# 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, 08th May 2018 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.

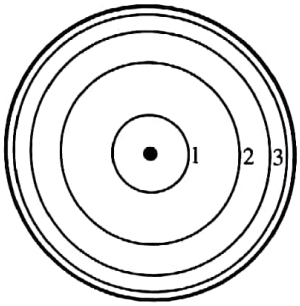





## SECTION A (40 Marks)

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

1. (a) Study carefully the Bohr's atomic model of hydrogen atom shown below then answer the questions that follow.




(i) State three basic postulates which led to Bohr's atomic model. Include mathematical expressions, if any, which qualify the postulate. **(3 marks)**

(ii) In a single sketch of Bohr's atom, show how Lyman and Paschen spectral series are formed. **(2 marks)**

(b) The energy difference between ground and excited state of atoms of a certain element was found to be $4.4\times10^{-19}$ J. Calculate the wavelength and wavenumber of the photons that excited the atoms. Show your work clearly including manipulations of units. **(3 marks)**

(c) Dalton's atomic theory consists of four main postulates. For each of the two postulates given below, briefly describe an experiment or a discovery which is against the postulate.

(i) Atoms can neither be created nor destroyed.

(ii) All atoms of the same element are alike. **(2 marks)**

2. (a) State the following:

(i) Boyle's law.

(ii) Charles' law.

(iii) Avogadro's law.

(iv) Dalton's law of partial pressure.

(v) Graham's law of diffusion. **(2.5 marks)**

(b) (i) A certain amount of a gas was found to occupy $100 cm^3$ at 33°C and $97\times10^3$ $Nm^{-2}$. Calculate the volume of the gas at standard temperature and pressure. Show your work clearly including manipulations of units. [1 atm = $101.3\times10^3$ N $m^{-2}$] . **(2 marks)**

(ii) At 1.0 atmosphere pressure and 30 °C, 1.236 g of a gas was found to occupy a volume of 512 $cm^3$. Calculate the relative molecular mass of the gas. Show your work clearly including manipulations of units. **(2 marks)**

(c) The compressibility factor, $Z$, is used to test the ideality or non-ideality of real gases.

(i) Write an expression for compressibility factor, $Z$. **(0.5 marks)**

(ii) At what values of $Z$ a real gas shows ideal behavior, positive and negative deviation from ideality? **(1.5 marks)**

(d) A gas was found to diffuse through a porous material 1.49 times faster than chlorine gas. Calculate the molecular mass of the gas giving your answer in two decimal places. [Molecular mass of chlorine = 71.0 g $mol^{-1}$]. **(1.5 marks)**

3. (a) State the meaning of an ideal gas. **(1 mark)**

(b) State two postulates of kinetic molecular theory of gases which are incorrect for real gases. Express their corresponding corrections and derive the van der Waals' equation. **(6 marks)**

(c) Calculate the pressure exerted by 1.00 mole of methane in a 250 mL container at 300 K. Show your work clearly including units manipulations. [van der Waals' constants $a = 2.253\ (dm^3)^2\ atm\ mol^{-2}$; $b = 0.0428\ dm^3\ mol^{-1}$] **(3 marks)**

4. Given the information that, nitric acid ($T_b$ = 87°C) and water form a constant boiling mixture of $T_b$ = 122 °C and composition 65% by mass nitric acid:

(a) (i) Draw the boiling temperature – composition curve for nitric acid and water. **(4 marks)**

(ii) State what is meant by a constant boiling point mixture. **(1 mark)**

(b) (i) State Raoult's law. **(1 mark)**

(ii) Identify whether the mixture of nitric acid and water shows a positive or a negative deviation from Raoult's law. **(1 mark)**

(iii) With reference to Raoult's law, distinguish positive deviation from negative deviation. **(2 marks)**

(iv) What interaction between nitric acid and water gives rise to this type of deviation? **(1 mark)**

5. (a) Classify the bonds in the following compounds as ionic, polar covalent or covalent.

(i) HCl(g) (ii) NaCl(s) (iii) $NCl_3$

(iv) Methane (v) Tetrachloromethane (vi) $CO_2$

**(2.5 marks)**

(b) For each of the following compounds, show from electron configurations the type of hybrid orbital of the underlined atom and draw the geometry of the corresponding molecule.

(i) $\underline{Be}Cl_2$ (ii) $\underline{C}Cl_4$ (iii) $\underline{C}_2F_4$ **(4.5 marks)**

(c) Study carefully the information in the following table, then answer the questions that follow.

| Name | Molecular weight | Boiling point, °C |
|---|---|---|
| Diethyl ether | 74 | 35 |
| *n*-butyl alcohol | 74 | 118 |
| Propionamide | 73 | 213 |

(i) Account on the high boiling point of *n*-butyl alcohol compared to diethyl ether, while the two compounds have the same molecular weight. **(1.5 marks)**

(ii) Account on the low boiling point of *n*-butyl alcohol compared to propionamide despite its high molecular weight. **(1.5 marks)**

6. (a) Briefly give the meaning of the following phrases as used in chemical energetics:
   (i) Heat of solution.
   (ii) Spontaneous reaction.
   (iii) Enthalpy change.
   (iv) Heat of sublimation.
   (v) Endothermic reaction.

**(2.5 marks)**

(b) During chemical reactions, bonds are broken (reactants) and formed (products), and the overall process may be exothermic or endothermic. Compare bond strengths in reactants and products if the overall reaction is
   (i) exothermic
   (ii) endothermic.

**(1 mark)**

(c) State the types of enthalpies in each of the following equations:

(i) $KOH(aq) + HCl(aq) \rightarrow KCl(aq) + H_2O(l)$ $\quad \Delta H^\circ = -57\ kJ\ mol^{-1})$

(ii) $H_2(g) + \frac{1}{2}O_2(g) \rightarrow H_2O(l)$ $\quad \Delta H^\circ = -286\ kJ\ mol^{-1})$

(iii) $\frac{1}{2}H_2(g) + \frac{1}{2}Cl_2(g) + (aq) \rightarrow HCl(aq)$ $\quad \Delta H^\circ = -164\ kJ\ mol^{-1})$

(iv) $Cl(g) + e^- \rightarrow Cl^-(g)$ $\quad \Delta H^\circ = -347\ kJ\ mol^{-1})$

**(2 marks)**

(d) Two liquids, trichloromethane ($CHCl_3$) and ethoxyethane ($CH_3CH_2OCH_2CH_3$), form intermolecular hydrogen bonds when mixed. In a certain experiment, 0.05 moles of trichloromethane and 0.3 moles of ethoxyethane were weighed into the same calorimeter. When the temperature of both liquids had equalized, the liquids were mixed. The temperature increase of 5.4°C was recorded upon mixing. Assume that the heat capacity of the calorimeter is negligible, while heat capacities of trichloromethane and ethoxyethane are 0.98 J $g^{-1}$ $K^{-1}$ and 2.28 J $g^{-1}$ $K^{-1}$, respectively. Calculate:
   (i) Heat change in this experiment.
   (ii) Enthalpy change of mixing one mole of trichloromethane with excess ethoxyethane. Show your work clearly including manipulations of units. [Atomic masses: C = 12, H = 1, O = 16, Cl = 35.5]

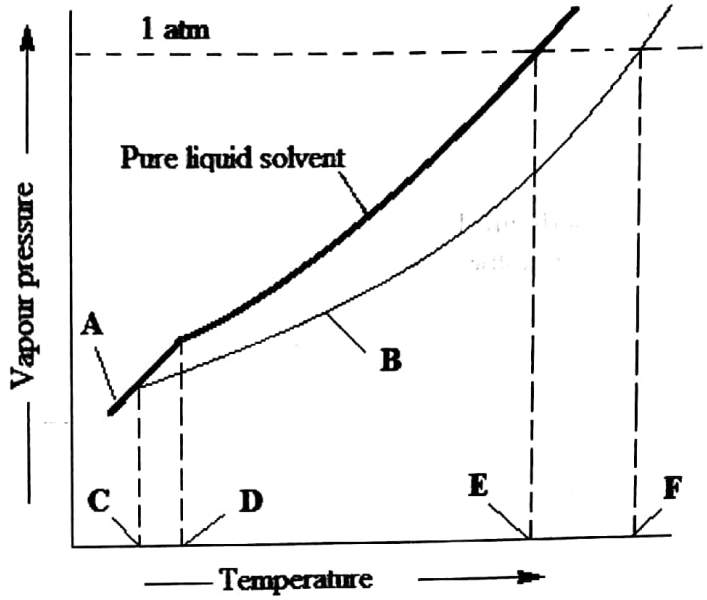
**(4.5 marks)**

## SECTION B (30 Marks)

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

7. (a) State the four colligative properties useful for determination of molecular masses. **(2 marks)**

(b) Study the following diagram and then answer the subsequent questions.




(i) Give the titles of the locations labeled **A**, **B**, **C**, **D**, **E** and **F**. **(3 marks)**

(ii) Give the names for the difference given by **F-E** (*i.e.*, **F** minus **E**) and **D-C**(*i.e.*, **D** minus **C**). **(2 marks)**

(c) Ammonium chloride solution was dissolved in pure water to make a 25% solution. Calculate the temperature at which this solution freezes. The molal boiling point constant for $NH_4Cl$ = -1.86 °C kg $mol^{-1}$? In your calculations, assume that the addition of the salt does not change the volume of water; show your work clearly including manipulations of units. **(3 marks)**

3. (a) Nitrobenzene ($C_6H_5NO_2$) and water form a mixture of immiscible liquids which boils at 99 °C. Calculate the percentage by mass of nitrobenzene in the distillate when the mixture is distilled at $1.013 \times 10^5$ Pa given that the vapour pressure of water at 99 °C is $9.749 \times 10^4$ Pa. Show your work clearly including manipulations of units.[Molar masses: nitrobenzene = 123 g $mol^{-1}$, Water = 18 g $mol^{-1}$] **(2 marks)**

(b) Water (b.p. 100 °C) and phenylamine (b.p. 184 °C) form a mixture of immiscible liquids that boils at 98 °C. With the aid of a diagram, show how steam distillation of this mixture can be achieved. **(3 marks)**

(c) Show how the equation for the partition law of solute "*x*" dissolved in two immiscible solvents **A** and **B** will be represented when solute "*x*":

(i) Associate in solvent A and remain normal in solvent B.

(ii) Dissociate in solvent A and associate in solvent B.

(iii) Dissociate in solvent B and remain normal in solvent A. **(1.5 marks)**

(d) Fifty (50) grams of the acid are dissolved in one litre (1000 $cm^3$) of water. The distribution coefficient of the acid between ether and water is 3. A volume of 1000 $cm^3$ of ether is available for use in the extraction process. Two experiments were performed to extract acid from water. In the first experiment, 1000 $cm^3$ of ether were used once, *i.e.*, single extraction. In the second experiment, two extractions were performed, each using 500 $cm^3$ of ether. Compare the amounts of the acid left in the aqueous solution in each case and recommend the best method to extract the acid from water. **(3.5 marks)**

9. (a) (i) State the law of mass action.
(ii) State the Le Chatelier's principle.
(iii) Define dynamic equilibrium.
(iv) State three factors that change the position of the chemical equilibrium. **(2 marks)**

(b) The equilibrium constant for the reaction $CO(g) + H_2O(g) \rightleftharpoons CO_2(g) + H_2(g)$ at 986 °C is 0.63. A mixture of 1.0 mole of water vapour and 3.0 mole of CO is allowed to come to equilibrium. The equilibrium pressure is 2.0 atm.
(i) Calculate the number of moles of $H_2$ present at equilibrium. **(4.5 marks)**
(ii) Calculate the partial pressure of gases at equilibrium mixture. **(2 marks)**

(c) The chief reaction used in contact process is $2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g) + 4200\ kJ$. On the basis of Le-Chatelier's principle, briefly explain three conditions that are required for the maximum yield of $2SO_3(g)$. **(1.5 marks)**

10. (a) Use appropriate examples to differentiate between dative and covalent bonds. **(1.5 marks)**

(b) With the help of sketches, briefly explain the following concepts:
(i) Two types of hydrogen bonding, giving one example for each. **(1 mark)**
(ii) Why *ortho*-nitrophenol has lower boiling point than *para* isomer? **(1.5 marks)**
(iii) Ethene has a planar geometry. **(1.5 marks)**
(iv) Methane has tetrahedron geometry. **(1.5 marks)**

(c) (i) State two conditions that are necessary for the formation of hydrogen bond. **(1 mark)**
(ii) State two effects of hydrogen bonding. **(1 mark)**
(iii) How many *s*- and *p*-bonds are formed between C-C in ethyne? **(1 mark)**

## SECTION C (30 Marks)

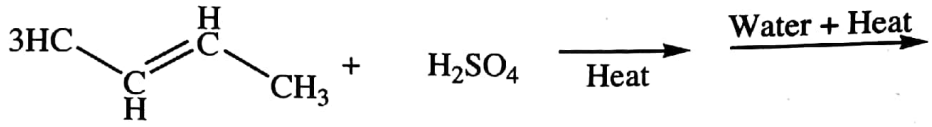
Answer **three (3)** questions from this section.

11. (a) $CH_3CH_2CH_2CH_3$ has a boiling point of -1 °C while $CH_3CHCH_3$ (with $CH_3$ branch) has a boiling point of -12 °C.

Briefly explain this observation. **(1 mark)**

(b) (i) With one example, state the meaning of "Friedel-Crafts acylation". **(1 mark)**
(ii) With the aid of illustration, show the reaction mechanism between benzene and nitric acid in presence of sulfuric acid. **(4 marks)**
(iii) 1,3-dimethylbenzene is oxidized by potassium dichromate(VI) solution. Draw the chemical structure of the product of the reaction. **(1.5 marks)**

(c) Write the product of each of the following reactions:
(i) $CH_4 + Cl_2 \xrightarrow{Uv}$ **(0.5 mark)**

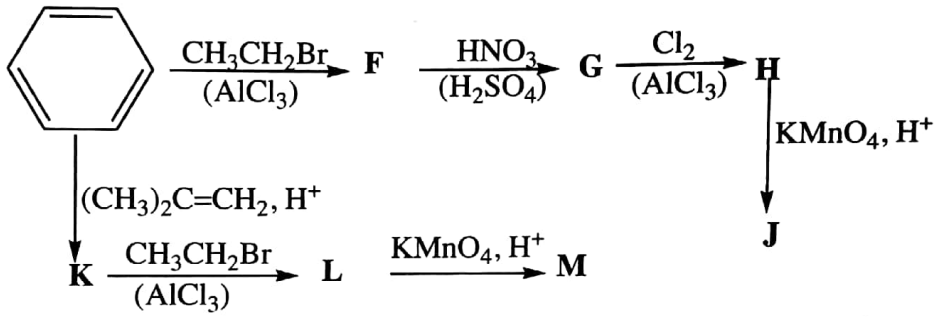
(ii) 

**(1 mark)**

(iii) $H_3C-C\equiv CH + CuCl(aq) \xrightarrow{NH_3}$ **(0.5 marks)**

(iv) $CaC_2 + H_2O \longrightarrow$ **(0.5 marks)**

12. (a) Give the structural formula of aromatic compounds F to M which are formed in the following reactions scheme: **(6 marks)**



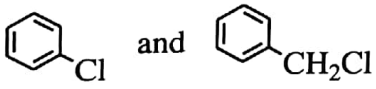
(b) What is the product for the chlorination of benzene and methylbenzene in the presence of:

(i) a halogen carrier catalyst **(2 marks)**

(ii) ultra-violet light. **(2 marks)**

13. (a) With the aid of reaction equations, outline six different applications of haloalkanes in organic synthesis processes. Use R—X as a haloalkane. **(6 marks)**

(b) For each pair of compounds given below, provide a chemical test to distinguish them.

(i)  and 

(ii) $H_3C-CH_2Br$ and $H_2C=\underset{H}{C}-CH_3$

**(2 marks)**

(c) Silver nitrate solution does not precipitate the chloride in 1-chloropropene, but it does so in 1-chloropropane. Give a reason to account for this. **(2 marks)**

14. (a) Arrange the following alkyl chlorides in order of decreasing reactivity in an $SN_1$ reaction:

(i) $CH_3Br$ (ii) $C(CH_3)_2Br$

(iii) $CH(CH_3)_2Br$ (iv) $CH_3CH_2CH_2Br$

**(2 marks)**

(b) Write mechanism for the following substitution reactions:

(i) $CH_3CH_2OH + HBr \longrightarrow CH_3CH_2Br + H_2O$ **(2 marks)**

(ii) $CH_3SCH_3 + CH_3I \longrightarrow (CH3)3S^{\oplus}I^{\ominus}$ **(2 marks)**

(c) When phenol is treated with $Br_2$, a mixture of mono bromo phenol, dibromo phenol and tribromo phenols are obtained. Write a synthesis mechanism to convert phenol to:

(i) 2-bromophenol **(2 marks)**

(ii) 4-bromophenol. **(2 marks)**