Index No:_____ **AM 06/I.14m**

MATRICULATION AND SECONDARY EDUCATION CERTIFICATE EXAMINATIONS BOARD

UNIVERSITY OF MALTA, MSIDA

MATRICULATION EXAMINATION
ADVANCED LEVEL
MAY 2014

SUBJECT:	CHEMISTRY
PAPER NUMBER:	I
DATE:	6th May 2014
TIME:	9.00 a.m. to 12.00 noon

Required Data: **Molar Mass / g mol^{-1} : O = 16 Na = 23 Cl = 35.5**
Avogadro's Number = 6.02 × 10^{23}

Answer all questions

1. The nucleus of an *isotope* of uranium contains 92 protons and 146 neutrons. The isotope decays by the emission of a particle **B** containing 2 protons and producing a nucleus **C**. The *half–life* of the process is 4.5 billion years. The process is part of a long series of decay processes which includes a process whereby a neutron changes into a proton with the emission of a particle, **D** with a very small mass.

   (a) Define the terms in italics:

   isotope _____

   _____

   half–life _____

   _____

   (2 marks)

   (b) Identify particle **B**. _____

   (1 mark)

   (c) Deduce the atomic mass and atomic number of **C**. _____

   _____

   (2 marks)

   (d) Identify particle **D**. _____

   (1 mark)

(e) A sample of uranium ore contains 1.28×10^{22} atoms of the isotope in question. Determine the *mass* of uranium atoms of the isotope present in the sample 13.5 billion years ago.

(4 marks)
(Total = 10 marks)

2. Chlorine gas reacts with dilute sodium hydroxide to form sodium chloride, sodium chlorate and water according to the following equation:

$$3Cl_2(g) + 6NaOH(aq) \rightarrow 5NaCl(aq) + NaClO_3(aq) + 3H_2O(l)$$

(a) Write the ionic equation for this reaction.

(1 mark)

(b) Indicate the oxidation number of chlorine in:

Cl_2 _____

NaCl _____

$NaClO_3$ _____

(3 marks)

(c) Calculate the volume of chlorine gas, at 1 atm pressure and 298 K, required to produce 5.32 g of $NaClO_3$.

(4 marks)
(Total: 8 marks)

3. This question is about the weak acid ethanoic acid (CH_3CO_2H).

(a) Write an ionic equation for the dissociation of ethanoic acid in aqueous solution and label each species in terms of *acid*, *base*, *conjugate acid*, and *conjugate base*.

Equation: _____ + _____ ⇌ _____ + _____

Label: _____ _____ _____ _____

(3 marks)

(b) Give the equation for the acid dissociation constant of ethanoic acid.

_____

_____

(1 mark)

(c) Consider a solution of ethanoic acid of concentration 0.10 mol dm^{-3}. The dissociation constant of ethanoic acid is 1.8×10^{-5} mol dm^{-3}.

(i) Calculate the concentration of hydrogen ions in solution.

_____

_____

_____

_____

(ii) Calculate the volume of 0.25 mol dm^{-3} sodium hydroxide which reacts with 25 cm^3 of the ethanoic acid solution.

_____

_____

_____

_____

(iii) What will be the effect on the dissociation of ethanoic acid if a small quantity of sodium ethanoate is added to the ethanoic acid solution? Explain your answer.

_____

_____

(9 marks)

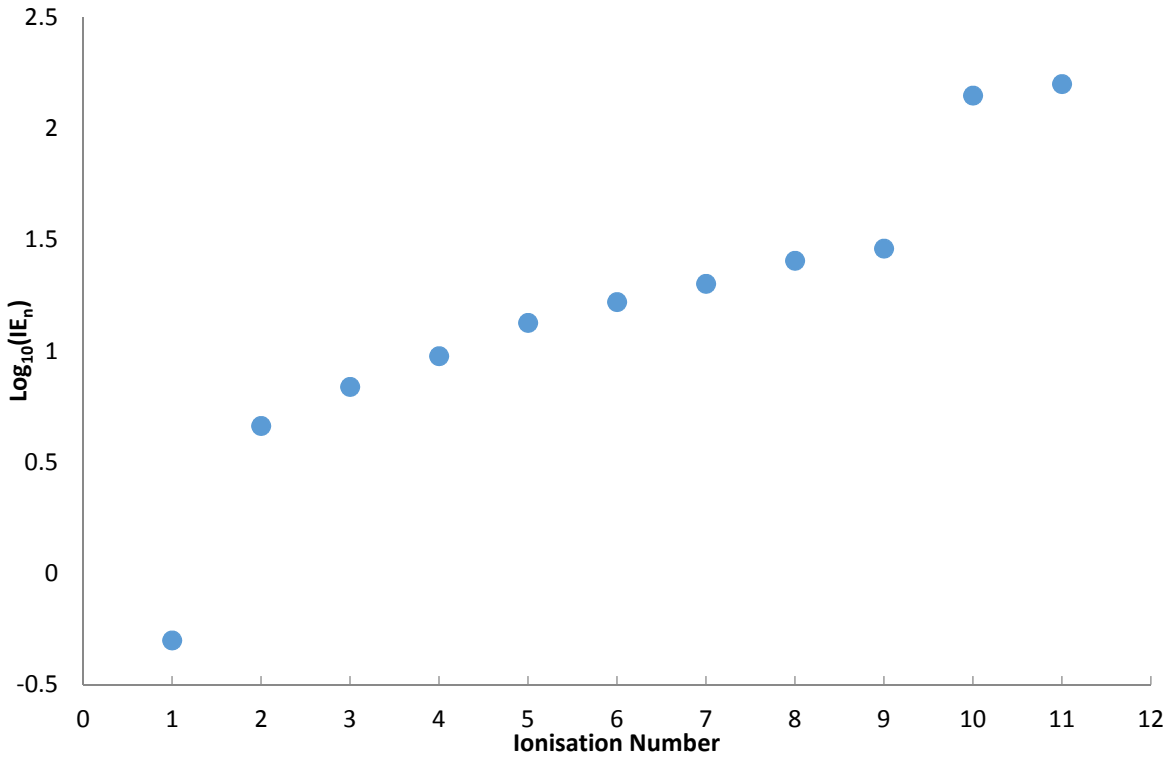
(Total 13 marks)

4. This question is about periodicity.

(a) Write an equation, including state symbols, for the reaction that occurs when the first ionisation energy of sodium is measured.

(1 mark)

(b) The figure below shows successive ionisation energies of sodium.



(i) Explain the difference between the first and second ionisation energies.

(ii) Explain the trend in ionisation energies between the second and ninth ionisation energies.

(2 marks)

(c) Giving an explanation in each case, state:

(i) the general trend in first ionisation energies from sodium to argon;

(ii) the elements that deviate from this trend;

(iii) the element in Group 1 with the highest ionisation energy;

(iv) the element in Period 3 with the largest atomic radius.

(10 marks)
(Total: 13 marks)

5. (a) Ammonium chloride (NH_4Cl) exhibits *covalent*, *co-ordinate* (*dative*) and *ionic* bonding. Draw a dot-cross diagram of ammonium chloride to illustrate the three types of bonding given in italics.

(4 marks)

(b) (i) Use the *VSEPR* theory to predict the shapes of the ammonia molecule and the ammonium ion.

(ii) State, with reason, the N-H bond angles in both ammonia and the ammonium ion.

(4 marks)

(c) Give explanations for the following statements:

(i) Ammonia is soluble in water.

(ii) Both water and ethoxyethane can dissolve some HCl, however, the solutions containing similar quantities of HCl have different electrical conductivity.

(3 marks)
(Total: 11 marks)

6. This question concerns chlorides of the elements in Period 3 of the Periodic Table.

(a) Give balanced chemical equations (including state symbols) for the preparation of:

(i) $Cl_2(g)$ from NaCl ;

(ii) S_2Cl_2 from elemental sulfur.

(4 marks)

(b) Consider the following reversible reaction:

$$PCl_5(g) \rightleftharpoons PCl_3(g) + Cl_2(g) \qquad \Delta H^{\ominus} = +92.5 \text{ kJ mol}^{-1}$$

(i) The bond dissociation energy for Cl_2 is + 242 kJ mol^{-1}. Estimate the bond energy for the P–Cl bond.

(ii) Fill in the blanks in the following paragraph:

When the reaction is heated under constant pressure, the equilibrium shifts to the _____ since it has a _____ enthalpy change of reaction. On increasing the pressure at constant temperature, the equilibrium will shift to the _____ because there are _____

(5 marks)

(c) Three solutions contain separately NaCl, $MgCl_2$ and $AlCl_3$. A few drops of sodium hydroxide is added to each and then added in excess. Fill in the following table with the appropriate observation and reactions (if any).

	After addition of a few drops of sodium hydroxide	After addition of excess sodium hydroxide
NaCl		
$MgCl_2$		
$AlCl_3$		

(5 marks)
(Total: 14 marks)

7. Compound **H** has an empirical formula of C_7H_8. This reacts with HNO_3/H_2SO_4 to give explosive **I**. **H** reacts with Br_2 and a catalyst to give mainly two products, **J** and **K**. When **H** reacts with alkaline $KMnO_4$ it gives **L** which can be converted into **M**, a compound with a characteristic almond smell.

   (a) Give the structures of molecules **H**, **I**, **J**, **K, L** and **M**.

(6 marks)

   (b) Give the conditions for the conversion of **L** to **M**.

(1 mark)

   (c) Explain why **J** and **K**, and not any other isomer, are formed in the reaction between **H** and bromine.

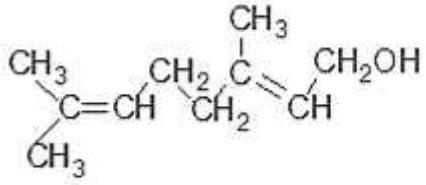
(2 marks)
(Total: 9 marks)

8. Geraniol and nerol are *geometrical isomers*.

(a) Define the term in italics.

(1 mark)

(b) The structure of geraniol is given below.



Geraniol

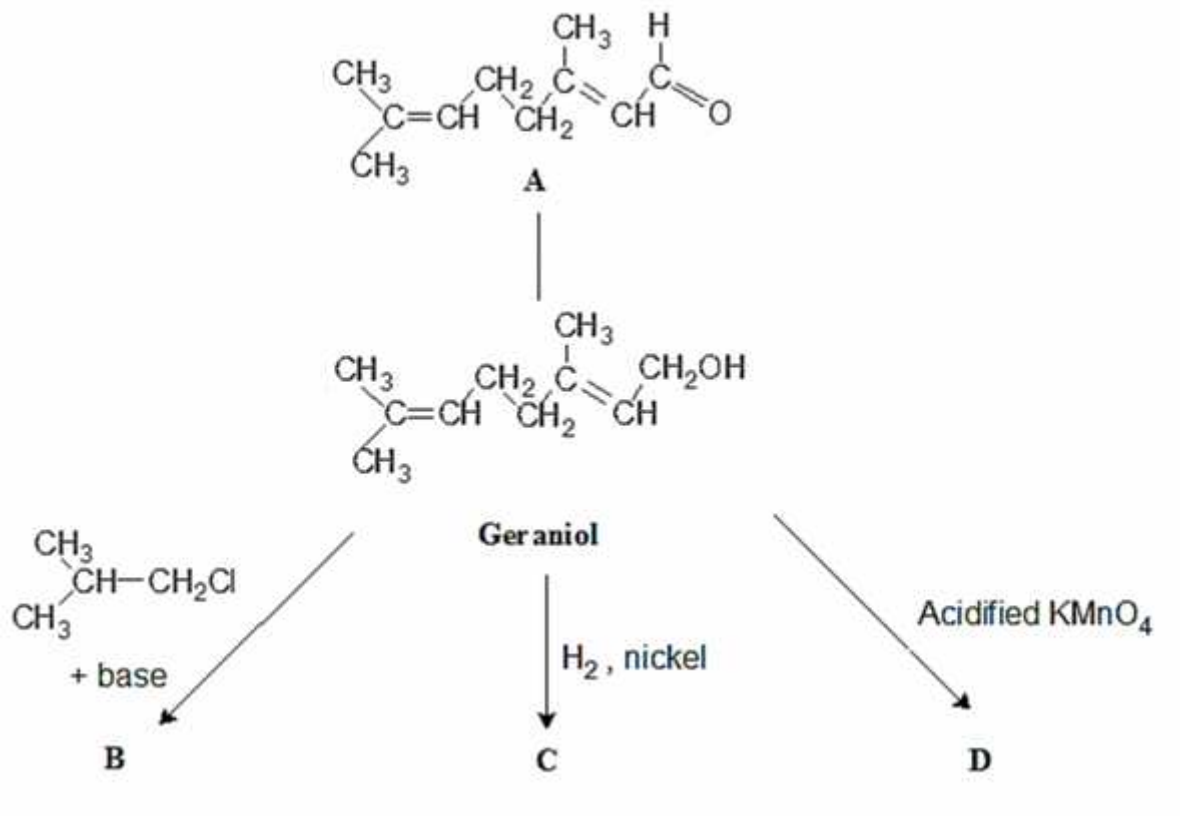
(i) Draw the structure of the geometric isomer, nerol.

(ii) Give the systematic name of geraniol.

(3 marks)

Please turn the page.

(c) Consider the following reaction scheme. In the spaces provided below give the structures of **B**, **C** and **D** and state the reaction conditions to synthesise geraniol from **A**.



B = _____

C = _____

D = _____

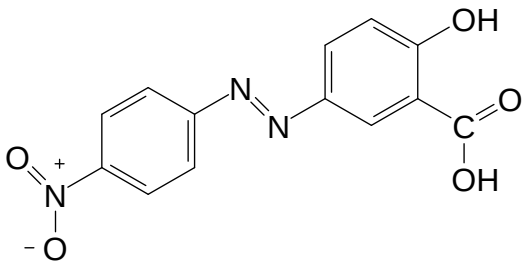
Conditions for **A** to geraniol: _____

(5 marks)

(d) Suggest the mechanism of the reaction of geraniol to give **B.**

(2 marks)
(Total: 11 marks)

9. Alizarin Yellow R (below), is a commonly used azo dye and can be synthesised from just two aromatic compounds.



Alizarin Yellow R

(a) Give the structures of the two compounds used for the synthesis of Alizarin Yellow R.

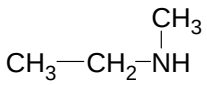
(2 marks)

(b) Give the reagents, conditions and intermediate of this reaction. Show these in a reaction scheme.

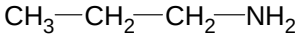
(3 marks)

Please turn the page.

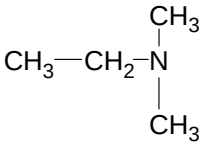
(c) Consider the following four molecules.



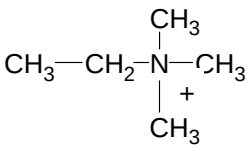
W



X



Y



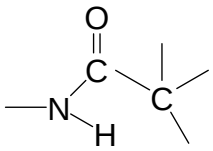
Z

(i) Identify the functional groups in the structures **W**, **X**, **Y** and **Z**, using terms such as "primary" or "secondary", etc., as appropriate for a full description.

(ii) Give reagents and experimental conditions to explain how substance **W** can be converted into **Y**.

(3 marks)

(d) Proteins have the following molecular feature as part of their polymeric structure.



(i) What is this molecular feature called?

(ii) Show how this molecular feature can be synthesised using **X** (above) and another substance and name the resulting product.

(3 marks)
(Total: 11 marks)

MATRICULATION AND SECONDARY EDUCATION CERTIFICATE EXAMINATIONS BOARD

UNIVERSITY OF MALTA, MSIDA

MATRICULATION EXAMINATION
ADVANCED LEVEL
MAY 2014

SUBJECT:	CHEMISTRY
PAPER NUMBER:	II
DATE:	7th May 2014
TIME:	9.00 a.m. to 12.00 noon

A Periodic Table is provided.

Answer two questions from each section and any other question.

Section A

1. Discuss each of the following statements; each part carries equal marks.

   (a) Ethoxyethane, butan-1-ol and butanal do not all exhibit hydrogen bonding.

   (b) Methylbenzene can undergo chlorination giving different compounds depending on conditions for the reaction.

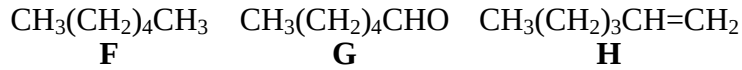
   (c) The reaction between an asymmetric alkene and HBr will give two different products in different amounts.

   (d) The carbon to carbon bond in the hydrocarbons ethane, ethene and ethyne involve different orbitals and result in molecules having different reactivities.

   (e) The structural isomers 1-hexanol and 1-Propanoxypropane can be distinguished by chemical means as well as mass spectrometry.

   (20 marks)

2. This question is about the following molecules:



F **G** **H**

   (a) Suggest a simple scheme based on test tube reactions which would allow you to distinguish between unlabelled samples of compounds F, G and H. Describe fully the observations you would make and give chemical equations to represent any changes.

   (5 marks)

   (b) Explain how infra-red spectroscopy of the unlabelled samples could be used to distinguish compound **G** from the hydrocarbons. (You are not required to give values of wavenumbers in your answer.)

   (1 mark)

   (c) Starting from **G** suggest a reaction scheme to produce **F** having produced **H** in the route. Give all inorganic reagents and reaction conditions.

   (5 marks)

   (d) Suggest, giving essential experimental detail, how **G** can be converted into (i) pentane; (ii) hexanenitrile.

   (9 marks)
   (Total: 20 marks)

3. Suggest explanations for each of the following, giving examples to illustrate your answers:

(a) In its compounds, fluorine exhibits an oxidation state of –1. However, the other halogens exhibit different oxidation states up to +7.

(4 marks)

(b) Lithium is the only alkali metal to react readily with nitrogen.

(3 marks)

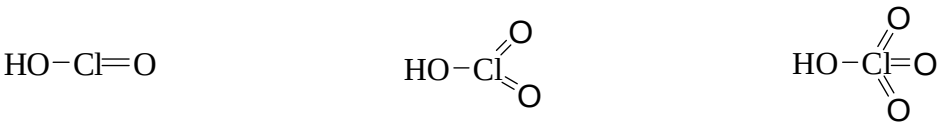
(c) Of the chlorides of the Group 2 elements only beryllium chloride is covalent.

(3 marks)

(d) Silicon tetrachloride is readily hydrolysed by water, but tetrachloromethane is not, in spite of the fact that energy would be liberated in each reaction.

(5 marks)

(e) Consider the following chloro acids:



(i) Draw canonical formulae for the species which form when chloric(III) and chloric(V) acids ionise.

(ii) In light of your answer to (i), suggest, giving reasons, which of the three acids is expected to be the strongest and the weakest.

(5 marks)
(Total: 20 marks)

4. (a) This question concerns a hydrated double salt A, $Cu_w(NH_4)_x(SO_4)_y.zH_2O$. Determine the formula of the double salt from the following experimental data:

(i) A sample of 2.00 g of salt A was boiled with excess sodium hydroxide and the ammonia expelled collected by absorption in 40 cm^3 of 0.5 mol dm^{-3} hydrochloric acid in a cooled flask. Subsequently this solution required 20 cm^3 of 0.5 mol dm^{-3} sodium hydroxide for neutralisation.

(ii) A second sample of 2.00 g of salt A was dissolved in water and treated with an excess of barium chloride solution. The mass of precipitate formed, after drying was found to be 2.33 g.

(iii) A third sample of 10 g of salt A was dissolved to give 250 cm^3 of solution. On heating 25 cm^3 of this solution with an excess of potassium iodide, iodine was formed equivalent to 25.0 cm^3 of 0.1 mol dm^{-3} sodium thiosulphate solution.
(Useful information $2Cu^{2+} + 4I^- \rightarrow 2\,CuI + I_2$, and $I_2 + 2\,S_2O_3^{2-} \rightarrow 2I^- + S_4O_6^{2-}$)

(17 marks)

(b) Account for the fact that, whereas Cu^{2+} ions are often coloured, the species involving Cu^+ ions are colourless.

(3 marks)
(Total: 20 marks)

Section B

5. (a) Give an account of the industrial manufacture of hydrogen. Your account should include the raw materials used, conditions for optimal yield and any environmental concerns. Name three uses of hydrogen in industry.

(5 marks)

(b) Describe, in outline, how small amounts of hydrogen can be produced in the laboratory, using the following materials: (i) sulfuric acid; (ii) calcium hydride; (iii) methanol.

(6 marks)

(c) Water is a very important hydride, which has particular physical properties. Which of these properties account for the difference in density between ice and liquid water, and why is it important in nature?

(3 marks)

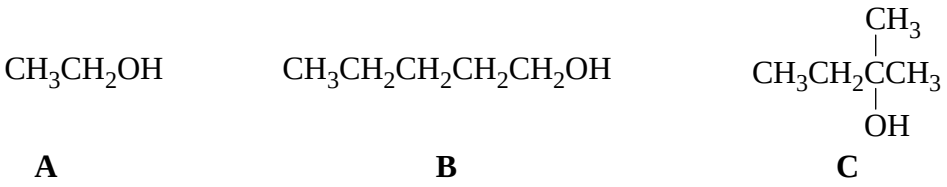
(d) (i) Hydrogen peroxide undergoes decomposition *catalysed* by the presence of small quantities of MnO_2. In the reaction, one of the elements undergoes *disproportionation*. Define the term *catalysed* and using the present reaction as an example illustrate what is meant by *disproportionation*.

(ii) Would you expect the same reaction by the addition of MgO instead of MnO_2? Explain your answer.

(iii) The reaction above is an example of heterogeneous catalysis. Mention a reaction which undergoes *homogeneous catalysis* naming all reactants and the catalyst involved.

(6 marks)
(Total: 20 marks)

6. Consider the following three molecules:



A **B** **C**

(a) List **A**, **B** and **C** in order of increasing boiling point and explain the reason for this increase.

(4 marks)

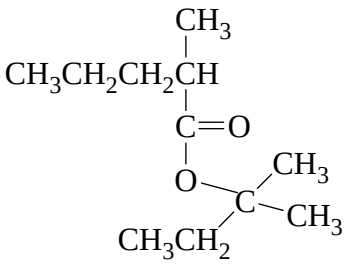
(b) (i) A mixture of **A**, **B** and **C** can be separated using fractional distillation. Explain why this technique is used in such separations instead of simple distillation.

(ii) Using a labelled diagram of the apparatus employed in fractional distillation, explain how this procedure works.

(iii) Explain why mixtures of ethanol and water cannot be separated through fractional distillation and explain why this procedure produces a mixture with a boiling point lower than that of both liquids.

(8 marks)

(c) Describe how you would obtain **D** using **TWO** of the compounds from **A-C**



D

(8marks)
(Total: 20 marks)

7. (a) A sample of liquid cyclohexanol (0.5060 g) undergoes complete combustion in a calorimeter set up. The calorimeter assembly has a heat capacity of 827.0 J/ °C and contains exactly 1000 grams of water of specific heat capacity 4.18 J /g °C. The initial temperature was measured as 24.98 °C and rose to 28.74 °C. Calculate the enthalpy change of combustion of cyclohexanol.

(9 marks)

(b) *Both the enthalpy change of a reaction and the entropy change are required in order to predict whether a reaction is energetically feasible or not.*

(i) Explain what is meant by *entropy change of a reaction* and give a suitable example of a reaction with a positive entropy change.
(ii) How can one predict the feasibility of a reaction from knowledge of the enthalpy change and entropy change of a reaction?
(iii) Explain how an endothermic reaction can become energetically feasible under certain conditions.
(iv) The change from diamond to graphite is energetically feasible yet this change appears not to occur at ambient temperatures. Explain this observation.

(11 marks)
(Total: 20 marks)

8. (a) The *rate equation* of a chemical reaction indicates how the rate of reaction is influenced, by the concentration of reactants; however, the *order* of the reaction with respect to each reactant in the rate equation is not necessarily the same as the stoichiometric coefficient of that reactant as it appears in the chemical equation. Rather, it is the *rate determining step* in the reaction mechanism which determines the order of reactants in the rate equation. The temperature alters the rate of reaction by affecting the *rate constant* in the rate equation.
Explain this paragraph using a suitable example.

(10 marks)

(b) Sketch a graph of how the concentration of a reactant varies with time and explain how you would use information from this graph to show that a reaction is 2^{nd} order with respect to the reactant.

(7 marks)

(c) A reaction is second order with respect to one reactant and first order with respect to another. Deduce the units of the rate constant.

(3 marks)
(Total: 20 marks)

MATRICULATION AND SECONDARY EDUCATION CERTIFICATE EXAMINATIONS BOARD
UNIVERSITY OF MALTA, MSIDA

MATRICULATION EXAMINATION
ADVANCED LEVEL
MAY 2014

SUBJECT:	CHEMISTRY
PAPER NUMBER:	III – *Practical*
DATE:	12th June 2014
TIME:	3 hours

There are three questions in this paper. Answer all questions.

1. In this experiment you are required to determine:
   i. the molar concentration of the sodium hydroxide in solution **S**,
   ii. the molar concentration of a solution of a metal hydrogenphthalate (MHP) labelled **P**,
   iii. the molecular mass of the **P** and hence the relative atomic mass of the metal **M**.

   You are provided with the following solutions:

   i. a solution (200 mL) of 0.10 M hydrochloric acid, labelled **H;**

   ii. a solution (200 mL) of sodium hydroxide of unknown concentration, labelled $\mathbf{S_n}$ (where n is your laboratory number)**;**

   iii. A solution of (200 mL) **P**, made by dissolving 31.26 g in a Litre of solution of a metal hydrogenphthalate, MHP, where **M** is an alkali metal;

   iv. Phenolphthalein indicator.

Lab Number: _____

*Determination of the concentration of solution **S***

(a) Fill the burette with solution **S**.

Titrate a 25.0 mL aliquot of **H** with solution **S** using phenolphthalein indicator. Record your reading in the table below. Repeat for concordant results.

	1st Titration	2nd Titration	3rd Titration
Initial burette reading (mL)			
Final burette reading (mL)			
Titre (mL)			

Mean titre: _____ mL

(b) Calculate the molar concentration of sodium hydroxide in solution **S**.

Determination of the relative molecular mass of the acid salt

(c) Fill the burette with solution **P**; titrate 25.0 mL aliquots of **S** with solution **P** using phenolphthalein indicator. Record your reading in the table below. Repeat for concordant results.

	1st Titration	2nd Titration	3rd Titration
Initial burette reading (mL)			
Final burette reading (mL)			
Titre (mL)			

Mean titre: _____ mL

(d) Calculate the relative molecular mass of the acid salt and hence determine the relative atomic mass of the metal **M**. The general formula of **P** is $C_8H_5O_4M$.

(50 marks)

Please turn the page.

2. You are provided with a substance labelled **D**. Carry out the tests as described below, record your observations and attempt to identify the compound.

(a) Dissolve about 0.5 g of substance **D** in about 10 mL of water. Warm the mixture gently if necessary. *Retain this solution for subsequent tests.*

Observation	*Inference*

(b) To about 1 mL of the solution prepared in test (a), add aqueous sodium hydroxide dropwise at first, and then in excess.

Observation	*Inference*

(c) To about 1 mL of the solution prepared in test (a), add aqueous ammonia dropwise at first, and then in excess.

Observation	*Inference*

(d) To about 1 mL of the solution prepared in test (a), add 3 drops of dilute hydrochloric acid. Carefully heat the mixture to boiling, followed by cooling under running water.

Observation	*Inference*

(e) To about 0.2 g of substance **D** held in a boiling tube or small beaker, add **two** drops of concentrated sulfuric acid and heat vigourously. Remove the tube away from the heat and carefully note any odours evolved.

Observation	*Inference*
_____	_____
_____	_____
_____	_____

Conclusion

Salt **D** is probably: _____

(25 marks)

Please turn the page.

3. You are provided with an organic substance labelled **G**. Carry out the tests as described below, record your observations and attempt to identify the compound.

(a) Add about 0.1 g of substance **G** to about 3mL of water and shake; heat if necessary to dissolve the solid, and test the solution with litmus paper.

Observation	*Inference*

(b) Add 1 mL of neutral iron (III) chloride solution to a few crystals of substance **G**.

Observation	*Inference*

(c) Dissolve about 0.1 g of sodium nitrite in about 1 mL of water and cool the solution in ice bath. Add about 0.2 g of substance **G** and shake the mixture.

Observation	*Inference*

(d) Add about 0.3 g of substance **G** to 2 mL of 4 M sodium hydroxide in a boiling tube and heat carefully. Test for any gases evolved. *Retain the reaction mixture for the next test.*

Observation	*Inference*

(e) To the products of test (d) add concentrated hydrochloric acid *dropwise* until no further change is observed. *Retain the reaction mixture for the next test.*

Observation	*Inference*

(f) Use a Pasteur pipette to remove as much of the supernatant as possible from the reaction mixture from test (e). Add 1 mL of methanol followed by 2 drops of concentrated sulfuric acid and heat in a boiling water bath for 3 minutes. Place approximately 10 mL of 10% sodium carbonate in a beaker and carefully pour the contents of the boiling tube into the beaker, noting any odours.

Observation	*Inference*

Conclusion

A possible structure for **G** is: _____

(25 marks)

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