

Empirical and Molecular Formulas

INFORMATION

An **empirical formula** is a "lowest common denominator" molecular formula for covalent molecules. It represents the ratio in which atoms (or MOLES of atoms) combine to form compounds, but not the actual numbers of atoms in the compound. Multiple compounds can have the same empirical formula.

Glucose, $C_6H_{12}O_6$, contains carbon, hydrogen, and oxygen. The ratio of carbon to hydrogen to oxygen is 1:2:1. CH_2O is the empirical formula for glucose.

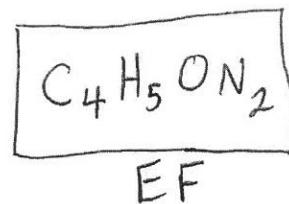
Since the percent composition of each element in an empirical formula represents the ratio in which they occur, the percent composition can be used, in conjunction with the molar masses of the elements, to determine the empirical formula of a compound. It is generally prudent to assume a 100.0 gram sample of the compound for the purpose of simplifying the calculations.



Key Question

1. Caffeine has the following percent composition: carbon, 49.48%; hydrogen 5.19%; oxygen, 16.48%; and nitrogen, 28.85%. What is its empirical formula?

C	$49.48g / 12.01 = 4.12$		$C = 4$
H	$5.19g / 1.01 = 5.14$	$\div 1.03$	$H = 5$
O	$16.48g / 16.00 = 1.03$	all	$O = 1$
N	$28.85g / 14.01 = 2.06$	by smallest	$N = 2$



INFORMATION

A **molecular formula** is a formula that represents the actual number of each atom in a compound. Whereas CH_2O is the empirical formula for glucose, $C_6H_{12}O_6$ is the molecular formula. An actual molecule of glucose contains six carbon atoms, twelve hydrogen atoms, and six oxygen atoms. (Or six moles of carbon atoms, 12 moles of hydrogen atoms, and six moles of oxygen atoms).

Since an empirical formula indicates the ratios of the elements in the compound, it can be used, along with the molar mass of the compound, to determine the molecular formula. As with empirical formulas, assume a 100.0 gram sample to simplify the calculations.

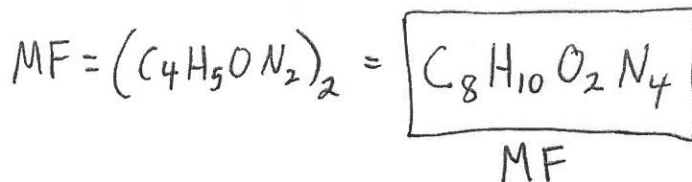


Key Question

$EF = C_4H_5ON_2$ Molar Mass = $4(12.01) + 5(1.01) + 16 + 2(14.01)$
 $= 97.11 \text{ g/mol}$

2. The molar mass of caffeine is 194.19 g/mol. What is its molecular formula?

$$n = \frac{194.19}{97.11} = 2$$



Hint for determining EF (Empirical Formula):

% to mass, mass to mole, divide by small, multiply till whole

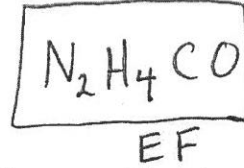
Hint for determining MF (Molecular Formula):

$$MF = (EF)_n$$

$$n = \frac{MF \text{ molar mass (given in problem)}}{EF \text{ molar mass}}$$

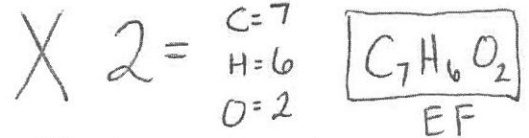
1. A compound is found to have 46.67% nitrogen, 6.70% hydrogen, 19.98% carbon and 26.65% oxygen. What is its empirical formula?

$$\begin{aligned} \text{N} & 46.67\text{g}/14.01 = 3.331/1.664 = 2 \\ \text{H} & 6.70\text{g}/1.01 = 6.634/1.664 = 4 \\ \text{C} & 19.98\text{g}/12.01 = \underline{1.664}/1.664 = 1 \\ \text{O} & 26.65\text{g}/16.00 = 1.666/1.664 = 1 \end{aligned}$$



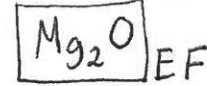
2. Benzoic acid contains 68.8% carbon, 4.95% hydrogen and 26.25% oxygen. Find the empirical formula.

$$\begin{aligned} \text{C} & 68.8/12.01 = 5.729 \\ \text{H} & 4.95/1.01 = 4.901 / 1.641 = \text{H} = 3 \\ \text{O} & 26.25/16.00 = \underline{1.641} / 1.641 = \text{O} = 1 \end{aligned}$$



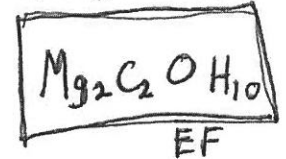
3. A compound consists of 75.0% magnesium and 25.0% oxygen by mass. What is the empirical formula?

$$\begin{aligned} \text{Mg} & 75.0\text{g}/24.31 = 3.085 \\ \text{O} & 25.0\text{g}/16.00 = \underline{1.563} / 1.563 \end{aligned}$$



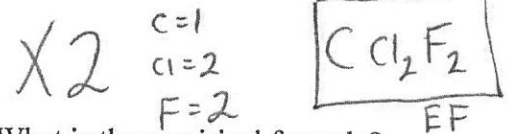
4. A compound contains 50.0% magnesium, 24.0% carbon, 16.0% oxygen, and 10.0% hydrogen. What is the empirical formula?

$$\begin{aligned} \text{Mg} & 50.0\text{g}/24.31 = 2.057 \\ \text{C} & 24.0\text{g}/12.01 = 2 \\ \text{O} & 16.0\text{g}/16.00 = \underline{1} \\ \text{H} & 10.0\text{g}/1.01 = 9.901 \end{aligned}$$



5. Freons are gaseous compounds used in refrigeration. A particular Freon contains 9.93% carbon, 58.64% chlorine, and 31.43% fluorine. What is the empirical formula?

$$\begin{aligned} \text{C} & 9.93\text{g}/12.01 = 0.8268 \\ \text{Cl} & 58.64\text{g}/35.45 = \underline{1.654} / 1.654 \\ \text{F} & 31.43\text{g}/19.00 = \underline{1.654} / 1.654 \end{aligned}$$



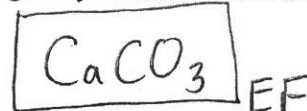
6. A compound consists of 85.0% silver and 15.0% fluorine by mass. What is the empirical formula?

$$\begin{aligned} \text{Ag} & 85.0\text{g}/107.87 = \underline{0.7880} / 0.7880 \\ \text{F} & 15.0\text{g}/19.00 = 0.7895 / 0.7880 \end{aligned}$$



7. A compound consists of 40.0% calcium, 12.0% carbon, and 48.0% oxygen by mass. What is the empirical formula by mass?

$$\begin{aligned} \text{Ca} & 40.0\text{g}/40.08 = 1 \\ \text{C} & 12.0\text{g}/12.01 = 1 \\ \text{O} & 48.0\text{g}/16.00 = 3 \end{aligned}$$



8. A compound with an empirical formula of CH is found to have a molar mass of 26.04 g/mol. What is its molecular formula?

$$\begin{aligned} \text{EF} & = \text{CH} = 13.02\text{g/mol} \\ \text{MF} & = ? = 26.04\text{g/mol} \end{aligned}$$

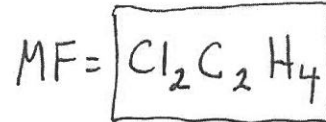
$$n = \frac{\text{MF}}{\text{EF}} = \frac{26.04}{13.02} = 2$$



9. A compound has an empirical formula of ClCH_2 , and its molar weight is 98.96 g/mol. What is the molecular formula of this compound?

$$\begin{aligned} \text{EF} & = \text{ClCH}_2 = 49.48\text{g/mol} \\ \text{MF} & = ? = 98.96\text{g/mol} \end{aligned}$$

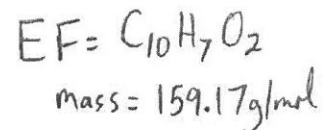
$$n = \frac{98.96}{49.48} = 2$$



10. A compound contains 75.46% carbon, 4.43% hydrogen, and 20.11% oxygen by mass. It has a molar weight of 318.31 g/mol. What is the molecular formula?

$$\begin{aligned} \text{C} & 75.46\text{g}/12.01 = 6.283 \\ \text{H} & 4.43\text{g}/1.01 = 4.386 / 1.257 \\ \text{O} & 20.11\text{g}/16.00 = \underline{1.257} / 1.257 \end{aligned}$$

$$\begin{aligned} \text{C} & = 5 \\ \text{H} & = 3.5 \\ \text{O} & = 1 \end{aligned} \quad \times 2 \quad \begin{aligned} \text{C} & = 10 \\ \text{H} & = 7 \\ \text{O} & = 2 \end{aligned}$$



$$n = \frac{\text{MF}}{\text{EF}} = \frac{318.31}{159.17} = 2$$

