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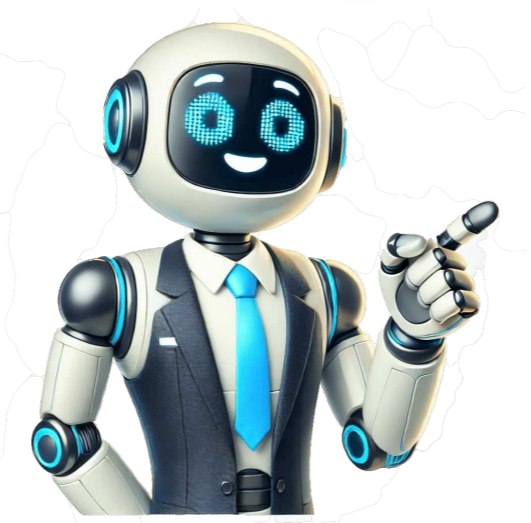




























Table (PageIndex{1}) shows the comparison between the empirical and molecular formula of methane, acetic acid, and glucose, and the different values of n. The molecular formula of methane is  $\text{C}_1\text{H}_4$  and because it contains one carbon atom, that is also its empirical formula. Methane is a simple whole number multiple of the empirical formula. Acetic acid is an organic acid that is the main component of vinegar. Its molecular formula is  $\text{C}_2\text{H}_4\text{O}_2$ . Glucose is a simple sugar that cells use as a primary source of energy. Its molecular formula is  $\text{C}_6\text{H}_{12}\text{O}_6$ . The structures of both molecules are shown in Figure (PageIndex{2}). They are very different compounds, yet both have the same empirical formula of  $\text{CH}_2\text{O}$ . Table (PageIndex{1}): Molecular Formula and Empirical Formula of Various Compounds. Name of Compound Molecular Formula Empirical Formula Methane  $\text{C}_1\text{H}_4$   $\text{CH}_4$  Acetic acid  $\text{C}_2\text{H}_4\text{O}_2$   $\text{CH}_2\text{O}$  Glucose  $\text{C}_6\text{H}_{12}\text{O}_6$   $\text{CH}_2\text{O}$  Figure (PageIndex{2}): Acetic acid (left) has a molecular formula of  $\text{C}_2\text{H}_4\text{O}_2$ , while glucose (right) has a molecular formula of  $\text{C}_6\text{H}_{12}\text{O}_6$ . Both have the empirical formula  $\text{CH}_2\text{O}$ . Empirical formulas can be determined from the percent composition of a compound as discussed in section 6.8. In order to determine its molecular formula, it is necessary to know the molar mass of the compound. Chemists use an instrument called a mass spectrometer to determine the molar mass of compounds. In order to go from the empirical formula to the molecular formula, follow these steps: Calculate the empirical formula molar mass (EFM). Divide the molar mass of the compound by the empirical formula molar mass. The result should be a whole number or very close to a whole number. Multiply all the subscripts in the empirical formula by the whole number found in step 2. The result is the molecular formula. The empirical formula of a compound of boron and hydrogen is  $\text{BH}_3$ . Its molar mass is  $27.7 \text{ g/mol}$ . Determine the molecular formula of the compound. Solutions to Example 6.9.1 Steps for Problem Solving Determine the molecular formula of  $\text{BH}_3$ . Identify the "given" information and what the problem is asking you to "find." Given: Empirical formula  $\text{BH}_3$  Molar mass  $(= 27.7 \text{ g/mol})$  Find: Molecular formula  $(= ?)$  Calculate the empirical formula mass (EFM).  $\text{EFM} = 13.84 \text{ g/mol}$  Divide the molar mass of the compound by the empirical formula mass. The result should be a whole number or very close to a whole number.  $\frac{\text{molar mass}}{\text{EFM}} = \frac{27.7 \text{ g/mol}}{13.84 \text{ g/mol}} = 2$  Multiply all the subscripts in the empirical formula by the whole number found in step 2. The result is the molecular formula.  $\text{BH}_3$  times 2 =  $\text{B}_2\text{H}_6$  Write the molecular formula. The molecular formula of the compound is  $\text{B}_2\text{H}_6$ . Think about your result. The molar mass of the molecular formula matches the molar mass of the compound. Vitamin C (ascorbic acid) contains 40.92 % C, 4.58 % H, and 54.50 % O, by mass. The experimentally determined molecular mass is 176 amu. What are the empirical and chemical formulas for ascorbic acid? Answer Empirical Formula  $\text{C}_3\text{H}_4\text{O}_3$  Answer Molecular Formula  $\text{C}_6\text{H}_8\text{O}_6$  What is Molecular Formula The molecular formula tells us the actual number of atoms of each element present in the compound. The molecular formula is always a simple multiple of the empirical formula. To calculate the molecular formula of a compound, you firstly calculate its empirical formula, and then compare the formula mass of the empirical formula with the molecular mass given in the question. If the two values match, the empirical formula and molecular formula are the same. If the two values differ, you divide the molecular mass by the empirical formula mass to deduce the factor by which each element in the empirical formula must be multiplied to produce the molecular formulae. The experimental and molecular formulae of a compound can be obtained experimentally as shown in the following worked examples. Hydrated copper sulphate crystals have the chemical formula  $\text{CuSO}_4 \cdot x\text{H}_2\text{O}$ . In an experiment to determine the value of x, 8.57g of the hydrated crystals was heated until it reached a constant mass of 4.79g. Use these results to determine the value of x in  $\text{CuSO}_4 \cdot x\text{H}_2\text{O}$ . Write down the masses of  $\text{CuSO}_4$  and  $\text{H}_2\text{O}$  in the crystals. Calculate the missing mass by subtracting the mass of  $\text{CuSO}_4$  from the total mass of the hydrated crystals: Mass of  $\text{CuSO}_4 = 4.79\text{g}$  Mass of  $\text{H}_2\text{O} = 8.57 - 4.79 = 3.78\text{g}$  Calculate the number of moles of  $\text{CuSO}_4$  and  $\text{H}_2\text{O}$  using the equation: number of moles = mass/molar mass  $\text{CuSO}_4: 4.79/159.5 = 0.03 \text{ mol}$   $\text{H}_2\text{O}: 3.78/18.0 = 0.21 \text{ mol}$  Divide each by the smallest number of moles to find the ratio:  $\text{CuSO}_4: 0.03/0.03 = 1$   $\text{H}_2\text{O}: 0.21/0.03 = 7$  Therefore, the value of x is 7 and the formula of the hydrated crystals is  $\text{CuSO}_4 \cdot 7\text{H}_2\text{O}$  Magnesium metal burns in oxygen gas to form magnesium oxide. The formula of this metal oxide can be determined by comparing the mass of the magnesium ribbon used to the mass of the magnesium oxide formed. In one experiment, 2.40g of magnesium burned to form 4.00g of magnesium oxide. Use these experimental results to deduce the empirical formula of magnesium oxide. Write down the masses of magnesium and oxygen used. Calculate the mass of oxygen added by subtracting the mass of magnesium from the total mass of the magnesium oxide formed. Mass of Mg = 2.40g Mass of O = 4.00 - 2.40 = 1.60g Calculate the number of moles of Mg and O using the equation: number of moles = mass/molar mass  $\text{Mg}: 2.40/24.0 = 0.1 \text{ mol}$   $\text{O}: 1.60/16.0 = 0.1 \text{ mol}$  The number of moles of Mg and O is the same therefore they are present in magnesium oxide on a 1:1 ratio and the empirical formula is MgO. The empirical formula of X is  $\text{C}_4\text{H}_{10}\text{S}_1$  and the relative formula mass of X is 180. What is the molecular formula of X? Relative Formula Masses: carbon : 12 hydrogen : 1 sulfur : 32 Answer: Step 1 - Calculate the relative empirical formula mass  $(\text{C} \times 4) + (\text{H} \times 10) + (\text{S} \times 1) = (12 \times 4) + (1 \times 10) + (32 \times 1) = 90$  Step 2 - Divide relative formula mass of X by the relative empirical mass  $180 / 90 = 2$  Step 3 - Multiply each number of elements by 2  $(\text{C}_4 \times 2) + (\text{H}_{10} \times 2) + (\text{S}_1 \times 2) = (\text{C}_8) + (\text{H}_{20}) + (\text{S}_2)$  Molecular formula of X =  $\text{C}_8\text{H}_{20}\text{S}_2$  Page 2 Aim: To determine the empirical formula of magnesium oxide by combustion of magnesium Diagram: Finding the empirical formula of magnesium oxide involves heating magnesium ribbon very strongly in a crucible. A lid is used to trap any smoke (not shown) Method: Measure mass of crucible with lid Add sample of magnesium into crucible and measure mass with lid (calculate the mass of the metal by subtracting the mass of empty crucible) Strongly heat the crucible over a Bunsen burner for several minutes Lift the lid frequently to allow sufficient air into the crucible for the magnesium to fully oxidise without letting magnesium oxide smoke escape Continue heating until the mass of crucible remains constant (maximum mass), indicating that the reaction is complete Measure the mass of crucible and contents (calculate the mass of metal oxide by subtracting the mass of empty crucible) Working out the empirical formula: Mass of metal: Subtract mass of crucible from magnesium and the mass of the empty crucible Mass of oxygen: Subtract mass of the magnesium used from the mass of magnesium oxide Step 1 - Divide each of the two masses by the relative atomic masses of the elements Step 2 - Simplify the ratio magnesium oxygen Mass a Moles a / Ar b / Ar = x = y Ratio x ; y Step 3 - Represent the ratio into the form 'MxOy' E.g. MgO Did this page help you?