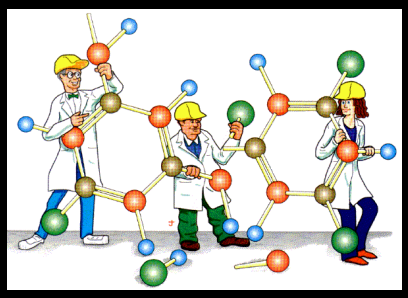
Empirical Formulas



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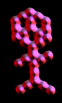
Formulas

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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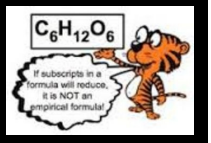
Which of these are empirical formulas?

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 x $\frac{1 \text{ mole}}{\text{atomic mass g}}$ = 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 g x $\frac{1 \text{ mole}}{55.847 \text{ g}}$ = 0.345945 → 0.3459 mol

For Oxygen (O)

8.304 g x $\frac{1 \text{ mole}}{16.00 \text{ g}}$ = 0.5190 → 0.5190 mol

Determine mole ratio of elements: ratio gives formula

Fe	0.3459 → 1.00	x 2 = 2
O	0.5190 → 1.50	x 2 = 3

Formula = Fe_2O_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 g x $\frac{1 \text{ mole}}{55.847 \text{ g}}$ = 0.361882 → 0.3619 mol

For Oxygen (O)

5.79 g x $\frac{1 \text{ mole}}{16.00 \text{ g}}$ = 0. 361875 → 0. 362 mol

Determine mole ratio of elements: ratio gives formula

Fe	0.3619 → 1.00
O	0.362 → 1.00

Formula = 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)

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

For Oxygen (O)

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

Determine mole ratio of elements: ratio gives formula

Pb	3.58 → 1.00	x 3 = 3
O	4.75 → 1.33	x 3 = 4

Formula = Pb_3O_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:

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

For hydrogen:

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

For chlorine:

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

Determine mole ratio of elements: ratio gives formula:

	C:	H:	Cl:	
Divide by 1.77 →	1.5	2.99	1	
Multiply by 2 →	3	6	2	→ $C_3H_6Cl_2$

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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:

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

For hydrogen:

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

For oxygen:

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

Determine Ratio:	C:	H:	O :	
Divide by 2.88 →	1.00	1.35	1.33	
Multiply by 3 →	3	4	4	→ $C_3H_4O_4$

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Molecular Formulas

Derived from empirical formula *and* molar mass

Molecular formula = (empirical formula) x n

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

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 2 x 30.07 = 61.94

O 5 x 16.00 = 80.00

Molar Mass = 141.94

Determine Ratio:

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

Molecular Formula:

P_2O_5 x 2 = P_4O_{10}

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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:

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

Molar Ratio Empirical Formula:

$C_2H_4Cl_2$ ➔ CH_2Cl

Empirical Formula Mass:

C: 1 x 12.011 = 12.011

H: 2 x 1.008 = 2.02

Cl: 1 x 35.45 = 35.45

Empirical Mass = 49.48

N = 98.96 / 49.48 = 2

Molar Formula:

$C_2H_4Cl_2$

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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% $H_2O(l)$
39% $N_2(g)$
10.5% $O_2(g)$
.44% Ar(g)
.06% $CO_2(g)$
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