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Warm-Up | Percent Composition and Molecular Formula

Lesson Objectives

By the end of this lesson, you should be able to:

- Solve problems to calculate percent composition.
- Determine the [ ] formula and the molecular formula of a substance through calculations.
- Explain the relationship between the empirical formula and the molecular formula of a compound.

Science Practice: Use math to solve percent [ ] problems and to determine empirical and molecular formulas.

Words to Know

Write the letter of the definition next to the matching word as you work through the lesson. You may use the glossary to help you.

_____ empirical formula	A. the percent by mass of each element that makes up a compound
_____ molecular formula	B. the simplest whole-number ratio of atoms in a molecule or formula unit
_____ percent composition	C. the true ratio of atoms in a molecule or formula unit

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Lesson Question

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Mole Ratios

- $CaCl_2$
  - Ratio of subscripts = 1:2
  - Mole ratio of Ca:Cl = 1: ☐
- Na_3PO_4
  - Ratio of subscripts = 3:1:4
  - Mole ratio of Na:P:O = ☐ :1:4
- $C_2H_3O_5N$
  - Ratio of ☐ = 2:3:5:1
  - Mole ratio of C:H:O:N = 2:3:5:1
- NO_2
  - Ratio of subscripts = 1:2
  - Mole ratio of N:O = ☐
- N_2O_4
  - Ratio of subscripts = 2:4 = 1:2
  - Mole ratio of ☐ = 2:4 = 1:2

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Empirical vs. Molecular Formula

- **Empirical formula**: simplest [ ] ratio of atoms in a molecule or formula unit
- **Molecular formula**: true ratio of atoms in a molecule or [ ] unit

Compound	Molecular Formula	Mole Ratio	Empirical Formula
Methane		1:4	CH_4
	C_2H_4	2:4	CH_2
Propene		3:6	CH_2
	C_4H_8	4:8	CH_2

The molecular formula is always a whole-number multiple of the empirical formula.

How to Determine Empirical and Molecular Formulas

- Determine the mole ratios of the [ ] in the compound.
- Determine whether the ratios are in their simplest forms.
  - If ratios are simplified, the empirical formula = the molecular formula.
  - If ratios are not simplified, divide by the greatest common [ ] to obtain the empirical formula.

A [ ] formula with nonsimplified mole ratios *must* be a molecular formula. If the ratios are simplified, it may be an empirical formula, a molecular formula, or both.

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Percent Composition

Percent composition: the percent by mass of each element that makes up a compound

- Accurate [ ] analysis
- Total percent of all elements in a formula = 100%
- Percent mass of each element calculated using:

$$\%\,\text{Element} = \frac{\text{Total mass of element in compound}}{[\ ]\ \text{mass of compound}} \times 100$$

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Percent Composition of an Element

Calculate the percent by mass of hydrogen ([ ]) in water (H_2O).

- Calculate the total molar mass of the [ ].

$$2 \times 1.01\ \text{g/mol} = 2.02$$
$$1 \times 16.00\ \text{g/mol} = 16.00$$
[ ]

- Calculate the [ ] of the element in question.

$$2 \times 1.01\ \text{g/mol} = 2.02$$

- Calculate the percent by mass of the element in question.

$$\frac{2.02\ \text{g/mol}}{18.02\ \text{g/mol}} \times 100 = [\ ]$$

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How to Calculate Percent Composition

- Calculate the total molar mass of the compound.
- Calculate the mass of the element in question.
- Calculate the percent by mass:

$$\%\,\text{Element} = \frac{\text{Total mass of element in compound}}{\text{molar mass of compound}} \times \square$$

- Repeat as necessary for all required elements.
  - Check that total ☐ add up to 100.

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Percent Composition of a Hydrate

Calculate the percent by mass of H_2O and $CuSO_4$ in ☐ $\cdot\ 5H_2O$.

- Calculate the total molar mass of the hydrate compound.

$$1 \times 63.55\ \text{g/mol} = 63.55$$
$$1 \times 32.07\ \text{g/mol} = 32.07$$
$$4 \times 16.00\ \text{g/mol} = 64.00$$
$$5 \times 18.02\ \text{g/mol} = 90.10$$

☐

- Calculate the mass of each substance in question.

$CuSO_4 = 63.55 + 32.07 + 64.00 =$ ☐ g/mol

$5H_2O =$ ☐ g/mol

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Percent Composition of a Hydrate

- Calculate the percent by mass of each substance in question.

$$\frac{159.62}{249.72} \times 100 = \square\ \%$$

$$\frac{90.10}{249.72} \times 100 = \square\ \%$$

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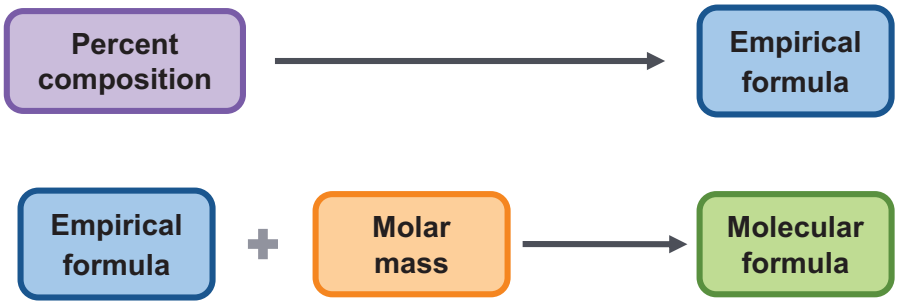
Molar Mass, Empirical/Molecular Formula, and Percent Composition



There are a number of ways of figuring out the percent by ☐ of the elements in a ☐, but they all yield percent composition.

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How to Calculate Empirical Formula from Percent Composition

A compound's percent composition is 40% C, 7% H, and 53% O by mass. What is the empirical formula of the compound?

- Assume 100 g of the compound.
- Calculate the mass of each element in the sample.

$$\text{Carbon (C)} = 100\text{ g} \times 40\% = \square\text{ g}$$

$$\text{Hydrogen (H)} = 100\text{ g} \times 7\% = 7\text{ g}$$

$$\text{Oxygen (O)} = 100\text{ g} \times 53\% = 53\text{ g}$$

- Calculate the number of **moles** of each element present.

$$\text{Carbon (C)} = 40\text{ g} \times \frac{1\text{ mol}}{12.01\text{ g}} = \square\text{ mol}$$

$$\text{Hydrogen (H)} = 7\text{ g} \times \frac{1\text{ mol}}{1.01\text{ g}} = 7\text{ mol}$$

$$\text{Oxygen (O)} = 53\text{ g} \times \frac{1\text{ mol}}{16.00\text{ g}} = 3.3\text{ mol}$$

- Calculate the **mole ratio** of elements present.

$\square$ Carbon : $\square$ Hydrogen : $\square$ Oxygen

- Write the empirical formula.

$\square$

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How to Calculate Empirical Formula from Percent Composition (Noninteger Ratios)

A compound's percent composition is 53% Al and 47% O by mass. What is the empirical formula of the compound?

- Assume 100 g of the compound.
- Calculate the mass of each element in the sample.

$$\text{Aluminum (Al)} = 100\text{ g} \times 53\% = \square\ \text{g}$$

$$\text{Oxygen (O)} = 100\text{ g} \times 47\% = 47\text{ g}$$

- Calculate the number of **moles** of each element present.

$$\text{Aluminum (Al)} = 53\text{ g} \times \frac{1\text{ mol}}{26.98\text{ g}} = \square\ \text{mol}$$

$$\text{Oxygen (O)} = 47\text{ g} \times \frac{1\text{ mol}}{16.00\text{ g}} = 2.9\text{ mol}$$

- Calculate the **mole ratio** of elements present.

$\square$ Aluminum : $\square$ Oxygen

- Write the empirical formula.

$\square$

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Molecular Formula from Empirical Formula and Molar Mass

The empirical formula for an organic compound is CH_2O. Its molar mass is 180.18 g/mol. What is its molecular formula?

- Calculate the molar mass of the empirical formula.

$$1 \times 12.01 \text{ g/mol} = 12.01$$
$$2 \times 1.01 \text{ g/mol} = 2.02$$
$$1 \times 16.00 \text{ g/mol} = 16.00$$

- Divide the given molar mass by the empirical molar mass.

$$\frac{180.18}{30.03} = \square$$

- Multiply the mole ratio of the empirical formula by the resulting value.

$$(CH_2O) \times 6 = \square$$

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Molecular Formula from Masses of Elements and Molar Mass

A sample of a compound contains 16.0 g C and 4.0 g H. Its molar mass is 30.0 g/mol. What are its empirical and molecular formulas?

- Calculate the number of moles of each element.

$$16\ \text{g C} \times \frac{1\ \text{mol}}{12.01\ \text{g}} = \square\ \text{mol}$$

$$4.0\ \text{g H} \times \frac{1\ \text{mol}}{1.01\ \text{g}} = 4.0\ \text{mol}$$

- Calculate the mole ratio and determine the empirical formula.

☐ Carbon : ☐ Hydrogen

- Calculate the empirical molar mass.

$$CH_3 = 12.01 + 3\ (1.01) = \square$$

- Divide the molar mass by the empirical mass to determine the molecular formula.

$$\frac{30.0}{15.04} = \square$$

Multiply CH_3 by 2, to get a molecular formula of ☐.

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Summary | Percent Composition and Molecular Formula

Lesson Question

How do scientists calculate the composition of the elements in a compound?

Answer

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Mole Ratios, Empirical Formulas, and Molecular Formulas

- Mole ratios can be determined from the _____ formula.
- The mole ratios of a compound are used to determine the percent _____ of the elements in the compound.
- Empirical and molecular formulas provide information about the elements that make up the compound or molecule.
- Empirical formulas are based on the simplest ratio of elements in the compound.
- Molecular formulas are the true ratio of elements in a compound.

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Percent Composition

Percent composition gives the [ ] masses of the elements in a compound.

$$\%\,\text{Element} = \frac{\text{Total mass of element in compound}}{\text{Molar mass of compound}} \times 100$$

Determining Empirical and Molecular Formulas

- [ ] composition or mass data can be used to determine the empirical formula for a compound.
- Empirical formula and molar mass can be used to determine the molecular formula for a compound.

Use this space to write any questions or thoughts about this lesson.

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