NATIONAL JUNIOR COLLEGE
SH1 PROMOTIONAL EXAMINATION
Higher 1

CANDIDATE NAME

SUBJECT CLASS

REGISTRATION NUMBER

CHEMISTRY

8873/02

Paper 2 Structured Questions

Mon 1 October 2018

Additional Materials: Data Booklet
Writing Papers

1.5 hours

READ THE INSTRUCTIONS FIRST

Write your subject class, registration number and name on all the work you hand in. Write in dark blue or black pen on both sides of the paper.

You may use a soft pencil for any diagrams, graphs or rough working.

Do not use paper clips, highlighters, glue or correction fluid.

Answer **all** questions in **Section A** **(40 marks)** in the space provided on the Question paper.

Answer **one** question in **Section B** **(20 marks)** on the writing paper provided separately.

The use of an approved calculator is expected, where appropriate.

A Data Booklet is provided.

At the end of the examination, fasten all your work securely together.

The number of marks is given in brackets [ ] at the end of each question or part question.

Appropriate significant figures and units are expected for final numerical answers

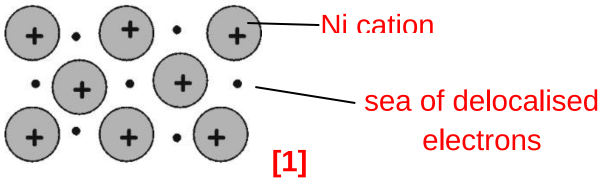
For Examiner's Use	
1	/ 8
2	/ 7
3	/ 7
4	/ 9
5	/ 9
6	/20
Paper 2	/ 60
Paper 1	/ 20
Overall Total	/ 80
Overall percentage	/ 100

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

1 **(a)** The element nickel was discovered in 1751 by Swedish chemist A. F. Cronstedt.

(i) Nickel is a transition metal.
Describe the bonding in the element nickel. You should draw a labelled diagram to illustrate your answer.

Metallic bonding is present in nickel, which is the **electrostatic attraction between** (positive) **nickel ions** and its **delocalised** (or a sea of) **electrons**. **[1]**



[1]

[2]

(ii) State **two** physical properties that you would expect nickel metal to possess. Explain, in terms of the bonding present, why it possesses these properties.

property **Good electrical conductivity** **[1/2]**
explanation **delocalised sea of electrons are mobile electrons that can act as charge carriers**. **[1]**

property **high melting/boiling point** **[1/2]**

explanation **strong** electrostatic force of attraction between positive metal ions and sea of delocalised electrons requiring a **large amount of energy** to break. **[1]**

[3]

(b) A common battery is the nickel-cadmium cell. It has one electrode of cadmium and one electrode of nickel (III) hydroxide, $Ni(OH)_3$. The two electrodes are connected using an electrolyte.

The two half-equations for this cell are:

$$Cd(OH)_2 + 2e^- \rightleftharpoons Cd + 2OH^-$$
$$Ni(OH)_3 + e^- \rightleftharpoons Ni(OH)_2 + OH^-$$

(i) Combine these two half-equations to show the above overall reaction.

$Cd + 2\ Ni(OH)_3 \rightarrow Cd(OH)_2 + 2Ni(OH)_2$

....[1]

(ii) Using your equation in **(b)(i)**, identify the species that have been reduced and oxidised respectively.

$Ni(OH)_3$

Species reduced: ....

Cd

Species oxidised: .... [2]

[Total: 8]

2 Sulfur is a common element on Earth that forms many important chemical compounds.

The table below shows the melting point of sulfur and some of its compounds.

Compound	**Melting point / °C**
Sulfur, S_8	115
Sodium thiosulfate, $Na_2S_2O_3$	49
Sodium sulfide, Na_2S	117

(a) Draw the dot-and-cross diagram of sodium sulfide, Na_2S.

[1] Na+

[1] S^{2-}

[2]

(b) By considering the bonding and structure, explain why sulfur has a higher melting point than sodium thiosulfate.

(i) **Sodium thiosulfate** has **giant ionic structure [1/2]** and **sulfur** has **simple covalent structure [1/2].**

The **large electron cloud size** in sulfur molecule leads to **stronger [1/2] instantaneous dipole-induced dipole interactions between molecules [1/2]** which require **more energy [1/2]** to overcome compared to **ionic bonds** in **sodium thiosulfate [1/2]**.

....

....

....

....

.... [3]

(ii) How would you expect the magnitude of the lattice energy of Na_2S to compare with that of $Na_2S_2O_3$? Explain your answer.

$$|L.E| \propto \frac{q_+ \times q_-}{r_+ + r_-}$$

Both compounds have the **same product of charges** but **interionic distance for Na_2S is smaller than that of $Na_2S_2O_3$ [1].** Magnitude of LE of **Na_2S is larger [1].**

Minus 0.5m for missing LE equation

…………………………………………………………………………………………...

…………………………………………………………………………………………...

…………………………………………………………………………………………...

…………………………………………………………………………………………...

………………………………………………………………………………………..... [2]

[Total: 7]

3 The following reaction scheme shows how compound **A**, $CH_3CHC\mathit{l}CH_2CH_3$ could be formed and converted to other useful organic products.

$$CH_3CH_2CH_2CH_3 \xrightarrow{\textbf{I}} \underset{\textbf{A}}{CH_3CHC\mathit{l}CH_2CH_3} \xrightarrow{\textbf{II}} \underset{\textbf{B}}{CH_3CH{=}CHCH_3}$$

(a) Give the name for compound **A**.
2-chlorobutane
……………………………………………………… [1]

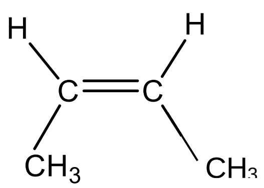
(b) Suggest the reagents and conditions for step **I** and **II**.
I: (limited) $C\mathit{l}_2$, uv
…………………………………………………………………………………………………
II: NaOH, ethanol, heat
…………………………………………………………………………………………………[2]

(c) Suggest the type of reaction for step **II**.
Elimination
…………………………………………………………………………………………………[1]

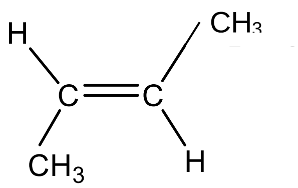
(d) Write a balanced equation for the reaction **B** with hydrogen.
$CH_3CH{=}CHCH_3 + H_2 \rightarrow CH_3CH_2CH_2CH_3$

…………………………………………………………………………………………………[1]

(e) Compound **B** exhibits cis-trans isomerism. Draw and name the isomers.
Draw and name “cis-isomer” [1]
Draw and name “trans-isomer” [1]



cis-isomer



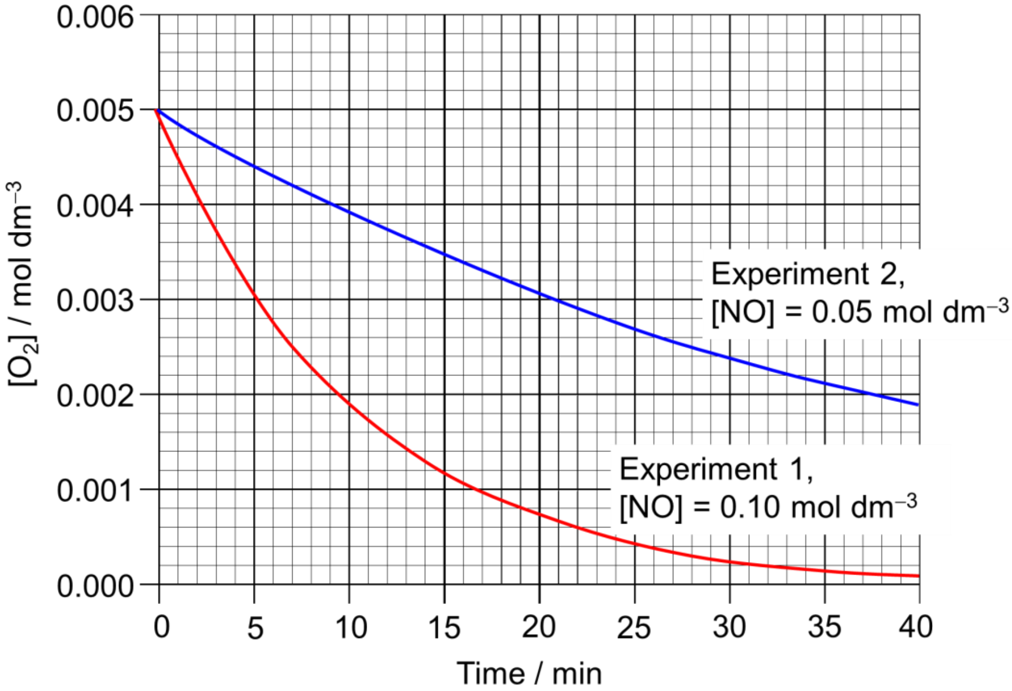
trans-isomer

[2]
[Total: 7]

4 Nitrogen monoxide reacts with oxygen gas according to the equation:

$$2NO(g) + O_2(g) \rightarrow 2NO_2(g)$$

An experiment is performed to determine the order of reaction with respect to nitrogen monoxide and oxygen. The concentration of oxygen used for both experiments is 0.005 mol dm$^{-3.}$ The results are as follows.



(a) Using the graphs above, determine the order of reaction with respect to O_2 and NO, showing your workings clearly.

When [NO] = 0.1 mol dm^{-3}, $t_1 = t_2 \approx$ **7 min**. The **half-lives** of O_2 are approximately **constant**. Order of reaction wrt O_2 is **1**. **[1]**

OR
When [NO] = 0.05 mol dm^{-3}, $t_1 = t_2 \approx$**28 min**. The **half-lives** of O_2 are approximately **constant**. Order of reaction wrt O_2 is **1**. **[1]**

When [NO] doubles, half-life decreases by 4 times. Rate increases by 4 times. Order of reaction wrt NO is **2**. **[1]**

OR Can solve by drawing tangent at t=0 to find initial rate for both graphs.

[2]

(b) Write a rate equation for the reaction.
Rate=k[O_2][NO]^2
……………………………………………………………………………………….[1]

(b) Calculate the initial rate of reaction for **Experiment 1**. ~~Hence, calculate the rate constant, including its units.~~
Draw a suitable tangent at t=0 for expt 1. [1]
Accept tangent range 4.17 x 10^{-4} to 5.56 x 10^{-4}

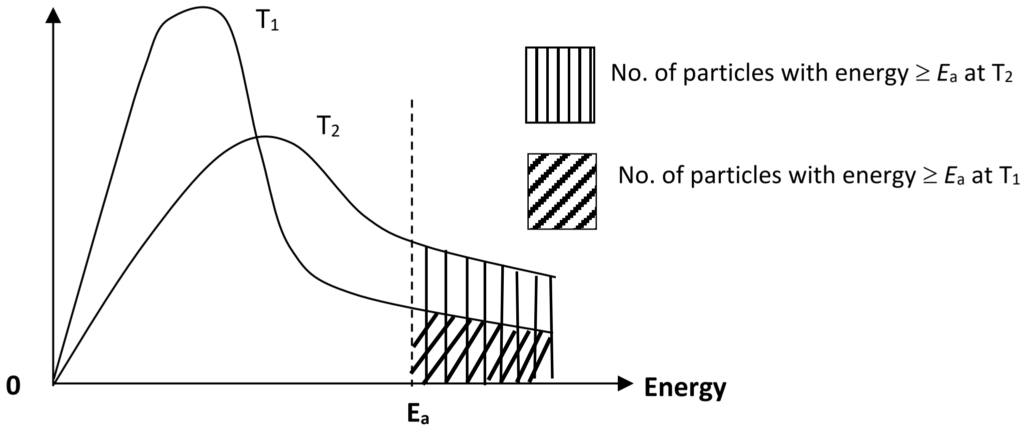
~~4.56 x 10^{-4} = k(0.1)^2(0.005)~~
~~k = 9.12 mol^{-2} dm^6 min^{-1} **[1] calculate k, [1] units of k**~~

[3]

(d) With the aid of a Maxwell-Boltzmann distribution curve, explain how the rate of reaction will be affected if the reaction was carried out at a higher temperature.

[1] diagram

Fraction of particles $T_2 > T_1$



As **temperature increase**s, the overall **kinetic energy** of the reactant particles **increases**. There are **more particles possessing energy ≥ activation energy. Frequency of effective collisions** between molecules **increases. [1]**

Hence **rate** of reaction **increases. [1]**

[3]
[Total: 9]

5 Instant cold packs are convenient replacements for ice used as first aid on injuries. They usually consist of two bags; an inner bag containing water placed inside a bag containing an ionic salt. When the instant cold pack is squeezed hard enough, the bag containing the water breaks. The ionic salt dissolves in the water in an endothermic process. For the instant ice pack to be effective, the overall temperature of the cold pack must decrease by at least 7.00 °C.

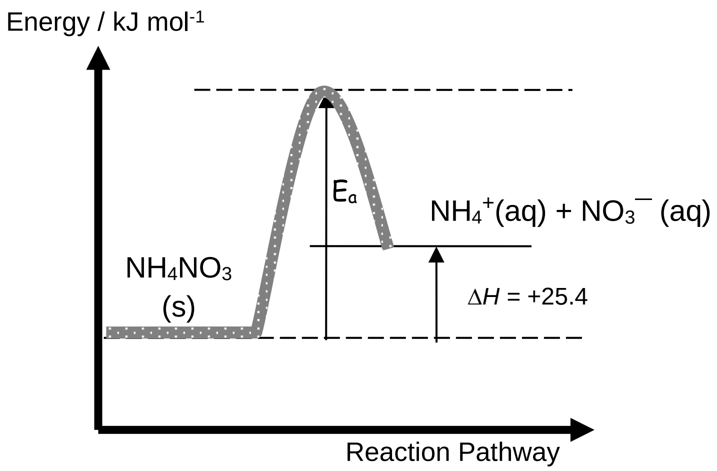
Company Z has been researching on the cost effectiveness of using either solid ammonium nitrate, NH_4NO_3, or solid ammonium chloride, NH_4Cl, as the ionic salt in its instant cold packs containing 100 cm^3 of water. It has been found that 25.4 kJ of energy is absorbed when 1 mol of solid NH_4NO_3 is fully dissolved in water at standard conditions according to the following reaction.

$$NH_4NO_3(s) \rightarrow NH_4^+(aq) + NO_3^-(aq)$$

The prices and molar masses of both ionic salts are listed in the table below.

Ionic Salt	Molar mass / g mol^{-1}	Cost of 1000 g of salt / $
NH_4NO_3	80.0	22.50
NH_4Cl	53.5	13.90

(a) Draw a fully labelled reaction pathway diagram for the dissolution of solid NH_4NO_3 in water under standard conditions.



[1] Label axes, reactant and products
[1] Label E_a and $\Delta H = +25.4$

[2]

(b) Calculate the minimum mass of solid NH_4NO_3 that company Z would need to add to the outer bag to make one effective cold pack. The specific heat capacity of water is 4.18 J g^{-1} K^{-1}.

Heat absorbed = mcΔT = 100 x 4.18 x 7 = 2926 J **[1]**
Minimum amount of NH_4NO_3 required = 2926 / (25.4 x 1000) = 0.1152 mol **[1] ecf from heat**
Minimum mass of NH_4NO_3 required = 0.1152 **x 80.0** = 9.22 g **[1] ecf from amt NH_4NO_3**

[3]

(c) It was found that at least 10.6 g of NH_4Cl was required to make one effective cold pack. Calculate the respective minimum costs of NH_4NO_3 and NH_4Cl required to make one instant cold pack of each type, leaving your answers to 2 decimal places. Hence, state which cold pack is more cost-effective.

Minimum cost of NH_4NO_3 to make 1 cold pack = 22.50 x 9.22 / 1000 = $0.21
Minimum cost of NH_4Cl to make 1 cold pack = 13.90 x 10.6 / 1000 = $0.15
[1] for both

The cold pack containing NH_4Cl is more cost-effective. **[1]**

[2]

(d) In recent times, most companies no longer use NH_4NO_3 in instant cold packs. The use of NH_4NO_3 poses a safety risk as it is readily decomposed when heated to release a great amount of heat and gases according to the following equation.

$$NH_4NO_3\ (s) \rightarrow N_2\ (g) + 2H_2O\ (l) + \frac{1}{2}\ O_2\ (g)$$

Calculate the volume of gaseous products formed at room temperature and pressure when 0.200 mol of ammonium nitrate was decomposed.

Amount of N_2 + 1/2 O_2 = 0.200 x (1+0.5) = 0.300 mol **[1]**
Volume of gaseous products = 0.300 x 24 = 7.20 dm^3 **[1] ecf**

[2]
[Total: 9]

Section B

Answer this section on separate answer paper.

6 **(a)** Hydrogen is used in large quantities in industry to convert nitrogen into ammonia, for use in fertilizers. One method of manufacturing hydrogen is to pass methane and steam over a heated nickel catalyst.

$$CH_4\,(g) + H_2O\,(g) \longrightarrow CO\,(g) + 3H_2\,(g) \qquad \Delta H_1 = +\,206 \text{ kJ mol}^{-1}$$

(i) Using the value of ΔH_1 above and the bond energy values from *Data Booklet*, calculate the total bond energy in the carbon monoxide molecule. [3]

Let the bond energy in the carbon monoxide be y kJ mol^{-1}.

Bonds broken	*No. of moles*	*Energy absorbed*
C–H	*4*	*4 X 410*
O–H	*2*	*2 X 460*

Bonds formed	*No. of moles*	*Energy released*
C≡O	*1*	*1 X y*
H–H	*3*	*3 X 436*

Enthalpy change of reaction = + 206

Σ B.E. (bonds broken) - Σ B.E. (bonds formed) = + 206

4(410) + 2(460) – [y + 3(436)] = 206

y = +1046 kJ mol^{-1}

[1] correct bonds broken
[1] correct bonds formed

Bond energy for C≡O = **1.05 x 10^{3} kJ mol^{-1} [1]**

(ii) Use the following data to calculate the enthalpy change of combustion of hydrogen gas.

$\Delta H_c\,[CO(g)] = -\,283$ kJ mol^{-1}

$\Delta H_c\,[CH_4(g)] = -\,891$ kJ mol^{-1}

[2]

$$\Delta H_r = \sum n\Delta H_c^\theta \text{ (reactants)} - \sum m\Delta H_c^\theta \text{ (products)}$$

$206 = -891 - [\,(-283) + 3\,\Delta H_c(H_2)\,]$ [1]

$\Delta H_c(H_2) = -$ **271 kJ mol^{-1}** [1]

(iii) By considering the VSEPR theory and the number of lone pairs and bond pairs, explain the difference in bond angles for CH_4 and H_2O. [3]

Since there are **4 bond pairs and 0 lone pair** on C of a methane molecule, the bond angle in methane is **109.5º**.

[1 for correct number of lp+bp+ bond angle for methane]

In a water molecule, there are **2 bond pairs and 2 lone pairs** on O. Since the **lone pair – lone pair repulsion > lone pair – bond pair repulsion > bond pair – bond pair repulsion [1]**, the bond angle in water is reduced to **104.5°**

[1 for correct number of lp+bp+ bond angle for water]

(b) Copper(II) hydroxide, a blue-green solid, is a popular colour pigment used in ceramics and paintings. Copper(II) hydroxide can be produced by adding aqueous sodium hydroxide to aqueous solution of copper(II) sulfate as shown in the following equation:

$$CuSO_4\,(aq) + 2\,NaOH\,(aq) \rightarrow Cu(OH)_2\,(s) + Na_2SO_4\,(aq)$$

50.0 cm^3 of 0.100 mol dm^{-3} sodium hydroxide solution is added to 25.0 cm^3 copper(II) sulfate solution of unknown concentration. The resulting solution is filtered to remove the solid copper(II) hydroxide.

The filtrate requires 12.50 cm^3 of 0.100 mol dm^{-3} hydrochloric acid for complete neutralisation.

(i) Calculate the amount, in moles of copper(II) sulfate solution. [2]

Amt. of excess NaOH = amt of HCl = $\frac{12.50}{1000} \times 0.100$ = 1.250 x 10^{-3} mol **[1/2]**

Amt. of NaOH initially = $\frac{50.0}{1000} \times 0.100$ = 5.000 x 10^{-3} mol **[1/2]**

Amt. of NaOH reacted with $CuSO_4$ = (5.000-1.250) x 10^{-3}
= 3.750 x 10^{-3} mol **[1/2]**

Amt. of $CuSO_4$ = $\frac{1}{2} \times 3.750 \times 10^{-3}$ = 1.875 x 10^{-3} mol **[1/2] ecf from amt NaOH**

(ii) Hence, determine the concentration of the copper(II) sulfate solution. [1]

Concentration of $CuSO_4$ = $\frac{1.875 \times 10^{-3}}{25.0 \times 10^{-3}}$ = 0.0750 mol dm^{-3} **[1] ecf**

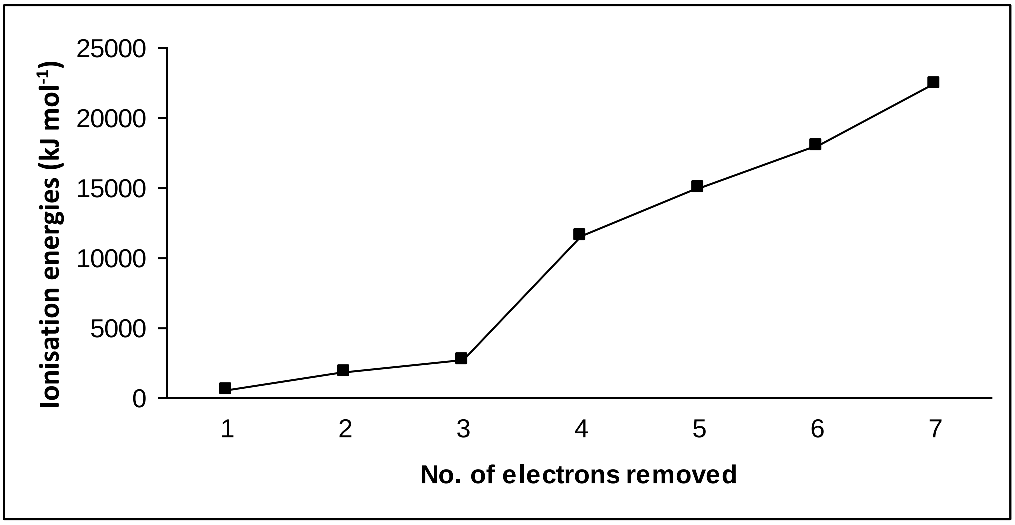
(iii) 0.16 g of copper (II) hydroxide was produced in the above reaction. Calculate the percentage yield of the reaction. [2]

Amt. of $Cu(OH)_2$ = Amt. of $CuSO_4$ = 1.875 x 10^{-3} mol
Theoretical mass of $Cu(OH)_2$ = 1.875 x 10^{-3} x (63.5 + 2 x 16.0 + 2 x 1.0)
= 0.1828 g **[1]**

Percentage yield = $\frac{0.16}{0.1828} \times 100\%$ = 87.5 % **[1]**

* Allow e.c.f from part **(i)**

(c) The graph below shows the successive ionisation energies of an element **X** in period 3.



(i) From the graph above, deduce the group number in which this element **X** belongs to. Explain a reason for the deduction. [2]

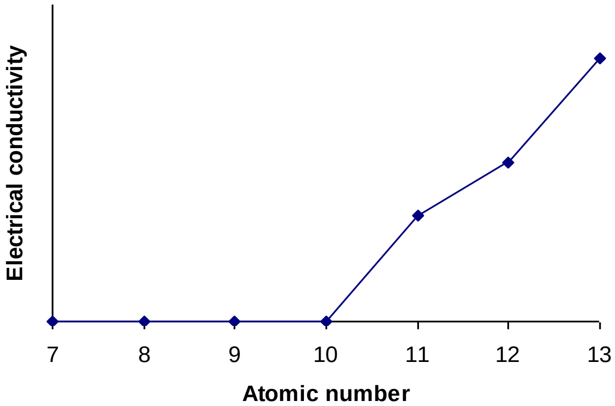
There is a **drastic increase in IE** between the 3rd IE and 4th IE. Hence, the 1st 3 electrons are removed from the outermost shell while the **4th electron is removed from the inner quantum shell**. **[1]**

This shows that X has 3 valence electrons and so, belongs to **Group 13 [1]** in the Periodic Table.

(ii) Deduce the electronic configuration of this element **X**. [1]

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

(d) **(i)** The following graph shows the trend of electrical conductivity for elements in Periods 2 and 3 in their standard states. Explain the observed trend. [2]



From N_2 to Ne, the **electrical conductivity** is **zero** as simple covalent molecules/atoms **do not have charge carriers**. **[1]**

From Na to A*l*, the **electrical conductivity increases** as the **number of delocalised electrons increases**. **[1]**

(ii) Describe and explain the trend in the ionic radius for the elements with atomic number 7 to 13. [2]

The ionic radius **decreases** from N^{3-} to Al^{3+}. **[1]**

The ions are **isoelectronic** with the same number of electrons. **[½]** There are **increasing** number of **protons** **[½]** attracting the same number of electrons.