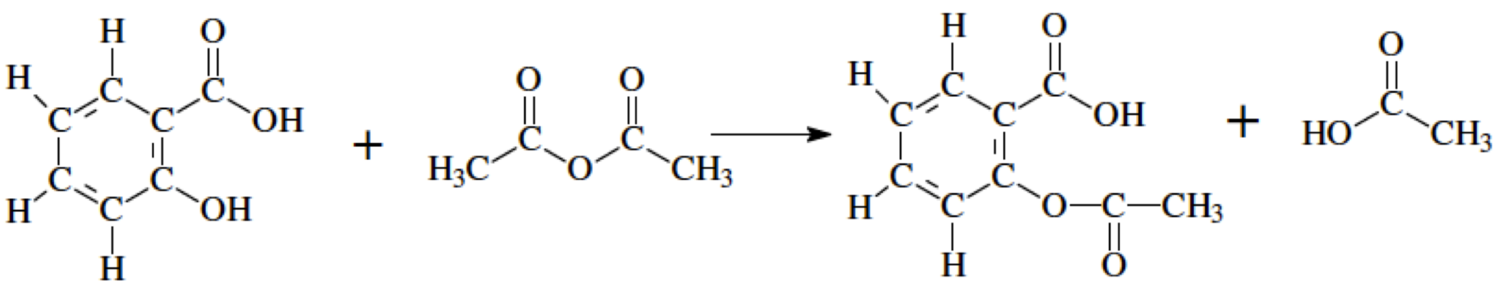
Chapter 8

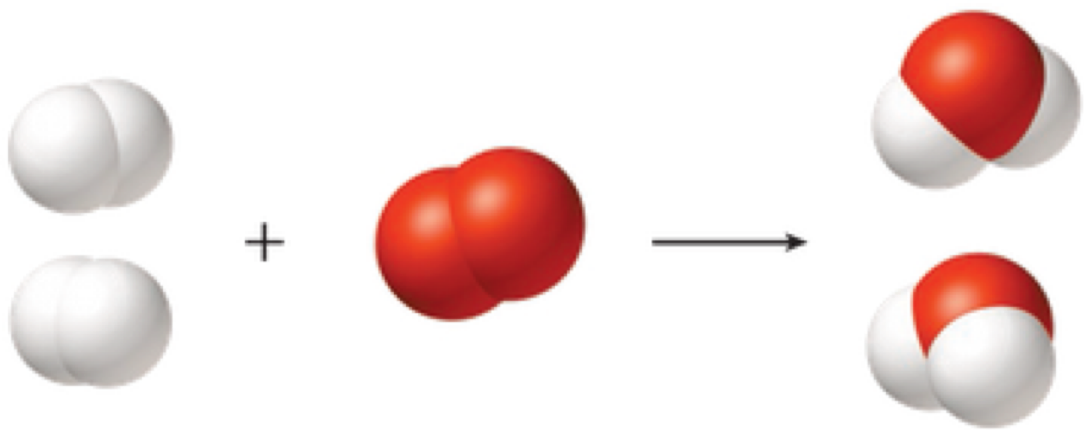
Aspirin



10.0 g + excess ⟶ ? g

Chemical Reactions

Chemical Equations



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

Chemical Equations

- Shorthand description of a chemical reaction
  - Like a recipe!

3  + 2c 

→ 

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- Symbols & formulas = elements & compounds
- Letters in parentheses = phases of matter

$$H_2(g) + 2C(s) + Cl_2(g) \rightarrow C_2H_2Cl_2(g)$$

Chemical Equations

$$H_2(g) + 2C(s) + Cl_2(g) \rightarrow C_2H_2Cl_2(g)$$

Reactants: Starting substances on left: H_2, C, Cl_2

Products: Substances formed on right: $C_2H_2Cl_2$

Values in front of symbols: **Stoichiometric coefficients**

Coefficients = # moles of that substance

→ If there is no #, the coefficient is 1

+ sign: Think of it as "and"; not mathematical adding!

Arrow (produces, yields) – change from reactants to products

→ Shows the direction of reaction ($\rightarrow$, $\leftarrow$, $\leftrightarrow$, $\rightleftharpoons$)

(g), (s), (l), (aq): chemical phase: gas, solid, liquid, aqueous

Remember naming.......

One mole of solid barium hydroxide reacts with two moles of aqueous nitric acid (HNO_3) to form one mole of aqueous barium nitrate and two moles of liquid water.

Law of Conservation of Mass

Total mass is constant during a chemical reaction

Mass of reactants must exactly match mass of products

2lbs potatoes + 3 ounces milk + 1 ounce butter = 2 lbs 4 oz mashed potatoes

Called mass balance

$$11.1\text{g } H_2\text{ (g)} + 88.9\text{g } O_2\text{ (g)} = 100.0\text{g } H_2O\text{ (l)}$$

Matter cannot be created or destroyed in chemical reactions!

Chemical Equations must be balanced!

Rules & Hints For Balancing Chemical Equations

Cannot make something out of nothing!

- **ONLY COEFFICIENTS CAN BE CHANGED!!! $H_2O \neq H_2O_2$**
- If an element(s) is present in just 1 compound on each side of the equation, balance that element(s) first.
- Balance free elements last. (O_2, C, H_2, etc.)
- Fractions can be cleared at any time by multiplying all coefficients by a common multiplier (often denominator)

$$2\ [C_4H_{10} + 13/2\ O_2 \rightarrow 4\ CO_2 + 5\ H_2O] \rightarrow 2\ C_4H_{10} + 13\ O_2 \rightarrow 8\ CO_2 + 10\ H_2O$$

- Groupings of atoms (such as in polyatomic ions) may remain unchanged. In such cases, you can balance these groupings as a unit.

Balancing Chemical Equations

Starting – Unbalanced (no coefficients):

1.) $H_2 + O_2 \rightarrow H_2O$

2.) $C_2H_5O_2 + O_2 \rightarrow CO_2 + H_2O$

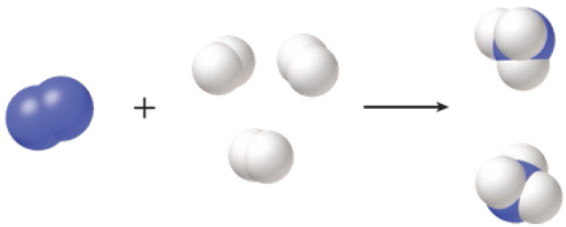
Balanced: 1.) $\underline{2}H_2 + O_2 \rightarrow \underline{2}H_2O$

2.) $\underline{4}C_2H_5O_2 + \underline{9}O_2 \rightarrow \underline{8}CO_2 + \underline{10}H_2O$

Some Basic Types of Chemical Reactions

Combination (aka Synthesis): Putting things together

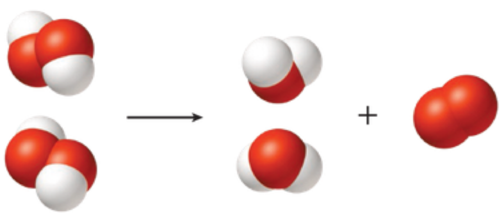
- Two or more reactants combine to form a single product



$N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$

Decomposition: Breaking things apart

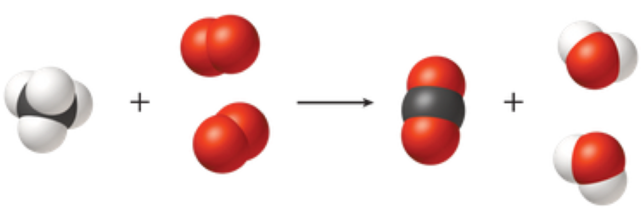
- Two or more products form from a single reactant



$2H_2O_2(aq) \rightarrow 2H_2O(l) + O_2(g)$

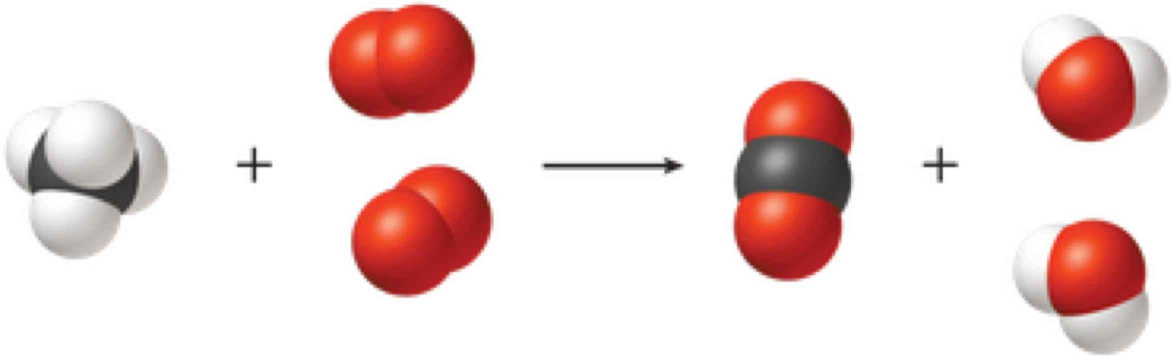
Combustion: Reacting with oxygen

- A substance burns in the presence of oxygen



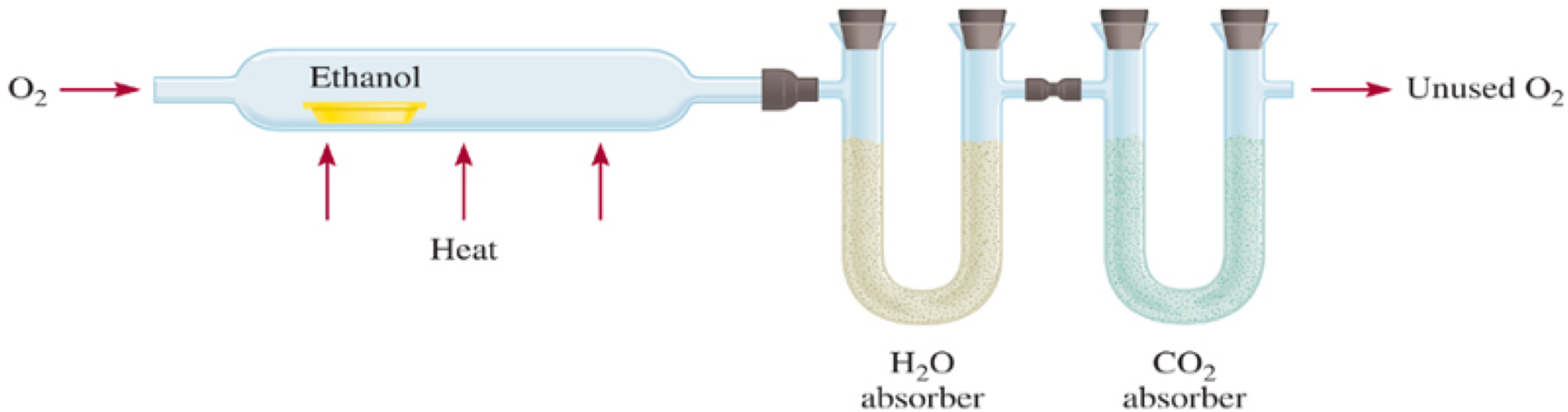
$CH_4(g) + 2O_2(g) \rightarrow 2H_2O(l) + CO_2(g)$

Combustion Analysis



$$CH_4(g) + 2O_2(g) \rightarrow 2H_2O(l) + CO_2(g)$$

Determination of Empirical Formulas by Elemental Analysis (Combustion)



- Burn measured amount of compound with excess O_2.
  - $C_xH_yO_z + O_2 \rightarrow CO_2 + H_2O + \text{Unused } O_2$
- Measure mass of products (must know what they are)
- Use mass of products to determine moles & mass of each element present
  - CO_2 and H_2O contain all C and H atoms
  - Determine amount of oxygen by difference
- If know molar mass can determine molecular formula

Determining Empirical Formula from Experiment

A 0.595g sample of a CHO compound burns in O_2 to produce 1.188g CO_2 and 0.486g H_2O. What is the empirical formula?

$$C_xH_yO_z + O_2 \rightarrow CO_2 + H_2O + \text{Unused } O_2$$

MM CO_2 = 44.01 g/mol   MM H_2O = 18.016 g/mol

Determine Moles & Mass of C from CO_2

Determine Moles & Mass of H from H_2O

Determine Mass & Moles of O from what is left

Divide by smallest # moles to get formula: C_2H_4O

What If You Don't get Whole Numbers?

Multiply Results from Empirical Formula by the smallest possible value to get whole numbers:

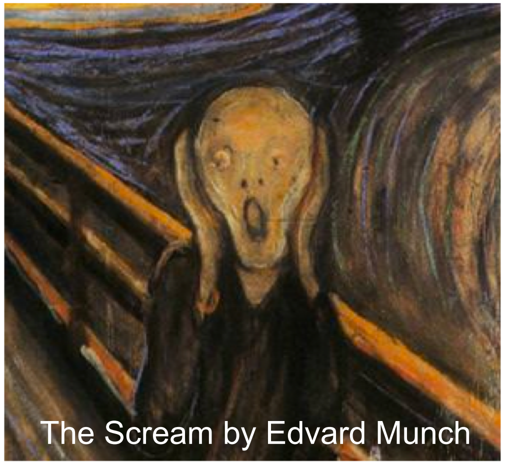
C = 1.5

O = 1

H = 3

Formula = $C_3H_6O_2$

Amounts of Reactants and Products: Stoichiometry



Calculations based on chemical reactions

How much do you need to make what you want?

Stoichiometry: Mole Ratios in Chemical Reactions

3 
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\+ 2c 

→ 

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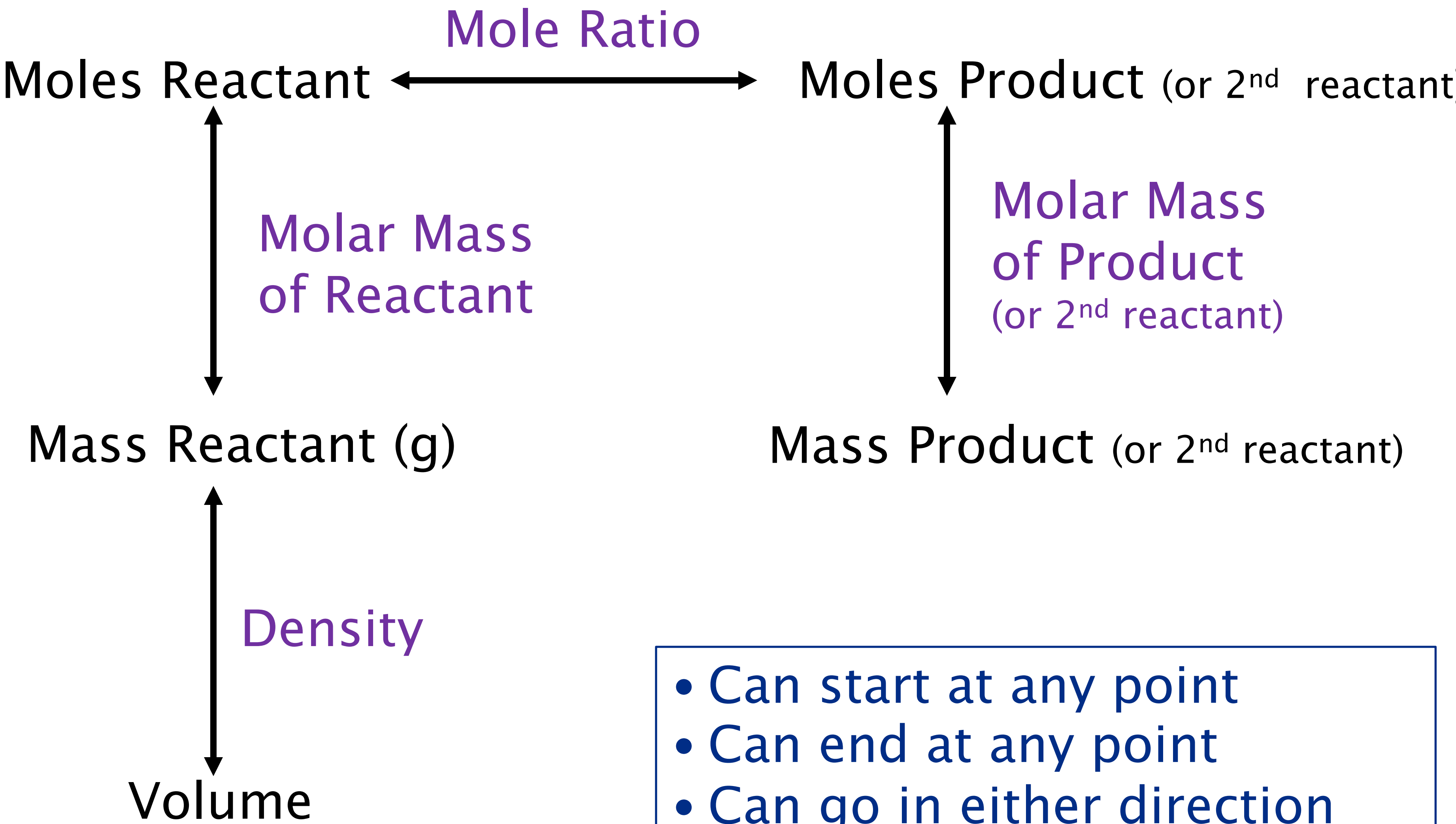
3 eggs and 2 cups of flour react to make one cake
ratio: 3:2:1

$$2C(s) + 1Cl_2(g) + 2H_2(g) \Rightarrow 1C_2H_4Cl_2(g)$$

2 moles of graphite (carbon), 1 mole of chlorine gas, and 2 moles of hydrogen gas react to form 1 mole of dichloroethane

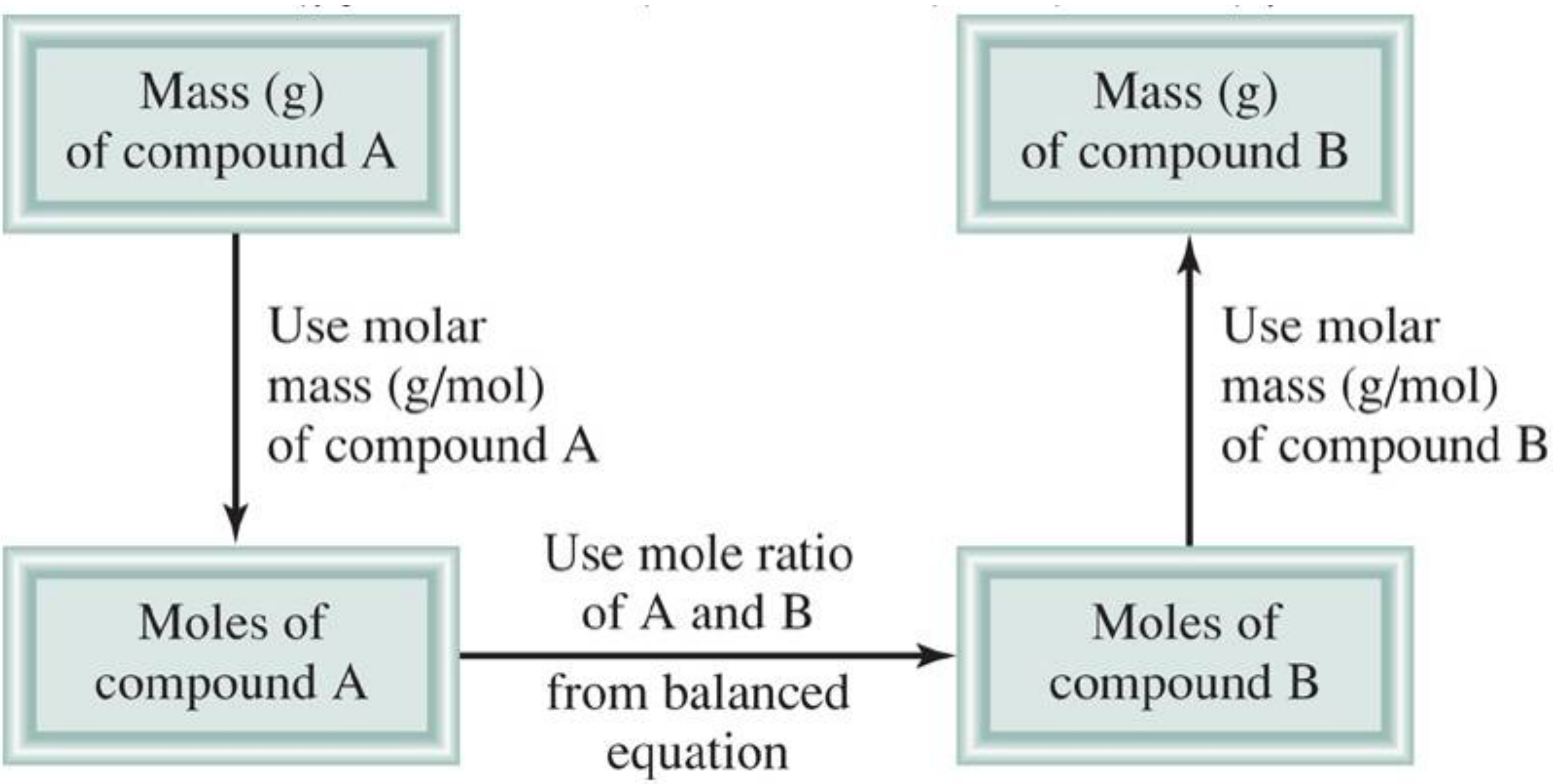
Mole ratio: 2:1:2:1

Stoichiometry Flow Chart



- Can start at any point
- Can end at any point
- Can go in either direction
- Can have additional steps

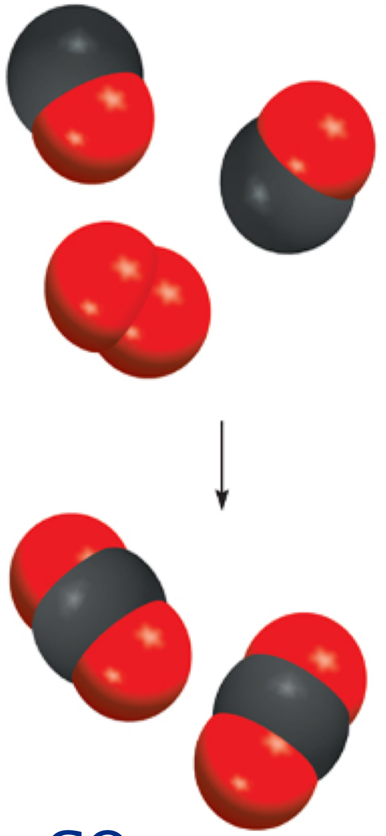
Stoichiometry Flow Chart 2



What is the mass of CO_2 produced when 10.7g of O_2 reacts with CO to form CO_2?

Write and balance the equation:

$$2CO\ (g) + 1O_2(g) \rightarrow 2CO_2(g)$$



Calculate moles of O_2 (31.9988 g/mol) in 10.7g of O_2. (0.33439mol O_2)

Calculate moles of CO_2 from mole ratio.

(0.668775mol CO_2)

Calculate grams CO_2 (44.0098g/mol) from moles CO_2.

(29.4g CO_2)

Limiting Reagents & Reaction Yield:

- **Limiting Reagent:** Reactant that runs out first!
  - Determines how much product you can make
  - Find by calculating the moles of 1 product from each given amount of reactant
  - Limiting reagent is the reactant producing the smallest amount of product

- **Theoretical Yield:**
  - Max amount of product that you can make
  - Based on limiting reagent!
  - Generally reported in grams

3 
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+ 2c 

→ 

12	unlimited
unlimited	12
12	12
12	6

$$Sb_4O_{10} + 6\,H_2O \rightarrow 4\,H_3SbO_4$$

If you start with 3.0 moles Sb_4O_{10} and 8.0 moles of water, what is your limiting reagent?

169.87 g/mol | 27.026 g/mol | | 133.886 g/mol |

$$AgNO_3 + HCN \longrightarrow AgCN + HNO_3$$

If you make silver cyanide, which is used in electroplating, from 20.0 g of silver nitrate and 15.0 g of hydrogen cyanide gas, what is your limiting reagent? What is your theoretical yield of AgCN?

Step 1: Make sure equation is balanced.

Step 2: Moles of reactants – for limiting reagent, need both!

Why might you want to make either silver nitrate or hydrogen cyanide your limiting reagent?

Step 3: Cross the mole bridge. Limiting reagent produces smallest amount of product! (LR = $AgNO_3$)

Step 4: Use the limiting reagent to determine the mass of AgCN.

(15.8 g)

Yields of Chemical Reactions

Reactions rarely produce maximum product

a. Impure reactants
b. Incomplete reaction
c. All product not fully recovered
d. Side reactions may occur

Actual yield: Yield recovered during experiment

Theoretical yield: Yield calculated from limiting reagent

$$\text{Percent yield} = \left(\frac{\text{Actual yield}}{\text{Theoretical yield}}\right) \text{X } 100$$

2.01588 g/mol 28.0134 g/mol 17.0305 g/mol

Step 1: $3\,H_2 + N_2 \longrightarrow 2\,NH_3$

If you start with 4.00 g of hydrogen gas and 22.00g of nitrogen gas, and make 18.5 g of ammonia, what is your percent yield?

Step 2:

Step 3:

Step 4:

Step 5:

82.1 % yield