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: Nov 1999**

Instructions

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

1. Choose the letter corresponding to the correct response from the five given options, then write it on the first page of your answer booklet in serial order.

(i) Steam and methane can react and produce hydrogen according to the following equation:

$CH_4 + H_2O$ -----> $CO + 3H_2$

The volume of methane needed to produce 150 cm^3 of hydrogen at the same conditions will be:

A. 25 cm^3
B. 50 cm^3
C. 75 cm^3
D. 100 cm^3
E. 150 cm^3

Solution
From the balanced equation, 1 mole of CH_4 produces 3 moles of H_2. The ratio is 1:3. If 150 cm^3 of H_2 is produced, the required volume of CH_4 is:
$(1/3) \times 150\ cm^3 = 50\ cm^3$
The correct answer is B. 50 cm^3.

(ii) The common property for all carbonates and hydrogen is that they:

A. are soluble in cold water
B. decompose on heating
C. are odourless chemical substances
D. react with dilute nitric acid
E. are not soluble in cold water

Solution
Carbonates decompose on heating to produce metal oxides and carbon dioxide gas. Similarly, hydrogen decomposes under specific conditions, such as in the presence of catalysts.
The correct answer is B. decompose on heating.

(iii) The equation which represents Haber's process is shown below:

$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$ (exothermic reaction)

The rate of formation of ammonia gas can be increased by:

A. increasing the temperature
B. increasing the concentration of nitrogen
C. decreasing the concentration of hydrogen

D. decreasing the amount of catalyst
E. increasing the volume of the container

Solution
According to Le Chatelier's principle, increasing the concentration of reactants (nitrogen and hydrogen) shifts equilibrium towards product formation.
The correct answer is B. increasing the concentration of nitrogen.

(iv) What are the products of electrolysis of aqueous sodium (I) chloride using platinum electrodes?

A. Sodium and chlorine
B. Hydrogen and oxygen
C. Hydrogen and chlorine
D. Oxygen and chlorine
E. Sodium and oxygen

Solution
Electrolysis of aqueous NaCl produces hydrogen gas at the cathode and chlorine gas at the anode.
The correct answer is C. Hydrogen and chlorine.

(v) Why is magnesium (II) chloride a deliquescent compound?

A. It decomposes when heated by heat
B. It has a low boiling point
C. It is readily fusible
D. It readily absorbs water from the atmosphere
E. It easily gives away water of crystallization

Solution
Deliquescent substances absorb moisture from the air until they dissolve in the absorbed water.
The correct answer is D. It readily absorbs water from the atmosphere.

(vi) The relative atomic mass of aluminium is 27. Its atomic number is 13. Therefore, this element has:

A. 13 neutrons
B. 14 electrons
C. 14 protons
D. 14 neutrons
E. 27 electrons

Solution
The number of neutrons is calculated as:
Neutrons = Mass number - Atomic number

= 27 - 13 = 14
The correct answer is D. 14 neutrons.

(vii) One of the following chemical formulae does not represent a carboxylic acid.

A. C_2H_4COOH
B. C_3H_7COOH
C. C_4H_6COOH
D. C_2H_5COOH

Solution
A carboxylic acid has the general formula R-COOH. The incorrect formula C_4H_6COOH does not fit this structure.
The correct answer is C. C_4H_6COOH.

(viii) How many atoms are there in 5g of lead(II) sulphate?

A. 1.59×10^{19} atoms
B. 1.59×10^{22} atoms
C. 1.59×10^{21} atoms
D. 1.59×10^{23} atoms
E. 1.59×10^{20} atoms

Solution
Using Avogadro's number and molar mass of $PbSO_4$, the number of atoms is determined to be 1.59×10^{22} atoms.
The correct answer is B. 1.59×10^{22} atoms.

(ix) The following is one of the characteristic properties of non-metals.

A. They are electromagnetic in nature
B. They behave as reducing agents
C. They form cations by gaining electrons
D. They do not react with acids
E. They form anions by loss of electrons

Solution
Non-metals gain electrons to form anions.
The correct answer is E. They form anions by loss of electrons.

(x) Each of the following constitutes one mole except:

A. Avogadro's constant of electrons

B. 2g of hydrogen molecules
C. 48g of carbon dioxide atoms
D. 19g of hydroxonium ions
E. 98g of sulphuric acid

Solution
The molar mass of CO_2 is 44g, not 48g, meaning 48g of carbon dioxide atoms does not constitute one mole.
The correct answer is C. 48g of carbon dioxide atoms.

(xi) The empirical formula of a compound is found to be CH_2 by analysis. If the relative molecular mass of the compound is 42, the molecular formula of this compound will be:

A. C_2H_4
B. C_3H_6
C. C_4H_8
D. C_6H_{12}
E. C_7H_{14}

Solution
The empirical formula CH_2 has a molar mass of 14. The molecular formula is $(42 \div 14) = 3 \times CH_2 = C_3H_6$.
The correct answer is B. C_3H_6.

(xii) What is the name of a gas produced when dilute hydrochloric acid is dropped slowly on an egg's shell?

A. Hydrogen chloride
B. Sulphur dioxide
C. Hydrogen sulphide
D. Carbon dioxide
E. Carbon disulphide

Solution
Eggshell contains calcium carbonate, which reacts with hydrochloric acid to produce carbon dioxide.
The correct answer is D. Carbon dioxide.

(xiii) One of the following organic compounds is not saturated.

A. C_2H_6
B. C_3H_8
C. C_4H_8
D. C_5H_{12}

Solution

Saturated hydrocarbons have only single bonds. C_4H_8 (alkene) contains a double bond.
The correct answer is C. C_4H_8.

(xiv) What is the mass of one mole of sodium nitrate required to be heated so as to produce one mole of oxygen gas?

A. 8g
B. 48g
C. 85g
D. 46g
E. 85g

Solution
The molar mass of $NaNO_3$ is 85g, which is the required amount.
The correct answer is E. 85g.

(xv) The function of limestone in the extraction of iron in the blast furnace is to:

A. reduce the iron oxide
B. precipitate earth materials to slag
C. remove carbon monoxide
D. separate molten iron from impurities
E. lower the temperature of the blast furnace

Solution
Limestone decomposes into CaO, which reacts with impurities to form slag.
The correct answer is B. precipitate earth materials to slag.

2. (a) Define the following terms:

(i) Empirical formula
(ii) Molecular formula

Solution
(i) The empirical formula of a compound is the simplest whole-number ratio of atoms of each element present in the compound. For example, the empirical formula of hydrogen peroxide (H_2O_2) is HO.

(ii) The molecular formula of a compound gives the actual number of atoms of each element in a molecule of the compound. It may be a multiple of the empirical formula. For example, the molecular formula of hydrogen peroxide is H_2O_2.

(b) If the molecular formula of calcium (II) sulphate is $CaSO_4$, what is the percentage of oxygen in this compound?

Solution
To find the percentage of oxygen, we use the formula:

Percentage of oxygen = (Mass of oxygen in the compound / Molar mass of the compound) × 100

The molar mass of $CaSO_4$ = (40) + (32) + (4 × 16) = 136 g/mol
The total mass of oxygen in $CaSO_4$ = 4 × 16 = 64 g

Percentage of oxygen = (64 / 136) × 100 = 47.06%

The correct answer is 47.06%.

(c) Given that the molar mass of compound X is 106 and its percentage by composition of its constituent elements is:
Na = 43.3%
C = 11.3%
O = 45.3%

Calculate the:

(i) Empirical formula
(ii) Molecular formula of the compound

Solution
Step 1: Convert percentages to moles
Moles of Na = 43.3 / 23 = 1.88
Moles of C = 11.3 / 12 = 0.94
Moles of O = 45.3 / 16 = 2.83

Step 2: Divide by the smallest value
Na = 1.88 / 0.94 = 2
C = 0.94 / 0.94 = 1
O = 2.83 / 0.94 = 3

Empirical formula = Na_2CO_3

Step 3: Find the molecular formula
Empirical formula mass = (2 × 23) + (1 × 12) + (3 × 16) = 106 g/mol
Since the molar mass is 106, the molecular formula is also Na_2CO_3.
The empirical and molecular formula of the compound is Na_2CO_3.

3. (a) What is the meaning of

(i) Allotropy
(ii) An isotope

Solution
(i) Allotropy is the property of an element to exist in two or more different physical forms in the same state. Examples include carbon, which exists as graphite and diamond, and oxygen, which exists as O_2 and O_3 (ozone).

(ii) An isotope is an atom of an element that has the same number of protons but a different number of neutrons. For example, carbon has isotopes such as C-12, C-13, and C-14.

(b) You are provided with a list of four atoms whose mass numbers and atomic numbers have been indicated:

$_{13}X$, $_{14}Y$, $_{14}W$, $_{14}Z$

(i) Which of the atoms above represent isotopes?
(ii) What is the number of protons in X?
(iii) What is the number of neutrons in Y?

Solution
(i) Isotopes are atoms with the same atomic number but different mass numbers. Since Y, W, and Z all have atomic number 14, they are isotopes of each other.

(ii) The number of protons in X is equal to its atomic number, which is 13.

(iii) The number of neutrons in Y is calculated as:
Neutrons = Mass number - Atomic number
= 14 - 14 = 0 (If this is an error in the question, and Y has a different mass number, it should be corrected).

(c) Explain why graphite can be used as an electrode as well as a lubricant but diamond cannot.

Solution
Graphite and diamond are allotropes of carbon, but they have different structures:

- Graphite consists of layers of carbon atoms arranged in hexagonal rings. These layers can slide over each other, making graphite a good lubricant. It also has free-moving electrons, allowing it to conduct electricity, making it useful as an electrode.
- Diamond has a strong tetrahedral structure with no free electrons, making it a poor conductor of electricity and unsuitable as an electrode. It is also very hard and cannot act as a lubricant.

4. (a) Study the following structural formula carefully, then state the homologous series to which each of compounds A, B, and C belong.

Solution
- Compound A: Alkane (single bonds only)
- Compound B: Alkene (double bond present)
- Compound C: Alcohol (-OH functional group)

(b) Write balanced chemical equations for the reactions between:

(i) A and chlorine in the presence of sunlight
(ii) B and hydrogen chloride
(iii) B and sodium metal

Solution
(i) $CH_4 + Cl_2$ ----> $CH_3Cl + HCl$ (In the presence of sunlight, methane reacts with chlorine in a substitution reaction)

(ii) $C_2H_4 + HCl$ -----> C_2H_5Cl (Ethene reacts with hydrogen chloride in an addition reaction)

(iii) $C_2H_4 + Na$ ------> No reaction (Alkenes do not react with sodium)

(c) Write the structures of the following organic compounds:

(i) 2,4-dimethylhexane
(ii) 1,2-dichloroethane
(iii) But-2-ene
(iv) Pent-2-yne

Solution
(i)

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

(ii) CH_2Cl-CH_2Cl

(iii) $CH_3-CH=CH-CH_3$

(iv) $CH_3-C\equiv C-CH_2-CH_3$

5. (a) With the help of balanced chemical equations where necessary, explain the following observations:

(i) Sugar turns black when concentrated sulphuric acid is slowly poured on it.
(ii) A bottle containing nitric acid appears yellowish brown.
(iii) Colorless nitrogen monoxide turns brown when exposed to air.
(iv) Fused sodium chloride conducts electricity while solid sodium chloride does not.
(v) Yellowish brown Iron (III) chloride turns pale green when hydrogen sulphide gas is passed through it.

Solution
(i) $C_{12}H_{22}O_{11} + H_2SO_4$ ----------> Carbon (black) + Water
Sulphuric acid dehydrates sugar, leaving behind black carbon.

(ii) Nitric acid decomposes to form NO_2 gas, which is brown.

(iii) $2NO + O_2$ ----------> $2NO_2$
NO reacts with oxygen to form brown NO_2 gas.

(iv) Fused NaCl has free-moving ions, while solid NaCl has a rigid structure.

(v) $FeCl_3 + H_2S$ ----------> $FeCl_2$ (green) + S
Iron (III) is reduced to Iron (II).

(b) Explain
(i) Why the colour of copper (II) sulphate is sometimes blue.
(ii) Why the blue colour of copper (II) sulphate disappears when this compound is electrolysed using platinum electrodes.

Solution
(i) The blue colour is due to hydrated Cu^{2+} ions in aqueous solution.
(ii) During electrolysis, Cu^{2+} ions are discharged as copper metal, removing the blue colour.

(c) The quantity of electricity passed during the electrolysis of copper (II) sulphate was 9650 coulombs. Calculate:

(i) The number of moles of the metal deposited
(ii) The mass of copper deposited

Solution
(i) $Q = n \times F \times z$
$n = 9650 / (96500 \times 2) = 0.05$ moles

(ii) Mass = moles × atomic mass
$= 0.05 \times 63.5$
$= 3.175$ g

The mass of copper deposited is 3.175 g.

Here is the corrected version of your response without asterisks or any unwanted formatting:

8. (a) Define the following:

(i) Reversible reaction
(ii) Rate of a chemical reaction
(iii) A catalyst

Solution

(i) A reversible reaction is a chemical reaction that can proceed in both forward and backward directions, reaching a dynamic equilibrium where the rate of the forward reaction equals the rate of the backward reaction. An example is the Haber process:
$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$.

(ii) The rate of a chemical reaction is the measure of how fast reactants are converted into products per unit time. It is influenced by factors such as temperature, concentration, surface area, and the presence of catalysts.

(iii) A catalyst is a substance that increases the rate of a chemical reaction without being consumed in the process. It works by lowering the activation energy required for the reaction to occur. For example, platinum acts as a catalyst in hydrogen fuel cells.

(b) Bahati attempted to prepare hydrogen gas by reacting zinc metal with sulphuric acid. In this experiment, zinc metal of about 0.5 cm diameter and 0.20 moles of the acid were used. The rate of formation of hydrogen gas was found to be slow.
Explain three ways in which the rate of formation of hydrogen could be increased.

Solution
The reaction occurring is:
$Zn(s) + H_2SO_4(aq) \text{------>} ZnSO_4(aq) + H_2(g)$.

The rate of hydrogen gas formation can be increased by:

(i) Increasing the concentration of sulphuric acid – A higher concentration of acid increases the number of H^+ ions available for reaction, thereby speeding up the process.

(ii) Increasing the surface area of zinc metal – Using zinc in powdered or smaller pieces increases the exposed area for reaction, leading to a faster rate of hydrogen gas formation.

(iii) Increasing the temperature of the reaction mixture – A higher temperature provides more energy to reactant molecules, increasing collision frequency and reaction speed.

(c) From the experiment described in (b) above, if Bahati wanted 36 dm^3 of hydrogen at standard temperature and pressure (s.t.p.), what amount of zinc metal would be required if 0.2 moles of the acid were used?

(The equation for the reaction is $Zn(s) + H_2SO_4(aq) \rightarrow ZnSO_4(aq) + H_2(g)$).

Solution

Step 1: Determine the number of moles of H_2 required.
From gas laws, 1 mole of any gas occupies 22.4 dm^3 at s.t.p.
So, moles of H_2 required = 36 dm^3 / 22.4 dm^3 = 1.607 moles.

Step 2: Find the moles of Zn required.
From the balanced equation, 1 mole of Zn reacts with 1 mole of H_2SO_4 to produce 1 mole of H_2.
Thus, 1.607 moles of Zn is required.

Step 3: Calculate the mass of Zn required.
Molar mass of Zn = 65 g/mol
Mass of Zn required = 1.607 × 65 = 104.46 g

The required amount of zinc metal is 104.46 g.

9. Study the following table carefully.

Element	Atomic Number
P	1
Q	8
R	11
S	17
T	12

(a) Write the electronic configuration of each of the elements in the table above.

Solution

The electronic configurations of the elements are:

P (1) = 1
Q (8) = 2, 6

R (11) = 2, 8, 1
S (17) = 2, 8, 7
T (12) = 2, 8, 2

(b) What is the valency of each of elements P, Q, R, and T?

Solution

Valency is determined by the number of electrons an atom gains, loses, or shares to complete an octet.

P (1) ----> Valency = 1 (loses 1 electron)
Q (8) ----> Valency = 2 (gains 2 electrons to complete octet)
R (11) -----> Valency = 1 (loses 1 electron)
T (12) -----> Valency = 2 (loses 2 electrons)

(c) Write well-balanced chemical equations and name the type of bonds found in the compounds formed when each of the following elements react:
(i) Q and R
(ii) P and T
(iii) P and Q
(iv) T and Q

Solution
(i) Q and R
Q (oxygen) and R (sodium) form sodium oxide:
$4Na + O_2 \text{ ---> } 2Na_2O$
Type of bond: Ionic bond (Na donates electrons to O).

(ii) P and T
P (hydrogen) and T (magnesium) form magnesium hydride:
$Mg + H_2 \text{ ----> } MgH_2$
Type of bond: Ionic bond (Mg loses electrons, H gains).

(iii) P and Q
P (hydrogen) and Q (oxygen) form water:
$2H_2 + O_2 \text{ -----> } 2H_2O$
Type of bond: Covalent bond (Hydrogen shares electrons with oxygen).

(iv) T and Q
T (magnesium) and Q (oxygen) form magnesium oxide:
$2Mg + O_2 \text{ ----> } 2MgO$
Type of bond: Ionic bond (Mg donates electrons to O).
10. (a) Give the meaning of the following terms.

(i) Saturated solution
(ii) Hygroscopic substance
(iii) Solubility of a solute

Solution
(i) A saturated solution is a solution that contains the maximum amount of dissolved solute at a given temperature and pressure. Any additional solute will not dissolve and will remain as a solid precipitate.

(ii) A hygroscopic substance is a material that readily absorbs moisture from the air without dissolving in it. Examples include concentrated sulfuric acid and anhydrous calcium chloride.

(iii) Solubility of a solute is the maximum amount of solute that can dissolve in a given amount of solvent at a specific temperature and pressure, usually expressed in grams of solute per 100 grams of solvent.

(b) You are provided with a graph of solubility vs temperature for sodium chloride (NaCl) and potassium chlorate ($KClO_3$).

(i) At what temperature are sodium chloride (NaCl) and potassium chlorate ($KClO_3$) equally soluble in water?

Solution
From the graph, the point at which the solubility curves of NaCl and $KClO_3$ intersect indicates the temperature at which both are equally soluble. By observing the graph, this temperature is approximately 30°C.
(ii) Which compound becomes more soluble in water as temperature increases?

Solution
By analyzing the graph, the solubility of $KClO_3$ increases significantly with temperature, whereas NaCl shows very little change in solubility. Therefore, potassium chlorate ($KClO_3$) becomes more soluble in water as temperature increases.

(iii) What is the maximum amount of potassium chlorate which can be dissolved in 100g of water at 70°C?

Solution
By reading the solubility curve for $KClO_3$ at 70°C, the maximum solubility is approximately 50g per 100g of water.

(iv) At what temperature would 10g of potassium chlorate be dissolved in water?

Solution
By locating 10g on the solubility curve for $KClO_3$, the corresponding temperature is approximately 20°C.