

Key

Percent Composition

Empirical Formula: a formula giving the proportions of the elements present in a compound but not the actual numbers or arrangement of atoms.

Ex: CH₃COOH has two carbons, four hydrogens and two oxygens. So we could write the formula like this: C₂H₄O₂ and so it reduces to CH₂O.

Molecular Formula: the formula of a compound in which the subscripts give the actual number of each element in the formula

Molecular Formula	Empirical Formula
H ₂ O	H ₂ O
CH ₃ COOH	CH ₂ O
CH ₂ O	CH ₂ O
C ₆ H ₁₂ O ₆	CH ₂ O

Try these:

Molecular Formula	Empirical Formula
C ₂ H ₂	CH
C ₂ H ₄	CH ₂
C ₂ H ₄ O	C ₂ H ₄ O
C ₆ H ₆	CH
C ₄ H ₈	CH ₂
C ₃ H ₆ O ₃	CH ₂ O

Molecular Weight Percentage—how much of the total mass is made up of each element?

1 proton/1 neutron = 1 a.m.u.

example: C₆H₁₂O₆ (Glucose)

Carbon mass = 12 amu x 6 C atoms = 72 amu
 Hydrogen mass = 1 amu x 12 H atoms = 12 amu
 Oxygen mass = 16 amu x 6 O atoms = 96 amu
 TOTAL: 180 amu

So, Carbon is 72/180 percent of the Glucose = .4 = 40%
 Hydrogen is 12/180 percent of the Glucose = .066 = 6.7%
 Oxygen is 96/180 percent of the Glucose = .533 = 53.3%

Example: The compound ethylene glycol is often used as an antifreeze. It contains 38.7% carbon, 9.75% hydrogen, and the rest oxygen. The molecular weight (molar mass) of ethylene glycol is 62.07 g/mol. What is the molecular formula of ethylene glycol?

48.45

Step 1: Calculate the empirical formula. Assume 100 g of the compound, which will contain 38.7g C, 9.75g H, and the rest oxygen. Oxygen = 51.55 g

Step 2: Calculate the moles of each element:

C = $38.7g \times \frac{1 \text{ mol}}{12 \text{ g}} =$ 3.225 H = $9.75g \times \frac{1 \text{ mol H}}{1 \text{ g H}} =$ 9.67 O = $51.55g \times \frac{1 \text{ mol}}{16 \text{ g}} =$ 3.22

Analyze your numbers: notice that the H is 3 times the number of moles as the C and the O. Therefore, the empirical formula must be: CH₃O

Step 3: Calculate the **ratio** of the molecular weight to the empirical formula weight. The molecular weight was given in the problem, it is: $\underline{62.07}$. And the empirical formula is CH_3O , so determine the empirical formula weight: $\text{C} + 3\text{H} + \text{O} = 12 + 3(1) + 16 = 31$.

Divide the molecular weight by the empirical formula weight:

$$\frac{\text{MW}}{\text{Emp. Form. Wt.}} = \frac{62}{31} = \underline{2}$$

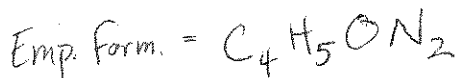
This ratio says that the molecular formula is $\underline{2 \times}$ the empirical...

So the Molecular Formula is: $\underline{\text{C}_2\text{H}_6\text{O}_2}$

You Try:

Caffeine has an elemental analysis of 49.48% C, 5.190% H, 16.47% O, and 28.85% N. It has a molar mass of 194.19g/mol. What is the molecular formula of caffeine?

$$\text{C} = \frac{49.48\text{g}}{1} \times \frac{1\text{mol}}{12\text{g}} = 4.12 \quad \text{H} = \frac{5.19\text{g}}{1} \frac{1\text{mol}}{1\text{g}} = 5.19 \quad \text{O} = \frac{16.47\text{g}}{1} \frac{1\text{mol}}{15.99\text{g}} = 1.03$$



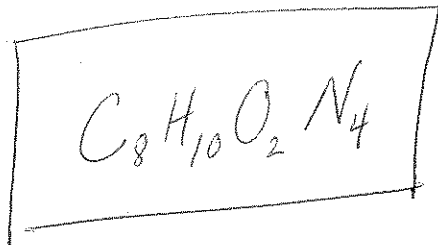
$$\text{N} = \frac{28.85\text{g}}{1} \frac{1\text{mol}}{14\text{g}} = 2.06$$

Divide $\frac{\text{MW}}{\text{E.F.W.}} = \frac{194.19\text{g/mol}}{97\text{g/mol}} = \underline{2}$

Empirical
formula
weight

$$\text{EFW} = 4(12) + 5(1) + (16) + 2(14) = \underline{97}$$

SO molecular formula is $2 \times$ the Empirical formula



EMPIRICAL AND MOLECULAR FORMULA WORKSHEET

1. An oxide of chromium is found to have the following % composition: 68.4 % Cr and 31.6 % O. Determine this compound's empirical formula.
2. The percent composition of a compound was found to be 63.5 % silver, 8.2 % nitrogen, and 28.3 % oxygen. Determine the compound's empirical formula.
3. A 170.00 g sample of an unidentified compound contains 29.84 g sodium, 67.49 g chromium, and 72.67 g oxygen. What is the compound's empirical formula?
4. A 60.00 g sample of tetraethyl lead, a gasoline additive, is found to contain 38.43 g lead, 17.83 g carbon, and 3.74 g hydrogen. Find its empirical formula.
5. A compound containing 5.9265 % H and 94.0735 % O has a molar mass of 34.01468 g/mol. Determine the empirical and molecular formula of this compound.

6. The empirical formula for trichloroisocyanuric acid, the active ingredient in many household bleaches, is OCNCl . The molar mass of this compound is 232.41 g/mol. What is the molecular formula of trichloroisocyanuric acid?

7. Determine the molecular formula of a compound with an empirical formula of NH_2 and a formula mass of 32.06 amu.

8. The empirical formula of a hydrocarbon (compound that contains only C and H) is found to be CH . Laboratory procedures have found that the molar mass of the compound is 78 g/mol. What is the molecular formula of this compound?

9. The molar mass of nicotine is 162.1 g/mol. It contains 74.0 % carbon, 8.7 % hydrogen, and 17.3 % nitrogen. Determine nicotine's empirical formula and molecular formula.

10. Phenyl magnesium bromide is used as a Grignard reagent in organic synthesis. Determine its empirical and molecular formula if its molar mass is 181.313 g/mol and it contains 39.7458 % C, 2.77956 % H, 13.4050 % Mg, and 44.0697 % Br.