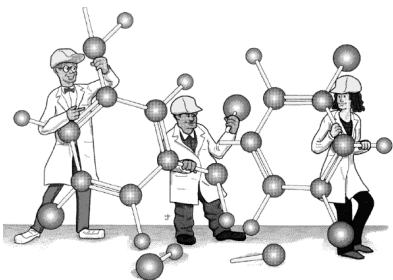


Empirical Formulas



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Formulas

Chemical = combination of elements & subscripts
= represents # of elements present in pure compound

Empirical = lowest (simplest) integer ratio of elements
= determined empirically (by experiment)
= maybe generalized (like C_nH_{n+2})
= formulas for ionic compounds
= RATIO of elements present

For $C_4H_8O_2$ = chemical For CH_3OH = chemical

C_2H_4O = empirical CH_4O = empirical

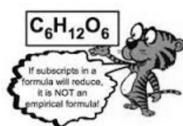


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Which of these are empirical formulas?

C_4H_{10}	No → C_2H_5
C_2H_6O	Yes
Hg_2Cl_2	No → $HgCl$
C_6H_6	No → CH
H_2O	Yes
H_2O_2	No → HO
CCl_4	Yes
C_4H_7	Yes
$C_6H_{12}O_6$	No → CH_2O



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To determine an Empirical Formula:
 Find masses (g) of each element in a sample of the compound
 Usually given
 Convert from grams to moles for each element
 Use Atomic Mass (determined from Periodic Table)
 grams each element $\times \frac{1 \text{ mole}}{\text{atomic mass g}} = \text{moles each element}$
 Express lowest integer ratio of moles
 Divide each number of moles by the smallest number of moles
 Write simplest formula using integer ratio
 Cation (most metallic) written first
 Subscripts must be whole numbers



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Find the empirical formula for a compound composed of 19.32 g iron and 8.304 g oxygen

Determine # moles of each element
 (Use Periodic Table to get atomic mass of Fe and O)



For Iron (Fe)

$$19.32 \text{ g} \times \frac{1 \text{ mole}}{55.847 \text{ g}} = 0.345945 \rightarrow 0.3459 \text{ mol}$$

For Oxygen (O)

$$8.304 \text{ g} \times \frac{1 \text{ mole}}{16.00 \text{ g}} = 0.5190 \rightarrow 0.5190 \text{ mol}$$

Determine mole ratio of elements: ratio gives formula

$$\text{Fe} \quad 0.3459 \rightarrow 1.00 \quad \times 2 = 2$$

$$\text{O} \quad 0.5190 \rightarrow 1.50 \quad \times 2 = 3$$

$$\text{Formula} = \text{Fe}_2\text{O}_3$$

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Find the empirical formula of a compound containing 20.21 g Fe and 5.79 g O.

Determine # moles of each element:
 (Use Periodic Table to get atomic mass of Fe and O)



For Iron (Fe)

$$20.21 \text{ g} \times \frac{1 \text{ mole}}{55.847 \text{ g}} = 0.361882 \rightarrow 0.3619 \text{ mol}$$

For Oxygen (O)

$$5.79 \text{ g} \times \frac{1 \text{ mole}}{16.00 \text{ g}} = 0.361875 \rightarrow 0.362 \text{ mol}$$

Determine mole ratio of elements: ratio gives formula

$$\text{Fe} \quad 0.3619 \rightarrow 1.00$$

$$\text{O} \quad 0.362 \rightarrow 1.00$$

$$\text{Formula} = \text{FeO}$$

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Find the empirical formula of a compound that contains 741 g lead and 76.0 g oxygen.

Determine # moles of each element:
(Use Periodic Table to get atomic mass of Pb and O)



For Lead (Pb)

$$741 \text{ g} \times \frac{1 \text{ mole}}{207.19 \text{ g}} = 3.57643 \rightarrow 3.58 \text{ mol}$$

For Oxygen (O)

$$76.0 \text{ g} \times \frac{1 \text{ mole}}{16.00 \text{ g}} = 4.75 \text{ mol}$$

Determine mole ratio of elements: ratio gives formula

$$\text{Pb} \quad 3.58 \rightarrow 1.00 \times 3 = 3$$

$$\text{O} \quad 4.75 \rightarrow 1.33 \times 3 = 4$$

$$\text{Formula} = \text{Pb}_3\text{O}_4$$

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Find the empirical formula of a compound that is 62.8% Cl, 31.9% C, and 5.3% H.

When given elemental %, assume 100 grams total
Get mass from the Periodic Table

For carbon:

$$31.9 \text{ g} \times \frac{1 \text{ mole}}{12.011 \text{ g}} = 2.6559 \rightarrow 2.66 \text{ mol}$$



For hydrogen:

$$5.3 \text{ g} \times \frac{1 \text{ mole}}{1.008 \text{ g}} = 5.25794 \rightarrow 5.3 \text{ mol}$$

For chlorine:

$$62.8 \text{ g} \times \frac{1 \text{ mole}}{35.453 \text{ g}} = 1.77136 \rightarrow 1.77 \text{ mol}$$

Determine mole ratio of elements: ratio gives formula:

$$\text{C: H: Cl:}$$

$$\text{Divide by } 1.77 \rightarrow 1.5 \quad 2.99 \quad 1$$

$$\text{Multiply by } 2 \rightarrow 3 \quad 6 \quad 2 \rightarrow \text{C}_3\text{H}_6\text{Cl}_2$$

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Find the empirical formula of malonic acid whose composition is 34.6% carbon, 3.9% hydrogen, and 61.5% oxygen.

When given elemental %, assume 100 grams total
Get mass from the Periodic Table

For carbon:

$$34.6 \text{ g} \times \frac{1 \text{ mole}}{12.011 \text{ g}} = 2.88069 \rightarrow 2.88 \text{ mol}$$

For hydrogen:

$$3.9 \text{ g} \times \frac{1 \text{ mole}}{1.008 \text{ g}} = 3.86905 \rightarrow 3.9 \text{ mol}$$



For oxygen:

$$61.5 \text{ g} \times \frac{1 \text{ mole}}{16.00 \text{ g}} = 3.84375 \rightarrow 3.84 \text{ mol}$$

Determine Ratio: C: H: O:

$$\text{Divide by } 2.88 \rightarrow 1.00 \quad 1.35 \quad 1.33$$

$$\text{Multiply by } 3 \rightarrow 3 \quad 4 \quad 4 \rightarrow \text{C}_3\text{H}_4\text{O}_4$$

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Molecular Formulas



Derived from empirical formula *and* molar mass
Molecular formula = (empirical formula) x n

$$n = \frac{\text{Molar Mass}}{\text{Empirical Formula Mass}}$$

Empirically:

Elemental analysis gives empirical formula

Molar Mass from variety of techniques:

Mass spectroscopy

Electrophoresis

Gel Chromatography

Gas Diffusion



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Molecular Formulas



Determine the molecular formula of a compound with an empirical formula of P_2O_5 (molar mass of 283.88 g/mol)

Determine Empirical Formula Mass:

$$P \quad 2 \times 30.07 = 61.94$$

$$O \quad 5 \times 16.00 = 80.00$$

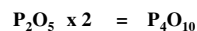
$$\text{Molar Mass} = 141.94$$

Determine Ratio:

$$\frac{283.88}{141.94} = 2$$

$$141.94$$

Molecular Formula:



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Molecular Formulas



Dichloroethane (98.96g/mol) is a common additive in gasoline that prevents engine knocking. Its percent composition is 71.65 % Cl; 24.27 % C; and 4.07% H. Determine its empirical and molecular formulas .

When given elemental %, assume 100 grams total
Get mass from the Periodic Table

For carbon:
 $24.27 \text{ g} \times \frac{1 \text{ mole}}{12.011 \text{ g}} = 2.02 \text{ mol}$

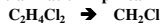
For hydrogen:
 $4.07 \text{ g} \times \frac{1 \text{ mole}}{1.008 \text{ g}} = 4.04 \text{ mol}$

For chlorine:
 $71.65 \text{ g} \times \frac{1 \text{ mole}}{35.453 \text{ g}} = 2.02 \text{ mol}$



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Molar Ratio Empirical Formula:



Empirical Formula Mass:

$$C: 1 \times 12.011 = 12.011$$

$$H: 2 \times 1.008 = 2.02$$

$$Cl: 1 \times 35.45 = 35.45$$

$$\text{Empirical Mass} = 49.48$$








$$N = 98.96 / 49.48 = 2$$

Molar Formula:



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**Think Moles
Not
Grams**

		
Optimist	Pessimist	Chemist
		
The Glass is Half Full	The Glass is Half Empty	The Glass Contains 50% H₂O(l) 39% N₂(g) 10.5% O₂(g) .44% Ar(g) .06% CO₂(g)
		

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