Chemistry II

014

11/11/ 2016 08.30am - 11.30am

REB
Rwanda Education Board

ADVANCED LEVEL NATIONAL EXAMINATIONS, 2016

SUBJECT: CHEMISTRY

PAPER II: THEORY

COMBINATIONS: - BIOLOGY-CHEMISTRY-GEOGRAPHY (BCG)
- MATHEMATICS-CHEMISTRY-BIOLOGY (MCB)
- PHYSICS-CHEMISTRY-BIOLOGY (PCB)
- PHYSICS-CHEMISTRY-MATHEMATICS (PCM)

DURATION: 3 HOURS

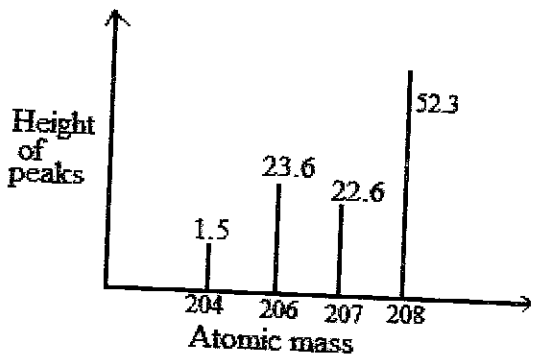
INSTRUCTIONS:

1. Do not open this question paper until you are told to do so.
2. Write your names and index number on the answer booklet as written on your registration form and **DO NOT** write your names and index number on additional answer sheets of paper if provided.
3. This paper consists of two sections: **A** and **B**.
   - **Section A**: Attempt **all** questions. **(70marks)**
   - **Section B**: Attempt any **three** questions. **(30marks)**
4. You do not need the **Periodic Table.**
5. Silent non-programmable calculator may be used.
6. Use a **blue** or **black** pen.

SECTION A: ATTEMPT ALL QUESTIONS. **(70marks)**

1) (a) Describe the term "isotopes" of an element. **(2marks)**

(b) The figure below shows the mass spectrum of lead (Pb). The heights of the peaks and the mass numbers of the isotopes are shown on the figure.
Calculate the relative atomic mass of lead. **(3marks)**



2) If $^{226}_{88}Ra$ undergoes a series of decays in which five α and four β particles are produced, what would be the final product? **(4marks)**

3) Aluminium oxide Al_2O_3, reacts readily with sodium hydroxide (NaOH) in the presence of water (H_2O) to produce sodium aluminate.

(a) Write a balanced equation of the reaction between Al_2O_3 and NaOH in the presence of H_2O. **(2marks)**

(b) Determine the mass of $NaAl(OH)_4$ produced when 4.5g of Al_2O_3 react completely with aqueous sodium hydroxide. **(2marks)**
(Atomic mass: Al=27, Na=23, O=16, H=1)

4) Methyl propan-1-ol and butan-1-ol are structural isomers.
(a) Explain the reason why methyl propan-1-ol has a lower boiling point than butan-1-ol. **(2marks)**

(b) State a reagent that can be used to distinguish the two isomers and the expected observable changes. **(2marks)**

(c) Write the structural formula of the two isomers. **(2marks)**

5) The solubility product (Ksp) of CaF_2 in pure water is 3.2×10^{-11} at 25^0C.

(a) Calculate the molar solubility of CaF_2 in pure water at 25^0C. **(3marks)**

(b) Calculate the mass (in g) of CaF_2 present in 200 ml of its saturated solution. **(2marks)**

Equation:

$CaF_{2\,(s)} \rightleftharpoons Ca^{2+}_{(aq)} + 2F^-_{(aq)}$

(Molar mass: Ca = 40, F =19)

6) (a) Complete combustion of 50 cm^3 of a saturated hydrocarbon vapour gave 350 cm^3 of carbon dioxide gas. Both gas volumes being measured at the same temperature and pressure.
Determine the molecular formula of the hydrocarbon. **(3marks)**

(b) A buffer solution with pH of 4.0 is made using benzene carboxylic acid and sodium benzene carboxylate.
Calculate the mass of sodium benzene carboxylate (molecular mass = 144) that should be dissolved in 1.0 dm^3 of a 0.012 mol dm^{-3} solution of benzene carboxylic acid to produce a buffer solution with pH of 4.0. **(3marks)**
(Ka for $C_6H_5COOH = 6.31 \times 10^{-5}$ mol dm^{-3})

7) (a) Copper is a metal with a high melting point.
(i) Indicate the block in the periodic table that contains copper. **(1mark)**
(ii) Explain in terms of its structure and bonding why copper has a high melting point. **(2marks)**
(iii) Explain why copper is ductile (can be stretched into wires). **(2marks)**

(b) Copper forms the compound copper I chloride (CuCl)
Write the full electronic configuration of Cu^+ ion
(in terms of s, p, d and f notation). **(1mark)**
(Atomic number: Cu =29)

8) The table below shows the electronegativity values of some elements.

Element	H	Li	B	C	O	F
Electronegativity	2.1	1.0	2.0	2.5	3.5	4.0

Describe the meaning of the term "electronegativity". **(2marks)**

(a) Suggest the formula of an ionic compound that is formed by the chemical combination of two different elements from the table. **(1mark)**

(b) Suggest the formula of the compound that forms the strongest hydrogen bonds and is formed by chemical combination of two of the elements from the table.

9) (a) State the name of the shape of boron trichloride, BCl_3. **(1mark)**

(b) Aluminium chloride dissolves in water to give Al^{3+} ions that hydrolyze H_2O molecules. **(1mark)**

(i) Write a balanced equation for the hydrolysis of H_2O by Al^{3+} ions. **(2marks)**

(ii) State 2 uses of aluminium metal on a large scale. **(2marks)**

(Atomic number: B=5, Cl=17)

10) (a) Define the term "first ionization energy" of an element. **(2marks)**

(b) The elements nitrogen and phosphorous are found in group Va of the periodic table.

(i) Explain the trend in first ionization energy as you move down the group. **(2marks)**

(ii) Explain the reason why P forms chlorides of PCl_3 and PCl_5 but N forms NCl_3 only. (Atomic number: N=7, P= 15, Cl=17) **(2marks)**

11) Distillation of crude oil is effected to separate different components.

(a) Describe the principle that is based on during separation of oil components by fractional distillation. **(2marks)**

(b) What name is given to the process of breaking down long chain hydrocarbons into smaller molecules? **(1mark)**

(c) Describe the term "catalytic reforming" of alkanes. **(2marks)**

(d) State the name of a pollutant substance that is present in unsafe petrol. **(1mark)**

12) An organic compound, Y containing 0.0173g by mass was mixed with 0.42g of camphor to form a homogeneous mixture melting at 170 ^{0}C. Determine the molecular mass of the organic compound Y. **(3marks)**

(Melting point of pure camphor is 178.4 ^{0}C; freezing point depression constant of camphor, K_f =37.7 ^{0}C/m; m= number of moles of solute/1Kg of solvent).

13) Balance the following redox reaction by first establishing half redox equations of $Mn^{2+}$and BiO_3^-, then give the overall equation: **(3marks)**

$Mn^{2+} + BiO_3^- + H^+ \longrightarrow MnO_4^- + Bi^{3+} + H_2O$

14) Nickel-Cadmium cells are used to power electrical equipments such as drills and shavers.

The electrode reactions are shown below:

$NiO_2 + 2H_2O + 2e \longrightarrow Ni(OH)_2 + 2OH^-$ $\quad E^\theta = +0.52$ V

$Cd + 2OH^- \longrightarrow Cd(OH)_2 + 2e$ $\quad E^\theta = -0.88$ V

(a) Calculate the standard e.m.f of a Nickel-Cadmium cell. **(2marks)**

(b) Deduce the overall equation for the reaction that occurs in the cell when it is used. **(2marks)**

15) Determine the values for a, b, c and d in the equations: **(3marks)**

(a) ${}^{35}_{17}Cl + {}^{1}_{0}n \longrightarrow {}^{a}_{b}X + {}^{1}_{1}H$

(b) ${}^{7}_{3}Li + {}^{2}_{1}H \longrightarrow {}^{c}_{d}Y + {}^{1}_{0}n$

SECTION B: ATTEMPT ANY THREE QUESTIONS. (30MARKS)

16) (a) The initial rate of reaction between ester A and aqueous sodium hydroxide was measured in a series of experiments at constant temperature. The data obtained are shown below:

Experiment	Initial concentration of NaOH (mol dm^{-3})	Initial concentration of A (mol dm^{-3})	Initial rate (mol $dm^{-3}s^{-1}$)
1	0.040	0.030	4.0×10^{-4}
2	0.040	0.045	6.0×10^{-4}
3	0.060	0.045	9.0×10^{-4}
4	0.120	0.060	To be calculated

(i) Use the data in the table to deduce the order of reaction with respect to A and the order of reaction with respect to NaOH. **(3marks)**

(ii) Determine the value of the rate constant K for the reaction. **(1mark)**

(iii) Calculate the initial rate of reaction in experiment 4. **(2marks)**

(b) In a further experiment at a different temperature, the initial rate of reaction was found to be 9.0×10^{-3} mol $dm^{-3}s^{-1}$ when the initial concentration of A was 0.020 mol dm^{-3} and the initial concentration of NaOH was 2.00 mol dm^{-3}.

Under these new conditions with the much higher concentration of NaOH, the reaction is first order with respect to A and appears to be zero order with respect to NaOH.

(i) Write a rate equation for the reaction under these new conditions. **(1mark)**

(ii) Calculate a value for the rate constant under these new conditions and state its units. **(2marks)**

(iii) Describe the nature of a "zero order" reaction. **(1mark)**

17) A student carried out an experiment on a pure sample of 2-methyl propan-2-ol, $(CH_3)_3COH$) to determine its enthalpy of combustion. A sample of the alcohol was placed into a spirit burner to heat 50 cm^3 of water. The spirit burner was ignited and allowed to burn for several minutes. The results for the experiment are shown in the table below:

Initial temperature of water /^{0}C	18.1
Final temperature of water /^{0}C	45.4
Initial mass of spirit burner and alcohol /g	208.80
Final mass of spirit burner and alcohol /g	208.58

(a) Calculate the value for the heat energy absorbed by 50 cm^3 water to be raised from 18.1^{0}C to 45.4 ^{0}C. **(2marks)**
(The specific heat capacity of water is 4.18 $JK^{-1}g^{-1}$)
(The density of water = 1g cm^{-3})

(b) Calculate the number of moles of 2-methyl propan-2-ol burned in the experiment. **(3marks)**
(Atomic mass: C =12, O =16, H =1)

(c) Calculate a value, in KJ mol^{-1} for the enthalpy of combustion of one mole of 2-methyl propan-2-ol (experiment value). **(3marks)**
(If you are unable to calculate the answer for17.a), you should assume that the heat energy released by 2-methyl propan-2-ol was 5580 J)

(d) Equation for the combustion of 2-methyl propan-2-ol is:

$$(CH_3)3COH_{(l)} + 6O_{2(g)} \longrightarrow 4CO_{2(g)} + 5H_2O_{(l)}$$

The table below contains some standard enthalpy of formation data.

Substance	$(CH_3)_3COH_{(l)}$	$O_{2(g)}$	$CO_{2(g)}$	$H_2O_{(l)}$
ΔH^{θ}_f KJmol^{-1}	-360	0	-393	-286

Using the data given above in the table:
Calculate the value for the standard enthalpy of combustion of 2-methyl propan-2-ol (theoretical value). **(2marks)**

18) (a) Sea water is a major source of iodine. The iodine extracted from sea water is impure. It is purified in a two-stage process.

Stage 1: $I_2 + 2H_2O + SO_2 \longrightarrow 2HI + H_2SO_4$.

Stage 2: $2HI + Cl_2 \longrightarrow I_2 + 2HCl$

(i) Deduce the oxidation state of sulphur in SO_2 and in H_2SO_4. **(2marks)**

(ii) State in terms of electrons, what has happened to chlorine in stage 2. **(1mark)**

(b) When concentrated sulphuric acid is added to potassium iodide, iodine is formed in the following redox equations.

$KI + H_2SO_4 \longrightarrow KHSO_4 + I_2 + S + H_2O$

$8KI + 9\ H_2SO_4 \longrightarrow 8\ KHSO_4 + 4\ I_2 + H_2S + 4H_2O$

(i) Balance the equation for the reaction that forms sulphur, S. **(2marks)**

(ii) Deduce the half-equation for the formation of iodine (I_2) from iodide ions. **(2marks)**

(iii) Deduce the half-equation for the formation of hydrogen sulphide (H_2S) from concentrated sulphuric acid. **(2marks)**

(c) A yellow precipitate is formed when silver nitrate solution ($AgNO_{3(aq)}$), acidified with dilute nitric acid is added to an aqueous solution containing iodide ions.
State what is observed when concentrated ammonia solution is added to this yellow precipitate. **(1mark)**

19) (a) Acid strength of hydrogen halides (group VII halides) increases down the group.

(i) Describe the term "acid" according to Lowry- BrÖnsted theory. **(2marks)**

(ii) Explain the reason why HBr is a stronger acid than HCl. (Atomic number : Cl = 17, Br = 35) **(2marks)**

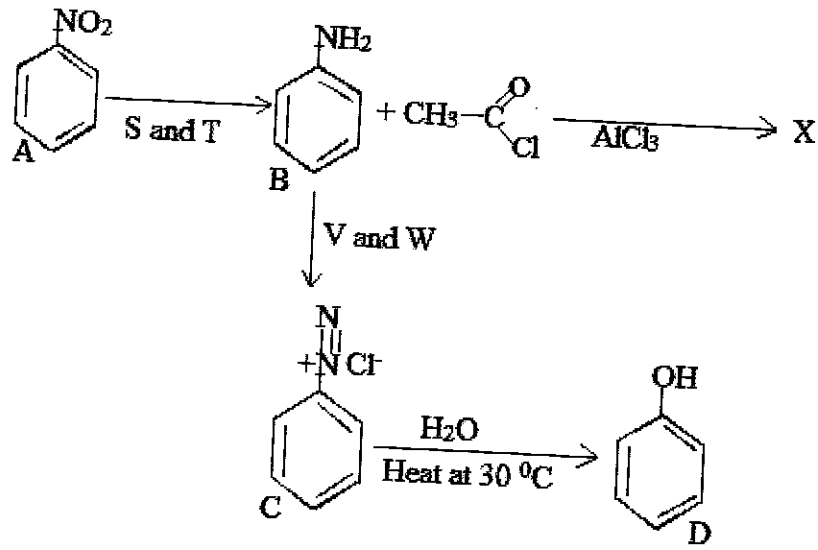
(b) (i) Define the term "Lewis acid". **(2marks)**

(ii) Write the chemical formula of 2 Lewis acids. **(1mark)**

(c) (i) Explain the reason why ethyl amine, $CH_3CH_2NH_2$ is a stronger base than ammonia, NH_3 . **(2marks)**

(ii) State 2 important uses of buffer solutions on a large scale. **(1mark)**

20) Study the diagram of benzene derivatives illustrated below and answer the questions that follow.



(a) Write the names or the chemical formulae of reagents S and T which are required to transform A into B. **(2marks)**

(b) Draw the structure of the organic compound X. **(1mark)**

(c) Write the name or the chemical formula of reagents V and W. **(2marks)**

(d) Give the scientific name of the organic compound D. **(1mark)**

(e) State 1 physical property of the organic compound D. **(1mark)**

(f) State a test (reagent) that can be used to differentiate organic compound B and amino butane ($CH_3CH_2CH_2CH_2NH_2$) and describe the observation of the reaction for each compound. **(3marks)**