THE UNITED REPUBLIC OF TANZANIA
NATIONAL EXAMINATIONS COUNCIL OF TANZANIA
ADVANCED CERTIFICATE OF SECONDARY EDUCATION EXAMINATION

132/1 **CHEMISTRY 1**

(For Both School and Private Candidates)

Time: 3 Hours **Tuesday, 07th May 2019 p.m.**

Instructions

1. This paper consists of sections A, B and C with a total of **fourteen (14)** questions.
2. Answer **four (4)** questions from section A and **three (3)** questions from each of sections B and C.
3. Each question carries **ten (10)** marks.
4. Mathematical tables and non-programmable calculators may be used.
5. Cellular phones and any unauthorized materials are **not** allowed in the examination room.
6. Write your **Examination Number** on every page of your answer booklet(s).
7. For calculations you may use the following constants:
   - Rydberg constant $R_H = 1.09678 \times 10^7\ m^{-1}$
   - Gas constant, $R = 8.31\ Jmol^{-1}\ K^{-1}$ or $0.0821\ atm\ mol^{-1}\ K^{-1}\ dm^3$
   - GMV = $22.4\ dm^3$
   - Standard temperature = 273 K
   - Standard pressure = 760 mmHg
   - Planck's constant, $h = 6.63 \times 10^{-34}\ Js$
   - Velocity of light, $c = 3.0 \times 10^8\ m/s$
   - Mass of an electron = $9.11 \times 10^{-31}\ kg$.

SECTION A (40 Marks)

Answer **four (4)** questions from this section.

1. (a) Use s, p, d, f notation to designate atomic orbitals with the given pairs of quantum numbers n and l.
   (i) $n = 2$ and $l = 1$.
   (ii) $n = 3$ and $l = 2$.
   (iii) $n = 4$ and $l = 3$.
   (iv) $n = 3$ and $l = 0$. **(2 marks)**

   (b) For the following sets of quantum numbers, state which are allowable and which are not allowable. Briefly explain your answer.
   (i) $n = 2;\ 1 = 2;\ m_l = 0;\ m_s = +\frac{1}{2}$.
   (ii) $n = 3;\ l = 1;\ m_l = 0;\ m_s = -\frac{1}{2}$.
   (iii) $n = 1;\ l = 0;\ m_l = +1;\ m_s = +\frac{1}{2}$.
   (iv) $n = 3;\ l = 2;\ m_l = +2;\ m_s = -\frac{1}{2}$.
   (2 marks)

   (c) Define the following phrases:
   (i) Atomic number.
   (ii) Mass number. **(1 mark)**

   (d) A nucleus of certain element is presented as $^{58}_{27}X$. What is the number of electrons and neutrons in atom X ? Show your work clearly. **(1 mark)**

   (e) Clearly state four postulates of Planck's quantum theory as derived from black body radiation. **(4 marks)**

2. (a) Sketch a hydrogen spectral series based on Bohr atom energy level. **(2 marks)**

   (b) (i) How does a mass spectrograph of a pure element is used to detect the presence of isotopes? **(1 mark)**
   (ii) The following data were obtained for a certain pure element:

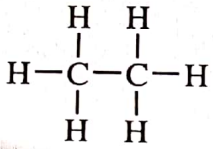
Isotope	Mass of isotope	Natural abundance (%)
1	28.0	92.0
2	29.0	5.0
3	30.0	3.0

   Calculate the relative atomic mass of an element. **(2 marks)**

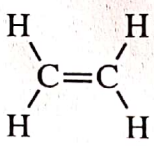
   (c) (i) Use wave and particle models for energy of a particle to derive the de Broglie equation. **(3 marks)**

(ii) Calculate the wavelength of an α-particle having mass of 6.6×10^{-27} kg moving with a speed of 10^5 cm s^{-1}. Show your work clearly including manipulations of units. **(2 marks)**

3. (a) Use the following chemical structures of ethane and ethene molecules to answer the questions that follow.



ethane



ethene

(i) What are the hybridizations of carbon atoms in each compound? **(1 mark)**

(ii) Use well labeled diagrams to describe types of C-C bonds in each compound. **(3 marks)**

(iii) In ethane molecule, each C-H has a bond length of 1.09 Å and C-C has bond length of 1.54 Å. Briefly explain this observation. **(0.5 mark)**

(vi) The C-C double bond in ethene (bond length 1.34 Å) is shorter than C-C single bond in ethane (bond length 1.54 Å). Briefly explain this observation. **(0.5 mark)**

(b) In chemical bond formation, the ionization enthalpy and electron affinity are involved. Briefly describe how:

(i) Ionic bond formation is favoured by ionization enthalpy and electron affinity.

(ii) Covalent bond formation is favoured by ionization enthalpy and electron affinity. **(2 marks)**

(c) Briefly describe the following phrases. Give one example of a chemical structure for each:

(i) Hydrogen bond.

(ii) Coordinate covalent bond. **(3 marks)**

4. (a) (i) State Raoult's law regarding solutions of liquids in liquids. **(1 mark)**

(ii) Define azeotropic mixture. **(1 mark)**

(iii) Use a well labeled hand sketch to show the difference between minimum boiling point azeotropic mixture and maximum boiling point azeotropic mixture. **(2 marks)**

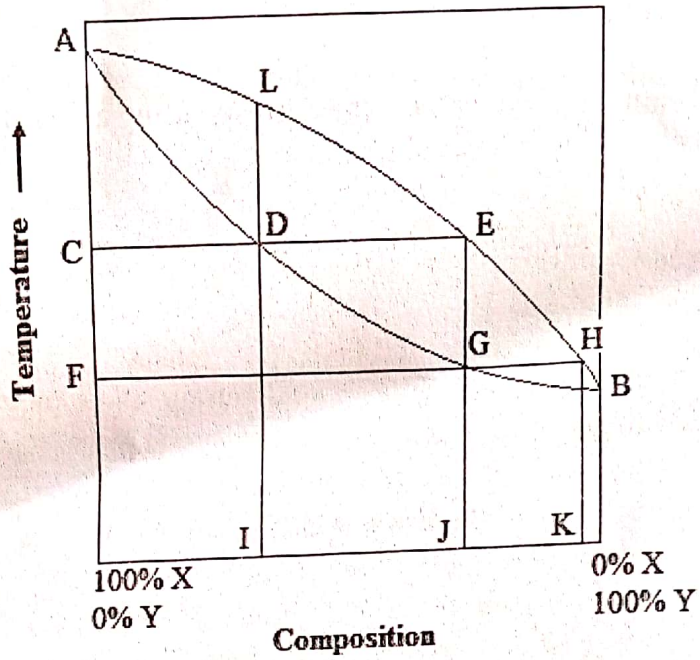
(b) Briefly explain the meaning of the following phrases:

(i) Freezing point depression.

(ii) Boiling point elevation.

(iii) Van't Hoff's factor-*i*. **(3 marks)**

(c) Study the following liquid-vapour phase diagram and then answer the questions that follow.



(i) If a liquid mixture of composition **I** is heated to temperature **C**, what will be the composition of the vapour phase? **(1 mark)**

(ii) If the vapour at **E** is cooled to temperature **F**, what will be the composition of the vapour phase? **(1 mark)**

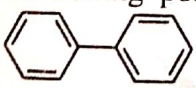
(iii) What temperature represents the boiling point of composition **J**? **(1 mark)**

5. (a) (i) Boiling point of a solvent is elevated by addition of a non-volatile solute. Briefly explain. **(1 mark)**

(ii) Arrange the following aqueous solutions in order of increasing freezing point: 0.01 M C_2H_5OH; 0.01 M $Ba_3(PO_4)_2$; 0.01 M Na_2SO_4; 0.01 M KCl; 0.01 M Li_3PO_4. Provide clear reason(s) for the arrangement. **(2 marks)**

(b) You are provided with the following information:

Entry	Value
Molal boiling point constant for benzene, K_b	2.53 °C kg mol^{-1}
Molal freezing point constant for benzene, K_f	5.12 °C kg mol^{-1}
Boiling point of benzene	80.1 °C
Freezing point of benzene	5.5 °C

Calculate the boiling point and freezing point of a solution made by dissolving 2.40 g of biphenyl,  , in 75.0 g of benzene,  . Show your work clearly including manipulations of units. **(3 marks)**

(c) An aqueous solution of urea, $CO(NH_2)_2$ at a concentration of 1.754 g dm^{-3} is isotonic at the same temperature with an aqueous solution of sugar at a concentration of 10.00 g dm^{-3}. Calculate the relative molecular mass of sugar. **(4 marks)**

6. (a) Briefly explain the following phrases, giving one example for each:
(i) Reversible reaction. **(1 mark)**
(ii) Heterogeneous equilibrium. **(1 mark)**

(b) (i) State the equilibrium law and provide the corresponding expression. **(2 marks)**
(ii) List four characteristics of chemical equilibrium. **(2 marks)**
(iii) Write the expression for the equilibrium constant, K_c, for the equation:

$$Cu(s) + 2Ag^+(aq) \rightleftharpoons Cu^{2+}(aq) + 2Ag(s)$$ **(0.5 mark)**

(c) The equilibrium equation for the oxidation of hydrogen chloride to chlorine is: $4HCl(g) + O_2(g) \rightleftharpoons 2Cl_2(g) + 2H_2O(g)$. In a certain experiment, 0.80 moles of hydrogen chloride was mixed with 0.20 moles of oxygen in a closed vessel of capacity 10.00 dm^3. At equilibrium, it was found that the mixture contained 0.20 moles of hydrogen chloride. Calculate the equilibrium constant, K_c, for the reaction. Show your work clearly including manipulations of units. **(3.5 marks)**

SECTION B (30 Marks)

Answer **three (3)** questions from this section.

7. (a) Use the kinetic gas equation to explain the following concepts:
(i) The pressure exerted by an ideal gas increases when it is heated at constant volume.
(ii) The volume occupied by an ideal gas increases when it is heated at constant pressure. **(4.5 marks)**

(b) A flammable gas made up of only carbon and hydrogen is generated by certain anaerobic bacteria in sewage drains. A pure sample of a gas was found to effuse through a certain porous barriers in 1.50 minutes. Under the same conditions of temperature and pressure it takes 4.73 minutes for an equal volume of bromine gas to effuse through the same barrier. Calculate the molar mass of the unknown gas and suggest the name of the gas. (Molecular mass of bromine = 159.8 g/m) **(2 marks)**

(c) In the determination of the molecular weight of chloroform vapour by Hofmann's method, the following results were obtained:
Weight of liquid in bulb = 0.2704 g; Volume of vapour = 110 cm^3; Temperature of vapour = 99.6 °C; Atmospheric pressure = 747 mmHg; Vapour pressure of water vapour at 99.6 °C = 285.2 mmHg. Calculate the relative molecular weight of chloroform if 1 dm^3 of H_2 at S.T.P. weighs 0.09 g. In your calculations, show your work clearly including manipulations of units. **(3.5 marks)**

8. (a) State the following gas laws, then provide their mathematical expressions:
(i) Boyle's law.
(ii) Charles' law.
(iii) Graham's law.
(iv) Dalton's law of partial pressures. **(2 marks)**

(b) State five assumptions of the kinetic theory of gasses. **(2.5 marks)**

(c) 50 cm^3 of carbon dioxide at 1×10^5 Nm^{-2} are mixed with 150 cm^3 of hydrogen at the same pressure. If the pressure of the mixture is 1.0×10^5 Nm^{-2}, calculate the partial pressure of hydrogen gas. **(2.5 marks)**

(d) In 5 minutes, 15 cm^3 of argon effuse through a pinhole. What volume of xenon will effuse through the same pinhole under the same condition? [Atomic masses: Ar = 39.95, Xe = 131.29] **(3 marks)**

9. (a) The enthalpy for the formation of ammonia, $NH_3(g)$, under standard conditions is -46.2 kJ mol^{-1}. Calculate the enthalpy for the reaction $2NH_3(g) \rightarrow N_2(g) + 3H_2(g)$. **(1.5 marks)**

(b) Study carefully the following chemical reactions, and then answer the questions that follow:

$\frac{1}{2}N_2(g) + \frac{1}{2}O_2(g) \rightarrow NO(g) \quad \Delta H_r^\circ = +90 \text{ kJ mol}^{-1}$.

$NO_2(g) \rightarrow \frac{1}{2}O_2(g) + NO(g) \quad \Delta H_r^\circ = +74 \text{ kJ mol}^{-1}$.

(i) Calculate the enthalpy for the reaction $N_2(g) + 2O_2 \rightarrow 2NO_2(g)$. **(1.5 marks)**

(ii) Which of the two species $NO_2(g)$ and $NO(g)$ is more thermodynamically stable? **(1.5 marks)**

(c) At 25 °C, the dissociation energies of $H_2(g)$ and Cl_2 are +435.4 kJ mol^{-1} and +243 kJ mol^{-1} respectively. The enthalpy of formation of HCl(g) is -92.2kJ mol^{-1}. Calculate the dissociation energy for HCl(g) **(4 marks)**

(d) Use the given average bond enthalpies to calculate the change in enthalpy, ΔH_r, for the reaction: $C_3H_8 + 5O_2(g) \rightarrow 3CO_2(g) + 4H_2O(g)$.

Bond	Enthalpy
C – H	= 414 kJ mol^{-1}
C – C	= 347 kJ mol^{-1}
C = O	= 741 kJ mol^{-1}
H – O	= 464 kJ mol^{-1}
O = O	= 498 kJ mol^{-1}
C – O	= 335 kJ mol^{-1}
O – O	= 138 kJ mol^{-1}

(1.5 marks)

10. (a) Define the following phrases as applied in energetics concept in chemistry:
(i) Heat (enthalpy) of formation.
(ii) Standard enthalpy of formation.
(iii) Heat (enthalpy) of fusion.
(vi) Heat (enthalpy) of neutralization. **(2 marks)**

(b) (i) State Hess's law of constant heat summation. **(1 mark)**

(ii) Given a hypothetical reaction $aA + bB \rightarrow cC + dD$, where A, B, C and D are compounds and a, b, c and d are stoichiometric values, determine an expression for enthalpy change $\Delta_r H^\circ$ of the reaction. **(2 marks)**

(c) The standard heat of combustion of ethanol, $\Delta_c H^\circ = -1386\ \text{kJ mol}^{-1}$. The standard heat of formation of carbon dioxide, $\Delta_f H^\circ(CO_2) = -393\ \text{kJ mol}^{-1}$, and standard heat of formation of water, $\Delta_f H^\circ(H_2O) = -287\ \text{kJ mol}^{-1}$: Calculate the standard heat (enthalpy) of formation of ethanol. **(2.5 marks)**

(d) The following data were obtained for Born-Haber cycle formation for one mole of crystalline NaCl.

Step	Heat (Enthalpy)
Sublimation of Na metal to gaseous Na atoms.	$\Delta_{sub}H^\circ = +107.3\ \text{kJ mol}^{-1}$
Ionization of gaseous Na atoms to Na^+ ions and e^-	$\Delta_I H^\circ = +495.8\ \text{kJ mol}^{-1}$
Formation of $Cl^-(g)$ by addition of e^- to Cl(g)	$\Delta_{eg}H^\circ = -348.6\ \text{kJ mol}^{-1}$
Formation of NaCl crystals from Na^+ and Na^+	$\Delta_L H^\circ = -787.3\ \text{kJ mol}^{-1}$

In a single step, $Na(s) + \frac{1}{2}Cl_2 \rightarrow NaCl$, it was found that $\Delta_f H^\circ(NaCl, \text{crystal}) = -412.3\ \text{kJ mol}^{-1}$. Calculate heat (enthalpy) of dissociation of one mole of Cl_2 gas. **(2.5 marks)**

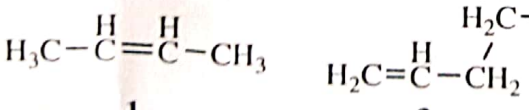
SECTION C (30 Marks)

Answer **three (3)** questions from this section.

11. (a) Suggest suitable tests to distinguish the following pairs of compounds:
(i) Chlorobenzene and (chloromethyl)benzene. **(1 mark)**
(ii) Cyclopentene and pent-2-yne. **(0.5 mark)**
(iii) Chloroform and carbon tetrachloride. **(0.5 mark)**

(b) (i) State and illustrate the type of hybridization at the functional group carbons in alkenes and alkynes. **(1.5 marks)**
(ii) Arrange the compounds (ethane, ethene, ethyne and benzene) in order of increasing acidic strength, *i.e.*, starting with less acidic. **(0.5 mark)**
(iii) Use sp^3, sp^2 or sp hybridized orbitals to differentiate sigma (σ)-bond and pie (π)-bond. **(1 mark)**

(c) You are provided with the hydrocarbons represented by the following molecular formulae:



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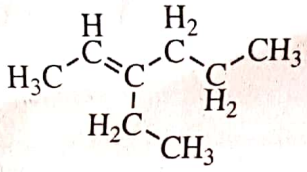
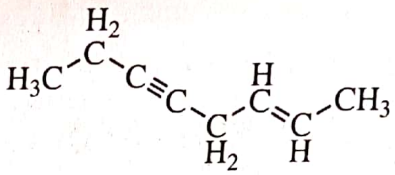
(i) Give systematic names for the hydrocarbons. **(1 mark)**
(ii) State how each hydrocarbon reacts with hydrogen bromide and give the corresponding systematic names for the products. **(1 mark)**

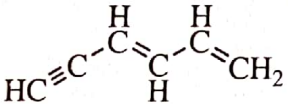
(d) Propene reacts with hydrogen bromide following Markovnikov's rule to give a substance **A**. When substance **A** is heated in the presence of potassium hydroxide, an alcohol **B** is formed.
(i) Deduce the chemical structures of substances **A** and **B**. **(1 mark)**
(ii) By referring to the reaction of substance **A** with potassium hydroxide under stated condition, illustrate the meaning of the terms "base" and "nucleophile". **(2 marks)**

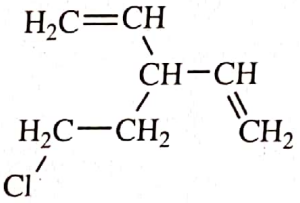
12. (a) (i) Define the term isomerism. **(0.5 mark)**
(ii) Pentane has three isomers. Draw their chemical structures and provide their corresponding IUPAC names. **(1.5 marks)**

(b) Give the IUPAC names of the following organic compounds:

(i) 

(ii) 

(iii) 

(iv) 

(2 marks)

(c) Compound **A** is known to be aromatic and contains 66.4% carbon, 5.5% hydrogen and 28.1% chlorine by mass. The vapour density of pure **A** was found to be 63.
(i) Find the empirical formula of compound **A**. **(1 mark)**
(ii) Find the relative molecular formula of compound **A**. **(1 mark)**
(iii) Give the chemical structures of the four isomers of compound **A** and their corresponding IUPAC names. **(2 marks)**
(iv) Which of the isomers of compound **A** will react with dilute KOH. Briefly explain your answer. **(2 marks)**

13. (a) Write all the isomers of C_5H_{12}. **(1.5 marks)**

(b) Draw the structural formulae of the following organic compounds:
(i) 2,2-dimethylpropane.
(ii) 4-methylpent-2-yne. **(1 mark)**

(c) Name the following compounds:
(i) $CH_3CH{=}CHCH_3$.
(ii) $CH_3C{\equiv}CCH_2CH_3$. **(1 mark)**

(d) Ozonolysis of a hydrocarbon **R** (C_5H_{10}) in the presence of zinc dust gives compounds **S** (C_2H_3O) and **T** (C_3H_5O). While compound **S** gives negative iodoform test, compound **T** responds positively to iodoform test.
(i) Give the structures of the compounds **R**, **S** and **T**. **(1.5 marks)**
(ii) Write all reaction equations that took place during the whole process. **(3 marks)**

(e) Using equations, briefly explain how you can differentiate $CH_3C{\equiv}CH$ from $CH_3C{\equiv}CCH_3$.
(2 marks)

14. (a) Show a one step reaction, how the following molecules can be prepared. Indicate suitable reagents and conditions for their preparation.
(i) Butan-2-ol from 2-iodobutane. **(1 mark)**
(ii) Propane from 1-chloropropane. **(1 mark)**
(iii) Ethylamine from iodoethane. **(1 mark)**
(iv) Butane from bromoethane. **(1 mark)**
(v) Methylbenzene from bromomethane **(1 mark)**
(vi) But-2-ene from 2-bromobutane **(1 mark)**

(b) A haloalkane **P** ($C_5H_{11}Br$) reacts with aqueous sodium hydroxide to give **Q** ($C_5H_{12}O$). **Q** reacts with concentrated H_2SO_4 at 170^oC to form **R** (C_5H_{10}) which decolourises bromine water. When **R** is reacted with ozone followed by hydrolysis, methanal and a branched aldehyde **S** is formed. Deduce the structural formula of **P**, **Q**, **R** and **S** by showing the chemical reactions involved.
(4 marks)