Acid-Base Equilibrium

- Acid-base reactions are also reversible reaction, so they have the ability to form an equilibrium
- Recall Arrhenius's modified definition of acids and bases
  - *Acids* are species that produce H^+/H_3O^+ ions in a reaction and have a pH lower than 7
  - Bases are species that produce OH^- ions in a reaction and have a pH higher than 7
- This definition of acids and bases is still true and applicable, but it is a limited.
- Bronsted and Lowry extended Arrenhius definition of an acid and base to overcome its limitations
- **Bronsted-Lowry** definition of acids and bases:
  - An *acid* is a substance that produces a hydrogen ion (H^+)/hydronium ion (H_3O^+) and is therefore called a *proton donor.* H^+ is a proton!
  - A *base* is a substance that can accept a hydrogen ion and is therefore also called a *proton acceptor*.

a list of common acids & bases are found on Pg. 8-9 of data booklet

- In order for an acid to able to donate a proton, there needs to be a base present to accept that proton (and vice versa). Therefore, an acid always needs a base to react with (and vice versa).
- Since most acids and bases are dissolved in water and water has the ability to accept and donate a proton, the acidic and basic properties of chemicals can be explained by a reaction with water.

EXAMPLES:

1. Write out the acid-base reactions for
   a. $HCN_{(aq)}$ acting as an acid

   $$HCN_{(aq)} + H_2O_{(l)} \rightleftharpoons CN^-_{(aq)} + H_3O^+_{(aq)}$$

   acid loses H^+ · base accepts H^+

   b. $NH_{3(aq)}$ acting as a base

   $$NH_{3(aq)} + H_2O_{(l)} \rightleftharpoons NH_4^+{}_{(aq)} + OH^-_{(aq)}$$

   base accepts H^+ · acid loses H^+

2. Write out the acid-base equilibrium reaction when potassium nitrite is mixed with hypoclorous acid (HOCl).

   KNO_2 → K^+ ↙ ↘ NO_2^-

   $$NO_2^-{}_{(aq)} + HOCl_{(aq)} \rightleftharpoons HNO_{2(aq)} + OCl^-_{(aq)}$$

   base · acid · conjugate acid · conjugate base

- When chemicals only differ from each other by the presence or absence of a single hydrogen ion/proton, we call the chemicals a **conjugate acid-base pair**
  - *Every* acid has a conjugate base and every base has a conjugate acid
  - ✱ The actual acid/base will always be on the reactant side and the conjugate will always be on the product side

EXAMPLE: Hydrogen bromide is a gas at room temperature, but is soluble in water to form hydrobromic acid. Identify the conjugate base for hydrobromic acid. Identify the other conjugate acid-base pair that is involved in the reaction.

$$HBr_{(aq)} + H_2O_{(l)} \rightleftharpoons Br^-_{(aq)} + H_3O^+_{(aq)}$$

acid | base | conjugate base | conjugate acid

∴ $Br^-_{(aq)}$ is conjugate base of $HBr_{(aq)}$

$H_2O_{(l)}/H_3O^+_{(aq)}$ is other conjugate acid-base pair

- Acids and bases have different strengths
  - Some acids donate protons more easily (stronger acids) and some bases accept protons more easily (stronger bases)
  - Stronger acids are found at the top left hand side of the table on pg. 8-9 of data booklet and decrease in strength as you go down (larger Ka values)
  - Stronger bases are found at the bottom right hand side of the table on pg. 8-9 of data booklet and decrease as you go up (smaller Ka values)
- If multiple acids and bases are present in a container, the reaction will be defined by the strongest acid reacting with the strongest base
- ✱ In an acid-base reaction, the reaction will favour the side of the reaction that contains the weaker acid or base

EXAMPLE: Predict the direction in which the following reaction will proceed.

a. $SO_4^{2-}{}_{(aq)} + CH_3COOH_{(aq)} \leftrightarrow HSO_4^-{}_{(aq)} + CH_3COO^-{}_{(aq)}$

base → weaker base; acid → weaker acid; conjugate acid → stronger acid; conjugate base → stronger base

∴ reactants favoured

b. $H_2PO_4^-{}_{(aq)} + NH_{3(aq)} \leftrightarrow NH_4^+{}_{(aq)} + HPO_4^{2-}{}_{(aq)}$

acid → stronger acid; base → stronger base; conjugate acid → weaker acid; conjugate base → weaker base

∴ products favoured

*****Now try pg. 687 #1, 2, 4 & pg. 690 #8 & Practice Problems*****

Practice Problems

1. Write the acid-base equilibrium equation for each of the following reactions. State whether the reactant or products are favoured.

   a. Carbonic acid is combined with ammonia (NH_3).

   b. Nitrous acid ($HNO_{2(aq)}$).

   c. Sodium cyanide is dissolved in water.

   d. Copper (II) sulphate is dissolved in hydrofluoric acid.

2. For each of the following reactions, identify each substance as a Brønsted-Lowry acid, Brønsted-Lowry base, a conjugate acid, or conjugate base.

a.	NH_4^+ (aq)	+	CN^- (aq)	→	HCN(aq)		NH_3(aq)
	__________		__________		__________		__________
b.	$(CH_3)_3N$(aq)	+	H_2O(l)	→	$(CH_3)_3NH^+$(aq)	+	OH^-(aq)
	__________		__________		__________		__________

Solutions

1.

a. $H_2CO_{3(aq)} + NH_{3(aq)} \leftrightarrow HCO_3^-{}_{(aq)} + HN_4^+{}_{(aq)}$ products favoured

b. $HNO_{2(aq)} + H_2O_{(l)} \leftrightarrow NO_2^-{}_{(aq)} + H_3O^+{}_{(aq)}$ reactants favoured

c. $CN^-{}_{(aq)} + H_2O_{(l)} \leftrightarrow HCN_{(aq)} + OH^-{}_{(aq)}$ reactants favoured

d. $SO_4^{2-}{}_{(aq)} + HF_{(aq)} \leftrightarrow HSO_4^-{}_{(aq)} + F^-{}_{(aq)}$ reactants favoured

2.

a.	NH_4^+ (aq)	+	CN^- (aq)	→	HCN(aq)		NH_3(aq)
	acid		**base**		**conjugate acid**		**conjugate base**
b.	$(CH_3)_3N$(aq)	+	H_2O(l)	→	$(CH_3)_3NH^+$(aq)	+	OH^-(aq)
	base		**acid**		**conjugate acid**		**conjugate base**