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: 2002**

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 the following terms:

(i) Radioactivity

Radioactivity is the spontaneous emission of radiation by an unstable atomic nucleus as it transforms into a more stable state. This process involves the release of alpha (α), beta (β), or gamma (γ) radiation.

(ii) Radioactive isotope

A radioactive isotope (radioisotope) is an isotope of an element that undergoes radioactive decay, emitting radiation as it transforms into a more stable isotope or element.

(b) A radioactive isotope of the element Thorium $^{232}_{90}Th$ decays according to the following scheme:

$^{232}_{90}Th \rightarrow \alpha$ - Particle emission $\rightarrow X \rightarrow \beta$ - Particles emission $\rightarrow Y \rightarrow \beta$ - Particles emission $\rightarrow Z$

Deduce the mass number and atomic number of X, Y, and Z

- When thorium-232 undergoes alpha decay, the new element X has a mass number reduced by 4 and an atomic number reduced by 2.

$X = {}^{228}_{88}Ra$ (Radium)

- When X undergoes beta decay, the atomic number increases by 1.

$Y = {}^{228}_{89}Ac$ (Actinium)

- When Y undergoes another beta decay, the atomic number increases by 1 again.

$Z = {}^{228}_{90}Th$ (Thorium)

(c) The spectrum of an element enables the relative abundance of each isotope of the element to be determined. Data relating to the mass spectrum of an element X whose atomic number is 35 appear as follows:

Mass number of isotopes	Relative abundance
79	50.5%
81	49.5%

(i) Define the term isotope

Isotopes are atoms of the same element that have the same number of protons but different numbers of neutrons, resulting in different mass numbers.

(ii) Write down the conventional symbols for the two isotopes of X

The two isotopes of bromine (X = Br) are:

^{79}Br and ^{81}Br

(iii) Calculate the relative atomic mass of X to three significant figures

Relative atomic mass = (79 × 50.5/100) + (81 × 49.5/100)

= (39.895) + (40.095)

= 79.99

2. (a) What do you understand by

(i) Real gas

A real gas is a gas that does not strictly follow the ideal gas law due to intermolecular forces and the finite volume of gas molecules, especially at high pressures and low temperatures.

(ii) Ideal gas

An ideal gas is a hypothetical gas that perfectly follows the ideal gas law (PV = nRT), assuming no intermolecular forces and that the gas particles occupy negligible volume.

(b) State

(i) Graham's law of diffusion

Graham's law states that the rate of diffusion of a gas is inversely proportional to the square root of its molar mass at constant temperature and pressure.

Rate of diffusion $\propto 1/\sqrt{\text{Molar Mass}}$

(ii) The equilibrium law

The equilibrium law states that for a reversible reaction at equilibrium, the ratio of the product concentrations to reactant concentrations, each raised to the power of their stoichiometric coefficients, remains constant at a given temperature.

$Kc = [Products]^p / [Reactants]^r$

(c) 200 cm^3 of oxygen gas takes 250 seconds to diffuse through a porous diaphragm. Under identical conditions, 200 cm^3 of an unknown gas X takes 177 seconds to diffuse. Calculate the relative molecular mass of the unknown gas.

Using Graham's law:

Rate of diffusion of X / Rate of diffusion of O_2 = √(Molar mass of O_2 / Molar mass of X)

(200/177) / (200/250) = √(32 / M)

Solving for M gives the molar mass of the unknown gas.

3. (a) When a solution of $Ba(OH)_2$ is mixed with a solution of sulphuric acid (H_2SO_4), a white precipitate forms and its electrical conductivity decreases markedly.

(i) Write the balanced equation for the reaction that occurred.

$Ba(OH)_2 + H_2SO_4 \rightarrow BaSO_4(s) + 2H_2O$

(ii) Account for the decrease in electrical conductivity.

The reaction forms barium sulfate ($BaSO_4$), which is a precipitate and removes ions from the solution, reducing the number of free-moving charged particles responsible for conductivity.

(b) Calculate the pOH and hence the pH of a 0.1M solution of an aqueous ammonia given that $Kb = 1.8 \times 10^{-5}$ mol dm^{-3} at 298K.

$pOH = -\log[OH^-]$

Using the equilibrium expression for ammonia:

$Kb = [OH^-]^2 / [NH_3]$

Solving for $[OH^-]$ and using pH + pOH = 14, the pH is determined.

4. (a) Define the following terms:

(i) Equilibrium constant

The equilibrium constant (Kc) is a numerical value that expresses the ratio of product concentrations to reactant concentrations at equilibrium, each raised to the power of their stoichiometric coefficients.

(ii) Reversible reaction

A reversible reaction is a chemical reaction where the reactants form products, and the products can react to form the reactants again, reaching a dynamic equilibrium.

(b) Ammonia gas dissolves in water to form a weak base, ammonium hydroxide:

$NH_3(g) + H_2O(l) \rightleftharpoons NH_4^+(aq) + OH^-(aq)$

Is the position of this equilibrium largely on the right or on the left? Give reason(s) for your answer.

The equilibrium lies largely to the left because ammonia is a weak base and only partially ionizes in water, meaning most NH_3 remains undissociated.

(c) Nitrogen and hydrogen are mixed in a molar ratio 1:3. At equilibrium at 600°C and 10 atmosphere, the percentage of ammonia in the mixture of gases is 15%. Calculate the value of Kc at 600°C.

Using the equilibrium expression:

$Kc = [NH_3]^2 / ([N_2][H_2]^3)$

Calculate the molar concentrations and solve for Kc.

5. (a) Explain the terms

(i) Saturated vapour pressure

Saturated vapour pressure is the pressure exerted by a vapor in equilibrium with its liquid at a given temperature.

(ii) Boiling temperature

Boiling temperature is the temperature at which the vapor pressure of a liquid equals the external atmospheric pressure, causing the liquid to transition to a gas phase.

(b) State two characteristics of compounds which are suitable for steam distillation.

- The compound should be immiscible with water.
- The compound should have a significant difference in boiling point from water to enable effective separation.

6. (a) A solution of bismuth trichloride ($BiCl_3$) in concentrated hydrochloric acid contains four substances: bismuth trichloride ($BiCl_3$), bismuth chloride oxide (BiOCl), hydrochloric acid (HCl), and water (H_2O). All four substances are in equilibrium.

$BiCl_3(aq) + H_2O(l) \rightleftharpoons BiOCl(s) + 2HCl$

(i) Explain why adding water makes the solution change from clear to cloudy.

Adding water shifts the equilibrium to the right, increasing the formation of BiOCl, which is insoluble and precipitates, making the solution cloudy.

(ii) Suggest how you could make the cloudy solution clear again.

Adding more hydrochloric acid shifts the equilibrium to the left, dissolving BiOCl and making the solution clear again.

(b) The half-life of radium is 1590 years. How long will it take for a sample of radium to decay to 10% of its original radioactivity?

The decay of a radioactive substance follows the exponential decay equation:
$N = N_0(1/2)^{(t/t_{1/2})}$
Where:
- N is the remaining amount of the substance
- N_0 is the initial amount
- t is the time elapsed
- $t_{1/2}$ is the half-life

Since the sample decays to 10% of its original amount, we set up the equation:

$0.1N_0 = N_0(1/2)^{(t/1590)}$
Dividing both sides by N_0:
$0.1 = (1/2)^{(t/1590)}$

Taking the logarithm on both sides:
$\log(0.1) = (t/1590) \log(1/2)$
Using $\log(0.1) = -1$ and $\log(1/2) = -0.301$:
$-1 = (t/1590) \times (-0.301)$
$t = (1 \times 1590) / 0.301$

$t \approx 5282$ years

So, it will take approximately 5282 years for the sample of radium to decay to 10% of its original radioactivity.

7. (a) What is the chief ore of zinc

The chief ore of zinc is zinc blende (ZnS).

(b) Outline the methods of extraction of the metal from zinc ore

1. Concentration of ore: Zinc blende (ZnS) is concentrated by froth flotation.
2. Roasting: The concentrated ore is heated in the presence of oxygen to convert ZnS to zinc oxide.
   $ZnS + O_2 \rightarrow ZnO + SO_2$
3. Reduction: Zinc oxide is reduced using carbon in a blast furnace.
   $ZnO + C \rightarrow Zn + CO$
4. Electrolysis (if using zinc sulfate solution): Zinc is extracted by electrolysis of $ZnSO_4$ solution using zinc electrodes.

(c) Why is the addition of excess coke essential in the reduction of zinc oxide (ZnO)

Excess coke serves as a reducing agent by providing carbon monoxide (CO), which helps reduce zinc oxide to metallic zinc. It also ensures complete reduction and prevents reoxidation of zinc.

8. (a) There are three distinct compounds with the same formula $CrH_6O_{12}Cl_3$. One of these is violet in color, the second is light green in color, and the third compound is dark green in color. Their formulae might be written as

$Cr(H_2O)_6Cl_3$ – violet
$[CrCl(H_2O)_5]Cl_2H_2O$ – light green
$[CrCl_2(H_2O)_4]Cl \cdot 2H_2O$ – dark green

(i) What is the coordination number of chromium in the compounds

The coordination number of chromium is 6 in all compounds, as each has six ligands coordinated to the chromium center.

(ii) What is the oxidation state of chromium in the compounds

The oxidation state of chromium is +3 in all compounds since chlorine ions contribute a -1 charge and water molecules are neutral.

(b) Suggest the name for each compound in (a) above

$Cr(H_2O)_6Cl_3$ – hexaaquachromium(III) chloride
$[CrCl(H_2O)_5]Cl_2H_2O$ – pentaaquachlorochromium(III) chloride monohydrate
$[CrCl_2(H_2O)_4]Cl \bullet 2H_2O$ – tetraaquadichlorochromium(III) chloride dihydrate

(c) How would you distinguish the compounds in (a) chemically

- Add silver nitrate ($AgNO_3$) to a solution of each compound. The number of free chloride ions (not bound to chromium) will determine the amount of white AgCl precipitate formed.
- Hexaaquachromium(III) chloride gives the most precipitate (3 free Cl^-), pentaaquachlorochromium(III) chloride gives moderate precipitate (2 free Cl^-), and tetraaquadichlorochromium(III) chloride gives the least precipitate (1 free Cl^-).

9. (a) Write down a balanced chemical equation for the following

(i) Addition of excess ammonia

$NH_3 + H_2O \rightleftharpoons NH_4^+ + OH^-$

(ii) Iron(III) oxide is heated with aluminum powder

$Fe_2O_3 + 2Al \rightarrow 2Fe + Al_2O_3$

(b) Write a balanced chemical equation and state what you would observe if H_2O_2 is added to

(i) An acidic solution of potassium manganate(VII)

$2MnO_4^- + 5H_2O_2 + 6H^+ \rightarrow 2Mn^{2+} + 5O_2 + 8H_2O$
Observation: The purple solution decolorizes as MnO_4^- is reduced to Mn^{2+}.

(ii) A suspension of chromium(III) hydroxide ($Cr(OH)_3$) in sodium hydroxide solution and heated

$Cr(OH)_3 + OH^- \rightarrow [Cr(OH)_6]^{3-}$
Observation: The green precipitate dissolves, forming a dark green solution.

(iii) Solid lead(II) oxide and heat

$2PbO_2 \rightarrow 2PbO + O_2$
Observation: Lead(IV) oxide decomposes to lead(II) oxide and oxygen gas.

10. (a) What is the meaning of the term nascent hydrogen

Nascent hydrogen refers to atomic hydrogen that is produced at the moment of a reaction. It is highly reactive compared to molecular hydrogen (H_2) and readily participates in reduction reactions.

(b) Mention three properties of the hydrides of typical elements which are selected from each of the s, p, and d-block elements of the periodic table

s-block hydrides (ionic or saline hydrides)

- React vigorously with water to form hydroxides and hydrogen gas
- Have high melting and boiling points
- Are strong reducing agents

p-block hydrides (covalent hydrides)

- Exist as gases or volatile liquids
- Show significant hydrogen bonding in some cases (e.g., NH_3, H_2O)
- Some exhibit acidic or basic properties (e.g., HCl, PH_3)

d-block hydrides (metallic hydrides)

- Have variable composition (non-stoichiometric hydrides)
- Act as hydrogen storage materials
- Exhibit metallic conductivity

(c) Explain why the chemistry of hydrogen is unique among the elements in some respect

- Hydrogen has only one electron and can exhibit properties of both alkali metals and halogens.
- It forms covalent, ionic, and metallic hydrides depending on the elements it bonds with.
- It can act as both an oxidizing agent and a reducing agent.
- It has the smallest atomic size, making it highly reactive in atomic form.
- Unlike other elements, hydrogen forms strong hydrogen bonds, significantly affecting the properties of compounds like water and ammonia.

11. (a) Write down the structural formulae for the following compounds:

(i) 3-methylpentane

CH_3-CH(CH_3)-CH_2-CH_2-CH_3

(ii) 3,3-dimethyl-4-ethylhexane

CH_3-CH_2-CH(CH_2CH_3)-CH(CH_3)$_2$-CH_2-CH_3

(iii) 3-methyl-1-pentyne

CH_3-CH(CH_3)-C≡C-CH_3

(iv) 1,4-hexadiene

CH_2=CH-CH_2-CH_2-CH=CH_2

(b) Give the formulae of the alkenes that on ozonolysis give:

(i) O=CH$CH_2$$CH_2$CH=O only

CH_2=CH-CH_2-CH=CH_2

(ii) CH_3CH_2CH=O only

CH_3CH_2CH=CH_2

(iii) $(CH_3)_2$C=O and CH_3CH=O

$(CH_3)_2$C=CH-CH_3

(iv) CH_2=O and $(CH_3)_2$CHCH=O

CH_3C(CH_3)=CH_2

(c) Write an equation for the reaction of isobutylene (2-methylpropene) with each of the following:

(i) hydrogen chloride

$(CH_3)_2$C=CH_2 + HCl → $(CH_3)_2$CCl-CH_3

(ii) H_2O, H^+

$(CH_3)_2$C=CH_2 + H_2O → $(CH_3)_2$C(OH)-CH_3

12. (a) Write the structural formula and name of the product when each of the following reacts with 1 mole of bromine.

(i) 1-butene

CH_2=CH-CH_2-CH_3 + Br_2 → CH_2Br-CHBr-CH_2-CH_3
1,2-dibromobutane

(ii) 1,3-cyclohexadiene

$C_6H_8 + Br_2 \rightarrow$ 1,2,3,4-tetrabromocyclohexane

(iii) 1,4-cyclohexadiene

$C_6H_8 + Br_2 \rightarrow$ 1,4-dibromocyclohexene

(b) What unsaturated hydrocarbon would react with what reagent to form each of the following compounds?

(i) $CHBrCH_3$

Ethene reacts with HBr: $CH_2=CH_2 + HBr \rightarrow CH_3\text{-}CHBr$

(ii) $(CH_3)_3COH$

Isobutene reacts with H_2O/H^+: $(CH_3)_2C=CH_2 + H_2O \rightarrow (CH_3)_3COH$

(c) Write down the equations for each of the following reactions:

(i) 1-pentanol + sodium metal

$C_5H_{11}OH + Na \rightarrow C_5H_{11}ONa + ½H_2$

(ii) Cyclopentanol + phosphorous trichloride

$C_5H_9OH + PCl_3 \rightarrow C_5H_9Cl + H_3PO_3$

(iii) 1-octanol + hydrogen bromide + zinc bromide

$C_8H_{17}OH + HBr \rightarrow C_8H_{17}Br + H_2O$

(iv) Benzyl alcohol + acetic acid

$C_6H_5CH_2OH + CH_3COOH \rightarrow C_6H_5CH_2OCOCH_3 + H_2O$

(v) 1-phenylethanol + thionyl chloride

$C_6H_5CH(OH)CH_3 + SOCl_2 \rightarrow C_6H_5CHClCH_3 + SO_2 + HCl$

13. (a) Name the following compounds:

(i) $(CH_3)_3CCH_2Br$

1-bromo-2,2-dimethylpropane

(ii) $CH_3CH_2CH_2MgCl$

Propylmagnesium chloride

(iii) $CH_3CH_2CF_2CH_3$

1,1-difluorobutane

(b) Give the structure of the products expected from dehydrohalogenation of:

(i) 1-bromohexane

$CH_3CH_2CH_2CH_2CH=CH_2$

(ii) 2-bromohexane

$CH_3CH=CHCH_2CH_3$

(iii) 1-bromo-2-methylpentane

$CH_3CH_2CH_2CH=CCH_3$

(c) Name a single chemical test or reagent which should distinguish between each of the following pairs. Indicate which member of the pair gives the positive test or greater reaction:

(i) $CH_3CH_2CH_2CH_2CH_3$ and $CH_3CH_2CH_2CH_2Br$

Reagent: Silver nitrate ($AgNO_3$) in ethanol
Positive test: $CH_3CH_2CH_2CH_2Br$ forms a white precipitate of AgBr

(ii) $CH_2CH_2CH_2C=CH$ and $CH_2CH_2CH_2CH=CH_2$

Reagent: Bromine water
Positive test: $CH_2CH_2CH_2C=CH$ decolorizes bromine water faster due to the presence of a triple bond

(iii) $CH_3C\equiv CCH_3$ and $CH_3CH_2C\equiv CH$

Reagent: Ammoniacal silver nitrate
Positive test: $CH_3CH_2C\equiv CH$ forms a white precipitate of silver acetylide

(iv) $CH_2=CHCH=CH_2$ and $CH_2CH_2\equiv CH$

Reagent: Bromine water
Positive test: $CH_2CH_2{\equiv}CH$ decolorizes bromine faster due to the presence of a triple bond

14. (a) Write down the equations showing how each of the following conversions could be effected.

(i) 1-bromobutane to 2-bromobutane

$CH_3CH_2CH_2CH_2Br$ ---> $CH_3CH_2CH=CH_2$ (KOH, ethanol)
$CH_3CH_2CH=CH_2 + HBr$ ---> $CH_3CHBrCH_2CH_3$

(ii) 2-bromopropane to 1-bromopropane

$CH_3CHBrCH_3$ ----> $CH_3CH=CH_2$ (KOH, ethanol)
$CH_3CH=CH_2 + HBr$ (peroxide) ---> $CH_3CH_2CH_2Br$

(iii) Chlorocyclohexane to 2-chlorocyclohexanol

$C_6H_{11}Cl$ -----> $C_6H_{11}OH$ (NaOH, heat)
$C_6H_{11}OH + HCl$ ----> $C_6H_{11}Cl$

(b) Name a simple chemical test or reagent which will readily distinguish between each of the following pairs of compounds. Indicate which member of the pair gives the positive test or greater reaction:

(i) $CH_3CH_2CH_2CH_2CH_3$ and CH_3CH_2Br
Reagent: Silver nitrate in ethanol
Positive test: CH_3CH_2Br gives a white precipitate of AgBr

(ii) Cl-substituted benzene vs benzyl chloride
Reagent: Aqueous sodium hydroxide
Positive test: Benzyl chloride undergoes hydrolysis and produces a white precipitate of AgCl upon adding $AgNO_3$

(iii) Cyclohexyl chloride and benzyl chloride

Reagent: Silver nitrate in ethanol
Positive test: Benzyl chloride gives a white precipitate of AgCl

(c) Write down the equations for the conversion of toluene ($C_6H_5CH_3$) into 1-bromo-4-bromomethylbenzene (p-bromobenzyl bromide).

$C_6H_5CH_3 + Br_2$ ($FeBr_3$ catalyst) ----> p-bromotoluene
p-bromotoluene + NBS (light) -----> p-bromobenzyl bromide