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 **ANSWERS** **Year: 2012**

Instructions

1. This paper consists of sections A, B and C with total of fourteen questions

2. Each question carries ten marks.

1. (a) Define mass spectrometer.

A mass spectrometer is an analytical instrument used to determine the mass-to-charge ratio of ions. It helps in identifying atomic and molecular masses, isotopic abundances, and molecular structures.

(b) Given below are the naturally occurring isotopes of oxygen:

Oxygen Isotopes:
^{16}O = 15.995 u (99.76%)
^{17}O = 16.999 u (0.04%)
^{18}O = 17.969 u (0.20%)

Relative atomic mass of oxygen:

= (15.995 × 99.76 + 16.999 × 0.04 + 17.969 × 0.20) / 100
= (15.956 + 0.0068 + 0.0359)
= 15.9987 ≈ 16.00 u

(c) Write the products of the following changes:

(i) Alpha decay of $^{24}_{12}Mg$ and $^{8}_{4}Be$

$^{24}_{12}Mg \rightarrow {}^{20}_{10}Ne + {}^{4}_{2}He$
$^{8}_{4}Be \rightarrow {}^{4}_{2}He + {}^{4}_{2}He$

(ii) Beta decay of $^{14}_{6}C$ and $^{31}_{14}Si$

$^{14}_{6}C \rightarrow {}^{14}_{7}N + \beta^-$
$^{31}_{14}Si \rightarrow {}^{31}_{15}P + \beta^-$

(d) If the wavelength of the first line in the Balmer series in a hydrogen spectrum is 6863 Å, calculate the wavelength of the first line in the Lyman series in the same spectrum.

Using the Rydberg equation:

$1/\lambda = R\_H (1/n_1^2 - 1/n_2^2)$

For the Lyman series, $n_1 = 1$, and $n_2 = 2$

$1/\lambda = (1.097 \times 10^7\ m^{-1}) \times (1/1^2 - 1/2^2)$
$= (1.097 \times 10^7) \times (1 - 1/4)$
$= (1.097 \times 10^7) \times (3/4)$
$\lambda = 1216$ Å

2. The remains of an ancient fire in a cave in Africa show a ^{14}C decay rate of 3.1 counts per minute per gram of carbon. Assuming that the decay rate of ^{14}C in fresh wood is 13.6 counts per minute per gram of carbon, calculate the age of the remains, given the half-life of ^{14}C is 5730 years.

Using the decay equation:

$N = N_0 e^{-rt}$

$\ln(N/N_0) = -\lambda t$

$\lambda = 0.693 / t_{1/2} = 0.693 / 5730 = 1.21 \times 10^{-4}$

$\ln(3.1/13.6) = - (1.21 \times 10^{-4}) t$

t = 10,034 years

3. (a) Briefly explain the following terms:

(i) Reversible reaction: A chemical reaction that can proceed in both forward and reverse directions under given conditions.

(ii) Rate constant: A proportionality constant in the rate equation that expresses the speed of a reaction at a specific temperature.

(b) The reaction $H_2(g) + I_2(g) \rightleftharpoons 2HI(g) - \Delta H$ kJ attains equilibrium at 47°C.

(i) The reaction is exothermic because ΔH is negative.

(ii) Effect on HI yield:
- Increasing pressure shifts equilibrium toward fewer moles (no effect in this case as moles are balanced).
- Increasing temperature decreases HI yield due to exothermic nature.
- Adding an inert gas does not affect equilibrium.

(iii) Equilibrium constant expression:

$Kp = (P\_HI)^2 / (P\_H_2 \times P\_I_2)$

(iv) Calculate equilibrium constant:

$Kp = (4.0 \times 10^1)^2 / (2.5 \times 10^1 \times 1.6 \times 10^1)$
$= 1600 / 40$
$= 40$

4. (a) State the following laws:

(i) Boyle's law: The volume of a gas is inversely proportional to its pressure at constant temperature (PV = constant).

(ii) Charles' law: The volume of a gas is directly proportional to its absolute temperature at constant pressure (V/T = constant).

(iii) Dalton's law of partial pressures: The total pressure of a gas mixture is the sum of the partial pressures of individual gases.

(b) A sample of PCl_5 weighing 2.69 g was placed in a 1.00 L flask and completely vaporized at 250°C. The pressure observed was 1 atm. Calculate the partial pressures of PCl_5, PCl_3, and Cl_2 under equilibrium conditions.

Using ideal gas law:

$PV = nRT$

$n = (2.69\ g) / (208.2\ g/mol)$
$= 0.0129\ mol$

$P_{total} = 1$ atm, dissociation:

$PCl_5 \rightleftharpoons PCl_3 + Cl_2$

Let α be the dissociation fraction.
Total pressure $= (1 + \alpha)\ P_0$

Solving for α:

$P_{PCl_3} = P_{Cl_2} = 0.5$ atm

$P_{PCl_5} = 0.5$ atm

5. (a) List four colligative properties of a solution.

- Boiling point elevation
- Freezing point depression
- Vapor pressure lowering
- Osmotic pressure

(b) Heptane and octane form an ideal solution.

(i) Raoult's law:

$P_{solution} = X_A P_A + X_B P_B$

(ii) Ideal solution forms under similar intermolecular forces.

(iii) Calculate vapor pressure:

$X_{heptane} = 50 / (50 + 38)$
$X_{octane} = 1 - X_{heptane}$

$P_{solution} = (X_{heptane} \times 473.2) + (X_{octane} \times 139.8)$

$= (0.568 \times 473.2) + (0.432 \times 139.8)$

$= 268.8 + 60.4$

$= 329.2$ Pa

6. (a) Briefly explain the following terms:

(i) Miscible liquids: Liquids that completely dissolve in each other in any proportion (e.g., ethanol and water).

(ii) Immiscible liquids: Liquids that do not mix and form separate layers (e.g., oil and water).

(iii) Partially miscible liquids: Liquids that mix in limited proportions (e.g., ether and water).

(iv) Partition law: A solute distributes itself between two immiscible solvents in a constant ratio at equilibrium.

(b) 10 g of compound Q were dissolved in 1 L of distilled water. The solution was shaken with 100 cm^3 of ethoxyethane, extracting 6 g of Q. Further extraction with another 100 cm^3 removed additional Q. Calculate the amount of Q left in the aqueous layer.

Partition coefficient, $K = (C_{ethoxyethane} / C_{water})$

$K = (6 / 100) / (4 / 1000)$

$= 15$

For second extraction:

$C_{remaining} = (4 \times 1000) / (15 \times 200 + 1000)$
$Q_{remaining} \approx 0.57$ g

7. (a) Explain the following laboratory observations:

(i) When potassium permanganate is used in volumetric analysis, it is acidified using dilute sulfuric acid but not dilute hydrochloric acid or nitric acid.
- HCl is not used because it reacts with $KMnO_4$, producing chlorine gas, which interferes with the reaction.
- HNO_3 is not used because it is an oxidizing agent and affects the redox reaction.

(ii) Aqueous sodium hydroxide absorbs carbon dioxide readily, but it is never used to test for the gas.
- NaOH forms sodium carbonate and bicarbonate, which dissolve in solution and do not form a visible precipitate.

(b) 0.50 g of hydrated iron (II) sulfate was dissolved in sulfuric acid and titrated against 0.1 M aqueous potassium permanganate. Calculate the volume of potassium permanganate required to complete the titration.

Reaction:
$MnO_4^- + 5Fe^{2+} + 8H^+ \rightarrow Mn^{2+} + 5Fe^{3+} + 4H_2O$

Moles of $Fe^{2+} = (0.50\ g) / (151.9\ g/mol) = 0.00329$ mol
Moles of $MnO_4^- = 0.00329 / 5 = 0.000658$ mol
Volume of $KMnO_4 = 0.000658$ mol / 0.1 M = 6.58 mL

8. Explain briefly the following facts:

(a) Nitric acid can be stored in aluminum tanks but not sulfuric acid or sodium hydroxide.
- Aluminum forms a protective oxide layer in nitric acid, preventing further reaction, but it reacts with sulfuric acid and sodium hydroxide.

(b) Galvanized iron sheets rust less rapidly than tinned iron sheets.
- Zinc forms a protective layer and acts as a sacrificial anode, whereas tin does not protect the iron once scratched.

(c) Hydrogen gas can be used to reduce copper oxide but not zinc oxide.
- Zinc has a higher affinity for oxygen than hydrogen, making it difficult to reduce with H_2.

(d) Sodium carbonate cannot precipitate lead carbonate from an aqueous solution of lead ions.

- Lead carbonate has low solubility but can still dissolve in water containing excess carbonate ions, preventing precipitation.

(e) Calcium phosphate is soluble in dilute HCl, but calcium sulfate is insoluble in dilute HCl.
- Calcium phosphate dissolves due to the formation of soluble calcium chloride, whereas calcium sulfate has low solubility in HCl.

9. (a) Briefly explain the term diagonal relationship.
- A diagonal relationship occurs in the periodic table where elements in adjacent groups and periods exhibit similar chemical properties due to comparable charge densities. Example: Li and Mg.

(b) Four similarities between lithium and magnesium:
1. Both form stable carbonates and nitrates.
2. Both react with nitrogen to form nitrides.
3. Both have similar ionic radii.
4. Both form hydroxides that are sparingly soluble.

(c) Differences between graphite and diamond:

(i) Hardness:
- Diamond is the hardest known material.
- Graphite is soft due to weak Van der Waals forces between layers.

(ii) Electrical and thermal conductivity:
- Diamond is a poor electrical conductor but a good thermal conductor.
- Graphite is a good electrical conductor due to delocalized electrons.

(iii) Lubricating qualities:
- Graphite is used as a lubricant due to its layered structure.
- Diamond lacks this property.

10. Element X exists in gaseous form at room temperature, whereas element Y exists in liquid form.

(a) Identify X and Y.
- X is fluorine (F_2), and Y is bromine (Br_2).

(b) Explain why X exists in gaseous form while Y is in liquid form.
- Fluorine has weak intermolecular Van der Waals forces, making it gaseous.
- Bromine has stronger intermolecular forces, making it liquid at room temperature.

(c) Give the reactions of X and Y with water, hot and concentrated alkali, as well as cold and dilute alkali.

- Fluorine with water:

$F_2 + H_2O \rightarrow HF + O_2$

- Bromine with water:
$Br_2 + H_2O \rightarrow HBr + HOBr$

- Fluorine with hot NaOH:
$F_2 + 2NaOH \rightarrow NaF + OF_2 + H_2O$

- Bromine with hot NaOH:
$3Br_2 + 6NaOH \rightarrow 5NaBr + NaBrO_3 + 3H_2O$

(d) Explain why X shows only negative oxidation states, while Y shows both negative and positive oxidation states.
- Fluorine is the most electronegative element and cannot exhibit positive oxidation states.
- Bromine can exhibit positive oxidation states due to the availability of d-orbitals.

(e) Which element will displace the other in an aqueous solution of its salt?
- Fluorine will displace bromine from bromide solutions because it is more reactive.

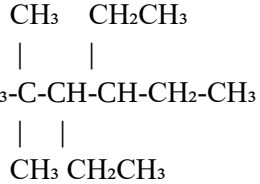
11. (a) Name the following organic compounds according to IUPAC rules:

(i) 2,2,3-Trimethylpentane
(ii) 2,4-Hexadiene
(iii) 3,3,5-Trimethylheptane
(iv) 2,4-Dimethylpent-2-ene
(v) 4-Amino-2-formylphenol

(b) Write the structural formulae of the following:

(i) Cyclo-octa-1,3,5,7-tetraene.
A cyclic compound with alternating double bonds:

(ii) 2,2-Dimethyl-3,4-diethylheptane
A branched heptane with methyl and ethyl substituents:



(iii) 2-Hydroxybenzoic acid (Salicylic acid)

A benzene ring with hydroxyl (-OH) and carboxyl (-COOH) groups:

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    OH
    |
benzene-COOH
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(iv) Butane-1,2,3-triol
A four-carbon chain with three hydroxyl (-OH) groups:

CH_3-CH(OH)-CH(OH)-CH_2OH

(v) Phenylethanone
A benzene ring attached to an ethanone (-$COCH_3$) group:

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    O
    ||
benzene-CH3
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12. (a) If the molecule gives a positive iodoform test,

(i) The reagents and conditions for the iodoform test:
- Reagents: I_2 (iodine) and NaOH (sodium hydroxide)
- Conditions: The compound is heated in an alkaline solution of iodine.

(ii) The part of the molecule P that gives tri-iodomethane (iodoform) is the -$COCH_3$ group (methyl ketone). This group undergoes oxidation and releases CHI_3 (yellow precipitate).

(b) The part of the molecule that reacts with 2,4-dinitrophenylhydrazine (2,4-DNP) is the carbonyl (-CO-) functional group. The reaction forms an orange or red precipitate, indicating the presence of a ketone.

(c) P would give a positive reaction with $[Ag(NH_3)_2]^+$ if it contains an aldehyde functional group (-CHO). However, since P has a ketone functional group, it will not give a positive result with Tollens' reagent.

(d) If molecule P reacts with aqueous sodium hydroxide:

(i) The group in P attacked by NaOH is the ester (-COO-) or acidic proton (-OH) if it undergoes hydrolysis.
(ii) The product formed would be a carboxylate salt if hydrolysis occurs or an alcohol if an ester undergoes cleavage.

13. (a) Write the reaction steps to convert the following organic compounds:

(i) Benzophenone to diphenyl methane
- Reduction with Zn/HCl:

$C_6H_5COC_6H_5$ -----> $C_6H_5CH_2C_6H_5$

(ii) Toluene to benzyl alcohol
- Oxidation with alkaline $KMnO_4$:
  $C_6H_5CH_3$ -----> $C_6H_5CH_2OH$

(iii) Acetone to propyne
- Reaction with PCl_5:
  CH_3COCH_3 -----> $CH_3CCl_2CH_3$
- Elimination with KOH in ethanol:
  $CH_3CCl_2CH_3$ -----> $CH_3C{\equiv}CH$

(iv) Propanal to 1-phenyl-1-propanol
- Reaction with phenylmagnesium bromide (Grignard reagent):
  $C_2H_5CHO + C_6H_5MgBr$ -----> $C_6H_5CH(OH)C_2H_5$

(b) Distinguish the following compounds:

(i) Phenol vs. Chlorobenzene
- Ferric chloride test: Phenol gives a violet color, chlorobenzene does not.

(ii) Acetone vs. Propyne
- Iodoform test: Acetone gives a yellow precipitate (CHI_3), propyne does not.

14. (a) Arrange the given compounds in order of:

(i) Increasing acidity:
A (Ethanol) < B (p-Cresol) < C (Phenol) < D (p-Nitrophenol)

(ii) Increasing basic strength:
D (p-Nitrophenol) < C (Phenol) < B (p-Cresol) < A (Ethanol)

(b) Outline the conversions:

(i) Conversion of nitrobenzoic acid to aminobenzene
- Reduction with Sn/HCl:
  O_2N-C_6H_4-COOH ------> NH_2-C_6H_4-COOH

(ii) Conversion of propene to isopropanol
- Hydroboration-oxidation:
  $CH_3CH{=}CH_2$ -----> $CH_3CH(OH)CH_3$

(c) Substance A is represented by a molecular formula $C_5H_{12}O$. A undergoes oxidation with acidified potassium permanganate to give compound B, which forms a crystalline derivative with 2,4-dinitrophenylhydrazine, but does not react with a mixture of iodine and sodium hydroxide.

(i) Write down the structural formulae of compounds A and B.

Structural formulae of A and B:
- A is pentan-2-ol ($CH_3CH(OH)CH_2CH_2CH_3$)
- B is pentan-2-one ($CH_3COCH_2CH_2CH_3$)

(ii) Show by means of an equation, how B reacts with 2,4-dinitrophenylhydrazine.
Given that substance A ($C_5H_{12}O$) undergoes oxidation to compound B, which reacts with 2,4-DNP but not with iodine-NaOH:
Reaction of B with 2,4-DNP:
$CH_3COCH_2CH_2CH_3$ + 2,4-DNP ----> Orange precipitate

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