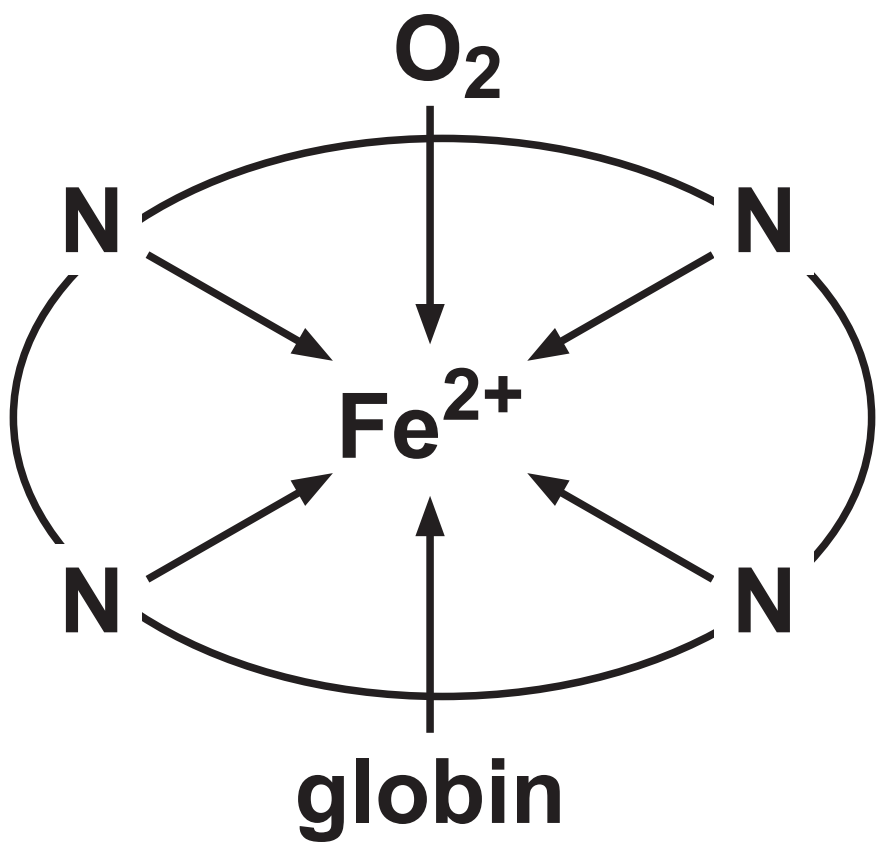
The expected yield is 82% and the students carried out the calculation correctly.

Discuss possible reasons for the yields obtained by these students. (4 marks)

(Continue your answer on next page)

(Question continues on next page)

(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 marks)

(Continue your answer on next page)

(Question continues on next page)

*(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 marks)

(Continue your answer on next page)

(Continue your answer on next page)

(Continue your answer on next page)

(Continue your answer on next page)

(Continue your answer on next page)

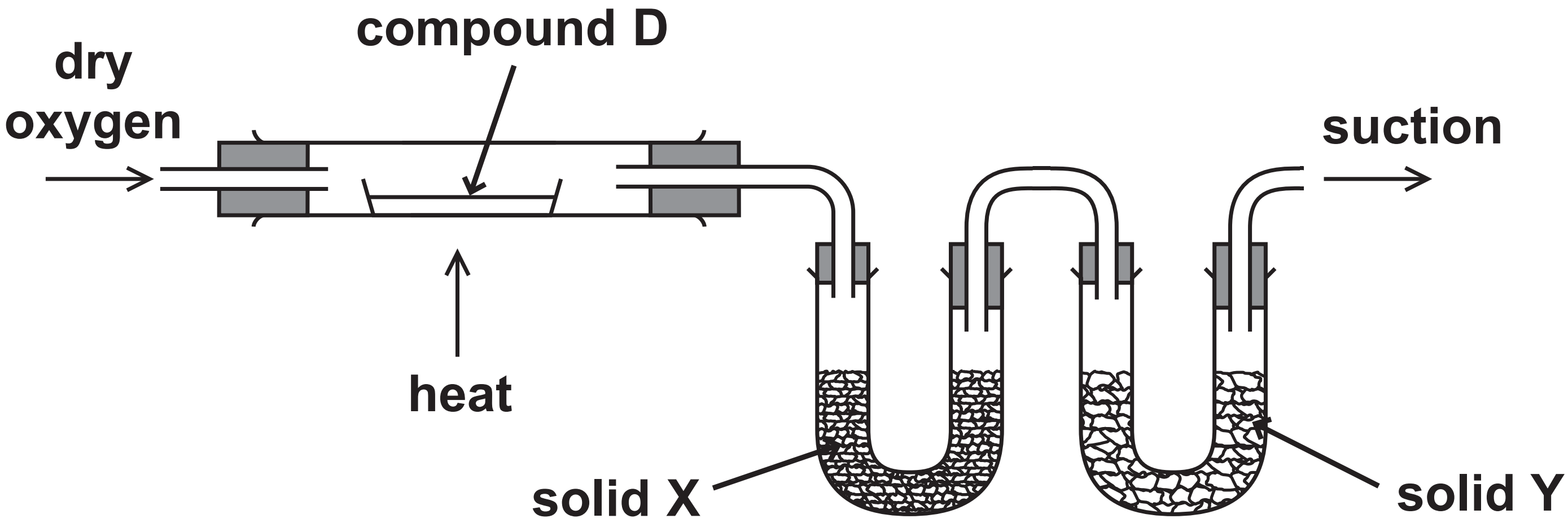
(Continue your answer on next page)

(TOTAL FOR QUESTION 9 = 16 MARKS)

(Questions continue on next page)

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.



(Question continues on next page)

(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 marks)

(Continue your answer on next page)

(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.

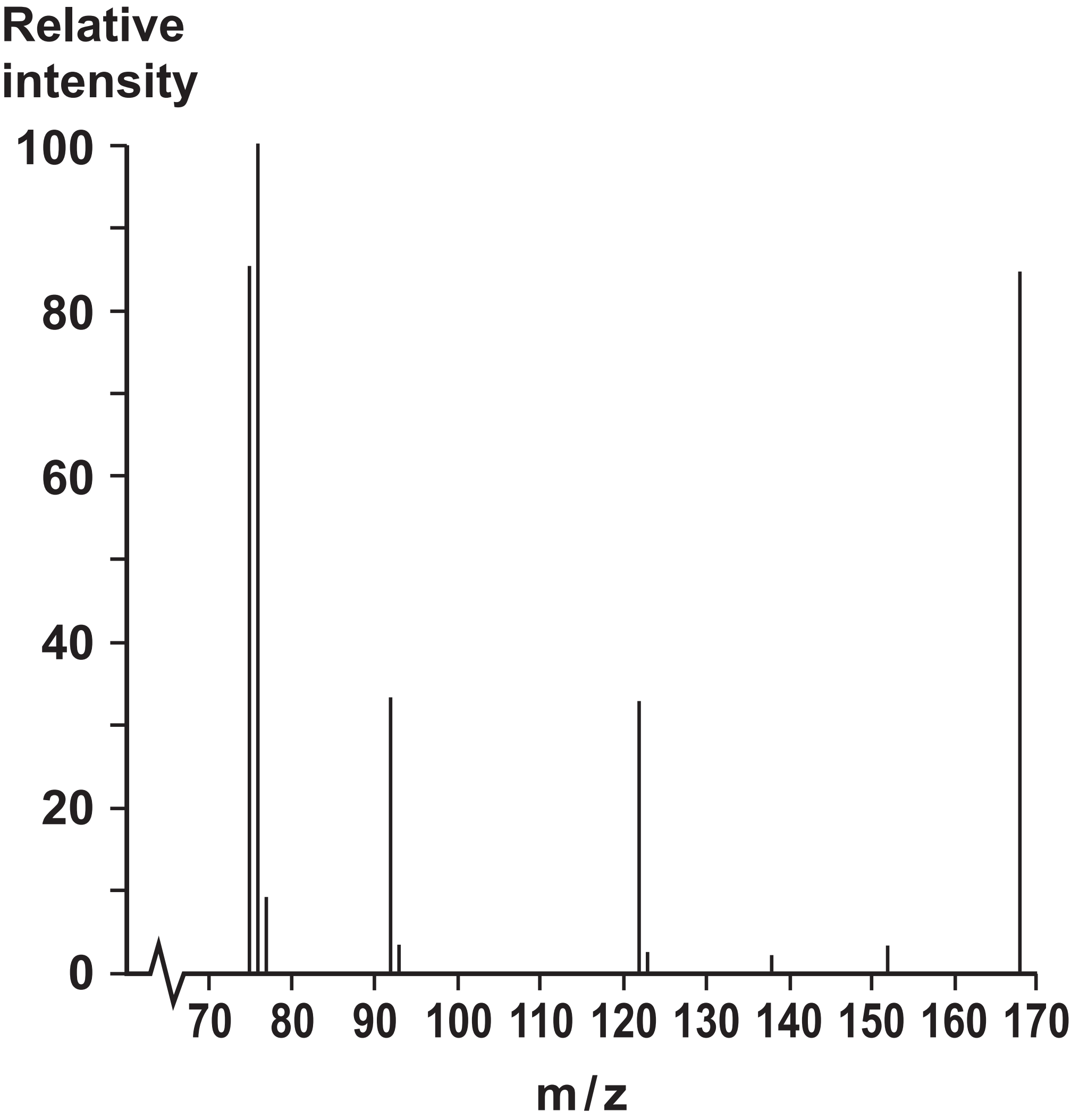
(5 marks)

(Continue your answer on next page)

(Continue your answer on next page)

(Question continues on next page)

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



(Question continues on next page)

Deduce the molecular formula of D. Justify your answer. (2 marks)

(c) Compound D contains a benzene ring.

(i) Give the molecular formula of the species that causes the peak at m/z = 76 in the mass spectrum of D. (1 mark)

(Question continues on next page)

(ii) Draw the structures of the THREE possible isomers of D containing a benzene ring. (2 marks)

(Question continues on next page)

(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 marks)

(Continue your answer on next page)

(TOTAL FOR QUESTION 10 = 16 MARKS)

TOTAL FOR PAPER = 120 MARKS

END