6.4 – Calculating $[H_3O^+]$ and $[OH^-]$ - Worksheet

1. Calculate $[H^+]$ in a 2.00 L solution of HCl in which 3.65 g of HCl is dissolved.

↳ 36.46 g/mol

$$M = \frac{wt}{mm \cdot V} = \frac{3.65g}{(36.46)(2L)} = 0.0501\,M$$

$$HCl_{(aq)} + H_2O_{(l)} \rightarrow H_3O^+_{(aq)} + Cl^-_{(aq)}$$

[0.0501 M] 0.0501M = $[H_3O^+]$

2. Calculate $[H^+]$ in a solution containing 3.20 g of HNO_3 in 250 mL of solution.

63.02 g/mol

$$HNO_{3(aq)} + H_2O_{(l)} \rightarrow H_3O^+_{(aq)} + NO_3^-_{(aq)}$$

$$M = \frac{wt}{mm \cdot V} = \frac{3.20g}{(63.02\,g/mol)(.25L)} = 0.203M$$

$\therefore [H_3O^+] = 0.20\,M$

3. An acetic acid ($HC_2H_3O_2$) solution is 0.25 M. Find $[H_3O^+]$. $Ka = 1.8 \times 10^{-5}$

$$HC_2H_3O_{2\,(aq)} + H_2O_{(l)} \rightleftharpoons H_3O^+_{(aq)} + C_2H_3O_2^-_{(aq)}$$

(0.25M) let $[H_3O^+] = x$

$$Ka = \frac{[H_3O^+][C_2H_3O_2^-]}{[HC_2H_3O_2]} \qquad 1.8\times10^{-5} = \frac{x^2}{0.25M}$$

$\sqrt{4.5\times10^{-6}M} = \sqrt{x^2}$ $\therefore x = 0.00212\,M$

$\therefore [H_3O^+] = 0.002$

4. A 500.0 mL solution contains 12.0 g of hydrofluoric acid. Calculate $[H^+]$.

$Ka = 6.7\times10^{-4}$

20.01 g/mol

$$M = \frac{wt}{mm \cdot V} = \frac{12.0g}{(20.01\,g/mol)(0.5L)} = 1.2M$$

let $[H_3O^+] = [F^-] = x$

$$HF_{(aq)} + H_2O_{(l)} \rightleftharpoons H_3O^+ + F^-$$

$$Ka = \frac{[H_3O^+][F^-]}{[HF]} \qquad 6.7\times10^{-4} = \frac{x^2}{1.2M}$$

$\therefore x = 0.02835\,M$

$\boxed{\therefore [H_3O^+] = 0.0284M}$

$\rightarrow 122.13 g/mol$

5. When 1.22 g of benzoic acid (C_6H_5COOH) is dissolved to make 1.00L of solution, the resulting $[H^+]$ = 8.0x10^{-4}M. Determine the K_a of the acid.

Initial: $M = \frac{wt}{mm \cdot V} = \frac{1.22g}{(122.13 \frac{g}{mol})(1L)} = 0.01M \Rightarrow [C_6H_5COOH]$

Equilibrium:
$[H^+] = 8.0 \times 10^{-4} M$
$[C_6H_5COO^-] = 8.0 \times 10^{-4} M$
$[C_6H_5COOH] = 0.01M - 8.0 \times 10^{-4} M = 0.0092M$

$Ka = \frac{[C_6H_5COO^-][H^+]}{[C_6H_5COOH]} = \frac{(8.0 \times 10^{-4})^2}{0.0092} = 6.956 \times 10^{-5}$

$\boxed{Ka = 7.0 \times 10^{-5}}$

$C_6H_5COOH_{(aq)} \rightleftharpoons C_6H_5COO^-_{(aq)} + H^+_{(aq)}$
0.1M 8.0×10^{-4}

6. Calculate $[H^+]$ **and** $[OH^-]$ at 25° C in:

a. a 5.0 M NaOH solution. NaOH is a strong base.

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

$\boxed{[NaOH] = [OH^-] = 5.0M}$

$Kw = [OH^-][H^+]$
$1.0 \times 10^{-14} = (5.0M)[H^+]$
$\therefore \boxed{[H^+] = 2.0 \times 10^{-15}}$

b. a 0.025 M ~~KOH~~ $Ca(OH)_2$ solution. ~~KOH~~ $Ca(OH)_2$ is a strong base.

$Ca(OH)_2 \rightarrow Ca^{2+}_{(aq)} + 2OH^-_{(aq)}$

$[OH^-] = 2[Ca(OH)_2]$
$= 2(0.025M)$
$\boxed{[OH^-] = 0.05M}$

$Kw = [OH^-][H^+]$
$1.0 \times 10^{-14} = (0.05M)[H^+]$
$\boxed{[H^+] = 2.0 \times 10^{-13}}$

c. a 0.10 M hypochlorous acid solution.

HClO = weak

$HClO \rightleftharpoons H^+_{(aq)} + ClO^-_{(aq)}$

$Ka = \frac{[H^+][ClO^-]}{[HClO]}$

$2.9 \times 10^{-8} = \frac{x^2}{0.10M}$

$\boxed{x = 5.38 \times 10^{-5} M = [H^+]}$

$K_w = [H^+][OH^-]$
$1.0 \times 10^{-14} = (5.38 \times 10^{-5})[OH^-]$
$\boxed{[OH^-] = 1.9 \times 10^{-10}}$

d. a 0.010 M Nitrous acid solution.

HNO_2 = weak

$HNO_{2(aq)} \rightleftharpoons H^+_{(aq)} + NO^-_{2(aq)}$
0.010M

$Ka = \frac{[H^+][NO_2^-]}{[HNO_2]}$

$5.1 \times 10^{-4} = \frac{x^2}{(0.01M)}$

$\boxed{\therefore x = 0.0023M = [H^+]}$

$Kw = [H^+][OH^-]$
$1.0 \times 10^{-14} = (0.0023M)[OH^-]$
$\boxed{[OH^-] = 4.3 \times 10^{-12} M}$