K_w and pH worksheet

(adapted from Glencoe Chapter 24 Concept Review)

H_3O^+ and OH^- Concentrations

Conductivity experiments have shown that water ionizes only slightly according to the equation

$$H_2O\ (l) + H_2O\ (l) \rightarrow H_3O^+ + OH^-\ (aq)$$

Because water ionizes, it is possible to find an equilibrium constant for the reaction. The concentration of pure water is constant. As a result, a new constant can be calculated. It is called the ion product constant of water, K_w.

$$K_w = [H_3O^+][OH^-] = 1.00 \times 10^{-14}$$

K_w is a constant for all dilute aqueous solutions. If an acid is added to water, the $[OH^-]$ decreases and the $[H_3O^+]$ increases, but the product of $[H_3O^+]$ and $[OH^-]$ remains constant.

Example:
What is the hydronium ion concentration in a solution with hydroxide ion concentration of 2.50×10^{-5} M?
Solving Process:

$[H_3O^+][OH^-] = 1.00 \times 10^{-14}$ $\quad [H_3O^+] = \frac{1.00 \times 10^{-14}}{[OH^-]}$ $\quad [H_3O^+] = \frac{1.00 \times 10^{-14}}{2.50 \times 10^{-5}} = 4.00 \times 10^{-10}$ M

7. What is the hydroxide ion concentration in a solution with $[H_3O^+] = 7.67 \times 10^{-9}$ M?

$[OH^-] = 1.3 \times 10^{-6}$ M

8. What is the hydronium ion concentration in a solution with $[OH^-] = 4.35 \times 10^{-2}$ M?

weakest acid (smallest $[H_3O^+]$) $[H_3O^+] = 2.30 \times 10^{-13}$ M strongest acid.

9. What is the hydroxide ion concentration in a solution with $[H_3O^+] = 6.12 \times 10^{-3}$ M?

$[OH^-] = 1.63 \times 10^{-12}$ M

10. The hydroxide ion concentration in a water solution is 8.39×10^{-11} M. What is the hydronium ion concentration?

$[H_3O^+] = 1.19 \times 10^{-4}$ M

~~Strongest acid~~

pH and pOH

Knowledge of K_w for water has enabled chemists to develop a simple acidity scale called the pH scale. The pH scale is a measure of the hydronium ion concentration. The scale can be used to indicate the basicity of a water solution as well.

$$pH = -\log [H_3O^+]$$

11. Find the pH of solutions with the following H_3O^+ concentrations.
    a. 1.15×10^{-6} M 5.94
    b. 1.00×10^{13} M 13
    c. 5.75×10^{-8} M 7.24
    d. 0.00001 M 1.0×10^{-5} 5
    e. 7.44×10^{-11} M 10.1
    f. 1.00×10^{-4} M 4

12. Find the $[H_3O^+]$ and the pOH of the following solutions. (Hint: pH + pOH = 14)
    a. pH = 3 pOH = 11 $[H_3O^+] = 1 \times 10^{-3}$
    b. pH = 9.35 pOH = 4.65 $[H_3O^+] = 4.47 \times 10^{-10}$
    c. pH = 11 pOH = 3 $[H_3O^+] = 1 \times 10^{-11}$
    d. pH = 6.34 pOH = 7.66 $[H_3O^+] = 4.57 \times 10^{-7}$

highest $[H_3O^+]$ → 0 ——— 14 ← lowest $[H_3O^+]$

strongest acid, weakest base → $[H_3O^+]$ ↓, $[OH^-]$ ↑ → weakest acid, strongest base

KEY

Ionization Constant Worksheet

(adapted from Glencoe Concept Review 23 and Study guide 23.2)

Refer to Section 23.2 of the textbook to help you solve the following problems.

Ionization Constant

Weak acids ionize only slightly. The equilibrium constant expression for a weak acid does not contain the concentration of H_2O because the concentration of H_2O remains nearly constant. The K_{eq} is multiplied by the $[H_2O]$ to obtain the ionization constant, K_a. The ionization constant is a special case of an equilibrium constant.

1. Write the equilibrium constant expression, K_{eq}, for the following acid ionization reaction.
   $HOBr + H_2O \rightleftharpoons H_3O^+ + OBr^-$

2. Write the ionization constant expression, K_a, for the reaction above.
   $$K_a = \frac{[H_3O^+][OBr^-]}{[HOBr]}$$

3. Calculate the hydronium ion concentration of a 0.25 M solution of hypochlorous acid, HOCl, for which $K_a = 3.5 \times 10^{-8}$. The equation for ionization of this acid is $HOCl + H_2O \leftrightharpoons H_3O^+ + OCl^-$.
   $$K_a = \frac{[H_3O^+][OCl^-]}{[HOCl]} \qquad 3.5\times10^{-8} = \frac{x \cdot x}{.25}$$
   $$x = 9.35\times10^{-5}$$
   $9.4\times10^{-5}\ M$

4. What is the hydronium ion concentration of 0.250 M solution of acetic acid, if the ionization constant is 1.76×10^{-5}?
   $$1.76\times10^{-5} = \frac{x \cdot x}{.250} \qquad x = 2.0976\times10^{-3}$$
   $[H_3O^+] = 2.10\times10^{-3}\ M$
   $HC_2H_3O_2 + H_2O \rightleftharpoons H_3O^+ + C_2H_3O_2^-$

Percent Ionization

When a weak acid or base is dissolved in H_2O it ionizes only slightly. The amount ionized is usually expressed as a percent of ionization. The percentage of ionization can be calculated from the ratio obtained by comparing the concentration of the ions in solution to the concentration of the solute before it dissolved.

5. Calculate the percent ionization of 0.010 M acetic acid solution if the hydronium ion concentration is 4.2×10^{-4} M.
   $$\%\ \text{ionization} = \frac{[H_3O^+]}{[\text{Acid}]} \times 100 \qquad \frac{4.2\times10^{-4}}{.01} \times 100 = 4.2\ \%$$

6. Find the percent ionization of propanoic acid, CH_3CH_2COOH, which as a Ka = 1.34×10^{-5}. The concentration of propanoic acid is 0.100 M.
   $CH_3CH_2COOH + H_2O \rightleftharpoons CH_3CH_2COO^- + H_3O^+$
   $$K_a = \frac{[H_3O^+][CH_3CH_2COO^-]}{[CH_3CH_2COOH]}$$
   $$\frac{1.16\times10^{-3}}{.100} \times 100 = 1.16\%$$
   $$1.34\times10^{-5} = \frac{x \cdot x}{.100} \qquad x = 1.1575\times10^{-3}$$
   $1.16\times10^{-3}\ M$