nChemistry 255
Spring 2011
Problem Set #5
Answer Key

1. 0 mL Na_2SO_4 added

have 0.0650 M Ca^{+2}

50.0 mL Na_2SO_4 added

initial Ca^{+2} = 0.0650 M x 0.025 L = 0.001625 moles Ca^{+2}

initial SO_4^{-2} = 0.01625 M x 0.050 L = 8.125 x 10^{-4} moles SO_4^{-2}

have 8.125 x 10^{-4} moles Ca^{+2} excess

$$\frac{8.125\times10^{-4} moles}{0.075L} = 1.083\times10^{-2} M \;\; Ca^{+2}$$

	Ca^{+2-} +	$SO4^{-2}$	$\Leftrightarrow$	$CaSO_4(s)$
Initial	$1.083x10^{-2}$	0		solid
Final	$1.083x10^{-2}$ + x	x		solid

Ksp = $[Ca^{+2}][SO_4^{-2}]$ = 2.4 x 10^{-5}

2.4 x 10^{-5} = ($1.083x10^{-2}$ + x)(x)

x2 + $1.083x10^{-2}$x – $2.4x10^{-5}$ = 0

x = $1.887x10^{-3}$ $[Ca^{+2}]$ = $1.887x10^{-3}$ +$1.083x10^{-2}$ = $1.27x10^{-2}$ M

$[Ca^{+2}]$ = $1.3x10^{-2}$ M

100.0 mL Na_2SO_4 added

initial Ca^{+2} = 0.0650 M x 0.025 L = 0.001625 moles Ca^{+2}

initial SO_4^{-2} = 0.01625 M x 0.100 L = 0.001625 moles SO_4^{-2}

have no excess Ca^{+2}

	Ca^{+2} +	$SO4^{-2}$	$\Leftrightarrow$ $CaSO_4(s)$
Initial	0	0	solid
Final	x	x	solid

Ksp = $[Ca^{+2}][SO_4^{-2}]$ = 2.4 x 10^{-5}

2.4 x $10^{-5} = x^2$

x = 4.9x10^{-3} M $[Ca^{+2}]$

125.0 mL Na_2SO_4 added

initial Ca^{+2} = 0.0650 M x 0.025 L = 0.001625 moles Ca^{+2}

initial SO_4^{-2} = 0.01625 M x 0.125 L = 2.03 x 10^{-3} moles SO_4^{-2}

have 4.06 x 10^{-4} moles SO_4^{-2} excess

$$\frac{4.06\times10^{-4}moles}{0.15L0} = 2.71\times10^{-3}M \ \ SO_4^{-2}$$

	Ca^{+2-} +	$SO4^{-2}$	$\Leftrightarrow$ $CaSO_4(s)$
Initial	0	2.71x10^{-3}	solid
Final	X	2.71x10^{-3} + X	solid

Ksp = $[Ca^{+2}][SO_4^{-2}]$ = 2.4 x 10^{-5}

2.4 x 10^{-5} = (X)(2.71x10^{-3} + X)

x2 + 2.71x10^{-3}X – 2.4x10^{-5} = 0

x = 3.7x10^{-3} $[Ca^{+2}]$

2. $8.65\ \text{g acetylsalicylic acid} \times \frac{1\ \text{mol}}{180.16\ \text{g}} = \frac{4.80 \times 10^{-2}\ \text{mol}}{0.750\text{L}} = 6.40\text{x}10^{-2}\ \text{M acetylsalicylic acid solution}$

0.00 mL NaOH

$$\frac{x^2}{0.0640 - x} = K_a = 3.24 \times 10^{-4} \Rightarrow x^2 + 3.24 \times 10^{-4} x - 2.074 \times 10^{-5} = 0$$

solve quadratic equation : $x = 4.395 \times 10^{-3} = [H^+]$

pH = 2.357

10.00 mL NaOH = 0.010 moles

	$HA +$	$OH^- \rightarrow$	$A^- + H_2O$
Initial	0.0480	0.010	0
Final	0.0380	0	0.010

pKa = 3.489

$$pH = 3.489 + \log \frac{0.010}{0.0380} = 2.909$$

$24.0\ \text{mL NaOH} = 0.0240\ \text{moles NaOH}$

	$HA +$	$OH^- \rightarrow$	$A^- + H_2O$
Initial	0.0480	0.0240	0
Final	0.0240	0	0.0240

$pKa = 3.489$

$$pH = 3.489 + \log\frac{0.024}{0.0240} = 3.489$$

$38.0\ \text{mL NaOH} = 0.0380\ \text{moles NaOH}$

	$HA +$	$OH^- \rightarrow$	$A^- + H_2O$
Initial	0.0480	0.038	0
Final	0.0100	0	0.0380

$pKa = 3.489$

$$pH = 3.489 + \log\frac{0.0380}{0.0100} = 4.069$$

$48.0\ \text{mL NaOH} = 0.0480\ \text{moles NaOH}$

	$HA\ +$	$OH^- \rightarrow$	$A^- + H_2O$
Initial	0.0480	0.0480	0
Final	0	0	0.0480

$$\frac{0.0480\ \text{moles}\ A^-}{0.798\ \text{L}} = 6.015\text{x}10^{-2}\ \text{M} = [A^-]$$

$$A^- + H_20 \Leftrightarrow HA + OH^-$$

	$A^-\ +$	$H_2O \rightarrow$	HA	$+\ OH^-$
Initial	F		0	0
Final	F - x		x	x

$$K_b = \frac{x^2}{F - x} = 3.086\text{x}10^{-11}$$

$$x^2 + 3.086\text{x}10^{-11} - 1.856\text{x}10^{-12} = 0$$

$x = 1.362\text{x}10^{-6} = [OH^-]$ $\quad pOH = 5.866$

$pH = 8.134$

$55.0\text{ mL NaOH} = 0.0550\text{ moles NaOH}$

use 0.0480 moles to get to equivalence point

have 0.0070 moles excess NaOH

$$[OH^-] = \frac{0.0070}{(0.750L + 0.0550L)} = \frac{0.0070}{0.805} = 8.696x10^{-3}\,M\,[OH^-]$$

$pOH = 2.061$

$pH = 11.939$

3. $49.00\text{ gm}/331.1\text{ gm/mol} = 0.148\text{ moles } H_2A$ $\quad 0.148\text{ moles}/1.000\text{ L} = 0.148\text{ M}$

0.00 mL NaOH

$$H_2A \Leftrightarrow H^+ + HA^- \qquad K_{a1}$$

$$\text{F - x} \qquad \text{x} \qquad \text{x}$$

$$\frac{x^2}{0.148 - x} = 1.00\times10^{-6} = K_{a1} \quad \text{solve quadratic equation: } x^2 + 1.00\times10^{-6}x - 1.48\times10^{-7} = 0$$

$x = 3.842\times10^{-4} = [H^+]$

pH = 3.415

36.00 mL NaOH $\qquad pKa_1 = 6.000$

$1.00\text{ M} * 0.0360\text{ L} = 0.0360\text{ moles } OH^-$

	H_2A +	OH^- $\Leftrightarrow$	HA^- + H_2O
Initial (rel)	0.148	0.0360	0
Final (rel)	0.112	0	0.036

$$pH = 6.000 + \log\frac{0.0360}{0.1120}$$

pH = 5.507

74.0 mL NaOH $\qquad pKa_1 = 6.000$

$1.00\text{ M} * 0.0740\text{ L} = 0.0740\text{ moles } OH^-$

	H_2A +	OH^- $\Leftrightarrow$	HA^- + H_2O
Initial (rel)	0.148	0.0740	0
Final (rel)	0.0740	0	0.0740

$$pH = 6.000 + \log\frac{0.0740}{0.0740}$$

pH = 6.000

142.00 mL NaOH $\qquad pKa_1 = 6.000$

$1.00\text{ M} * 0.1420\text{ L} = 0.1420\text{ moles } OH^-$

	H_2A +	OH^- $\Leftrightarrow$	HA^- + H_2O
Initial (rel)	0.148	0.1420	0
Final (rel)	0.0060	0	0.1420

$$pH = 6.000 + \log\frac{0.1420}{0.0060}$$

pH = 7.374

$148.00\text{ mL} = \text{first equivalence point}$

$$\text{All } H_2A \rightarrow HA^- \qquad [H^+] = \sqrt{\frac{K_1K_2F + K_1K_w}{K_1 + F}} \qquad K_{a1} = 1.00 \times 10^{-6} \qquad K_{a2} = 1.58 \times 10^{-9}$$

$$F = \frac{0.148\text{mole}}{1.148\text{L}} = 0.1289\text{ M } HA^-$$

$$[H^+] = \sqrt{\frac{(1.00 \times 10^{-6})(1.58 \times 10^{-9})(0.1289) + (1.00 \times 10^{-6})(1 \times 10^{-14})}{1.00 \times 10^{-6} + 0.1289}} = 3.975 \times 10^{-8}$$

$pH = 7.401$

$186.00\text{ mL NaOH} \qquad pKa_1 = 6.000 \qquad pKa_2 = 8.801$

$1.00\text{ M} * 0.186\text{ L} = 0.186\text{ moles } OH^- - 0.148\text{moles used to first eq. point} = 0.038\text{ moles left}$

	HA^- +	OH^-	$\Leftrightarrow$ $A^{-2} + H_2O$
Initial (rel)	0.148	0.038	0
Final (rel)	0.110	0	0.038

$$pH = 8.801 + \log\frac{0.038}{0.110}$$

$pH = 8.339$

$222.00\text{ mL NaOH} \qquad pKa_1 = 6.000 \qquad pKa_2 = 8.801$

$1.00\text{ M} * 0.222\text{ L} = 0.222\text{ moles } OH^- - 0.148\text{moles used to first eq. point} = 0.074\text{ moles left}$

	HA^- +	OH^-	$\Leftrightarrow$ $A^{-2} + H_2O$
Initial (rel)	0.148	0.074	0
Final (rel)	0.074	0	0.074

$$pH = 8.801 + \log\frac{0.074}{0.074}$$

$pH = 8.801$

$267.00\text{ mL NaOH} \qquad pKa_1 = 6.000 \qquad pKa_2 = 8.801$

$1.00\text{ M} * 0.267\text{ L} = 0.267\text{ moles } OH^- - 0.148\text{moles used to first eq. point} = 0.119\text{ moles left}$

	HA^- +	OH^-	$\Leftrightarrow$ $A^{-2} + H_2O$
Initial (rel)	0.148	0.119	0
Final (rel)	0.029	0	0.119

$$pH = 8.801 + \log\frac{0.119}{0.029}$$

$pH = 9.414$

$296\text{ mL} = \text{2nd equivalence point} \quad \text{All } HA^{-} \rightarrow A^{-2}$

$$F = \frac{0.148\text{moles}}{1.296\text{L}} = 0.1142\text{M}$$

$$A^{-2} + H_2O \Leftrightarrow HA^{-} + OH^{-} \qquad K_{b1} = \frac{1\times10^{-14}}{1.58\times10^{-9}} = 6.329\times10^{-6}$$

$$\frac{x^2}{0.1142 - x} = 6.329\times10^{-6} \quad \text{solve quadratic equation: } x^2 + 6.329\times10^{-6}x - 7.2278\times10^{-7} = 0$$

$x = 8.47\times10^{-4} = [OH^{-}]$

$pOH = 3.072$

$pH = 10.928$

325.00 mL

$1.00\text{ M} * 0.325\text{ L} = 0.325\text{ moles } OH^{-} - 0.296\text{moles used to second eq. point} = 0.029\text{ moles left}$

$$[OH^{-}] = \frac{0.029\text{moles}}{1.325\text{L}} = 2.189\text{x}10^{-2}\text{M}$$

$pOH = 1.6598$

$pH = 12.340$

4. (0.264 g Fe_2O_3) / (159.69 g/mol) = 1.65x10^{-3} moles Fe_2O_3

1.65x10^{-3} moles Fe_2O_3 x 2 = 3.306 x 10^{-3}moles Fe^{+3} = 3.306 x 10^{-3}moles $FeSO_4\cdot7H_2O$

3.306 x 10^{-3}moles $FeSO_4\cdot7H_2O$ x 278.01 g/mol = 0.919 g $FeSO_4\cdot7H_2O$

$$\frac{0.919g\ \ FeSO_4\cdot 7H_2O}{x\ \ g} in \frac{2.998g\ \ sample}{22.131g\ \ sample}$$

x = 6.7856 g $FeSO_4\cdot7H_2O$ in 20 tablets

$\therefore$6.7856 g $FeSO_4\cdot7H_2O$ in 20 tablets / 20 tablets = **0.339 g $FeSO_4\cdot7H_2O$ per tablet**

5.

0 mL added:	**pH = 10.92**
12.0 mL added:	**pH = 9.57**
½ V_e added:	**pH = 9.35**
30 mL added:	**pH = 8.15**
V_e added:	**pH = 5.53**
35.0 mL added:	**pH = 2.74**

6. 0 mL added: **pH = 11.36**

10.0 mL added: **pH = 10.21**

20.0 mL added: **pH = 9.73**

30.0 mL added: **pH = 9.25**

40.0 mL added: **pH = 7.53**

50.0 mL added: **pH = 5.81**

60.0 mL added: **pH = 5.33**

70.0 mL added: **pH = 4.86**

80.0 mL added: **pH = 3.41**

90.0 mL added: **pH = 2.11**

100.0 mL added: **pH = 1.85**