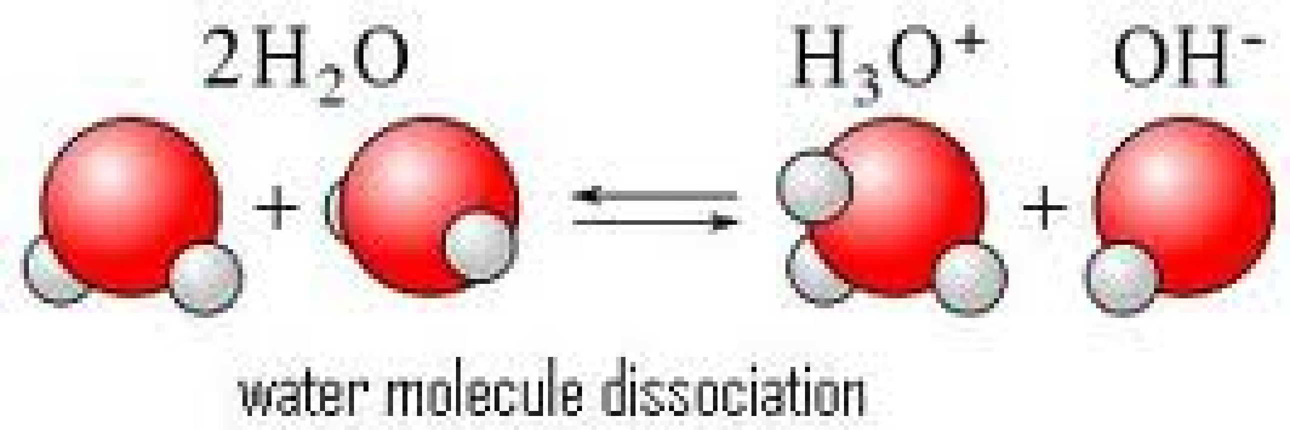
Equilibrium of Water



Outcomes:

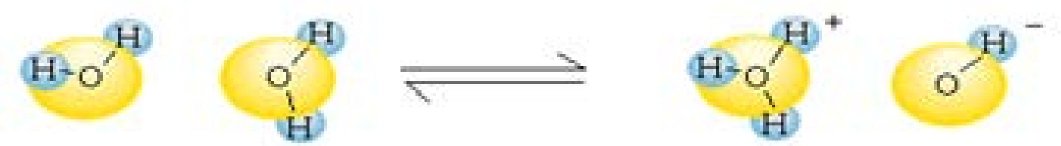
- Discuss the hydronium and hydroxide concentrations in water. Include the ion product of water.
- Given and one of the values pH, $[H_3O^+]$, $[OH^-]$, find the remaining values.

Equilibrium of Water:

Self-Ionization (Autoionization) of Water:

- Experiments have shown that **PURE WATER** can **CONDUCT** electricity **VERY SLIGHTLY**.
- Water can act as a **PROTON DONOR** and **ACCEPTOR** for **ITSELF**.
- When a **PROTON** is **TRANSFERRED** from one water molecule to another, the result is H_3O^+ and OH^-.

i.e.)



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

This equilibrium can also be written as:

$$H_2O_{(l)} \leftrightarrow H^+_{(aq)} + OH^-_{(aq)}$$

Equilibrium of Water:

- In the above equilibrium, water acts as **BOTH** an **ACID** and a **BASE** → **AMPHOTERIC**
- Very few water molecule swill **AUTOIONIZE** (2 in 1 billion).
- The water equilibrium will obey the **LAW** of **MASS** **ACTION**, so:

$$K_{eq} = \frac{[H^+_{(aq)}][OH^-_{(aq)}]}{[H_2O_{(l)}]}$$

- Recall that **LIQUIDS** do **NOT** appear in an equilibrium law, so:

$$K_{eq} = [H^+_{(aq)}][OH^-_{(aq)}]$$

- It has been determined that at 25°C, $[H^+]$ and $[OH^-]$ are **$1x10^{-7}$ M**. Therefore,

$$K_{eq} = [1x10^{-7}][1x10^{-7}] = 1.0x10^{-14}$$ — Kw

- This value is called the **ION PRODUCT CONSTANT** for **WATER (Kw)**

Kw & Temperature:

Note: **K_w** will change with **TEMPERATURE**!

Effect of Temperature on K_w

$$H_2O_{(l)} + 56.4kJ \leftrightarrow H^+_{(aq)} + OH^-_{(aq)}$$

- If we increase the **TEMPERATURE** → reaction shifts **RIGHT** to reduce excess **HEAT**.
  - *[H^+] and [OH^-] will increase*
  - *[H_2O] will decrease*

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- If we increase temperature to 60°C, [H^+] and [OH^-] become $3.0x10^{-2}$ M, therefore:

$$K_w = [3.0x10^{-2}][3.0x10^{-2}] = 9.55x10^{-4}$$

Note:

→*Always assume temperature is 25°C, unless otherwise told, so K_w=1.0x10^{-14}*

Not all solutions are neutral:

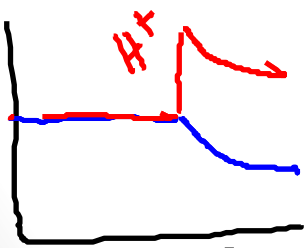
Le Chatelier's Principle applies to acidic/basic solutions…

Addition of $[H^+]$ or $[OH^-]$ will **SHIFT** the equilibrium, **DECREASING** the concentration of the **OTHER ION**.

- i.e. If $[H^+]$ increases, $[OH^-]$ will decrease (and vice versa)

1. ***Neutral Solutions:***
   - - ***$[H^+]$ and $[OH^-]$ are equal, ($1x10^{-7}$ M)***

2. ***Acidic Solutions:***
   - ***$[H^+]$ is greater than $[OH^-]$ ($[H^+] > 1.0x10^{-7}$ M)***
   - What would happen to $[H^+]$ and $[OH^-]$ if HCl is added to water?



$$H_2O_{(l)} \leftrightarrow H^+_{(aq)} + OH^-_{(aq)}$$

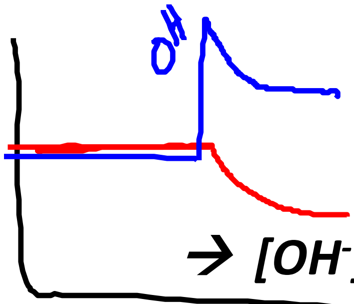
$$HCl_{(g)} \leftrightarrow H^+_{(aq)} + Cl^-_{(aq)}$$

→ $[H^+]$ increases (shifts to the left), so $[OH^-]$ decreases. Therefore pH will decrease.

Not all solutions are neutral:

3. ***Basic Solutions:***
   - ***$[OH^-]$ is greater than $[H^+]$. ($[OH^-] > 1.0x10^{-7}$ M)***
   - What would happen to $[H^+]$ and $[OH^-]$ if NaOH is added to water?

$$H_2O_{(l)} \leftrightarrow H^+_{(aq)} + OH^-_{(aq)}$$



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

→ ***$[OH^-]$ increases (shifts to the left), so $[H^+]$ decreases. Therefore pH will increase.***

- If we know the concentration of either $[H^+]$ or $[OH^-]$, we can use the mass action expression and K_w to find the other concentration.

- We can use these concentrations to determine whether a solution is acidic or basic.

If, ***$[H^+] > 1.0x10^{-7}$ M → Acidic***
$[OH^-] > 1.0x10^{-7}$ M → Basic

Example:

If $[H^+]$ = 1.0 x 10^{-5} M, find the $[OH^-]$ and determine whether the solution is acidic, basic, or neutral.

Sol$^{\underline{n}}$

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

$$1 \times 10^{-14} = (1 \times 10^{-5})[OH^-]$$

$$[OH^-] = 1 \times 10^{-9} \frac{mol}{L}$$

∴ Solution is acidic $[H^+] > [OH^-]$

$$[H^+] > 1 \times 10^{-7} \frac{mol}{L}$$

Try these ones:

1. If the $[OH^-]$ is 1.0×10^{-3} M, what is the $[H^+]$ in the solution, and determine whether the solution is acidic, basic, or neutral.

$$K_w = [H_3O^+][OH^-]$$
$$1 \times 10^{-14} = [H_3O^+](1 \times 10^{-3})$$
$$[H_3O^+] = 1 \times 10^{-11} \frac{mol}{L}$$

∴ Basic
$[OH^-] > [H_3O^+]$

2. What is the $[H^+]$ in a solution of 0.030 M ~~NaOH~~ $Mg(OH)_2$? Determine whether the solution is acidic or basic.

$$Mg(OH)_2 \longrightarrow Mg^{2+} + 2OH^-$$
$$0.03 \frac{mol}{L} \qquad\qquad 0.06 \frac{mol}{L}$$

$$K_w = [H_3O^+][OH^-]$$
$$1 \times 10^{-14} = [H_3O^+](0.06)$$
$$[H_3O^+] = 1.67 \times 10^{-13} \frac{mol}{L}$$

∴ Soln is Basic