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

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4.2 - Net Ionic Equations

- equations can represent physical and chemical processes
  - $H_2O_{(s)} \rightarrow H_2O_{(l)}$ 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
  - $2\,H_{2(g)} + O_{2(g)} \longrightarrow 2\,H_2O_{(l)}$ 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 $Cu(OH)_2$:
  - balanced molecular equation: $2\,NaOH_{(aq)} + CuSO_{4(aq)} \longrightarrow Na_2SO_{4(aq)} + Cu(OH)_{2,(s)}$
  - complete ionic equation: $2\,Na^+{}_{(aq)} + 2\,OH^-{}_{(aq)} + Cu^{2+}{}_{(aq)} + Cu(OH)_{2(s)} \longrightarrow 2\,Na^+{}_{(aq)} + SO_4{}^{2+}{}_{(aq)} + Cu(OH)_{2(s)}$
  - net ionic equation: $2\,OH^-{}_{(aq)} + Cu^{2+}{}_{(aq)} \longrightarrow Cu(OH)_{2(s)}$

📢 - 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

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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

$$C_3H_{8\,(g)} + 4\,Cl_{2\,(g)} \longrightarrow C_3H_4Cl_{4\,(g)} + 4\,HCl_{(g)}$$

A 6.0 mol sample of $C_3H_{8\,(g)}$ and a 20. mol sample of $Cl_{2\,(g)}$ 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 $HCl_{(g)}$ have been produced?

$$6.0\,\text{mol}\ C_3H_8 \times \frac{4\,\text{mol}\ Cl_2}{1\,\text{mol}\ C_3H_8} = 24\,\text{mol}\ Cl_2$$

$$20\cdot\text{mol}\ Cl_2 \times \frac{1\,\text{mol}\ C_3H_8}{4\,\text{mol}\ Cl_2} = 5.0\,\text{mol}\ C_3H_8$$

Chlorine is the limiting reactant

$$20\cdot\text{mol}\ Cl_2 \times \frac{4\,\text{mol}\ HCl}{4\,\text{mol}\ Cl_2} = 20\cdot\text{mol}\ HCl$$

$$2\,H_2 + O_2 \longrightarrow 2\,H_2O$$

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?

$$4\,\text{mol}\,H_2 \times \frac{1\,\text{mol}\,O_2}{2\,\text{mol}\,H_2} \longrightarrow 2\,\text{mol}\,O_2$$

$$4\,\text{mol}\,O_2 \times \frac{2\,\text{mol}\,H_2}{1\,\text{mol}\,O_2} \longrightarrow 8\,\text{mol}\,H_2$$

Hydrogen is the limiting reactant

$$4\,\text{mol}\,H_2 \times \frac{2\,\text{mol}\,H_2O}{2\,\text{mol}\,H_2} \longrightarrow 4\,\text{mol}\,H_2O$$

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

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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 flash 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

$$2\,MnO_4{}^-{}_{(aq)} + 5\,H_2O_{2(aq)} + 6\,H^+{}_{(aq)} \longrightarrow 2\,Mn^{2+}{}_{(aq)} + 5\,O_{2(g)} + 8\,H_2O_{(l)}$$

A student was given the task of determining the molarity of an unknown concentration of $H_2O_{2(aq)}$. She analyzed a 10.0 mL sample of $H_2O_{2(aq)}$ by titrating it with 0.0330 M $KMnO_4$, which has a dark purple color. The balanced chemical equation for the reaction that occured 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.

$$10.69 mL \times \frac{1\,L}{1000\,mL} \times \frac{0.0330\,mol\,KMnO_4}{1\,L} = 3.53 \times 10^{-4}\,mol\,KMnO_4$$

$$3.53 \times 10^{-4}\,mol\,KMnO_4 \times \frac{1\,mol\,MnO_4{}^-}{1\,mol\,KMnO_4} = 3.53 \times 10^{-4}\,mol\,MnO_4{}^-$$

Calculate the concentration of H_2O_2 in the solution

$$3.53 \times 10^{-4}\,mol\,MnO_4{}^- \times \frac{5\,mol\,H_2O_2}{2\,mol\,MnO_4{}^-} = 8.82 \times 10^{-4}\,mol\,H_2O_2$$

$$\frac{8.82 \times 10^{-4}\,mol\,H_2O_2}{0.0100\,L} = 0.0882\,M\,H_2O_2$$

📢 - 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 transfered 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
- **precipiation 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: $HC_2H_3O_{2(aq)} \longrightarrow {C_2H_3O_2}^-{}_{(aq)}$
  - base and conjugate acid: $OH^-{}_{(aq)} \longrightarrow H_2O_{(l)}$

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