

FEDERAL BOARD 1ST YEAR CHEMISTRY NOTES

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# Introduction to Fundamental Concepts of Chemistry Atom It is the smallest particle of an element which can exist with all the properties of its own element but it cannot exist in atmosphere alone. Molecule When two or more than two atoms are combined with each other a molecule is formed. It can exist freely in nature. Formula Weight It is the sum of the weights of the atoms present in the formula of a substance. Molecular Weight It is the sum of the atomic masses of all the atoms present in a molecule. Chemistry It is a branch of science which deals with the properties, composition and the structure of matter. Empirical Formula Definition It is the simplest formula of a chemical compound which represents the element present of the compound and also represent the simplest ratio between the elements of the compound. Examples The empirical formula of benzene is "CH". It indicates that the benzene molecule is composed of two elements carbon and hydrogen and the ratio between these two elements is 1:1. The empirical formula of glucose is "CH2O". This formula represents that glucose molecule is composed of three elements carbon, hydrogen and oxygen. The ratio between carbon and oxygen is equal but hydrogen is double. Determination of Empirical Formula To determine the empirical formula of a compound following steps are required. 1. To detect the elements present in the compound. 2. To determine the masses of each element. 3. To calculate the percentage of each element. 4. Determination of mole composition of each element. 5. Determination of simplest ratio between the element of the compound. Illustrated Example of Empirical Formula Consider an unknown compound whose empirical formula is to be determined is given to us. Now we will use the above five steps in order to calculate the empirical formula. Step I - Determination of the Elements By performing test it is found that the compound contains magnesium and oxygen elements. Step II - Determination of the Masses Masses of the elements are experimentally determined which are given below. Mass of Mg = 2.4 gm Mass of Oxygen = 1.6 gm Step III - Estimation of the Percentage The percentage of an element may be determined by using the formula. % of element = Mass of element / Mass of compound x 100 In the given compound two elements are present which are magnesium and oxygen, therefore mass of compound is equal to the sum of the mass of magnesium and mass of oxygen. Mass of compound = 2.4 + 1.6 = 4.0 gm % Mg = Mass of Mg / Mass of Compound x 100 = 2.4 / 4.0 x 100 = 60% % O = Mass of Oxygen / Mass of Compound x 100 = 1.6 / 4.0 x 100 = 40% Step IV - Determination of Mole Composition Mole composition of the elements is obtained by dividing percentage of each element with its atomic mass. Mole ratio of Mg = Percentage of Mg / Atomic Mass of Mg = 60 / 24 = 2.5 Mole ratio of Mg = Percentage of Oxygen / Atomic Mass of Oxygen = 40 / 16 = 2.5 Step V - Determination of Simplest Ratio To obtain the simplest ratio of the atoms the quotients obtained in the step IV are divided by the smallest quotients. Mg = 2.5 / 2.5 = 1 O = 2.5 / 2.5 = 1 Thus the empirical formula of the compound is MgO Note If the number obtained in the simplest ratio is not a whole number then multiply this number with a smallest number such that it becomes a whole number maintain their proportion. Molecular Formula Definition The formula which shows the actual number of atoms of each element present in a molecule is called molecular formula. OR It is a formula which represents the element ratio between the elements and actual number of atoms of each type of elements present per molecule of the compound. Examples The molecular formula of benzene is "C6H6". It indicates that 1. Benzene molecule is composed of two elements carbon and hydrogen. 2. The ratio between carbon and hydrogen is 1:1. 3. The number of atoms present per molecule of benzene are 6 carbon and 6 hydrogen atoms. The molecular formula of glucose is "C6H12O6". The formula represents that 1. Glucose molecule is composed of three elements carbon, hydrogen and oxygen. 2. The ratio between the atoms of carbon, hydrogen and oxygen is 1:2:1. 3. The number of atoms present per molecule of glucose are 6 carbon atoms. 12 hydrogen atoms and 6 oxygen atoms. @import "/extensions/GoogleAdSense/GoogleAdSense.css"; Determination of Molecular Formula The molecular formula of a compound is an integral multiple of its empirical formula. Molecular formula = (Empirical formula)n Where n is a digit = 1, 2, 3 etc. Hence the first step in the determination of molecular formula is to calculate its empirical formula by using the procedure as explained in empirical formula. After that the next step is to calculate the value of n n = Molecular Mass / Empirical Formula Mass Example The empirical formula of a compound is CH2O and its molecular mass is 180. To calculate the molecular formula of the compound first of all we will calculate its empirical formula mass Empirical formula mass of CH2O = 12 + 1 x 2 + 16 = 30 n = Molecular Mass / Empirical Formula Mass = 180 / 30 = 6 Molecular formula = (Empirical formula)n = (CH2O)6 = C6H12O6 Molecular Mass Definition The sum of masses of the atoms present in a molecule is called as molecular mass. OR It is the comparison that how mach a molecule of a substance is heavier than 1/12th weight or mass of carbon atom. Example The molecular mass of CO2 may be calculated as Molecular mass of CO2 = Mass of Carbon + 2 (Mass of Oxygen) = 12 + 2 x 16 = 44 a.m.u Molecular mass of H2O = (Mass of Hydrogen) x 2 + Mass of Oxygen = 1 x 2 + 16 = 18 a.m.u Molecular mass of HCl = Mass of Hydrogen + Mass of Chlorine = 1 + 35.5 = 36.5 a.m.u Gram Molecular Mass Definition The molecular mass of a compound expressed in gram is called gram molecular mass or mole. Examples 1. The molecular mass of H2O is 18. If we take 18 gm H2O then it is called 1 gm molecular mass of H2O or 1 mole of water. 2. The molecular mass of HCl is 36.5. If we take 36.5 gm of HCl then it is called as 1 gm molecular mass of HCl or 1 mole of HCl. Mole Definition It is defined as atomic mass of an element, molecular mass of a compound or formula mass of a substance expressed in grams is called as mole. OR The amount of a substance that contains as many number of particles (atoms, molecules or ions) as there are atoms contained in 12 gm of pure carbon. Examples 1. The atomic mass of hydrogen is one. If we take 1 gm of hydrogen, it is equal to one mole of hydrogen. 2. The atomic mass of Na is 23 if we take 23 gm of Na then it is equal to one mole of Na. 3. The atomic mass of sulphur is 32. When we take 32 gm of sulphur then it is called one mole of sulphur. From these examples we can say that atomic mass of an element expressed in grams is called mole. Similarly molecular masses expressed in grams is also known as mole e.g. The molecular mass of CO2 is 44. If we take 44 gm of CO2 it is called one mole of CO2 or the molecular mass of H2O is 18. If we take 18 gm of H2O it is called one mole of H2O. When atomic mass of an element expressed in grams it is called gram atom While The molecular mass of a compound expressed in grams is called gram molecule. According to the definition of mole. One gram atom contain 6.02 x 10(23) atoms While One gram molecule contain 6.02 x 10(23) molecules. Avagadro's Number An Italian scientist, Avagadro's calculated that the number of particles (atoms, molecules) in one mole of a substance are always equal to 6.02 x 10(23). This number is known as Avogadro's number and represented as N(A). Example 1 gm mole of Na contain 6.02 x 10(23) atoms of Na. 1 gm mole of Sulphur = 6.02 x 10(23) atoms of Sulphur. 1 gm mole of H2SO4 = 6.02 x 10(23) molecules H2SO4 1 gm mole of H2O = 6.02 x 10(23) molecules of H2O On the basis of Avogadro's Number "mole" is also defined as Mass of 6.02 x 10(23) molecules, atoms or ions in gram is called mole. Determination Of The Number Of Atoms Or Molecules In The Given Mass Of A Substance Example 1 Calculate the number of atoms in 9.2 gm of Na. Solution Atomic mass of Na = 23 a.m.u If we take 23 gm of Na, it is equal to 1 mole. 23 gm of Na contain 6.02 x 10(23) atoms 1 gm of Na contain 6.02 x 10(23) / 23 atoms 9.2 gm of Na contain 9.2 x 6.02 x 10(23) /23 = 2.408 x 10(23) atoms of Na Determination Of The Mass Of Given Number Of Atoms Or Molecules Of A Substance Example 2 Calculate the mass in grams of 3.01 x 10(23) molecules of glucose. Solution Molecular mass of glucose = 180 a.m.u So when we take 180 gm of glucose it is equal to one mole So, 6.02 x 10(23) molecules of glucose = 180 gm 1 molecule of glucose = 180 / 6.02 x 10(23) gm 3.01 x 10(23) molecules of glucose = 3.01 x 10(23) x 180 / 6.02 x 10(23) = 90 gm Stoichiometry (Calculation Based On Chemical Equations) Definition The study of relationship between the amount of reactant and the products in chemical reactions as given by chemical equations is called stoichiometry. In this study we always use a balanced chemical equation because a balanced chemical equation tells us the exact mass ratio of the reactants and products in the chemical reaction. There are three relationships involved for the stoichiometric calculations from the balanced chemical equations which are 1. Mass - Mass Relationship 2. Mass - Volume Relationship 3. Volume - Volume Relationship Mass - Mass Relationship In this relationship we can determine the unknown mass of a reactant or product from a given mass of teh substance involved in the chemical reaction by using a balanced chemical equation. Example Calculate the mass of CO2 that can be obtained by heating 50 gm of limestone. Solution Step I - Write a Balanced Equation CaCO3 ----> CaO + CO2 Step II - Write Down The Molecular Masses And Moles Of Reactant & Product CaCO3 ----> CaO + CO2 Method I - MOLE METHOD Number of moles of 50 gm of CaCO3 = 50 / 100 = 0.5 mole According to equation 1 mole of CaCO3 gives 1 mole of CO2 0.5 mole of CaCO3 will give 0.5 mole of CO2 Mass of CO2 = Moles x Molecular Mass = 0.5 x 44 = 22 gm Method II - FACTOR METHOD From equation we may write as 100 gm of CaCO3 gives 44 gm of CO2 1 gm of CaCO3 will give 44/100 gm of CO2 50 gm of CaCO3 will give 50 x 44 / 100 gm of CO2 = 22 gm of CO2 Mass - Volume Relationship The major quantities of gases can be expressed in terms of volume as well as masses. According to Avogardro One gm mole of any gas always occupies 22.4 dm3 volume at S.T.P. So this law is applied in mass-volume relationship. This relationship is useful in determining the unknown mass or volume of reactant or product by using a given mass or volume of some substance in a chemical reaction. Example Calculate the volume of CO2 gas produced at S.T.P by combustion of 20 gm of CH4. Solution Step I - Write a Balanced Equation CH4 + 2 O2 ----> CO2 + 2 H2O Step II - Write Down The Molecular Masses And Moles Of Reactant & Product CH4 + 2 O2 ----> CO2 + 2 H2O Method I - MOLE METHOD Convert the given mass of CH4 in moles Number of moles of CH4 = Given Mass of CH4 / Molar Mass of CH4 From Equation 1 mole of CH4 gives 1 moles of CO2 1.25 mole of CH4 will give 1.25 mole of CO2 No. of moles of CO2 obtained = 1.25 But 1 mole of CO2 at S.T.P occupies 22.4 dm3 1.25 mole of CO2 at S.T.P occupies 22.4 x 1.25 = 28 dm3 Method II - FACTOR METHOD Molecular mass of CH4 = 16 Molecular mass of CO2 = 44 According to the equation 16 gm of CH4 gives 44 gm of CO2 1 gm of CH4 will give 44/16 gm of CO2 20 gm of CH4 will give 20 x 44/16 gm of CO2 = 55 gm of CO2 44 gm of CO2 at S.T.P occupy a volume 22.4 dm3 1 gm of CO2 at S.T.P occupy a volume 22.4/44 dm3 55 gm of CO2 at S.T.P occupy a volume 55 x 22.4/44 = 28 dm3 Volume - Volume Relationship This relationship determine the unknown volumes of reactants or products from a known volume of other gas. This relationship is based on Gay-Lussac's law of combining volume which states that gases react in the ratio of small whole number by volume under similar conditions of temperature & pressure. Consider this equation CH4 + 2 O2 ----> CO2 + 2 H2O In this reaction one volume of CH4 gas reacts with two volumes of oxygen gas to give one volume of CO2 and two volumes of H2O Examples What volume of O2 at S.T.P is required to burn 500 litres (dm3) of C2H4 (ethylene)? Solution Step I - Write a Balanced Equation C2H4 + 3 O2 ----> 2 CO2 + 2 H2O Step II - Write Down The Moles And Volume Of Reactant & Product C2H4 + 3 O2 ----> 2 CO2 + 2 H2O According to Equation 1 dm3 of C2H4 requires 3 dm3 of O2 500 dm3 of C2H4 requires 3 x 500 dm3 of O2 = 1500 dm3 of O2 Limiting Reactant In stoichiometry when more than one reactant is involved in a chemical reaction, it is not so simple to get actual result of the stoichiometric problem by making relationship between any one of the reactant and product, which are involved in the chemical reaction. As we know that when any one of the reactant is completely used or consumed the reaction is stopped no matter the other reactants are present in very large quantity. This reactant which is totally consumed during the chemical reaction due to which the reaction is stopped is called limiting reactant. Limiting reactant help us in calculating the actual amount of product formed during the chemical reaction. To understand the concept the limiting reactant consider the following calculation. Problem We are provided 50 gm of H2 and 50 gm of N2. Calculate how many gm of NH3 will be formed when the reaction is irreversible. The equation for the reaction is as follows. N2 + 3 H2 ----> 2 NH3 Solution In this problem moles of N2 and H2 are as follows Moles of N2 = Mass of N2 / Mol. Mass of N2 = 50 / 28 = 1.79 Moles of H2 = Mass of H2 / Mol. Mass of H2 = 50 / 2 = 25 So, the provided moles for the reaction are nitrogen = 1.79 moles and hydrogen = 25 moles But in the equation of the process 1 mole of nitrogen require 3 mole of hydrogen. Therefore the provided moles of nitrogen i.e. 1.79 require 1.79 x 3 moles of hydrogen i.e. 5.37 moles although 25 moles of H2 are provided but when nitrogen is consumed the reaction will be stopped and the remaining hydrogen is useless for the reaction so in this problem N2 is a limiting reactant by which we can calculate the actual amount of product formed during the reaction. N2 + 3 H2 ----> 2 NH3 1 mole of N2 gives 2 moles of NH3 1.79 mole of N2 gives 2 x 1.79 moles of NH3 = 3.58 moles of NH3 Mass of NH3 = Moles of NH3 x Mol. Mass = 3.58 x 17 = 60.86 gm of NH3