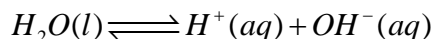
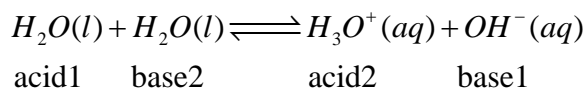


## The Acid-Base Properties of water and Ion Product

As we know, the water is a unique and universal solvent on this planet. One of its special properties is its ability to function as an acid or as a base. Water is a very weak electrolyte and due to that it is a poor conductor of electricity. It undergoes ionization to a small extent as shown below:



This reaction is also known as *autoionization* (partial ionization). Within the framework of Bronsted, autoionization of water can be explained by the following equation.

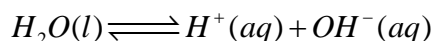


Here one water molecule acts as an acid and another water molecule as a base. Therefore, the conjugate acid-base pairs are (1)  $H_2O(\text{acid1})$  and  $OH^-(\text{base1})$  and (2)  $H_3O^+(\text{acid2})$  and  $H_2O(\text{base2})$ .

Among the above two equations, it does not make any difference which equation is used to explain the ionization of water. Even though, the second equation is more appropriate, the first equation offers the simplistic view of the ionization. Hence, we will use the first equation in the following discussion.

## The Ion-Product of Water

In this topic, we are going to apply the concept of equilibrium to deduce the ion-product of water. For that, let us consider the following equation that represents the ionization of water:



The equilibrium constant is given by,

$$K = \frac{[H^+][OH^-]}{[H_2O]}$$

Since the  $[H_2O]$  is very large, it can be considered as a constant. Therefore, we rearrange the above equation by collecting the constant terms on one side and renaming the K as  $K_w$ .

$$Kx[H_2O] = K_w = [H^+][OH^-]$$

Here  $K_w$  is known as the **ion-product of water**, which is *the product of molar concentrations of hydrogen ion ( $H^+$ ) and hydroxide ion ( $OH^-$ ) at a particular temperature*.

In pure water at  $25^\circ\text{C}$ , the concentrations of  $H^+$  and  $OH^-$  are equal and have been found to be

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

Substituting these values into ion-product of water equation, we have  $K_w$  at  $25^\circ\text{C}$  as

$$K_w = [H^+] [OH^-] = (1.0 \times 10^{-7}) (1.0 \times 10^{-7}) = 1.0 \times 10^{-14}$$

This equation is very useful in calculating either  $H^+$  ion concentration knowing  $OH^-$  concentration or  $OH^-$  ion concentration knowing  $H^+$  concentration through the following equations:

$$[H^+] = \frac{K_w}{[OH^-]} = \frac{1.0 \times 10^{-14}}{[OH^-]}$$

and  $[OH^-] = \frac{K_w}{[H^+]} = \frac{1.0 \times 10^{-14}}{[H^+]}$

**Things to remember:**

- |                       |   |
|-----------------------|---|
| If $[H^+] = [OH^-]$ , | neutral solution                                  |
| If $[H^+] > [OH^-]$ , | acidic solution, more $H^+$ ions than $OH^-$ ions |
| If $[H^+] < [OH^-]$ , | basic solution, more $OH^-$ ions than $H^+$ ions  |

**Example**

If hydrogen ion concentration in a particular acid is  $2.5 \times 10^{-3} \text{M}$ , what is the hydroxide concentration?

**Answer**

$$[OH^-] = \frac{K_w}{[H^+]} = \frac{1.0 \times 10^{-14}}{2.5 \times 10^{-3}} = 4.0 \times 10^{-12} \text{M}$$

**Example**

The concentration of  $OH^-$  ions in a particular household ammonia cleaning solution is  $0.075 \text{M}$ . What is the  $H^+$  ion concentration?

**Answer**

$$[H^+] = \frac{K_w}{[OH^-]} = \frac{1.0 \times 10^{-14}}{[OH^-]} = \frac{1.0 \times 10^{-14}}{0.075} = 1.3 \times 10^{-13} M$$

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