Chapter 3: Stoichiometry

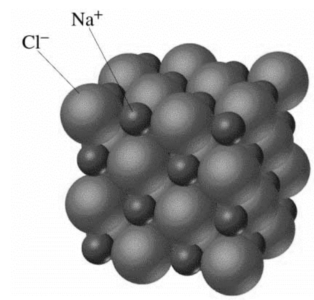
Molecular and Formula Masses: Not the same

Molecular Compounds
H_2O

Molecular Mass -
mass of one molecule

Mass of water?

Ionic Compounds
NaCl



Formula Mass -
mass of one formula unit

Mass of NaCl?

Some more:

Molecular compounds -

NO_2 mol. mass =

CH_3CH_2OH mol. mass =

PCl_5 mol. mass =

$C_6H_{12}O_6$ mol. mass =

Ionic compounds -

$FeCl_3$ form. mass =

Al_2O_3 form. mass =

H_2SO_4 form. mass =

$(NH_4)_3PO_4$ form. mass =

$CuSO_4 \cdot 5\ H_2O$ form. mass =

The Mole and Molar Mass

No, not the little furry guy.

Molar Mass
mass of proton or neutron = 1 amu

$$1 \text{ amu} = 1.66054 \times 10^{-24} \text{ g}$$
$$12 \times (1.66054 \times 10^{-24} \text{ g}) = 1.99265 \times 10^{-23} \text{ g}$$
$$(1.99265 \times 10^{-23} \text{ g}) \times (6.022137 \times 10^{23} \text{ mol}^{-1}) = 12.0000 \text{ g mol}^{-1}$$

Atomic masses on periodic chart are also in g mol^{-1}

Our masses revisited: Molar Mass (MM)
Molecular compounds -

MM (NO_2) =
MM (PCl_5) =
MM (CH_3CH_2OH) =
MM ($C_6H_{12}O_6$) =

Ionic compounds -

MM ($FeCl_3$) =
MM (H_2SO_4) =
MM (Al_2O_3) =
MM ($(NH_4)_3PO_4$) =
MM ($CuSO_4 \cdot 5\ H_2O$) =

Using Molar Mass and More

The mole: 1 mole = 6.022137×10^{23} whatevers

Molar Mass: 1 mole = 12.00 g carbon-12

- ☻ What is the mass of 1.027×10^{22} molecules of methanol? (CH_3OH)

  What volume does this mass of methanol occupy?

- ☻ Calculate the number of moles of CO_2 in 225 g of the gas.

Mass % Composition

Deals with mass proportions, proportion of an element's mass to the whole mass of the compound.

Find the mass percent of each element in CH_3COOH: (acetic acid)

How many grams of oxygen are there in 52.16 g of acetic acid?
Method 1 (already <u>know</u> mass % oxygen in acetic acid):

Method 2 (<u>don't know</u> mass % oxygen in acetic acid)

Empirical Formulas From Mass%

1. Convert percent of each element to mass (assume 100 g).

2. Convert mass of each element to moles each.

3. Use # moles as tentative subscripts.

4. Attempt to get integers as subscripts; divide through by smallest subscript.

5. If fractions, find smallest integer to multiply all by to get integer values.

☻ Diethylene glycol, used as an antifreeze, has the mass composition of 45.27% C, 9.50 % H, and 45.23% O. Determine the empirical formula.

A Balancing Act

Reactant(s) ⟶ Product(s)

$H_2 + O_2 \rightarrow H_2O$ $Na + Cl \rightarrow NaCl$ $Fe(III) + O_2 \rightarrow Fe_2O_3$

Balancing chemical equations:

1. Write down the formula with the correct form of reactants and products.

   $Fe + O_2 \rightarrow Fe_2O_3$

2. Add up the number of atoms on both sides of the equation.

	Reactants	Products
Fe	1	2
O	2	3

3. Determine which element to start with and go from there.

$$\underline{2}Fe + O_2 \rightarrow Fe_2O_3$$

	Reactants	Products
Fe	$\underline{2}$	2
O	2	3

4. Adjust the coefficients to balance the next element.

$$2Fe + \underline{3}O_2 \rightarrow \underline{2}Fe_2O_3$$

	Reactants	Products
Fe	2	$\underline{4}$
O	$\underline{6}$	$\underline{6}$

(*Note:* coefficient in front of a formula multiplies every element (or atom) by that quantity.)

5. Double check the balance on the other elements and, if necessary, adjust their coefficients.

$$\underline{4}Fe + 3O_2 \rightarrow 2Fe_2O_3$$

	Reactants	Products
Fe	$\underline{4}$	4
O	6	6

☻ Some more:

$C_2H_6 + O_2 \rightarrow CO_2 + H_2O$
$C_4H_{10} + O_2 \rightarrow CO_2 + H_2O$
$H_3PO_4 + NaCN \rightarrow HCN + Na_3PO_4$
$FeCl_3 + NaOH \rightarrow Fe(OH)_3 + NaCl$
$Be_3N_2 + H_2O \rightarrow Be(OH)_2 + NH_3$

Stoichiometry

Stoichiometry: The study of the amounts of products and reactants in chemical reactions.

$$4Fe + 3O_2 \rightarrow 2Fe_2O_3$$

Fe -	**O_2 -**	**Fe_2O_3 -**
4 atoms	**3 molecules**	**2 molecules**
4 x 10^6 atoms	**3 x 10^6 molecules**	**2 x 10^6 molecules**
<u>4 moles</u>	**<u>3 moles</u>**	**<u>2 moles</u>**

The coefficients in a balanced chemical equation specify the proportion in moles of each substance in the reaction. Any ratio of these coefficients to each other is called a mole ratio between those two formula components.

Examples:

The ratio of iron (Fe) to iron(III) oxide is $\left(\frac{4 \text{ mol Fe}}{2 \text{ mol } Fe_2O_3}\right)$ **or**

vice versa (flip ratio) for iron (III) oxide to iron.

- ☻ **Likewise, oxygen to iron; iron (III) oxide to oxygen; iron (III) oxide to Fe.**

Mole - Mole Calculations

$$C_6H_{12}O_6 \text{ (glucose)} + 6O_2 \rightarrow 6CO_2 + 6H_2O$$

Given 1.35 moles of glucose, how many moles of water will be produced?

$$1.35 \text{ moles glucose} \left(\frac{6 \text{ mol water}}{1 \text{ mol glucose}}\right) = 8.10 \text{ moles water}$$

How much CO_2 will be produced?

$$8.10 \text{ moles water} \left(\frac{6 \text{ mol } CO_2}{6 \text{ mol water}}\right) = 8.10 \text{ moles } CO_2$$

☻ **Given the reaction $4Cr + 3O_2 \rightarrow 2Cr_2O_3$, how many moles of Cr_2O_3 will be produced from 0.278 moles of chromium?**

Mole - Mass Calculations

$$C_6H_{12}O_6 \text{ (glucose)} + 6O_2 \rightarrow 6CO_2 + 6H_2O$$

Given 1.35 moles of glucose, how many grams of water will be produced?

$$1.35 \text{ moles glucose} \left(\frac{6 \text{ mol water}}{1 \text{ mol glucose}}\right)\left(\frac{18.0 \text{ g water}}{1 \text{ mol water}}\right) = 146 \text{ g water}$$

How many moles of glucose are needed to produce 38.60 g of CO_2?

$$38.60 \text{ g } CO_2 \left(\frac{1 \text{ mol } CO_2}{44.01 \text{ g } CO_2}\right)\left(\frac{1 \text{ mol glucose}}{6 \text{ mol } CO_2}\right) = 0.1462 \text{ moles glucose}$$

☻ **How many grams of oxygen is required to make 7.0 moles of chromium (III) oxide?**

Mass - Mass Calculations

$$C_6H_{12}O_6 \text{ (glucose)} + 6O_2 \rightarrow 6CO_2 + 6H_2O$$

How many grams of glucose are needed to produce 38.60 g of CO_2?

$$38.60 \text{ g } CO_2 \left(\frac{1 \text{ mol } CO_2}{44.01 \text{ g } CO_2}\right)\left(\frac{1 \text{ mol glucose}}{6 \text{ mol } CO_2}\right)\left(\frac{180.2 \text{ g glucose}}{1 \text{ mol glucose}}\right)$$

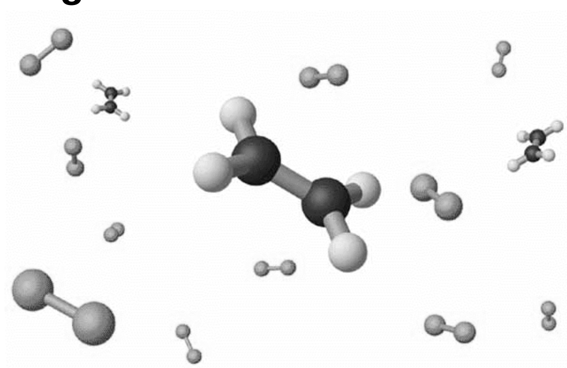
$$= 26.34 \text{ g glucose}$$

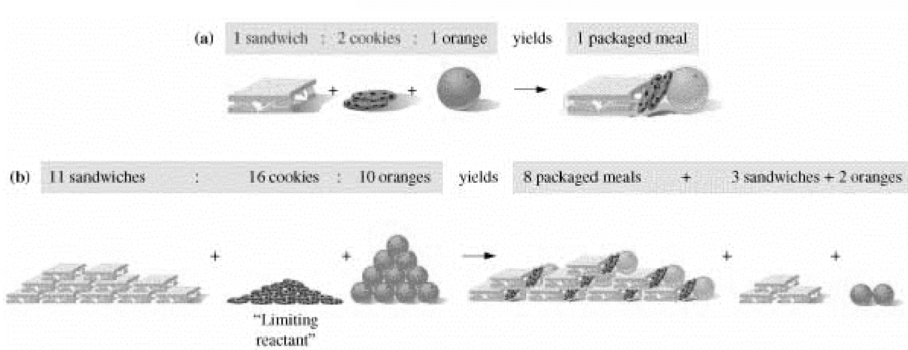
☻ $$4Cr + 3O_2 \rightarrow 2Cr_2O_3$$

Given 13.270 grams of Cr, how much Cr_2O_3 in grams will be produced?

You Limit Me So

Limiting reagent: the reagent that limits the amount of products produced.





$C_6H_{12}O_6$ (glucose) + $6O_2$ → $6CO_2$ + $6H_2O$

Given 35.0 grams of glucose and 87.0 grams of oxygen, which is the limiting reagent?

$$35.0\text{ g glucose}\left(\frac{1\text{ mol glucose}}{180.2\text{ g glucose}}\right)\left(\frac{6\text{ mol }CO_2}{1\text{ mol glucose}}\right) = 1.16\text{ moles }CO_2$$

$$87.0\text{ g }O_2\left(\frac{1\text{ mol }O_2}{18.0\text{ g }O_2}\right)\left(\frac{6\text{ mol }CO_2}{6\text{ mol }O_2}\right) = 4.83\text{ moles }CO_2$$

Percent Yield

percent yield = (actual yield ÷ theoretical yield) x 100%

Theorectically 35.0 grams of glucose will yield 1.16 moles of CO_2. This is equivalent to 51.1 grams of CO_2. If only 48.7 grams of CO_2 were actually produced, what would the percent yield be for this reaction?

$$\left(\frac{48.7\text{ g}}{51.1\text{ g}}\right) \text{X } 100\% = 95.3\%$$