Ion Product of Water

Since water is amphoteric, it is capable of acting as both an acid and a base. As an acid, it donates an H^+ ion to become an OH^- ion. As a base, it accepts an H^+ to become an H_3O^+ ion.

It has been shown experimentally that two water molecules will react with one another to form ions according to the following equation.

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

In this reaction, water acts as both the acid and the base. This reaction will occur even in pure water, resulting in a small amount of ionization. In fact, it has been determined that pure water at $25°C$ contains both H_3O^+ and OH^- ions at concentrations of $1.0 \times 10^{-7}\ mol/L$.

Using the above equation and the known concentrations of H_3O^+ and OH^- ions, we can write an equilibrium expression for pure water and calculate the value of the ion product for water (K_W).

$$\begin{aligned} K_W &= [H_3O^+][OH^-] \\ &= (1.0 \times 10^{-7})(1.0 \times 10^{-7}) \\ K_W &= 1.0 \times 10^{-14} \end{aligned}$$

K_W is useful because it applies not only to pure water, but to every water solution at $25°C$, even a solution in which the concentrations of H_3O^+ and OH^- ions are not equal.

Example 1

The concentration of H_3O^+ ions in an acid solution were measured to be $1.0 \times 10^{-2}\ mol/L$. Determine the concentration of OH^- ions in the solution.

The fact that water itself ionizes to form both H_3O^+ and OH^- ions means that all acidic, basic, and neutral solutions contain both H_3O^+ and OH^- ions. It is possible to determine the nature of a water solution (acidic, basic, or neutral) by comparing the relative concentrations of these two ions.

- If $\left[H_3O^+\right]=\left[OH^-\right]$, the solution is neutral.
- If $\left[H_3O^+\right]>\left[OH^-\right]$, the solution is acidic.
- If $\left[H_3O^+\right]<\left[OH^-\right]$, the solution is basic.

Example 2
If the concentration of H_3O^+ in blood is $4.0\times10^{-8}\ mol/L$, is blood acidic, basic, or neutral?

Worksheet

1. What is the concentration of OH^- ions in chocolate milk if $\left[H_3O^+\right]=4.5\times10^{-7}\ mol/L$? Is chocolate milk acidic, basic, or neutral?

2. What is the concentration of H_3O^+ ions in black coffee if $\left[OH^-\right]=1.3\times10^{-9}\ mol/L$? Is black coffee acidic, basic, or neutral?

3. What is the concentration of OH^- ions in saturated lime if $\left[H_3O^+\right]=3.98\times10^{-13}\ mol/L$? Is lime acidic, basic, or neutral?

4. What is the concentration of H_3O^+ ions in a wheat flour and water solution if $\left[OH^-\right]=1.0\times10^{-8}\ mol/L$? Is this solution acidic, basic, or neutral?

5. Complete the following table by determining the missing concentrations. State whether each solution is acidic, basic, or neutral.

$\left[H_3O^+\right]$	$\left[OH^-\right]$	Acidic, basic, or neutral?
	$1.0\times10^{-5}\ mol/L$	
	$4.0\times10^{-9}\ mol/L$	
$1.2\times10^{-8}\ mol/L$		