THE UNITED REPUBLIC OF TANZANIA

NATIONAL EXAMINATIONS COUNCIL OF TANZANIA

CERTIFICATE OF SECONDARY EDUCATION EXAMINATION

032/1 **CHEMISTRY 1**

(For Both School and Private Candidates)

Time: 3 Hours **ANSWERS** **Year: 2009**

Instructions

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

For each of the items (i) – (x), choose the correct answer among the given alternatives and write its letter beside the item number in the answer booklet(s) provided.

i. Consider the following:
P has 4 protons, 4 neutrons, and 4 electrons.
Q has 4 protons, 5 neutrons, and 4 electrons.
Which of the following statements is true about P and Q?

A. They have the same chemical properties but different mass number
B. They have different chemical and physical properties
C. They all have the same atomic weight
D. They have the same chemical properties but different atomic number
E. They all have the same physical and chemical properties.

Answer: A. They have the same chemical properties but different mass number
Explanation: P and Q have the same number of protons and electrons, meaning they are the same element (beryllium), but they have different numbers of neutrons, making them isotopes. Isotopes have the same chemical properties but different mass numbers.

ii. The following set of laboratory equipment consists of volume-measuring items:

A. Beaker, balance, measuring cylinder
B. Burette, pipette, thermometer
C. Burette, pipette, measuring cylinder
D. Cylinder can, balance, volumetric flask
E. Spatula, funnel, conical flask.

Answer: C. Burette, pipette, measuring cylinder
Explanation: A burette, pipette, and measuring cylinder are all used for accurate measurement of liquid volumes in a laboratory.

iii. An anhydrous salt X (relative molecular mass = 106) will combine with water to form hydrated salt $X_nY \cdot H_2O$. It is found that 21.2 g of X combine with 36 g of water. What is the value of y in the hydrated salt?

A. 2
B. 5
C. 8
D. 10
E. 12.

Answer: B. 5
Explanation:

- Moles of X = 21.2 g / 106 g/mol = 0.2 moles
- Moles of H_2O = 36 g / 18 g/mol = 2 moles
- Ratio of water to salt = 2 / 0.2 = 5
Thus, y = 5, meaning the formula of the hydrated salt is $X \cdot 5H_2O$.

iv. Which of the following is true about ionic compounds?

A. They are easily vaporized
B. They easily dissolve in organic solvents
C. They are electronically neutral
D. They are all poor conductors of electricity
E. They form covalent bonds with transition cations.

Answer: C. They are electronically neutral
Explanation: Ionic compounds are formed by the transfer of electrons, leading to a neutral overall charge due to the balance between positively charged cations and negatively charged anions.

v. Precipitation can be represented by the following equation:

A. $H^+(aq) + OH^-(aq) \rightarrow H_2O(l)$
B. $ROH + RCOOH \rightarrow RCOOR + H_2O$
C. $Ba^{2+}(aq) + SO_4^{2-}(aq) \rightarrow BaSO_4(s)$
D. $Na^+(aq) + Cl^-(aq) \rightarrow NaCl(aq)$
E. $2KClO_3(s) \rightarrow MnO_2 \rightarrow 2KCl(s) + 3O_2(g)$.

Answer: C. $Ba^{2+}(aq) + SO_4^{2-}(aq) \rightarrow BaSO_4(s)$
Explanation: A precipitation reaction occurs when two soluble ions in solution react to form an insoluble solid. In this case, $BaSO_4$ is an insoluble salt that precipitates from solution.

vi. Which group of organic compounds are prepared by the dehydration of the corresponding alcohol?

A. Alkanes
B. Alkenes
C. Alkynes
D. Esters
E. Carboxylic acids.

Answer: B. Alkenes
Explanation: Dehydration of alcohols involves the removal of a water molecule, leading to the formation of alkenes. For example, ethanol (C_2H_5OH) can be dehydrated to ethene (C_2H_4) using concentrated sulfuric acid.

vii. Insoluble salts like barium sulfate generally can be obtained in the laboratory by

A. Evaporation of its concentrated solution
B. Crystallization
C. Precipitation
D. Decomposition
E. Decrepitation.

Answer: C. Precipitation
Explanation: Insoluble salts like $BaSO_4$ are prepared by precipitation reactions where two soluble salts react in solution to form an insoluble product.

viii. A mixture of a liquid and insoluble powder which has not settled down is called a

A. Solute
B. Suspension
C. Solvent
D. Condensate
E. Residue.

Answer: B. Suspension
Explanation: A suspension is a heterogeneous mixture where solid particles do not dissolve in a liquid but remain dispersed throughout it.

ix. The same current passing through solutions of the same concentrations of silver nitrate and copper sulfate liberates 0.23 g of silver (equivalent weight = 108). The weight of copper (equivalent weight = 31.8) that will be liberated will be

A. 31.8 g
B. 0.0677 g
C. 0.23 g
D. 0.033 g
E. 3.180 g.

Answer: B. 0.0677 g
Explanation: Using Faraday's law, the mass deposited is proportional to the equivalent weight. Since the equivalent weight of copper is 31.8 and that of silver is 108, the mass of copper deposited is calculated as: $(0.23\ g \times 31.8) / 108 = 0.0677\ g$

x. Which of the following metals is most ductile?
A. Aluminium
B. Silver
C. Copper
D. Tin

E. Mercury.
Answer: B. Silver
Explanation: Silver is the most ductile metal, meaning it can be drawn into very thin wires without breaking.
2. Match the items in List A with the responses in List B by writing the letter of the correct response beside the item number.

List A

i. Boiling
ii. Hard water
iii. Water pollution
iv. Chlorofluorocarbons
v. Mg and S
vi. Urea
vii. Top dressing
viii. Recycling of solid materials
ix. Crop rotation
x. $C_7H_{16}(l) + 11O_2(g)$ --------> $7CO_2(g) + 8H_2O(l)$

List B

A. Burning of coal
B. Artificial fertilizer
C. Macronutrients
D. Removes temporary hardness of water
E. Air pollution
F. Managing the loss of plant nutrients from the soil
G. Untreated sewage
H. Micronutrients
I. Preventing terrestrial pollution
J. Has pleasant taste due to the dissolved compounds
K. Fertilizer application method
L. Burning of petrol
M. Removes permanent hardness of water
N. Less soap is used for washing
O. Has sour taste due to the presence of dissolved acid
P. Process of obtaining clean and safe water
Q. Manures

Answers

i M
ii N

iii G
iv E
v H
vi B
vii K
viii I
ix F
x L

3. a. Why doesn't water have any effect on litmus paper?

- Pure water is neutral, meaning it does not contain a significant concentration of hydrogen ions (H^+) or hydroxide ions (OH^-) to change the color of litmus paper. The litmus paper remains unchanged in pure water.

b.

i. What would happen to a well-stoppered bottle full of water left in a deep freezer overnight? Why does this happen?

- The water in the bottle would expand upon freezing, which could cause the bottle to crack or burst. This occurs because water expands as it turns into ice due to the formation of an open lattice structure in the solid phase, increasing its volume.

ii. Why isn't iron usually recommended in the construction of steam pipes and boilers? Explain.

- Iron is not recommended for steam pipes and boilers because it easily reacts with oxygen and moisture to form rust (iron oxide). The corrosion weakens the structure, leading to potential failures, leaks, and reduced efficiency of the system.

c.

i. Name two ions which cause temporary hardness of water and two ions which cause permanent hardness.

- Temporary hardness: HCO_3^- (Bicarbonate), Ca^{2+} (Calcium ion)
- Permanent hardness: SO_4^{2-} (Sulfate), Mg^{2+} (Magnesium ion)

ii. Give equations for two ways to remove temporary hardness of water and one way to remove permanent hardness.

- Removing temporary hardness:

1. Boiling
$Ca(HCO_3)_2 \rightarrow CaCO_3(s) + CO_2(g) + H_2O(l)$

2. Adding lime (calcium hydroxide)
$Ca(HCO_3)_2 + Ca(OH)_2 \rightarrow 2CaCO_3(s) + 2H_2O$

- Removing permanent hardness:

3. Using ion exchange resins
$Ca^{2+} + 2Na^+(resin) \rightarrow Ca^{2+}(resin) + 2Na^+(solution)$

4. a. i. Give the names of the gases evolved at each electrode during electrolysis of sodium hydroxide solution.

- At the anode: Oxygen (O_2)
- At the cathode: Hydrogen (H_2)

ii. Write ionic equations of the reactions taking place at the electrodes.

- At the anode (oxidation):
$4OH^-(aq) \text{-----> } O_2(g) + 2H_2O(l) + 4e^-$

- At the cathode (reduction):
$2H_2O(l) + 2e^- \text{----> } H_2(g) + 2OH^-(aq)$

iii. Calculate the number of moles of each gas produced and the volume each gas would occupy at S.T.P.

- Given:
0.02 moles of electrons passed
1 mole of O_2 requires 4 moles of electrons
1 mole of H_2 requires 2 moles of electrons

- Moles of oxygen gas:
(0.02 moles of e^-) ÷ (4 e^- per O_2) = 0.005 moles

- Moles of hydrogen gas:
(0.02 moles of e^-) ÷ (2 e^- per H_2) = 0.01 moles

- Volume at STP (1 mole of gas occupies 22.4 dm^3):

- Oxygen gas: 0.005 × 22.4 = 0.112 dm^3 (112 cm^3)
- Hydrogen gas: 0.01 × 22.4 = 0.224 dm^3 (224 cm^3)

b. What mass of copper will be liberated during electrolysis of copper sulfate solution by a charge of one faraday?

- 1 Faraday deposits 1 mole of copper divided by its charge ($Cu^{2+} = 2$)
- Mass of copper deposited = $(1 \times 63.5) \div 2 = 31.75$ g

c. An element X has a relative atomic mass of 88. When a current of 0.5A was passed through the fused chloride of X for 32 minutes 10 seconds, 0.44 g of X was deposited at the cathode.

i. Calculate the number of faradays needed to liberate 1 mole of X.

- Charge passed = It = (0.5 A × 1930 s) = 965 C
- Number of moles of X deposited =

5.

a. How can the rates of chemical reactions be increased? Describe at least four factors.

The rate of a chemical reaction refers to the speed at which reactants are converted into products. Several factors affect reaction rates, including:

i. Temperature: Increasing temperature provides more kinetic energy to the reacting particles, leading to more frequent and energetic collisions, which increases the rate of reaction. For example, sugar dissolves faster in hot water than in cold water.

ii. Concentration of reactants: A higher concentration of reactants increases the number of particles in a given volume, leading to more frequent collisions and a faster reaction rate. For instance, hydrochloric acid reacts faster with a high concentration of magnesium than a diluted solution.

iii. Surface area of reactants: When a solid reactant is broken into smaller pieces or turned into a powder, it has a larger surface area exposed to the reactant, leading to more collisions and a higher reaction rate. This explains why powdered calcium carbonate reacts faster with acid than a large chunk of marble.

iv. Presence of a catalyst: A catalyst provides an alternative reaction pathway with lower activation energy, allowing reactants to convert into products more quickly. For example, enzymes in the human body speed up biochemical reactions without being consumed.

b. Study the following reaction equation:

$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g) \quad \Delta H = -46.2$ kJ/mol

Using the Le Chatelier's principle, suggest how you would use temperature and pressure to obtain the highest production of ammonia at equilibrium.

Le Chatelier's principle states that if a system at equilibrium is subjected to a change in conditions (such as temperature or pressure), the system will adjust to oppose that change and restore equilibrium.

i. Effect of temperature: The given reaction is exothermic ($\Delta H = -46.2$ kJ/mol), meaning that heat is released. Lowering the temperature favors the forward reaction, leading to increased ammonia production. However, very low temperatures can slow down the reaction rate, so an optimal temperature (around 450°C) is used in industrial settings like the Haber process.

ii. Effect of pressure: The reaction involves four moles of gas on the reactant side ($N_2 + 3H_2$) and two moles on the product side ($2NH_3$). Increasing pressure shifts the equilibrium towards the side with fewer gas molecules, which increases ammonia yield. Industrially, pressures of 150-250 atmospheres are used to maximize production.

c. The formation of methanol from hydrogen and carbon monoxide can be represented by

$CO(g) + 2H_2(g) \rightleftharpoons CH_3OH(g) \quad \Delta H = 91$ kJ/mol

What mass of hydrogen would react to cause a heat change of 91 kJ?

From the reaction equation, 2 moles of H_2 react with CO to form 1 mole of CH_3OH, releasing 91 kJ of heat.

- The molar mass of hydrogen (H_2) = 2 g/mol
- Since 2 moles of H_2 cause a heat change of 91 kJ, the mass of hydrogen required is:

Mass = 2 g (since 1 mole of H_2 = 2 g)

Thus, 2 g of hydrogen is required to cause a heat change of 91 kJ.

6. a. Balance the following equations:

i. $Ca + H_3PO_4$ ------> $Ca_3(PO_4)_2 + H_2$

Balanced equation:
$3Ca + 2H_3PO_4$ ---------> $Ca_3(PO_4)_2 + 3H_2$

ii. $Cu + HNO_3$ ----------> $Cu(NO_3)_2 + NO_2 + H_2O$

Balanced equation:
$Cu + 4HNO_3$ ----------> $Cu(NO_3)_2 + 2NO_2 + 2H_2O$

iii. $SnCl_4 + FeCl_3$ ---------> $SnCl_4 + FeCl_2$

Balanced equation:

$SnCl_4 + 2FeCl_3$ ----------> $SnCl_4 + 2FeCl_2$

b. Suggest one best method for separating each of the following mixtures:

i. Sodium chloride and water

- Evaporation: Heating the solution allows the water to evaporate, leaving behind solid sodium chloride.

ii. Iodine and sand

- Sublimation: Iodine sublimes directly from solid to gas upon heating, leaving sand behind.

iii. Alcohol and water

- Fractional distillation: Since alcohol and water have different boiling points, heating the mixture allows alcohol (lower boiling point) to evaporate first and be collected separately.

c. When water and kerosene are mixed in the same container, which one forms the upper layer? Give reasons.

- Kerosene forms the upper layer because it has a lower density than water. Water has a density of approximately 1.0 g/cm³, while kerosene has a lower density (around 0.8 g/cm³), making it float on top of the water. Additionally, water is polar, while kerosene is nonpolar, causing them to remain separate instead of mixing.

7. a. Describe the effect of

i. Strongly heating a piece of marble in a Bunsen burner flame

- Marble, composed mainly of calcium carbonate ($CaCO_3$), undergoes thermal decomposition upon strong heating. The reaction is:

$CaCO_3(s)$ ----------> $CaO(s) + CO_2(g)$

- The white solid calcium carbonate turns into calcium oxide (quicklime), which is a highly reactive substance used in cement and lime production.

ii. Moistening the residue from (i) above with water

- When calcium oxide (quicklime) is moistened with water, it reacts exothermically to form calcium hydroxide (slaked lime):

$CaO(s) + H_2O(l)$ --------> $Ca(OH)_2(s)$

- The reaction releases heat and forms a white, powdery solid, commonly used in agriculture to neutralize acidic soils.

b. i. For what reason is slaked lime added to the soil in gardening?

- Slaked lime ($Ca(OH)_2$) is added to acidic soils to neutralize excess acidity, improving soil conditions for plant growth. It also provides calcium, which is essential for plant health.

ii. Why is concentrated sulfuric acid used as a drying agent?

- Concentrated sulfuric acid is a strong dehydrating agent that absorbs moisture from substances, making it useful for drying gases that do not react with acid, such as oxygen and nitrogen.

c. Why is zinc used as a coat for iron and not vice versa?

- Zinc is more reactive than iron and provides sacrificial protection by corroding first, preventing rust formation on iron. This is used in galvanization, where a zinc coating protects iron structures from rusting. Iron, being less reactive than zinc, would not provide the same protection if used as a coating for zinc.

8. a. Table 1 shows a part of the periodic table with atomic numbers from 3 to 18. Some elements are shown by letters but the letters are not the true symbols of the elements. Study it, then answer the questions that follow.

i. Among the elements lettered K to Q, which one

- Is a halogen? QCl
- Is a noble gas? Q
- Would react most readily with chlorine? K

b. Give the formula of the following:

i. Hydride of P: PH_3
ii. Oxide of O: O_2

c. Indicate whether the bonding in the oxide of O and P will be ionic or covalent. Give reasons for your answer.

- The oxide of O (O_2) has covalent bonding because oxygen atoms share electrons to complete their octets.
- The oxide of P (P_2O_5) also has covalent bonding, as phosphorus forms bonds by sharing electrons with oxygen.

9. a. State the following laws:

i. Boyle's law

Boyle's law states that the volume of a fixed mass of gas is inversely proportional to its pressure, provided the temperature remains constant. Mathematically, it is expressed as:

$P_1V_1 = P_2V_2$

This means that if the pressure on a gas increases, its volume decreases and vice versa. For example, when a syringe is pressed, the volume of air inside decreases as the pressure increases.

ii. Charles' law

Charles' law states that the volume of a fixed mass of gas is directly proportional to its absolute temperature (Kelvin) at constant pressure. Mathematically, it is expressed as:

$V_1/T_1 = V_2/T_2$

This implies that when the temperature of a gas increases, its volume also increases. A real-life application is the expansion of a hot air balloon when heated.

b. A volume of 840 cm^3 of gas was collected at 546°C and 2 atmospheric pressure. What would be the volume at S.T.P?

Using the combined gas law:

$(P_1V_1) / T_1 = (P_2V_2) / T_2$

Where:
$P_1 = 2$ atm, $V_1 = 840\ cm^3$, $T_1 = 546 + 273 = 819$ K
$P_2 = 1$ atm (S.T.P), $T_2 = 273$ K, $V_2 = ?$

Rearranging the formula:

$V_2 = (P_1V_1T_2) / (P_2T_1)$

$V_2 = (2 \times 840 \times 273) / (1 \times 819)$

$V_2 = 560\ cm^3$

Thus, the volume of the gas at S.T.P would be 560 cm^3.

c. If the gas in (b) above was collected from the complete thermal decomposition of calcium carbonate:

i. What is the name of the gas?

The gas released is carbon dioxide (CO_2).

ii. What mass of calcium carbonate produced this amount of gas?

From the equation:

$CaCO_3 \rightarrow CaO + CO_2$

1 mole of $CaCO_3$ (100 g) produces 1 mole of CO_2 (22.4 dm^3 or 22,400 cm^3 at S.T.P).

Mass of $CaCO_3$ required = (Mass of CO_2 × Molar mass of $CaCO_3$) / Molar volume of CO_2

Mass = (560 × 100) / 22400

Mass = 2.5 g

Thus, 2.5 g of calcium carbonate decomposed to produce 560 cm^3 of CO_2.

10. a. Briefly explain each of the following:

i. Soil pH

Soil pH is a measure of the acidity or alkalinity of the soil, expressed on a scale of 0 to 14. A pH of 7 is neutral, below 7 is acidic, and above 7 is alkaline. It affects nutrient availability and microbial activity in the soil.

ii. Basic soil

Basic soil, also called alkaline soil, has a pH greater than 7. It often contains excess sodium, calcium, or magnesium, which can limit the availability of certain essential nutrients to plants.

iii. Terracing

Terracing is an agricultural method used on sloped lands to prevent soil erosion. It involves creating stepped levels to slow water runoff and reduce soil loss, improving land productivity.

b. The weight of a fresh soil sample from a school farm was 55 g. The sample was dried in an oven at 200°C, cooled in a desiccator, and reweighed. The weight of the sample, after cooling to constant weight, was 46 g. What was the percentage of water in the soil sample?

Percentage of water = [(Initial weight - Final weight) / Initial weight] × 100

= [(55 - 46) / 55] × 100

= (9 / 55) × 100

= 16.36%

Thus, the percentage of water in the soil sample was 16.36%.

c. i. List at least two chemical substances used to neutralize soil acid.

- Calcium carbonate ($CaCO_3$)
- Slaked lime ($Ca(OH)_2$)

ii. Why do we classify nitrogen as a macronutrient in regarding plants' nutrients?

Nitrogen is classified as a macronutrient because plants require it in large quantities for growth. It is essential for the formation of amino acids, proteins, chlorophyll, and nucleic acids, all of which are critical for plant development.

11.The preparation of ammonia in the laboratory is done by heating a mixture of ammonium chloride and sodium hydroxide.

a.

i. Write a balanced chemical equation for the above reaction.

$NH_4Cl + NaOH \rightarrow NH_3 + NaCl + H_2O$

ii. Using balanced chemical equations, state how ammonia reacts with hydrogen chloride gas and heated copper (II) oxide.

Reaction with hydrogen chloride gas:

$NH_3 + HCl \rightarrow NH_4Cl$

Observation: A white smoke of ammonium chloride is formed.

Reaction with heated copper (II) oxide:

$3CuO + 2NH_3 \rightarrow 3Cu + N_2 + 3H_2O$

Observation: The black copper (II) oxide turns reddish-brown due to the formation of copper metal.

b. i. State two uses of ammonia.

- Ammonia is used in the production of fertilizers such as ammonium nitrate and urea.
- It is used as a refrigerant in industrial cooling systems.

ii. Name the catalyst used in the preparation of ammonia.

The catalyst used is finely divided iron with traces of molybdenum as a promoter.

c. Explain each of the following reactions, giving observations and equations.

i. Aqueous ammonia is added to iron (III) chloride, little by little, until excess.

Equation:

$FeCl_3 + 3NH_3 + 3H_2O \rightarrow Fe(OH)_3 + 3NH_4Cl$

Observation: A reddish-brown precipitate of iron (III) hydroxide is formed.

ii. Sodium nitrate is strongly heated.
Equation:

$2NaNO_3$ ----> $2NaNO_2 + O_2$

Observation: Sodium nitrite ($NaNO_2$) is formed, and oxygen gas is released.

12. a. Define the following terms:

i. Standard solution

A standard solution is a solution of known concentration used in titration to determine the concentration of an unknown solution.

ii. Equivalent point of titration

The equivalent point of titration is the stage in a titration where the amount of titrant added is exactly enough to completely react with the analyte in the solution.

iii. Basicity of an acid

The basicity of an acid refers to the number of hydrogen ions (H^+) that a molecule of the acid can donate in a reaction. For example, H_2SO_4 has a basicity of 2.

b. 25 cm^3 of a solution containing 0.196 g of a metal hydroxide YOH, were neutralized by 35 cm^3 of a 0.1 M hydrochloric acid solution.

i. Write down a balanced chemical equation for the reaction.

YOH + HCl ------> YCl + H_2O

ii. Calculate the molarity of the hydroxide solution.

Moles of HCl = concentration × volume (L)

= 0.1 × (35 / 1000)

= 0.0035 moles

Since the reaction ratio is 1:1, moles of YOH = 0.0035 moles

Molarity of YOH = moles / volume (L)

= 0.0035 / (25 / 1000)

= 0.14 M

iii. Calculate the relative molecular mass of YOH.

Relative molecular mass = mass / moles

= 0.196 / 0.0035

= 56 g/mol

c. Name the indicator you would choose for the following titrations:

i. Hydrochloric acid versus ammonia solution

- Methyl orange

ii. Acetic acid versus sodium hydroxide

- Phenolphthalein