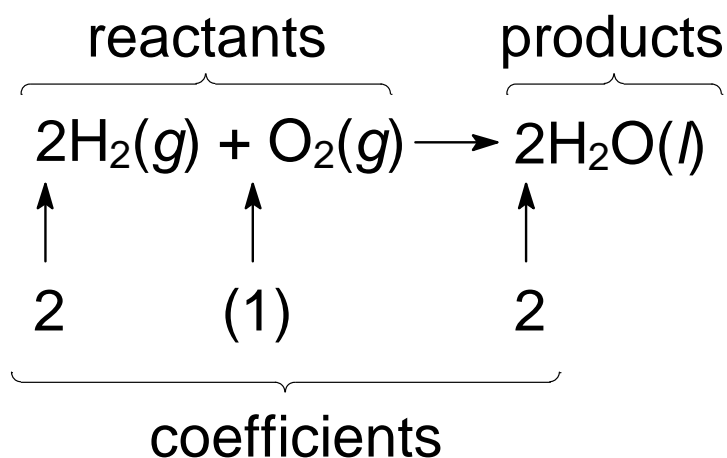# Chemical Equations

In a balanced chemical equation the total numbers of atoms of each kind on both sides of the equation are the same.

reactants   products

$$2H_2(g) + O_2(g) \longrightarrow 2H_2O(l)$$

2   (1)   2

coefficients

Reactants: H = 4, O = 2
Products: H = 4, O = 2

Ratios, Not Individual Atoms or Molecules

☞ Balanced equations indicate the ratio relationships among atoms, ions, and molecules that may comprise reactants and products.

> ✓ "For every two molecules of hydrogen and one of oxygen, two molecules of water are produced."

☞ In general, a chemical equation *does not* indicate how a reaction proceeds on the atomic/molecular level.

> ✗ "Two molecules of hydrogen react with one molecule of oxygen to produce two molecules of water."

Knowledge of how the reaction may occur at the atomic/molecular level involves indirect inference from studies of the rate of the reaction under varying conditions (*chemical kinetics*).
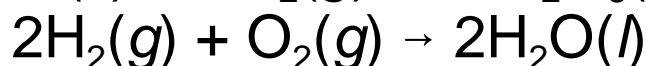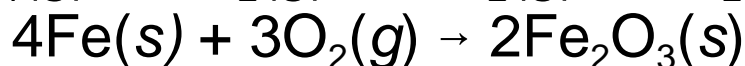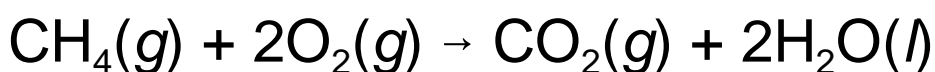
Balancing Equations by Inspection

1. Do not add new species or change the formulas of given species in the skeletal equation.

2. First balance elements that occur in only one reactant and one product (if such exist).

3. Fractional coefficients may be useful in achieving a balance (e.g., when a diatomic reactant yields an odd number of atoms in product molecules), but fractions usually should be cleared by multiplying both sides of the equation by a suitable constant.

4. If polyatomic ions or fragments of such occur as both reactants and products, treat them as discrete units (i.e., don't break them up).

5. Check element by element to be sure that the same numbers of each element occur on both sides of the equation (i.e., make sure the equation is really balanced).
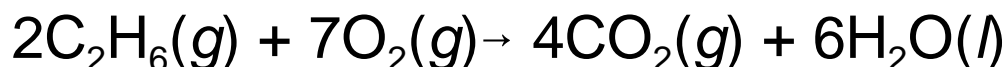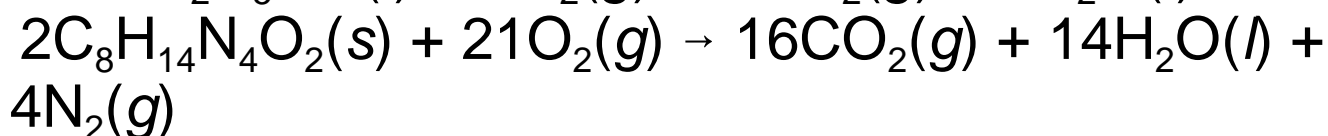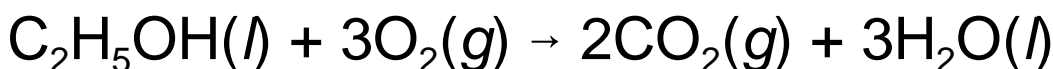
Basic Equation Types
Combustion

✏ A **combustion reaction** is a flame-producing reaction between oxygen and another substance to produce one or more oxides.

$$CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(l)$$
$$4Fe(s) + 3O_2(g) \rightarrow 2Fe_2O_3(s)$$
$$2H_2(g) + O_2(g) \rightarrow 2H_2O(l)$$

☞ Combustion of a **hydrocarbon** (compound of C & H) in abundant oxygen always yields equivalent amounts of $CO_2(g)$ and $H_2O(l)$.
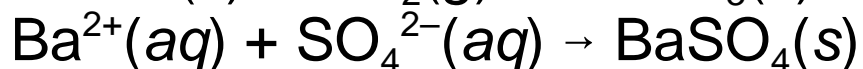
$$2C_2H_6(g) + 7O_2(g) \rightarrow 4CO_2(g) + 6H_2O(l)$$
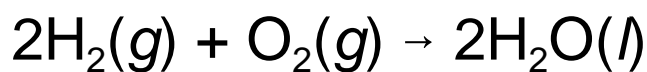
☞ Organic compounds that contain O and/or N combust to give $CO_2(g)$, $H_2O(l)$, and/or $N_2(g)$.

$$C_2H_5OH(l) + 3O_2(g) \rightarrow 2CO_2(g) + 3H_2O(l)$$
$$2C_8H_{14}N_4O_2(s) + 21O_2(g) \rightarrow 16CO_2(g) + 14H_2O(l) + 4N_2(g)$$

Basic Equation Types
Combination

✏ In a **combination reaction**, two or more reactants come together to form a single product.

$$2H_2(g) + O_2(g) \rightarrow 2H_2O(l)$$
$$N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$$
$$CaO(s) + CO_2(g) \rightarrow CaCO_3(s)$$
$$Ba^{2+}(aq) + SO_4^{2-}(aq) \rightarrow BaSO_4(s)$$
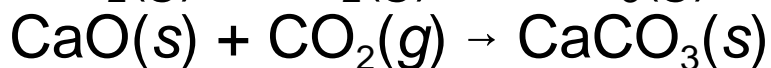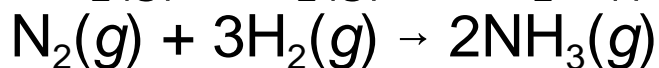
Basic Equation Types
Decomposition

✏ In a **decomposition reaction** a single reactant decomposes to two or more products.

$$2H_2O_2(l) \rightarrow 2H_2O(l) + O_2(g)$$
(Decomposition of hydrogen peroxide in light)

$$CaCO_3(g) \rightarrow CaO(s) + CO_2(g)$$
(Thermal decomposition of limestone)

$$8HgS(s) \rightarrow 8Hg(l) + S_8(s)$$
(Roasting of cinnabarite to obtain mercury)
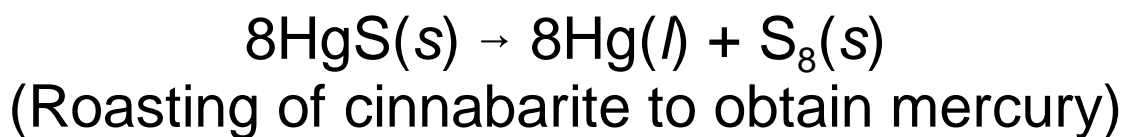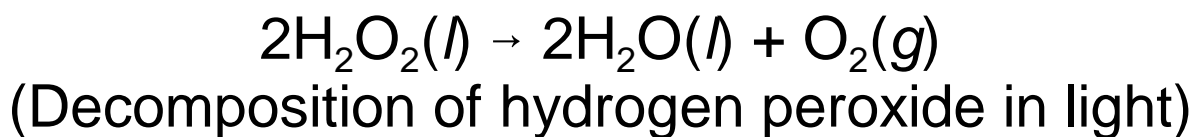
Formula Weights and Molecular Weights

☞ The **formula weight** of a compound is the sum of the atomic weights of all the atoms making up the *empirical formula*.

f.w. $CaCl_2$ = 40.08 u + (2)(35.45) u = 110.98 u

☞ For a molecular compound or polyatomic ion, **molecular weight** is the sum of the atomic weights of all the atoms in the molecule.

m.w. C_2H_6 = (2)(12.01) u + (6)(1.01) u = 30.08 u

☞ The molecular weight of a compound is always a whole-number multiple of its formula weight.

f. w. CH_3 = 12.01 u + (3)(1.01) u = 15.04 u

m.w. C_2H_6/f. w. CH_3 = 30.08/15.04 = 2

☞ Ionic compounds and network solids only have formula weights, because they only have empirical formulas.

Percent Composition

☞ The percent composition of an element in a compound is the ratio of the mass of the element in the formula to the total mass of the formula, expressed as a percentage.

- Either the molecular formula or empirical formula can be used.

  %C in C_2H_6:

  $$\% \; C \; = \; \frac{(2)(12.01)}{30.08} \; \times \; 100\% \; = \; 79.85 \; \%$$

  %C in CH_3:

  $$\% \; C \; = \; \frac{12.01}{15.04} \; \times \; 100\% \; = \; 79.85 \; \%$$

- The sum of percentages of composition of all elements in a compound is 100%.

  %H in C_2H_6:

  $$\% \; H = (100 - 79.85)\% = 20.15\%$$