Physical Science Notes Chapter 11- Water and Solutions

11.1- Water

What are the properties of water?

Water's properties make it ideal for sustaining life on Earth:

- A water molecule contains one oxygen atom bonded to two hydrogen atoms via polar covalent bonds.
- The polarity of the covalent bonds causes oxygen to be slightly negative and hydrogen to be slightly positive. Thus, water is a polar molecule.
- The polarity of water molecules causes them to bind to one another through hydrogen bonds, which connect the hydrogen of one water molecule with the oxygen of another.
- Water (H_2O) molecules dissociate into hydronium (H_3O^+) and hydroxide (OH^-) ions.
- Water is one of the few substances that exist in all three states of matter on Earth's surface.
- Water is cohesive, which refers to the fact that hydrogen bonds hold water molecules together.
- Water is adhesive, which means that it can also stick, through hydrogen bonds, to other substances.
- Water has a high **surface tension**, which means that it is difficult to break the surface of water.
- Water is a versatile **solvent**, meaning that many substances on Earth can dissolve in water.
- Water is unique from most substances in that it expands upon freezing. Solid water in the form of ice is less dense than **liquid** water.
- Water has a high **specific heat** capacity. It takes a relatively large amount of energy to change the temperature of water.
- Due to its high specific heat, water can store energy from the air around it. Water absorbs energy from warmer air and releases energy into cooler air.
- Water is able to moderate the temperature of surrounding air, keeping climates within a suitable range for living things.

11.2- Solutions

What are the various parts of a solution?

A **solution** is a **homogeneous** mixture from which the components will not settle out.

- A **solute** is the substance dissolved in the solution.

- The **solvent** comprises most of the solution; it dissolves the solute.
- Water is often called the **universal solvent**.
- An **electrolyte** is a solution that contains ions.

Which factors impact the rate at which a solute dissolves?

Solubility describes how much of a solute will **dissolve** in a solvent in specific conditions.

- Solubility increases with increased temperature and **surface area** of the solute. As the temperature of a solvent increases, the solubility of gases in that solvent decreases.
- Henry's Law states that as the pressure of a gas over a liquid is increased, the solubility of that gas is increased.
- Solutes of a specific **polarity** will dissolve more readily in solvents with similar polarity. Like dissolves like.
- A saturated solution contains the maximum amount of dissolved solute.
- An unsaturated solution contains less solute than can be dissolved in the solute under existing conditions.
- A supersaturated solution contains more dissolved solute than a saturated solution would contain under existing conditions.

What are the various colligative properties of solutions?

Colligative properties are properties of solutions that depend on the number of solute particles present, not the type of solute.

- Boiling point will generally increase and **freezing** point will generally decrease as solid solute is added to a solution.
- **Boiling point elevation** is calculated using the formula $\Delta T_b = iK_b m$.
- **Freezing point depression** is calculated using the formula $\Delta T_f = iK_f m$.
- The vapor pressure of a solution is dependent on the vapor pressure and **mole fraction** of each chemical component present in the solution.
- **Osmotic pressure** increases as solute is added to a solution.

How do you calculate concentrations of solutions using molarity, molality, mass percent, volume percent, and parts-per-million (ppm)?

Molar ratios are used to describe solutions with high solute concentrations.

- molarity $(M) = \frac{\text{moles of solute}}{\text{liters of solution}}$
- mole fraction $(X) = \frac{\text{moles of solute}}{\text{moles of solute and solvent combined}}$
- molality $(m) = \frac{\text{moles of solute}}{\text{1 kg of solvent}}$

Mass percent and **volume percent** describe the relative amount of a solute in a solution.

- mass $\% = \frac{\text{mass of solute}}{\text{mass of solution}} \times 100\%$
- volume $\% = \frac{\text{volume of solute}}{\text{volume of solution}} \times 100\%$

Parts per million (ppm) is used to describe solutions with low solute concentrations.

- $\text{ppm} = \frac{\text{mass of solute}}{\text{mass of solution}} \times 10^6$

11.3- Acids, Bases, and Salts

What are similarities and differences between the Arrhenius, Brønsted-Lowry, and Lewis acid-base theories?

The various theories differ in their definitions of acids and bases:

- Arrhenius acids tend to increase the number of H^+ ions present in an **aqueous solution**, whereas Arrhenius bases tend to increase the number of OH^- ions present.

- Brønsted-Lowry acids donate a **hydrogen ion** (proton), whereas Brønsted-Lowry bases accept a hydrogen ion (proton).
- Lewis acids are electron pair acceptors, whereas Lewis bases are electron pair donors.

What are the similarities and differences between acid or base strength and concentration?

Acid strength, base strength, and **concentration** are measured using different calculations:

- The strength of an acid is measured using the acid **dissociation** constant (K_a), and the strength of a base is measured using the base dissociation constant (K_b).
- Strong acids and bases will dissociate almost 100% in an aqueous solution.
- The **concentration** of an acid or base is defined as the ratio of the amount of solute to the amount of solvent in a solution.

How are hydronium ions formed?

A **protic acid** is added to water and releases a hydrogen ion.

- The hydrogen ion immediately bonds with a nearby water atom.

What products are formed in acid-base reactions?

Reactions between acids and bases produce a **salt** and water.

- Some resulting solutions will be slightly basic and others will be slightly acidic.
- The **pH** of the product depends on the strength of the acids and bases reacting.

What occurs during the neutralization process?

Neutralization is a chemical reaction in which a **strong acid** and a **strong base** interact and a neutral solution results.

- Salts also form during neutralization reactions.

What are are pH and pOH?

- **pH** is the measure of a substance's acidity.
- **pOH** is the measure of a substance's alkalinity.

What is the correlation between logarithmic pH scale changes and corresponding changes in concentration?

- A low pH indicates a high concentration of hydronium ions.
- A high pH indicates a low concentration of hydronium ions.

How is K_w (water dissociation constant) related to pH, pOH, concentration of hydrogen ions, and concentration of hydroxide ions?

Water is an amphoteric substance.

- **Amphoterism** is the ability of a chemical to act as either an acid or a base.
- Whether an amphoteric chemical acts as an acid or base depends upon what other chemicals are present.
- Salts dissociate into component ions when placed in water, behaving similarly to acids and bases.
- The K_a and K_b values of the salt determine if it is more acidic or basic when dissolved in water.
- K_w can be calculated using the dissociation constants of the salt: $K_w = K_a \times K_b$.
- K_w can also be calculated using the concentrations of hydrogen and hydroxide ions in the solution: $K_w = [H^+][OH^-] = 1.0 \times 10^{-14}$.