Chapter 14

93) A 1.00 mol sample of $CO_2$ is heated to 1000. K with excess solid graphite in a container of volume 40.0 L. At 1000. K, $K_c$ is $2.11 \times 10^{-2}$ for the reaction

$$C_{graphite} + CO_2(g) \leftrightarrow 2\,CO(g)$$

a) What is the composition of the equilibrium mixture at 1000. K?

| | $CO_2$ | CO |
|---|---|---|
| I | 1.00/40.0 L | 0 |
| C | -x | +2x |
| E | 0.0250 - x | 2x |

$$K_c = 2.11 \text{ x } 10^{-2} = \frac{[CO]^2}{[CO_2]} = \frac{(2x)^2}{0.0250 - x} = \frac{4x^2}{0.0250 - x}$$

$0 = 4x^2 + 0.0211x - 0.0005275$ solve for x using quadratic equation

x = 0.009145

[CO] = 0.0183 [$CO_2$] = 0.0159

b) If the volume of the flask is changed such that [$CO_2$] = [CO], what is the volume of the new flask?

If [$CO_2$] = [CO] then the following equality must hold true at equilibrium:

1.00 mol – x = 2x and x = 0.333

This would make it so there where 0.666 mol $CO_2$ and 0.666 mol CO.

$$K_c = 2.11x10^{-2} = \frac{\left(0.666M/xL\right)^2}{\left(0.666M/xL\right)} = \frac{0.666M}{xL}$$

x = 31.6 L

95 i and iii)

a) right, right
b) left, left
c) right, left

Chapter 16

7)

a) $HNO_3$(aq) + $H_2O$ (l) ←→ $H_3O^+$(aq) + $NO_3^-$(aq)
acid base conjugate acid conjugate base

b) $NH_4^+$(aq) + $CN^-$ (aq) ←→ $NH_3$(aq) + HCN(aq)
acid base conjugate base conjugate acid

9) Solution A has 100 times greater [$H_3O^+$] than solution B

11)

a) HBr(aq) + $H_2O$ (l) ←→ $H_3O^+$(aq) + $Br^-$(aq)

b) $CF_3COOH$(aq) + $H_2O$ (l) ←→ $H_3O^+$(aq) + $CF_3COO^-$(aq)

c) $HSO_4^-$(aq) + $H_2O$ (l) ←→ $H_3O^+$(aq) + $SO_4^{-2}$(aq)

d) $HNO_2$(aq) + $H_2O$ (l) ←→ $H_3O^+$(aq) + $NO_2^-$(aq)

15)

a) $H^-$(aq) + $H_2O$ (l) ←→ $H_2$(g) + $OH^-$(aq)

b) $HCO_3^-$(aq) + $H_2O$ (l) ←→ $H_2O$ (l) + $CO_2$(g) + $OH^-$(aq)

c) $NO_2^-$(aq) + $H_2O$ (l) ←→ $HNO_2$(aq) + $OH^-$(aq)

27)

a) $H_2PO_4(aq)$ + $HCO_3^-$ (aq) ←→ $H_2O$ (l) + $CO_2$ (aq) + $HPO_4^-$(aq)
acid base conjugate acid conjugate base

b) $NH_3$(aq) + $NH_2^-$ (aq) ←→ $NH_2^-$ (aq) + $NH_3$(aq)
acid base conjugate base conjugate acid

c) $HSO_4^-$(aq) + $CO_3^{-2}$ (aq) ←→ $SO_4^{-2}$ (aq) + $HCO_3^-$ (aq)
acid base conjugate base conjugate acid

Note in this set of problems, $HCO_3^-$ is serving as both a base (eq a) and a base (eq c). If you are perplexed about the fact that $HCO_3^-$ decomposes when treated with acid to water and $CO_2$, remember the Alka-Seltzer lab. The Alka-Seltzer is a source of $HCO_3^-$ Vinegar ($CH_3COOH$) is an acid.
How could you look at the formula for $H_2CO_3$ and know that it would decompose into $CO_2$ and water? I don't think you could from first principles. However, watching the dramatic reaction will help you to remember this fact.

33) pH = -log $[H_3O^+]$

$[H_3O^+] = 5.0 \times 10^{-5}$ M

47)

a) $CH_3COOH$(aq) + $H_2O$ (l) ←→ $CH_3COO^-$(aq) + $H_3O^+$(aq)

$$K_a = \frac{[H_3O^+][CH_3COO^-]}{[CH_3COOH]}$$

b) HCN(aq) + $H_2O$ (l) ←→ $CN^-$(aq) + $H_3O^+$(aq)

$$K_a = \frac{[H_3O^+][CN^-]}{[HCN]}$$

c) $SO_3^{-2}(aq)$ + $H_2O$ (l) ←→ $OH^-(aq)$ + $HSO_3^-(aq)$

$$K_b = \frac{[OH^-][HSO_3^-]}{[SO_3^-]}$$

d) $PO_4^{-3}(aq)$ + $H_2O$ (l) ←→ $OH^-(aq)$ + $HPO_4^{-2}(aq)$

$$K_b = \frac{[OH^-][HPO4^{-2}]}{[PO_4^{-3}]}$$

e) $NH_4^+(aq)$ + $H_2O$ (l) ←→ $NH_3(aq)$ + $H_3O^+(aq)$

$$K_a = \frac{[H_3O^+][NH_3]}{[NH_4^+]}$$

f) $H_2SO_4(aq)$ + $H_2O$ (l) ←→ $HSO_4^-(aq)$ + $H_3O^+(aq)$

$$K_a = \frac{[H_3O^+][HSO_4^-]}{[H_2SO_4]}$$

49) For these problems, you need to look up the $K_a$ value in Table 16.2. The large the value of Ka, the greater dissociation of the acid in water, the greater $[H_3O^+]$, and the more acidic the acid. In each example below, the more acidic acid is boxed.

a) $\boxed{H_2CO_3 = 4.2 \text{ x } 10^{-7}}$ $NH_4Cl = 5.6 \text{ x } 10^{-10}$

b) $HF = 7.2 \text{ x } 10^{-4}$ $\boxed{KHSO_4 = 1.2 \text{ x } 10^{-2}}$

c) $\boxed{NaHCO_3 = 4.8 \text{ x } 10^{-11}}$ $Na_2HPO_4 = 3.6 \text{ x } 10^{-13}$

d) $\boxed{H_2S = 1 \text{ x } 10^{-7}}$ $HCN = 4.0 \text{ x } 10^{-10}$

53) 0.015 M cyanic acid as pH = 2.67. $2.67 = -\log[H_3O^+]$ $[H_3O^+] = 2.14 \text{ x } 10^{-3}$

$$K_a = \frac{[H_3O^+][A^-]}{[HA]} = \frac{(2.14x10^{-3})^2}{1.286x10^{-2}} = 3.58x10^{-4}$$

65) 0.650 g aspirin = 0.650g/180.16 g/mol = 0.00361 mols

0.00361 mol/0.200 L = 0.01804 M and $K_a$ = 3.27 x $10^{-4}$

$$K_a = \frac{[H_3O^+][A^-]}{[HA]} = \frac{x^2}{0.01804 - x} = 3.27x10^{-4}$$

solving quadratic equation x = 0.00227

pH = -log(0.00227) = 2.6

69)

a) $H_2O$ (l) + $HNO_3$(aq) ←→ $H_3O^+$ (aq) + $NO_3^-$(aq) $K_a$=20

For a 1 M solution the $HNO_3$ would be ~95% dissociated. The reaction favors products.

b) $H_3PO_4$(aq) + $H_2O$(l) ←→ $H_2$PO4-(aq) + $H_3O^+$(aq) $K_a$=7.5 x $10^{-3}$

For a 1 M solution the $H_3PO_4$ would be ~8% dissociated. The reaction favors reactants.

c) CN-(aq) + HCl(aq) ←→ Cl-(aq) + HCN(aq)

HCl $K_a$=large
$CN^-$ $K_b$=2.5 x $10^{-5}$

HCN $K_a$= 4.0 x $10^{-10}$
$Cl^-$ $K_b$= very small

The left side of this equation contains the stronger acid and the stronger base. This means the reaction will lie strongly to products.

d) $NH_4^+$(aq) + $F^-$(aq) ←→ $NH_3$(aq) + HF(aq)

$NH_4^+$ $K_a$=5.6 x $10^{-10}$
$F^-$ $K_b$=1.4 x $10^{-11}$

HF $K_a$= 7.2 x $10^{-4}$
$NH_3$ $K_b$= 1.8 x $10^{-5}$

The right side of this equation contains the stronger acid and the stronger base. This means the reaction will lie strongly to reactants.