X) The Ionization of Water

January 17, 2018 11:08 PM

XI) The Ionization of Water

Water is amphiprotic, meaning it can act as an ACID in the presence of a base, and a base in the presence of an acid. If two water molecules collide with enough kinetic energy and with correct geometry, what can occur?

(l) not included in equilibrium equation

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

Write a K_{eq} equation for the reaction above: $K_{eq} = [H_3O^+][OH^-]$

[products] / [reactants]

The K_{eq} for this equation is called K_w, as 'w' stands for water.

$K_w = [H_3O^+][OH^-] = 1.0 \times 10^{-14}$ at 25°C

Notice how small the K_w is, meaning reactants are heavily favoured in the above reaction, which suggests… $2H_2O_{(l)} \rightleftharpoons H_3O^+_{(aq)} + OH^-_{(aq)}$ Fav.

There are very few effective collisions between 2 H_2O molecules. ⟹ meaning there is very little H_3O^+ and OH^- in solution

This small concentration of ions is why water can moderately conduct. → not enough charge +/- to create much e⁻ flow.

*2 in every 550 million water molecules have an effective collision at 25°C.

Pure water is neutral. What does the term 'neutral' mean?

neutral, no charge $[H_3O^+] = [OH^-]$ cations = anions

Since $K_w = [H_3O^+][OH^-] = 1.0 \times 10^{-14}$, and pure water is neutral, then $[H_3O^+] = [OH^-]$, so $[H_3O^+]$ in pure water = 1.0×10^{-7} M and $[OH^-]$ in pure water = 1.0×10^{-7} M

$[H_3O^+]$ and $[OH^-]$ must be the same in **pure water** because every reaction between two water molecules produces 1 of H_3O^+ and 1 of OH^-

If an acid is placed into water, the acid will react with water to produce (H^+ →) H_3O^+ ions, thereby causing $[H_3O^+]$ to be Greater than $[OH^-]$. In this case, we have an ACIDIC solution. If base is placed in water (H^+) (H_2O is the acid) more OH^- ions will be produced, thereby creating a BASIC ∴ $[OH^-]$ solution.

→ H_2O is acting as the acid to donate H^+; therefore only OH^- left.

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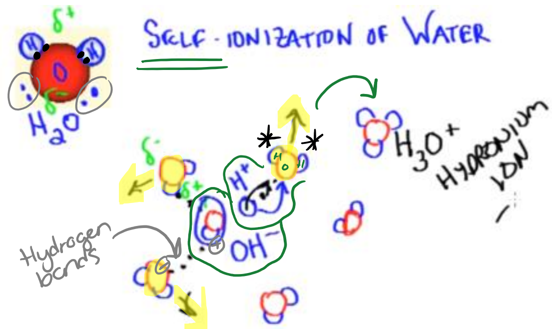
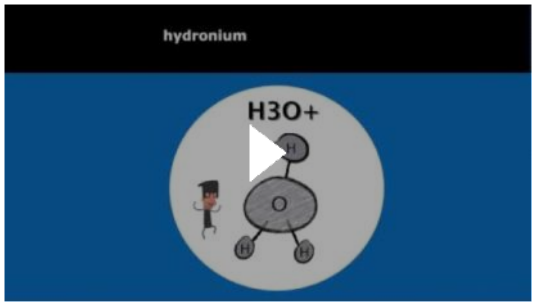


https://www.youtube.com/watch?v=IjsgLU8C5X4

What forms when water dissociates? Hydroxide and Hydronium Ions



When acid or base is placed in water, the concentration of H_3O^+ and OH^- changes, but the K_w remains constant at 1.0×10^{-14} (remember, the only thing that alters K_{eq} is Temperature.

Therefore, according to the K_w equation $1.0 \times 10^{-14} = [H_3O^+][OH^-]$, if one of the hydronium ion or hydroxide ion concentrations increases, the other must Decrease. (inversely proportional to each other)

Investigate these scenarios using the water equilibrium and LeChatelier's Principle:

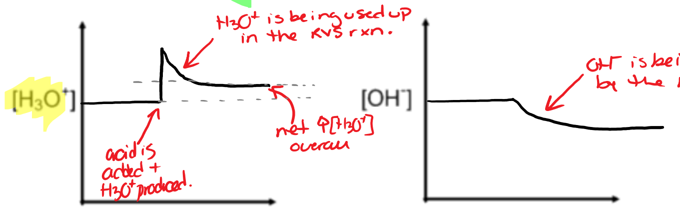
Acid added to water:

- acid will donate H^+ proton
- $H^+ + H_2O \rightarrow$ more H_3O^+ produced.

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

$\uparrow[H_3O^+]$

- more $H_3O^+ + OH^-$ collisions
- reverse rxn rate ↑
- ∴ SHIFT LEFT



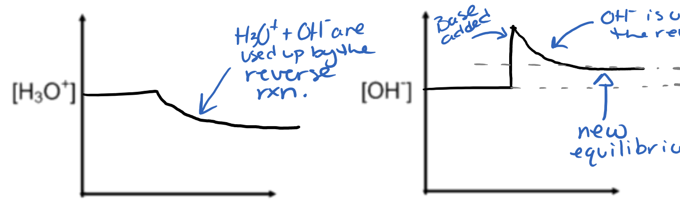
Base added to water:

- H_2O will donate a H^+ to the base
- the H_2O molec ⟶ becomes OH^-
- ↑[OH^-]

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

(acid) $\rightarrow H^+$; $\uparrow[OH^-]$

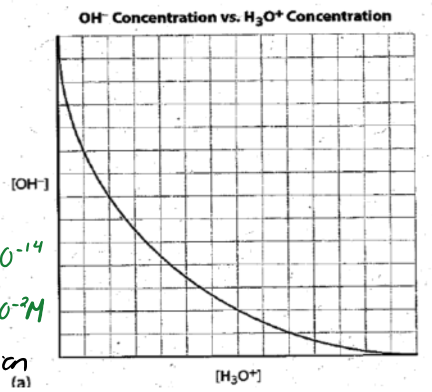
- more [OH^-] ∴ more collision
- reverse rxn rate will ↑
- = shift LEFT!



Conclusion:

In acid: $[H_3O^+]$ > 1.0 x 10^{-7}M and $[OH^-]$ < 1.0 x 10^{-7}M

In base: $[H_3O^+]$ < 1.0 x 10^{-7}M and $[OH^-]$ > 1.0 x 10^{-7}M



Practice Questions:

1. Calculate the $[OH^-]$ in a solution in which $[H_3O^+]$ is 1.0×10^{-12}M. Is the solution neutral, acidic, or basic?

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

   $[OH^-] = \frac{1.0 \times 10^{-14}}{1.0 \times 10^{-12} M} = 1.0 \times 10^{-2} M$

   $[H_3O^+]$ 1.0×10^{-12}M < $[OH^-]$ 1.0×10^{-2}M ∴ Basic solution

2. Calculate the $[H_3O^+]$ in a solution in which $[OH^-]$ is 1.0×10^{-8}M. Is the solution acidic, basic, or neutral?

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

   $[H_3O^+] = \frac{1.0 \times 10^{-14}}{1.0 \times 10^{-8} M} = 1.0 \times 10^{-6}$M

   ∴ $[H_3O^+] > [OH^-]$ ∴ ACIDIC

3. What is the $[H_3O^+]$ and $[OH^-]$ in 0.0010M HCl?

   $HCl + H_2O \rightarrow H_3O^+ + Cl^-$

   0.0010M (dissoc. 100%) 0.0010M

   $K_w = [H_3O^+][OH^-]$

   $[OH^-] = \frac{1.0 \times 10^{-14}}{(0.0010 M)}$

   $[OH^-] = 1.0 \times 10^{-11}$M

   $[H_3O^+] = 1.0 \times 10^{-3}$M

   $[H_3O^+] > [OH^-]$ * makes sense since HCl is a STRONG acid.

4. What is the $[H_3O^+]$ and $[OH^-]$ in 4.2×10^{-2}M $Sr(OH)_2$?

   strong base ∴ dissociate 100%

   $Sr(OH)_2 \rightarrow Sr^{2+} + 2OH^-$

strong base ∴ dissociate 100%.

$Sr(OH)_2 \rightarrow Sr^{2+} + 2OH^-$

$4.2\times10^{-2}M$ ×2 $8.4\times10^{-2}M = [OH^-]$

[H₃O⁺] > [OH⁻]

* makes sense since HCl is a STRONG acid.

$K_w = [H_3O^+][OH^-]$ ∴ $[H_3O^+] = \frac{1.0\times10^{-14}}{8.4\times10^{-2}M}$

$[H_3O^+] = 1.2\times10^{-13}$

$[OH^-] > [H_3O^+]$

$8.4\times10^{-2}M > 1.2\times10^{-13}M$

* makes sense since $Sr(OH)_2$ is a STRONG base.