

Chapter 9 Answers

9-F see the back of the text.

$$9-3 \quad [\text{H}^+] = 2[\text{SO}_4^{2-}] + [\text{HSO}_4^-] + [\text{OH}^-]$$

$$9-5 \quad 2[\text{Mg}^{2+}] + [\text{H}^+] = [\text{Br}^-] + [\text{OH}^-]$$

9-8

- (a) $0.20 \text{ M} = [\text{Mg}^{2+}]$
- (b) $0.40 \text{ M} = [\text{Br}^-]$
- (c) $0.20 \text{ M} = [\text{Mg}^{2+}] + [\text{MgBr}^+]$
- (d) $0.40 \text{ M} = [\text{MgBr}^+] + [\text{Br}^-]$

9-9

$$\text{Ac}^- + \text{H}^+ = \text{HAc}$$

$$0.1 \text{ M} = [\text{HAc}] + [\text{Ac}^-]$$

9-13

CBE $2[\text{Mg}^{2+}] + [\text{H}^+] = [\text{OH}^-]$
 MBE **$4.8\text{e-}8 = [\text{Mg}^{2+}]$** also $2[\text{Mg}^{2+}] + [\text{H}^+] = [\text{OH}^-]$
 Kw $1.00\text{e-}14 = [\text{H}^+][\text{OH}^-]$

$$[\text{H}^+] = 1.00\text{e-}14/[\text{OH}^-]$$

$$2[\text{Mg}^{2+}] + 1.00\text{e-}14/[\text{OH}^-] = [\text{OH}^-]$$

$$2 \cdot 4.8\text{e-}8 + 1.00\text{e-}14/[\text{OH}^-] = [\text{OH}^-]$$

$$[\text{OH}^-]^2 - 9.6\text{e-}8[\text{OH}^-] - 1.00\text{e-}14 = 0$$

use quadratic formula **$[\text{OH}^-] = 1.6\text{e-}7$**
 $[\text{H}^+] = 6.2\text{e-}8$

9-14 (a) $K_{\text{sp}} = [\text{Pb}^{2+}][\text{F}^-]^2 = 3.6\text{e-}8$ $K'_{\text{sp}} = [\text{Sr}^{2+}][\text{F}^-]^2 = 2.9\text{e-}9$

$$K_{\text{sp}}/K'_{\text{sp}} = [\text{Pb}^{2+}]/[\text{Sr}^{2+}] = 12$$

(b)

CBE $2[\text{Pb}^{2+}] + 2[\text{Sr}^{2+}] + [\text{H}^+] + [\text{PbOH}^+] = [\text{F}^-] + [\text{OH}^-]$
 MBE $[\text{F}^-] + [\text{HF}] = 2[\text{Pb}^{2+}] + 2[\text{PbOH}^+] + 2[\text{Sr}^{2+}]$
 $[\text{Pb}^{2+}][\text{F}^-]^2 = 3.6\text{e-}8$
 $[\text{Sr}^{2+}][\text{F}^-]^2 = 2.9\text{e-}9$
 $[\text{H}^+][\text{OH}^-] = 1.00\text{e-}14$
 $[\text{PbOH}^+][\text{OH}^-]/[\text{Pb}^{2+}] = B_1$

9-15

CBE $2[\text{M}^{2+}] + [\text{MX}^+] + [\text{H}^+] = [\text{X}^-] + [\text{OH}^-]$ $2[\text{M}^{2+}] + [\text{MX}^+] \approx [\text{X}^-]$
 MBE $0.10\text{M} = [\text{MX}_2] + [\text{MX}^+] + [\text{M}^{2+}]$
 $K_1 = [\text{MX}^+]/[\text{M}^{2+}][\text{X}^-]$
 $K_2 = [\text{MX}_2]/[\text{MX}^+][\text{X}^-]$
 $K_w = [\text{H}^+][\text{OH}^-]$

$$[\text{MX}^+] = [\text{M}^{2+}][\text{X}^-] K_1 \quad [\text{MX}_2] = [\text{MX}^+][\text{X}^-] K_2$$

$$[MX_2] = [M^{2+}][X^-]^2 K_1 K_2$$

for $[X^-]$ start with CBE

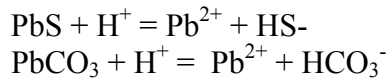
$$2[M^{2+}] + [MX^+] \approx [X^-]$$

$$2[M^{2+}] + [M^{2+}][X^-] K_1 \approx [X^-]$$

$$[X^-] = 2[M^{2+}](1 - [M^{2+}]K_1)$$

MBE $0.10M = [M^{2+}][X^-]^2 K_1 K_2 + [M^{2+}][X^-] K_1 + [M^{2+}]$
 $0.10M = [M^{2+}][2[M^{2+}](1 - [M^{2+}]K_1)]^2 K_1 K_2 + [M^{2+}][2[M^{2+}](1 - [M^{2+}]K_1)] K_1 + [M^{2+}]$

9-16 H^+ reacts with conjugate pulling the equilibrium to the product side:



9-19 let $A^- = CH_2CHCOO^-$

$$K_{sp} = [M^{2+}][A^-]^2 = 6.3e-14$$

$$K_b = [HA][OH^-]/[A^-] = 1.8e-10$$

$$[OH^-] = 1.8e-10$$

MBE $2[M^{2+}] = [A^-] + [HA]$
 CBE none available – fixed pH

$$[M^{2+}][A^-]^2 = 6.3e-14$$

$$[A^-] = 2.5e-7/[M^{2+}]^{1/2}$$

$$[HA][OH^-]/[A^-] = 1.8e-10$$

$$[HA]1.8e-10/(6.3e-14/[M^{2+}]) = 1.8e-10$$

$$[HA] = 2.5e-7/[M^{2+}]^{1/2}$$

$$2[M^{2+}] = [A^-] + [HA]$$

$$2[M^{2+}] = 2 * \{2.5e-7/[M^{2+}]^{1/2}\}$$

$$[M^{2+}] = 4.0e-5 M$$

9-20 Let $HA^+ = R_3NH^+$

$$K_{sp} = 4.0e-8 = [HA^+][Br^-]$$

$$K_a = 2.3e-9 = [H^+][A] / [HA^+]$$

$$K_w = 1.00e-14 = [H^+][OH^-]$$

$$[H^+] = 3.2e-10$$

MBE $[Br^-] = [HA^+] + [A]$
 CBE N/A

$$2.3e-9 = [H^+][A] / [HA^+] \quad [H^+] = 3.2e-10$$

$$[A] = 7.19 [HA^+]$$

$$4.0e-8 = [\text{HA}^+][\text{Br}^-]$$

$$[\text{HA}^+] = 4.0e-8/[\text{Br}^-]$$

$$[\text{Br}^-] = [\text{HA}^+] + [\text{A}] = 4.0e-8/[\text{Br}^-] + 7.19 \cdot 4.0e-8/[\text{Br}^-] = 3.28e-7/[\text{Br}^-]$$

$$[\text{Br}^-] = 5.7e-4 \text{ M}$$

9-21 (a) $K = 5.0e-16 = [\text{Pb}^{2+}][\text{OH}^-]^2$
 $K_w = 1.00e-14 = [\text{H}^+][\text{OH}^-]$
 $[\text{H}^+] = 3.2e-11$

MBE N/A Besides K_w and K_{sp} $[\text{OH}^-]$ is produced by the pH buffering system

$$[\text{OH}^-] = 1.00e-14/3.2e-11 = 3.12e-4$$

$$5.0e-16 = [\text{Pb}^{2+}][\text{OH}^-]^2 = [\text{Pb}^{2+}][3.12e-4]^2$$

$$[\text{Pb}^{2+}] = 5.1e-9$$

(b) $K = 5.0e-16 = [\text{Pb}^{2+}][\text{OH}^-]^2$
 $K_a = 2.5e-8 = [\text{PbOH}^+][\text{H}^+]/[\text{Pb}^{2+}]$
 $K_w = 1.00e-14 = [\text{H}^+][\text{OH}^-]$
 $[\text{H}^+] = 3.2e-11$

MBE N/A

$$K_a = 2.5e-8 = [\text{PbOH}^+][\text{H}^+]/[\text{Pb}^{2+}] = [\text{PbOH}^+]3.2e-11/5.1e-9$$

$$[\text{PbOH}^+] = 4.0e-6$$

$$\text{Total } [\text{Pb}](\text{aq}) = [\text{PbOH}^+] + [\text{Pb}^{2+}] = 4.0e-6$$

9-22 $K_{sp} = 2.8e-18 = [\text{Ag}^+]^3[\text{X}^{3-}]$
 $K_{b1} = 2.3e-2 = [\text{HX}^{2-}][\text{OH}^-]/[\text{X}^{3-}]$
 $K_{b2} = 1.6e-7 = [\text{H}_2\text{X}^-][\text{OH}^-]/[\text{HX}^{2-}]$
 $K_{b3} = 1.4e-12 = [\text{H}_3\text{X}][\text{OH}^-]/[\text{H}_2\text{X}^-]$
 $K_w = 1.00e-14 = [\text{H}^+][\text{OH}^-]$
 $[\text{H}^+] = 1.0e-6$

MBE $[\text{Ag}^+] = 3 \{ [\text{H}_3\text{X}] + [\text{H}_2\text{X}^-] + [\text{HX}^{2-}] + [\text{X}^{3-}] \}$

$$[\text{OH}^-] = 1.00e-14/1.0e-6 = 1.0e-8$$

$$2.3e-2 = [\text{HX}^{2-}][\text{OH}^-]/[\text{X}^{3-}]$$

$$2.3e-2 = [\text{HX}^{2-}][1.0e-8]/[\text{X}^{3-}]$$

$$[\text{HX}^{2-}] = 2.3e-2[\text{X}^{3-}]/[1.0e-8] = 2.3e6[\text{X}^{3-}]$$

$$1.6e-7 = [\text{H}_2\text{X}^-][\text{OH}^-]/[\text{HX}^{2-}]$$

$$1.6e-7 = [\text{H}_2\text{X}^-][1.0e-8]/[\text{HX}^{2-}]$$

$$[\text{H}_2\text{X}^-] = 16 [\text{HX}^{2-}]$$

$$[\text{H}_2\text{X}^-] = 3.7e7[\text{X}^{3-}]$$

$$1.4e-12 = [\text{H}_3\text{X}][\text{OH}^-]/[\text{H}_2\text{X}^-]$$

$$1.4e-12 = [\text{H}_3\text{X}][1.0e-8]/[\text{H}_2\text{X}^-]$$

$$[\text{H}_3\text{X}] = 1.4e-4[\text{H}_2\text{X}^-]$$

$$[\text{H}_3\text{X}] = \mathbf{5.2e3[X^{3-}]}$$

$$[\text{Ag}^+] = 3\{[\text{H}_3\text{X}] + [\text{H}_2\text{X}^-] + [\text{HX}^{2-}] + [\text{X}^{3-}]\}$$

$$[\text{Ag}^+] = 3\{5.2e3[\text{X}^{3-}] + 3.7e7[\text{X}^{3-}] + 2.3e6[\text{X}^{3-}] + [\text{X}^{3-}]\}$$

$$[\text{Ag}^+] = 1.2e8[\text{X}^{3-}]$$

$$2.8e-18 = [\text{Ag}^+]^3[\text{X}^{3-}]$$

$$[\text{X}^{3-}] = 2.8e-18/[\text{Ag}^+]^3$$

$$[\text{Ag}^+] = 1.2e8 * 2.8e-18/[\text{Ag}^+]^3$$

$$[\text{Ag}^+] = \mathbf{4.3e-3 \text{ M}}$$

19- 23 (a) CBE $[\text{NH}_4^+] + [\text{H}^+] = 2[\text{SO}_4^{2-}] + [\text{HSO}_4^-] + [\text{OH}^-]$
 (b) MBE $[\text{NH}_4^+] + [\text{NH}_3] = 2[\text{SO}_4^{2-}] + 2[\text{HSO}_4^-]$

$$[\text{H}^+] = 5.6e-10$$

$$K_{sp} = 276 = [\text{NH}_4^+]^2[\text{SO}_4^{2-}]$$

$$K_a = 5.70e-10 = [\text{NH}_3][\text{H}^+]/[\text{NH}_4^+]$$

$$K_b = 9.8e-13 = [\text{HSO}_4^-][\text{OH}^-]/[\text{SO}_4^{2-}]$$

$$[\text{OH}^-] = 1.00e-14/5.6e-10 = 1.79e-5$$

$$9.8e-13 = [\text{HSO}_4^-][\text{OH}^-]/[\text{SO}_4^{2-}]$$

$$9.8e-13 = [\text{HSO}_4^-][1.8e-5]/[\text{SO}_4^{2-}]$$

$$[\text{HSO}_4^-] = \mathbf{5.4e-8[\text{SO}_4^{2-}]}$$

$$5.70e-10 = [\text{NH}_3][\text{H}^+]/[\text{NH}_4^+]$$

$$5.70e-10 = [\text{NH}_3][5.6e-10]/[\text{NH}_4^+]$$

$$[\text{NH}_3] = \mathbf{1.0[\text{NH}_4^+]}$$

$$[\text{NH}_4^+] + [\text{NH}_3] = 2[\text{SO}_4^{2-}] + 2[\text{HSO}_4^-]$$

$$[\text{NH}_4^+] + \mathbf{1.0[\text{NH}_4^+]} = 2[\text{SO}_4^{2-}] + 2 * \mathbf{5.4e-8[\text{SO}_4^{2-}]}$$

$$2.0[\text{NH}_4^+] = 2.0[\text{SO}_4^{2-}]$$

$$[\text{NH}_4^+] = [\text{SO}_4^{2-}]$$

$$276 = [\text{NH}_4^+]^2[\text{SO}_4^{2-}] = [\text{NH}_4^+]^3$$

$$[\text{NH}_4^+] = 6.5$$

$$[\text{NH}_3] = \mathbf{1.0[\text{NH}_4^+] = 6.5}$$