

Unit 4: Chemical Reactions

4.1 - Introduction for Reactions

- **physical change:** a change in the state of the substance
 - going from liquid to solid or vice versa
 - no change in the composition of the substance
- **chemical change:** when a substance undergoes a reaction and a new substance is formed
 - heat or light can be produced
 - formation of a new precipitate
 - changes in color (or scent??)



- A physical change is a change in state, while a chemical change is the creation of a new substance

4.2 - Net Ionic Equations

- equations can represent physical and chemical processes
 - $\text{H}_2\text{O}_{(s)} \rightarrow \text{H}_2\text{O}_{(l)}$ shows a physical change, or a change in state
 - the number of atoms and the mass is conserved, meaning its the same on both sides
 - $2\text{H}_{2(g)} + \text{O}_{2(g)} \rightarrow 2\text{H}_2\text{O}_{(l)}$ shows a chemical change, or creation of a new substance
 - the number of atoms is still conserved even if a new compound is formed
- **balanced molecular equations** show that mass is conserved, because all of the atoms are used up in the equation
- **complete ionic equations** show ions in an aqueous solution as separate charged particles, and can be used to easily identify spectator ions
- **net ionic equations** do not include spectator ions and only show the substances that are going through a chemical change
- given a precipitate reaction with CuSO_4 and NaOH that results in Na_2SO_4 and $\text{Cu}(\text{OH})_2$:
 - balanced molecular equation: $2\text{NaOH}_{(aq)} + \text{CuSO}_{4(aq)} \rightarrow \text{Na}_2\text{SO}_{4(aq)} + \text{Cu}(\text{OH})_{2(s)}$
 - complete ionic equation:
 $2\text{Na}^+_{(aq)} + 2\text{OH}^-_{(aq)} + \text{Cu}^{2+}_{(aq)} + \text{Cu}(\text{OH})_{2(s)} \rightarrow 2\text{Na}^+_{(aq)} + \text{SO}_4^{2+}_{(aq)} + \text{Cu}(\text{OH})_{2(s)}$
 - net ionic equation: $2\text{OH}^-_{(aq)} + \text{Cu}^{2+}_{(aq)} \rightarrow \text{Cu}(\text{OH})_{2(s)}$



- Balanced molecular equations show all of them atoms used in the equation in their compound forms
- Complete ionic equations show all of the ions used in the equation
- Net ionic equations only show the ions going through a chemical change, and not ions that didnt affect the outcome

4.3 - Representations of Reactions

- use subscripts to denote what state the compound is in - solid, liquid, gaseous, or aqueous
- particulate models are diagrams that show what reactants are used up in an equation, and which ones are leftover
 - they can also be used to show molecule shape or size
 - the amount of atoms of each type in the before and after diagrams must be the same



- Particular models can be used to show physical and chemical processes

4.4 - Physical and Chemical Changes

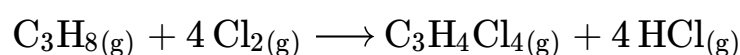
- bonds are usually not broken or formed when a substance undergoes a physical change
 - sometimes physical processes can involve breaking bonds and forming intermolecular interactions (between molecules)
- processes that *do* involve breaking or forming bonds are called chemical reactions
 - these reactions are irreversible as the chemical composition of the original material is changed
- dissolution can be a physical or a chemical process
 - ionic bonds are broken but the process is reversible



- Processes that involve breaking or forming molecular bonds are called chemical reactions

4.5 - Stoichiometry

- **stoichiometry** is the study of relationships between quantities of substances that participate in a chemical reaction
 - useful for predicting products produced or reactants required for reactions
 - the coefficients of a substance in a chemical reaction can mean how many moles of substance are required to create a balanced equation
- increasing the moles of limiting reactant will increase the amount of product produced



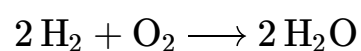
A 6.0 mol sample of $\text{C}_3\text{H}_{8(g)}$ and a 20. mol sample of $\text{Cl}_{2(g)}$ are placed in a previously evacuated vessel, where they react according to the equation above. After one of the reactants has been totally consumed, how many moles of $\text{HCl}_{(g)}$ have been produced?

$$6.0 \text{ mol C}_3\text{H}_8 \times \frac{4 \text{ mol Cl}_2}{1 \text{ mol C}_3\text{H}_8} = 24 \text{ mol Cl}_2$$

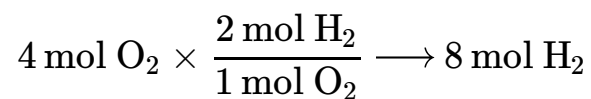
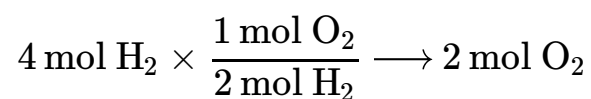
$$20 \cdot \text{mol Cl}_2 \times \frac{1 \text{ mol C}_3\text{H}_8}{4 \text{ mol Cl}_2} = 5.0 \text{ mol C}_3\text{H}_8$$

Chlorine is the limiting reactant

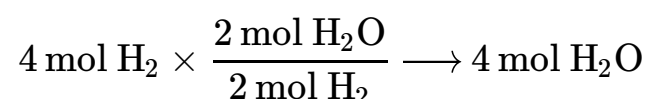
$$20 \cdot \text{mol Cl}_2 \times \frac{4 \text{ mol HCl}}{4 \text{ mol Cl}_2} = 20 \cdot \text{mol HCl}$$



Consider the reaction between hydrogen gas and oxygen gas described by the equation below. There are 4 moles of H_2 and 4 moles of O_2 . What would be present after the reaction?



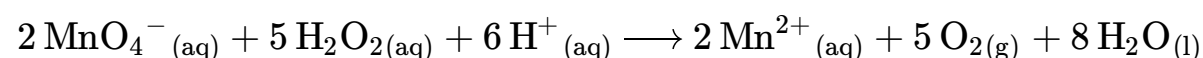
Hydrogen is the limiting reactant



- Stoichiometry helps you solve chemical reaction problems for reactants, products, and excess material

4.6 - Introduction to Titration

- **titration** is an experiment where a solution of known concentration is combined with a solution of unknown concentration to determine the amount of moles in the unknown solution
 - the **titrant** is the solution of known concentration and is in the buret (the pipe up top)
 - the **analyte** is the solution of unknown concentration and is in the flask at the bottom
- the **equivalence point** is reached when the titrant has reacted with all of the analyte in the flask according to their stoichiometric ratios
 - one indicator of when the equivalence point is reached is usually a change in color in the flask
- **titration curve** can be used to determine the equivalence point
 - in an acid-base titration a pH meter monitors the progress of the titration and there will usually be a very drastic change in the graph once the equivalence point is reached
- a **redox titration** can be used to determine the concentration of an unknown solution



A student was given the task of determining the molarity of an unknown concentration of $\text{H}_2\text{O}_{2(\text{aq})}$. She analyzed a 10.0 mL sample of $\text{H}_2\text{O}_{2(\text{aq})}$ by titrating it with 0.0330 M KMnO_4 , which has a dark purple color. The balanced chemical equation for the reaction that occurred during the titration is shown above. A total of 10.69 mL of 0.0330 M KMnO_4 was required to reach the equivalence point.

Calculate the number of moles of MnO_4^- that reacted with the H_2O_2 .

$$10.69 \text{ mL} \times \frac{1 \text{ L}}{1000 \text{ mL}} \times \frac{0.0330 \text{ mol KMnO}_4}{1 \text{ L}} = 3.53 \times 10^{-4} \text{ mol KMnO}_4$$

$$3.53 \times 10^{-4} \text{ mol KMnO}_4 \times \frac{1 \text{ mol MnO}_4^-}{1 \text{ mol KMnO}_4} = 3.53 \times 10^{-4} \text{ mol MnO}_4^-$$

Calculate the concentration of H_2O_2 in the solution

$$3.53 \times 10^{-4} \text{ mol MnO}_4^- \times \frac{5 \text{ mol H}_2\text{O}_2}{2 \text{ mol MnO}_4^-} = 8.82 \times 10^{-4} \text{ mol H}_2\text{O}_2$$

$$\frac{8.82 \times 10^{-4} \text{ mol H}_2\text{O}_2}{0.0100 \text{ L}} = 0.0882 \text{ M H}_2\text{O}_2$$



- A titration is an experiment where a solution of known concentration is slowly added to a solution of unknown concentration to determine the concentration of the unknown solution

4.7 - Types of Chemical Reactions

- **acid-base reactions** involve the mixing of an acid and a base, which results in a neutralization reaction
 - a Bronsted-Lowry acid-base reaction involves the transfer of one or more protons from the acid to the base
 - acids donate protons while bases accept protons
 - in an acid-base reaction, every acid has a conjugate base (formed by removing an H^+) and every base has a conjugate acid (formed by adding a H^+)
- **oxidation-reduction (redox) reactions** involve the transfer of one or more electrons between reactants
 - electrons are transferred from the oxidized species to the reduced species
 - **oxidation numbers** can be assigned to atoms to identify the oxidized and reduced species
 - atoms in their elemental form have oxidation numbers of zero
 - monatomic ions have oxidation numbers equal to their charge
 - hydrogen is +1 when bonded to a nonmetal and -1 when bonded to a metal
 - the sum of all oxidation numbers must add up to zero in neutral compounds
 - the sum of all oxidation numbers in a polyatomic ion must equal the charge
- **precipitation reactions** involve the mixing of ions in aqueous solutions to produce an ionic compound called a precipitate



- Redox reactions usually have a substance in its elemental form on one side
- Oxidation-reduction reactions usually have the substances differ by an H^+
- Precipitate reactions usually form a solid from aqueous solutions

4.8 - Introduction to Acid-Base Reactions

- when acids and bases are mixed, protons are transferred in the form of H^+ and the solution is neutralized
 - a Bronsted-Lowry acid is a proton donor, while a Bronsted-Lowry base is a proton acceptor
- in aqueous acid-base reactions, water can act like an acid and donate a proton OR act like a base and accept a proton
- the conjugate acid-base pair is the compound before and after it donates
 - acid and conjugate base: $\text{HC}_2\text{H}_3\text{O}_2(\text{aq}) \longrightarrow \text{C}_2\text{H}_3\text{O}_2^-(\text{aq})$
 - base and conjugate acid: $\text{OH}^-(\text{aq}) \longrightarrow \text{H}_2\text{O}(\text{l})$



- In acid-base reactions, a proton is donated from an acid to a base