27

13.28
(a) $A_2 + C_2 \rightleftharpoons 2AC$ (most product molecule)
(b) $A_2 + B_2 \rightleftharpoons 2AB$ (fewer product molecule)

28

13.30
(a) Only run (3), $K_c = \frac{[A]_o [AB]}{[A_2][C_2]} = \frac{(2)(4)}{(1)(1)} = 8$, is of Equil.

\[ (b) \quad Q_c = \frac{[A][AB]}{[A_2][C_2]} = \frac{(3)(5)}{(1)(1)} = 15 \text{ for run (1)} \]

Since $Q_c > K_c$, the run will go in reverse to reach equil.

\[ (c) \quad Q_c = \frac{[A][AB]}{[A_2][C_2]} = \frac{(1)(3)}{(5)(7)} = \frac{1}{5} \text{ for run (2)} \]

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

29

13.31
(a) $A_2 + 2B \rightleftharpoons 2AB$
(b) The # of $AB$ molecules will increase, because as the volume goes down at a constant temperature, the pressure will increase, so the run will shift to the side with fewer molecules to reduce the pressure.

35

The equilibrium mixture has a $K_c = \frac{(2)(2)}{(7)^2}$, it is less than 1.

Which means that $K_c < K_r$. 

13.40
(a) \[ K_c = \frac{[\text{CO}][\text{H}_2]^2}{[\text{CH}_4][\text{H}_2\text{O}]} \]
(b) \[ K_c = \frac{[\text{CF}_3]^2}{[\text{C}_2\text{F}_6][\text{Ar}]} \]
(c) \[ K_c = \frac{[\text{HF}]^2}{[\text{H}_2][\text{F}_2]} \]

13.41
(a) \[ K_c = \frac{[\text{CH}_3][\text{H}_2\text{O}]^2}{[\text{C}_2\text{H}_4][\text{H}_2\text{O}]} \]
(b) \[ K_c = \frac{[\text{NH}_3][\text{CO}_2]}{[\text{NO}]^2} \]
(c) \[ K_c = \frac{[\text{NO}]^4[\text{H}_2\text{O}]^6}{[\text{NH}_3]^4[\text{O}_2]^5} \]

13.44
\[ K_c = \frac{[\text{C}_2\text{H}_5][\text{OH}][\text{C}_2\text{H}_5\text{OH}][\text{H}_2\text{O}]}{[\text{C}_2\text{H}_5\text{OH}]^2} \]

46
13.48: The two reactions are the reverse of each other.
\[ K_c(\text{rev}) = \frac{1}{K_c(\text{fw})} = \frac{1}{7.5 \times 10^{-9}} = 1.3 \times 10^8 \]
\[ K_c = \frac{[Pd_2][Ca_2]}{[Pd_2]} = \frac{(1.5 \times 10^{-2}) (3.2 \times 10^{-2})}{(8.7 \times 10^{-3})} = 0.058 \]

\[ 13.58 \quad (a) \quad K_c = \frac{[CO_2]^3}{[CO]^3} \quad \text{or} \quad K_p = P_{CO_2}^3 \]

\[ (b) \quad K_c = \frac{1}{[CO_2]^3} \quad \text{or} \quad K_p = \frac{1}{P_{CO_2}^3} \]

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

\[ (d) \quad K_c = [Ca^{2+}][SO_4^{2-}] \]

\[ 13.60 \quad (a) \quad \text{Since } K_c \text{ is very large, the equilibrium mixture is mostly product.} \]

\[ (b) \quad \text{Since } K_c \text{ is very small, the equilibrium mixture is mostly reactant.} \]

\[ 13.62 \quad (a) \quad \text{does not go much in the forward direction.} \]

\[ (b) \quad \text{goes almost to completion.} \]
13.69 \[ Q_c = \frac{[CO]_e [H_2]_e^3}{[H_2O]_e [CH_4]_e} = \frac{(0.15)(0.20)^3}{(0.075)(0.050)} = 0.69 \]

The reaction is not at equilibrium since \( Q_c < K_c \) (0.69 < 4.7)

The reaction will proceed from left to right to reach equilibrium.

13.70 \[ K_c = \frac{[NH_3]^2}{[N_2][H_2]^3} = 0.29 \quad \text{Equilibrium: } [N_2] = 0.056 \text{M} + [H_2] = 0.15 \text{M} \]

\[ [NH_3] = \sqrt{[N_2][H_2]^3} \cdot K_c = \sqrt{0.056 \cdot 0.15^3 \cdot 0.29} = 5.9 \times 10^{-3} \text{M} \]

13.71 \[ K_c = 2.7 \times 10^2 = \frac{[SO_3]^2}{[SO_2]^2 [O_2]} \quad \text{Because } [SO_3] = [SO_2], \quad \text{then } 2.7 \times 10^2 = \frac{1}{[O_2]} \]

\[ [O_2] = 3.7 \times 10^{-3} \text{M} \]
\[ \frac{13.28}{x} \quad \text{ClF}_3(g) \rightleftharpoons \text{ClF}(g) + \text{F}_2(g) \]

\[
\begin{array}{c}
\text{stat} \quad 1.47 \\
\uparrow \\
\text{D} \quad -x \\
\text{K} = \frac{P_{\text{ClF}} P_{\text{F}_2}}{P_{\text{ClF}_3}} = 0.140 = \frac{x^2}{1.47-x} \\
\end{array}
\]

\[ x^2 + 0.140x - 0.2058 = 0 \]

\[ x = -0.140 \pm \sqrt{0.140^2 - 4 \cdot 1.7 \cdot 0.2058} = \frac{-0.140 \pm 0.918}{2} \]

\[ x = 0.385 \quad \text{or} \quad x = -0.569 \]

\[ P_{\text{ClF}} = P_{\text{F}_2} = x = 0.385 \quad \text{atm}, \quad P_{\text{ClF}_3} = 1.47 - 0.385 = 1.085 \text{ atm}. \]
17.80  (a) If Cl\(^-\) is added, AgCl(s) increases.
(b) Ag\(^+\) is added, AgCl(s) increases.
(c) Ag\(^+\) is removed, AgCl(s) decreases.
(d) Cl\(^-\) removed, AgCl(s) decreases.
If [Cl\(^-\)]\uparrow Q_c increases to a value greater than K_c, therefore the reaction must go from right to left to decrease AgCl(s).

13.81  (a) UNO added, NO\(_2\) ↓
(b) NO added, NO\(_2\) ↑
(c) NO removed, NO\(_2\) ↓
(d) UNO\(_2\) added, NO\(_2\) ↑
Adding UNO\(_2\) decreases Q_c, the reaction must shift from left to right to reach equilibrium, thus increasing the NO\(_2\) concentration.

17.83 As the volume \(\uparrow\), the Pressure \(\downarrow\), at constant temp.
(a) The reaction will shift to the side with larger \# of molecules — since the stress is the decrease in Pressure — or an increase in volume. — Toward Product.
(b) The reaction will shift to the reactants, since that is the side with the greater \# of moles.
(c) This reaction is not altered by change in volume or pressure, since there are equal \# of molecules on both sides — No change.
17.86 (2) NCE is a source of $\text{Ce}^-$, the rexn. shifts left, the equil. $[\text{CoCl}_4^{2-}]$ increases.

(b) $\text{Co(NO}_3\text{)}_2$ is a source of $\text{Co(H}_2\text{O)}_6^{3+}$, the rexn. shifts left. The equil. conc. of $[\text{CoCl}_4^{2-}]$ increases.

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

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

17.87

(a) $\text{Fe(NO}_3\text{)}_2$ is a source of $\text{Fe}^{3+}$. $\text{Fe}^{3+}$ added, the $\text{FeCl}^{2+}$ conc. increases.

(b) $\text{Cl}^-$ removed, the $\text{FeCl}^{2+}$ conc. decreases.

(c) An endo, exothermic rexn. shifts to the right as the temp increases; the $\text{FeCl}^{2+}$ conc. increases.

(d) A catalyst does not affect the composition of the equil. mixture; no change in $\text{FeCl}^{2+}$ conc.
\[ k_c = \frac{k_e}{h_r} = \frac{0.13}{6.2 \times 10^{-4}} = 210 \]

\[ V = 9.0L \]

\[ \text{H}_2(g) + \text{I}_2(g) \rightleftharpoons 2 \text{HI}(g) \]

\[ (\text{H}_2) = (\text{I}_2) = \text{start} 0.2 \quad 0.2 \quad 0.5 \]

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

\[ \Delta -x \quad -x \quad +2x \]

\[ \begin{align*}
\text{[HI]} &= \text{equiv.} 0.2-x \quad 0.2-x \quad 0.5+2x \\
2.5 - 2 / 5L &= 0.5M \\
K_c &= \frac{[\text{HI}]^2}{[\text{H}_2][\text{I}_2]} = \frac{129 = (0.50+2x)^2}{(0.20-x)^2} \\
\sqrt{129} &= \sqrt{\frac{(0.50+2x)^2}{(0.20-x)^2}} = 11.4 = \frac{0.50+2x}{0.20-x} \quad x = 0.133 \\
[\text{HI}] &= (\text{I}_2) = 0.2 - 0.133 = 0.087M \\
[\text{H}_2] &= 0.5 + 2(0.133) = 0.74 \]
\]

\[ 106 \quad \text{(13.95L)} \]

\[ (\text{O}_3) = 1 \text{mol} / 5L = 0.2M \]

\[ \text{PCl}_5(g) \rightleftharpoons \text{PCl}_3(g) + \text{Cl}_2(g) \]

\[ \text{start} \quad 0.2 \quad - \\
\Delta - (0.2)(0.7859) + (0.2)(0.7859) + (0.2)(0.7859) \quad \text{equiv.} \quad 0.0470 + 0.1570 + 0.1570 \]

\[ K_c = \frac{[\text{PCl}_3][\text{Cl}_2]}{[\text{PCl}_5]} = \frac{(0.1570)^2}{0.0470} = 5.73 \]

\[ \Delta n = 1 + k_p = K_c (RT)^{\Delta n} = 0.573(0.0821)(500) = 27.5 \]
\[ 2 \text{NO}_2(\text{g}) \rightleftharpoons \text{N}_2\text{O}_4(\text{g}) \]

\[ \Delta n = 1 - 2 = -1 \quad K_p = K_c \left(\frac{RT}{V_f}\right)^{-1} = \left(\frac{216}{0.0821 \times 273}\right)^{-1} \]

\[ = 8.83 \]

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

Let \( X = P_{\text{N}_2\text{O}_4} \) and \( Y = P_{\text{NO}_2} \)

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

Now, using the 2 equation we can solve for \( X + Y \)

\[ X = 1.50 - Y \]

\[ \frac{1.50 - Y}{Y^2} = 8.83 \quad \Rightarrow \quad 8.83 Y^2 + Y - 1.50 = 0 \]

\[ Y = \frac{-1 \pm \sqrt{1^2 - 4 \times 8.83 \times (-1.50)}}{2 \times 8.83} = \frac{-1 \pm 7.35}{17.7} \]

\[ Y = -0.42 \pm 0.355 \]

\[ Y = P_{\text{NO}_2} = 0.355 \text{ atm} \]

\[ X = P_{\text{N}_2\text{O}_4} = 1.50 - Y = 1.5 - 0.355 = 1.14 \text{ atm} \]