

6. Equilibrium Dissociation for Water, Acids and Bases

a) What is Dissociation of Water?

i) Liquid water is in equilibrium with its aqueous ions:



ii) $K_w = [\text{H}_3\text{O}^+][\text{OH}^-] = 1.00 \times 10^{-14}$

iii) Water is neutral so: $[\text{H}_3\text{O}^+] = [\text{OH}^-]$

b) What Does K_w Tell Us Immediately?

i) There will always be a wee bit of **acid** in an aqueous solution. Even in a strong base! Since the value is so small, if a strong base is present, we can ignore the value!

ii) What is $[\text{H}_3\text{O}^+]$ in water?

$$K_w = [\text{H}_3\text{O}^+][\text{OH}^-] = 1.00 \times 10^{-14}$$

Since $[\text{H}_3\text{O}^+] = [\text{OH}^-]$ $[x][x] = 1.00 \times 10^{-14}$ **$x = 1.00 \times 10^{-7} \text{ M}$**

iii) There will always be a wee bit of **base** in an aqueous solution. Even in a strong acid! Since the value is so small, if a strong acid is present, we can ignore the value!

iv) What is $[\text{OH}^-]$ in water?

$$K_w = [\text{H}_3\text{O}^+][\text{OH}^-] = 1.00 \times 10^{-14}$$

Since $[\text{H}_3\text{O}^+] = [\text{OH}^-]$ $[x][x] = 1.00 \times 10^{-14}$ **$x = 1.00 \times 10^{-7} \text{ M}$**

c) Use of K_w Expression

i) We can find the $[\text{OH}^-]$ if we know the $[\text{H}_3\text{O}^+]$ and vice versa!

ii) Example: What is $[\text{H}_3\text{O}^+]$ and $[\text{OH}^-]$ in 0.015M HCl?

① HCl is a strong acid, so is 100% dissociated

② Therefore $[\text{HCl}] = [\text{H}_3\text{O}^+] = 0.015\text{M}$

$$\textcircled{3} [\text{OH}^-] = \frac{K_w}{[\text{H}_3\text{O}^+]} = \frac{1.00 \times 10^{-14}}{0.015\text{M}} = 6.7 \times 10^{-13} \text{ M}$$

iii) Example: What is $[\text{H}_3\text{O}^+]$ and $[\text{OH}^-]$ in $1.5 \times 10^{-6} \text{ M}$ NaOH?

① NaOH is a metal hydroxide, so is a strong base, so is 100% dissociated

② Therefore $[\text{NaOH}] = [\text{OH}^-] = 1.5 \times 10^{-6} \text{ M}$

$$\textcircled{3} [\text{H}_3\text{O}^+] = \frac{K_w}{[\text{OH}^-]} = \frac{1.00 \times 10^{-14}}{1.5 \times 10^{-6} \text{ M}} = 6.7 \times 10^{-9} \text{ M}$$

d) Acid Dissociation

i) Recall, only weak acids will form an equilibrium.



$$\text{ii) } K_a = \frac{[\text{HS}^-][\text{H}_3\text{O}^+]}{[\text{H}_2\text{S}]} = 9.1 \times 10^{-8}$$

iii) K_a is called the Acid Ionization Constant

iv) The greater the value of K_a , the stronger the acid (see Table of Relative Strengths of Acids p.334)

v) Example: Write the reaction and the K_a expression of H_2SO_3 with water



$$K_a = \frac{[\text{HSO}_3^-][\text{H}_3\text{O}^+]}{[\text{H}_2\text{SO}_3]} = 1.5 \times 10^{-2}$$

d) Base Dissociation

i) Recall, only weak bases will form an equilibrium.



$$\text{ii) } K_b = \frac{[\text{HCO}_3^{-}][\text{OH}^{-}]}{[\text{CO}_3^{2-}]} = 1.8 \times 10^{-4}$$

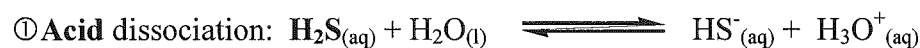
iii) K_b is called the Base Ionization Constant

iv) The greater the value of K_b , the stronger the base.

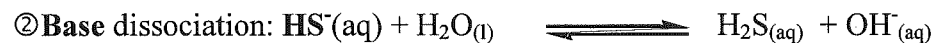
e) Finding K_b

i) Theory

There is a relationship between K_a and K_b



$$K_a = \frac{[\text{HS}^{-}][\text{H}_3\text{O}^{+}]}{[\text{H}_2\text{S}]} = 9.1 \times 10^{-8}$$



$$K_b = \frac{[\text{H}_2\text{S}][\text{OH}^{-}]}{[\text{HS}^{-}]} = 1.1 \times 10^{-7}$$

$$\text{③ } K_a \times K_b = \frac{[\text{HS}^{-}][\text{H}_3\text{O}^{+}]}{[\text{H}_2\text{S}]} \times \frac{[\text{H}_2\text{S}][\text{OH}^{-}]}{[\text{HS}^{-}]} = [\text{H}_3\text{O}^{+}][\text{OH}^{-}] = K_w$$

ii) Procedure:

① Look on *Base side* of Table of Relative Strengths to find your base species

② Find the K_a for the reverse reaction.

③ Calculate K_b from $K_a \times K_b = K_w$

iii) Example: Find the K_b for SO_4^{2-}



$$K_b = K_w / K_a = 1.00 \times 10^{-14} / 1.2 \times 10^{-2} = 8.3 \times 10^{-13}$$

Do questions: #29-30 page 127; #31-34 page 128; #35-37 page 130