Class	Register Number	Name

南洋女子中學校

Nanyang Girls' High School

A

End-of-Year Examination 2021
Secondary 3

IP CHEMISTRY
Paper 2

1hour 45 minutes

Wednesday 6 October **0845 – 1030**

READ THESE INSTRUCTIONS FIRST

Write your name, register number and class in the spaces at the top of this page.
Write in dark blue or black pen.
You may use a pencil for any diagrams or graphs.
Do not use staples, paper clips, glue or correction fluid / tape.

Section A
Answer all questions in the spaces provided.

You are advised to spend no longer than 1 hour on **Section A**, and no longer than 45 minutes on **Section B**.

The number of marks is given in brackets [ ] at the end of each question or part question.
A copy of the Periodic Table is on page **12**.

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

Section A (40 marks)	
Section B (30 marks)	
Total (70 marks)	

This document consists of **12** printed pages and **0** blank pages.

Section A (40 marks)

Answer **all** questions.
Write your answers in the spaces provided.

A1 Group 17 elements show trends in their melting points and boiling points.

Table 1

element	melting point/°C	boiling point/ °C
chlorine	–101	–35
bromine	–7	59
iodine	114	184

(a) The change in temperature against time graph for bromine is represented in **Figure 1**.

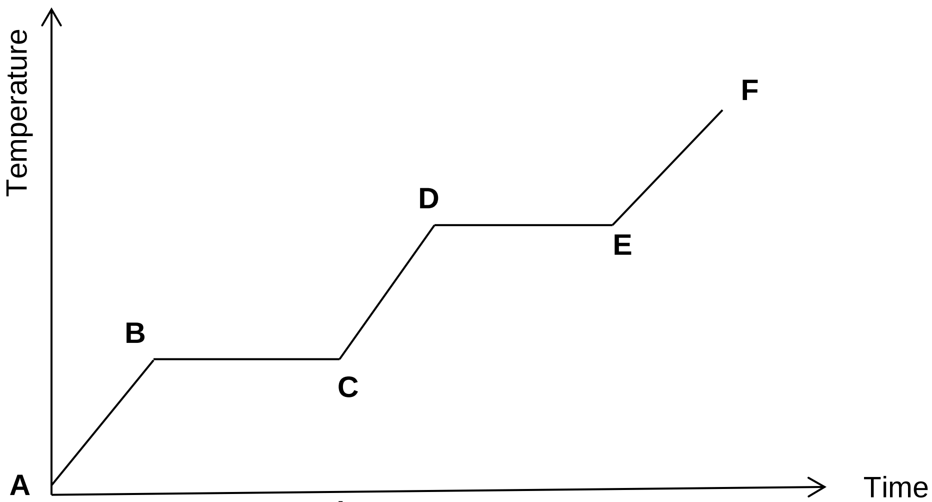


Figure 1

(i) State the process occurring at point **D**–**E**. Hence, explain why temperature remained unchanged.

....

....

....

.... [3]

(ii) Describe the arrangement and movement of the particles at point **A**.

....

....

....

.... [2]

(b) Describe and explain the trend in boiling point down the group 17 elements.

....

....

....

.... [3]

Total [8]

A2 The radii of atoms and ions can be measured.

Table 2 shows information about atomic radii and ionic radii of some of the group 1 elements.

Table 2

element	number of protons	electronic configuration of atom	atomic radius/pm	electronic configuration of +1 ion	ionic radius/pm
lithium	3	2.1	152	2	68
sodium	11	2.8.1	185		98
potassium	19	2.8.8.1	227		133

(1 000 000 000 000pm = 1m)

(a) Complete the table to show the electronic configuration in the **ions** of Group 1. [1]

(b) **(i)** Describe and explain the trend in atomic radii down Group 1.

....

....

....

....

.... [3]

(ii) Describe and explain the change in the radius when a lithium atom forms a lithium ion.

....

....

.... [2]

(c) **(i)** The group 1 elements react with water vigorously. Write an equation to illustrate the reaction between lithium and water. State symbols are not required.

.... [1]

(ii) Using the data for atomic radius given in Table 2, suggest the relationship between reactivity and atomic radii of the Group 1 elements.

....

....

....

.... [2]

Total [9]

A3 When aqueous ammonia is added to an aqueous solution of an aluminium salt, a precipitate is formed as an amorphous gelatinous mass. When dried, this precipitate forms a white crystalline compound called boehmite, consisting of A*l*, O and H atoms.

A 100g sample of boehmite was found to contain 53.3g of oxygen atoms and 1.7g of hydrogen atoms have the following composition by mass: A*l*, 45.0%; O, 53.3%; H, 1.7%.

(a) Calculate the mass of aluminium atoms present in the sample.

[1]

(b) **(i)** Show, with calculations, that the empirical formula of boehmite is AlO_2H.

[2]

(ii) The formation of boehmite from aluminium ions and hydroxide produces water as a by-product.

Write a balanced ionic equation, with state symbols, for the formation of boehmite and its by-products from aluminium ions and hydroxide ions.

.... [2]

(c) Aluminium metal can be found in metal ores which may also contain zinc impurities.

The reaction of a sample of these ores with nitric acid results in the formation of a solution containing these metal **ions.**

Describe a test and the results that can be used to distinguish between the two ions in a solution.

Test: ....

Observation for Al^{3+}: ....

....

Observation for Zn^{2+}: ....

....

[3]

(d) Metallic aluminium is very reactive with atmospheric oxygen to form a thin layer of aluminium oxide, Al_2O_3, which is resistant to corrosion.

In the space below, draw the "dot and cross" diagram of aluminium oxide.

[2]

Total [10]

A4 25.0 cm^3 of diluted hydrogen peroxide solution**,** **FA2**, completely reacts with 22.50 cm^3 of 0.0200 mol dm^{-3} acidified potassium manganate(VII) solution.

The ionic equation for the reaction is given below.

$$2MnO_4^- (aq) + 5H_2O_2 (aq) + 6H^+ (aq) \rightarrow 2Mn^{2+} (aq) + 5O_2 (g) + 8H_2O (l)$$

(a) Calculate the number of moles of manganate ions, MnO_4^- required to react with 25.0 cm^3 of diluted H_2O_2, **FA2**.

[1]

(b) Calculate the number of moles of H_2O_2 present in 25.0 cm^3 of **FA2**.

[1]

(c) Hence, calculate the number of moles of H_2O_2 present in 500 cm^3 of **FA2**.

[1]

(d) **FA2** solution is prepared by diluting **FA1** which contains hydrogen peroxide, H_2O_2, of an unknown concentration.

12.50 cm^3 of **FA1** was diluted to a final total volume of 500 cm^3 with distilled water to prepare **FA2.**

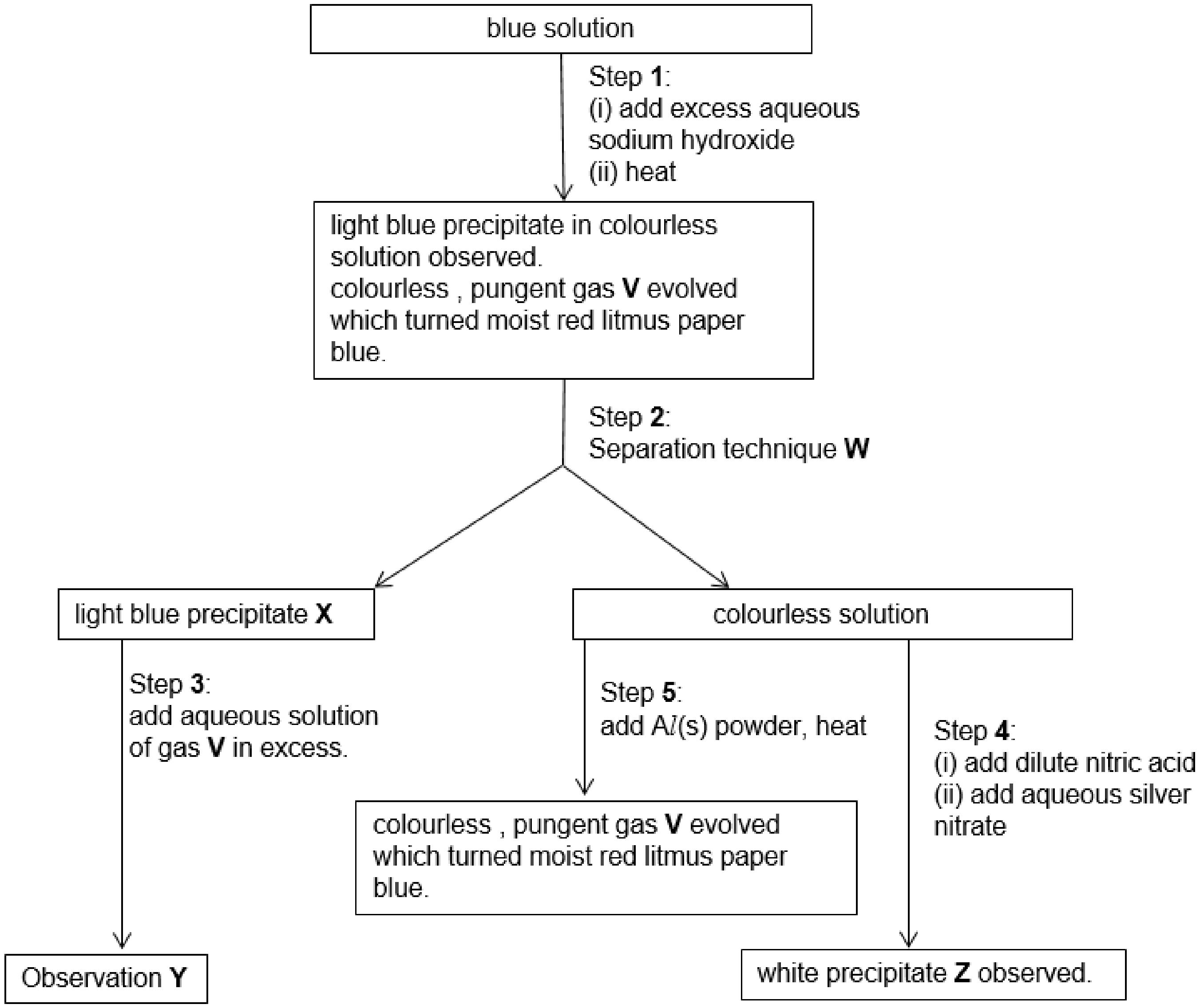
Given that the number of moles of H_2O_2 present in 500 cm^3 of **FA2** is equivalent to the number of moles in 12.5 cm^3 of H_2O_2 in **FA1,** calculate the concentration of H_2O_2 in **FA1**.

[1]

Total [4]

A5 Some tests were carried on a blue solution that contains 2 unknown cations and 2 anions.

The flowchart below shows the tests conducted on the solution.



(a) **(i)** Identify the following:

gas **V** ....

separation technique **W** ....

precipitate **X** .... [3]

(ii) Describe observation **Y**.

.... [1]

(iii) Hence, deduce the identities of the two **cations** present in the mixture.

.... [2]

(b) **(i)** Explain why it is necessary to add nitric acid in step **4**.

.... [1]

(ii) Deduce the identities of the **anions** present in the mixture.

.... [2]

Total [9]

End of Section A

The Periodic Table of Elements

Key: atomic number
atomic symbol
name
relative atomic mass

Group 1	2											13	14	15	16	17	18
							1 H hydrogen 1.0										2 He helium 4.0
3 Li lithium 6.9	4 Be beryllium 9.0											5 B boron 10.8	6 C carbon 12.0	7 N nitrogen 14.0	8 O oxygen 16.0	9 F fluorine 19.0	10 Ne neon 20.2
11 Na sodium 23.0	12 Mg magnesium 24.3	3	4	5	6	7	8	9	10	11	12	13 Al aluminium 27.0	14 Si silicon 28.1	15 P phosphorus 31.0	16 S sulfur 32.1	17 Cl chlorine 35.5	18 Ar argon 39.9
19 K potassium 39.1	20 Ca calcium 40.1	21 Sc scandium 45.0	22 Ti titanium 47.9	23 V vanadium 50.9	24 Cr chromium 52.0	25 Mn manganese 54.9	26 Fe iron 55.8	27 Co cobalt 58.9	28 Ni nickel 58.7	29 Cu copper 63.5	30 Zn zinc 65.4	31 Ga gallium 69.7	32 Ge germanium 72.6	33 As arsenic 74.9	34 Se selenium 79.0	35 Br bromine 79.9	36 Kr krypton 83.8
37 Rb rubidium 85.5	38 Sr strontium 87.6	39 Y yttrium 88.9	40 Zr zirconium 91.2	41 Nb niobium 92.9	42 Mo molybdenum 95.9	43 Tc technetium –	44 Ru ruthenium 101.1	45 Rh rhodium 102.9	46 Pd palladium 106.4	47 Ag silver 107.9	48 Cd cadmium 112.4	49 In indium 114.8	50 Sn tin 118.7	51 Sb antimony 121.8	52 Te tellurium 127.6	53 I iodine 126.9	54 Xe xenon 131.3
55 Cs caesium 132.9	56 Ba barium 137.3	57–71 lanthanoids	72 Hf hafnium 178.5	73 Ta tantalum 180.9	74 W tungsten 183.8	75 Re rhenium 186.2	76 Os osmium 190.2	77 Ir iridium 192.2	78 Pt platinum 195.1	79 Au gold 197.0	80 Hg mercury 200.6	81 Tl thallium 204.4	82 Pb lead 207.2	83 Bi bismuth 209.0	84 Po polonium –	85 At astatine –	86 Rn radon –
87 Fr francium –	88 Ra radium –	89–103 actinoids	104 Rf rutherfordium –	105 Db dubnium –	106 Sg seaborgium –	107 Bh bohrium –	108 Hs hassium –	109 Mt meitnerium –	110 Ds darmstadtium –	111 Rg roentgenium –	112 Cn copernicium –		114 Fl flerovium –		116 Lv livermorium –		

lanthanoids	57 La lanthanum 138.9	58 Ce cerium 140.1	59 Pr praseodymium 140.9	60 Nd neodymium 144.2	61 Pm promethium –	62 Sm samarium 150.4	63 Eu europium 152.0	64 Gd gadolinium 157.3	65 Tb terbium 158.9	66 Dy dysprosium 162.5	67 Ho holmium 164.9	68 Er erbium 167.3	69 Tm thulium 168.9	70 Yb ytterbium 173.1	71 Lu lutetium 175.0
actinoids	89 Ac actinium –	90 Th thorium 232.0	91 Pa protactinium 231.0	92 U uranium 238.0	93 Np neptunium –	94 Pu plutonium –	95 Am americium –	96 Cm curium –	97 Bk berkelium –	98 Cf californium –	99 Es einsteinium –	100 Fm fermium –	101 Md mendelevium –	102 No nobelium –	103 Lr lawrencium –

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Section B
Answer all questions in the spaces provided.

The last question, **B8** is in the form of an **EITHER/ OR** and only one of the alternatives should be attempted.

The number of marks is given in brackets [ ] at the end of each question or part question.
A copy of the Periodic Table is on page **23**.

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

Indicate the question attempted for **B8** with a tick (✓).	
Either ☐	**Or** ☐

Section B (30 marks)	

This document consists of **11** printed pages and **1** blank page.

Section B (30 marks)

Answer all **three** questions from this section in the spaces provided.

The last question is in the form of either/or and only **one** of the alternatives should be attempted.

B6 A solution of hydrochloric acid was made by dissolving 18 g of the acid in 1 dm^3 of distilled water. The acid was then heated before being reacted with an impure sample of aluminium oxide weighing 5 g.

$$Al_2O_3(s) + 6HCl(aq) \rightarrow 2AlCl_3(aq) + 3H_2O(l)$$

25.0 cm^3 of the cooled resulting mixture was then pipetted into a conical flask. The contents of the conical flask were titrated against 0.250 mol dm^{-3} aqueous potassium hydroxide.

The results of the titration are shown in the table below.

titration number	1	2	3
final burette reading / cm^3	22.50	25.10	24.30
initial burette reading / cm^3	0.10	2.40	1.50
volume of KOH(aq) used / cm^3	22.40	22.70	22.80

(a) **(i)** Using the best titration results, calculate the number of moles of potassium hydroxide used for the titration. [1]

(ii) Calculate the concentration of hydrochloric acid present in the cooled resulting mixture that reacted with potassium hydroxide. [2]

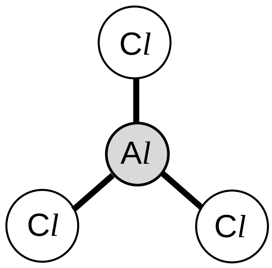
(iii) Assuming that the volume of the cooled resulting mixture was 1 dm^3, calculate the number of moles of hydrochloric acid that reacted with the aluminium oxide. [2]

(iv) Determine the percentage purity of the impure sample of aluminium oxide used. [3]

(v) State one assumption that must be made about the impurities present in aluminium oxide. [1]

....

(b) The structure of aluminium chloride is shown below.



Suggest what is unusual about the structure of aluminium chloride. [1]

....

....

....

Total [10]

B7 The general equation for a monobasic acid, H**A**, is shown below.
H**A** represents the acid molecule and **A**$^-$ represents the anion of the acid.

$$HA \rightleftharpoons H^+ + A^-$$

The ionisation of carbonic acid, H_2CO_3, a weak dibasic acid, occurs in two steps as shown below.

	equation
step 1	$H_2CO_3 \rightleftharpoons H^+ + HCO_3^-$
step 2	**(a)(ii)**:

(a) **(i)** Define *dibasic acid*. [1]

....

....

(ii) Given that each step produces one hydrogen ion at a time, suggest the equation for *step 2* involving the partial ionisation of HCO_3^- in the table above. [1]

(iii) Different acids have varying degrees of ionisation. The measure of the degree of ionisation can be determined by the acid dissociation constant, K_a, which is expressed as

$$\mathbf{K_a = \frac{[H^+][A^-]}{[HA]}}$$

where the brackets [ ] represent "concentration of" the species found within the brackets in mol dm^{-3}.

The K_a values of H_2CO_3 compared to H_2SO_4 are shown below.

acid	K_a
H_2CO_3	4.3×10^{-7}
H_2SO_4	1.0×10^{3}

Describe the relationship between K_a value and the strength of an acid.
Explain your answer with respect to the concentration of hydrogen ions. [2]

....

....

....

....

(iv) Write an expression for K_a for *step 1* of H_2CO_3. [1]

(v) The concentrations of H_2CO_3 and HCO_3^- were 1.50 mol dm^{-3} and 0.750 mol dm^{-3} respectively.

Calculate the concentration of H^+ ions present at this point using the expression in **(iv)**. Show your working clearly. [1]

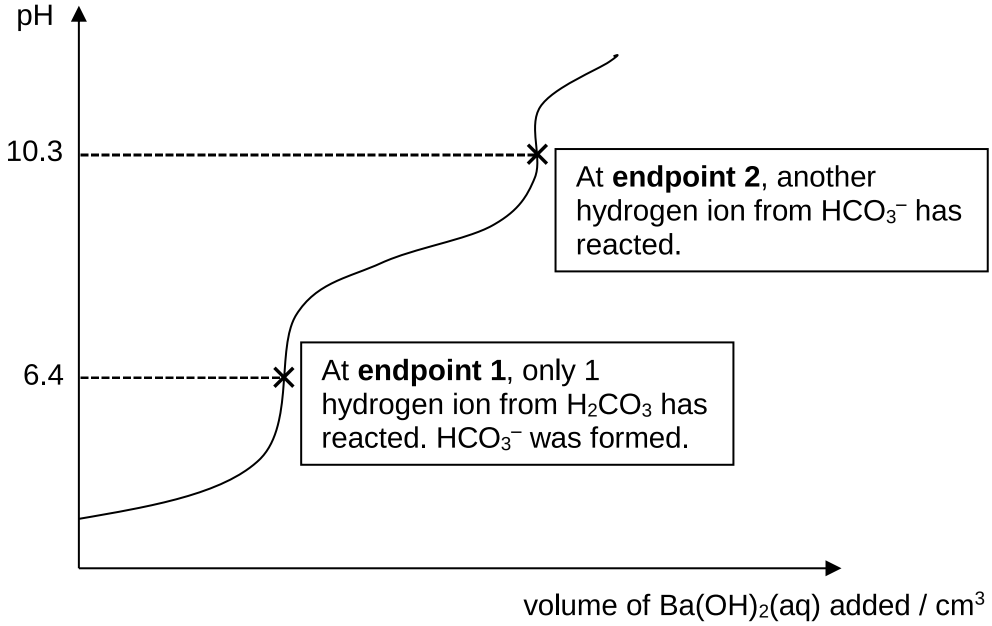
concentration of H^+ ions = ………………………………. mol dm^{-3}

(b) In an experiment, a conical flask containing a fixed volume of carbonic acid was titrated against a known concentration of aqueous barium hydroxide.

(i) Write the overall chemical equation for the reaction between carbonic acid and aqueous barium hydroxide. State symbols are not required. [1]

(ii) With reference to your equation in **(b)(i)**, state what you would observe in the conical flask as the titration proceeds. [1]

(iii) A graph of pH against volume of aqueous barium hydroxide added was generated below using a pH meter.



The table below shows some pH indicators and the pH range at which a gradual colour change is seen.

pH indicator	pH range at which a gradual colour change is seen
bromothymol blue	6.0 – 7.6
methyl orange	3.1 – 4.4
thymolphthalein	9.3 – 10.5
trinitrobenzene	12.0 – 13.4

State the most suitable pH indicator needed to give an accurate titration volume of barium hydroxide required for the **complete neutralisation** of H_2CO_3, when a pH meter is not used.

Explain your answer. [2]

....

....

....

....

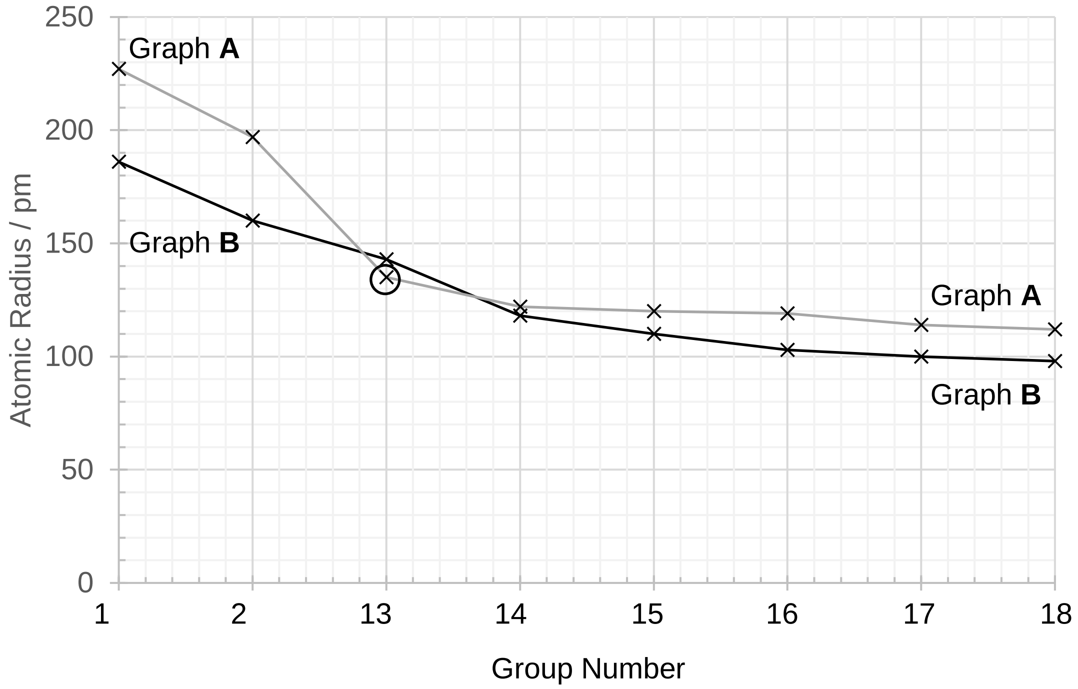
....

Total [10]

EITHER

B8 The atomic radius of an atom is a measure of the size of the atom. It is generally stated as being the total distance from an atom's nucleus to its valence electrons.

The graphs below compares the atomic radii of elements across Periods 3 and 4.



(a) **(i)** Suggest which period the elements in Graph **B** belong to. [1]

....

(ii) The atomic radius of one of the elements produced an anomalous point that was circled in Graph **A**.

Write the electronic configuration, in spdf notation, of an atom of this element. [1]

....

(b) Describe and explain the general trend of atomic radii of the elements moving across a period from left to right. [4]

(c) The melting points of two elements belonging to Period 3, silicon and chlorine, are shown in the table below.

	melting point / °C
silicon	1410
chlorine	–100

With reference to their structure and bonding, explain the difference in melting points between silicon and chlorine. [4]

Total [10]

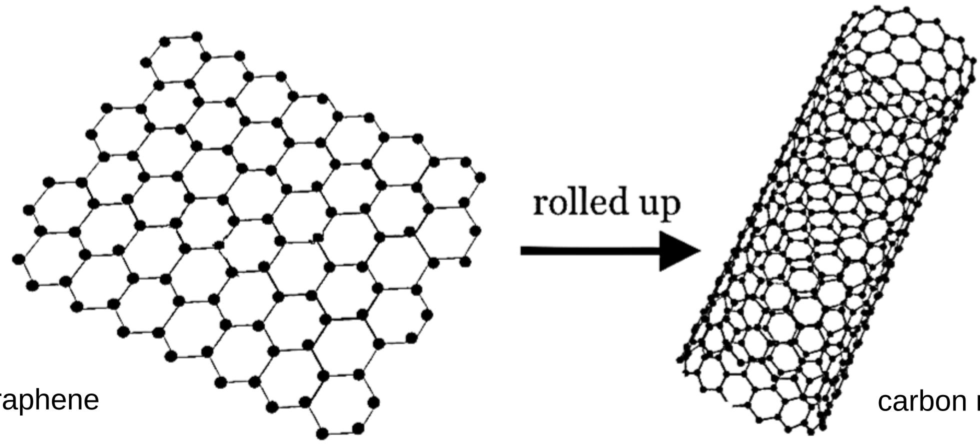
OR

B8 The relative electrical conductivities of some metals in Period 4 of the Periodic Table are shown below.

metal	relative electrical conductivity	metal	relative electrical conductivity
potassium	0.143	cobalt	0.160
calcium	0.218	nickel	0.145
iron	0.100	copper	0.593

From the table above, most metals are reasonably good electrical conductors.
Copper has the highest electrical conductivity amongst the metals in Period 4. Due to copper's high electrical conductivity, it is most commonly used in electrical wiring and making electrical circuits.

An alternative conducting material is the carbon nanotube, which is an allotrope of carbon. The simplest carbon nanotube is formed by rolling up a sheet of a honeycomb network of carbon atoms (graphene) seamlessly into a tubular form as shown below.



graphene

carbon nanotube

Carbon nanotubes are one of the lightest and strongest known materials in the world, with excellent heat and electrical conductivity abilities.

(a) **(i)** Write the electronic configuration, in spdf notation, of an atom of copper. [1]

....

(ii) Describe, with the aid of a well-labelled diagram in the box below, the structure and bonding of metals. [2]

....

....

(iii) Other than having good electrical conductivity, state another property of transition metals like iron, cobalt, nickel and copper. [1]

....

(iv) State the purpose of transition metals like iron in the production of ammonia via the Haber Process. [1]

....

(b) By stating the number of valence electrons, suggest a reason for the difference in electrical conductivity between potassium and calcium metal. [2]

....

....

....

(c) With reference to its bonding, explain how carbon nanotubes are able to conduct electricity. [3]

....

....

....

....

....

....

Total [10]

END OF PAPER

The Periodic Table of Elements

Key

atomic number atomic symbol name relative atomic mass

Group																	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
							1 H hydrogen 1.0										2 He helium 4.0
3 Li lithium 6.9	4 Be beryllium 9.0											5 B boron 10.8	6 C carbon 12.0	7 N nitrogen 14.0	8 O oxygen 16.0	9 F fluorine 19.0	10 Ne neon 20.2
11 Na sodium 23.0	12 Mg magnesium 24.3											13 Al aluminium 27.0	14 Si silicon 28.1	15 P phosphorus 31.0	16 S sulfur 32.1	17 Cl chlorine 35.5	18 Ar argon 39.9
19 K potassium 39.1	20 Ca calcium 40.1	21 Sc scandium 45.0	22 Ti titanium 47.9	23 V vanadium 50.9	24 Cr chromium 52.0	25 Mn manganese 54.9	26 Fe iron 55.8	27 Co cobalt 58.9	28 Ni nickel 58.7	29 Cu copper 63.5	30 Zn zinc 65.4	31 Ga gallium 69.7	32 Ge germanium 72.6	33 As arsenic 74.9	34 Se selenium 79.0	35 Br bromine 79.9	36 Kr krypton 83.8
37 Rb rubidium 85.5	38 Sr strontium 87.6	39 Y yttrium 88.9	40 Zr zirconium 91.2	41 Nb niobium 92.9	42 Mo molybdenum 95.9	43 Tc technetium –	44 Ru ruthenium 101.1	45 Rh rhodium 102.9	46 Pd palladium 106.4	47 Ag silver 107.9	48 Cd cadmium 112.4	49 In indium 114.8	50 Sn tin 118.7	51 Sb antimony 121.8	52 Te tellurium 127.6	53 I iodine 126.9	54 Xe xenon 131.3
55 Cs caesium 132.9	56 Ba barium 137.3	57–71 lanthanoids	72 Hf hafnium 178.5	73 Ta tantalum 180.9	74 W tungsten 183.8	75 Re rhenium 186.2	76 Os osmium 190.2	77 Ir iridium 192.2	78 Pt platinum 195.1	79 Au gold 197.0	80 Hg mercury 200.6	81 Tl thallium 204.4	82 Pb lead 207.2	83 Bi bismuth 209.0	84 Po polonium –	85 At astatine –	86 Rn radon –
87 Fr francium –	88 Ra radium –	89–103 actinoids	104 Rf rutherfordium –	105 Db dubnium –	106 Sg seaborgium –	107 Bh bohrium –	108 Hs hassium –	109 Mt meitnerium –	110 Ds darmstadtium –	111 Rg roentgenium –	112 Cn copernicium –		114 Fl flerovium –		116 Lv livermorium –		

lanthanoids	57 La lanthanum 138.9	58 Ce cerium 140.1	59 Pr praseodymium 140.9	60 Nd neodymium 144.2	61 Pm promethium –	62 Sm samarium 150.4	63 Eu europium 152.0	64 Gd gadolinium 157.3	65 Tb terbium 158.9	66 Dy dysprosium 162.5	67 Ho holmium 164.9	68 Er erbium 167.3	69 Tm thulium 168.9	70 Yb ytterbium 173.1	71 Lu lutetium 175.0
actinoids	89 Ac actinium –	90 Th thorium 232.0	91 Pa protactinium 231.0	92 U uranium 238.0	93 Np neptunium –	94 Pu plutonium –	95 Am americium –	96 Cm curium –	97 Bk berkelium –	98 Cf californium –	99 Es einsteinium –	100 Fm fermium –	101 Md mendelevium –	102 No nobelium –	103 Lr lawrencium –

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