7-4 Determining Chemical Formulas

Empirical Formula – chemical formula of a compound with subscripts reduced to lowest whole number mole ratios

Examples of Empirical Formulas…

C_4H_8	$C_6H_{12}O_6$
Simplifies to:	Simplifies to:
CH_2	CH_2O

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7-4 Determining Chemical Formulas

Find the Empirical formula for a compound with…

Na → 32.38% S → 22.65% O → 44.99%

Assume a sample of 100.0g and convert into moles.

$$32.38 \text{ g Na} \left[\frac{1 \text{ mole Na}}{23.0 \text{ g Na}}\right] = 1.41 \text{ moles Na}$$

$$22.65 \text{ g S} \left[\frac{1 \text{ mole S}}{32.1 \text{ g S}}\right] = 0.706 \text{ moles S}$$

$$44.99 \text{ g O} \left[\frac{1 \text{ mole O}}{16.0 \text{ g O}}\right] = 2.81 \text{ moles O}$$

Continued…

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7-4 Determining Chemical Formulas

Continued…

Divide each amount by the smallest amount to get the lowest whole number ratios

$$\frac{1.41 \text{ moles Na}}{0.706} \approx 2 \text{ moles Na} \qquad \frac{0.706 \text{ moles S}}{0.706} \approx 1 \text{ mole S}$$

$$\frac{2.81 \text{ moles O}}{0.706} \approx 4 \text{ moles O}$$

The empirical formula is Na_2SO_4

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7-4 Determining Chemical Formulas

Find the Empirical formula for …

A 10.150 g sample of a compound made only of phosphorus and oxygen was measured to have 4.433 g of phosphorus.

Find the mass of oxygen present…

10.150 g Compound - 4.433 g P = 5.717 g O

$$4.433 \text{ g P} \left[\frac{1 \text{ mole P}}{31.0 \text{ g P}}\right] = 0.143 \text{ moles P}$$

$$5.717 \text{ g O} \left[\frac{1 \text{ mole O}}{16.0 \text{ g O}}\right] = 0.357 \text{ moles O}$$

Continued…

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7-4 Determining Chemical Formulas

Continued…

Divide each amount by the smallest amount to get the lowest whole number ratios

$$\frac{0.143 \text{ moles P}}{0.143} \approx 1 \text{ moles P} \qquad \frac{0.357 \text{ moles O}}{0.143} \approx 2.5 \text{ mole O}$$

$PO_{2.5}$ must have whole number subscripts…

$PO_{2.5} \rightarrow (PO_{2.5})_2 = P_2O_5$

The empirical formula is P_2O_5

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7-4 Determining Chemical Formulas

Molecular Formulas

A correct molecular formula may be the multiple of an empirical formula. We can use "x" as a multiplier.

$$\frac{\text{molecular formula mass}}{\text{empirical formula mass}} = x$$

$(\text{empirical formula})_x = \text{molecular formula}$

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7-4 Determining Chemical Formulas

Find the molecular formula…

A compound has an empirical formula of P_2O_5 but has a molar mass of 284.0 g/mol.

(Molar mass of P_2O_5 = 142.0 g/mol)

$$\frac{284.0\ g/mol}{142.0\ g/mol} = 2 \quad \rightarrow \quad (P_2O_5)_2 = \quad \mathbf{P_4O_{10}}$$

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7-4 Determining Chemical Formulas

Determine the correct formula for $CoCl_2 \cdot nH_2O$?

A 15 gram sample of hydrated cobalt(II)chloride was heated to the remove water. The anhydrous product had a final weight of 8.25 grams.

First we need the molar masses of H_2O and $CoCl_2$…

$$\underset{2 \times 1.0\ g/mol}{H_2} + \underset{16.0\ g/mol}{O} = \boxed{18.0\ g/mol}$$

$$\underset{58.9\ g/mol}{Co} + \underset{2 \times 35.5\ g/mol}{Cl_2 \cdot} = \boxed{129.9\ g/mol}$$

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7-4 Determining Chemical Formulas

Determine the correct formula for $CoCl_2 \cdot nH_2O$?

Next, determine how much water is removed…

$$15\ g\ CoCl_2 \cdot nH_2O - 8.25\ g\ CoCl_2 = 6.75\ g\ H_2O$$

Calculate the number of moles for both water and the anhydrous compound…

$$8.25\ \cancel{g\ CoCl_2} \left[\frac{1\ mole\ CoCl_2}{129.9\ \cancel{g\ CoCl_2}}\right] = 0.0635\ moles\ CoCl_2$$

$$6.75\ \cancel{g\ H_2O} \left[\frac{1\ mole\ H_2O}{18.0\ \cancel{g\ H_2O}}\right] = 0.375\ moles\ H_2O$$

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7-4 Determining Chemical Formulas

Determine the correct formula for $CoCl_2 \cdot nH_2O$?

Divide each amount by the smallest amount to get the lowest whole number ratios

$$\frac{0.0635\ moles\ CoCl_2}{0.0635\ moles\ CoCl_2} \approx 1\ moles\ CoCl_2$$

$$\frac{0.375\ moles\ H_2O}{0.0635\ moles\ CoCl_2} \approx 5.9\ moles\ H_2O$$

The formula for the hydrated is $CoCl_2 \cdot 6\ H_2O$

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