Name ____ Date ____________________

MORE REVIEW

1. Calculate the pH of each of the following solutions in water.
   a. 0.10 M HCl
   b. 5.0 M HCl
   c. 1.0×10^{-11} M HCl

$HCl \rightarrow H^+ + Cl^-$

$[HCl] = [H^+]$

a) pH = −log(0.10) = 1

b) pH = −log(5.0) = −0.70

c) pH = −log(1.0×10^{-11}) = ~~11~~ 7

2. Calculate the pH of each of the following solutions in water.
   a. 0.10 M NaOH
   b. 5.0 M NaOH
   c. 1.0×10^{-11} M NaOH

$NaOH \rightarrow Na^+ + OH^-$

$[NaOH] = [OH^-]$

a) pOH = −log(0.10) = 1 pH = 13

b) pOH = −log(5.0) = −0.70 pH = 14.7

c) pOH = −log(1.0×10^{-11}) = 11 pH = ~~3~~ 7

3. A solution is prepared by adding 50.0 ml of 0.050 M HCl to 150.0 ml of 0.10 M HNO_3. Calculate the concentrations of all species in this solution.

HCl M = moles / L

0.050 M = x / 0.050 L

x = 0.0025 moles HCl

$HCl \rightarrow H^+ + Cl^-$

$[H^+]$ = 0.0175 moles / 0.200 L = 0.0875 M

$[Cl^-]$ = 0.0025 moles / 0.200 L = 0.0125 M

$[NO_3^-]$ = 0.015 moles / 0.200 L = 0.075 M

HNO_3 M = moles / L

0.10 M = x / 0.150 L

x = 0.015 moles HNO_3

$HNO_3 \rightarrow H^+ + NO_3^-$

4. Formic acid (HCO_2H) is secreted by ants. Calculate $[H^+]$ and the pH of a 0.025 M solution of formic acid ($K_a = 1.8 \times 10^{-4}$)

$$K_a = \frac{[H^+][HCO_2^-]}{[HCO_2H]}$$

	HCO_2H	$\rightarrow$ H^+	+ HCO_2^-
I	.025	0	0
C	$-x$	$+x$	$+x$
E	$.025-x$	x	x

$$1.8\times10^{-4} = \frac{x^2}{.025-x}$$

$x = .00212$

5% ✓

$.05(.025) = .00125$

FAILS!

$$1.80\times10^{-4}(.025-x) = x^2$$

$$4.5\times10^{-6} - 1.80\times10^{-4}x - x^2 = 0$$

$$x^2 + 1.80\times10^{-4}x - 4.5\times10^{-6} = 0$$

$$\frac{-(1.80\times10^{-4}) \pm\sqrt{(+1.8\times10^{-4})^2 - 4(1)(-4.5\times10^{-6})}}{2}$$

$$\frac{-1.8\times10^{-4} \pm 0.00425}{2}$$

$x = 2.04\times10^{-3}$

$pH = -\log(2.04\times10^{-3}) = 2.69$

5. A 0.20 M solution of a weak acid is 2.5% dissociated. Calculate the K_a.

$HA \rightleftharpoons H^+ + A^-$

	HA	H^+	A^-
I	0.20	0	0
C	-x	+x	+x
E	0.20 - x	x	x

$x = (0.20)(0.025) = 0.005$

$K_a = \frac{[H^+][A^-]}{[HA]} = \frac{(0.005)^2}{0.20} = 1.25 \times 10^{-4}$

6. Arsenic acid (H_3AsO_4) is a triprotic acid with $K_{a1} = 5 \times 10^{-3}$, $K_{a2} = 8 \times 10^{-8}$, and $K_{a3} = 6 \times 10^{-10}$. Calculate $[H^+]$, $[OH^-]$, $[H_3AsO_4]$, $[H_2AsO_4^-]$, $[HAsO_4^{-2}]$ and $[AsO_4^{-3}]$ in a 2.0 M arsenic acid solution.

$H_3AsO_4 \rightleftharpoons H^+ + H_2AsO_4^-$

	H_3AsO_4	H^+	$H_2AsO_4^-$
I	2.0	0	0
C	-x	+x	+x
E	2.0 - x	x	x

$K_{a1} = \frac{[H^+][H_2AsO_4^-]}{[H_3AsO_4]}$

$5 \times 10^{-3} = \frac{x^2}{2.0 - x}$

$x = 0.10 M = [H^+] = [H_2AsO_4^-]$

5% $\frac{0.10}{2.0} \times 100 = 5\%$ ✓ $[H_3AsO_4] = 2.0 M$

$H_2AsO_4^- \rightleftharpoons H^+ + HAsO_4^{-2}$

	$H_2AsO_4^-$	H^+	$HAsO_4^{-2}$
I	0.10	0.10	0
C	-x	+x	+x
E	0.10 - x	0.10 + x	x

$K_{a2} = \frac{[H^+][HAsO_4^{-2}]}{[H_2AsO_4^{-1}]} = \frac{(0.10 + x)(x)}{0.10 - x}$

$x = K_{a2} = 8 \times 10^{-8} M = [HAsO_4^{-2}]$

* has to be insignificant

$$HAsO_4^{-2} \rightleftharpoons H^+ + AsO_4^{-3}$$

	$HAsO_4^{-2}$	H^+	AsO_4^{-3}
I	8×10^{-8}	0.10	0
C	$-x$	$+x$	$+x$
E	$8\times10^{-8}-x$	$0.10+x$	x

$$K_{a3} = \frac{[H^+][AsO_4^{-3}]}{[HAsO_4^{-2}]}$$

$$6\times10^{-10} = \frac{(0.10+x)(x)}{8\times10^{-8}-x}$$

$x = 4.8\times10^{-16}$ M $= [AsO_4^{-3}]$

* has to be insignificant

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

$$[OH^-] = \frac{1\times10^{-14}}{0.10} = 1\times10^{-13} M$$

7. Calculate the pH of a 2.0 M H_2SO_4 solution.

$$H_2SO_4 \longrightarrow H^+ + HSO_4^-$$

$[H_2SO_4] = [H^+] = 2.0M$

$$HSO_4^- \rightleftharpoons H^+ + SO_4^{-2}$$

	HSO_4^-	H^+	SO_4^{-2}
I	2.0	2.0	0
C	$-x$	$+x$	$+x$
E	$2.0-x$	$2.0+x$	x

$$K_a = \frac{[H^+][SO_4^{-2}]}{[HSO_4^-]} = 1.2\times10^{-2}$$

$$= \frac{(2.0+x)(x)}{2.0-x}$$

$x = 1.2\times10^{-2}$

5% $\frac{1.2\times10^{-2}}{2.0}\times100 = 0.6\%$ ✓

$[H^+] = 2.0$ M

pH = $-\log(2.0) = -0.30$

8. Calculate the pH of a solution that contains 1.23 M benzoic acid, C_6H_5COOH (K_a = 6.14×10^{-5}) and .713 M arsenious acid H_3AsO_3 ($K_a = 6.0 \times 10^{-10}$). What is the concentration of the benzoate ion ($C_6H_5COO^-$), hydroxide ion (OH^-) and arsenite ion ($H_2AsO_3^-$)?

$C_6H_5COOH \rightleftharpoons H^+ + C_6H_5COO^-$ $K_a = 6.14 \times 10^{-5}$

$H_3AsO_3 \rightleftharpoons H^+ + H_2AsO_3^-$ $K_a = 6.0 \times 10^{-10}$

$H_2O \rightleftharpoons H^+ + OH^-$ $K_w = 1 \times 10^{-14}$

$C_6H_5COOH \rightleftharpoons H^+ + C_6H_5COO^-$

	C_6H_5COOH	H^+	$C_6H_5COO^-$
I	1.23	0	0
C	$-x$	$+x$	$+x$
E	$1.23 - x$	x	x

$$K_a = \frac{[H^+][C_6H_5COO^-]}{[C_6H_5COOH]}$$

$$6.14 \times 10^{-5} = \frac{x^2}{1.23 - x}$$

$x = 8.7 \times 10^{-3}$ M $= [H^+] = [C_6H_5COO^-]$

$H_3AsO_3 \rightleftharpoons H^+ + H_2AsO_3^-$

	H_3AsO_3	H^+	$H_2AsO_3^-$
I	0.713	8.7×10^{-3}	0
C	$-x$	$+x$	$+x$
E	$0.713 - x$	$8.7 \times 10^{-3} + x$	x

$$K_a = \frac{[H^+][H_2AsO_3^-]}{[H_3AsO_3]}$$

$$6.0 \times 10^{-10} = \frac{(8.7 \times 10^{-3} + x)(x)}{(0.713 - x)}$$

$x = 4.9 \times 10^{-8}$ M $= [H_2AsO_3^-]$

$$5\% = \frac{4.9 \times 10^{-8}}{0.713} \times 100 = 6.9 \times 10^{-6}\% \checkmark$$

$$[OH^-] = \frac{1 \times 10^{-14}}{8.7 \times 10^{-3}} = 1.15 \times 10^{-12} \text{ M}$$

$$pH = -\log(8.7 \times 10^{-3}) = 2.06$$

9. Calculate the $[OH^-]$, $[H^+]$ and the pH of 0.20 M solution of hydroxylamine ($HONH_2$, K_b = 1.1×10^{-8})

$HONH_2 + H_2O \rightleftharpoons HONH_3^+ + OH^-$

I 0.20 — 0 — 0

C −x — +x — +x

E 0.20 − x — x — x

$K_b = \frac{[HONH_3^+][OH^-]}{[HONH_2]} = 1.1 \times 10^{-8} = \frac{x^2}{0.20 - x}$

$x = 4.69 \times 10^{-5}$ M = [H+]

5% $\frac{4.69 \times 10^{-5}}{0.2} \times 100 = 0.023\%$ ✓

$pH = -\log(4.69 \times 10^{-5}) = 4.33$

$[OH^-] = \frac{K_w}{[H^+]} = \frac{1 \times 10^{-14}}{4.69 \times 10^{-5}} = 2.13 \times 10^{-10}$ M

10. Calculate the concentration of all species and the pH of a 0.10 M NH_4NO_3 solution. The Kb for ammonia is 1.8×10^{-5}

$NH_4NO_3 \rightarrow NH_4^+ + NO_3^-$

$NH_4^+ \rightleftharpoons H^+ + NH_3$

I 0.10 — 0 — 0

C −x — +x — +x

E 0.10 − x — x — x

$K_a = \frac{K_w}{K_b} = \frac{1 \times 10^{-14}}{1.8 \times 10^{-5}} = 5.56 \times 10^{-10} = \frac{[H^+][NH_3]}{[NH_4^+]}$

$5.56 \times 10^{-10} = \frac{x^2}{0.10 - x}$

$x = 7.5 \times 10^{-6}$ M = [H+]

5% $\frac{7.5 \times 10^{-6}}{0.10} \times 100 = 7.5 \times 10^{-3}\%$ ✓

$pH = -\log(7.5 \times 10^{-6}) = 5.12$

11. Calculate the concentration of all species and the pH in a 0.010 M solution of NaN_3. The Ka for hydrozoic acid (HN_3) is 1.9×10^{-5}.

$$NaN_3 \rightleftharpoons Na^+ + N_3^-$$

$$N_3^- + H_2O \rightleftharpoons HN_3 + OH^-$$

$$K_b = \frac{K_w}{K_a} = \frac{1.0 \times 10^{-14}}{1.9 \times 10^{-5}} = 5.3 \times 10^{-10}$$

	N_3^- + H_2O	$\rightleftharpoons$ HN_3	+ OH^-
I	0.010	0	0
C	−x	x	x
E	0.010 − x	x	x

$$K_b = \frac{[HN_3][OH^-]}{[N_3^-]} = 5.3 \times 10^{-10} = \frac{x^2}{0.010 - x}$$

$x = 2.3 \times 10^{-6}\ M = [OH^-]$

$0.05(0.010) = 5 \times 10^{-4}$ ✓

$[HN_3] = [OH^-] = 2.3 \times 10^{-6}\ M$

$[Na^+] = 0.010\ M$

$[N_3^-] = 0.010$

$$[H^+] = \frac{1.0 \times 10^{-14}}{2.3 \times 10^{-6}} = 4.3 \times 10^{-9}\ M$$