H

ANDERSON JUNIOR COLLEGE
2014 JC2 PRELIMINARY EXAM
Higher 1

CANDIDATE NAME

PDG _____ / 13

CHEMISTRY 8872/02

Paper 2 **3 September 2014**
2 hours

Candidates answer Section A on the Question Paper.

Additional Materials: Answer Paper
Data Booklet
Insert for Q7(c)

READ THESE INSTRUCTIONS FIRST

Write your name and PDG on all the work you hand in.
Write in dark blue or black pen.
You may use a pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, highlighters, glue or correction fluid.

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

Section A
Answer **all** the questions.

Section B
Answer **two** questions on separate answer paper.

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.

For Examiner's Use	
Paper 1	**/ 30**
Overall	**%**
Grade	

For Examiner's Use	
Section A	
Q 1	
Q 2	
Q 3	
Q 4	
Section B	
Q ___	
Q ___	
Total	**/ 80**

Section A

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

1 Oxalic acid, $H_2C_2O_4$, also known as ethanedioic acid, is a substance found in many plant foods. Green leafy vegetables, such as chives, parsley and spinach are among the plant foods with the highest oxalic acid content. In a study of about 240,000 people published in the July 2007 issue of *Journal of the American Society of Nephrology*, spinach was found to be the highest dietary contributor to an average daily oxalic acid intake of about 200 milligrams.

Inhalation and consumption of excess oxalic acid can be dangerous. Its toxic effects include destruction of tissues in the upper respiratory tract and kidney failure. In humans, ingested oxalic acid has an oral $\mathbf{LD_{Lo}}$ of 600 mg/kg body weight.

[Oral $\mathbf{LD_{Lo}}$ is the lowest published lethal oral dose of oxalic acid per unit of body weight known to have resulted in fatality].

The following investigation was carried out on a sample of oxalic acid, $H_2C_2O_4$, extracted from 100 g of spinach (about one serving) using 50 cm^3 of an inert organic solvent.

Solutions prepared were:

FA 1 The given inert organic solvent containing the oxalic acid was mixed with deionised water to a total volume of 250 cm^3 in a volumetric flask and left to stand.

FA 2 1.0 mol dm^{-3} sulfuric acid, H_2SO_4

FA 3 3.65 g of potassium manganate(VII), $KMnO_4$, was dissolved in deionised water in a 1 dm^3 volumetric flask and made up to the mark with deionised water.

Procedure and results:

25.0 cm^3 of **FA 1** was first pipetted into a conical flask. 25 cm^3 of **FA 2** and 40 cm^3 of deionised water were then added to the same flask. The resultant mixture was heated to a temperature of 65 ^oC over a Bunsen burner before being titrated with **FA 3** from the burette. It was found that 18.80 cm^3 of **FA 3** was required to react completely with the hot mixture.

(a) (i) The reaction between oxalate ion, $C_2O_4^{2-}$, and manganate(VII) ion, MnO_4^-, can be described by the two incomplete half–equations below.

For each half–equation, name the type of reaction that has taken place and state the number of electrons required to balance the electrical charges.

Type of reaction: *Half–equation*

..... : $MnO_4^- + 8H^+ + \_\_\_\_\_\ e^- \longrightarrow Mn^{2+} + 4H_2O$

..... : $C_2O_4^{2-} \longrightarrow 2CO_2 + \_\_\_\_\_\ e^-$

(ii) State the colour change that is observed at the end–point of the titration.

.....

[3]

(b) **(i)** Calculate the number of moles of MnO_4^- in **FA 3** which reacted with $C_2O_4^{2-}$ in 25.0 cm^3 of **FA 1**.

(ii) Using your answers to **(a)(i)** and **(b)(i)**, calculate the number of moles of $C_2O_4^{2-}$ in 25.0 cm^3 of **FA 1**.

(iii) Hence, determine the concentration, in mol dm^{-3}, of $C_2O_4^{2-}$ in **FA 1**.

[3]

(c) (i) Calculate the mass of oxalic acid in one serving of spinach.

(ii) Assuming that spinach is the only dietary source of oxalic acid on a particular day, what is the minimum number of servings of spinach must a healthy person, with a body weight of 65 kg, consume in a meal before he suffers from oxalic acid toxicity?

(iii) The mass of oxalic acid in one serving of spinach calculated in **(c)(i)** is lower than the actual mass present in the spinach.

Suggest one source of error during the preparation of **FA 1** which may contribute to this discrepancy.

.....

.....

[4]

[Total: 10]

2 **(a)** The chlorides of Period 3 elements react differently with water.

(i) Describe what you would observe when silicon(IV) chloride, $SiCl_4$, is mixed with moist air.

.....

.....

(ii) Write an equation for the reaction of phosphorus(III) chloride, PCl_3, with water and state the pH of the resulting solution.

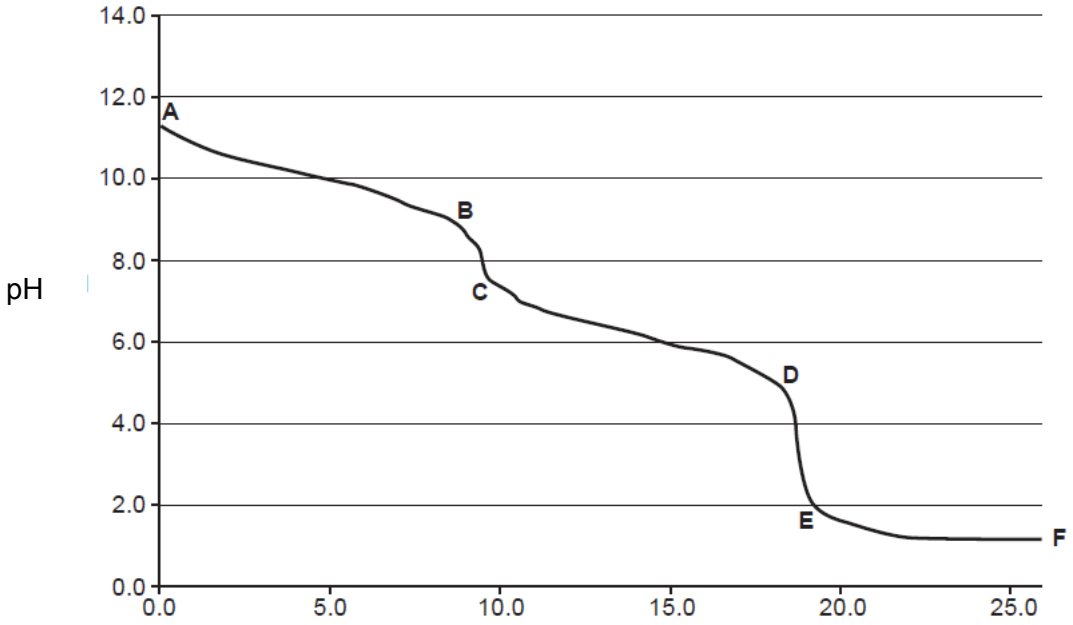
Equation: .....

pH: .....

[3]

(b) Commercial concentrated hydrochloric acid, HCl, fumes strongly on exposure to moist air and hence it is also known as 'fuming hydrochloric acid'.

A student conducted an experiment to determine the concentration of a sample of 'fuming hydrochloric acid'. 10.0 cm^3 of the 'fuming hydrochloric acid' sample was diluted to 250 cm^3 with deionised water. The resulting solution was labelled **X** and was then added gradually to 20.0 cm^3 of 0.10 mol dm^{-3} aqueous sodium carbonate, Na_2CO_3. The pH change was monitored as shown in the graph below.



(i) Write ionic equations for the reactions which occur in the solution between point **A** and point **B**, and between point **C** and point **D** on the graph.

Between **A** and **B**: .....

Between **C** and **D**: .....

(ii) The table below shows some information about four different indicators.

Indicator	Working pH range	Colour change	
		acid	alkali
Thymol blue	1 – 3	yellow	blue
Methyl yellow	2 – 4	red	yellow
Chlorophenol red	5 – 7	yellow	red
Cresol purple	7 – 9	yellow	purple

From the information given in the table, choose a suitable indicator for determining the end–point occurring between points **D** and **E** on the graph. State the colour change that will be observed and explain your choice of the indicator.

Indicator : .....

Colour change : .....

Explanation : .....

.....

(iii) Write a balanced equation for the complete neutralisation of aqueous sodium carbonate by solution **X**. Calculate the concentration of HC*l* in solution **X** given that 19.0 cm^3 of solution **X** was required to completely neutralise the aqueous sodium carbonate.

(iv) Hence, or otherwise, calculate the concentration of the sample of 'fuming hydrochloric acid'.

[7]

[Total: 10]

3 (a) **A**, **B** and **C** are atoms of elements in the Periodic Table. Some data concerning the particles derived from **A**, **B** and **C** are given in the table below.

Particle	Mass number	Number of		
		protons	electrons	neutrons
$\mathbf{A^{2+}}$	53		22	
B		24		26
$\mathbf{C^{2-}}$	51		27	

(i) Complete the above table.

(ii) Which two atoms represent isotopes of the same element?

.....

(iii) State the number of electrons present in atom **C** and hence write its full electronic configuration.

.....

(iv) When a beam of $^{40}Ca^{2+}$ particles travels through a uniform electric field which is at right angles to its direction of travel, it is deflected at an angle of +10.0°.

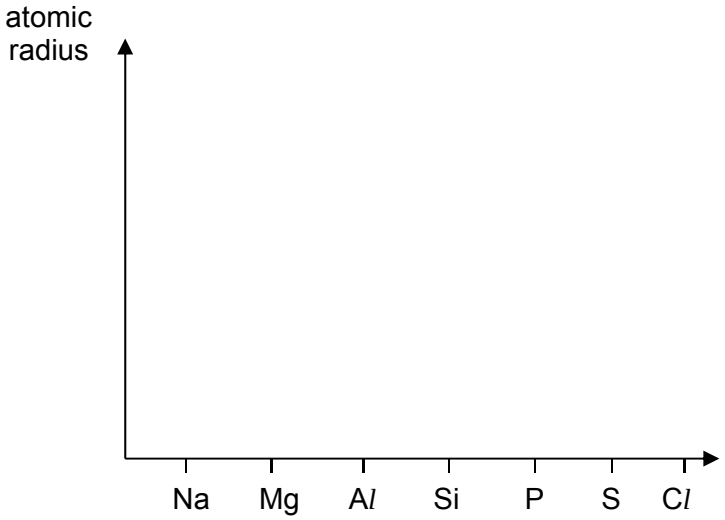
Determine the angle of deflection of a beam of $\mathbf{C^{2-}}$ particles if it travels at the same speed through the same electric field.

Angle of deflection = ...

[7]

(b) Elements of the third period in the Periodic Table show various trends in their physical properties.

(i) On the axes below, sketch a graph to illustrate the variation of atomic radius of the elements from sodium to chlorine.



(ii) Explain the shape of your sketch.

.....

.....

.....

[3]

[Total: 10]

4 **(a)** Define the following terms and write the corresponding balanced chemical equations, with state symbols.

(i) *standard enthalpy change of combustion of propane*

.....

.....

Equation: .....

(ii) *standard enthalpy change of formation of carbon dioxide*

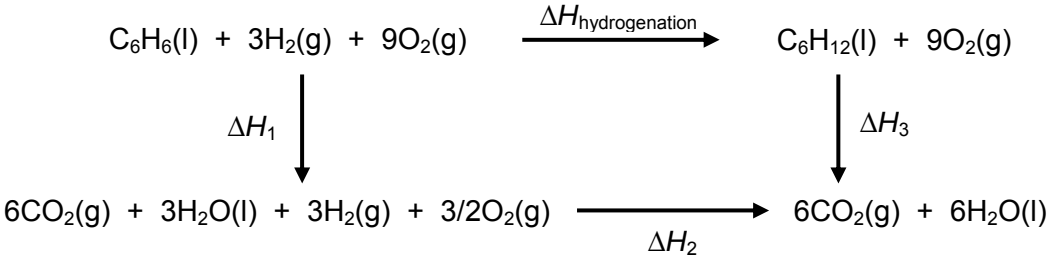
.....

.....

Equation: .....

[4]

(b) The diagram below shows an energy cycle involving the hydrogenation of benzene, C_6H_6, to form cyclohexane, C_6H_{12}.



(i) Using the bond energy data given in the *Data Booklet*, calculate the enthalpy change of combustion of benzene, C_6H_6, ΔH_1.

ΔH_1 = ...

The enthalpy change of combustion data of some substances are given below.

Substance	$\Delta H_{combustion}$ / kJ mol^{-1}
cyclohexane, $C_6H_{12}(l)$	–3920
hydrogen gas	–286

(ii) Using the enthalpy change of combustion data given above, write down the values of ΔH_2 and ΔH_3.

ΔH_2: ----------

ΔH_3: ----------

(iii) Hence, use the energy cycle and your answers to **(b)(i)** and **b(ii)** to calculate the enthalpy change of hydrogenation, $\Delta H_{hydrogenation}$, of benzene.

$\Delta H_{hydrogenation}$ = ----------

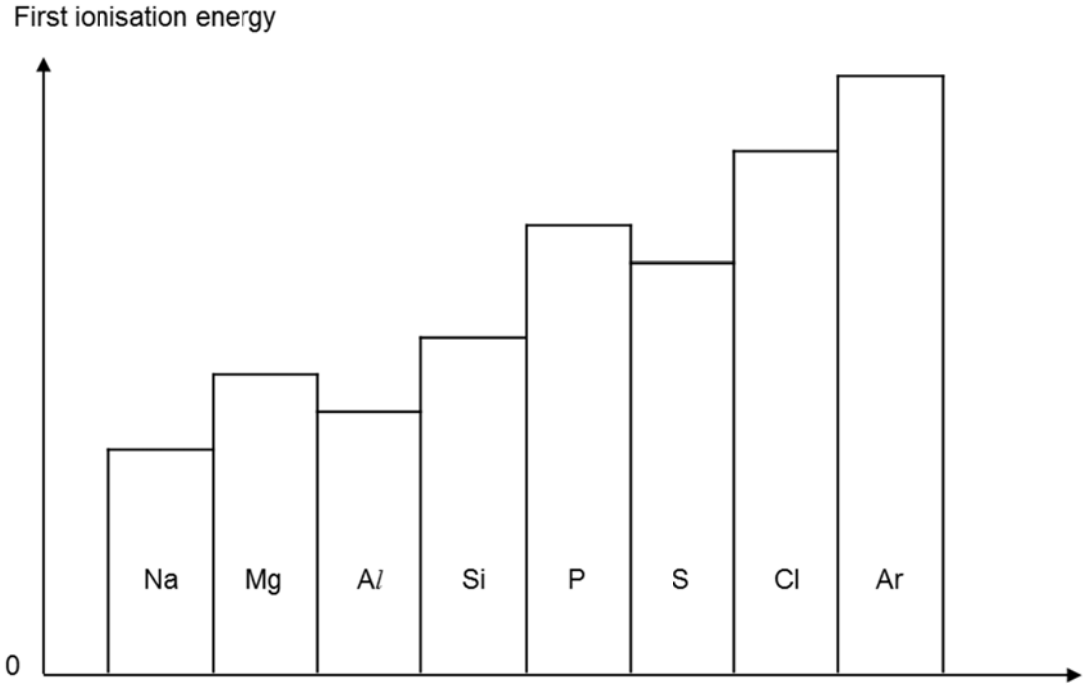
[6]

[Total: 10]

Section B

Answer **two** questions from this section on separate answer paper.

5 The first ionisation energies of the elements in Period 3 are shown in the diagram below.



(a) **(i)** Define what is meant by the *first ionisation energy* of an element.

(ii) Explain why the first ionisation energy of phosphorus is higher than that of either of the elements immediately preceding or following it in the Periodic Table.

(iii) Ionic compounds of magnesium contain the Mg^{2+} ion. The corresponding ion of aluminium is Al^{3+}. Using relevant data from the *Data Booklet*, explain in thermodynamic terms why Mg^{3+} compounds do not exist but Al^{3+} compounds exist.

[6]

(b) Both magnesium and aluminium react with phosphorus to form magnesium phosphide and aluminium phosphide respectively. Some properties of the two phosphides are shown below.

	magnesium phosphide	**aluminium phosphide**
formula	Mg_3P_2	AlP
appearance	yellow crystalline solid	colourless solid but appears grey green–yellow due to impurities present
melting point / ^oC	> 750	2000
reaction with water	vigorous reaction; produces phosphine, PH_3, and one other product	
reaction with acids		

(i) Briefly relate the high melting point of Mg_3P_2 to its structure and bonding.

(ii) Aluminium phosphide has a crystal structure similar to that of diamond and is described as a covalent compound with ionic character.

Use this information to explain why aluminium phosphide has a higher melting point than magnesium phosphide, and suggest why aluminium phosphide displays ionic character in its covalent bonds.

(iii) Using **one** of the phosphides, suggest balanced equations for its reactions with water and dilute hydrochloric acid.

[5]

(c) Phosphine, PH_3, is a toxic gas and is used as rodenticides to kill rodents which destroy crops.

The use of phosphine as rodenticides has been associated with accidental poisoning incidents. An article in the January 2013 issue of *Journal of Medical Hypotheses and Ideas* proposed the use of boric acid, $B(OH)_3$, as an antidote for PH_3 poisoning. It was suggested that $B(OH)_3$ 'traps' PH_3 by reacting with it in a 1 : 1 molar ratio, forming a compound, **Z**, which is non–toxic. Compound **Z** will subsequently be excreted from the body.

(i) PH_3 and $B(OH)_3$ have simple molecular structures. Draw dot–and–cross diagrams to show the bonding in the molecules of PH_3 and $B(OH)_3$.

(ii) Explain why PH_3 and $B(OH)_3$ form **Z** when they react in the molar ratio 1 : 1.

(iii) Draw diagrams to illustrate the likely shapes of PH_3, $B(OH)_3$ and **Z**. In your diagrams, clearly indicate the values of the bond angles with respect to the P and B atom in each molecule.

(iv) Suggest, in terms of the intermolecular forces present, how the 'trapped' PH_3, in the form of compound **Z**, may be removed from the body.

[9]

[Total: 20]

6 (a) (i) Write balanced equations for the reactions that occur when separate samples of sodium, aluminium and sulfur are burnt in excess oxygen.

(ii) Describe the reactions, if any, of each of the products formed in **(a)(i)** with water, stating the approximate pH of any solution formed, and writing a balanced equation for any reaction that takes place.

[6]

(b) Compound **M** is an ester that provides honey flavour in the food industry. When **M** is heated under reflux with dilute sulfuric acid, a carboxylic acid **N**, $C_8H_8O_2$, and alcohol **P**, are produced in equal amounts.

N reacts with hot concentrated potassium manganate(VII) to form a white precipitate **Q**, $C_7H_6O_2$. 1 mole of **Q** reacts with excess aqueous sodium carbonate to produce 0.5 mole of gas.

When **P** is warmed with acidified potassium dichromate and distilled, compound **R** is formed. **R** produces an orange precipitate with 2,4–dinitrophenylhydrazine and gives a silver mirror with Tollens' reagent. **R** also reacts with alkaline aqueous iodine to produce a yellow precipitate.

Suggest the structures for **M**, **N**, **P**, **Q** and **R** and explain the reactions described.

[10]

(c) Ethyl ethanoate (M_r = 88) is the most common ester found in wines. The aroma of ethyl ethanoate contributes towards the general perception of "fruitiness" in the wine. It is formed naturally from an organic acid and alcohol. This reaction is reversible.

(i) Write a balanced equation for the formation of ethyl ethanoate in the wine, giving the structural formulae of the organic acid and alcohol involved.

(ii) Write an expression for the equilibrium constant, K_c, for the equation you have given in **(c)(i)**.

(iii) To replicate the natural production of ethyl ethanoate in the laboratory, an equal amount of the organic acid and alcohol represented by your answer in **(c)(i)** are reacted in the presence of a catalyst. When equilibrium is reached, it is found that only 67% of the organic acid has reacted. Determine the value of K_c for this reaction.

[4]

[Total: 20]

7 **(a)** Many chemists have contributed to the development of the Periodic Table. John Newland was one of the first few chemists who attempted to classify elements in a systematic way, based on atomic weight. In 1866, he suggested that there was a repeating pattern of elements with similar properties in every eight elements. Part of Newland's Periodic Table is shown below.

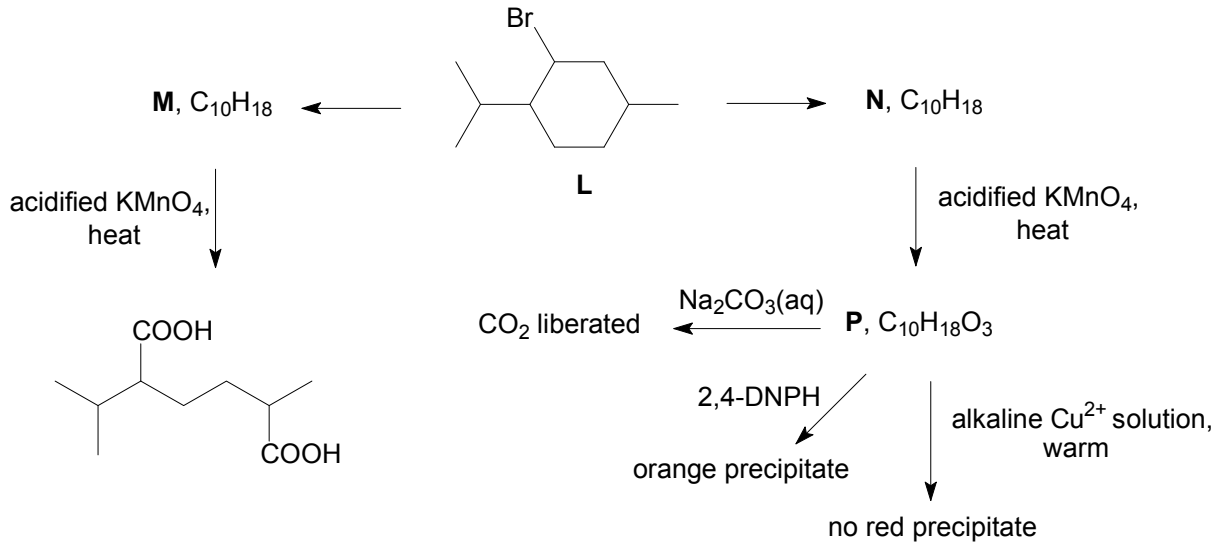
$_{5}$B	$_{6}$C	$_{7}$N	$_{8}$O	**$_{9}$F**	**$_{11}$Na**	**$_{12}$Mg**	**$_{13}$Al**
$_{14}$Si	**$_{15}$P**	**$_{16}$S**	$_{17}$Cl	$_{19}$K	$_{20}$Ca	$_{24}$Cr	$_{22}$Ti

(i) Sketch the general trends of the melting point and electrical conductivity of the elements from **fluorine to sulfur** according to Newland's Periodic Table.

(ii) Describe and explain the trend of the melting point as shown in your sketch in **(a)(i)**.

[5]

(b) A cyclobromoalkane, **L**, undergoes the following reactions:



M and **N** are isomers and both decolourise aqueous bromine. They are formed from **L** using the same reagent and condition.

(i) Suggest the reagent and condition to produce **M** and **N** from **L**.

(ii) Suggest the structural formulae of **M**, **N** and **P**.

(iii) State the type of isomerism shown by **M** and **N**.

[5]

(c) 2–iodo–2–methylpropane undergoes a substitution reaction with hot aqueous sodium hydroxide. Two separate experiments were carried out to study the kinetics of this reaction.

In Experiment 1, sodium hydroxide was used in large excess and the concentration of 2–iodo–2–methylpropane was measured against time. A graph of concentration of 2–iodo–2–methylpropane against time was plotted and shown on the **INSERT.**

In Experiment 2, 2–iodo–2–methylpropane was used in large excess and the concentration of sodium hydroxide was measured against time. The following results were obtained.

Time / s	[NaOH] / mol dm^{-3}
0	0.0100
100	0.0082
200	0.0064
380	0.0032
500	0.0010

(i) Using the **INSERT** provided, plot a graph for Experiment 2.

(ii) Use the half–life method to deduce the order of reaction with respect to 2–iodo–2–methylpropane. Show all your working clearly.

(iii) Using the graph plotted in **(c)(i)**, determine the order of reaction with respect to sodium hydroxide. Explain your answer.

(iv) Hence, write an overall rate equation for the substitution reaction.

(v) Suggest a reason why 2–chloro–2–methylpropane reacts with sodium hydroxide at a slower rate than 2–iodo–2–methylpropane.

(vi) With the aid of a sketch of the Boltzmann distribution, explain how an increase in temperature affects the rate of the substitution reaction.

[10]

[Total: 20]

INSERT FOR QUESTION 7(c)

ATTACH THIS GRAPH TO YOUR ANSWER SCRIPT FOR QUESTION 7