



Rewarding Learning

ADVANCED SUBSIDIARY (AS)
General Certificate of Education
2023

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 16 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 fifteen** 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 **13(a)**.

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

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

13618.06R



Section A

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

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

1 Which one of the following bond angles is **not** present in a PF_5 molecule?

- A 90°
- B 109.5°
- C 120°
- D 180°

Answer B [1]

2 Which one of the following gives the correct formulae for potassium chromate(VI) and potassium dichromate(VI)?

- A KCrO_4 KCr_2O_7
- B KCrO_4 $\text{K}_2\text{Cr}_2\text{O}_7$
- C K_2CrO_4 KCr_2O_7
- D K_2CrO_4 $\text{K}_2\text{Cr}_2\text{O}_7$

Answer D [1]



3 7.10 g of anhydrous sodium sulfate were dissolved in water and made up to 250 cm³ in a volumetric flask. What is the concentration of sodium ions in this solution?

- A 0.05 mol dm⁻³
- B 0.10 mol dm⁻³
- C 0.20 mol dm⁻³
- D 0.40 mol dm⁻³

Answer D [1]

4 Which one of the following bonds is the least polar?

- A O—F
- B N—F
- C Cl—F
- D I—F

Answer A [1]

5 Which one of the following is **not** a disproportionation reaction?

- A $\text{Br}_2 + \text{H}_2\text{O} \rightarrow \text{HBr} + \text{HBrO}$
- B $\text{Cl}_2 + 2\text{NaBr} \rightarrow 2\text{NaCl} + \text{Br}_2$
- C $\text{Cl}_2 + 2\text{NaOH} \rightarrow \text{NaCl} + \text{NaClO} + \text{H}_2\text{O}$
- D $3\text{Cl}_2 + 6\text{NaOH} \rightarrow 5\text{NaCl} + \text{NaClO}_3 + 3\text{H}_2\text{O}$

Answer B [1]

[Turn over]

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6 Which one of the following is the number of atoms present in 3.20 g of sulfur dioxide?

A 3.01×10^{22}

B 6.02×10^{22}

C 9.03×10^{22}

D 6.02×10^{23}

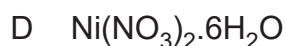
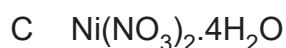
Answer C [1]

7 Which one of the following shows the **incorrect** colour for the substance given?

	Substance	Colour
A	$I_2(aq)$	brown
B	$I_2(g)$	red-brown
C	$I_2(\text{hexane})$	purple
D	$I_2(s)$	grey-black

Answer B [1]

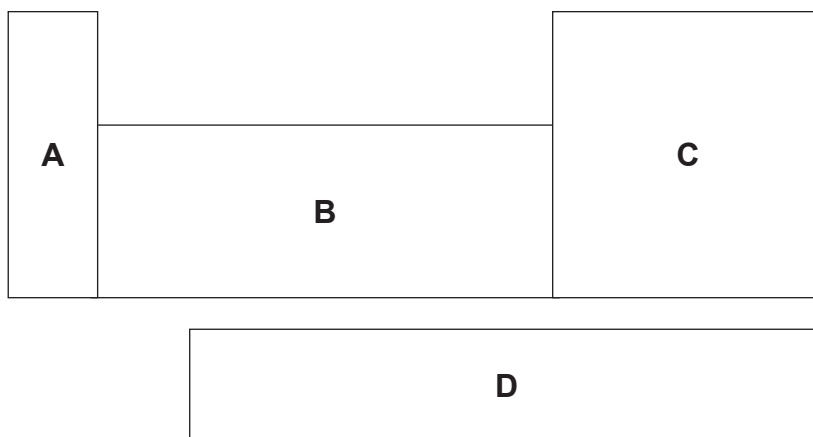
8 Hydrated nickel(II) nitrate is a green crystalline solid which contains approximately 37% water by mass. Which one of the following is the correct formula of hydrated nickel(II) nitrate?



Answer D [1]



9 Which one of the following letters represents the d-block of the Periodic Table?



Answer B [1]

10 Which one of the following is correct for a p subshell?

	Number of orbitals	Maximum number of electrons in subshell
A	1	2
B	3	6
C	5	10
D	7	14

Answer B [1]



Section B

Answer all **five** questions in this section

11 Magnesium has three naturally occurring isotopes: ^{24}Mg , ^{25}Mg and ^{26}Mg .

- (a) (i)** State the number of protons, neutrons and electrons in an atom of the ^{26}Mg isotope.

protons 12

neutrons 14

electrons 12

[1]

- (ii)** Write the electronic configuration of an atom of the ^{26}Mg isotope.

$1s^2 2s^2 2p^6 3s^2$

[1]

- (b)** The percentage abundance and relative isotopic mass of each isotope are given in the table below.

Isotope	Abundance /%	Relative isotopic mass
^{24}Mg	79.0	23.985
^{25}Mg	10.0	24.986
^{26}Mg	11.0	25.983

- (i)** Define **relative isotopic mass**.

The mass of an atom of an isotope of an element relative to

one-twelfth of the mass of an atom of carbon-12.

[2]



(ii) Calculate the relative atomic mass of magnesium to 1 decimal place.

$$\text{RAM} = \frac{(79.0 \times 23.985) + (10.0 \times 24.986) + (11.0 \times 25.983)}{100}$$

$$= (1894.815 + 249.86 + 285.813) \div 100$$

$$= 2430.488 \div 100 = 24.30$$

$$= 24.3$$

Answer 24.3 [2]

(c) The successive ionisation energies of magnesium give evidence for the existence of shells.

(i) Define **third ionisation energy**.

The energy required to convert one mole of gaseous ions with a
double positive charge (2+) into one mole of gaseous ions with a
triple positive charge (3+).

[2]

(ii) Write an equation, including state symbols, which represents the third ionisation energy of magnesium.



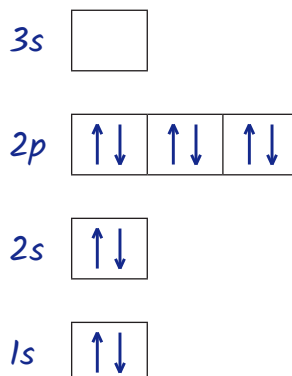
[1]

[Turn over]

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- (iii) Label the subshells in the diagram and, using electrons in boxes notation, give the electronic configuration of the $^{26}\text{Mg}^{2+}$ ion.



[2]

- (iv) The second ionisation energy of magnesium is 1500 kJ mol^{-1} and the third ionisation energy of magnesium is 7700 kJ mol^{-1} . State three reasons why the third ionisation energy of magnesium is much greater than the second.

The third electron is removed from the 2p subshell, which is closer to the nucleus than the 3s subshell.

The third electron is less shielded by inner electrons.

The third electron is removed from a filled (stable) 2p subshell.

There is a greater ratio of protons to electrons in Mg^{2+} , so the electrons are held more strongly.

[3]



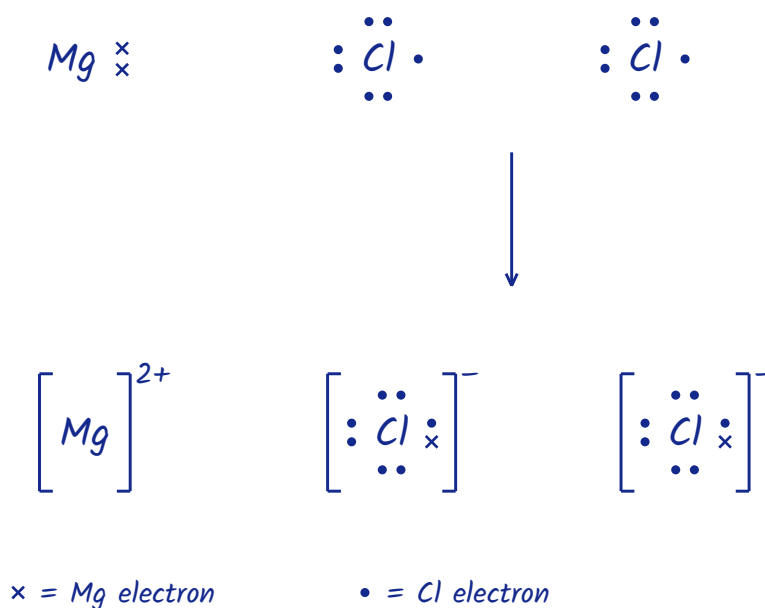
(d) Magnesium reacts with chlorine to form magnesium chloride in a redox reaction.

(i) Write half-equations for the oxidation and reduction reactions which occur.

oxidation half-equation $Mg \rightarrow Mg^{2+} + 2e^{-}$

reduction half-equation $Cl_2 + 2e^{-} \rightarrow 2Cl^{-}$ [2]

(ii) Using a dot and cross diagram show how magnesium chloride is formed from magnesium and chlorine atoms.



[2]

[Turn over]



12 Concentrated sulfuric acid reacts with the solids, sodium chloride, sodium bromide and sodium iodide. Concentrated sulfuric acid is a source of sulfate ions.

(a) Give the systematic name of the sulfate ion.

sulfate(VI) [1]

(b) The reaction between concentrated sulfuric acid and solid sodium chloride is not a redox reaction. One of the products is hydrogen chloride.

(i) Write an equation for this reaction.

$\text{NaCl} + \text{H}_2\text{SO}_4 \rightarrow \text{NaHSO}_4 + \text{HCl}$ [1]

(ii) Describe a test which would indicate the presence of hydrogen chloride.

Hold a glass rod dipped in concentrated ammonia solution in the
gas.

Dense white smoke forms. [2]

(c) During the reaction between concentrated sulfuric acid and solid sodium bromide, hydrogen bromide is formed and oxidised by the acid. Write an equation for oxidation of hydrogen bromide by concentrated sulfuric acid.

$2\text{HBr} + \text{H}_2\text{SO}_4 \rightarrow \text{Br}_2 + \text{SO}_2 + 2\text{H}_2\text{O}$ [2]

(d) Iodide ions are stronger reducing agents than bromide ions.

(i) Define **reducing agent**.

An electron donor. [1]

(ii) Suggest why iodide ions are stronger reducing agents than bromide ions.

The outer electron in iodide is further from the nucleus and more
shielded, so it is lost more easily. [1]



(e) When concentrated sulfuric acid is added to solid sodium iodide, iodine and three sulfur containing products are formed.

(i) Determine the oxidation state of sulfur in each of the following sulfur containing products.

SO₂ _____ *+4* _____

S _____ *0* _____

H₂S _____ *-2* _____ [2]

(ii) What observation would suggest the formation of H₂S in this reaction?

A smell of rotten eggs. _____ [1]

(iii) What observation would suggest the formation of sulfur in this reaction?

A yellow solid forms. _____ [1]

(iv) Complete the half-equation for the formation of H₂S.

SO₄²⁻ + *10* H⁺ + *8e*⁻ → H₂S + *4* H₂O [2]

(v) Write a half-equation for the formation of iodine.

2I⁻ → I₂ + *2e*⁻ _____ [1]

(vi) Combine the half-equations in (e)(iv) and (e)(v) to give a balanced redox equation.

*SO*₄²⁻ + *10H*⁺ + *8I*⁻ → H₂S + *4H*₂O + *4I*₂ _____ [1]

[Turn over



13 Elements and compounds show different types of bonding and structure.

- (a)** Describe the bonding and structure of carbon (graphite) and oxygen and explain the difference in the melting points of the two substances.

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

Graphite has covalent bonding. Each carbon atom is covalently

bonded to three other carbon atoms in a giant covalent structure.

The atoms are arranged in flat hexagonal layers, and the layers are

held together by weak van der Waals' forces, so graphite has a layer structure.

Oxygen also has covalent bonding: two oxygen atoms share two pairs

of electrons to form O_2 molecules, so oxygen has a molecular

covalent structure.

Graphite has a very high melting point because a substantial amount

of energy is required to break the many strong covalent bonds.

Oxygen has a very low melting point because little energy is required

to overcome the weak van der Waals' forces between the molecules;

the strong $O=O$ covalent bonds within the molecules are not broken

on melting.

Therefore graphite has a much higher melting point than oxygen.

[6]



(b) Carbon (graphite) reacts with oxygen and with ozone (O₃). Both reactions form carbon dioxide.

(i) Write an equation for the reaction of carbon (graphite) with ozone.



(ii) Describe a chemical test for carbon dioxide.

Bubble the gas through limewater, which turns from colourless to milky. [1]

(iii) Explain why carbon dioxide is non-polar.

The molecule is linear (symmetrical), so the dipoles of the two equally polar C=O bonds cancel. [2]

(c) Carbon dioxide reacts with potassium hydroxide to form potassium carbonate. Potassium carbonate is an ionic compound which melts at 891°C and is very soluble in water.

(i) State how you could show experimentally that potassium carbonate is an ionic compound based on its physical properties.

It does not conduct electricity when solid, but it does conduct electricity when molten. [1]

(ii) Write an equation for the formation of potassium carbonate from carbon dioxide and potassium hydroxide.



[Turn over]



(iii) Describe how you would carry out a flame test on a sample of solid potassium carbonate to show the presence of potassium ions.

Dip a nichrome wire into concentrated hydrochloric acid.

Dip the wire into the solid sample and hold it in a blue Bunsen burner flame.

A lilac flame colour shows that potassium ions are present.

[3]





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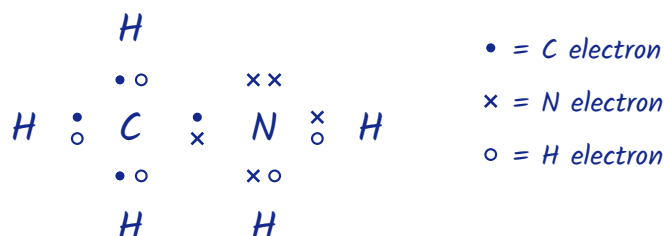
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14 Ethane (CH_3CH_3) and methylamine (CH_3NH_2) have similar relative molecular masses.

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



[1]

- (ii) State the value for the $\text{H}-\text{C}-\text{H}$ bond angles in a methylamine molecule.

109.5°

[1]

- (iii) Suggest and explain the shape around the nitrogen atom in a methylamine molecule.

The shape around the nitrogen atom is pyramidal.

Nitrogen has three bonding pairs and one lone pair of electrons.

Lone pair-bonding pair repulsion is greater than bonding

pair-bonding pair repulsion, so the bonds are pushed closer

together.

[3]

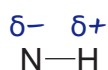


(b) (i) Define **electronegativity**.

The extent to which an atom attracts the bonding electrons in a covalent bond.

[1]

(ii) Show the polarity of the N—H bond below, using partial charges.



[1]

(iii) Predict which of the compounds, ethane or methylamine, has the higher boiling point. Explain the difference in boiling points between these two compounds.

Methylamine has the higher boiling point.

There are permanent dipole-dipole attractions (hydrogen bonds) between methylamine molecules, which are much stronger than van der Waals' forces.

There are only weak van der Waals' forces between ethane molecules, so less energy is needed to separate them.

[3]

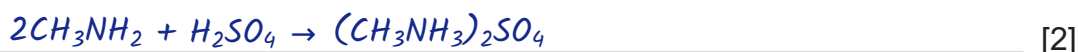
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(c) Methylamine is a weak base and a solution of methylamine reacts with strong acids to form the methylammonium ion (CH_3NH_3^+).

(i) Write an equation for the reaction of methylamine with sulfuric acid to form methylammonium sulfate.



(ii) Explain, with reference to the type of bond formed, how a methylamine molecule forms a methylammonium ion.

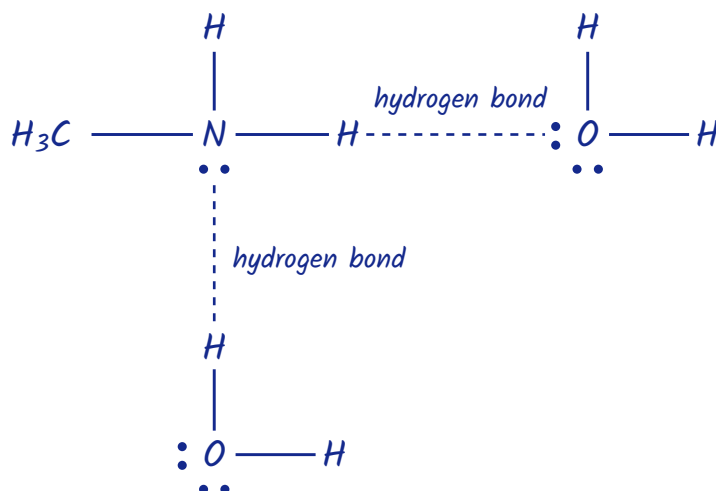
A co-ordinate (dative covalent) bond forms.

The nitrogen donates its lone pair to an H^+ ion, so both

electrons in the shared pair come from nitrogen.

[2]

(iii) Draw a diagram to show two hydrogen bonds which can form between one methylamine molecule and two water molecules. Show all lone pairs.



[2]





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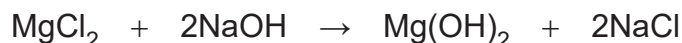
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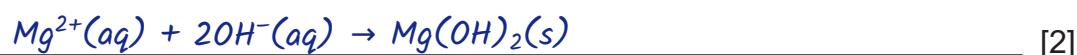


15 Sodium hydroxide solution is used in precipitation reactions and in titrations.

- (a) When a sample of 175 cm^3 of a 0.100 mol dm^{-3} solution of sodium hydroxide is added to 125 cm^3 of a 0.100 mol dm^{-3} solution of magnesium chloride, magnesium hydroxide forms as a white precipitate.



- (i) Write an ionic equation, including state symbols, for this reaction.



- (ii) Calculate the maximum mass of magnesium hydroxide which could form. Give your answer to 3 significant figures.

$$\text{moles NaOH} = 175 \times 0.100 \div 1000 = 0.0175 \text{ mol}$$

$$\text{moles MgCl}_2 = 125 \times 0.100 \div 1000 = 0.0125 \text{ mol}$$

$$0.0125 \text{ mol MgCl}_2 \text{ needs } 0.0250 \text{ mol NaOH, so NaOH is limiting}$$

$$\text{moles Mg(OH)}_2 = 0.0175 \div 2 = 0.00875 \text{ mol}$$

$$M_r \text{ Mg(OH)}_2 = 24 + 2(16 + 1) = 58$$

$$\text{mass Mg(OH)}_2 = 0.00875 \times 58 = 0.5075 \text{ g}$$

Answer 0.508 g [4]



- (b) In a titration, 25.0 cm^3 of sulfuric acid were titrated using 0.18 mol dm^{-3} sodium hydroxide solution. The table below shows the titration values obtained. The mean titre was calculated to be 21.2 cm^3 .

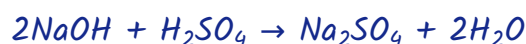
	Rough	Accurate 1	Accurate 2
Initial burette reading / cm^3	1.5	23.4	24.9
Final burette reading / cm^3	23.4	44.5	46.2
Titre / cm^3	21.9	21.1	21.3

- (i) Complete the table. [3]

- (ii) Calculate the concentration of the sulfuric acid in g dm^{-3} . Give your answer to an appropriate number of significant figures.

$$\text{mean titre} = (21.1 + 21.3) \div 2 = 21.2 \text{ cm}^3$$

$$\text{moles NaOH} = 21.2 \times 0.18 \div 1000 = 3.816 \times 10^{-3} \text{ mol}$$



$$\text{moles H}_2\text{SO}_4 = 3.816 \times 10^{-3} \div 2 = 1.908 \times 10^{-3} \text{ mol}$$

$$\text{conc} = 1.908 \times 10^{-3} \times 1000 \div 25.0 = 0.07632 \text{ mol dm}^{-3}$$

$$\text{conc} = 0.07632 \times 98 = 7.479 \text{ g dm}^{-3}$$

Answer 7.5 g dm^{-3} [4]

- (iii) Name a suitable indicator for this titration and state the colour change observed at the end point.

Indicator: phenolphthalein

Colour change: colourless to pink [2]

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Examiner Number

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