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: 1997**

Instructions

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

I. When substance A and substance B react to produce a new substance, the reaction of A and B is said to

A. undergo a chemical change
B. form a mixture
C. form a solution
D. undergo a physical change

Solution
A chemical change occurs when substances react to form a new product with different properties. Physical changes, on the other hand, do not produce new substances.
The correct answer is A. undergo a chemical change.

II. According to the Dalton's atomic theory, the smallest particle which can undergo a chemical change is

A. an atom
B. a molecule
C. an ion
D. a proton

Solution
Dalton's atomic theory states that atoms are the smallest units that participate in chemical reactions.
The correct answer is A. an atom.

III. In two jars labelled X and Y contain 22.4 dm^3 of oxygen gas and nitrogen gas at s.t.p. respectively. Then it is true that

A. There were 6.02×10^{23} oxygen molecules in jar X and 6.02×10^{23} nitrogen molecules in jar Y
B. 6.02×10^{23} oxygen atoms were in jar X and 6.02×10^{23} atoms of nitrogen were in jar Y
C. There were 12.04×10^{23} molecules of oxygen and nitrogen in the two gas jars
D. $0.5g \times 10^{23}$ molecules of oxygen and nitrogen were in the two gas jars

Solution
At standard temperature and pressure (s.t.p.), one mole of a gas occupies 22.4 dm^3 and contains Avogadro's number of molecules, which is 6.02×10^{23}. Therefore, each jar contains one mole of the gas, meaning both jars have the same number of molecules.
The correct answer is A. There were 6.02×10^{23} oxygen molecules in jar X and 6.02×10^{23} nitrogen molecules in jar Y.

IV. Element of atomic number 12 is found in

A. group I and period 3
B. group II and period 3
C. group II and period 2

D. group I and period 2

Solution

An element with atomic number 12 corresponds to magnesium (Mg). Magnesium belongs to group II (alkaline earth metals) and period 3 of the periodic table.

The correct answer is B. group II and period 3.

V. When hydrogen chloride molecules are formed covalently, how many electrons are shared between hydrogen and chlorine atoms?

A. 1 electron
B. 2 electrons
C. 3 electrons
D. 4 electrons

Solution

A covalent bond is formed when atoms share electrons. Hydrogen and chlorine each need one more electron to complete their outer shells, so they share one electron.

The correct answer is A. 1 electron.

VI. When an alcohol reacts with a carboxylic acid, which of the following organic compounds is formed?

A. An ester
B. An ether
C. An alkane
D. An alkene

Solution

Alcohols react with carboxylic acids in a process called esterification to form esters and water.

The correct answer is A. An ester.

VII. Which of the following equations represents a neutralization reaction?

A. $2AgNO_3(aq) + NaCl(aq) \rightarrow AgCl(s) + NaNO_3(aq)$
B. $H_2(g) + O_2(g) \rightarrow H_2O(l)$
C. $NaOH(aq) + HCl(aq) \rightarrow NaCl(aq) + H_2O(l)$
D. $H_2SO_4(aq) \rightarrow H_2O(l) + SO_3(g)$

Solution

A neutralization reaction occurs when an acid reacts with a base to form salt and water.

The correct answer is C. $NaOH(aq) + HCl(aq) \rightarrow NaCl(aq) + H_2O(l)$.

VIII. When 0.125 Faraday of electricity are passed through a copper (II) sulphate solution, the mass of copper deposited will be

A. 1 g
B. 2 g
C. 3 g
D. 4 g

Solution
One Faraday deposits one mole of the element divided by its charge. The electrochemical equivalent of copper is 31.75 g per Faraday. So,
Mass deposited = 31.75 g × 0.125 = 3.97 g
The correct answer is D. 4 g.

IX. The reaction between iodine and hydrogen can be represented by the equation below

$H_2 + I_2 \rightleftharpoons 2HI \ \Delta H = + x \ kJ \ mol^{-1}$

This shows that the reaction is

A. Endothermic
B. Exothermic
C. Neutralization
D. Thermal decomposition

Solution
Since the reaction has a positive enthalpy change ($\Delta H > 0$), it means heat is absorbed, making the reaction endothermic.
The correct answer is A. Endothermic.

X. Which of the following sets of symbols could represent isotopes of the same element?

A. ^{16}X, ^{16}Y, ^{17}X
B. ^{16}X, ^{17}X, ^{18}X
C. ^{16}X, ^{17}X, ^{18}Y
D. ^{15}X, ^{16}Y, ^{17}Z

Solution
Isotopes are atoms of the same element with the same number of protons but different numbers of neutrons. Only option B has symbols that share the same atomic symbol but different mass numbers.
The correct answer is B. ^{16}X, ^{17}X, ^{18}X.

XI. When methane (CH_4) is completely burnt in oxygen the products will be

A. Carbon, carbon dioxide, and water vapor
B. Hydrogen, carbon dioxide, and water vapor
C. Carbon dioxide and water vapor
D. Green monoxide and water vapor

Solution
Complete combustion of methane produces carbon dioxide and water vapor:
$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$
The correct answer is C. Carbon dioxide and water vapor.

XII. The method of separating a mixture of two liquids by using their differences in boiling points is known as

A. Filtration
B. Evaporation
C. Fractional distillation
D. Decantation

Solution
Fractional distillation is used to separate liquid mixtures with different boiling points.
The correct answer is C. Fractional distillation.

XIII. The volume of 0.2M H_2SO_4 required to neutralize completely 25.0 cm^3 of 0.05M NaOH is

A. 6.25 cm^3
B. 4.512 cm^3
C. 5.0 cm^3
D. 3.125 cm^3

Solution
Using the formula:
$M_1V_1 = M_2V_2$
$(0.2 \times V_1) = (0.05 \times 25)$
$V_1 = (0.05 \times 25) / 0.2 = 6.25\ cm^3$
The correct answer is A. 6.25 cm^3.

XIV. When a green solution of iron (II) salt was exposed to air for 10 minutes, the solution turned reddish-brown because

A. Fe^{2+} ions were reduced to Fe^{3+} ions
B. Fe^{2+} ions were oxidized to Fe^{3+} ions

C. Fe^{3+} ions were oxidized to Fe^{2+} ions
D. Fe^{2+} ions reacted with oxygen

Solution
Iron (II) oxidizes to iron (III) in the presence of oxygen.
The correct answer is B. Fe^{2+} ions were oxidized to Fe^{3+} ions.

XV. What numbers do the letters X and Y represent in the following balanced equation?

A. X is 3 while Y is 2
B. X is 2 while Y is 3
C. X is 1 while Y is 2
D. X is 2 while Y is 1

Solution
To determine the values of X and Y, we balance the given chemical equation by ensuring the number of atoms of each element on both sides of the equation is equal.
From the equation, the correct values of X and Y are:

The correct answer is A. X is 3 while Y is 2.

2. (a) Define the following terms

(i) anode
(ii) electrode

Solution

(i) An anode is the electrode in an electrochemical cell where oxidation occurs. In an electrolytic cell, it is the positive electrode that attracts anions, while in a galvanic cell, it is the negative electrode where electrons are lost by the oxidized species.

(ii) An electrode is a conductor through which electricity enters or leaves a substance in an electrochemical cell. It serves as a medium for the transfer of electrons between the external circuit and the electrolyte. Examples include graphite, platinum, and metal electrodes like copper and zinc.

(b) What will the product be at the cathode if a solution of copper (II) sulphate is electrolyzed using platinum electrodes?

Solution

During the electrolysis of copper (II) sulphate ($CuSO_4$) solution using platinum electrodes:

- The electrolyte contains Cu^{2+}, SO_4^{2-}, H^+, and OH^- ions.
- At the cathode (negative electrode), Cu^{2+} ions are preferentially reduced because copper has a higher reduction potential than hydrogen.
- The reduction reaction occurring at the cathode is:

$Cu^{2+}(aq) + 2e^- \text{-------> } Cu(s)$

- Copper metal is deposited at the cathode as a reddish-brown solid.

Thus, the product at the cathode is solid copper (Cu).

3. (a) Give the meaning of

(i) empirical formula
(ii) molecular formula

Solution

(i) The empirical formula is the simplest whole-number ratio of atoms of each element in a compound. It does not necessarily show the exact number of atoms but represents the simplest proportion. For example, the empirical formula of glucose ($C_6H_{12}O_6$) is CH_2O.

(ii) The molecular formula shows the actual number of atoms of each element in a molecule of a compound. It is a multiple of the empirical formula. For example, the molecular formula of glucose is $C_6H_{12}O_6$.

(b) A compound of relative molecular mass of 106 was found to be composed of 43.4% sodium, 11.3% carbon, and 45.3% oxygen. Determine its:

(i) empirical formula
(ii) molecular formula if its molar mass is 106

Solution

Step 1: Convert mass percentages to moles

- Moles of Na = 43.4 / 23 = 1.89
- Moles of C = 11.3 / 12 = 0.94
- Moles of O = 45.3 / 16 = 2.83

Step 2: Divide by the smallest value

- Na = 1.89 / 0.94 = 2

- C = 0.94 / 0.94 = 1
- O = 2.83 / 0.94 = 3

Empirical formula = Na_2CO_3

Step 3: Determine the molecular formula

- Empirical formula mass = (2 × 23) + (1 × 12) + (3 × 16) = 106 g/mol
- Since the molecular mass is given as 106, the molecular formula is the same as the empirical formula.

Thus, the empirical formula and molecular formula are Na_2CO_3.

4. (a) You are provided with compounds which have the following structural formulae

A:

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    H
    |
H – C – C – H
    |
    H
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B:

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    H
    |
H – C = C – H
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C:

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    H
    |
H – C – C – OH
    |
    H
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D:

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    H
    |
H – C – C – C – OH
    |
    H
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(i) Give the name of the functional groups in each of the compounds, B, C, and D.

Solution

- Compound B contains a carbon-carbon double bond, which is characteristic of an alkene functional group.
- Compound C contains a hydroxyl (-OH) group, which is characteristic of an alcohol functional group.
- Compound D also contains a hydroxyl (-OH) group, making it part of the alcohol functional group.

(ii) Give the systematic (IUPAC) names of the compounds A, B, and D.

Solution

- Compound A: Ethane (C_2H_6) – a saturated hydrocarbon (alkane).
- Compound B: Ethene (C_2H_4) – an unsaturated hydrocarbon (alkene).
- Compound D: Propanol (C_3H_8O) – an alcohol with three carbon atoms.

(b) By using potassium permanganate, how can you distinguish between compound A and compound B?

Solution

- Potassium permanganate test (Baeyer's test) is used to distinguish between alkanes and alkenes.
- When potassium permanganate ($KMnO_4$) is added to compound B (ethene), the solution decolorizes because the alkene undergoes oxidation, forming a diol (glycol).
- When $KMnO_4$ is added to compound A (ethane), there is no color change because alkanes do not react with potassium permanganate under normal conditions.

Thus, compound B will cause decolorization of potassium permanganate, while compound A will not.

5. (a) Why are metals used as

(i) reducing agents?
(ii) conductors of electricity?

Solution

(i) Metals are used as reducing agents because they have low electronegativity and readily lose electrons to form positive ions. This means they donate electrons in redox reactions, reducing other substances. For example, sodium (Na) and magnesium (Mg) act as reducing agents in chemical reactions.

(ii) Metals are good conductors of electricity because they have free-moving valence electrons that allow the flow of electric current. The metallic bond consists of a "sea of delocalized electrons," which facilitates electrical conductivity.

(b) Give the name of the metals which fit the following descriptions:

(i) It must be kept under kerosene to protect it from water or air.

(ii) The metallic element in limestone.
(iii) Its green-colored carbonate decomposes when heated to give a black oxide.
(iv) Its oxide is yellow when hot and white when cold.

Solution

(i) Sodium (Na) or Potassium (K) – These are highly reactive alkali metals that react with moisture and oxygen in the air, requiring storage under kerosene.
(ii) Calcium (Ca) – It is found in limestone, which is composed of calcium carbonate ($CaCO_3$).
(iii) Copper (Cu) – Its carbonate ($CuCO_3$) is green and decomposes upon heating to form copper (II) oxide (CuO), which is black.
(iv) Zinc (Zn) – Zinc oxide (ZnO) is yellow when hot and turns white when it cools.

6. (a) Define nitrogen fixation.

Solution

Nitrogen fixation is the process by which atmospheric nitrogen (N_2) is converted into nitrogen compounds, such as ammonia (NH_3) or nitrates (NO_3^-), that plants can absorb and use for growth. This can occur biologically (by nitrogen-fixing bacteria) or industrially (through the Haber process).

(b) Explain why the naturally occurring nitrogen gas is not available to plants directly.
Solution
Nitrogen gas (N_2) is chemically very stable due to its triple bond ($N \equiv N$), which requires a large amount of energy to break. Plants cannot use nitrogen in this form; they depend on nitrogen fixation by bacteria or industrial processes to convert nitrogen into a usable form like nitrates or ammonia.

(c) Which are the three major processes by which atmospheric nitrogen is transformed into usable forms?

Solution

(i) Biological nitrogen fixation – Bacteria such as Rhizobium and Azotobacter convert N_2 into ammonia.
(ii) Industrial nitrogen fixation – The Haber process converts nitrogen into ammonia for fertilizers.
(iii) Lightning fixation – Energy from lightning converts nitrogen gas into nitrates that dissolve in rain and enter the soil.

Here is the corrected version without any special formatting:

8. (a) (i) What is a catalyst?

Solution

A catalyst is a substance that increases the rate of a chemical reaction without being consumed in the process. It works by providing an alternative reaction pathway with a lower activation energy, allowing reactants to convert into products more efficiently. Catalysts are widely used in industrial processes, such as the Haber process for ammonia synthesis, where iron is used as a catalyst.

(ii) Mathias set out to prepare oxygen by two different methods.

In the first experiment, he mixed 5 cm^3 of hydrogen peroxide with 30 cm^3 of water and added in the mixture 0.5 g of solid manganese dioxide (MnO_2). He managed to collect 20 cm^3 of oxygen within the first 20 seconds at room temperature.

In his second experiment, 5 cm^3 of the same hydrogen peroxide with 30 cm^3 of water was also at room temperature, but it took 360 seconds to collect 20 cm^3 of oxygen.

Explain why the time he needed for collecting 20 cm^3 of oxygen was different in the two experiments.

Solution

The difference in the time required to collect the same volume of oxygen is due to the presence of a catalyst in the first experiment.

- In the first experiment, manganese dioxide (MnO_2) was added, which acted as a catalyst. This catalyst sped up the decomposition of hydrogen peroxide (H_2O_2) into water and oxygen gas:
  $2H_2O_2 \rightarrow 2H_2O + O_2$
  The catalyst provided an alternative pathway with lower activation energy, allowing the reaction to proceed faster.

- In the second experiment, no catalyst was added. The decomposition of hydrogen peroxide occurred at a much slower rate, taking longer to produce the same amount of oxygen.

Thus, the presence of manganese dioxide significantly increased the reaction rate, leading to a much shorter reaction time in the first experiment compared to the second.

(b) What are the three factors which affect the equilibrium position of a balanced reversible chemical reaction?

Solution

The position of equilibrium in a reversible reaction is influenced by the following three factors:

(i) Concentration of reactants and products – Increasing the concentration of reactants shifts the equilibrium to the right (toward the products), while increasing the concentration of products shifts the equilibrium to the left (toward the reactants).

(ii) Temperature – If the reaction is exothermic, increasing temperature shifts equilibrium to the left (favoring reactants). If the reaction is endothermic, increasing temperature shifts equilibrium to the right (favoring products).

(iii) Pressure – This affects reactions involving gases. An increase in pressure shifts equilibrium toward the side with fewer gas molecules, while a decrease in pressure shifts equilibrium toward the side with more gas molecules.

(c) Solid iodine and gaseous hydrogen were kept in a closed system and heated until the following equilibrium was established:

$H_2(g) + I_2(s) \rightleftharpoons 2HI(g)$

If water was introduced into the system and the hydrogen iodide dissolved in it,

(i) In which direction would the equilibrium position be shifted?
(ii) What would happen to the production of hydrogen iodide upon the introduction of water into the reaction system?

Solution

(i) The equilibrium position would shift to the right (favoring product formation). Since HI dissolves in water, its concentration in the gaseous phase decreases, causing the reaction to shift forward to replace the lost HI.

(ii) The production of hydrogen iodide would increase as the reaction adjusts to the new conditions. More H_2 and I_2 would react to form additional HI in an attempt to restore equilibrium.

9. (a) (i) State the Charles' Law.

Solution

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

$V_1/T_1 = V_2/T_2$

where V is volume and T is temperature in Kelvin.

(ii) Write an expression of the combined Charles' and Boyle's Laws.

Solution

The combined gas law combines Boyle's Law and Charles' Law:

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

where P is pressure, V is volume, and T is temperature in Kelvin. This equation shows the relationship between pressure, volume, and temperature for a fixed amount of gas.

(b) What will happen to the volume of a given mass of gas if its pressure is doubled at constant temperature?

Solution

According to Boyle's Law:

$P_1V_1 = P_2V_2$

If the pressure is doubled ($P_2 = 2P_1$) while keeping the temperature constant, the volume will be halved:

$V_2 = V_1/2$

This means that when pressure doubles, the gas volume decreases by half.

(c) Calculate the volume of a gas at 273K and 760mmHg if its volume is 198cm³ at 297K and 740mmHg pressure.

Solution
Using the combined gas law:

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

Substituting values:

$(740 \times 198) / 297 = (760 \times V_2) / 273$

Solving for V_2:

$V_2 = (740 \times 198 \times 273) / (297 \times 760)$

$V_2 = (39932640) / (225720)$

$V_2 = 176.9\ cm^3$

The volume of the gas at 273K and 760mmHg is 176.9 cm³.

10. The figure below is part of the Periodic table where the transition metals are not included. The numbers in the table are the atomic numbers of some of the elements.

(a) (i) For each number, write the symbol of the corresponding element.

Solution

Atomic Number	Symbol
1	H
2	He
4	Be
6	C
8	O
11	Na
12	Mg
17	Cl

(ii) Considering the elements with atomic number 12 and 17, which is a metal and which is a non-metal?

Solution
- Magnesium (atomic number 12) is a metal.
- Chlorine (atomic number 17) is a non-metal.

(iii) Write one equation which represents a reaction between the element with atomic number 1 and the element with atomic number 17.

Solution

Hydrogen (H) and chlorine (Cl) react to form hydrogen chloride:

$H_2 + Cl_2$ ------> 2HCl

(b) (i) What are the types of oxides formed by elements with atomic numbers 11 and 12?

Solution
- Sodium (Na, atomic number 11) forms a basic oxide (Na_2O).
- Magnesium (Mg, atomic number 12) forms an amphoteric oxide (MgO).

(ii) Write a balanced chemical equation between the oxide of the element with atomic number 11 and aqueous solution of the compound formed in (a)(iii).

Solution
Sodium oxide reacts with hydrogen chloride solution to form sodium chloride and water:

$Na_2O + 2HCl$ ------> $2NaCl + H_2O$

(iii) Write the symbol of an inert gas element represented by the given atomic numbers.

Solution

From the table, the noble gases include:

- Helium (He, atomic number 2)