AP Chemistry Review: Chapter 15

1. Calculate the pH of a solution of 2.0 M HF when 1.5 M KF is added to it. (Ka for HF = 7.2×10^{-4}) (Answer: pH = 3.02)

$HF \rightleftharpoons H^+ + F^-$

	HF	H^+	F^-
I	2.0 M	~0	1.5 M
C	−x	+x	+x
E	2.0 − x	x	1.5 + x

$K_a = 7.2 \times 10^{-4} = \frac{(x)(1.5+x)}{(2.0-x)}$ $\quad x = 9.60 \times 10^{-4}$

$[H^+] = x = 9.60 \times 10^{-4}$ $\quad$ pH = 3.02

OR $\quad pH = -\log(7.2 \times 10^{-4}) + \log\left(\frac{1.5\ M}{2.0\ M}\right)$

2. Calculate the pH of a buffered solution that is made by adding 1.5 M HNO_2 and 1.5 M $NaNO_2$. (Ka for HNO_2 is 4.0×10^{-4}.) (Answer: pH = 3.40)

$HNO_2 \rightleftharpoons H^+ + NO_2^-$

	HNO_2	H^+	NO_2^-
I	1.5 M	~0	1.5 M
C	−x	+x	+x
E	1.5 − x	x	1.5 + x

$HNO_2, NO_2^-, Na^+, H_2O$

$K_a = 4.0 \times 10^{-4} = \frac{x(1.5+x)}{(1.5-x)}$

$x = [H^+] = 4.0 \times 10^{-4}$

pH = 3.40

OR

$pH = -\log(4.0 \times 10^{-4}) + \log\left(\frac{1.5}{1.5}\right)$

3. How would the pH in number two change if 0.30 mol of HCl is added to 1.0 L of the solution in number 2? (Answer: pH = ~~4.00~~ 3.22)

$HNO_2, NO_2^-, Na^+, H^+, H_2O, Cl^-$

$H^+ + NO_2^- \rightleftharpoons HNO_2$

	H^+	NO_2^-	HNO_2
B	0.3 mol	1.5 mol	1.5 mol
Δ	−0.3 mol	−0.3 mol	+0.3 mol
A	0	1.2 mol	1.8 mol

$HNO_2 \rightleftharpoons H^+ + NO_2^-$

	HNO_2	H^+	NO_2^-
I	1.8 mol	~0	1.2 mol
C	−x	+x	+x
E	1.8 − x	x	1.2 + x

$K_a = 4.0 \times 10^{-4} = \frac{x(1.2+x)}{(1.8-x)}$

$x = [H^+] = 6.0 \times 10^{-4}$ $\quad$ pH = 3.22

OR

$pH = -\log(4.0 \times 10^{-4}) + \log\left(\frac{1.2}{1.8}\right)$

4. Bromthymol blue, an indicator with a Ka value of 1.0×10^{-7}, is yellow in its HIn form and blue in its In- form. Suppose we put a few drops of this indicator in a strongly acidic solution. If the solution is then titrated with NaOH, at what pH will the indicator color change first be visible? (Answer: pH = ~~6.00~~ 6.00)

See p. 743 for book example!

$K_a = 1.0 \times 10^{-7} = \frac{[H^+][In^-]}{[HIn]}$

Color Δ is visible when $\frac{[In^-]}{[HIn]} = \frac{1}{10}$

$K_a = 1.0 \times 10^{-7} = \frac{[H^+]\ 1}{10}$

$[H^+] = 1.0 \times 10^{-6}$ $\quad$ pH = 6.00

HIn ⇌ In^- + H^+ (strong acid)

↑ HIn yellow. Color Δ occurs when In^- ↑ to 10x HIn

(20.0 mL × 0.500 M = 10.0 mmol $HC_2H_3O_2$) CH_3COOH Na^+ OH^-

5. In the titration of 20.00 mL of 0.500 M CH_3COOH with 0.500 M NaOH. (Ka for acetic acid is 1.8×10^{-5}).

   a. Calculate the pH at the point in the titration where 7.45 mL of 0.500 M NaOH has been added. (Answer: pH = 4.52) (7.45 mL)(0.500 M) = 3.725 mmol OH^-

	OH^-	+ $HC_2H_3O_2$	⇌ H_2O	+ $C_2H_3O_2^-$
B	3.725 mmol	10 mmol		0
Δ	−3.725 mmol	−3.725 mmol		+3.725 mmol
A	0	6.275 mmol		3.725 mmol

	$HC_2H_3O_2$	⇌ H^+	+ $C_2H_3O_2^-$
I	$\frac{6.275\text{ mmol}}{27.45\text{ mL}} = .23\text{M}$	~0	$\frac{3.725\text{ mmol}}{27.45\text{ mL}} = 0.136\text{M}$
C	−x	+x	+x
E	0.23 − x	x	0.136 + x

OR $pH = -\log(1.8\times10^{-5}) + \log\left[\frac{(.136)}{(.23)}\right]$

$K_a = 1.8\times10^{-5} = \frac{x(0.136+x)}{(0.23-x)}$ $x = 3.04\times10^{-5} = [H^+]$

pH = 4.52

   b. Calculate the pH at the point in the titration where 20.00 mL of NaOH has been added. (Answer: pH = 9.07) (20.0 mL)(.500 M) = 10 mmol OH^- Equiv. pt!

	OH^-	+ $HC_2H_3O_2$	⇌ H_2O	+ $C_2H_3O_2^-$
B	10	10		0
Δ	−10	−10		+10
A	0	0		10 mmol

	$C_2H_3O_2^-$	+ H_2O	⇌ $HC_2H_3O_2$	+ OH^-
I	$\frac{10\text{ mmol}}{40\text{ mL}} = .25\text{M}$		0	~0
C	−x		+x	+x
E	.25 − x		x	x

OR pH = −log(1.8×10⁻⁵) + log(.25M)

$K_b = \frac{K_w}{K_a} = 5.6\times10^{-10} = \frac{x^2}{.25}$ $x = 1.18\times10^{-5}$ = [OH⁻]

pOH = 4.93

pH = 9.07

6. Calculate the K_{sp} value for bismuth sulfide (Bi_2S_3), which has a solubility of 1.0×10^{-15} mol/L at 25°C. (Answer: $K_{sp} = 1.1 \times 10^{-73}$)

$Bi_2S_3 \rightleftharpoons 2Bi^{3+} + 3S^{2-}$

	Bi_2S_3	⇌	$2Bi^{3+}$	+	$3S^{2-}$
I			0		0
C			2(x)		3(x)
E	1.0×10^{-15}		$2(1.0\times10^{-15})$		$3(1.0\times10^{-15})$

$Bi_2S_{3(s)} \rightleftharpoons 2Bi^{3+} + 3S^{2-}$

$K_{sp} = [Bi^{3+}]^2[S^{2-}]^3$

$K_{sp} = (2.0\times10^{-15})^2(3.0\times10^{-15})^3$

$K_{sp} = 1.1\times10^{-73}$

7. The K_{sp} value for copper (II) iodate, $Cu(IO_3)_2$, is 1.4×10^{-7} at 25°C. Calculate its solubility at 25°C. (Answer: 3.3×10^{-3} mol/L)

$Cu(IO_3)_2 \rightleftharpoons Cu^{2+} + 2IO_3^-$ $K_{sp} = [Cu^{2+}][IO_3^-]^2$

		Cu^{2+}	+	$2IO_3^-$
I		0		0
C		+x		+2x
E		x		2x

$1.4\times10^{-7} = (x)(2x)^2$

$1.4\times10^{-7} = 4x^3$

$x = 3.3\times10^{-3}$ mol/L

8. Write equations for the stepwise formation of the following complex ion: $Co(NH_3)_6^{2+}$

$Co^{2+} + NH_3 \rightleftharpoons Co(NH_3)^{2+}$

$Co(NH_3)^{2+} + NH_3 \rightleftharpoons Co(NH_3)_2^{2+}$

$Co(NH_3)_2^{2+} + NH_3 \rightleftharpoons Co(NH_3)_3^{2+}$

$Co(NH_3)_3^{2+} + NH_3 \rightleftharpoons Co(NH_3)_4^{2+}$

$Co(NH_3)_4^{2+} + NH_3 \rightleftharpoons Co(NH_3)_5^{2+}$

$Co(NH_3)_5^{2+} + NH_3 \rightleftharpoons Co(NH_3)_6^{2+}$