Chapter 2
Stoichiometry

• 2-1 Writing Balanced Chemical Equations
• 2-2 Using Balanced Chemical Equations
• 2-3 Limiting Reactant and Percentage Yield
• 2-4 The Stoichiometry of Reactions in Solution
• 2-5 the Scale of Chemical Processes
2-1 Stoichiometry:

Writing Balanced Chemical Equations

Step 1: Assign 1 as the coefficient of one reactant or product. The best choice is the most complicated species, with the largest number of different elements.

Step 2: Identify, in sequence, elements that appear in only one chemical species for which the coefficient is not yet determined. Choose that coefficient to balance the number of moles of atoms of that element. Continue until all coefficients are identified.

Step 3: It is often desirable to eliminate fractional coefficients. To do so, multiply the entire equation by the smallest integer that eliminates the fractions.
Chapter 2-1
Balancing Chemical Equations

- Chemical Reactions tell us two things
  - What atoms or molecules are reacting together to form other products
  - How much reactant & product are formed

- A Chemical reaction is a statement of experimental fact:
  \[ \text{KClO}_3 (s) \rightarrow \text{KCl}(s) + \text{O}_2 (g) \]
  - Reactants on left, products on right

- What is equation missing?
- Need balanced reaction—Why?
Chemical Equations

• Because the same atoms are present in a reaction at the beginning and at the end, the amount of matter in a system does not change.

• The Law of the Conservation of Matter
Chemical Equations

Because of the principle of the conservation of matter, it must have the same number of atoms of the same kind on both sides. This means an equation must be balanced!
Balancing Equations
Limiting Reactants

excess limiting

REACTANTS

PRODUCTS

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Limiting Reactant

\[2 \text{A} + \text{B} \rightarrow \text{A}_2\text{B}\]

1. Select any one product
2. Use the balanced equation to calculate the amount of the selected product that would form if the entire supply of the first reactant were used up.
3. Repeat with respect to every other reactant
4. Identify the limiting reactant as the reactant that gives the smallest amount to the selected product.
Limiting Reactant
Short-Cut Method

\[ 2 \text{A} + \text{B} \rightarrow \text{A}_2\text{B} \]

1. Figure out the number of moles of every reactant.
   
   \( \text{(moles} = \text{g per Molar Mass)} \)

2. Divide each answer by the coefficient that the reactant has in the balanced equation
   
   \( \text{(moles per mole of reactant)} \)

3. The reactant for which the answer is the smallest is the limiting reactant.
Chemical Equations

4 Al(s) + 3 O_2(g)  

---> 2 Al_2O_3(s)

This equation means

4 Al atoms + 3 O_2 molecules  

---give---->  

2 molecules of Al_2O_3

4 moles of Al + 3 moles of O_2  

---give---->  

2 moles of Al_2O_3
Balancing Equations

\[ \_\_ \text{C}_3\text{H}_8(g) + \_\_ \text{O}_2(g) \rightarrow \_\_ \text{CO}_2(g) + \_\_ \text{H}_2\text{O}(g) \]
Chapter 2-1
Balancing Chemical Equations

• Tips for balancing equations

  Coefficients

  \[ 2 \text{H}_2\text{O}(l) \rightarrow 2\text{H}_2(g) + \text{O}_2(g) \]

  Subscripts

• \textit{Never} change subscripts, only change molar coefficients.

• Balance simple equations by inspection

• Start with heaviest atom, balance, then next heaviest, etc.

• Balance H & O last—there is often \text{H}_2\text{O}, \text{H}_2, \text{O}_2, \text{OH}^-, \text{or H}^+ \text{ in equations}
Writing Balanced Chemical Equations

\[ \text{PbO}_2 + \text{Pb} + \text{H}_2\text{SO}_4 \rightarrow \text{PbSO}_4 + \text{H}_2\text{O} \]

**Problem:** Suppose we have 1.45 grams of Pb in the presence of excess lead oxide and sulfuric acid. How many grams of Lead Sulfate are produced?
Mass of one reactants or products is known

Ratio of known mass to its molar mass

Finding the number of moles of the known species

Ratio of known to unknown

Finding the number of moles of the unknown species

Ratio of unknown mass to its molar mass

Mass of one reactants or products is known

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\[ \text{PbO}_2 + \text{Pb} + 2\text{H}_2\text{SO}_4 \rightarrow 2\text{PbSO}_4 + 2\text{H}_2\text{O} \]

- Mass of one reactant or product is known
- Ratio of known mass to its molar mass
- Finding the number of moles of the known species
- Ratio of known to unknown
- Finding the number of moles of the unknown species
- Ratio of unknown mass to its molar mass
- Mass of one reactant or product is known

= 42.5 g PbSO\(_4\)
Problem #16b, page 83:

What mass (in grams) of the first reactant ... would be required to react completely with 1.000 g of the second reactant?

\[ \text{XeF}_4 + 2 \text{ H}_2\text{O} \rightarrow \text{Xe} + 4 \text{ HF} + \text{O}_2 \]

\[ x \text{ g XeF}_4 \]

\[ = \frac{1.000 \text{ g H}_2\text{O}}{1 \text{ mol H}_2\text{O}} \times \frac{1 \text{ mol XeF}_4}{2 \text{ mol H}_2\text{O}} \times \frac{1 \text{ mol H}_2\text{O}}{18.015 \text{ g H}_2\text{O}} \times \frac{207.28 \text{ g XeF}_4}{1 \text{ mol XeF}_4} \]

\[ = 5.753 \text{ g XeF}_4 \]
At one point in the purification of silicon, gaseous SiHCl\(_3\) reacts with gaseous H\(_2\) to give gaseous HCl and solid Si.

(a) Determine the chemical amount (in moles) of H\(_2\) required to react with 160.4 mol of SiHCl\(_3\).

(b) Determine the chemical amount of HCl that is produced.

(c) Determine the mass (in grams) of Si that is produced.

\[
\text{SiHCl}_3 (g) + \text{H}_2 (g) \rightarrow 3 \text{HCl} (g) + \text{Si} (s)
\]
At one point in the purification of silicon, gaseous SiHCl$_3$ reacts with gaseous H$_2$ to give gaseous HCl and solid Si.

(a) Determine the chemical amount (in moles) of H$_2$ required to react with 160.4 mol of SiHCl$_3$.

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\[
\text{SiHCl}_3 \ (g) + \text{H}_2 \ (g) \rightarrow 3 \ \text{HCl} \ (g) + \text{Si} \ (s)
\]
Volume Relationships of Gases in Chemical Equations

Exercise 2-5:

Some H₂ and N₂ react to form 5.00 L of NH₃(g), according to the equation

\[ 3 \text{H}_2(g) + \text{N}_2(g) \rightarrow 2 \text{N}_3 \text{H}_3(g). \]

What volume of H₂(g) reacted, assuming that the pressure and temperature are the same after the reaction as before?
Exercise 2-7

Suppose that 1.00 g of sodium and 1.00 g of chlorine react to form sodium chloride (NaCl). Which of these is in excess, and what mass (in grams) of it remains when all of the limiting reactant is consumed?

\[
2 \text{Na} + \text{Cl}_2 \rightarrow 2 \text{NaCl}
\]
The Stoichiometry of Reactions in Solution

The actual amount of solute (the substance dissolved in the solvent) in any given volume of solution depends on how concentrated or dilute the solution happens to be.

This is expressed by a ratio.

The concentration \( (c) \) of a solute in a solution equals the chemical amount of the solute \( (n) \) divided by the volume \( (V) \) of the entire solution.
Exercise 2-9

Calculate the molarity of a solution by dissolving 10.0 g of Al(NO₃)₃ in enough water to make 250.0 mL of solution.
Chapter 2
Stoichiometry

• Example / exercise
  all 2-1 to 2-12
• Problems