Section Three: Extended answer **30% (53 Marks)**

This section contains four (4) questions. You must answer all questions. Write your answers in the spaces provided.

Where questions require an explanation and/or description, marks are awarded for the relevant chemical content and also for coherence and clarity of expression.

Final answers to calculations should be expressed to the appropriate number of significant figures and include appropriate units where applicable.

Spare pages are included at the end of this booklet. They can be used for planning your responses and/or as additional space if required to continue an answer.

- Planning: If you use the spare pages for planning, indicate this clearly at the top of the page.
- Continuing an answer: If you need to use the space to continue an answer, indicate in the original answer space where the answer is continued, i.e. give the page number. Fill in the number of the question(s) that you are continuing to answer at the top of the page.

Suggested working time: 50 minutes

Question 32 **(11 marks)**

Consider the following pure substances:

Mg **S_8** **$Mg_3(PO_4)_2$**

(a) Describe a physical test to distinguish between magnesium (Mg) and magnesium phosphate ($Mg_3(PO_4)_2$), other than physical appearance. (3 marks)

Pure substances	Physical test	Observation
Magnesium Magnesium phosphate	• Test for electrical conductivity, use light globe, power pack etc or • hit with a hammer	Mg • Will conduct electricity - globe will light up. • Will bend $Mg_3(PO_4)_2$ • Will not conduct electricity, - globe does not light up • Crystal will shatter

(b) With reference to structure and bonding explain why magnesium phosphate is hard and brittle and sulfur is soft and powdery. (3 marks)

Magnesium phosphate is ionic, whilst Sulpur is covalent molecular.
$Mg_3(PO_4)_2$ is a 3-D lattice of oppositely charged ions held by strong forces of attraction, hence it is hard.
When force is applied, the layers of ions are displaced and like charges are alligned, causing repulsion and the ionic bond is disrupted. The crystal lattice shatters. Sulpur molecules are held by weak intermolecular forces allowing the molecules to move past one another making it soft.

(c) Complete the table below by stating the particles present and describing the physical appearance of each substance at room temperature. (3 marks)

substance	particles present	describe the physical appearance
Mg	Cations and delocalised electrons	Silver / grey Solid
S_8	Molecules	yellow powdery solid
$Mg_3(PO_4)_2$	Mg^{2+} and PO_4^{3-} ions	White Solid

(d) Magnesium phosphate can be produced by reacting phosphoric acid solution (H_3PO_4) with magnesium metal.Hydrogen gas is also produced. Write a balanced equation for this reaction. (2 marks)

$3Mg_{(s)} + 2H_3PO_{4(aq)} \longrightarrow Mg_3(PO_4)_{2(s)} + 3H_{2(g)}$

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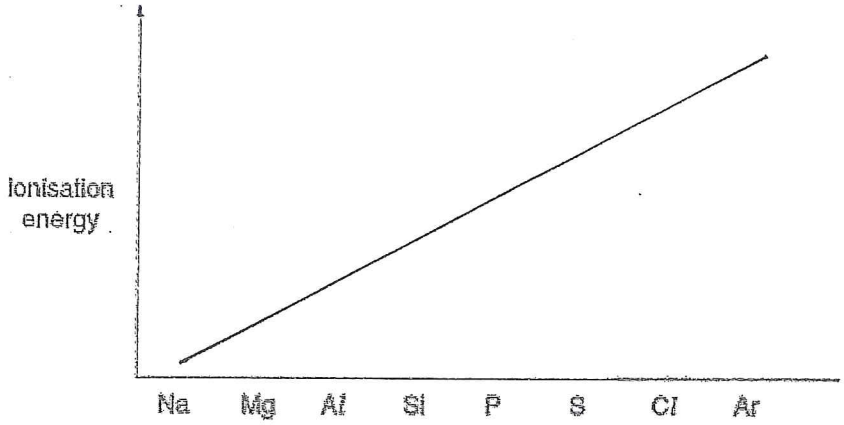
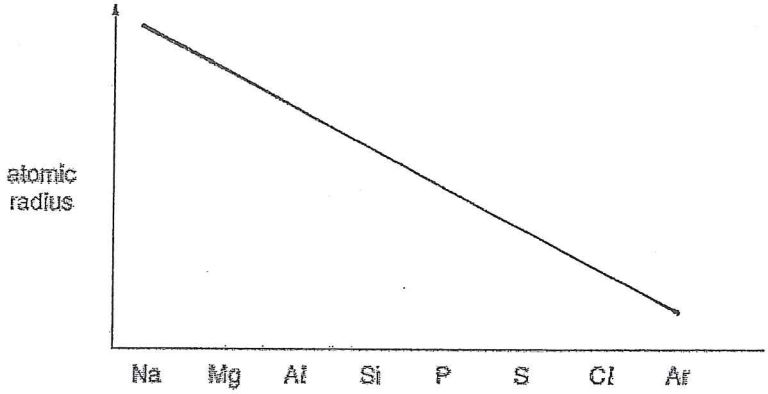
Question 33 **(14 marks)**

(a) Scientists often use sketch graphs to show trends. (2 marks)

(i) Draw a sketch graph to show the trend in **1st ionisation energy** across Period 3.



(ii) Draw a sketch graph to show the trend in **atomic radius** across Period 3.



(b) Explain the trend in atomic radius across Period 3 (2 marks)

Nuclear charge increases, shielding by inner e^- is constant ∴ greater force of attraction between nucleus + outer valence shell hence it is pulled closer to nucleus.

(c) Periodic table trends assist us in making predictions about the physical and chemical properties of elements. List the elements given in order from lowest to highest in relation to:

(i) Melting point **Na, Al, K**

lowest K, Na, Al highest (1 mark)

(ii) Chemical reactivity **At_2, F_2, Cl_2**

lowest At_2 Cl_2, F_2 highest (1 mark)

(d) Explain how the measurement of successive ionisation energies can assist in determining the electron configuration of an element. (2 marks)

Within a particular shell successive IE ↑ in a steady pattern. Big 'Jump' in IE indicates an e^- is removed from a shell closer to nucleus. By counting e^- up to, not including the big jump the number of e^- in each shell can be determined

(e) State and explain the trends in electronegativity across periods and down groups and discuss how the differences in electronegativity between reacting elements determines whether the substance formed is ionic or covalent. (6 marks)

Across a period - Electronegativity increases
• Atomic radius decreases, outer shell on average closer to nucleus, effective charge ↑, as shielding is constant and incoming e^- experiences a greater force of attraction.

Down a group - Electronegativity decreases
• Atomic radius increases, effective charge is constant as shielding offsets the increase in nuclear charge. There is a weaker force of attraction between incoming e^- and nucleus.

Elements with similar, high, electronegativities tend to form covalent bonds. ∴ covalent substances.

Elements with great differences in electronegativity will form ionic substances.

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Question 34 **(11 marks)**

Some rocks are found to contain silica (SiO_2) and calcium carbonate ($CaCO_3$). The percentage by mass of calcium carbonate in an 8.64 g sample of a particular rock was determined by crushing and mixing the sample with excess hydrochloric acid solution.

The equation for the reaction between calcium carbonate and hydrochloric acid is given below.

$$CaCO_3(s) + 2H^+(aq) \Rightarrow Ca^{2+}(aq) + H_2O(l) + CO_2(g)$$

The resulting solution was filtered and the residue (SiO_2) was washed and dried. The mass of SiO_2 recovered was 1.55 g.

(a) Using your knowledge of structure and bonding, suggest a reason why the silica does not react with hydrochloric acid solution. (1 mark)

SiO_2 is covalent network solid, strong covalent bonds extend throughout giant lattice, hence unreactive as hard to break these vast bonds.

(b) Why was **excess** hydrochloric acid added to the rock sample? (1 mark)

Ensure all the $CaCO_3$ has reacted completely.

(c) Calculate the % by mass of calcium carbonate in the rock sample. (2 marks)

$m(CaCO_3) = 8.64 - 1.55$
$= 7.09g$

$\% (CaCO_3) = \frac{7.09}{8.64} \times 100 = 82.1\%$

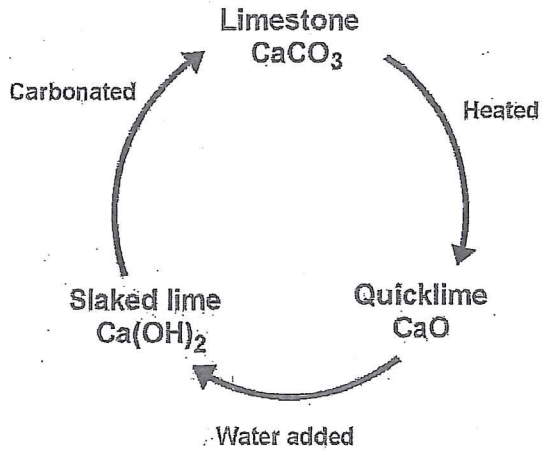
(d) The melting point of calcium carbonate is 825°C and of silica is 1600°C. With reference to structure and bonding explain the difference in the melting points of these two compounds. (3 marks)

Calcium carbonate is ionic, whereas silica has a covalent network structure
The ionic bond must be broken to melt Calcium carbonate, this is the electrostatic force of attraction between the cations and anions
In silica due to the huge network of very strong covalent bonds that need to be broken to melt the substance, this takes more energy and hence it melts at a higher temperature

Many of calcium carbonate's properties make it an extremely useful building material. It can be used in its natural form as limestone or marble.

It can be converted to calcium oxide (quicklime) or calcium hydroxide (slaked lime), as shown in the **Lime Cycle** at right.

Slaked lime (calcium hydroxide) can be used to manufacture mortar, plaster and cement.



(e) Mortar, plaster and cement are heterogeneous mixtures of slaked lime and sand and water. Explain the term "**heterogeneous**". (1 mark)

Non-uniform, variable in composition and properties

(f) Use the diagram of the Lime cycle to write a balanced equation to show how calcium carbonate is converted into quicklime (CaO) when heated to 900°C. (1 mark)

$CaCO_{3(s)} \longrightarrow CaO_{(s)} + CO_{2(g)}$

Slaked lime, calcium hydroxide, is dissolved in water to produce lime water, a solution of calcium hydroxide, which is used to test for carbon dioxide gas. Calcium hydroxide is soluble in water whereas calcium carbonate is insoluble.

(g) What type of bond must be broken in order to dissolve both of these compounds? (1 mark)

ionic bonds

(h) What can you infer about the strength of these bonds in calcium carbonate compared to calcium hydroxide? (1 mark)

Bonds in $CaCO_{3(s)}$ are stronger than in $Ca(OH)_{2(s)}$

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Question 35 **(17 marks)**

(a) Why are hydrocarbons used extensively as fuels? (1 mark)

(b) When planning an MLC adventure camp, two students decided to research which fuel would be most energy efficient (produce the most energy per mL) as this would reduce the total volume they would need to carry. Their results are given in the table below.

Fuel	Molar mass	Enthalpy of combustion ΔH	density at 20°C	Energy released per 15.0 mL of fuel
Pentane	72.15 g/mol	3450 $kJmol^{-1}$	0.626 g/mL	449 kJ
Octane	114.2 g/mol	5460 $kJmol^{-1}$	0.692 g/mL	

Note: (i) **enthalpy of combustion (ΔH)** is the heat released in the burning of the fuel per mole of the compound

(ii) **density** = $\frac{\text{mass}}{\text{volume}}$

(c) One student, being an expert at chemical calculations quickly calculated that 15.0 mL of pentane could produce a maximum of 449 kJ of energy. However, another student needs your help to determine the maximum energy that could be released from 15.0 mL of octane.
Fill in the missing energy released for octane in the last column in the table and show your calculation below. (3 marks)

m (octane) = density × volume = 0.692 × 15
= 10.38 g

n (octane) = $\frac{m}{M}$ = $\frac{10.38}{114.2}$ = 0.09039 mols

Energy released = n × 5460
= 496 kJ

(d) Write a balanced equation for the burning of liquid octane in a plentiful supply of oxygen. (2 marks)

$2\,C_8H_{18(l)} + 25O_{2(g)} \rightarrow 16CO_{2(g)} + 18H_2O_{(g)}$

(e) In the reaction between octane and oxygen gas, 7.50L of liquid octane is reacted in excess air. What volume of carbon dioxide gas is produced at STP? (4 marks)

m(octane) = 7500 × 0.692 = 5190 g

n(octane) = $\frac{m}{M}$ = $\frac{5190}{114.2}$ = 45.45

n(CO_2) = $\frac{16}{2}$ × n(octane) = 363.572 mols

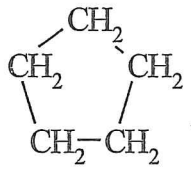
V(CO_2) = n · 22.71 = 8.26×10^3 L

(f) Most reactions are not carried out at STP conditions but at higher temperatures, often at room temperature of approximately 25°C. If the combustion reaction was carried out at room temperature, how would this affect the volume of gas produced, assuming that the atmospheric pressure remains constant? Explain. (2 marks)

Volume of CO_2 would be greater
As temperature increases, average KE increases and gas expands, moving with greater velocity. (ASSUMING NOT IN FIXED CONTAINER)

(g) Two isomers of C_6H_{12} have the following structures.

A



B

$CH_2{=}CH{-}CH_2{-}CH_2{-}CH_3$

Both are colourless liquids. Describe a chemical test that could be used to distinguish between the two compounds. (3 marks)

Test	Observations
Add Br_2 (aq) Shake test tube In absence of U.V light	isomer A: Orange colour remains
	Isomer B: Orange solution Immediately decolourises

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(h) Give the equation, showing structural formula, for the distinguishing reaction described. (2 marks)

$CH_2=CH-CH_2-CH_2-CH_3 + Br_2 \longrightarrow CH_2Br-CHBr-CH_2CH_2CH_3$

END OF QUESTIONS