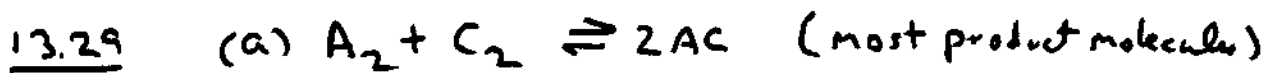


Chapter 13



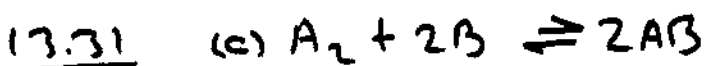
13.30 (a) Only rxn. (3), $K_c = \frac{[A][AB]}{[A_2][B]} = \frac{(2)(4)}{(2)(1)} = 2$, is at Equil.

(b) $Q_c = \frac{[A][AB]}{[A_2][B]} = \frac{(3)(5)}{(1)(1)} = 15$ for rxn (1)

Since $Q_c > K_c$, the rxn will go in ~~reverse~~^{reverse} to reach equil.

~~13.30~~ $Q_c = \frac{[A][AB]}{[A_2][B]} = \frac{(1)(3)}{(3)(3)} = \frac{1}{3}$ for rxn (2)

Since $Q_c < K_c$, the rxn will go in the forward direction.



(b) The # of AB molecules will increase, because as the volume goes down at a constant temperature, the pressure will increase & the rxn. will shift to the side with fewer molecules to reduce the pressure.

13.37 This equil. mixture has a $K_c \propto \frac{(2)(2)}{(3)^2}$ & is less than 1.

which means that $K_c < Q_c$.

13.40

$$(a) K_c = \frac{[CO][H_2]^2}{[CH_4][H_2O]}$$

$$(b) K_c = \frac{[ClF_3]^2}{[F_2]^3[Cl_2]}$$

$$(c) K_c = \frac{[HF]^2}{[H_2][F_2]}$$

13.41

$$(a) K_c = \frac{[CH_3CHO]^2}{[C_2H_4]^2[O_2]}$$

$$(b) K_c = \frac{[N_2][O_2]}{[NO]^2}$$

$$(c) K_c = \frac{[NO]^4[H_2O]^6}{[NH_3]^4[O_2]^5}$$

13.44

$$K_c = \frac{[C_2H_5OC_2H_5][H_2O]}{[C_2H_5OH]^2}$$

13.48 The two rxns. are the reverse of each other -

$$K_c(\text{rev}) = \frac{1}{K_c(\text{found})} = \frac{1}{7.5 \times 10^9} = 1.3 \times 10^{-10}$$

13.50
$$K_c = \frac{[PCl_3][Cl_2]}{[PCl_5]} = \frac{(1.5 \times 10^{-2})(3.2 \times 10^{-2})}{(8.7 \times 10^{-3})} = 0.058$$

13.60 (a)
$$K_c = \frac{[CO_2]^3}{[CO]^3} \quad \Rightarrow \quad K_p = \frac{P_{CO_2}^3}{P_{CO}^3}$$

(b)
$$K_c = \frac{1}{[O_2]^3} \quad \text{or} \quad K_p = \frac{1}{P_{O_2}^3}$$

(c)
$$K_c = [SO_3] \quad \text{or} \quad K_p = P_{SO_3}$$

(d)
$$K_c = [Ba^{+2}][SO_4^{2-}]$$

13.62 (a) Since K_c is very ~~small~~ ^{large}, the equil. mixture is mostly product.

(b) Since K_c is very small, the equil. mixture is mostly reactant.

13.63 (a) does not go much in the forward direction

(b) goes almost to completion -

$$13.69 \quad Q_c = \frac{[CO]_t [H_2]_t^3}{[H_2O]_t [CH_4]_t} = \frac{(0.15)(0.20)^3}{(0.075)(0.050)} = 0.69$$

The rxn is not at equil. since $Q_c < K_c$ ($0.69 < 4.7$)
 The rxn. will proceed from left to right to reach equilibrium

13.70

$$K_c = \frac{[NH_3]^2}{[N_2][H_2]^3} = 0.29 \quad @ \text{ equil } [N_2] = 0.036 M +$$

$$[H_2] = 0.15 M$$

$$[NH_3] = \sqrt{[N_2] \cdot [H_2]^3 \cdot K_c} = \sqrt{0.036 \cdot 0.15^3 \cdot 0.29} =$$

$$5.9 \times 10^{-3} M$$

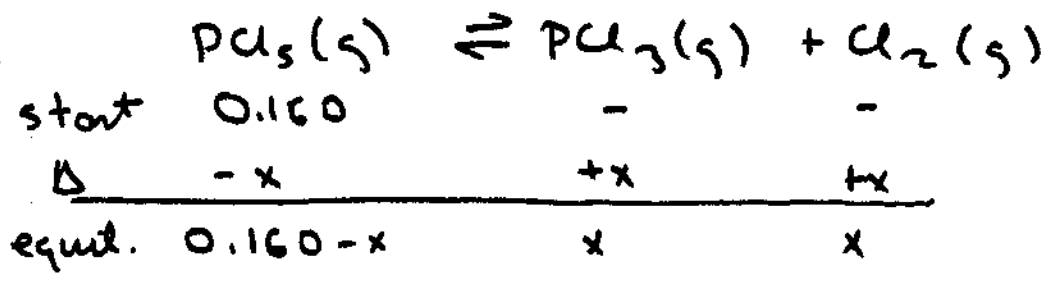
13.71

$$K_c = 2.7 \times 10^2 = \frac{[SO_3]^2}{[SO_2]^2 [O_2]}$$

; Because $[SO_3] = [SO_2]$,
 then $2.7 \times 10^2 = \frac{1}{[O_2]}$

$$[O_2] = 3.7 \times 10^{-3} M$$

13.74



$$K_c = \frac{[PCl_3][Cl_2]}{[PCl_5]} = 5.8 \times 10^{-2} = \frac{x^2}{0.160-x}$$

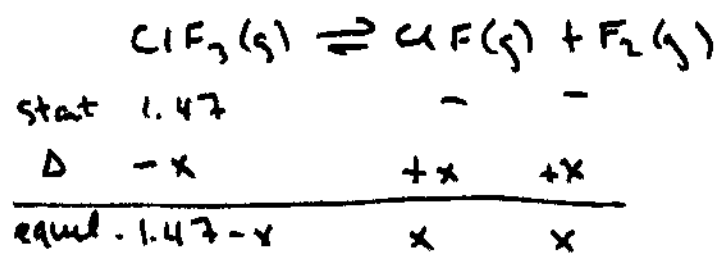
$$x^2 + (5.8 \times 10^{-2})x - 0.00928 = 0$$

$$x = \frac{-5.8 \times 10^{-2} \pm \sqrt{(5.8 \times 10^{-2})^2 - 4(1)(-0.00928)}}{2(1)} = \frac{-5.8 \times 10^{-2} \pm 0.2058}{2}$$

$$x = 0.071 + \cancel{-0.129} \quad [PCl_3] = [Cl_2] = x = 0.071M$$

$$[PCl_5] = 0.160 - x = 0.160 - 0.071 = 0.089M$$

13.75



$$K_p = \frac{P_{ClF} P_{F_2}}{P_{ClF_3}} = 0.140 = \frac{x^2}{1.47-x}$$

$$x^2 + 0.140x - 0.2058 = 0$$

$$x = \frac{-0.140 \pm \sqrt{0.140^2 - 4(1)(-0.2058)}}{2(1)} = \frac{-0.140 \pm 0.918}{2}$$

$$x = 0.389 + \cancel{-0.529} \quad P_{ClF} = P_{F_2} = x = 0.389 \text{ atm}, \quad P_{ClF_3} = 1.47 - 0.389 = 1.081 \text{ atm}$$

13.80 (a) if Cl^- is added, $\text{AgCl}(s)$ increases

(b) Ag^+ is added, $\text{AgCl}(s)$ increases.

(c) Ag^+ is removed, $\text{AgCl}(s)$ decreases

(d) Cl^- removed, $\text{AgCl}(s)$ decreases.

if $[\text{Cl}^-] \uparrow$ Q_c increases to a value greater than K_c , therefore the rxn must go from right to left to decrease $\text{AgCl}(s)$

13.81

(a) ClNO added, $\text{NO}_2 \downarrow$

(b) NO added, $\text{NO}_2 \uparrow$

(c) NO removed, $\text{NO}_2 \downarrow$

(d) ClNO_2 added, $\text{NO}_2 \uparrow$

Adding ClNO_2 decrease Q_c , the rxn must shift from left to right to ~~reach~~ reach equilibrium, thus increasing the NO_2 conc.

13.83

As the Volume \uparrow , the Pressure \downarrow @ constant temp.

(a) the rxn will shift to the side with larger # of molecules - since the stress is the decrease in pressure - or an increase in volume. - Toward Products.

(b) The rxn will shift to the reactants, since that is the side with the greater # of molecules.

(c) This rxn is not altered by changes in volume or pressure, since there are equal # of molecules on both sides - No change.

13.86- (a) HCl is a source of Cl^- , the rxn. shifts left, the equil. $[\text{CoCl}_4^{2-}]$ increases

(b) $\text{Co}(\text{NO}_3)_2$ is a source of $\text{Co}(\text{H}_2\text{O})_6^{2+}$, the rxn. shifts left, the equil. conc. of $[\text{CoCl}_4^{2-}]$ increases.

(c) All conc. will initially decrease, & the rxn. will shift right, the equil. conc. of $[\text{CoCl}_4^{2-}]$ decreases

(d) For an exothermic rxn.: the rxn. shifts to the left when the temp increases. the equil. $[\text{CoCl}_4^{2-}]$ increases

13.87

(a) $\text{Fe}(\text{NO}_3)_3$ is a source of Fe^{3+} . Fe^{3+} added; the FeCl^{2+} conc. increases.

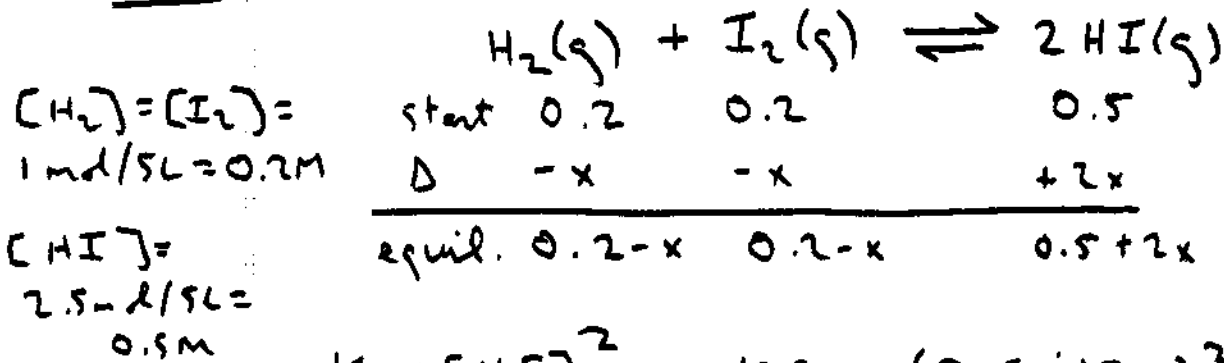
(b) Cl^- removed; the FeCl^{2+} conc. decreases.

(c) An endo ferric rxn. shifts to the right as the temperature increases; the FeCl^{2+} conc. increases.

(d) A catalyst does not affect the composition of the equil. mixture; no change in FeCl^{2+} conc.

13.52 $K_c = \frac{k_f}{k_r} = \frac{0.13}{6.2 \times 10^{-4}} = 210$

13.99 $V = 5.0L$



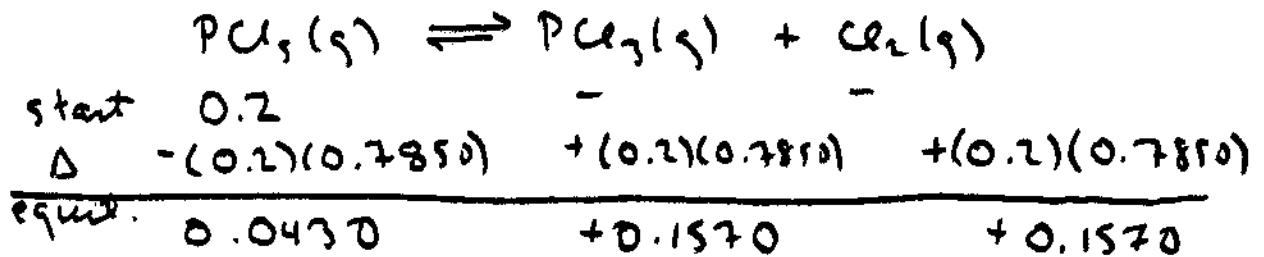
$$K_c = \frac{[HI]^2}{[H_2][I_2]} = 129 = \frac{(0.50 + 2x)^2}{(0.20 - x)^2}$$

$$\sqrt{129} = \sqrt{\frac{(0.50 + 2x)^2}{(0.20 - x)^2}} = 11.4 = \frac{0.50 + 2x}{0.20 - x}; \quad x = 0.133$$

$$[H_2] = [I_2] = 0.2 - 0.133 = 0.067M; \quad [HI] = 0.5 + 2(0.133) = 0.766M$$

13.104

$[PCl_5] = 1 \text{ mol} / 5L = 0.2M$



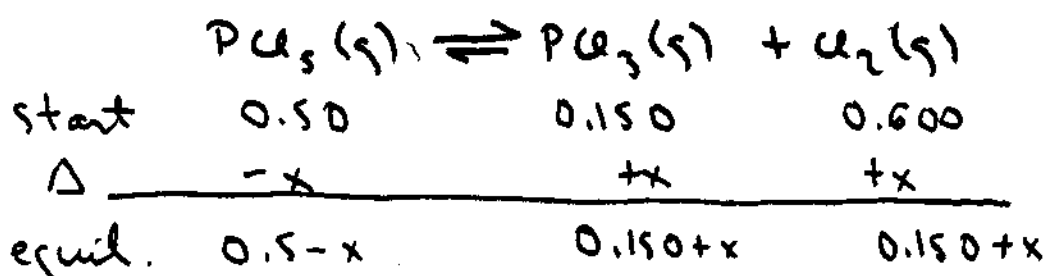
$$K_c = \frac{[PCl_3][Cl_2]}{[PCl_5]} = \frac{(0.1570)^2}{(0.0430)} = 0.573$$

$$\Delta n = 1 \quad \therefore K_p = K_c (RT)^{\Delta n} = 0.573 (0.0821)(500) = 23.5$$

13.104 cont

$$(b) Q_c = \frac{[PCl_3][Cl_2]}{[PCl_5]} = \frac{(0.150)(0.60)}{(0.500)} = 0.18$$

Since $Q_c < K_c$ the rxn will proceed to the right to reach equilibrium



$$K_c = \frac{[PCl_3][Cl_2]}{[PCl_5]} = 0.573 = \frac{(0.150+x)(0.600+x)}{(0.50-x)}$$

$$x^2 = 1.323x - 0.1965 = 0$$

$$x = \frac{-1.323 \pm \sqrt{1.323^2 - 4 \cdot 1 \cdot (-0.1965)}}{2(1)} = \frac{-1.323 \pm 1.553}{2}$$

$$x = \cancel{-1.458} + 0.135$$

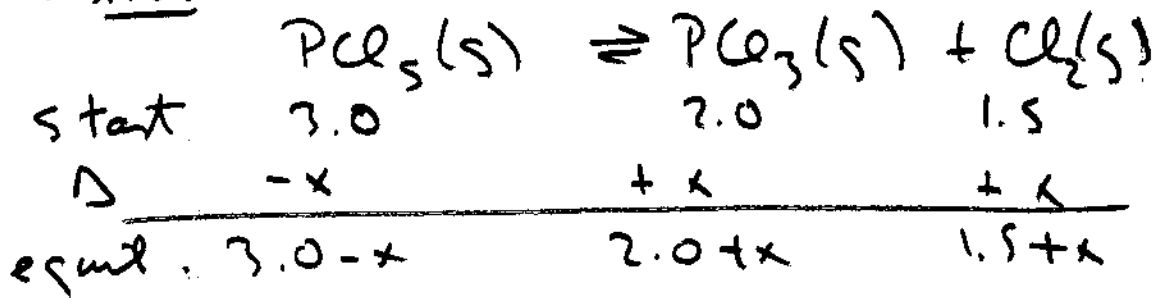
$$[PCl_5] = 0.5 - x = 0.5 - 0.135 = 0.365 M$$

$$[PCl_3] = 0.150 + x = 0.150 + 0.135 = 0.285 M$$

$$[Cl_2] = 0.60 + x = 0.60 + 0.135 = 0.735 M$$

$$Q_p = \frac{(2.0)(1.50)}{(3.0)} = 1, \quad Q_p < K_p \text{ (rxn. goes toward products)} \quad \textcircled{A}$$

13.105



$$K_p = \frac{P_{\text{PCl}_3} P_{\text{Cl}_2}}{P_{\text{PCl}_5}} = \frac{(1.5+x)(2.0+x)}{(3.0-x)} = 1.42 \Rightarrow x^2 + 4.92x - 1.26 = 0$$

using quadratic -

$$x = \frac{-4.92 \pm \sqrt{(4.92)^2 - 4(1)(-1.26)}}{2(1)} = \frac{-4.92 \pm 5.41}{2}$$

$$x = 0.245 \text{ or } -5.165$$

~~13.106~~

$$P_{\text{PCl}_5} = 3.0 - x = 2.76 \text{ atm}$$

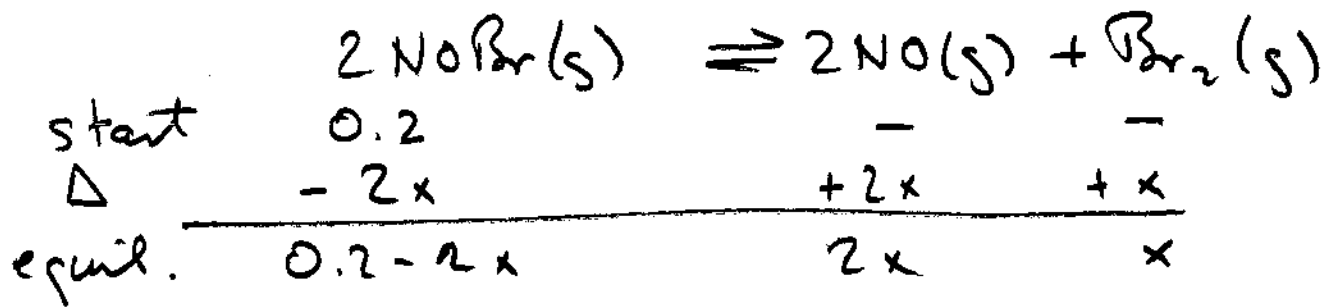
$$P_{\text{PCl}_3} = 2.0 + x = 2.24 \text{ atm}$$

$$P_{\text{Cl}_2} = 1.5 + x = 1.74 \text{ atm}$$

$$P_{\text{total}} = P_{\text{PCl}_5} + P_{\text{PCl}_3} + P_{\text{Cl}_2} = 2.76 + 2.24 + 1.74 = 6.74 \text{ atm}$$

(9c)

$$15.112 \quad (a) PV = nRT \rightarrow n_{\text{total}} = \frac{PV}{RT} = \frac{(0.588 \text{ atm})(1.0 \text{ L})}{(0.0821 \frac{\text{L}\cdot\text{atm}}{\text{mol}\cdot\text{K}})(300 \text{ K})} = 0.0239 \text{ mol}$$



$$n_{\text{total}} = 0.0239 \text{ mol} = (0.02 - 2x) + 2x + x = 0.02 + x$$

$$x = 0.0239 - 0.02 = 0.0039 \text{ mol}$$

Because the volume is 1.0 L, the molarity equals the # of moles.

$$[\text{NOBr}] = 0.02 - 2x = 0.02 - 2(0.0039) = 0.0122 \text{ M}$$

$$[\text{NO}] = 2x = 2(0.0039) = 0.0078 \text{ M}$$

$$[\text{Br}_2] = x = 0.0039 \text{ M}$$

$$K_c = \frac{[\text{NO}]^2 [\text{Br}_2]}{[\text{NOBr}]^2} = \frac{(0.0078)^2 (0.0039)}{(0.0122)^2} = 1.6 \times 10^{-3}$$

$$(b) \Delta n = 3 - 2 = 1, \quad K_p = K_c (RT) = (1.6 \times 10^{-3})(0.0821)(300) = \underline{0.039}$$

13.116



$$\Delta n = 1 - 2 = -1 \quad K_p = K_c (RT)^{-1} = [(216)(0.0821)(298)]^{-1} = 8.83$$

$$K_p = \frac{P_{\text{N}_2\text{O}_4}}{(P_{\text{NO}_2})^2} = 8.83$$

Let $X = P_{\text{N}_2\text{O}_4}$ & $Y = P_{\text{NO}_2}$

$$P_{\text{total}} = 1.50 \text{ atm} = X + Y + \frac{X}{Y^2} = 8.83$$

Now using these 2 equations we can solve for X + Y

$$X = 1.50 - Y$$

$$\frac{1.50 - Y}{Y^2} = 8.83 \quad \rightarrow \quad 8.83Y^2 + Y - 1.50 = 0$$

$$Y = \frac{-1 \pm \sqrt{1^2 - 4(8.83)(-1.50)}}{2(8.83)} = \frac{-1 \pm 7.35}{17.2}$$

$$Y = \cancel{-0.472} + 0.359$$

$$Y = P_{\text{NO}_2} = 0.359 \text{ atm}$$

$$X = P_{\text{N}_2\text{O}_4} = 1.50 - Y = 1.5 - 0.359 = 1.14 \text{ atm}$$

13.125 - H2O = 18.015 g mol^-1 -> 125.4 g H2O = 6.96 mol H2O

since mol CO = mol H2O = 6.96 mol.

P_CO = P_H2O = nRT/V = (6.96 mol)(0.0821 L-atm/mol K)(700) / 10.0 L = 40.0 atm

Table with 4 columns: CO(g), H2O(g), CO2(g), H2(g). Rows: start (40.0, 40.0, -, -), equil. (9.80, 9.80, 40.0-9.80=30.2, 40.0-9.80=30.2)

Kp = (P_CO2 * P_H2) / (P_CO * P_H2O) = (30.2^2) / (9.80^2) = 9.50

(b) 31.4 g H2O => 1.743 mol H2O, P_H2O = nRT/V = (1.743)(0.0821)(700) / 10.0 L = 10.0 atm

P_H2O has increased by 10.0 atm, + a new equilibrium will be established.

Table with 4 columns: CO(g), H2O(g), CO2(g), H2(g). Rows: start (9.80, 9.80+10.0, 30.2, 30.2), Delta (-x, -x, +x, +x), equil. (9.8-x, 19.8-x, 30.2+x, 30.2+x)

Kp = (P_CO2 * P_H2) / (P_CO * P_H2O) = 9.50 = (30.2+x)(30.2+x) / ((9.80-x)(19.80-x))

cont - next pg ->

13.125 cont.

$$8.50x^2 - 341.6x + 931.34 = 0$$

$$x = \frac{-(-341.6) \pm \sqrt{(-341.6)^2 - 4(8.50)(931.34)}}{2(8.50)} =$$

$$\frac{341.6 \pm 291.6}{17.0} \Rightarrow x = \cancel{37.25} + 2.94$$

too large.

$$P_{CO} = 9.80 - x = 9.80 - 2.94 = 6.86 \text{ atm}$$

$$P_{H_2O} = 19.8 - x = 19.8 - 2.94 = 16.9 \text{ atm}$$

$$P_{CO_2} = P_{H_2} = 30.2 + x = 30.2 + 2.94 = 33.1 \text{ atm}$$

$$n_{H_2} = \frac{PV}{RT} = \frac{(33.1 \text{ atm})(10.0 \text{ L})}{\left(\frac{0.0821 \text{ L}\cdot\text{atm}}{\text{mol}\cdot\text{K}}\right)(700)} = 5.76 \text{ mol } H_2$$

$$\frac{5.76 \text{ mol } H_2}{10.0 \text{ L}} \times \frac{1 \text{ L}}{1000 \text{ mL}} \times \frac{1 \text{ mL}}{1 \text{ cm}^3} \times \frac{6.02 \times 10^{23} \text{ } H_2 \text{ molecules}}{1 \text{ mol } H_2} =$$

$$3.47 \times 10^{20} \text{ } H_2 \text{ molecules/cm}^3$$