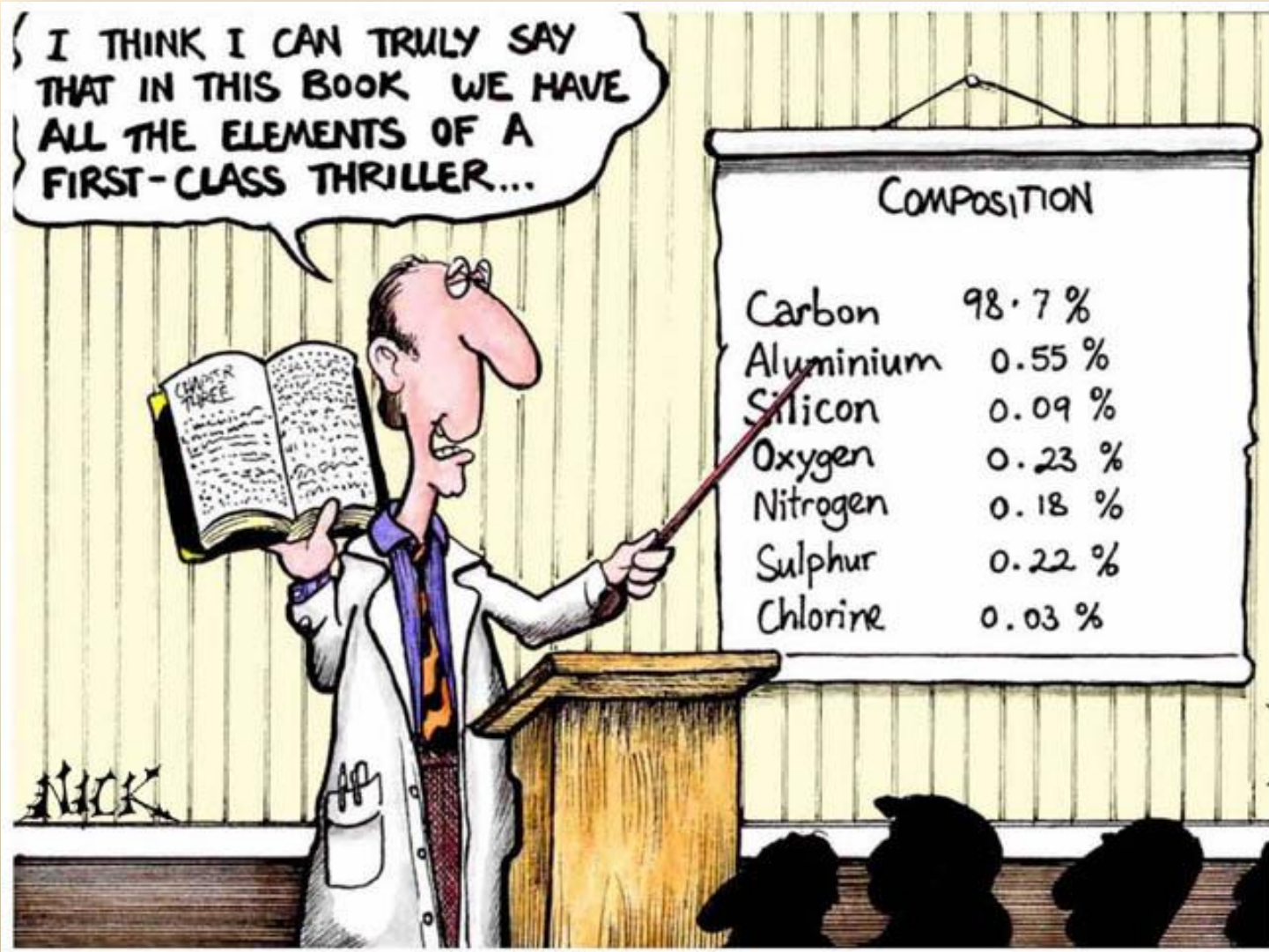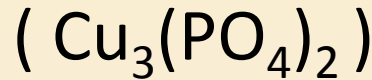# Percent Composition, Empirical and Molecular Formulas

Calculating Percent by Mass

- What is the percent by mass of metal in the compound copper II phosphate? ($Cu_3(PO_4)_2$)

- Find total mass
- Find mass due to the part
- Divide mass of part by total
- Multiply by 100

($Cu_3(PO_4)_2$)

subscript   from P.T.

Cu   3 x 63.55   +

P   2 X 30.97   +

O   8 x 16.00   =

Total mass=   380.59 amu

Mass of metal = 190.7 amu

$\dfrac{190.7}{380.59}$ x   100   =   50.1%

Calculating Percentage Composition

Calculate the percentage composition of magnesium carbonate, $MgCO_3$.

Formula mass of magnesium carbonate:

24.31 g + 12.01 g + 3(16.00 g) = 84.32 g

$$Mg = \left(\frac{24.31}{84.32}\right) \bullet 100 = 28.83\%$$

$$C = \left(\frac{12.01}{84.32}\right) \bullet 100 = 14.24\%$$

$$O = \left(\frac{48.00}{84.32}\right) \bullet 100 = \underline{56.93\%}$$

100.00

Formulas

Empirical formula: the lowest whole number ratio of atoms in a compound.
Molecular formula: the true number of atoms of each element in the formula of a compound.

- ❑ molecular formula = (empirical formula)$_n$
- ❑ molecular formula = C_6H_6 = $(CH)_6$
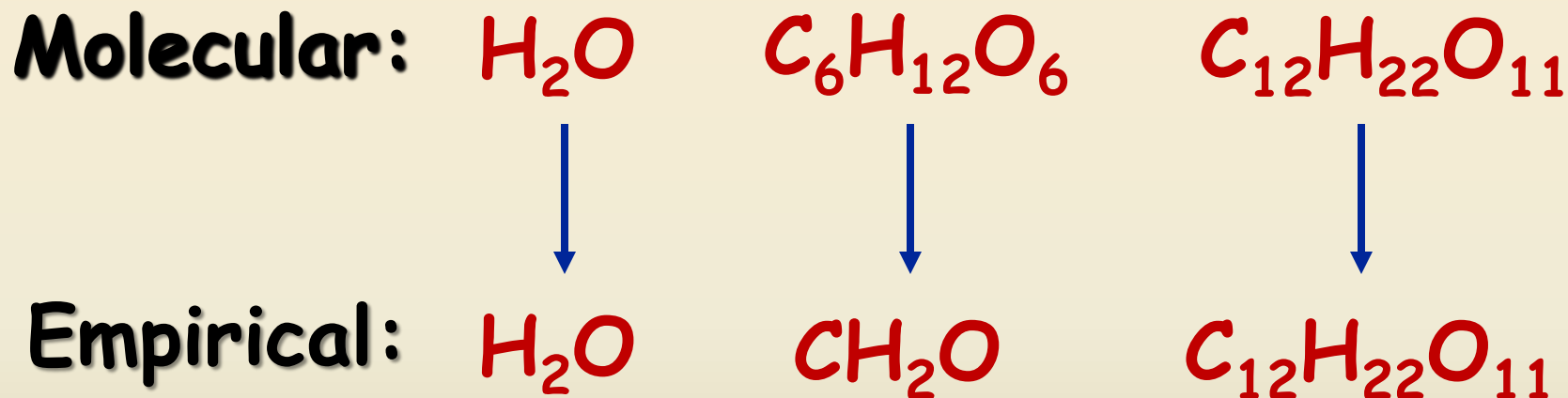- ❑ empirical formula = CH

Formulas (continued)

Formulas for ionic compounds are <u>ALWAYS</u> empirical (lowest whole number ratio).

Examples:

$NaCl$ $Al_2(SO_4)_3$

$MgCl_2$ K_2CO_3

Formulas (continued)

Formulas for molecular compounds <u>MIGHT</u> be empirical (lowest whole number ratio).

Molecular: H_2O $C_6H_{12}O_6$ $C_{12}H_{22}O_{11}$

Empirical: H_2O CH_2O $C_{12}H_{22}O_{11}$

How to calculate an empirical formula

- ## How to calculate:
  - STEP 1: You will be given either masses or percent composition.
  - STEP 2: If you are given % composition, turn it into grams by assuming a 100.0 g sample. NOTE: If you are given mass, you do not need to do this step.
  - STEP 3: Convert the masses to the number of moles of each element.

- STEP 4: Figure out the proportion of moles of each element in the compound by dividing each by the smallest number of moles.

- STEP 5: If step 4 resulted in whole numbers, you are done! However, if there were decimals, you will need to multiply by small, whole numbers until you have whole numbers.

A way to remember those steps:

- A Poem by Joel Thompson:
- *Percent to mass*
- *Mass to mole*
- *Divide by small*
- *Multiply 'til whole*

Empirical Formula Determination

Adipic acid contains 49.32% C, 43.84% O, and 6.85% H by mass. What is the empirical formula of adipic acid?

1. Treat % as mass, and convert grams to moles

$$\frac{49.32 \, g \, carbon}{} \left| \frac{1 \, mol \, carbon}{12.01 \, g \, carbon} = 4.107 \, mol \, carbon \right.$$

$$\frac{6.85 \, g \, hydrogen}{} \left| \frac{1 \, mol \, hydrogen}{1.01 \, g \, hydrogen} = 6.78 \, mol \, hydrogen \right.$$

$$\frac{43.84 \, g \, oxygen}{} \left| \frac{1 \, mol \, oxygen}{16.00 \, g \, oxygen} = 2.74 \, mol \, oxygen \right.$$

Empirical Formula Determination

2. Divide each value of moles by the smallest of the values.

Carbon: $\dfrac{4.107\,mol\,carbon}{2.74\,mol} = 1.50$

Hydrogen: $\dfrac{6.78\,mol\,hydrogen}{2.74\,mol} = 2.47$

Oxygen: $\dfrac{2.74\,mol\,oxygen}{2.74\,mol} = 1.0$

Empirical Formula Determination

3. Multiply each number by an integer to obtain all whole numbers.

Carbon: 1.50   Hydrogen: 2.50   Oxygen: 1.00

x 2   x 2   x 2

3   5   2

Empirical formula: $C_3H_5O_2$

Finding the Molecular Formula

The empirical formula for adipic acid is $C_3H_5O_2$. The molecular mass of adipic acid is 146 g/mol. What is the molecular formula of adipic acid?

1. Find the formula mass of $C_3H_5O_2$

3(12.01 g) + 5(1.01) + 2(16.00) = 73.08 g

Finding the Molecular Formula

The empirical formula for adipic acid is $C_3H_5O_2$. The molecular mass of adipic acid is 146 g/mol. What is the molecular formula of adipic acid?

3(12.01 g) + 5(1.01) + 2(16.00) = 73.08 g

2. Divide the molecular mass by the mass given by the emipirical formula.

$$\frac{146}{73} = 2$$

Finding the Molecular Formula

The empirical formula for adipic acid is $C_3H_5O_2$. The molecular mass of adipic acid is 146 g/mol. What is the molecular formula of adipic acid?

$$\frac{146}{73} = 2$$

$(C_3H_5O_2) \times 2 = C_6H_{10}O_4$

3. Multiply the empirical formula by this number to get the molecular formula.