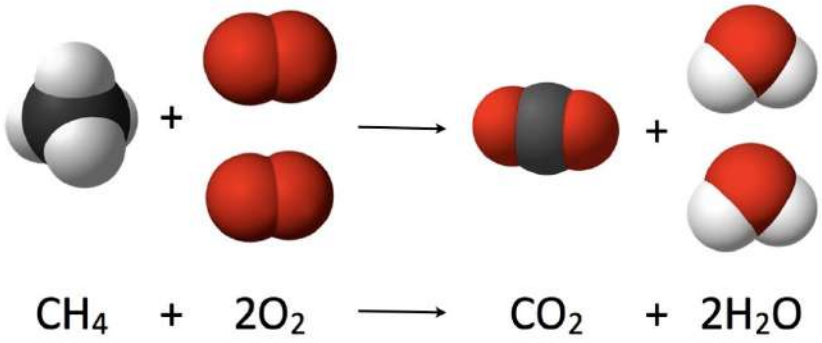
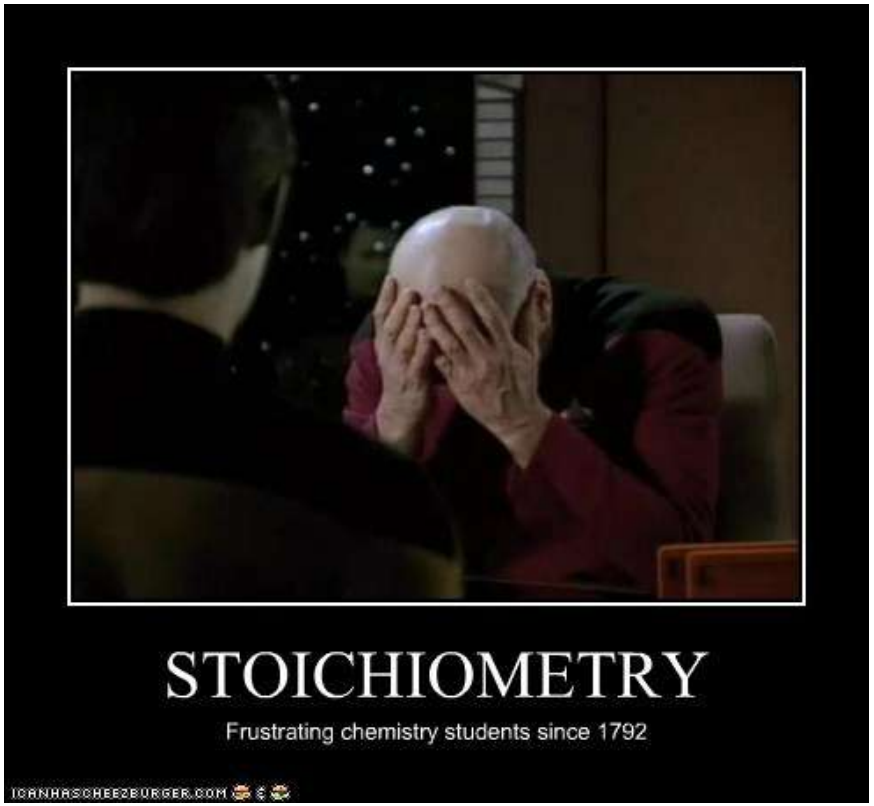


$$CH_4 + 2O_2 \longrightarrow CO_2 + 2H_2O$$



Chapter 12: Stoichiometry

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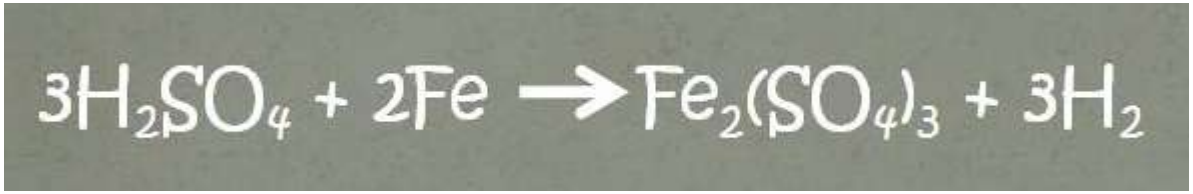
Section 12.1 – The Arithmetic of Equations

- A balanced chemical equation provides quantitative information.
- Chemists use balanced equations as a basis to calculate how much reactant is needed or product is formed in a reaction.
- The calculation of quantities in chemical reactions is called stoichiometry.

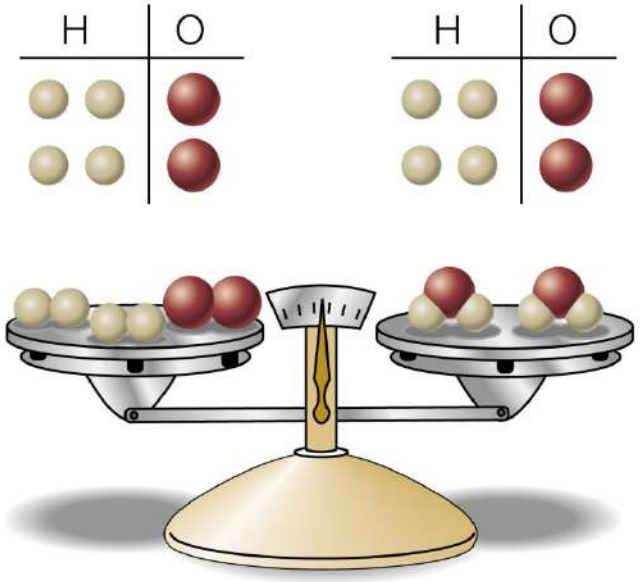


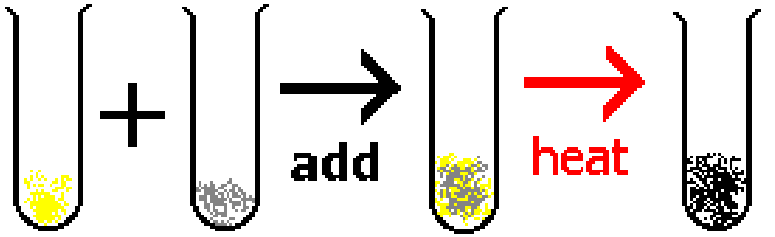
Balanced Equations

N_2 +	$3H_2$ →	$2NH_3$
2 atoms N	6 atoms H	2 atoms N, 6 atoms H
1 m/c N_2	3 m/c H_2	2 m/c NH_3
6.02×10^{23} m/c N_2	1.806×10^{24} m/c H_2	1.204×10^{24} m/c NH_3
1 mol N_2	**3 mol H_2**	**2 mol NH_3**
28g N_2	6g H_2	34g NH_3
22.4L N_2	67.2L H_2	44.8L NH_3

Law of Conservation

- In a balanced chemical equation, only mass and number of atoms are conserved.





S + Fe ==> FeS

32g + 56g reactants ===> 88g products

Section 12.1 Assessment

1. What quantities are always conserved in chemical reactions?
2. Interpret the given equation in terms of relative numbers of atoms, numbers of moles, and masses of the reactants and products.

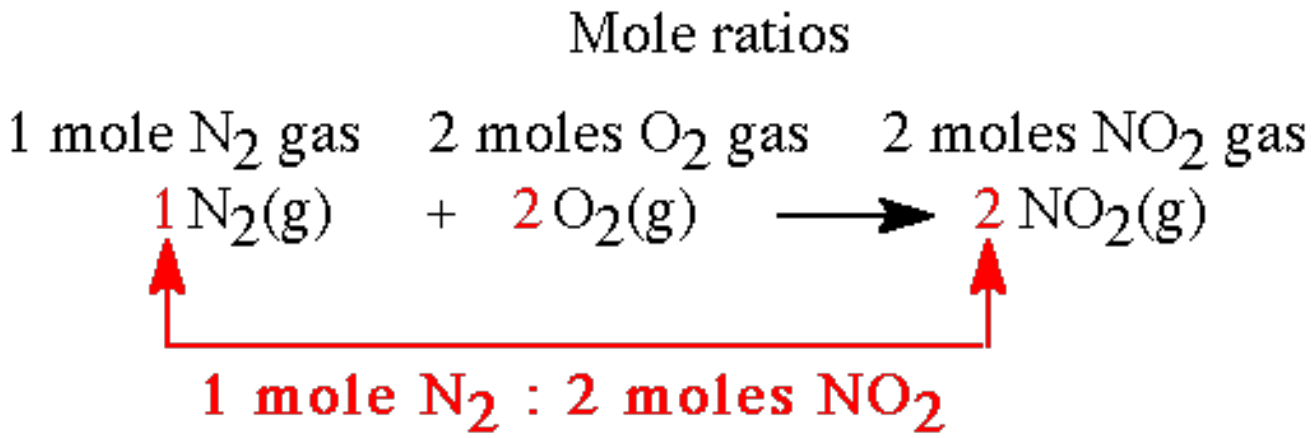
$$2K + 2H_2O \rightarrow 2KOH + H_2$$

3. Balance the following equation and show how it obeys the law of conservation of mass.

$$C_2H_5OH + O_2 \rightarrow CO_2 + H_2O$$

Section 12.2 – Chemical Calculations

- A mole ratio is a conversion factor derived from the coefficients of a balanced equation.
- Mole ratios are used to convert from one substance to another.



Sample Problem

- How many moles of ammonia are produced when 0.60 mol of nitrogen reacts with hydrogen?

$$N_2 + 3H_2 \rightarrow 2NH_3$$

Practice Problems

$$4Al + 3O_2 \rightarrow 2Al_2O_3$$

- How many moles of aluminum are needed to form 3.7 mol Al_2O_3?

- How many moles of oxygen are required to react with 14.8 mol of Al?

- How many moles of Al_2O_3 are formed when 0.78 mol O_2 reacts with aluminum?

Stoichiometry Problems

- When doing stoichiometry problems, you follow 3 steps.

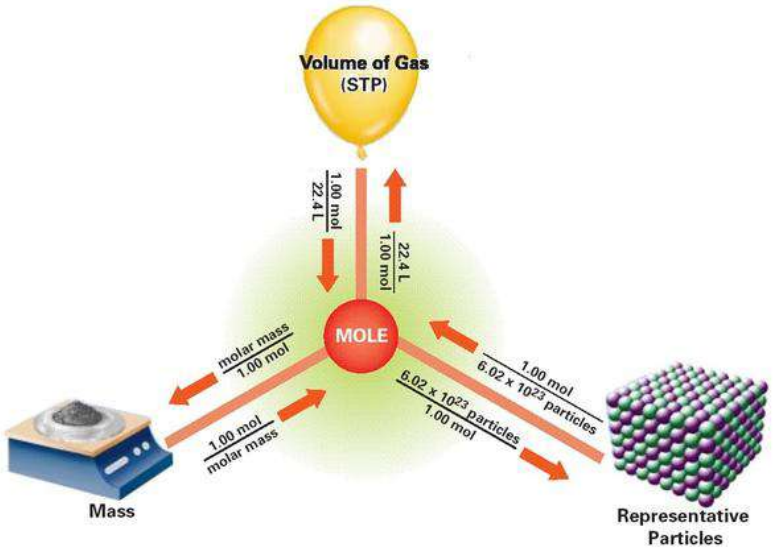
- Step 1 – convert to moles
- Step 2 – mole ratio
- Step 3 – convert to unit asked for

- Sometimes you can skip one or two steps.

Conversion Factors

- Remember that we have 3 conversion factors for the mole.

- 1 mol = 6.02 x 10^{23} r.p.
- 1 mol = molar mass
- 1 mol = 22.4L (at STP)



Sample Problem

- How many liters of acetylene gas (C_2H_2) at STP are produced by adding water to 5.00g CaC_2?

$$CaC_2 + 2H_2O \rightarrow C_2H_2 + Ca(OH)_2$$

Practice Problems

- How many molecules of oxygen are produced by the decomposition of 6.54g of potassium chlorate?

$$2KClO_3 \rightarrow 2KCl + 3O_2$$

- Propane, C_3H_8, is a common fuel used for cooking and home heating. What mass of O_2 is consumed in the combustion of 0.023 mol of propane?

Practice Problems

- How many molecules of oxygen are required to burn 3.86L of carbon monoxide?

$$2CO + O_2 \rightarrow 2CO_2$$

- How many moles of phosphorus trihydride are formed when 0.42L of hydrogen reacts with phosphorus?

$$P_4 + 6H_2 \rightarrow 4PH_3$$

Section 12.2 Assessment

1. The combustion of acetylene gas is represented by the following equation. How many grams of CO_2 and grams of H_2O are produced when 2.56 mol C_2H_2 burns in oxygen?

$$2C_2H_2 + 5O_2 \rightarrow 4CO_2 + 2H_2O$$

Section 12.3 – Limiting Reagent and Percent Yield

- In a chemical reaction, an insufficient quantity of any of the reactants will limit the amount of product that forms.
- BUILD A SANDWICH!

Limiting vs. Excess

- A limiting reagent is fully consumed in the reaction and determines the amount of product produced.
- An excess reagent is not fully consumed in the reaction, so some is left over.

Sample Problem

- What is the maximum number of grams of Cu_2S that can be formed when 80.0g Cu reacts with 25.0g S?

$$2Cu + S \rightarrow Cu_2S$$

Limiting Reagent → **Cu produces 100.16g Cu_2S**

Excess Reagent → **S produces 124.22g Cu_2S**

Total produced

Practice Problems

- If 1.43 mol C_2H_4 is reacted with 2.61 mol O_2, how many grams of CO_2 is produced?

$$C_2H_4 + 3O_2 \rightarrow 2CO_2 + 2H_2O$$

- When 6.00g HCl reacts with 5.00g Mg, how many moles of magnesium chloride is produced?

$$Mg + 2HCl \rightarrow MgCl_2 + H_2$$

Sample Exercise

- How many moles of NH_3 can be formed from 3.0 mol of N_2 and 6.0 mol of H_2?

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

Sample Exercise

- A mixture of 1.50 mol of Al and 3.00 mol of Cl_2 is allowed to react.

$$2Al_{(s)} + 3Cl_{2(g)} \rightarrow 2AlCl_{3(s)}$$

a. Which is the limiting reagent?

Sample Exercise

- How many moles of $AlCl_3$ are formed?

- How many moles of the excess reactant remain at the end of the reaction?

Sample Exercise

- Suppose a fuel cell is set up with 150g of hydrogen gas and 1500g of oxygen gas. How many grams of water can be formed?

$$2H_{2(g)} + O_{2(g)} \rightarrow 2H_2O_{(g)}$$

Practice Exercise

- A strip of zinc metal with a mass of 2.00g is placed in an aqueous solution containing 2.50g of silver nitrate, causing the following reaction to occur:

$$Zn_{(s)} + 2AgNO_{3(aq)} \rightarrow 2Ag_{(s)} + Zn(NO_3)_{2(aq)}$$

a. Which reactant is limiting?

Practice Exercise

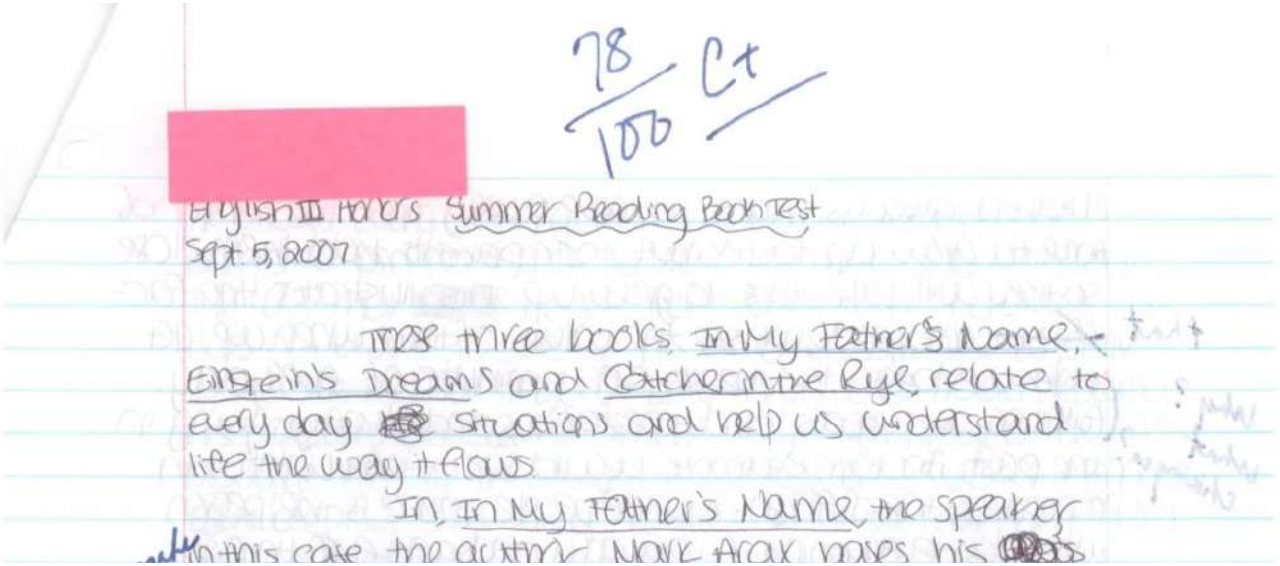
b. How many grams of Ag will form?

c. How many grams of $Zn(NO_3)_2$ will form?

d. How many grams of the excess reagent will be left?

Percent Yield

- The theoretical yield is the maximum amount of product that can be formed from a given amount of reactants. (calculated)
- The actual yield is the amount of product that is produced in the lab.



Percent Yield

- The percent yield is the ratio of the actual yield to the theoretical yield times 100.

$$\text{Percent Yield} = \frac{\text{actual yield}}{\text{theoretical yield}} \times 100$$

- Since the theoretical yield is the maximum amount of product, the percent yield can never be over 100%.

Sample Problem

- What is the percent yield if 13.1g CaO is actually produced when 0.248 mol $CaCO_3$ is heated?

$$CaCO_3 \rightarrow CaO + CO_2$$

Practice Problems

- If 50.0g of silicon dioxide is heated with an excess of carbon, 0.698 mol of silicon carbide is produced. What is the percent yield?

$$SiO_2 + 3C \rightarrow SiC + 2CO$$

- When 0.044 mol Sb_2S_3 reacts with an excess of Fe, 0.081 mol Sb is produced. What is the percent yield of the reaction?

$$Sb_2S_3 + 3Fe \rightarrow 2Sb + 3FeS$$

Sample Exercise

- Adipic acid, $H_2C_6H_8O_4$, is used to produce nylon. Adipic acid is made by the following reaction:

$$2C_6H_{12(l)} + 5O_{2(g)} \rightarrow 2H_2C_6H_8O_{4(l)} + 2H_2O_{(g)}$$

a. Assume that you carry out this reaction starting with 25.0g of cyclohexane and that cyclohexane is the limiting reagent. What is the theoretical yield of the adipic acid?

Sample Exercise

b. If you obtain 33.5g of adipic acid from your reaction, what is the percent yield of adipic acid?

Practice Exercise

a. If you start with 150g of Fe_2O_3 as the limiting reagent, what is the theoretical yield of Fe?

$$Fe_2O_{3(s)} + 3CO_{(g)} \rightarrow 2Fe_{(s)} + 3CO_{2(g)}$$

b. If the actual yield of Fe in your test was 87.9g, what is the percent yield?

Practice Problem

- If 15g of nitrogen reacts with 15g of hydrogen, 10.5g of ammonia is produced. What is the percent yield of the reaction?

$$N_2 + 3H_2 \rightarrow 2NH_3$$

**Hint: This is a limiting reagent and percent composition problem.

Section 12.3 Assessment

- In a chemical reaction, how does an insufficient quantity of a reactant affect the amount of product formed?
- What is the percent yield if 4.65g of copper is produced when 1.87g of aluminum reacts with an excess of copper (II) sulfate?

$$2Al + 3CuSO_4 \rightarrow Al_2(SO_4)_3 + 3Cu$$