REVIEW: TOPIC 9

NAME: ________

DUE: ________

UNIT 9 – MAJOR UNDERSTANDINGS

- ☆ 3.1uu Behavior of many acids and bases can be explained by the Arrhenius theory. Arrhenius acids and bases are electrolytes.
- ☆ 3.1rr An electrolyte is a substance which, when dissolved in water, forms a solution capable of conducting an electric current. The ability of a solution to conduct an electric current depends on the concentration of ions.
- ☆ 3.1vv Arrhenius acids yield $H^+(aq)$ (hydrogen ion) as the only positive ion in an aqueous solution. The hydrogen ion may also be written as $H_3O^+(aq)$, hydronium ion.
- ☆ 3.1ww Arrhenius bases yield $OH^-(aq)$, hydroxide ion as the only negative ion in an aqueous solution.
- ☆ 3.1xx In the process of neutralization, an Arrhenius acid and an Arrhenius base react to form a salt and water.
- ☆ 3.1zz Titration is a laboratory process in which a volume of a solution of known concentration is used to determine the concentration of another solution.
- ☆ 3.1yy There are alternate acid-base theories. One theory states that an acid is an H^+ donor and a base is an H^+ acceptor.

UNIT 9 – MAJOR UNDERSTANDINGS (CONTINUED)

- ☆ 3.1ss The acidity or alkalinity of an aqueous solution can be measured by its pH value. The relative level of acidity or alkalinity of these solutions can be shown by using indicators.
- ☆ 3.1tt On the pH scale, each decrease of one unit of pH represents a tenfold increase in hydronium ion concentration.

INTRODUCTION

An **electrolyte** (i.e., various ions, such as sodium, potassium, or chloride) will dissolve in water to form a solution that will conduct an electric current. The ability of a solution to conduct an electric current is due to the presence of ions that are free to move. Therefore, all ionic compounds are electrolytes. Also, some polar covalent compounds form ions and conduct electricity when dissolved in water. For example, HCl and HBr. However, nonelectrolytes, such as organic solvents, do not conduct electricity.

ACIDS + BASES

A – ACIDS & BASES

One means of defining a substance is to list its properties and reactions. This form of definition is called an **operational definition** and is based on experimental observations, which include a set of conditions.

As the understanding of acid-base reactions has grown, conceptual definitions (those that try to answer the questions: Why? How?) of acids and bases have been extended. These conceptual definitions have also been applied to reactions that do not necessarily take place in aqueous solutions.

ACIDS

Acids may be defined in terms of their characteristic properties. These properties can be observed experimentally and form the basis of the operational definition of an acid. They include:

CONCEPTUAL DEFINITION OF ACIDS

Arrhenius' Theory – An acid is a substance that yields hydrogen ions in aqueous solutions. This conceptual definition is adequate when considering reactions in aqueous solutions. As knowledge of the mechanism of chemical reactions has increased, more inclusive definitions have been advanced. The characteristic properties of acids in aqueous solution are due to an excess of hydrogen ions (hydronium ions) which combine with water molecules to become H_3O^+ (hydronium ion).

Brönsted-Lowry Theory – An acid is any species (molecule or ion) that can donate a proton to another species. The *Brönsted-Lowry Theory* does not replace the *Arrhenius' Theory*, but extends it. The Brönsted-Lowry definition of an acid includes all substances that are acids according to the Arrhenius definition.

In addition, some molecules and ions are classified as acids under the Brönsted-Lowry definition that are not acids in the Arrhenius sense. For example, in the reaction:

$$NH_3 + H_2O \leftrightarrow NH_4^+ + OH^-$$

The water molecule donates a proton to the ammonia and is considered an acid in the Brönsted-Lowry sense. In the reverse reaction, the ammonium ion will donate a proton and act as the acid, while the hydroxide ion accepts the proton and acts as a base.

Operational Definition of Acids

- **Aqueous solutions of acids conduct electricity** – They conduct electricity in relation to the degree of their ionization. A few acids ionize almost completely in aqueous solution and are strong electrolytes (strong acids). Others ionize only to a slight degree and are weak electrolytes (weak acids).

- **Acids will react with certain active metals to liberate hydrogen gas** – Those metals above hydrogen as shown in *Reference Table J, Activity Series*, will react with acids to produce a salt of the metal and hydrogen gas.

Note: Some acids, in addition to their acid properties, have strong oxidizing ability. Therefore, except in very dilute solution, they do not release hydrogen gas on reaction with metals. For example, nitric acid and concentrated sulfuric acid have strong oxidizing properties.

- Acids cause color changes in acid-base indicators. Acid-base indicators are substances that have different colors in acid and basic solutions. Two common indicators are litmus which is blue in basic solution and red in acid solution, and phenolphthalein which is pink in basic solution and colorless in acid solution.

Note: These indicators do not change color exactly at pH 7. Different indicators change color at different concentrations of hydrogen ions.

- Acids react with hydroxides to form water and a salt. When hydrogen ions react with hydroxide ions, water is formed. This reaction is called **neutralization**. For example:

$$HCl + NaOH \rightarrow NaCl + H_2O$$

- Dilute aqueous solutions of acids have a sour taste, such as vinegar and acetic acid.

- Acids react with metallic oxides to form salts and water.

Bases

Conceptual Definition of Bases

Arrhenius' Theory – A base is a substance that yields hydroxide ions as the only negative ions in aqueous solution. According to the Arrhenius definition, the only bases are hydroxides. The characteristic properties of bases in an ion aqueous solution are due to the hydroxide ion.

Brönsted-Lowry Theory – A base is any species (molecule or ion) that can accept a proton. The Brönsted-Lowry definition extends the Arrhenius' definition to include many species in addition to the OH^- that can accept a proton. For example, in the reaction:

$$H_2O + HCl \rightarrow H_3O^+ + Cl^-$$

The water molecule combines with a proton to form the hydronium ion and is here considered a base in the Brönsted-Lowry sense. In the reverse reaction, the hydronium ion will donate a proton and act as an acid. While the chloride ion, which accepts the proton, acts as a base.

Operational Definitions of Bases

- **Aqueous solutions of bases conduct electricity**.

- **Bases cause color changes in acid-base indicators** – They cause red litmus to turn blue and phenolphthalein (a weak, colorless acid) to turn pink.

- **Bases react with acids to form water and a salt**.

- **Aqueous solutions of bases feel slippery**.

- **Strong bases have a caustic action on the skin**.

Interpreting Acid-base Indicators

Certain dyes in solutions are sensitive to changes in hydrogen ion concentration. This sensitivity causes visible reactions when the indicator is combined with a substance to be tested. The chart below lists some indicators and the color changes they undergo [see *Reference Table M*].

dye	acidic color	basic color
litmus	red	blue
phenolphthalein	colorless	red
methyl red	red	yellow
bromthymol blue	yellow	blue

B – Acid-Base Reactions

Neutralization

Acid-base neutralization pertains to the reaction that occurs when equivalent quantities of an acid and a hydroxide are mixed. One mole of hydrogen ions will react with one mole of hydroxide ions to form water.

$$H^+ + OH^- \rightarrow H_2O$$

In acid-base neutralization reactions, the products are a salt and water.

$$NaOH + HCl \rightarrow NaCl + H_2O$$

Acid-base Titration

The molarity of an acid (or base) of unknown concentration can be determined by slowly combining it with a base (or acid) of known molarity. The acid or base solution of a known molarity is called the **standard solution**. This process of metering a standard solution into a solution of unknown concentration is called **titration**. During titration, when the molar quantities of acid and base mixed are equal, neutralization has occurred. This point of neutralization is called the "equivalence point."

The molarity of a solution of unknown concentration can be calculated from an understanding of the molar relationship involved. By knowing the concentration of the standard solution and the volumes of both solutions needed to reach the equivalence point, the following procedure is used to find the molarity of the unknown solution:

- After writing the balanced equation, the molar ratio of the reactants and products can be determined from the coefficients.
- By using the following equation, the number of moles of standard solution required to neutralize the solution of unknown concentration can be determined.

moles of known solute = volume of solution in liters x molarity

- By substituting in the above equation, find the molarity of the solution of unknown concentration. When **monoprotic acids**, which provide one proton per molecule, or bases which can accept one proton per molecule are used, the following titration equation, as stated in *Reference Table T* is used: $M_A V_A = M_B V_B$

molarity of acid x volume of acid = molarity of base x volume of base

Sample Problem

How many milliliters of 0.5 M NaOH solution are required to neutralize 50 ml of 0.2 M HCl solution?

Solution

Since both the acid and base are monoprotic, the volumes (given in milliliters) can be convert to liters and use the equation.

liters of acid x molarity of acid = liters of base x molarity of base

$$0.050\ L \times 0.2\ M = V_B \times 0.5\ M$$

$$\frac{\overset{0.1}{\cancel{0.050}}\ L \times 0.2\ \cancel{M}}{\underset{1}{\cancel{0.5\ M}}} = V_B$$

$$V_B = 0.002\ \text{liters}$$ (answer)

C – Salts

A **salt** is an ionic compound containing positive ions other than hydrogen and negative ions other than hydroxide. Most salts are strong electrolytes and are considered to be completely dissociated in aqueous solution. Some salts in aqueous solution react with the water to form solutions that are acidic or basic.

This process is called **hydrolysis**, and it is considered to be the opposite of a **neutralization reaction**. For example, in a neutralization reaction, an acid and base react to form a salt and water. In hydrolysis, the salt is added to the water to form the acid and base, which originally formed the salt.

Real World Connections

Household chemicals used to unclog drains contain both potassium hydroxide (KOH) and sodium hypochlorite (NaOCl). These substances are very caustic, and small children are known to swallow them. Some cleaning agents contain quaternary ammonium compounds.

Soaps are the metallic salts of fatty acids having a chain of 10-18 carbon atoms. The most common soaps are sodium and potassium soaps of stearic or palmitic acids. Sodium soaps, like sodium stearate, are hard and widely used. The potassium soaps tend to lather easily and are used in creams and cosmetics. Soap is produced in the process of **saponification**. Melted fats react with strong alkali to produce glycerol and soap.

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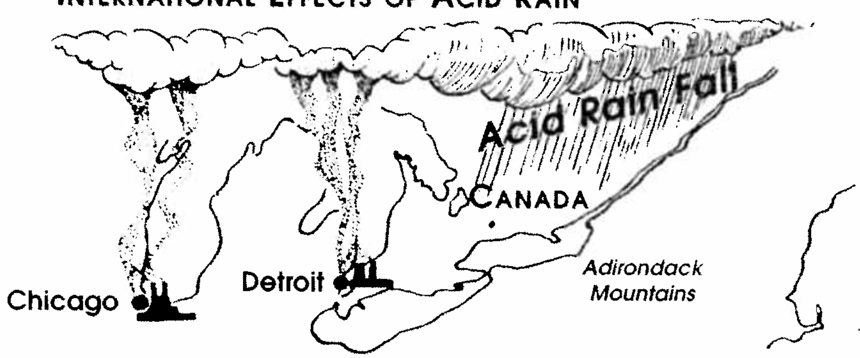
melted fats + **strong bases** → **glycerol** + **soap**

(glycerol stearate) (sodium hydroxide) → (sodium stearate) $CH_3(CH_2)_{16}COO^-Na^+$

Acid rain results from the wastes. Industrial smoke and exhaust emissions (mostly sulfur dioxide and nitrogen oxide) pollute the air so much that precipitation becomes acid. This acidic rain falls into the lakes and surrounding water sheds, lowering the pH of the water making it impossible for animals and plants to survive.

International Effects of Acid Rain



pH

The logarithm (exponent) of the reciprocal (negative logarithm) of the hydrogen ion concentration is called **pH**. Therefore, if the hydrogen ion concentration is 1 x 10^{-5}, its reciprocal would be 1 x 10^5, and its logarithm (exponent) is 5. Its pH is expressed as 5. The pH of a solution indicates the concentration of hydrogen ions (acid strength) in a solution.

A pH of 7 is neutral. A pH of less than 7 is acidic; pH greater than 7 is basic. Pure water has a pH of 7 at 25°C. Mathematically, pH is expressed as pH $-\log[H_3O^+]$. On the pH scale, each decrease of one unit of pH represents a ten-fold increase in hydronium ion concentration.

pH Scale

Acid & Base Identification

	Scale	pH	Substance
BASES	14		
	13	13.0	lye
		12.2	lime
	12	12.0	ammonia
	11	11.1	Milk of Magnesia
	10		
	9		
		8.5	sea water
	8	8.1	Baking Soda
		8.0	Lake Ontario water
NEUTRAL	7	7.0	distilled water
	6		
		5.6	unpolluted rain
	5	5.0	tomatoes
ACIDS	4 (Acid Rain)		
		3.5	orange juice
	3	3.0	carbonated drinks
		2.8	vinegar
	2	2.0	lemon juice
		1.2	sulfuric acid
	1	1.0	hydrochloric acid
		1.0	battery acid
	0		

Unit 9 - Acids, Bases, and Salts

Key Concepts

- Arrhenius Theory
- Electrolytes
- Hydrogen Ions/Hydronium Ions
- Hydroxide Ions
- Neutralization
- Titration
- Bronsted - Lowry Theory
- pH

I. Arrhenius Theory

The Arrhenius Theory can explain behavior of many acids and bases. **Arrhenius acids** yield **H^+ (hydrogen ions)** as the only positive ion in an aqueous solution. The hydrogen ion may also be written as **H_3O^+ (hydronium ion)**. Arrhenius bases yield OH. (Hydroxide **ion**) as the only negative ion in an aqueous solution. Arrhenius acids and bases are **electrolytes**. An electrolyte is a substance which, when dissolved in water, forms a solution capable of conducting an electric current. The ability of a solution to conduct an electric current depends on the concentration of ions.

There is an alternative acid-base theory called the **Bronsted-Lowry Theory**. **Bronsted acids** are said to be proton donors and **Bronsted Bases** are said to be proton acceptors.

Example: $NH_3 + H_2O \rightarrow NH_4^+ + OH^-$

In this proceeding example, H_2O is the Bronsted Acid because it donates a proton and becomes OH^-. NH_3 is the Bronsted Base because it accepts a proton to become NH_4^+.

II. Neutralization

In the process of **neutralization**, an Arrhenius acid and an Arrhenius base react to form salt and water.

Neutralization Example: Acid + Base → Salt + Water

$HCl + NaOH \rightarrow NaCl + H_2O$

Titration is a laboratory process in which a volume of solution of known concentration is used to determine the concentration of another solution. The equation for it is in Table T of the Reference Tables.

Example Problem: How much of a 0.5 M solution of NaOH (base) is needed to neutralize 150 ml of a 2.5 molar solution of HCl (acid)?

Solution: $M_AV_A = M_BV_B$

$$(2.5\ M)(150\ ml) = (0.5\ M)(X)$$

$$X = 750\ ml\ of\ NaOH\ (base)$$

III Indicators and pH

The acidity and alkalinity of an aqueous solution can be measured by it's pH value. The relative level of acidity of alkalinity of a solution can be shown by using indicators that change color at different pH levels. A pH of 7 is neutral, as a pH drops, the more acidic a solution is, as the pH increases, the more basic it is. On the pH scale, each **decrease** of one unit of pH represents a ten-fold **increase** in hydronium ion concentration.

Example Problem: What color would Bromthymol Blue be in a solution with a pH of 8?

Solution: See Table M → Bromthymol Blue has a color change (yellow to blue) in the pH range of 6.0 to 7.6. That means that the indicator is yellow for pH's less than 6.0 and blue for pH's greater than 7.6. Since the solution has a pH of 8 the solution must be blue.