9) Consider the equilibrium between dinitrogen tetra oxide and nitrogen dioxide:

$N_2O_4\,(g) \rightleftharpoons 2NO_2\,(g)$ $\quad K_p = 0.660$ at 319 K

a) What is the value of K_c for this reaction? (Ans: 0.0252)

b) What is value of K_p for the reaction $2NO_2\,(g) \rightleftharpoons N_2O_4\,(g)$ (Ans: 1.52)

c) If the equilibrium partial pressure of NO_2 (g) is 0.332 atm, what is the equilibrium partial pressure of N_2O_4 (g)? (Ans: 0.167 atm)

a) $K_p = K_c(RT)^{\Delta n}$; $K_c = \dfrac{K_p}{(RT)^{\Delta n}} = \dfrac{0.66}{(0.0821 \times 319)^{2-1}} = 0.0252$

b) ..... Inverse K_p $\quad \dfrac{1}{0.660} = 1.52$

c) $K_p = \dfrac{P_{NO_2}^2}{P_{N_2O_4}}$; $\quad 0.66 = \dfrac{(0.332)^2}{P_{N_2O_4}}$

$P_{N_2O_4} = 0.167$ atm

10) If a 2.50 L vessel at 1000 °C contains 0.525 mol CO_2, 1.25 mol CF_4, and 0.750 mol COF_2, in what direction will a net reaction occur to reach the equilibrium? (Ans: 0.857, left)

$CO_2\,(g) + CF_4\,(g) \rightleftharpoons 2COF_2\,(g)$ $\quad K_c = 0.50$ at 1000 K

$0.525/2.5L$ $\quad 1.25/2.5L$ $\quad 0.75/2.5L$

0.21 $\quad 0.5$ $\quad 0.3$

$Q_c = \dfrac{[COF_2]^2}{[CO_2][CF_4]} = \dfrac{(0.3)^2}{(0.21)(0.5)} = 0.857$

$Q_c > K_c$

$0.857 \quad 0.5$ eq. moving to left.

11) In a 10.0 L vessel at 1000 K, 0.250 mol SO_2 and 0.200 mol O_2 react to from 0.162 mol SO_3 at equilibrium. What is the K_c, at 1000 K for the reaction shown below? (Ans: 8.92×10^3)

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$$

	$2SO_2(g)$	$O_2(g)$	$2SO_3(g)$
	$0.25/10L$	$0.2/10L$	$0.162/10L$
I	0.025	0.02	0.0162
C	$(0.025 - 0.0162)$	$0.02 - 0.0162)$	
E	0.0088	0.0038	0.0162

$$K_c = \frac{[SO_3]^2}{[SO_2]^2[O_2]} = \frac{(0.0162)^2}{(0.0088)^2(0.0038)} = \boxed{8.92 \times 10^3}$$

12) The following substances are added to a 7.25 L flask at 773 °C: 0.103 mol CO, 0.205 mol H_2, 2.10 mol CH_4 and 3.15 mol H_2O. In what direction will a net reaction occur to reach the equilibrium? (Ans: 97; forward)

$$CO(g) + 3H_2 \rightleftharpoons CH_4 + H_2O \quad K_p = 102 \text{ at } 773 \text{ K}$$

$0.103/7.25$ $\quad 0.205/7.25$ $\quad \frac{2.10}{7.25}$ $\quad 3.15/7.25$

$$Q_c = \frac{(0.2897)(0.4345)}{(0.0142)(0.0283)^3} = 3.91 \times 10^5$$

$$Q_p = Q_c(RT)^{\Delta n} = (3.91 \times 10^5) \times (0.0821 \times 773)^{-2}$$
$$= 97.1$$

$Q_p < K_p$ reaction going forward.

$97.1 \quad 102$

13) Starting with 0.100 mol each of CO and H_2O in a 5.00 L flask, equilibrium is established in the following reaction at 600K:

$$CO(g) + H_2O(g) \rightleftharpoons CO_2(g) + H_2(g) \qquad K_c = 23.2 \text{ at } 600 \text{ K}$$

What is the concentration of hydrogen at equilibrium? (Ans: 0.0165 M)

I	$0.1 mol/5L$	$0.1/5L$	0	0
C	$-x$	$-x$	$+x$	$+x$
E	$0.02-x$	$0.02-x$	x	x

$$K_c = 23.2 = \frac{(x)(x)}{(0.02-x)(0.02-x)} = \frac{x^2}{(0.02-x)^2}$$ take $\sqrt{}$ both sides.

$$4.82 = \frac{x}{0.02-x} \; ; \; \boxed{x = 0.0165M}$$

14) Starting with 0.100 mol CO and 0.200 mol CO_2 in a 25.0 L flask, how many mols of $COCl_2$ will be present at equilibrium? (Ans: 8.5×10^{-2} mol)

$CO\ (g) + Cl_2\ (g) \rightleftharpoons COCl_2\ (g)$ $\quad K_c = 1.2 \times 10^3$

0.1 mol/25L 0.2/25 0

$-x$ $-x$ $+x$

$(0.004-x)$ $(0.008-x)$ x

$K_c = 1.2 \times 10^3 = \dfrac{x}{(0.004-x)(0.008-x)} = \dfrac{x}{3.20 \times 10^{-5} - 0.012x + x^2}$

$1.2 \times 10^3 x^2 - 14.4x - 3.84 \times 10^{-2} = x$

$1.2 \times 10^3 x^2 - 15.4x - 3.84 \times 10^{-2} = 0$

$x = \dfrac{-b \pm \sqrt{b^2 - 4ac}}{2a}$

$= \dfrac{1.28 \times 10^{-2} \pm \sqrt{(1.28 \times 10^{-2})^2 - 4(1)(3.2 \times 10^{-5})}}{2(1)}$

Practice/Equilibrium-Le Chatelier's Principle ***DO NOT SUBMIT***

15) The reaction between carbon monoxide and steam is given below.

$CO\ (g) + H_2O\ (g) \rightleftharpoons CO_2\ (g) + H_2\ (g)$ $\Delta H = -41$ KJ; $K_c = 9.03$ at 698 K

$x = 3.4 \times 10^{-3}$ M

$3.4 \times 10^{-3}\ M \times 25\ L = 8.5 \times 10^{-2}$ mol

Using LeChatlier's principles predict which direction the equilibrium will proceed when the following changes are made.

a) Carbon monoxide is added →

b) Carbon dioxide is removed →

c) The reaction is heated up ←

d) The reaction vessel is compressed to half its volume no change

e) A catalyst is added no change

f) A 1 L of argon is added to the reaction vessel no change.