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DUNMAN HIGH SCHOOL

Preliminary Examination 2014

Year 6

H2 CHEMISTRY

Paper 2 Structured

9647/02

16 September 2014

2 hours

Additional Materials: Data Booklet

INSTRUCTIONS TO CANDIDATES

- 1 Write your **name**, **index number** and **class** on this cover page.
- 2 Answer **all** questions.
- 3 Write your answers in the spaces provided on the question paper.
- 4 A *Data Booklet* is provided.
- 5 The number of marks is given in brackets [] at the end of each question or part question.
- 6 You may use a calculator.

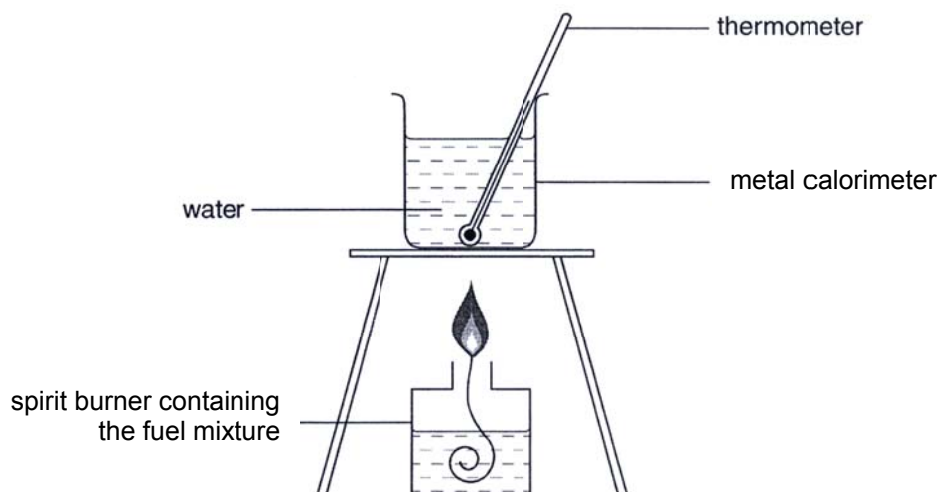
Question No.	1	2	3	4	5	6	Total	%
Marks	12	9	15	9	12	15	[72]	

This question paper consists of **15** printed pages and **1** blank page.

Answer **all** questions in the spaces provided.

1 Planning (P)

A student was provided with a spirit burner containing a 'fuel mixture' which was prepared by mixing equimolar amounts of pentane and ethanol. The enthalpy change of combustion of this 'fuel mixture' is -11.8 kJ per mole of 'fuel mixture'. He was told to use the enthalpy change of combustion of this 'fuel mixture' to find the heat capacity of a metal calorimeter using the apparatus shown below. Heat capacity is defined as the number of joules of heat needed to raise the temperature of the calorimeter by one Kelvin or one degree Celsius.



Additional information:

1. Specific capacity of water is $4.2 \text{ J g}^{-1} \text{ K}^{-1}$.
2. The maximum capacity of the metal calorimeter is between 100 to 150 cm^3 .
3. A temperature rise of 5°C is considered to be significant for this experiment.

- (a) Construct a balanced equation for the complete combustion of the 'fuel mixture' with state symbols.

[1]

- (b) Identify one possible source of error and suggest an improvement to overcome this error in the experiment.

Error

.....

Improvement

.....

[2]

- (c) Calculate the minimum mass of the fuel mixture required to bring about a 5°C temperature rise.

[2]

- (d) Write a plan to determine the heat capacity of the metal calorimeter using the apparatus provided.

In your plan you should give details of the procedure (number your steps) and provide a table to record the readings to be taken, including the units. Details about the appropriate mass of water and fuel used, and temperature rise should also be included. You do not need to describe the preparation of the fuel mixture.

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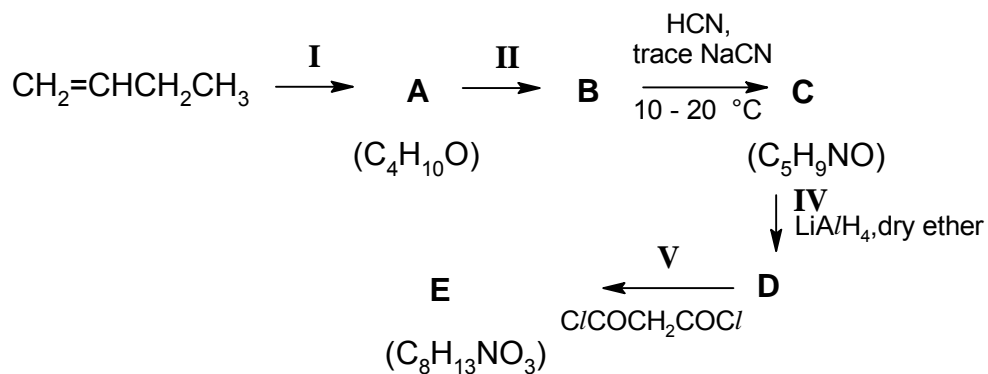
Table:

[4]

- (e) Show how you would calculate, from your above proposed plan and experimental results, the heat capacity of the metal calorimeter.

[3]
[Total: 12]

- 2 But-1-ene can be converted to compound **E** via the following series of reactions.



Both compounds **A** and **B** produce a yellow precipitate on warming separately with aqueous alkaline iodine.

- (a) Iodine undergoes a disproportionation reaction with hot dilute NaOH(aq). Describe what is observed and write a balanced equation for the reaction.

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[1]

- (b) State the reagents and conditions for steps **I** and **II**.

Step **I**:

Step **II**:

[2]

- (c) In the boxes below, draw the structural formulae of compounds **A**, **B**, **D** and **E**.

A	B
D	E

[4]

- (d) Explain why the reaction in Step **III** produces an equimolar mixture of two stereoisomers of compound **C**.

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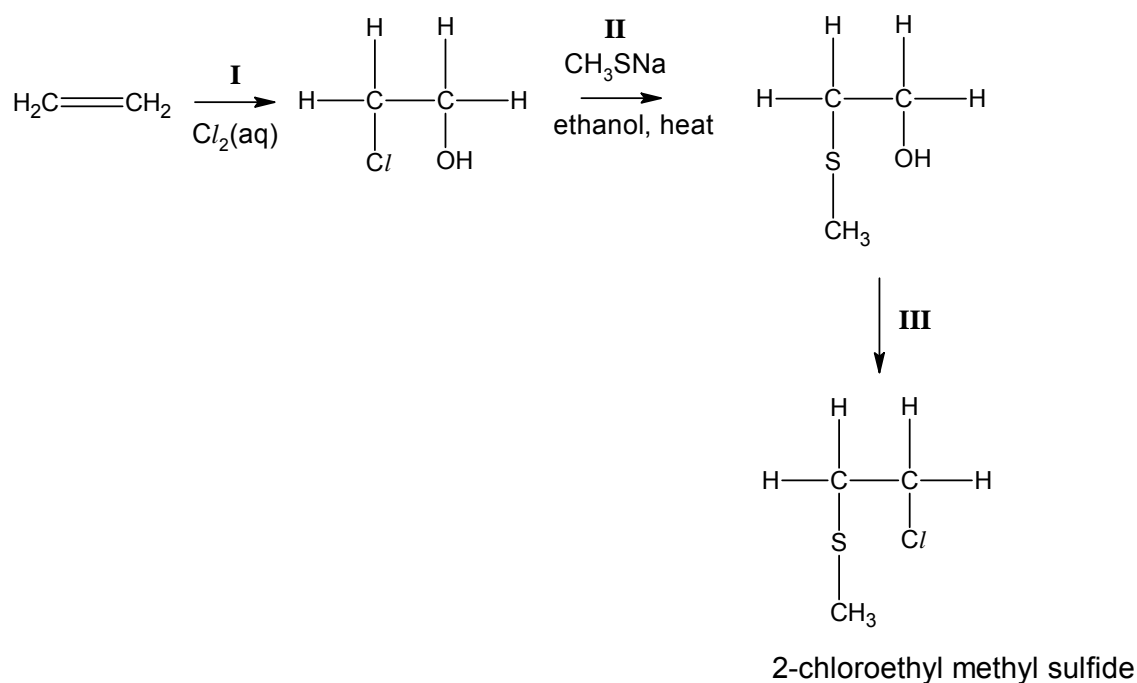
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[2]

[Total: 9]

- 3 2-chloroethyl methyl sulfide may be synthesised from ethane.



- (a) Describe a simple chemical test to distinguish between $\text{CH}_3\text{SCH}_2\text{CH}_2\text{OH}$ and $\text{CH}_3\text{SCH}_2\text{CH}_2\text{Cl}$, of the reaction in Step **III**, stating the expected observation for each compound.

Test:

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Observation:

.....

[2]

- (b) The kinetics of the reaction in Step II was studied.

The experimental results are given in the table below.

Run	$[\text{CH}_3\text{SNa}] / \text{mol dm}^{-3}$	$[\text{CH}_2\text{C/CH}_2\text{OH}] / \text{mol dm}^{-3}$	Relative rate / min^{-1}
1	0.100	0.150	6
2	0.150	0.150	9
3	0.200	0.200	16

Use the data to determine the order of reaction with respect to both CH_3SNa and $\text{CH}_2\text{C/CH}_2\text{OH}$.

Hence, write a rate equation for the reaction and state the units for the rate constant.

Order of reaction with respect to CH_3SNa :

Order of reaction with respect to $\text{CH}_2\text{C/CH}_2\text{OH}$:

Rate equation:

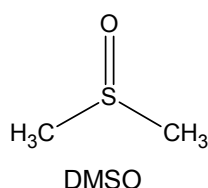
Units for rate constant:

[4]

- (c) In organic syntheses, the choice of solvent can affect the rate of a reaction. Ethanol is the solvent of choice in Step II above.

The process of forming ion-dipole interactions between ions and solvent molecules is called solvation. Polar protic solvents such as ethanol, contains at least one hydrogen atom directly bonded to an electronegative atom. These solvents solvate both cations and anions. It is known that the concentration of ions is inversely proportional to the degree of solvation of the ions involved.

Polar aprotic solvents contain no hydrogen atom directly bonded to an electronegative atom. These solvents solvate cations well, but not anions. Dimethyl sulfoxide (DMSO) is an example of a polar aprotic solvent.



- (i) State the ion which acts as the nucleophile in the reaction in Step II.

Nucleophile:

- (ii) Suggest why DMSO does not solvate anions effectively.

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- (iii) With reference to your answers in (b) and (c)(ii), explain why the rate of reaction is 1000 times faster when the reaction in Step II is carried out in DMSO instead of ethanol.

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[5]

- (d) Sodium methanethiolate, used in Step II, CH_3SNa , can be made from methanethiol, CH_3SH .

Although methanethiol is structurally similar to methanol, the two compounds have significant different $\text{p}K_{\text{a}}$ values at 298 K.

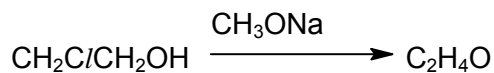
compound	formula	$\text{p}K_{\text{a}}$
methanol	CH_3OH	15.5
methanethiol	CH_3SH	10.4

Explain briefly why methanethiol has a smaller $\text{p}K_{\text{a}}$ value than methanol.

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[2]

(e) $\text{CH}_2\text{Cl}/\text{CH}_2\text{OH}$ reacts with CH_3ONa to give compound **W**, $\text{C}_2\text{H}_4\text{O}$.



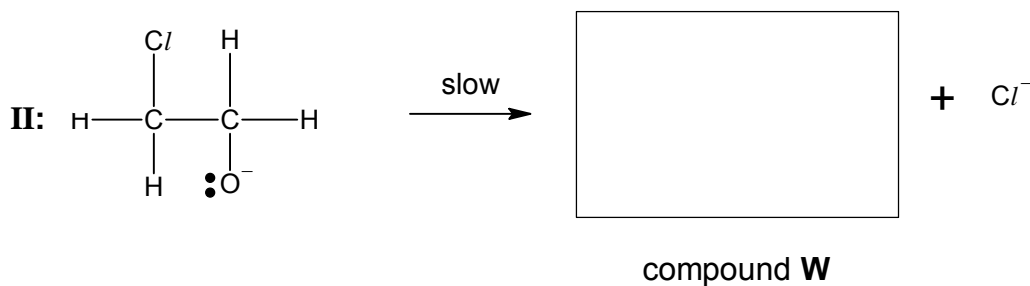
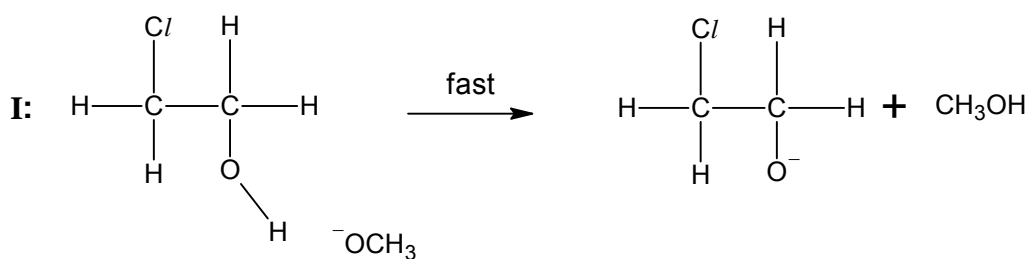
The reaction between CH_3ONa and $\text{CH}_2\text{Cl}/\text{CH}_2\text{OH}$ occurs in two steps.

The first step involves an acid-base reaction.

The second step involves an intramolecular reaction and it is rate determining.

In each step below,

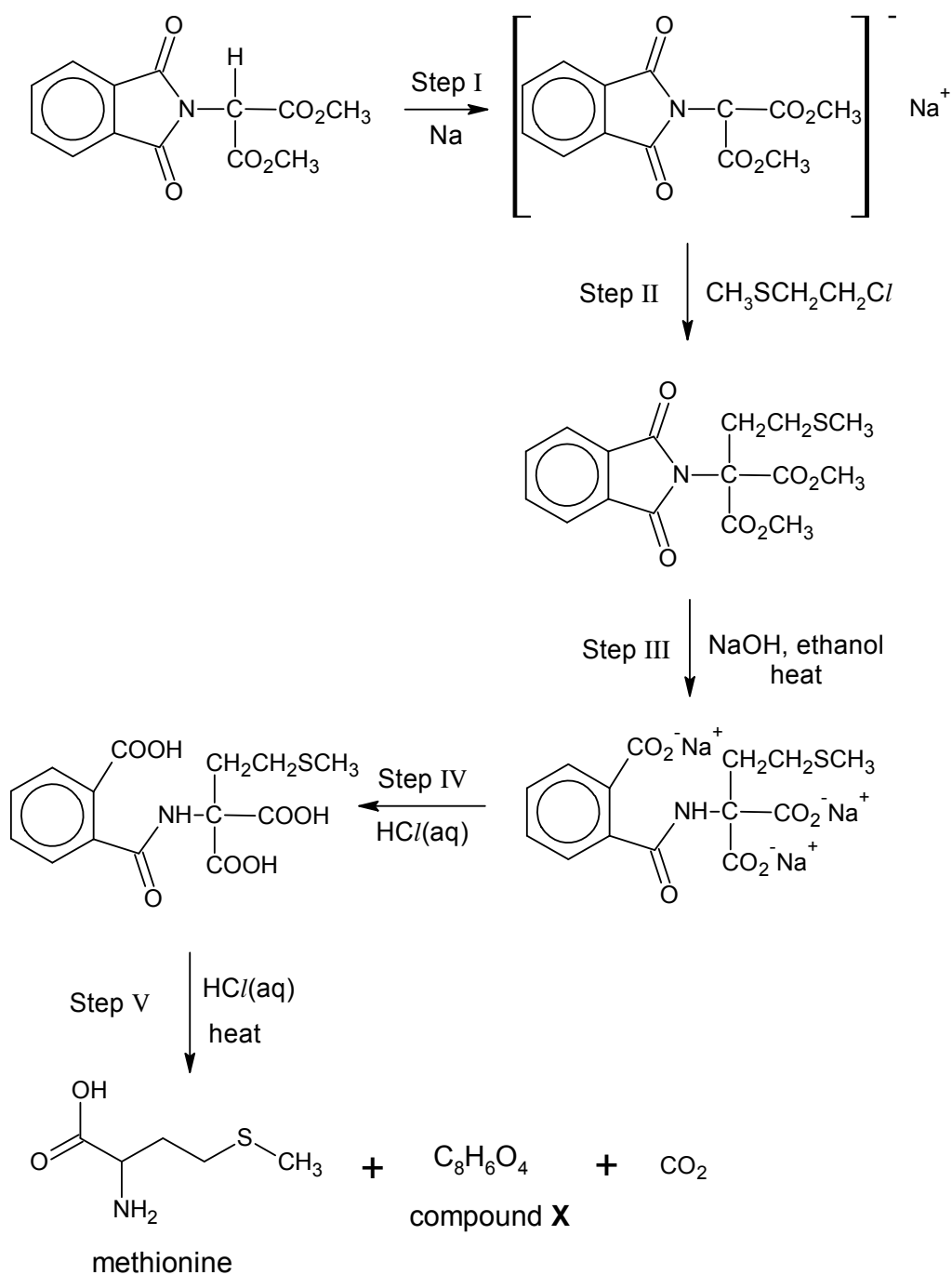
- label the partial charges and lone pair of electrons on the reacting species, $\text{CH}_2\text{Cl}/\text{CH}_2\text{OH}$ and $\text{CH}_2\text{Cl}/\text{CH}_2\text{O}^-$.
- draw curly arrows to show the flow of electrons during the reaction.
- draw the **displayed** formula of compound **W**.



[2]
[Total: 15]

- 4 Sulfur compounds can be used in the synthesis of organic compounds. Methionine is an α -amino acid which is essential to humans and is also used by plants to synthesise ethane.

(a) In the 1930s, Barger and Weichselbaum reported the synthesis of methionine using the sodium salt of ethyl phthalimidomalonate and 2-chloroethyl methyl sulfide.



(i) What type of reaction are steps I and III?

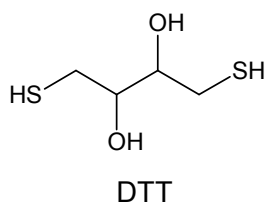
Step I:

Step III:

- (ii) Compound **X**, $C_8H_6O_4$, obtained as a by-product in Step V, is sparingly soluble in water. 1 mol of **X** reacts with exactly 1 mol of sodium carbonate. Give the structure of compound **X**.

[3]

- (b) Dithiothreitol (DTT) is used in biochemical laboratories to maintain *tertiary* proteins. The structure of DTT is shown below.



- (i) Suggest two suitable R group interactions between DTT and an amino acid side chain of a tertiary protein.

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- (ii) Predict the number of optical isomers for DTT which results in optical activity and explain why DTT has this number of optical isomers.

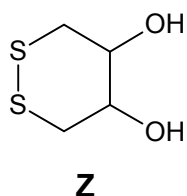
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- (iii) DTT can be used to form **Z**.



Suggest the type of reaction for the conversion of DTT to **Z** and state the type of stereoisomerism exhibited by **Z**. Name a natural α -amino acid that is able to undergo such a reaction.

Type of reaction:

Type of stereoisomerism:

Amino acid:

[6]

[Total: 9]

- 5 Phosphorus is able to form various compounds with halogens such as chlorine. An example of a compound formed between phosphorus and chlorine is phosphorus trichloride. At 373 K, both phosphorus trichloride and chlorine exist as gases.

- (a) State one assumption in the kinetic theory of gases that causes the deviation of a real gas from ideal behaviour.

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[1]

- (b) Predict with reasons, which of the two gases will deviate more from ideality.

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[2]

- (c) Phosphorus trichloride can react with water to form 2 compounds, a phosphorus based compound and a **non**-phosphorus based compound.

- (i) Write a balanced equation for the reaction between phosphorus trichloride and water.

- (ii) Describe what happens when aqueous silver nitrate is added to aqueous solution of the **non**-phosphorus based compound. Write balanced equation(s) for the reaction, if any.

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[2]

(d) Phosphorus triiodide is frequently used in organic synthesis and can be prepared by addition of iodine to phosphorus in carbon disulfide. Alternatively, phosphorus triiodide can be formed by reacting phosphorus trichloride with hydrogen iodide.

(i) Write a balanced equation for the preparation of phosphorus triiodide.

(ii) State the physical state and colour of iodine under room conditions.

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(iii) Write the electronic configuration of iodine-131 using the noble gas core configuration and state the number of protons and neutrons in iodine-131.

(iv) Explain, with the aid of balanced equations, why low yield of hydrogen iodide will be obtained when concentrated sulfuric acid is reacted with solid sodium iodide.

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[7]
 [Total: 12]

6 This question is about periodic trends that can be observed in the Periodic Table and thermal stability of Group II elements. The thermal decomposition of Group II carbonates can be investigated by heating the respective carbonates and recording the total volume of carbon dioxide evolved.

(a) (i) Write an equation to represent the thermal decomposition of calcium carbonate.

(ii) How and why does the magnitude of the lattice energy of calcium carbonate differ from its residue after it has been formed from decomposition?

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- (iii) Given that the decomposition of MgCO_3 is an endothermic process, predict and explain the sign of ΔG for the reaction at high temperatures.

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- (iv) A 4.19 g sample of a carbonate of a Group II metal, **X**, lost 1.25 g in mass when heated strongly. Identify metal **X**.

[8]

- (b) Beryllium, in Period 2, is the only element in Group II that shares very similar chemical properties with aluminium which is in Period 3.

(i) Write the balanced equation for the reaction of BeO with dilute HCl(aq) .

- (ii) Describe what happens if dilute NaOH(aq) is slowly added to the solution in (i) until in excess.

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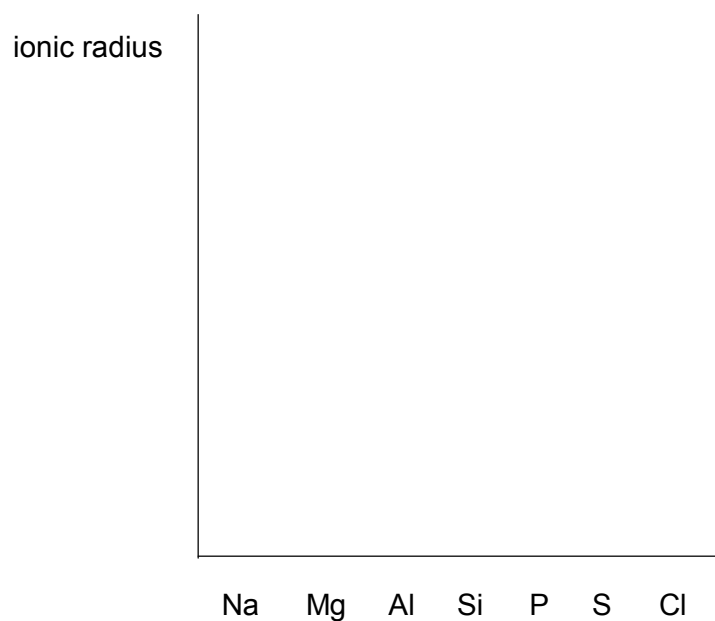
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[3]

- (c) (i) Sketch the ionic radius of the elements in Period 3 on the axes provided.



- (ii) Explain the shape of the sketch.

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[4]
[Total: 15]

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