



Rewarding Learning

ADVANCED SUBSIDIARY (AS)
General Certificate of Education
2024

Centre Number

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Candidate Number

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Chemistry

StemUp Model Solution

Assessment Unit AS 1

assessing

Basic concepts in Physical
and Inorganic Chemistry



[SCH14]

SCH14

TUESDAY 14 MAY, MORNING

TIME

1 hour 30 minutes.

INSTRUCTIONS TO CANDIDATES

Write your Centre Number and Candidate Number in the spaces provided at the top of this page.

Answer **all sixteen** questions in **Sections A and B**.

You must answer the questions in the spaces provided.

Do not write outside the boxed area on each page or on blank pages.

Complete in black ink only. **Do not write with a gel pen or a pencil.**

INFORMATION FOR CANDIDATES

The total mark for this paper is 90.

Quality of written communication will be assessed in Question **16(a)**.

The figures in brackets printed down the right-hand side of pages indicate the marks awarded to each question or part question.

A Periodic Table of Elements, containing some data, is included with this question paper.



Section A

For each of the following questions, only **one** of the lettered responses (A–D) is correct.

Select the correct response for each question and write the appropriate letter in the space provided.

- 1 Which one of the following shows the total number of bonding pairs of electrons and lone pairs of electrons in the outer shells of the atoms of BeCl_2 ?

	Number of bonding pairs of electrons	Number of lone pairs of electrons
A	2	0
B	2	2
C	2	6
D	4	6

Answer C [1]

- 2 Which one of the following is a reagent used in the test for the ammonium ion?

- A chlorine water
- B hydrochloric acid
- C sodium hydroxide solution
- D starch solution

Answer C [1]

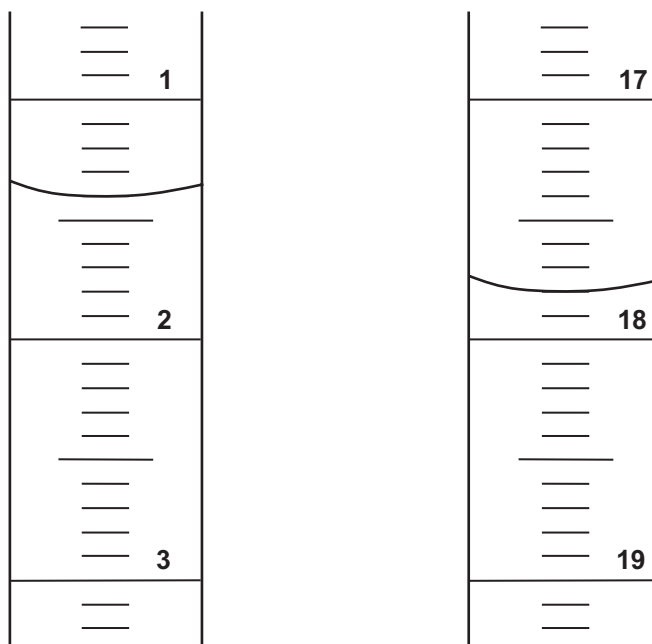


3 Which one of the following has the highest boiling point?

- A CH_4
- B HCl
- C H_2O
- D NH_3

Answer C [1]

4 The diagrams below show the initial and final burette readings for a titration.



Which one of the following is the titre value for this titration?

- A 15.6 cm^3
- B 16.4 cm^3
- C 17.8 cm^3
- D 19.2 cm^3

Answer B [1]

[Turn over]

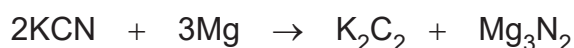


- 5 Which one of the following is the number of uranium atoms in a sample of 417 mg of U_2O_5 ?

- A 2.28×10^{20}
B 4.52×10^{20}
C 9.03×10^{20}
D 2.26×10^{21}

Answer C [1]

- 6 10.0 g of potassium cyanide are allowed to react with 10.0 g of magnesium. The equation for the reaction is given below.



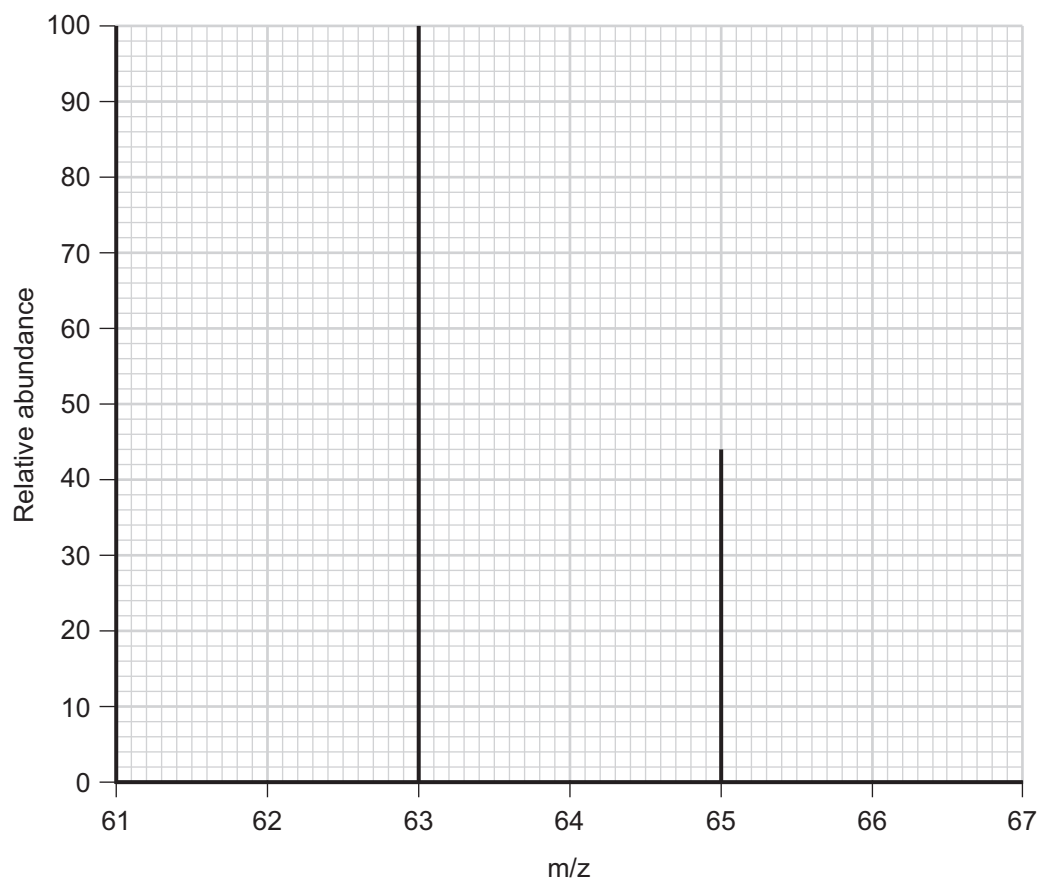
Which one of the following is the mass of magnesium remaining when the reaction is complete?

- A 3.7 g
B 4.5 g
C 7.4 g
D 8.2 g

Answer B [1]



7 The mass spectrum of a sample of an element is shown below.



Which one of the following is the relative atomic mass of the element to 1 decimal place?

- A 63.4
- B 63.6
- C 63.8
- D 64.0

Answer *B* [1]

[Turn over

13885

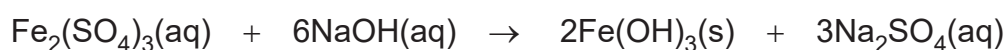


8 Which one of the following is the total number of subatomic particles in an atom of ^{37}Cl ?

- A 17
- B 20
- C 37
- D 54

Answer D [1]

9 150 cm^3 of sodium hydroxide solution (an excess) were added to 250 cm^3 of a solution of iron(III) sulfate. 0.428 g of solid iron(III) hydroxide are formed. The equation for the reaction is:



Which one of the following is the concentration, in mol dm^{-3} , of sulfate ions in the final solution?

- A 0.005
- B 0.010
- C 0.015
- D 0.024

Answer C [1]



10 In which one of the following molecules do all atoms in the molecule follow the octet rule?

- A BF_3
- B NCl_3
- C PCl_5
- D SO_2

Answer *B* [1]



Section B

Answer **all six** questions in this section.

- 11 The table below shows some details of five chemical tests used to identify the ions present in a solution or in a solid sample. The tests are labelled **A** to **E**.

Test	Practical procedure	Observations	Ion present
A	Add 1 cm ³ of silver nitrate solution to a solution	white precipitate	<i>chloride</i>
B	Add 1 cm ³ of dilute hydrochloric acid to a solid sample	<i>bubbles / fizzing</i>	carbonate
C	<i>Add barium chloride solution to a solution of it</i>	<i>white precipitate</i>	sulfate
D	Add a few drops of concentrated sulfuric acid to a solid sample	misty fumes red-brown vapour	<i>bromide</i>
E	Carry out a flame test on a solid sample	<i>blue-green flame</i>	copper(II)

- (a) Complete the table.

[6]

- (b) What would be observed if excess dilute ammonia solution was added to the solution containing the white precipitate in Test **A**?

The white precipitate dissolves, forming a colourless solution.

[1]



- (c) Write an ionic equation for the reaction of the carbonate ion in Test B.



- (d) Name the red-brown vapour in Test D.

bromine [1]

- (e) How would the observations in Test D differ if concentrated phosphoric acid was used in place of concentrated sulfuric acid? Explain your answer.

No red-brown vapour would be seen, only misty fumes of HBr.

Phosphoric acid is too weak an oxidising agent to oxidise HBr to

bromine. [2]

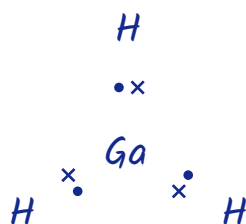
[Turn over]



12 Gallium (atomic number 31) forms many compounds including gallane, GaH_3 , and gallium(III) nitrate which is used to treat some bone disorders.

(a) Gallane is a colourless gas at room temperature. The shape of a gallane molecule is trigonal planar. Gallane is non-polar.

(i) Draw a dot and cross diagram to show the bonding in a molecule of gallane.



• = H electron
× = Ga electron

[1]

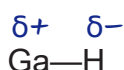
(ii) Suggest the bond angle in a molecule of gallane.

120°

[1]

(b) The electronegativity of gallium is 1.6 and the electronegativity of hydrogen is 2.1.

(i) Show the polarity of the Ga—H bond using partial charges.



[1]

(ii) Explain why gallane is non-polar.

The three Ga—H bonds are equally polar and are arranged
symmetrically (trigonal planar), so the dipoles cancel.

[1]



(c) Gallane, GaH_3 , forms when lithium tetrahydridogallate(III), LiGaH_4 , reacts with gallium(III) chloride. The only other product is lithium chloride. Lithium tetrahydridogallate(III) contains the tetrahydridogallate(III) ion, GaH_4^- .

(i) Write an equation for the reaction of lithium tetrahydridogallate(III) with gallium(III) chloride.



(ii) Suggest the shape of the tetrahydridogallate(III) ion, GaH_4^- .

tetrahedral [1]

(iii) A hydride ion bonds with gallane to form the tetrahydridogallate(III) ion. Explain how a hydride ion bonds with gallane and name the type of bond formed.

The hydride ion, H^- , donates (shares) a lone pair of electrons

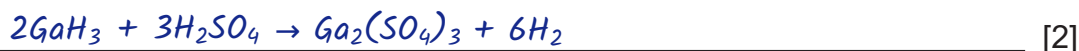
with the gallium atom in gallane, which has an empty orbital.

This forms a co-ordinate (dative covalent) bond.

[2]

(d) Gallane reacts with strong acids to form gallium(III) salts and hydrogen gas.

(i) Write an equation for the reaction of gallane with sulfuric acid.



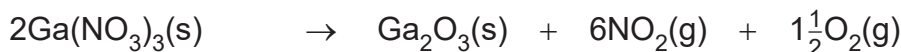
(ii) Describe how you would test for hydrogen gas.

A burning splint gives a squeaky pop. [1]

[Turn over]



- (e) One hydrated form of gallium(III) nitrate, $\text{Ga}(\text{NO}_3)_3 \cdot 8\text{H}_2\text{O}$, is heated to constant mass. During this process, it loses its water of crystallisation and the gallium(III) nitrate also decomposes to form gallium(III) oxide, Ga_2O_3 , nitrogen dioxide gas and oxygen gas. The equations for the reactions are:



- (i) Define the term **water of crystallisation**.

Water which is chemically bonded within the crystal structure of

a compound.

[1]

- (ii) Calculate the total loss in mass when a sample of 3.15 g of hydrated gallium(III) nitrate is heated to constant mass. Give your answer to 3 significant figures.

$$\text{moles } \text{Ga}(\text{NO}_3)_3 \cdot 8\text{H}_2\text{O} = 3.15 \div 400 = 7.875 \times 10^{-3}$$

$$\text{moles } \text{Ga}_2\text{O}_3 = 7.875 \times 10^{-3} \div 2 = 3.9375 \times 10^{-3}$$

$$\text{mass } \text{Ga}_2\text{O}_3 = 3.9375 \times 10^{-3} \times 188 = 0.740 \text{ g}$$

$$\text{loss in mass} = 3.15 - 0.740 = 2.41 \text{ g}$$

Answer 2.41 g [4]

- (iii) Suggest one reason why the actual loss in mass obtained practically may not be the same as the value calculated in (e)(ii).

The decomposition may not be complete, or some solid may be

lost from the container.

[1]





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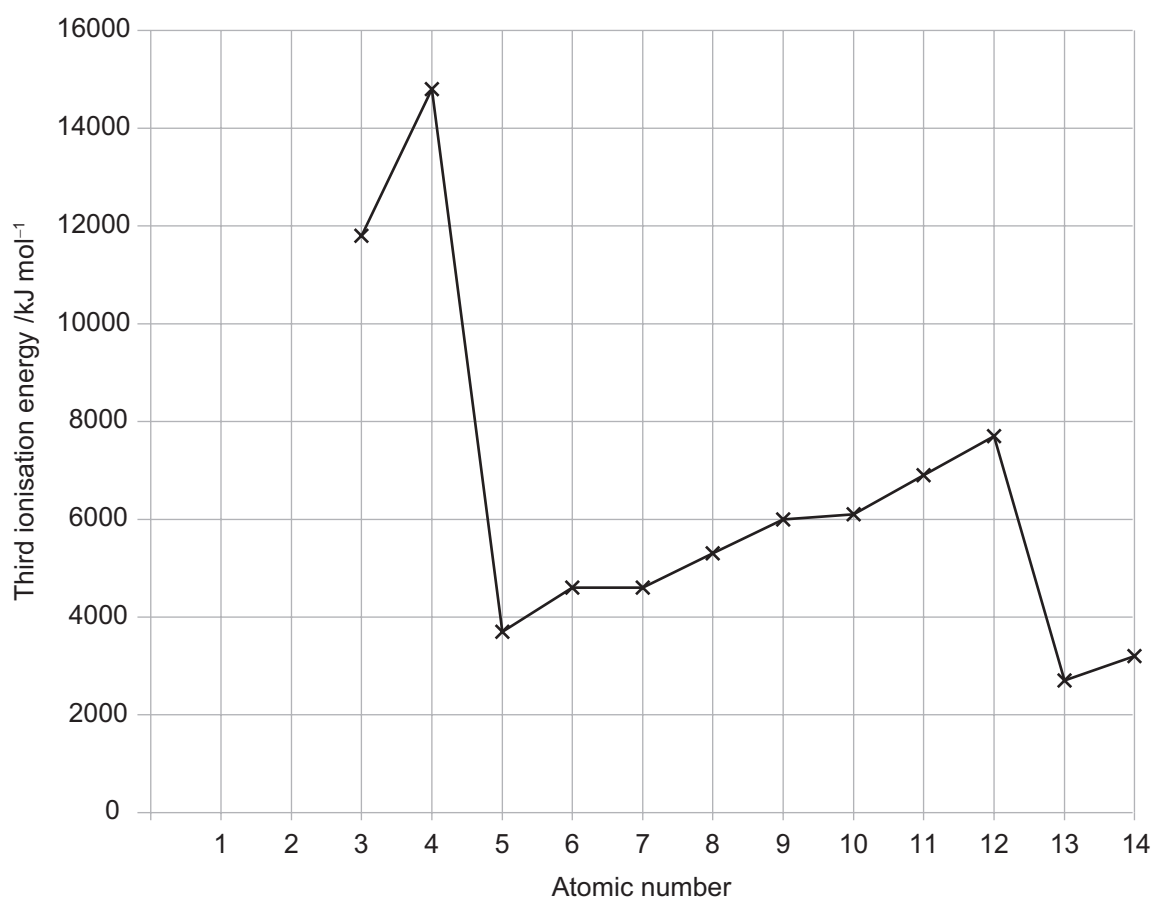
(Questions continue overleaf)

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[Turn over



- 13 (a) The graph below shows the **third** ionisation energies of elements with atomic numbers 3–14.



- (i) Define the term **third ionisation energy**.

The energy required to convert one mole of gaseous ions with a 2+ charge into one mole of gaseous ions with a 3+ charge.

[2]

- (ii) Explain why there are no values for the elements with atomic numbers 1 and 2.

Hydrogen has only one electron and helium only two, so there is no third electron to remove.

[1]



- (iii) Write an equation which represents the third ionisation energy of fluorine.



- (iv) Explain, giving three reasons, why the value of the third ionisation energy of the element with atomic number 12 is significantly greater than the value of the third ionisation energy of the element with atomic number 13.

For element 12 (Mg) the third electron is removed from the second energy level, which is closer to the nucleus than the third energy level used by element 13 (Al).

The electron is removed from a filled 2p subshell, which is stable.

This electron experiences less shielding, so it is more strongly attracted to the nucleus.

[3]

- (v) State one factor which would explain the general increase in the value of the third ionisation energy from the element with atomic number 5 to the element with atomic number 12.

The nuclear charge increases (decreasing ionic radius), so the electron is held more strongly.

[1]

[Turn over]



(b) Elements with atomic numbers 23, 24 and 25 are vanadium, chromium and manganese. All three elements form a 2+ ion.

(i) Complete the table below to give the electronic configuration of the atoms of these elements and their 2+ ion.

Element	Electronic configuration of atom	Electronic configuration of 2+ ion
V	$1s^2 2s^2 2p^6 3s^2 3p^6 3d^3 4s^2$	$1s^2 2s^2 2p^6 3s^2 3p^6 3d^3$
Cr	$1s^2 2s^2 2p^6 3s^2 3p^6 3d^5 4s^1$	$1s^2 2s^2 2p^6 3s^2 3p^6 3d^4$
Mn	$1s^2 2s^2 2p^6 3s^2 3p^6 3d^5 4s^2$	$1s^2 2s^2 2p^6 3s^2 3p^6 3d^5$

[3]

(ii) Based on the electronic configurations, state and explain which 2+ ion would be most stable.

The manganese(II) ion, Mn^{2+} , would be the most stable.

It has a half-filled 3d subshell ($3d^5$), which is especially stable.

[2]

(iii) Deduce the oxidation state of Cr, V and Mn in the compounds and ions below.

$K_2Cr_2O_7$ +6

NH_4VO_3 +5

MnO_4^{2-} +6

[2]



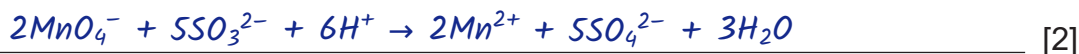
- (c) Manganate(VII) ions may be used to oxidise sulfate(IV) ions, SO_3^{2-} , to sulfate(VI) ions. The half-equation for the reduction of manganate(VII) ions, MnO_4^- , to manganese(II) ions, Mn^{2+} is:



- (i) Write a half-equation for the oxidation of sulfate(IV) ions to sulfate(VI) ions.



- (ii) Write a redox equation for the overall reaction between manganate(VII) ions and sulfate(IV) ions.



[Turn over]



14 Substances can be classified based on their bonding and structure. In general, substances within the same classification have similar physical properties.

(a) Write the **formula** of one example of each of the following:

A molecular covalent element with a relative formula mass greater than 200.



A non-polar covalent compound containing oxygen



A polar covalent compound which dissolves in water forming an alkaline solution.



[3]



(b) Graphite and diamond are classified as giant covalent. There are similarities in the physical properties of graphite and diamond but also some differences, for example graphite conducts electricity and diamond does not.

(i) Describe how the bonding in graphite and in diamond results in the difference in their electrical conductivity.

Graphite: each carbon forms only three covalent bonds, so one outer electron per atom is delocalised; these electrons can move and carry charge.

Diamond: each carbon uses all four outer electrons in covalent bonds, so there are no delocalised electrons and it cannot conduct. [3]

(ii) State and explain, in terms of bonding and structure, one **other** difference in the physical properties of graphite and diamond.

Diamond is very hard but graphite is soft.

Diamond has a rigid giant 3D tetrahedral structure with every carbon covalently bonded to four others.

Graphite has layers held together only by weak van der Waals' forces, so the layers slide over each other. [3]

(iii) State and explain, in terms of bonding and structure, one similarity in the physical properties of graphite and diamond.

Both have very high melting points.

A lot of energy is needed to break the many strong covalent bonds in the giant structure.

[2]

[Turn over]



- 15 The halogens (Group VII) are a group of highly reactive non-metals. They form ions and compounds in which the halogen has a variety of oxidation states. The main oxidation states of the halogens are shown in the table below. All elements can exist in the -1 oxidation state as halide ions.

Element	Oxidation states
Fluorine	-1
Chlorine	$-1, +1, +3, +5, +7$
Bromine	$-1, +1, +3, +5, +7$
Iodine	$-1, +1, +3, +5, +7$

- (a) Suggest why fluorine does not exist in positive oxidation states.

Fluorine is the most electronegative element, so it always attracts the bonding electrons more strongly than the atom it is bonded to.

[1]

- (b) Chlorine reacts with sodium hydroxide solution in one of two ways depending on the conditions used. Both reactions are examples of disproportionation.

- (i) Define **disproportionation**.

A reaction in which the same element is both oxidised and reduced in the same reaction.

[1]

- (ii) Write an equation for the reaction of chlorine with sodium hydroxide solution forming products with chlorine in -1 and $+5$ oxidation states.



[2]



(iii) State the conditions required for the reaction in (b)(ii).

Hot, concentrated sodium hydroxide solution. [1]

(c) Write the formula of potassium chlorate(VII).

KClO₄ [1]

(d) Chlorine is a stronger oxidising agent than iodine.

(i) Define **oxidising agent**.

An electron acceptor (a species which gains electrons).
[1]

(ii) Write an equation for the redox reaction which occurs when chlorine reacts with a solution of potassium iodide.

Cl₂ + 2KI → 2KCl + I₂ [1]

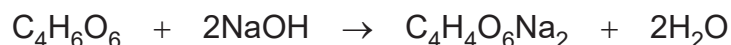
(iii) State the colour change observed in the solution during the reaction in (d)(ii).

colourless to yellow-brown [1]

[Turn over]



- 16 Tartaric acid, $\text{C}_4\text{H}_6\text{O}_6$, is a weak acid and is used to clean copper coins. It is found naturally in grapes. Tartaric acid reacts with sodium hydroxide according to the equation below.



A solution of tartaric acid was prepared by dissolving 3.18 g of solid tartaric acid in 125 cm^3 of deionised water. 25.0 cm^3 samples of this solution were titrated against 0.480 mol dm^{-3} sodium hydroxide solution.

- (a) For this titration, state the name of a suitable indicator and the colour change observed at the end point and describe how you would obtain accurate results.

In this question you will be assessed on your written communication skills including the use of specialist scientific terms.

Rinse the burette with the sodium hydroxide solution and the pipette with the tartaric acid solution before use.

Pipette 25.0 cm^3 of the tartaric acid solution into a conical flask and add a few drops of phenolphthalein indicator.

Add the sodium hydroxide from the burette while swirling the flask, adding it dropwise near the end point.

Rinse down the inside of the conical flask with deionised water during the titration.

At the end point the indicator changes from colourless to pink.

Read the burette at the bottom of the meniscus with the eye level with it.

Repeat until concordant titres are obtained and calculate the mean titre.

[6]



- (b) (i) Calculate the volume of sodium hydroxide solution, in cm^3 , which would be required to react with a 25.0 cm^3 sample of the tartaric acid solution. Give your answer to an appropriate number of significant figures.

$$\text{moles of tartaric acid} = 3.18 \div 150 = 0.0212 \text{ mol}$$

$$\text{moles in } 25.0 \text{ cm}^3 = 0.0212 \div 5 = 0.00424 \text{ mol}$$

$$\text{moles of NaOH} = 0.00424 \times 2 = 0.00848 \text{ mol}$$

$$\begin{aligned} \text{volume of NaOH} &= (0.00848 \times 1000) \div 0.480 = 17.67 \text{ cm}^3 \\ &= 17.7 \text{ cm}^3 \text{ (to 3 sig figs)} \end{aligned}$$

Answer 17.7 cm^3 [5]

- (ii) Suggest why the volume of sodium hydroxide solution calculated in (b)(i) may be different to the mean titre value in the titration.

Not all of the solid may have dissolved, or the tartaric acid may
contain impurities. [1]

THIS IS THE END OF THE QUESTION PAPER



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Question Number	Marks
Section A	
1–10	
Section B	
11	
12	
13	
14	
15	
16	
Examiner Number	Total Marks

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SCH14/7
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General Information

1 tonne = 10^6 g

1 metre = 10^9 nm

One mole of any gas at 293 K and a pressure of 1 atmosphere (10^5 Pa) occupies a volume of 24 dm³

Avogadro Constant = 6.02×10^{23} mol⁻¹

Planck Constant = 6.63×10^{-34} Js

Specific Heat Capacity of water = $4.2 \text{ J g}^{-1} \text{ K}^{-1}$

Speed of Light = $3 \times 10^8 \text{ m s}^{-1}$



Characteristic absorptions in IR spectroscopy

Wavenumber/cm ⁻¹	Bond	Compound
550–850	C–X (X = Cl, Br, I)	Haloalkanes
750–1100	C–C	Alkanes, alkyl groups
1000–1300	C–O	Alcohols, esters, carboxylic acids
1450–1650	C=C	Arenes
1600–1700	C=C	Alkenes
1650–1800	C=O	Carboxylic acids, esters, aldehydes, ketones, amides, acyl chlorides
2200–2300	C≡N	Nitriles
2500–3200	O–H	Carboxylic acids
2750–2850	C–H	Aldehydes
2850–3000	C–H	Alkanes, alkyl groups, alkenes, arenes
3200–3600	O–H	Alcohols
3300–3500	N–H	Amines, amides

Proton Chemical Shifts in Nuclear Magnetic Resonance Spectroscopy (relative to TMS)

Chemical Shift	Structure	
0.5–2.0	–CH	Saturated alkanes
0.5–5.5	–OH	Alcohols
1.0–3.0	–NH	Amines
2.0–3.0	–CO–CH	Ketones
	–N–CH	Amines
	C ₆ H ₅ –CH	Arene (aliphatic on ring)
2.0–4.0	X–CH	X = Cl or Br (3.0–4.0) X = I (2.0–3.0)
4.5–6.0	–C=CH	Alkenes
5.5–8.5	RCONH	Amides
6.0–8.0	–C ₆ H ₅	Arenes (on ring)
9.0–10.0	–CHO	Aldehydes
10.0–12.0	–COOH	Carboxylic acids

These chemical shifts are concentration and temperature dependent and may be outside the ranges indicated above.

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Data Leaflet

Including the Periodic Table of the Elements

For the use of candidates taking
Advanced Subsidiary and
Advanced Level Examinations

Copies must be free from notes or additions of any kind. No other type of data booklet or information sheet is authorised for use in the examinations

gce a/as examinations chemistry

THE PERIODIC TABLE OF ELEMENTS																	
Group																	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1 H Hydrogen 1												4 He Helium 2					
7 Li Lithium 3	9 Be Beryllium 4											11 B Boron 5	12 C Carbon 6	14 N Nitrogen 7	16 O Oxygen 8	19 F Fluorine 9	20 Ne Neon 10
23 Na Sodium 11	24 Mg Magnesium 12											27 Al Aluminium 13	28 Si Silicon 14	31 P Phosphorus 15	32 S Sulfur 16	35.5 Cl Chlorine 17	40 Ar Argon 18
39 K Potassium 19	40 Ca Calcium 20	45 Sc Scandium 21	48 Ti Titanium 22	51 V Vanadium 23	52 Cr Chromium 24	55 Mn Manganese 25	56 Fe Iron 26	59 Co Cobalt 27	59 Ni Nickel 28	64 Cu Copper 29	65 Zn Zinc 30	70 Ga Gallium 31	73 Ge Germanium 32	75 As Arsenic 33	79 Se Selenium 34	80 Br Bromine 35	84 Kr Krypton 36
85 Rb Rubidium 37	88 Sr Strontium 38	89 Y Yttrium 39	91 Zr Zirconium 40	93 Nb Niobium 41	96 Mo Molybdenum 42	98 Tc Technetium 43	101 Ru Ruthenium 44	103 Rh Rhodium 45	106 Pd Palladium 46	108 Ag Silver 47	112 Cd Cadmium 48	115 In Indium 49	119 Sn Tin 50	122 Sb Antimony 51	128 Te Tellurium 52	127 I Iodine 53	131 Xe Xenon 54
133 Cs Caesium 55	137 Ba Barium 56	139 La [*] Lanthanum 57	178 Hf Hafnium 72	181 Ta Tantalum 73	184 W Tungsten 74	186 Re Rhenium 75	190 Os Osmium 76	192 Ir Iridium 77	195 Pt Platinum 78	197 Au Gold 79	201 Hg Mercury 80	204 Tl Thallium 81	207 Pb Lead 82	209 Bi Bismuth 83	210 Po Polonium 84	210 At Astatine 85	222 Rn Radon 86
223 Fr Francium 87	226 Ra Radium 88	227 Ac [†] Actinium 89	261 Rf Rutherfordium 104	262 Db Dubnium 105	266 Sg Seaborgium 106	264 Bh Bohrium 107	277 Hs Hassium 108	268 Mt Meitnerium 109	271 Ds Darmstadtium 110	272 Rg Roentgenium 111	285 Cn Copernicium 112						
a X b a = relative atomic mass (approx) x = atomic symbol b = atomic number * 58 – 71 Lanthanum series † 90 – 103 Actinium series			140 Ce Cerium 58	141 Pr Praseodymium 59	144 Nd Neodymium 60	145 Pm Promethium 61	150 Sm Samarium 62	152 Eu Europium 63	157 Gd Gadolinium 64	159 Tb Terbium 65	162 Dy Dysprosium 66	165 Ho Holmium 67	167 Er Erbium 68	169 Tm Thulium 69	173 Yb Ytterbium 70	175 Lu Lutetium 71	
			232 Th Thorium 90	231 Pa Protactinium 91	238 U Uranium 92	237 Np Neptunium 93	242 Pu Plutonium 94	243 Am Americium 95	247 Cm Curium 96	245 Bk Berkelium 97	251 Cf Californium 98	254 Es Einsteinium 99	253 Fm Fermium 100	256 Md Mendelevium 101	254 No Nobelium 102	257 Lr Lawrencium 103	

* 58 – 71 Lanthanum series
† 90 – 103 Actinium series

$\begin{matrix} a \\ \boxed{X} \\ b \end{matrix}$ a = relative atomic mass (approx)
x = atomic symbol
b = atomic number