

nChemistry 255
Spring 2011
Problem Set #5
Answer Key

1. 0 mL Na₂SO₄ added

have 0.0650 M Ca⁺²

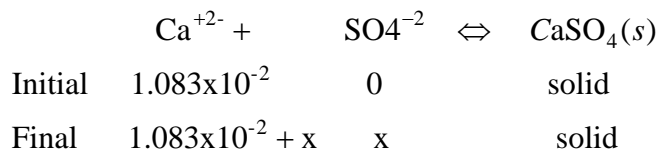
50.0 mL Na₂SO₄ added

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

initial SO₄⁻² = 0.01625 M x 0.050 L = 8.125 x 10⁻⁴ moles SO₄⁻²

have 8.125 x 10⁻⁴ moles Ca⁺² excess

$$\frac{8.125 \times 10^{-4} \text{ moles}}{0.075 \text{ L}} = 1.083 \times 10^{-2} \text{ M Ca}^{+2}$$



$$K_{sp} = [\text{Ca}^{+2}][\text{SO}_4^{-2}] = 2.4 \times 10^{-5}$$

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

$$x^2 + 1.083 \times 10^{-2}x - 2.4 \times 10^{-5} = 0$$

$$x = 1.887 \times 10^{-3} \quad [\text{Ca}^{+2}] = 1.887 \times 10^{-3} + 1.083 \times 10^{-2} = 1.27 \times 10^{-2} \text{ M}$$

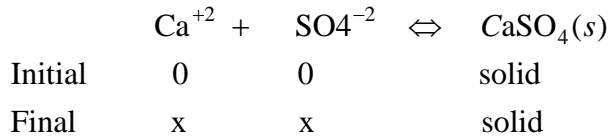
$$[\text{Ca}^{+2}] = \mathbf{1.3 \times 10^{-2} \text{ M}}$$

100.0 mL Na₂SO₄ added

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

$$\text{initial SO}_4^{-2} = 0.01625 \text{ M} \times 0.100 \text{ L} = 0.001625 \text{ moles SO}_4^{-2}$$

have no excess Ca^{+2}



$$K_{sp} = [\text{Ca}^{+2}][\text{SO}_4^{-2}] = 2.4 \times 10^{-5}$$

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

$$x = 4.9 \times 10^{-3} \text{ M } [\text{Ca}^{+2}]$$

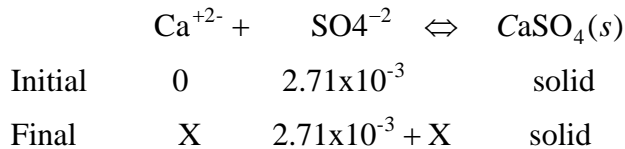
125.0 mL Na_2SO_4 added

$$\text{initial Ca}^{+2} = 0.0650 \text{ M} \times 0.025 \text{ L} = 0.001625 \text{ moles Ca}^{+2}$$

$$\text{initial SO}_4^{-2} = 0.01625 \text{ M} \times 0.125 \text{ L} = 2.03 \times 10^{-3} \text{ moles SO}_4^{-2}$$

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

$$\frac{4.06 \times 10^{-4} \text{ moles}}{0.15 \text{ L}} = 2.71 \times 10^{-3} \text{ M } \text{SO}_4^{-2}$$



$$K_{sp} = [\text{Ca}^{+2}][\text{SO}_4^{-2}] = 2.4 \times 10^{-5}$$

$$2.4 \times 10^{-5} = (X)(2.71 \times 10^{-3} + X)$$

$$x^2 + 2.71 \times 10^{-3}X - 2.4 \times 10^{-5} = 0$$

$$x = 3.7 \times 10^{-3} [\text{Ca}^{+2}]$$

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

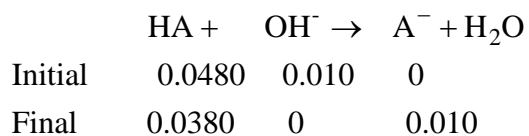
0.00 mL NaOH

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

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

$$\text{pH} = 2.357$$

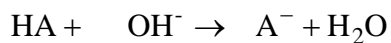
10.00 mL NaOH = 0.010 moles



$$\text{pKa} = 3.489$$

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

24.0 mL NaOH = 0.0240 moles NaOH



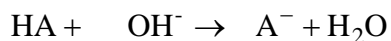
Initial 0.0480 0.0240 0

Final 0.0240 0 0.0240

pKa = 3.489

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

38.0 mL NaOH = 0.0380 moles NaOH



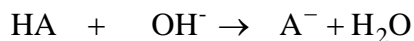
Initial 0.0480 0.038 0

Final 0.0100 0 0.0380

pKa = 3.489

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

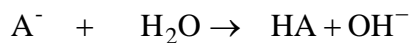
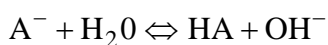
48.0 mL NaOH = 0.0480 moles NaOH



Initial 0.0480 0.0480 0

Final 0 0 0.0480

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



Initial F 0 0

Final F - x x x

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

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

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

$$\text{pH} = 8.134$$

55.0 mL NaOH = 0.0550 moles NaOH

use 0.0480 moles to get to equivalence point

have 0.0070 moles excess NaOH

$$[\text{OH}^-] = \frac{0.0070}{(0.750\text{L} + 0.0550\text{L})} = \frac{0.0070}{0.805} = 8.696 \times 10^{-3} \text{M} [\text{OH}^-]$$

$$\text{pOH} = 2.061$$

$$\text{pH} = 11.939$$

3.49.00 gm/ 331.1 gm/mol = 0.148 moles H₂A 0.148 moles/1.000 L = 0.148 M

0.00 mL NaOH



$$\frac{x^2}{0.148 - x} = 1.00 \times 10^{-6} = K_{a1} \quad \text{solve quadratic equation : } x^2 + 1.00 \times 10^{-6}x - 1.48 \times 10^{-7} = 0$$

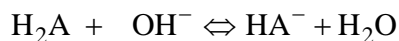
$$x = 3.842 \times 10^{-4} = [\text{H}^+]$$

$$\text{pH} = 3.415$$

36.00 mL NaOH

$$\text{p}K_{a1} = 6.000$$

1.00 M * 0.0360 L = 0.0360 moles OH⁻



Initial (rel) 0.148 0.0360 0

Final (rel) 0.112 0 0.036

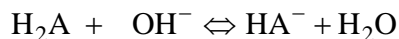
$$\text{pH} = 6.000 + \log \frac{0.0360}{0.1120}$$

$$\text{pH} = 5.507$$

74.0 mL NaOH

$$\text{p}K_{a1} = 6.000$$

1.00 M * 0.0740 L = 0.0740 moles OH⁻



Initial (rel) 0.148 0.0740 0

Final (rel) 0.0740 0 0.0740

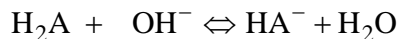
$$\text{pH} = 6.000 + \log \frac{0.0740}{0.0740}$$

$$\text{pH} = 6.000$$

142.00 mL NaOH

$$\text{p}K_{a1} = 6.000$$

1.00 M * 0.1420 L = 0.1420 moles OH⁻



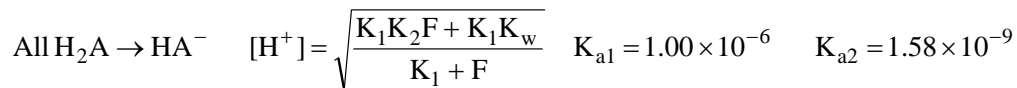
Initial (rel) 0.148 0.1420 0

Final (rel) 0.0060 0 0.1420

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

$$\text{pH} = 7.374$$

148.00 mL = first equivalence point



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

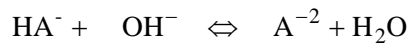
$$[\text{H}^+] = \sqrt{\frac{(1.00 \times 10^{-6})(1.58 \times 10^{-9})(0.1289) + (1.00 \times 10^{-6})(1 \times 10^{-14})}{1.00 \times 10^{-6} + 0.1289}} = 3.975 \times 10^{-8}$$

$$\text{pH} = 7.401$$

186.00 mL NaOH

$$\text{p}K_{a1} = 6.000 \quad \text{p}K_{a2} = 8.801$$

1.00 M * 0.186 L = 0.186 moles OH⁻ - 0.148 moles used to first eq. point = 0.038 moles left



$$\text{Initial (rel)} \quad 0.148 \quad 0.038 \quad 0$$

$$\text{Final (rel)} \quad 0.110 \quad 0 \quad 0.038$$

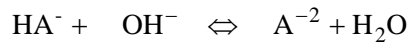
$$\text{pH} = 8.801 + \log \frac{0.038}{0.110}$$

$$\text{pH} = 8.339$$

222.00 mL NaOH

$$\text{p}K_{a1} = 6.000 \quad \text{p}K_{a2} = 8.801$$

1.00 M * 0.222 L = 0.222 moles OH⁻ - 0.148 moles used to first eq. point = 0.074 moles left



$$\text{Initial (rel)} \quad 0.148 \quad 0.074 \quad 0$$

$$\text{Final (rel)} \quad 0.074 \quad 0 \quad 0.074$$

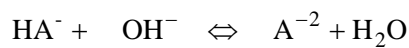
$$\text{pH} = 8.801 + \log \frac{0.074}{0.074}$$

$$\text{pH} = 8.801$$

267.00 mL NaOH

$$\text{p}K_{a1} = 6.000 \quad \text{p}K_{a2} = 8.801$$

1.00 M * 0.267 L = 0.267 moles OH⁻ - 0.148 moles used to first eq. point = 0.119 moles left



$$\text{Initial (rel)} \quad 0.148 \quad 0.119 \quad 0$$

$$\text{Final (rel)} \quad 0.029 \quad 0 \quad 0.119$$

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

$$\text{pH} = 9.414$$

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

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



$$\frac{x^2}{0.1142 - x} = 6.329 \times 10^{-6} \quad \text{solve quadratic equation: } x^2 + 6.329 \times 10^{-6}x - 7.2278 \times 10^{-7} = 0$$

$$x = 8.47 \times 10^{-4} = [\text{OH}^-]$$

$$\text{pOH} = 3.072$$

$$\text{pH} = 10.928$$

325.00 mL

1.00 M * 0.325 L = 0.325 moles OH^- - 0.296 moles used to second eq. point = 0.029 moles left

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

$$\text{pOH} = 1.6598$$

$$\text{pH} = 12.340$$

$$4. (0.264 \text{ g Fe}_2\text{O}_3) / (159.69 \text{ g/mol}) = 1.65 \times 10^{-3} \text{ moles Fe}_2\text{O}_3$$

$$1.65 \times 10^{-3} \text{ moles Fe}_2\text{O}_3 \times 2 = 3.306 \times 10^{-3} \text{ moles Fe}^{+3} = 3.306 \times 10^{-3} \text{ moles FeSO}_4 \cdot 7\text{H}_2\text{O}$$

$$3.306 \times 10^{-3} \text{ moles FeSO}_4 \cdot 7\text{H}_2\text{O} \times 278.01 \text{ g/mol} = 0.919 \text{ g FeSO}_4 \cdot 7\text{H}_2\text{O}$$

$$\frac{0.919 \text{ g FeSO}_4 \cdot 7\text{H}_2\text{O}}{x \text{ g}} \text{ in } \frac{2.998 \text{ g sample}}{22.131 \text{ g sample}}$$

$$x = 6.7856 \text{ g FeSO}_4 \cdot 7\text{H}_2\text{O in 20 tablets}$$

$$\therefore 6.7856 \text{ g FeSO}_4 \cdot 7\text{H}_2\text{O in 20 tablets} / 20 \text{ tablets} = \mathbf{0.339 \text{ g FeSO}_4 \cdot 7\text{H}_2\text{O per tablet}}$$

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