## IV.7 - The Equilibrium Constant for the Ionization of Water

- Acidic Solution: has $[H_3O^+] > [OH^-]$
- Basic Solution: has $[H_3O^+] < [OH^-]$
- Neutral Solution: has $[H_3O^+] = [OH^-]$

Example: A typical acid-base reaction: HCl + NaOH

Formula Equation:

$$HCl_{(aq)} + NaOH_{(aq)} \rightleftharpoons NaCl_{(aq)} + H_2O_{(l)} + 59kJ$$

Total Ionic Equation:

$$H^+_{(aq)} + Cl_{(aq)} + OH^-_{(aq)} \rightleftharpoons Na^+_{(aq)} + Cl^-_{(aq)} + H_2O_{(l)} + 59kJ$$

Net Ionic Equation:

$$H^+_{(aq)} + OH^-_{(aq)} \rightleftharpoons H_2O_{(l)} + 59kJ$$

Therefore, the ***self-ionization of water*** can be written as:

$$H_2O_{(l)} + 59kJ \rightleftharpoons H^+_{(aq)} + OH^-_{(aq)}$$

The equilibrium expression ($K_w$) for this reaction is:

$$K_w = [H^+][OH^-] = 1.00 \times 10^{-14} \quad \text{(at 25°C)}$$

- We can also write the self-ionization of water as follows:

$$2H_2O_{(l)} + 59kJ \rightleftharpoons H_3O^+_{(aq)} + OH^-_{(aq)}$$

so that the equilibrium expression ($K_w$) is:

$$K_w = [H_3O^+][OH^-] = 1.00 \times 10^{-14} \quad \text{(at 25°C)}$$

*Recall that $[H_2O_{(l)}]$ is a constant and not included in the expression.*

- What happens if the temperature increases?

*Increased $[H_3O^+]$ and $[OH^-]$, increased electrical conductivity*

- What happens if temperature is decreased?

*Decreased $[H_3O^+]$ and $[OH^-]$, decreased electrical conductivity*

- As $[H_3O^+]$ increases $[OH^-]$ decreases, keeping $K_w$ at a constant $1.00 \times 10^{-14}$
- As $[H_3O^+]$ decreases $[OH^-]$ increases, keeping $K_w$ at a constant $1.00 \times 10^{-14}$
- If we add an acid, $[H_3O^+]$ will increase and the water equilibrium will shift to use up some of the additional $H_3O^+$ .

$$2H_2O_{(l)} \rightleftharpoons H_3O^+_{(aq)} + OH^-_{(aq)} \quad (\text{shift} \leftarrow)$$

H+ ↑

- However, the $[H_3O^+]$ and $[OH^-]$ are very low in neutral water:

$$[H_30^+] = [OH^-] = 1.0 \times 10^{-7}M$$

so that very little of this additional $H_3O^+$ can be neutralized by this small amount of OH-. The $[H_3O^+]$ builds up while the $[OH^-]$ decreases. BUT even in acidic solution (lots of $H_3O^+$) a small amount of $OH^-$ will be present.

***Unless you are told otherwise, you should always assume the temperature is 25°C and therefore the value of Kw = 1.00 X $10^{-14}$.***

Try these…

1. What is the $[H_30^+]$ and $[OH^-]$ in 0.0010 M $HCl_{(aq)}$?

2. What is the $[H_3O^+]$ of a 0.01 M NaOH at 25°C?

3. Find $[H_3O^+]$ at 25°C of 2.0 M $Sr(OH)_2$?

4. January 2002

The ionization of water can be represented by

A. $2H_2O_{(\ell)} \rightarrow 2H_{2(g)} + O_{2(g)}$

B. $H_2O_{(\ell)} \rightarrow 2H^+_{(aq)} + O^{2-}_{(aq)}$

C. $H_2O_{(\ell)} \rightarrow H_3O_{(aq)} + OH_{(aq)}$

D. $2H_2O_{(\ell)} \rightarrow H_3O^+_{(aq)} + OH^-_{(aq)}$

5. January 1999

Consider the following equilibrium:

$$2H_2O + \text{energy} \rightleftarrows H_3O^+ + OH^-$$

In pure water at a temperature of 50° C,

A. $pH < 7$

B. $pH + pOH = 14$

C. $K_w = 1.0 \times 10^{-14}$

D. $[OH^-] < 1.0 \times 10^{-7}$

*****Do Hebden Questions #28 - 30, pg 127*****