Name ___________________________________Chem 161, Section: _______Group Number: ______

ALE 16. Strong versus Weak Electrolytes and Acid-Base Reactions

(Reference: Section 4.4 in *Silberberg 5th edition*)

What happens when an acid reacts with a base?

The Model: Strong versus Weak Electrolytes

Consider the salt MX, where "M" and "X" stand for generic elements (or possibly polyatomic ions) that as ions will have charges of either 1+ or 1-. If MX is soluble in water:

$$MX \xrightarrow{H_2O} M^+(aq) + X^-(aq)$$

Strong electrolyte: Aqueous MX exists 100% as dissociated ions.

$$MX \underset{}{\overset{H_2O}{\rightleftharpoons}} M^+(aq) + X^-(aq)$$

Weak electrolyte: Aqueous MX exists as a mixture of dissociated ions and associated formula units.

Key Questions

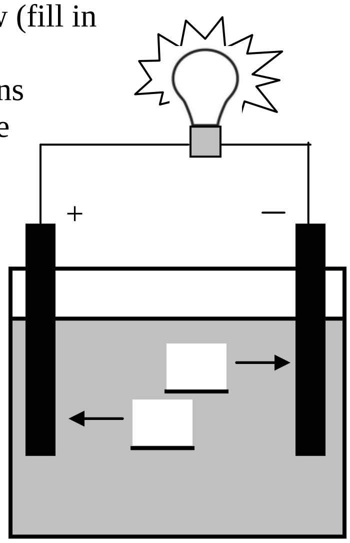
1 a. What does the arrow (→) in "$MX \rightarrow M^+(aq) + X^-(aq)$" inform the reader of?

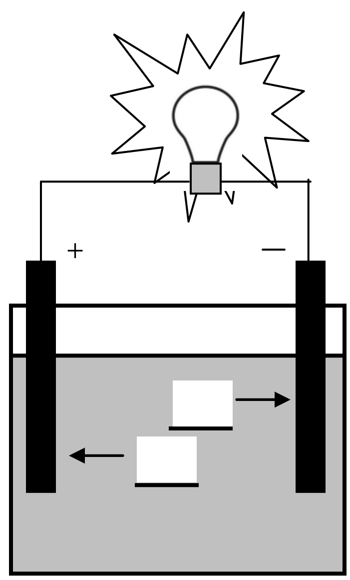
b. What do the arrows (⇌) in "$MX \rightleftharpoons M^+(aq) + X^-(aq)$" inform the reader of?

2. Suppose you have two aqueous solutions: 0.1 *M* AB and 0.1 *M* CD (where **A** and **C** are ***cations***, and **B** and **D** are ***anions***). **AB** is a ***strong electrolyte*** and **CD** is a ***weak electrolyte***.

   a. Which solution, 0.1 *M* AB or 0.1 *M* CD, has more ions dissolved in solution? Circle your choice and *explain your reasoning*.

   b. Label the two diagrams below (fill in the blanks) with the identities (A^+, B^-, C^+ or D^-) of the cations and anions flowing toward the appropriate electrodes.





The Model: Strong Acids and Strong Bases

Let HX represent a ***strong acid*** where **X**$^-$ represents a _monatomic or polyatomic anion_. The equation below represents what happens to HX when dissolved in water:

$$HX \xrightarrow{H_2O} H^+(aq) + X^-(aq)$$

Let MOH represent a ***strong base*** where M^+ represents a metal cation. The equation below represents what happens to MOH when dissolved in water:

$$MOH \xrightarrow{H_2O} M^+(aq) + OH^-(aq)$$

The 7 Strong Acids		**The 7 Strong Bases**	
HCl	HNO_3	NaOH	
HBr	$HClO_3$	KOH	$Ca(OH)_2$
HI	$HClO_4$	RbOH	$Sr(OH)_2$
	H_2SO_4	CsOH	$Ba(OH)_2$

Strong electrolytes are written as dissociated cations and anions in the total ionic equation. For example:

$HCl(aq) = H^+(aq) + Cl^-(aq)$ $\qquad$ $NaOH(aq) = Na^+(aq) + OH^-(aq)$

- ***If an acid or base is not on one of the above lists, assume it is weak***.
- **A weak electrolyte must be written as the associated formula unit ("molecular formula") in the total ionic equation.**

Key Questions

3. Distinguish an acid from a base in terms of what is the product of _every_ acid when dissolved in water and what is the product of _every_ base when dissolved in water.

   a.) Acids dissolve in water to produce ________________________________ .

   a.) Bases dissolve in water to produce ________________________________ .

4. Are strong acids and strong bases electrolytes? _Yes_ or _No_ Circle your choice and _explain your reasoning_.

5. How should the following compounds be written in a total ionic equation? (Include phases.)

a. HNO_3 ________________________ e. LiOH ________________________

b. KOH ________________________ f. HF ________________________

c. H_3PO_4 ________________________ g. RbOH ________________________

d. $Cu(OH)_2$ ________________________ h. $HClO_2$ ________________________

The Model: Ammonia

When **ammonia** is added to water, the following reaction occurs:

$$NH_3(aq) + H_2O(l) \rightleftharpoons NH_4^+(aq) + OH^-(aq)$$

Key Questions

6 a. When you see the formula "HX", what are you prone to expect the compound HX to be?

b. For many nonmetal hydrides, the formula is written with the hydrogen atoms first. Why is the formula of ammonia not written as "H_3N"?

7. Ammonia is a (circle one)

(A) strong acid. (B) weak acid. (C) strong base. (D) weak base.

8. Aqueous solutions of ammonia are often labeled as "$NH_4OH(aq)$". Explain why this may ***not*** be an appropriate way to label such a solution.

The Model: Neutralization Reactions

In general: An acid and a base react to form a salt and water. ***A double displacement reaction will occur spontaneously if the products are weaker electrolytes than the reactants.***

Example 1. Strong acid reacting with a strong base.

"Molecular" equation:

$$H_2SO_4\,(aq) + 2\,KOH\,(aq) \rightarrow K_2SO_4\,(aq) + 2\,H_2O\,(l)$$

Total ionic equation:

$$2\,H^+(aq) + SO_4^{2-}(aq) + 2\,K^+(aq) + 2\,OH^-(aq) \rightarrow 2\,K^+(aq) + SO_4^{2-}(aq) + 2\,H_2O(l)$$

Net ionic equation:

$$H^+(aq) + OH^-(aq) \rightarrow H_2O(l)$$

Note:

Since H_2SO_4 is a strong acid, the loss of the first proton, H^+, from sulfuric acid is complete:

Loss of the 1st proton: $H_2SO_4(aq) \rightarrow H^+(aq) + HSO_4^-(aq)$ (100% dissociation)

Since the hydrogen sulfate ion, HSO_4^-, is a weak acid, loss of the 2nd proton is incomplete:

Loss of the 2nd proton: $HSO_4^-(aq) \rightleftharpoons H^+(aq) + SO_4^{2-}(aq)$ (less than 100% dissociation)

Although the second deprotonation of H_2SO_4 is incomplete, we've shown it as complete in the total ionic equation (above) since the presence of hydroxide ions, OH^-, helps to remove both protons (H^+) from each molecule of H_2SO_4.

Example 2. Weak acid reacting with a strong base.

"Molecular" equation: $HF(aq) + NaOH(aq) \rightarrow NaF(aq) + H_2O(l)$

Total ionic equation: $HF(aq) + Na^+(aq) + OH^-(aq) \rightarrow Na^+(aq) + F^-(aq) + H_2O(l)$

Net ionic equation: $HF(aq) + OH^-(aq) \rightarrow F^-(aq) + H_2O(l)$

Example 3. Strong acid reacting with a weak base.

"Molecular" equation: $HNO_3(aq) + NH_3(aq) \rightarrow NH_4NO_3(aq)$

Total ionic equation: $H^+(aq) + NO_3^-(aq) + NH_3(aq) \rightarrow NH_4^+(aq) + NO_3^-(aq)$

Net ionic equation: $H^+(aq) + NH_3(aq) \rightarrow NH_4^+(aq)$

Key Questions

9. It is said, "In general: An acid and a base react to form a salt and water." Why can it not be said, "An acid and a base always react to form a salt and water"? *Give a specific example from the model above to support your response*.

10. The net ionic equation between a strong acid and a strong base is *always*:

$$H^+(aq) + OH^-(aq) \rightarrow H_2O(l)$$

Why is this true? *Use the reaction between HCl(aq) and NaOH(aq) to support your response.*

Exercises

Write the *net ionic equation* when each of the following pairs of aqueous solutions are added together. (Although not required, it *may* be a good idea to first write the *total ionic equation*.)

A. $NaOH(aq) + HNO_2(aq) \rightarrow ?$

Net ionic equation:

B. $HCl(aq) + NH_3(aq) \rightarrow ?$

Net ionic equation:

C. $KC_2H_3O_2(aq) + H_2SO_4(\text{dilute},aq) \rightarrow ?$

Net ionic equation:

D. $(NH_4)_2CO_3(aq) + HClO_3(aq) \rightarrow ?$

Net ionic equation: