INNOVA JUNIOR COLLEGE
JC 2 PRELIMINARY EXAMINATION 2
in preparation for General Certificate of Education Advanced Level
Higher 1

CANDIDATE NAME			
CLASS		INDEX NUMBER	

CHEMISTRY 8872/02

Paper 2 Structured and Free Response Questions **24 September 2009**

2 hours

Section A: Structured
Candidates answer Section A on the Question Paper

Section B: Free Response
Additional Materials: Writing Papers
Data Booklet

READ THESE INSTRUCTIONS FIRST

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

Section A: Structured Questions (40m)
Answer **all** questions in the space provided.

Section B: Free Response Questions (40m)
Answer **two** questions on separate writing papers.

You are advised to show all working in calculations.
You are reminded of the need for good English and clear presentation in your answers.
You are reminded of the need for good handwriting.
Your final answers should be in 3 significant figures.

You may use a calculator.

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

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

For Examiner's Use	
Section A	
1	/10
2	/10
3	/9
4	/11
Significant Figures	
Total	/40

This document consists of **17** printed pages and **1** blank page.

For Examiner's Use

Section A
Answer <u>ALL</u> questions on the space provided.

1 The purity of iodates (VII) can be estimated by adding an acidified solution of potassium iodide and titrating the iodine produced with aqueous sodium thiosulphate.

In one such analysis, a 0.100 g sample of impure sodium iodate (VII), Na_5IO_6, was dissolved in water and treated with an excess of acidified KI.

$$IO_6^{5-} + 7I^- + 12H^+ \rightarrow 4I_2 + 6H_2O$$

The iodine liberated required 22.0 cm^3 of 0.100 $moldm^{-3}$ sodium thiosulphate, $Na_2S_2O_3$ to reach its end point. Calculate the purity of the sodium iodate (VII).

(a) (i) Write a balanced ionic equation for the reaction between thiosulphate and iodine.

(ii) Calculate the number of moles of iodine liberated.

(iii) Calculate the number of moles of pure Na_5IO_6 required to produce the iodine in part **(ii)**.

(iv) Calculate the mass of pure Na_5IO_6 in the sample.

(v) Calculate the purity of the sodium iodate (VII).

[5]

(b) In the 1980s, there was an international agreement to destroy all stockpiles of mustard gas, $ClCH_2CH_2SCH_2CH_2CH_2Cl$. When this substance contacts the moisture in eyes, nasal passages, and skin, the OH groups of water replace the C*l* atoms and create high local concentrations of hydrochloric acid, which cause severe blistering and tissue destruction.

Given the balanced equation,

$$ClCH_2CH_2SCH_2CH_2Cl + 2\ H_2O \rightarrow HOCH_2CH_2SCH_2CH_2OH + 2\ HCl$$

Use the table of average bond energies given below to calculate ΔH_r for this reaction.

bond	average bond energy / kJ mol^{-1}
C – C	350
C – H	410
C – C*l*	340
C – O	360
H – C*l*	431
O – H	460
S – C	272
S – H	347

[3]

(c) It is observed that when a beam of $^{238}_{92}U^{+}$ is passed through an electric field, it gives an angle of deflection of 1.5°. Calculate the angle of deflection for a sample consisting $^{206}_{82}Pb^{2+}$ when it passes through the same electric field.

[2]

[Total:10]

2 Benzoic acid, $C_7H_6O_2$ (or C_6H_5COOH), is a colourless crystalline solid and the simplest aromatic carboxylic acid. The name is derived from gum benzoin, which was for a long time the only source for benzoic acid. When dissolved in organic solvent, it is capable of dimerisation. A dimer is a chemical or biological entity consisting of two structurally similar subunits called monomers.

(a) **(i)** Identify the type of bonding between the benzoic acid molecules during dimerisation.

Type of Bonding: ……

(ii) Draw a diagram to illustrate your answer in (**i**).

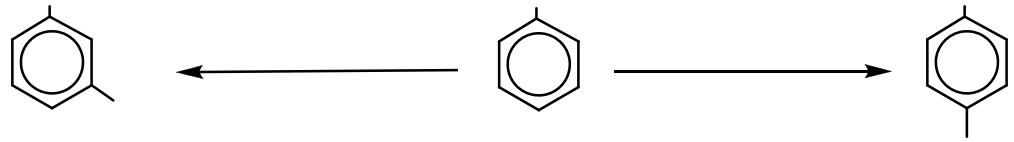
[3]

For Examiner's Use

(b) During aromatic substitution, the position of the incoming group, is determined by the nature of the substituent already present in the ring.

If Y is an electron-withdrawing group, the incoming group will be in position 3.
If Y is an electron-releasing group, the incoming group will be mostly in position 4.

Using nitration as an example,

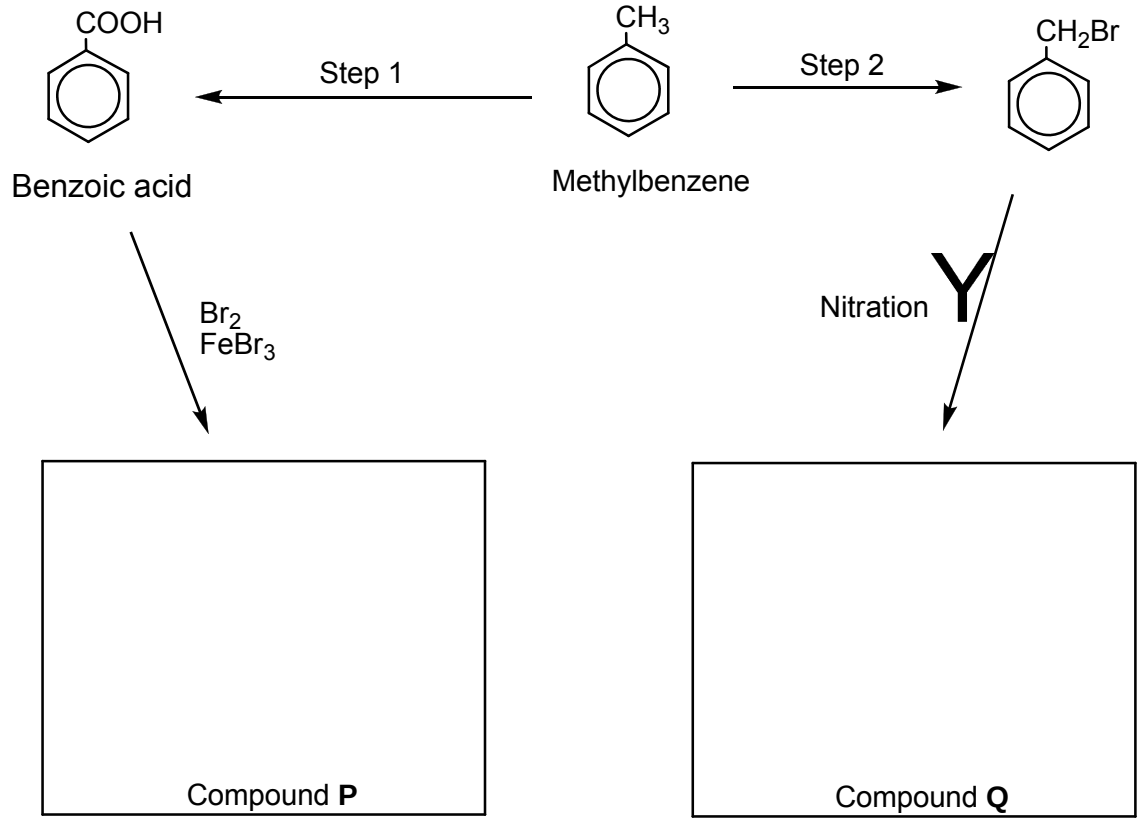


The following table lists some electron-withdrawing and electron-donating substituents.

electron-withdrawing substituents	electron-donating substituents
$-NO_2$	$-NH_2$
– COOH	$-CH_2Br$

Benzoic acid is an important precursor for the synthesis of many other organic substances. Study the reaction schemes below involving benzoic acid and its derivatives.

(i) Use the above information to draw relevant structural formulae of compounds **P** and **Q** in the boxes provided. [2]



(ii) Give reagent(s) and condition(s) for each of the steps 1 and 2.

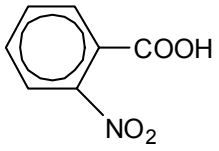
Step	Reagent(s) and Condition(s)
1	
2	

[2]

(iii) Draw the structural formula of the product formed when benzoic acid is refluxed with ethanol in the presence of concentrated sulphuric acid.

[1]

(iv) Explain if 3-nitrobenzoic acid is more or less acidic than benzoic acid.



3-nitrobenzoic acid

……

……

……

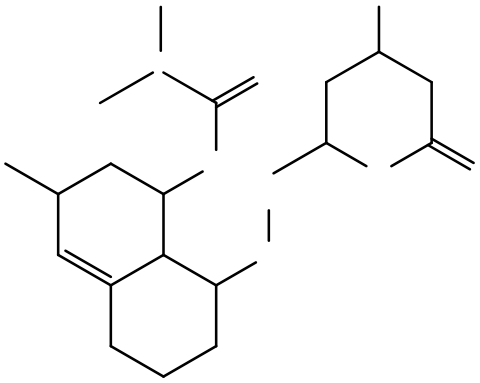
……

……[2]

[Total: 10]

3 Lovastatin is a member of the drug class of statins, used for lowering cholesterol in those with hypercholesterolemia and so preventing cardiovascular disease.

A derivative of lovastatin is shown below.



(a) Upon hydrolysis, all the hydrolysed products of the derivative of lovastatin react with aqueous sodium carbonate readily to give effervescence.

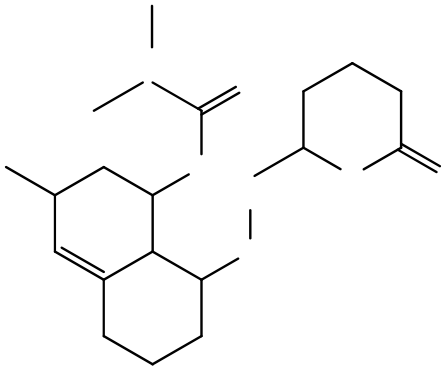
(i) Suggest suitable reagents and conditions to perform this hydrolysis.

……

(ii) Give the structural formulae of all the hydrolysed products.

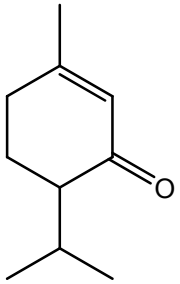
(iii) One of the hydrolysed products of the derivative of lovastatin in **(a)(ii)** can subsequently react with acidified potassium manganate (VII) solution to give compound **Q**. Draw the structural formula of compound **Q**.

(iv) Complete the outline structure of the product formed when the derivative of lovastatin reacts with propanoic acid.



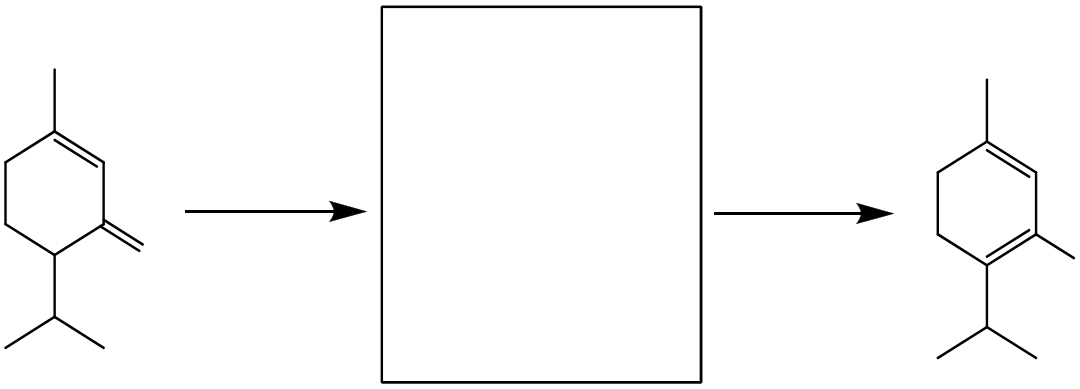
[6]

(b) Piperitone is a component of some essential oils and has a peppermint like aroma.



Piperitone

Piperitone can be converted into compound **S** via a two step synthesis with compound **R** as an intermediate.



(i) Draw the structural formula of compound **R** in the box provided above.

For Examiner's Use

(ii) State the reagent(s) and condition(s) for each of the steps 1 and 2.

Step	Reagent(s) and condition(s)
1	
2	

[3]

[Total: 9]

4 The rate of reaction between aqueous sodium thiosulphate, $Na_2S_2O_3$ and aqueous hydrochloric acid, HC*l* is investigated at room temperature and pressure by measuring the time taken for sulphur to be formed.

$$Na_2S_2O_3\,(aq) + 2HCl\,(aq) \longrightarrow 2NaCl\,(aq) + H_2O\,(l) + SO_2\,(aq) + S\,(s)$$

The data obtained for the above reaction was recorded as shown:

Experiment	**$[Na_2S_2O_3]$ / mol dm^{-3}**	**[HCl] / mol dm^{-3}**	**Relative rate / s^{-1}**
1	0.25	0.25	$\frac{1}{16}$
2	0.20	0.30	$\frac{1}{20}$
3	0.10	0.20	$\frac{1}{40}$
4	0.15	0.20	$\frac{1}{27}$

(a) (i) From the data given, deduce the order of reaction with respect to sodium thiosulphate and aqueous hydrochloric acid.

[2]

(ii) Write a rate equation for the reaction.

[1]

(iii) Given that the initial rate in experiment 1 is 0.0140 mol dm^{-3} s^{-1}, calculate the rate constant, k, and state its units.

[1]

(iv) Hence, determine the half life of this reaction.

[1]

(b) The chlorides of the elements sodium, aluminium and silicon all dissolve in water to give solutions of different pH values.

(i) Write down the suggested pH values of the resulting solutions.

Chlorides of	sodium	aluminium	silicon
pH of resulting solution			

(ii) Write balanced equations to illustrate the different behaviours of the chlorides in water.

Sodium chloride with water

……

……

Aluminium chloride with water

……

……

Silicon chloride with water

……

……

(iii) Explain why sodium chloride and silicon chloride differ in their reaction with water.

……

……

[5]

(c) An unknown element, **X** burns in air to form a nitride, X_3N_2. When 0.200 g of nitride reacts with water, ammonia is liberated. The ammonia gas liberated reacts with 27.10 cm^3 of 0.100 mol dm^{-3} of HC*l*. Calculate the relative atomic mass of **X**.

$$X_3N_2 + 6H_2O \longrightarrow 2NH_3 + 3X(OH)_2$$

[1]

[Total: 11]

Section B

Answer **two** of the three questions on separate writing papers.

5 Much interest has been shown in the production of the fuel biodiesel from algae. Biodiesel is a fuel that can be used in cars, lorries, buses and trains. Up to 55% of the mass of the dried algae is composed of lipids, the majority of which are triglycerides.

Biodiesel can be obtained from triglycerides by the following reaction.

Triglyceride, Mr = 809 glycerol

Biodiesel

(a) **(i)** Name **one** functional group present in triglyceride.

(ii) Suggest reactants and conditions for steps 1 and 2 respectively.

(iii) Calculate the mass of biodiesel that can be produced from 1.5 tonne of dried algae, assuming that 48% of the algae mass is triglycerides.
(1 tonne = 1000 kg)

(iv) Construct an equation for the complete combustion of biodiesel and calculate the volume of CO_2 produced at s.t.p when 2 kg of biodiesel is burned.

(v) Suggest a reason why the development of biodiesel as an alternative fossil fuels is important although the production is at present an expensive process.

[8]

(b) Ethanol is another alternative fuel which is widely used in Brazil and United States. Ethanol is also used as cooking and lighting fuel.

When 2.00 g of ethanol was burned under a container of water, it was found that 70 g of water was heated from 28°C to 65°C. The process was known to be 90% efficient.

Use the above data and values from the *Data Booklet* to calculate the enthalpy change of combustion per mole of ethanol.

[2]

(c) The reaction below has an activation energy of +174 kJ mol^{-1}.

$$H_2 + I_2\ (g) \longrightarrow 2HI\ (g) \qquad \Delta H = -9.0\ kJ\ mol^{-1}$$

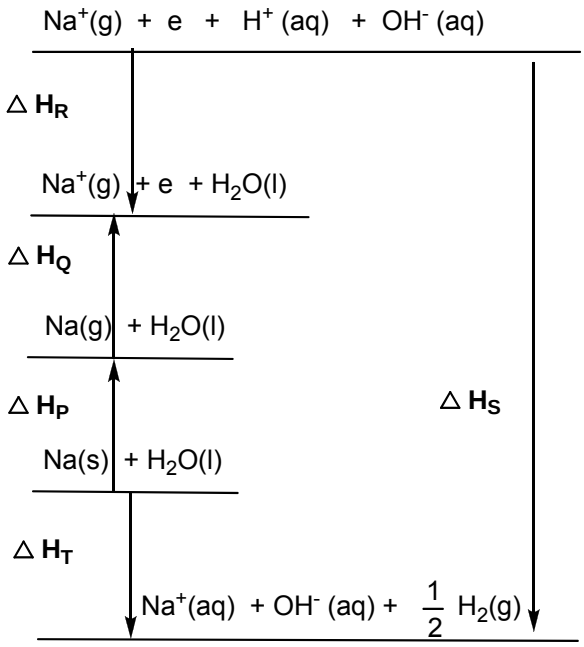
(i) Calculate the activation energy of the reverse reaction.

(ii) Describe how a change in temperature will increase the rate of reaction. [3]

(d) Sodium reacts with metal and water to form aqueous sodium hydroxide.

$$Na\ (s)\ +\ H_2O\ (l) \longrightarrow Na^+(aq)\ +\ OH^-\ (aq)\ +\ H_2(aq)$$

An energy cycle which starts with Na (s) and H_2O (*l*) is provided below.



Using the given data and relevant data from the Data Booklet,

Enthalpy change	Δ H / kJ mol^{-1}
Δ H_P	+107
Δ H_R	–58
Δ H_S	–850

(i) Name the enthalpy changes involved in Δ H_Q and Δ H_R.

(ii) State the enthalpy change of Δ H_Q.

(iii) Calculate the enthalpy change for Δ H_T.

[4]

(e) Compound **L** with molecular formula C_8H_7OCl, gives an orange precipitate with 2,4–dinitrophenylhydrazine reagent and silver mirror with Tollens' reagent.

On heating Compound **L** under reflux with aqueous acidified potassium manganate (VII), compound **M**, molecular formula $C_8H_6O_4$ is formed.

On warming with aqueous sodium hydroxide, compound **L** gives compound **N**. Upon acidifying with nitric acid, and then adding aqueous silver nitrate, white precipitate is formed.

Suggest possible identity for each of the organic compounds **L**, **M** and **N**. [3]

[Total: 20]

6 The following questions deals with many chemical species that is make up of hydrogen and oxygen.

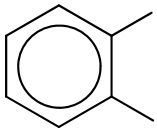
Hydrogen is the most abundant chemical element, constituting roughly 75% of the universe's elemental mass.

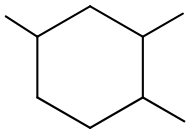
(a) Draw a dot-and-cross diagram to illustrate the electron distribution and bonding in H_3O^+. Predict and explain the shape in terms of the numbers and types of electron pairs they contain. Indicate the bond angle. [2]

(b) Explain in terms of its structure and bonding, why sodium ethanoate $CH_3COO^-Na^+$ is soluble in water. [2]

(c) Sodium, silicon and phosphorus form the oxides Na_2O, MgO and P_4O_{10} upon reaction with oxygen. Describe the action of water on the oxides of sodium and phosphorus, write equations for any reactions that occur, and suggest the pH of each solution formed. [4]

(d) The esters Aspirin and menthol have the following structures:





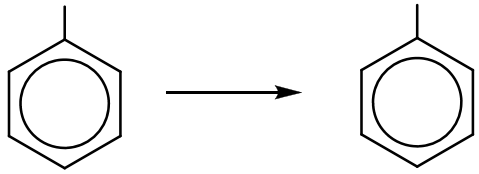
(i) Explain how the two compounds can be distinguished from each other with a simple chemical test.

(ii) An isomer of menthol, can be distinguished from menthol itself by the tri-iodomethane test.

State the reagents and conditions for tri-iodomethane test and suggest the structural formula of this isomer of menthol.

[4]

(e) Compound **Z** can be synthesised from phenylmethanol, in two steps.



State clearly the reagents and conditions required in each step, and identify the intermediate formed. Give the balanced equation for each step.

[3]

(f) Oxygen and hydrogen are also commonly found in acids and bases.

(i) Define the terms *acids* and *bases* according to the Brønsted-Lowry theory.

(ii) Using the Brønsted-Lowry definitions of acid and base, identify the Brønsted acid and the Brønsted base, and their corresponding conjugate base and conjugate acid, for the following equilibrium.

$$HSO_4^-(aq) + CO_3^{2-}(aq) \rightleftharpoons SO_4^{2-}(aq) + HCO_3^-$$

(iii) A 0.05 mol dm^{-3} of aqueous ammonia has a pH value of 11.2 at 25°C. Write an expression for K_b and show that ammonia is a weak base using the information provided.

[5]

[Total: 20]

7 The following data indicates the effect of temperature and pressure on the equilibrium concentration of the product in a gaseous equilibrium.

Temperature/ K	% of product present in equilibrium mixture at		
	5 kPa	10 kPa	20 kPa
400	0.09	2.10	15.70
600	0.05	1.55	7.20
800	0.02	0.62	2.80

(a) **(i)** Use the above information to explain whether the production of the product is due to increase or decrease in the total number of gaseous molecule.

(ii) Use the above information to explain whether the production of the product is an exothermic or endothermic process.

(iii) State the optimum conditions of temperature and pressure for the commercial production of this product.

[5]

(b) A sample of lime juice contains 0.01 mol dm^{-3} of citric acid, HA.

(i) Calculate the pH of the citric acid, given that the K_a of citric acid is 1.70×10^{-5} mol dm^{-3}.

(ii) Calculate the degree of dissociation for citric acid.

(iii) 25.0 cm^3 of the lime juice solution was titrated against 0.500 mol dm^{-3} of aqueous sodium hydroxide. Given that the pH of the titration mixture at the equivalence point is 9.5, suggest a suitable indicator for the titration and state the colour change.

[3]

(c)

Oxide	Na_2O	MgO	Al_2O_3	SiO_2	P_4O_{10}	SO_2
Melting point / K	1193	3125	2345	1883	297	200
Boiling point / K	1548	3873	3253	2503	448	263

Suggest in terms of structure and bonding the explanations for the following:

(i) The melting point of MgO is higher than that of Na_2O.

(ii) The melting point of Al_2O_3 is lower than that of MgO.

(iii) Draw the dot-and-cross diagram to illustrate the bonding in Al_2O_3.

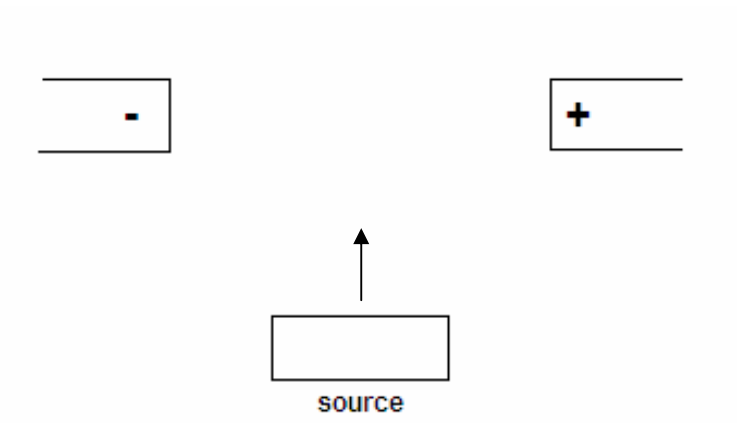
(iv) A student went to the chemistry laboratory and realised that three chemical bottles have missing labels. The compounds in the bottles are “sodium oxide”, “aluminum oxide”, “phosphorous (V) oxide”. He decided to perform some tests to deduce the identities of the chemicals in the unlabeled bottles, so that they can be re-labeled correctly. The student named the three bottles **A** to **C**. The following solubility tests were conducted and the observations were as follows:

*Sample from bottles **A** is insoluble in water. However, sample **B** dissolves readily in hydrochloric acid, while sample **C** dissolves readily in aqueous sodium hydroxide. Compound **A** dissolves in both hydrochloric acid and aqueous sodium hydroxide.*

Suggest identities of **A** to **C** and write equations to show the acid-base behaviour of the oxides.

[10]

(d) Individual beams of protons, electrons and neutrons are subjected to an electric field as shown. Copy the diagram below and sketch how beams of the following particles are affected by the electric field.



[2]

[Total: 20]

BLANK PAGE