6.1 Introduction to Acids & Bases

In your years of studying chemistry, you probably have heard of a few common acids and bases; ie. hydrochloric acid, sodium hydroxide, ammonia ,sulfuric acid, nitric acid, etc. Acids and bases are classified according to various definitions that have been created throughout the years; you will be reviewing these definitions today.

When Chemists take acid trips.

Based on the textbook reading (Heath; pages 558 -564) and the handout provided complete the following questions:

1. List 3 common *household* acids and 3 common *household* bases.

2. In the t-chart below, list 5 physical and/or chemical characteristics of acids and of bases to help determine the **operational definition** of acids and bases. Note: operational definitions are based on what you can actually observe in the lab

Acids	Bases

3. Briefly explain the process of self-ionization in water and provide a balanced chemical equation to show your understanding.

4. Explain why H^+ and H_3O^+ can be used interchangeably.

5. Fill in the table below using the appropriate definitions.

	Acid	**Base**
Arrhenius's Definition		
Brønsted-Lowry Definitions		

6. Describe which model (from question 5) is better used to describe why NH_3 is a base and why using a balanced chemical equation.

7. Define & give an example for: an acid, a base, electrolyte (strong and weak).

8. Explain why a single arrow is used in a strong electrolyte reaction equation (as in HCl) and a double arrow is used in a weak electrolyte reaction equation (as in NH_3).

9. Define amphiprotic (sometimes referred to as amphoteric) substances. Use examples to help in your explanation.

10. CHALLENGE! Explain why CH_3COOH is not considered a polyprotic acid. Hint: draw the Lewis Structure.

SUPPLEMENTAL NOTES

Acid or Base?

Theories of Acids and Bases:

- *Arrhenius* explained the phenomenon of electrolytes by stating that ions must be present in the solutions to carry the electric current (electrolytes conduct current when dissolved in solution).
  - Since acids and bases are electrolytes, he proposed:
    - All acids produce hydrogen ions (H^+)when dissolved in water.
    - All bases produce hydroxide ions (OH^-) when dissolved in water.
  - Unfortunately, his model was oversimplified and could not explain the role of the solvent in acid/base theory and could not explain why salts with no hydrogen or hydroxide could exhibit acidic or basic properties.
- *Bronsted-Lowry Theory* was developed that explained the role of the solvent and the existence of acidic and basic salts, the theory stated:
  - An acid is a molecule or ion that can give up a hydrogen ion.
    - a proton, H^+, donor
    - H_3O is called a *hydronium ion* which is a *hydrogenated* hydrogen ion – $H^+_{(aq)}$ is equivalent to the H_3O^+ ion.
  - A base is a molecule or ion that can react with a hydrogen ion.
    - A *proton (H^+) acceptor* (a substance that produces a hydroxide, OH^- ion)
  - Acid-base reactions are hydrogen-ion exchange reactions
  - Water is the most important solvent and aqueous solutions are most common.
- **Indicators** are compounds that can be used to detect the presence of acids or bases. Litmus paper is a common type of indicator.

Weak and Strong Acids and Bases

- Ionization – any process in which ions are formed:
    - Dissociation to form ions (the separation of an **ionic compound** into its constituent ions)
    - A reaction of a **molecular compound** with a solvent (usually water to form ions)
- *Strong acids* ionize completely and are strong electrolytes , HCl, HNO_3, $HClO_4$
  - [acid] = [H^+]
- *Weak acids* ionize partially and are weak electrolytes, most often found as HF
  - $HF + H_2O_{(l)} \leftrightarrow H_3O^+_{(aq)} + F^-_{(aq)}$
  - The forward and the reverse reaction are occurring simultaneously
- *Strong bases* dissociate completely and are strong electrolytes, NaOH
- *Weak bases* dissociate partially and are weak electrolytes, NH_3

Water

- Water is a unique substance as it can act as either an acid or a base, depending on what other ions are present. These types of substances are known as ***amphiprotic.***
- However, even without other ions present, water conducts some electricity (although very little). This must be due to the presence of ions:
  - Self-Ionization: in pure water, one water molecule donates one H^+ ion to another water molecule, which results in a hydronium ion and a hydroxide ion.
- *Self-ionization further exemplifies water's amphiprotic properties.*

Types of Acids

1) **Monoprotic** – a solution that produces one mole of H+ ions per mole of acid. Ex. HCl, HNO_3
2) **Polyprotic** - Acids that can give up more than one hydrogen ion per molecule are called polyprotic acids
   - Diprotic – H_2SO_4
   - Triprotic – H_3PO_4
   - polyprotic acids are given in the table on the right here. Knowing their names and familiar with their properties (ionization for example) is an asset for you.
   - They ionize to give more than one H^+ ions per *molecule*.
   - Possible forms of three polyprotic acids are given below after their dissociation into H^+ ions.

     H_2S, HS^-, S^{2-}

     H_2SO_4, HSO_4^-, SO_4^{2-}

     H_3PO_4, $H_2PO_4^-$, HPO_4^{2-}, PO_4^{3-}

Some Polyprotic Acids	
Formula	**Name**
H_2S	Hydrogen sulfide
H_2SO_4	Sulfuric acid
H_2SO_3	Sulfurous acid
H_3PO_4	Phosphoric acid
$H_2C_2O_4$	Oxalic acid
H_2CO_3	Carbonic acid
$H_2C_3H_2O_4$	Malonic acid

Rules for Naming Acids, Bases and Salts

1) Binary Acids: are made of only two elements
   i. Prefix is always hydro
   ii. Name the second element with the suffix "ic"
2) Ternary acids: more than two elements(usually contain a polyatomic ion)
   i. For the acid containing the most common polyatomic ion of its group simply use the first part of the polyatomic ion name and follow with the suffix "ic"

      Chloric acid $HClO_3$

   ii. For the acid containing the polyatomic with one less oxygen than the "ic", use the suffix "ous"

      Chlorous acid $HClO_2$

   iii. For the acid containing the polyatomic with two less oxygen than the "ic", us the prefix "hypo" and the suffix "ous".

      Hypochlorous acid HClO

   iv. For the acid containing the polyatomic with one more oxygen than the "ic", use the prefix "per" and the suffix "ic"

      Perchloric acid $HClO_4$

3) Bases and salts: simply use the normal rules for naming compounds (ionic or covalent)

TABLE 6.6 Compounds that are acids in water solution and their anions

Acid formula	*Oxidation number of nonmetal*	*Name in aqueous solution*	*Name and formula of anion*
*HNO_3	+5	nitric acid	nitrate, NO_3^-
HNO_2	+3	nitrous acid	nitrite, NO_2^-
*H_2SO_4	+6	sulfuric acid	sulfate, SO_4^{-2}
H_2SO_3	+4	sulfurous acid	sulfite, SO_3^{-2}
*H_3PO_4	+5	phosphoric acid	phosphate, PO_4^{-3}
H_2CO_3	+4	carbonic acid	carbonate, CO_3^{-2}
$HClO_4$	+7	perchloric acid	perchlorate, ClO_4^-
*$HClO_3$	+5	chloric acid	chlorate, ClO_3^-
$HClO_2$	+3	chlorous acid	chlorite, ClO_2^-
#HClO	+1	hypochlorous acid	hypochlorite, ClO^-
HCl	−1	hydrochloric acid	chloride, Cl^-

* These acids are the most common for a particular nonmetal.
\# Although only chlorine is shown, similar compounds are formed by the other halogens and would be named the same way as are these chlorine-containing compounds.

6.1 Introduction to Acids and Bases Assignment

1. Write the balanced ionization or dissociation reaction for the following acids and bases. (Don't worry about the states of the reactants, but the states of the products are important.)

   a. Nitric acid

   b. Chloric acid

   c. Acetic acid

   d. Lithium hydroxide

   e. Sulfurous acid

2. Name each of the following acids.

a. H_3PO_4

b. H_3BO_3

c. HI

d. CH_3COOH

e. HF

3. Identify the hydrogen-ion donor(s) & acceptor(s) in each of the following reactions:

	H^+ donors (the acids)	**H^+ acceptors (the bases)**
a. HNO_3 *(l)* + H_2O*(l)* → H_3O^+ *(aq)* + NO_3^- *(aq)*		
b. $C_2H_5NH_2$ *(l)* + H_2O*(l)* → $C_2H_5NH_3^+$ *(aq)* + OH^-*(aq)*		
c. CH_3CO_2 H*(l)* + H_2O*(l)* → $CH_3CO_2^-$*(aq)* + H_3O^+*(aq)*		

4. Which of the following would you expect to act as Brønsted-Lowry bases. Why? Hint – think about charge!

a) Br^- b) Li^+ c) H_3PO_4 d) NH_4^+ e) H_2O f) NH_2^-

5. Consider the following two reactions. In which reaction does $H_2PO_4^-$ act as a base? In which does it act as an acid?

	Is $H_2PO_4^-$ an acid or base?
a. $H_2PO_4^-$ *(aq)* + H_2O*(l)* → H_3PO_4*(aq)* + OH^-*(aq)*	
b. $H_2PO_4^-$*(aq)* + H_2O*(l)* → HPO_4^{2-}*(aq)* + H_3O^+*(aq)*	