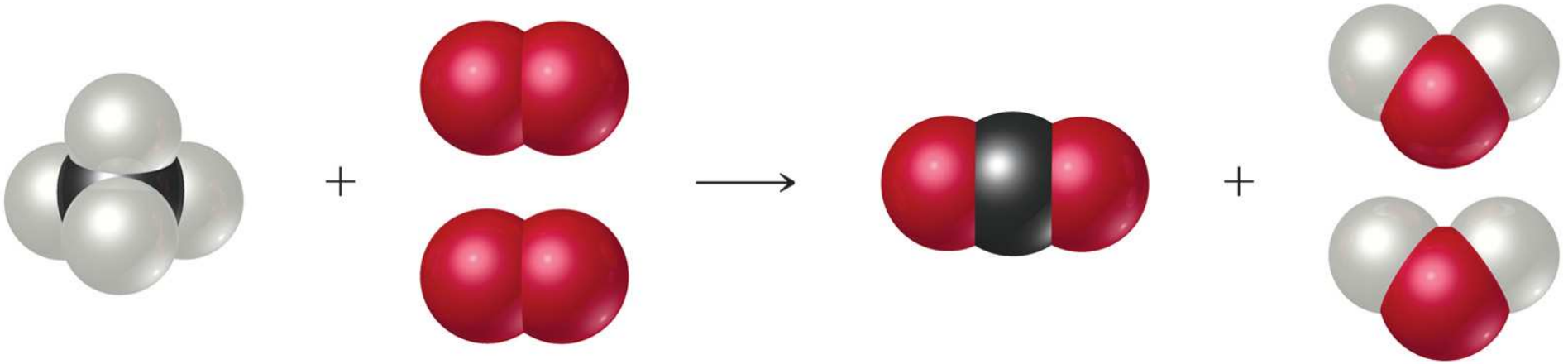
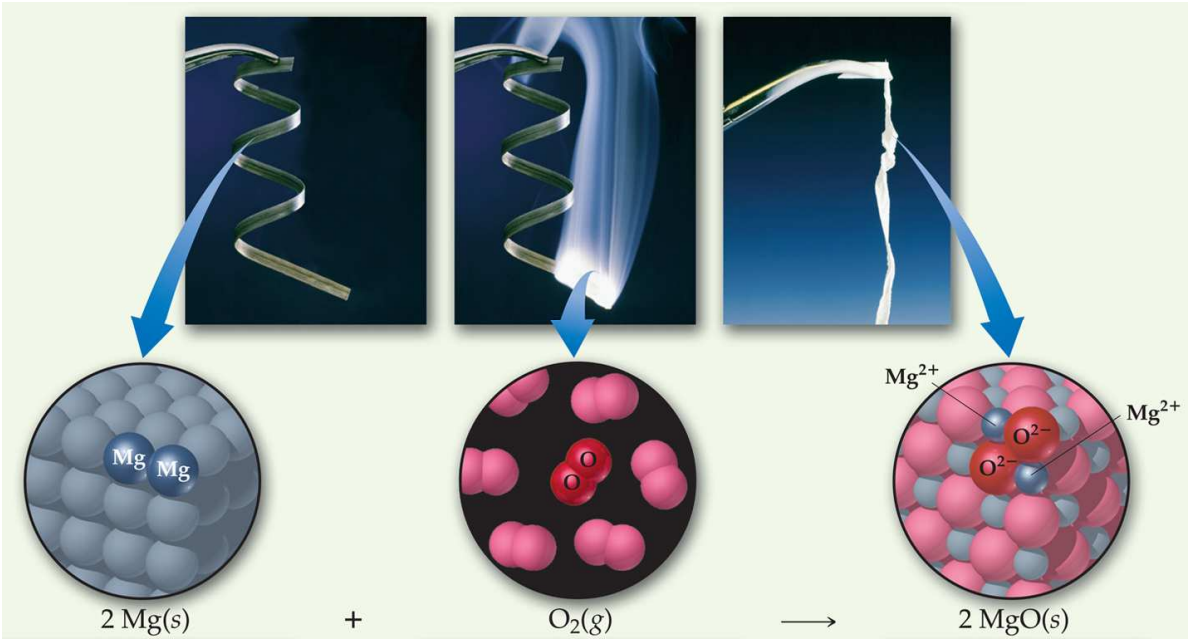
Chapter 3: Stoichiometry & Chemical Equations

$$CH_{4\,(g)} + 2\,O_{2\,(g)} \longrightarrow CO_{2\,(g)} + 2\,H_2O_{\,(g)}$$



$\begin{pmatrix} 1\,C \\ 4\,H \end{pmatrix}$ $(4\,O)$ $\begin{pmatrix} 1\,C \\ 2\,O \end{pmatrix}$ $\begin{pmatrix} 2\,O \\ 4\,H \end{pmatrix}$

Types of Reactions: Combination Reactions



Combination RXNS: Two or more substances react to form one product

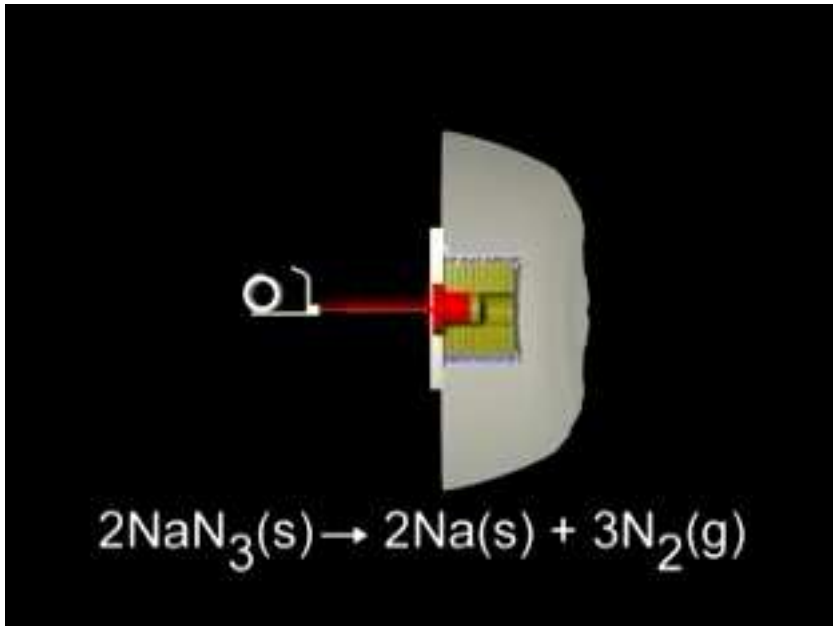
- Examples:

$$N_{2\,(g)} + 3\,H_{2\,(g)} \longrightarrow 2\,NH_{3\,(g)}$$

$$C_3H_{6\,(g)} + Br_{2\,(l)} \longrightarrow C_3H_6Br_{2\,(l)}$$

$$2\,Mg_{\,(s)} + O_{2\,(g)} \longrightarrow 2\,MgO_{\,(s)}$$

Types of Reactions: Decomposition Reactions



<u>Decomposition RXNS:</u> One substance breaks down into two or more substances

- Examples:

$$CaCO_{3\,(s)} \longrightarrow CaO_{\,(s)} + CO_{2\,(g)}$$

$$2\ KClO_{3\,(s)} \longrightarrow 2\ KCl_{\,(s)} + O_{2\,(g)}$$

$$2\ NaN_{3\,(s)} \longrightarrow 2\ Na_{\,(s)} + 3\ N_{2\,(g)}$$

Types of Reactions: Combustion Reactions

<u>Combustion RXNS:</u> Rapid reactions that produce a flame, often involve hydrocarbons reacting with oxygen in the air

- Examples:

$$CH_{4\,(g)} + 2\,O_{2\,(g)} \longrightarrow CO_{2\,(g)} + 2\,H_2O_{\,(g)}$$

$$C_3H_{8\,(g)} + 5\,O_{2\,(g)} \longrightarrow 3\,CO_{2\,(g)} + 4\,H_2O_{\,(g)}$$

How much does an atom of ^{12}C weigh?

1 amu = 1.66×10^{-24}g

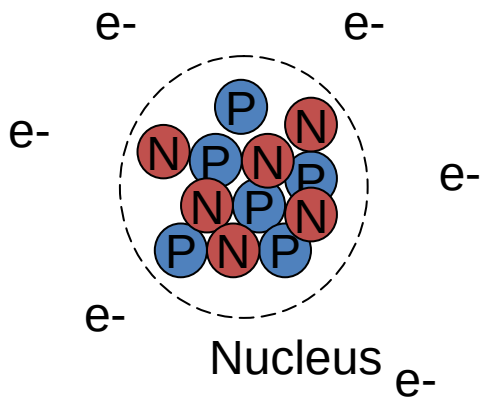
Particle	Charge	Mass (amu)
Proton	Positive (1+)	1.0073
Neutron	None (neutral)	1.0087
Electron	Negative (1−)	5.486×10^{-4}

A) 12 g

B) $12 \times (1.66 \times 10^{-24})$ g

C) $6 \times (1.66 \times 10^{-24})$ g

D) $6 \div 1.66 \times 10^{-24}$ g



Formula Weight (FW) and Molecular Weight (MW)

- Sum of the atomic weights for the atoms in a chemical formula
- FW – ionic compounds
- The formula weight of calcium chloride, $CaCl_2$, is:

Ca: 1(40.1 amu)
+ Cl: 2(35.5 amu)
111.1 amu

- MW – molecular compounds
- For ethane C_2H_4:

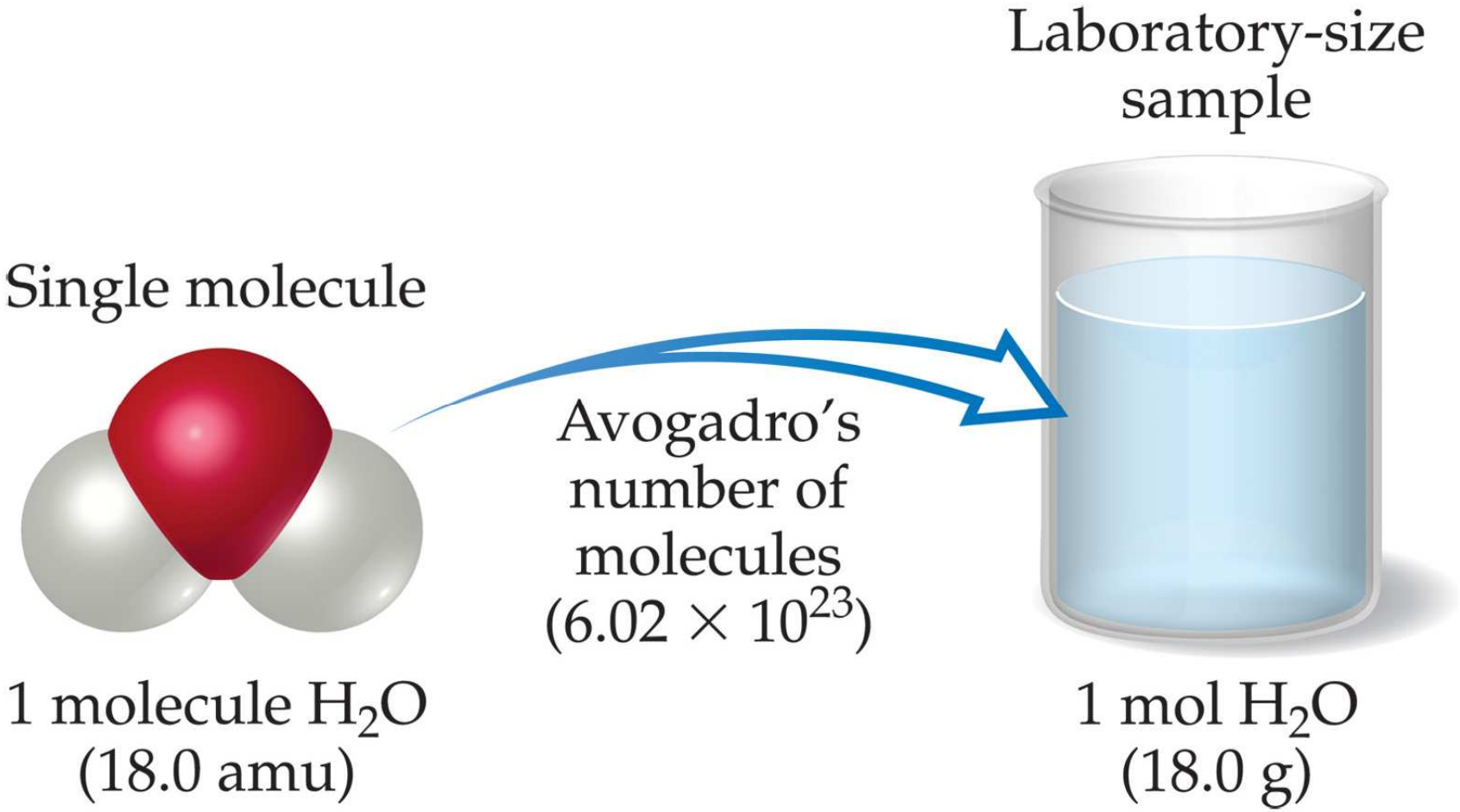
C: 2(12.0 amu)
+ H: 6(1.0 amu)
30.0 amu

Percent Composition

the percentage of the mass of a compound that comes from each of the elements in the compound :

$$\% \text{ element} = \frac{(\text{number of atoms})(\text{atomic weight})}{(\text{FW of the compound})} \times 100$$

Avogadro's Number & the Mole



1 mole of ^{12}C has a mass of 12 g

Avogadro's Number & the Mole

One mole of atoms, ions, or molecules contains Avogadro's number of those particles

1 mol H_2O, contains 6.02 x 10^{23} H_2O molecules

One mole of molecules or formula units contains Avogadro's number times the number of atoms or ions of each element in the compound

1 mol H_2O, contains 6.02 x 10^{23} O atoms
and 2*(6.02) x 10^{23} H atoms

How much does an atom of ^{12}C weigh?

1 amu = 1.66×10^{-24}g

A) 12 g

B) $12 \times (1.66 \times 10^{-24})$ g

C) $6 \times (1.66 \times 10^{-24})$ g

D) $6 \div 1.66 \times 10^{-24}$ g

How much would 6.02×10^{23} ^{12}C atoms weigh?

A) 12 g

B) 6.02×10^{23} g

C) 1.66×10^{-24} g

D) $12 \times (1.66 \times 10^{-24})$ g

How much would 1 mole (mole = mol) of ^{12}C weigh?

A) 12 g

B) 6.02×10^{23} g

C) 1.66×10^{-24} g

D) $12 \times (1.66 \times 10^{-24})$ g

Molar Mass (g/mol)

By definition, these are the mass of 1 mol of a substance (i.e., g/mol)

The molar mass of an element is the mass number for the element that we find on the periodic table

The formula weight (in amu's) will be the same number as the molar mass (in g/mol)

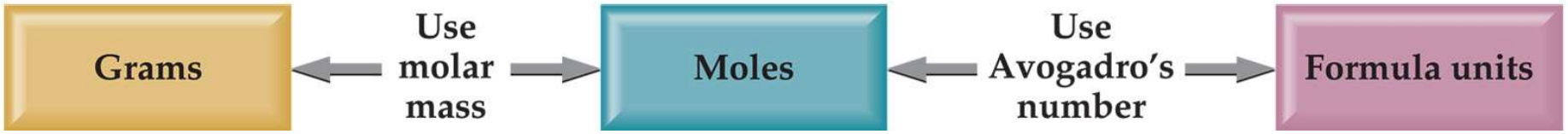
Name of substance	Formula	Formula Weight (amu)	Molar Mass (g/mol)	Number and Kind of Particles in One Mole
Atomic nitrogen	N	14.0	14.0	6.022×10^{23} N atoms
Molecular nitrogen	N_2	28.0	28.0	6.022×10^{23} N_2 molecules $2(6.022 \times 10^{23})$ N atoms
Silver	Ag	107.9	107.9	6.022×10^{23} Ag atoms
Silver ions	Ag^+	107.9[a]	107.9	6.022×10^{23} Ag^+ ions
Barium chloride	$BaCl_2$	208.2	208.2	6.022×10^{23} $BaCl_2$ units 6.022×10^{23} Ba^{2+} ions $2(6.022 \times 10^{23})$ Cl^- ions

[a]Recall that the electron has negligible mass; thus, ions and atoms have essentially the same mass.

Avogadro's Number & the Mole

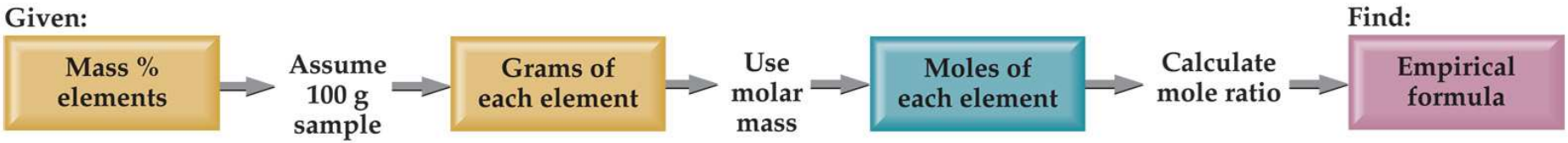
One mole of atoms, ions, or molecules contains Avogadro's number of those particles

One mole of molecules or formula units contains Avogadro's number times the number of atoms or ions of each element in the compound



Calculating Empirical Formulas

One can calculate the empirical formula from the percent composition

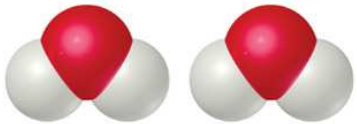


The compound *para*-aminobenzoic acid (you may have seen it listed as PABA on your bottle of sunscreen) is composed of:

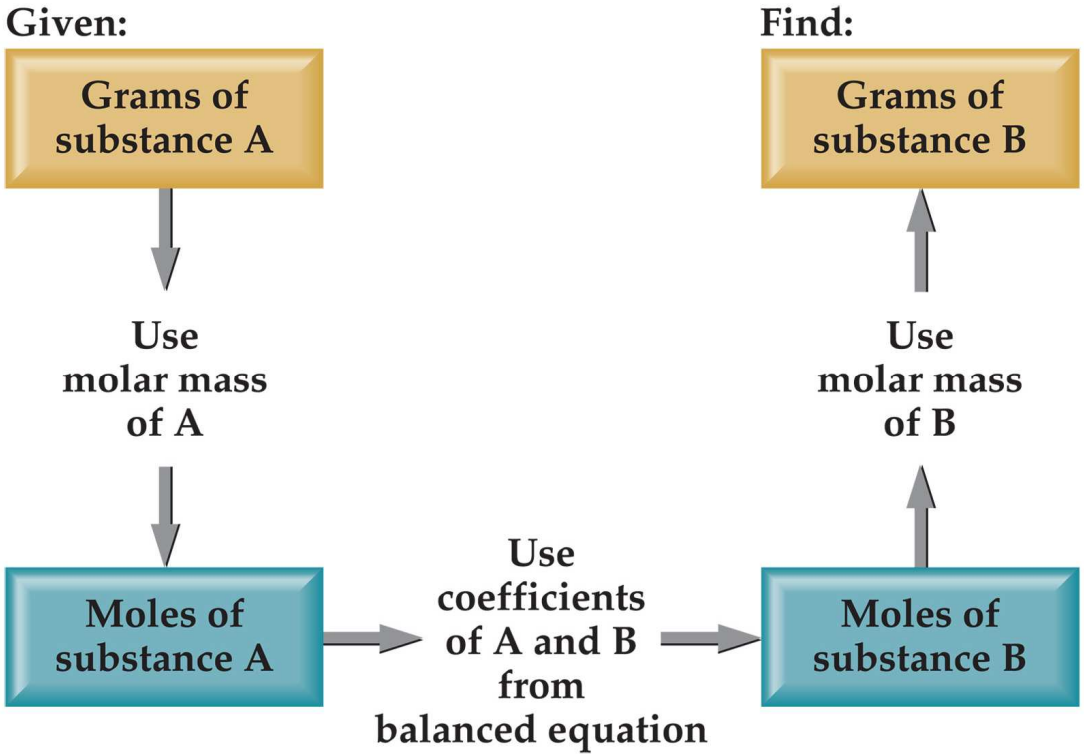
carbon (61.31%),
hydrogen (5.14%),
nitrogen (10.21%),
oxygen (23.33%).

Find the empirical formula of PABA.

Using Chemical Equations in Calculations

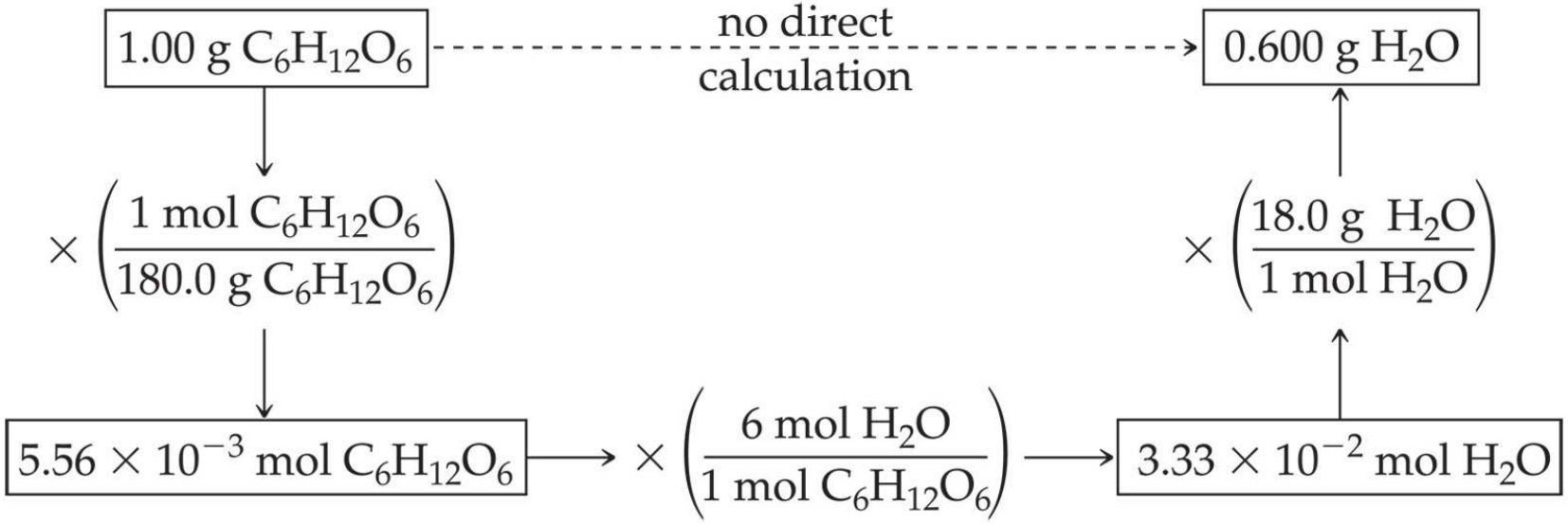
Equation:	**$2\ H_2(g)$**	**+**	**$O_2(g)$**	**⟶**	**$2\ H_2O(l)$**
Molecules:	2 molecules H_2	+	1 molecule O_2	⟶	2 molecules H_2O
					
Mass (amu):	4.0 amu H_2	+	32.0 amu O_2	⟶	36.0 amu H_2O
Amount (mol):	2 mol H_2	+	1 mol O_2	⟶	2 mol H_2O
Mass (g):	4.0 g H_2	+	32.0 g O_2	⟶	36.0 g H_2O

The coefficients in the balanced equation give the ratio of *moles* of reactants and products



Stoichiometric Calculations

$$C_6H_{12}O_6 + 6\ O_2 \rightarrow 6\ CO_2 + 6\ H_2O$$



Starting with 1.00 g of $C_6H_{12}O_6$…

we calculate the moles of $C_6H_{12}O_6$…

use the coefficients to find the moles of H_2O…

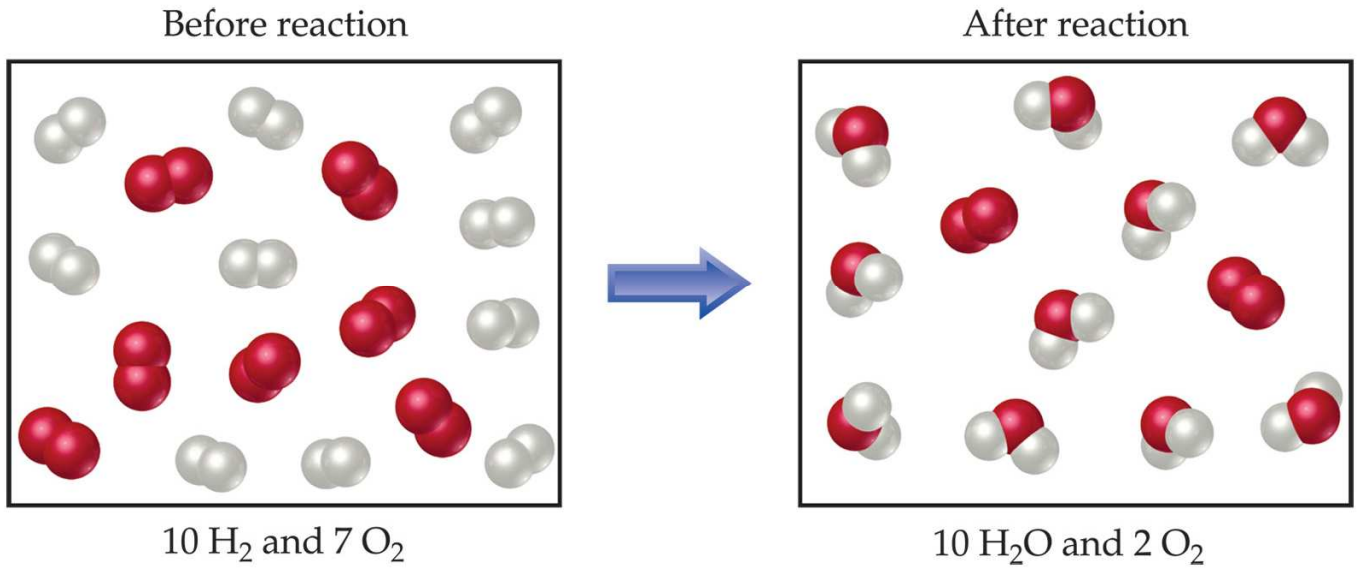
and then turn the moles of water to grams

Limiting Reagents : How Many Cookies Can I Make?

- You can make cookies until you run out of one of the ingredients

Limiting Reactants

- The limiting reactant is the reactant present in the smallest stoichiometric amount
  - In other words, it's the reactant you'll run out of first (in this case, the H_2)



Theoretical & Percent Yield

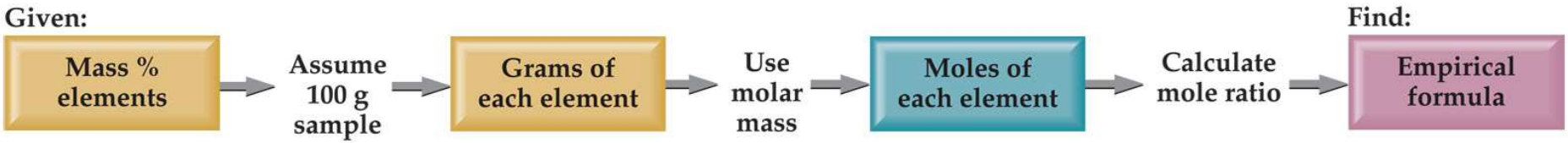
Theoretical yield : the amount of product possible as calculated through the stoichiometry problem

Actual yield: the amount one actually produces and measures

Percent yield = Actual / Theoretical x 100%

Calculating Empirical Formulas

One can calculate the empirical formula from the percent composition



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