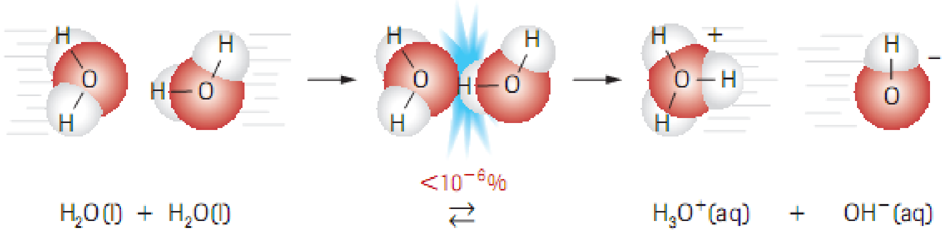
Outcome 3 - Kw, Ka and Kb

__Part 1:The Equilibrium of Water, pH and pOH__

Purified water has a very slight conductivity that is only observable if measurements are made with very sensitive instruments

According to Arrhenius' theory, conductivity is due to the presence of ions

Therefore, the conductivity observed in pure water must be the result of ions produced by the ionization of some water molecules into hydronium ions and hydroxide ions.



$$K_c = \frac{[H_3O^+(aq)][OH^-(aq)]}{\cancel{[H_2O(l)][H_2O(l)]}} \quad \text{or} \quad K_c = [H_3O^+(aq)][OH^-(aq)]$$

The water ionization equilibrium relationship is so important in chemistry that this particular K_c constant is given its own special symbol and name.

This new constant is called the ionization constant for water, K_w.

$$K_w = [H_3O^+(aq)][OH^-(aq)] = 1.00 \times 10^{-14} \text{ at SATP}$$

0.00000000000001

The equilibrium equation for the ionization of water shows that hydronium ions and hydroxide ions form in a 1:1 ratio.

Therefore, the concentration of hydronium ions and hydroxide ions in pure water must be equal.

This equality is also true for any neutral aqueous solution

$$[H_3O^+(aq)] = [OH^-(aq)] = \sqrt{1.00 \times 10^{-14}} = 1.00 \times 10^{-7} \text{ mol/L}$$

The Relationship between Kw, [$H_3O^{\pm}_{(aq)}$] and [$OH^{=}_{(aq)}$]

The most important point about K_w is that it applies to pure water, and also to any solution that is mostly water.

This means that this ionization equilibrium will be involved in any other reaction going on in aqueous solution, if that reaction involves hydronium ions or hydroxide ions in any way

We can easily use K_w to calculate either the hydronium ion amount concentration or the hydroxide ion amount concentration in an aqueous solution, if the other concentration is known

For any aqueous solution:

$$\text{Since } [H_3O^+(aq)][OH^-(aq)] = K_w$$

$$\text{then } [H_3O^+(aq)] = \frac{K_w}{[OH^-(aq)]}$$

$$\text{and } [OH^-(aq)] = \frac{K_w}{[H_3O^+(aq)]}$$

Example:

A 0.15 mol/L solution of hydrochloric acid at 25 °C is found to have a hydronium ion concentration of 0.15 mol/L. Calculate the amount concentration of the hydroxide ions

H_3O^+

OH^-

$[H_3O^+] = 0.15 \text{ mol/L}$

$[OH^-] = \frac{k_w}{[H_3O^+]} = \frac{10^{-14}}{0.15 \text{ mol/L}} = \boxed{6.7 \times 10^{-14} \text{ mol/L}}$

Example:

Calculate the amount concentration of the hydronium ion in a 0.25 mol/L solution of barium hydroxide.

$[Ba(OH)_2] = 0.25\ mol/L$

$\underline{1}\ Ba(OH)_2 \rightarrow Ba^{2+}_{(aq)} + \underline{2}\ OH^-_{(aq)}$

$0.25\ mol/L$ $\qquad [OH^-] = 0.50\ mol/L$

$[H_3O^+] = \frac{k_w}{[OH^-]} = \frac{10^{-14}}{0.50\ mol/L}$

$= \boxed{2.0 \times 10^{-14}\ mol/L}$

Example:

Determine the hydronium ion and hydroxide ion amount concentrations in 500 mL of an aqueous solution for home soap-making containing 2.6 g of dissolved sodium hydroxide.

$NaOH_{(aq)} \rightarrow Na^+_{(aq)} + OH^-_{(aq)}$

$m = 2.6g$

$M = 40.00g/mol$

$n = 0.065\ mol$

$V = 0.500L$

$[NaOH] = 0.13\ mol/L$ $\xrightarrow{\times 1} [OH^-] = 0.13\ mol/L$

$[H_3O^+] = \frac{k_w}{[OH^-]}$

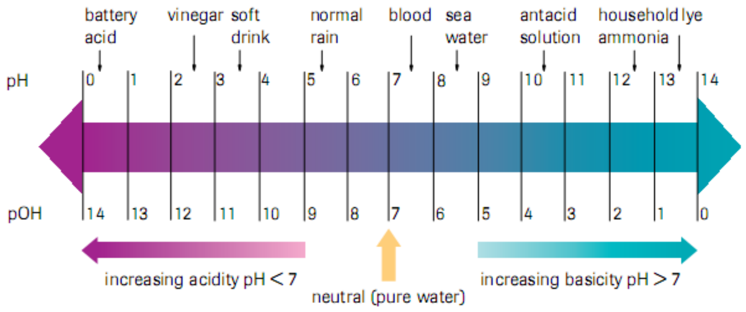
$= \boxed{7.7 \times 10^{-14}\ mol/L}$

Review of Chem 20: pH and pOH

$$pH = -\log[H_3O^+(aq)] \qquad [H_3O^+(aq)] = 10^{-pH}$$

$$pOH = -\log[OH^-(aq)] \qquad [OH^-(aq)] = 10^{-pOH}$$

$$pH + pOH = 14.00$$



$$K_w = [H_3O^+(aq)][OH^-(aq)] = 1.0 \times 10^{-14}$$

Strong Acids

A **strong acid** is one which reacts quantitatively (>99.9%) with water to form hydronium ions

There are 6 strong acids: hydrochloric, nitric, sulfuric, hydrobromic, hydroiodic, and perchloric acid solutions.

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

Weak Acids

A **weak acid** is an acid that reacts partially with water to form hydronium ions.

Measurements of pH indicate that most weak acids react less than 50%

$$CH_3COOH(aq) + H_2O(l) \overset{1.3\%}{\rightleftarrows} H_3O^+(aq) + CH_3COO^-(aq)$$