Chemistry 12

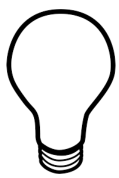
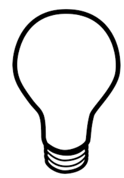
Acid-Base Equilibrium II

Name:
Date:
Block:

1. **Strengths of Acids and Bases**
2. **Relative Strengths of Brønsted-Lowry Acids and Bases**
3. **K_a, K_b**
4. **Ionization of Water**

Strengths of Acids and Bases

Demo: Consider two acid solutions – hydrochloric acid, HCl and acetic acid, CH_3COOH.

HCl	**CH_3COOH**
	

In order for a solution to conduct electricity, __________ must be present.

A strong acid (or base) is a substance that _________________ ionizes in aqueous solution.

A weak acid (or bases) is a substance that _________________ ionizes in aqueous solution.

HCl is a **strong** acid.

$$HCl_{(aq)} + H_2O_{(l)} \rightarrow H_3O^+_{(aq)} + Cl^-_{(aq)}$$

- The reaction goes to completion – therefore, $\rightarrow$ is used.
- Other strong acids: $HClO_4$, HI, HBr, HNO_3 and H_2SO_4.
- Strong bases include: NaOH, KOH, $Ca(OH)_2$, and $Mg(OH)_2$

CH_3COOH is a **weak** acid.

- The reaction does not go to completion – therefore $\leftrightharpoons$ is used.
- There are many weak acids and bases.

Classify the following as a strong acid (SA), weak acid (WA), strong base (SB), weak base (WB) or a spectator ion (S).

$HClO_4$	$HCOOH$	NH_3	CN^-
$Mg(OH)_2$	HNO_2	NO_3^-	HNO_3
HPO_4^{2-}	F^-	Br^-	Cl^-
NH_4^+	SO_3^{2-}	HSO_4^-	$LiOH$

Relative Strengths of Brønsted-Lowry Acids and Bases

The higher the K_a or K_b value, the _______________ $[H_3O^+]$ or $[OH^-]$ respectively.

Acids are listed on the ___________ of the table and their ____________________ bases are listed on the ____________.

Example.
A student tests the electrical conductivity of 0.5 M solutions of the following: carbonic acid, methanoic acid, phenol acid and boric acid. Rank these solutions in order from most conductive to least conductive.

When a BL-acid and base react, the position of the equilibrium is determined by their relative strengths.

Example:

$$NH_{3\,(aq)} + HCOOH_{(aq)} \leftrightharpoons NH_4^+{}_{(aq)} + HCOO^-{}_{(aq)}$$

- Label the respective acids and bases in the above equation.
- According to the BL-acid/base strength table:
    - Determine which of the two acids is weaker or stronger.
    - Determine which of the two bases is weaker or stronger.
- **The equilibrium favours the direction in which the stronger acid and base react to form the weaker conjugate acid and base.**

Practice:

1. Predict whether reactants or products will be favoured when HCN reacts with HCO_3^-.

- What is the reaction? Identify the weaker/stronger acid, weaker/stronger base.

2. Predict whether reactants or products will be favoured when HSO_4^- reacts with $HC_2O_4^-$.

    a. Will the K_{eq} value be greater or less than 1?

3. If 0.10 M HSO_3^- is mixed with 0.10 M $HC_2O_4^-$, which species will ***donate*** a proton?

4. If 0.10 M HSO_4^- is mixed with 0.10 M $HC_6H_5O_7^{2-}$, which species will ***accept*** a proton?

Strengths of Acids & Bases Worksheet
Hebden Workbook Pg. 125 # 21-24, Pg 133 # 38 - 46

K_a, K_b

$$CH_3COOH_{(aq)} + H_2O_{(l)} \leftrightharpoons H_3O^+_{(aq)} + CH_3COO^-_{(aq)}$$

In the acetic acid example above, because the reaction reaches an equilibrium, a K_{eq} expression can be written. This specific expression is called **the K_a expression** and K_a is called the **acid ionization constant**.

$$K_{eq} = K_a =$$

Similarly for weak bases,

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

The K_b expression is:

$$K_{eq} = K_b =$$

K_b is called the base ionization constant.

Practice:

1. HF is a weak acid.
   a. Write an equation showing how HF acts in solution.

   b. Write the K_a expression for HF.

2. The hydrogen oxalate ion is amphiprotic.
   a. Write an equation showing how this ion acts as an acid in solution. Write a K_a expression.

   b. Write an equation showing how this ion acts as a base in solution. Write a K_b expression.

<u>Lab Simulation: Strengths of Acids and Bases</u>

Ionization of Water

Water is amphiprotic so it can donate and accept a proton ion.

- One water can donate a proton to another water molecule – this is called **autoionization.**

$$H_2O_{(l)} + H_2O_{(l)} \leftrightharpoons H_3O^+_{(aq)} + OH^-_{(aq)}$$

What would be the equilibrium constant expression?

$K_{eq} =$

The equilibrium constant expression for the autoionization of water is called K_w, or the water ionization constant or ion product constant.

At equilibrium, $[H_3O^+] = [OH^-]$

$$\begin{array}{cccc} H_2O_{(l)} + H_2O_{(l)} \leftrightharpoons & H_3O^+_{(aq)} & + & OH^-_{(aq)} \\ & x & & x \end{array}$$

Both H_3O^+ and OH^- exist in all aqueous solution.

- If $[H_3O^+] < [OH^-]$, the solution is _______________.
- If $[H_3O^+] = [OH^-]$, the solution is _______________.
- If $[H_3O^+] > [OH^-]$, the solution is _______________.

Example:

What is the $[H_3O^+]$ and $[OH^-]$ in 0.50M HCl? Is this solution acidic or basic?

- Is HCl a strong or weak acid?

- Substitute known values into the K_w expression and solve.

Practice 1:

Calculate the $[H_3O^+]$ and $[OH^-]$ in a **saturated** solution of magnesium hydroxide. Is this solution acidic or basic?

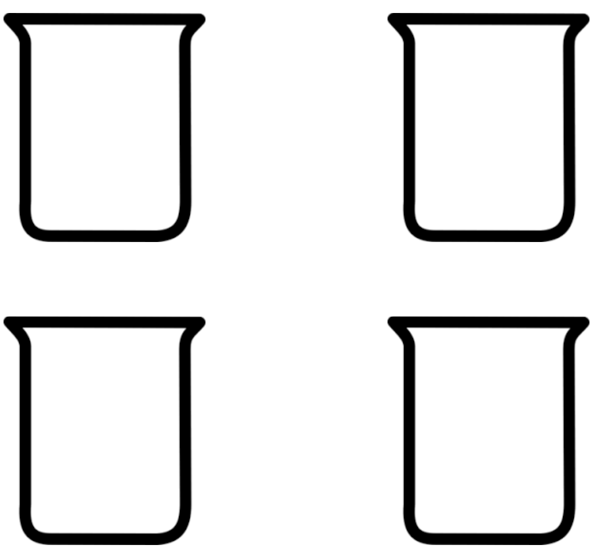
Practice 2:

A student dissolved 1.42g of NaOH in 250. mL of solution. Calculate the resulting $[H_3O^+]$ and $[OH^-]$. Is this solution acidic or basic?

$[H_3O^+]$ and $[OH^-]$ when 2 solutions are MIXED:

When two solutions are mixed:

- The solutions ______________ each other. ($c_1v_1 = c_2v_2$)
- The acid and base ______________ each other.



Practice 1:

What is the final [H_3O^+] in a solution formed when 25 mL of 0.30 M HCl is added to 35 mL of 0.50 M NaOH?

- When two solutions are combined, both are diluted. Calculate the new concentrations of HCl and NaOH in the mixed solution.

- The hydronium ions and hydroxide ions will neutralize each other.
- Since there is more _______________, there will be _______________ left over. Calculate how much will be left over.

- Use K_w to calculate the hydronium ion concentrations from the hydroxide ion concentration.

Practice 2:

Calculate the final [H_3O^+] and [OH^-] in a solution formed when 150. mL of 1.5 M HNO_3 is added to 250. mL of 0.80 M KOH.

Practice 3:

Calculate the resulting $[H_3O^+]$ and $[OH^-]$ when 18.4 mL of 0.105 M HBr is added to 22.3 mL of 0.256 M HCl.

Practice 4:

What mass of NaOH must be added to 500.0 mL of a solution of 0.020 M HI to obtain a solution with a final hydronium ion concentration of 0.0032 M?