Equilibrium/Practice **Name:** Key

1) The reaction of steam and coke (a form of carbon) produces a mixture of carbon monoxide and hydrogen (water gas). The reaction is given below; write the K_c expression for the reaction.

$$C(s) + H_2O(g) \rightleftharpoons CO(g) + H_2(g)$$

$$K_c = \frac{[CO][H_2]}{[H_2O]}$$

2) If the equilibrium concentrations of Cl_2 and $COCl_2$ are the same at 395 °C, find the equilibrium concentration of CO in the reaction shown below: (ans: 8.3×10^{-4}M)

$$CO(g) + Cl_2(g) \rightleftharpoons COCl_2(g) \qquad K_c = 1.2 \times 10^3 \text{ at } 395\ °C.$$

$$K_c = \frac{[COCl_2]}{[CO][Cl_2]} = 1.2 \times 10^3$$

$$\frac{1}{[CO]} = 1.2 \times 10^3 \qquad [CO] = 8.3 \times 10^{-4}\ M$$

3) The equilibrium constant for the reaction given below is 7.07 at 718 K.

$$\tfrac{1}{2} H_2(g) + \tfrac{1}{2} I_2(g) \rightleftharpoons HI(g)$$

What is the K_c value at 718 K for the two reactions given below?

a) $HI(g) \rightleftharpoons \tfrac{1}{2} H_2(g) + \tfrac{1}{2} I_2(g)$

inv. K_c ∴ $\frac{1}{K_c} = \frac{1}{7.07} = 0.141$

b) $H_{2(g)} + I_{2(g)} \rightleftharpoons 2HI(g)$

twice of K_c ∴ $K_c^2 = (7.07)^2 = 50.0$

4) Consider the equilibrium between dinigrogen tetraoxide and nitrogen doxide:

$$N_2O_4(g) \rightleftharpoons 2NO_2(g) \qquad K_p = 0.660 \text{ at } 319\text{ K}$$

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) $K_p = K_c(RT)^{\Delta n}$

$$K_c = \frac{K_p}{(RT)^{\Delta n}} = \frac{0.660}{(0.0821 \times 319)^{2-1}} = 0.0252$$

(b) inverse K_p $\frac{1}{K_p} = \frac{1}{0.660} = 1.52$

(c) $K_p = \frac{(P_{NO_2})^2}{(P_{N_2O_4})}$; $0.660 = \frac{(0.332)^2}{P_{N_2O_4}}$

$P_{N_2O_4} = 0.167$ atm

5) If a 2.50 L vessel at 1000 °C containes 0.525 mol CO_2, 1.25 mol CF_4, and 0.75 mol COF_2, in what direction will a net reaction occur to reach the equilibrium? (*P50* – ans: 0.857,left)

CO_2 (g) + CF_4 (g) ⇌ $2COF_2$ (g) $K_c = 0.50$ at 1000 K

0.525/2.5L 1.25/2.5L 0.75/2.5L

0.21m 0.5m 0.3m.

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

$Q_c > K_c$
0.857 0.5

eq. proceeds to reactants left.

6) 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: 2.8 x 10^2)

$2SO_2$(g) + O_2 (g) ⇌ $2SO_3$ (g)

	$2SO_2$	O_2	$2SO_3$
	0.250/10L	0.2/10L	0.162/10L
I	0.0250	0.0200	0.0162
C	(0.0250−0.0162)	−0.0162	0.0162
E	0.0088	0.0119	0.0162

$$K_c = \frac{[SO_3]^2}{[SO_2]^2[O_2]} = \frac{(0.0162)^2}{(0.0088)^2(0.0119)} = 2.8 \times 10^2$$

7) The following substances are added to a 7.25 L flask at 773 °C contains 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? (*P51*; ans: 1.84-left)

CO(g) + $3H_2$ ⇌ CH_4 + H_2O $K_p = 102$ at 773 K

0.103/7.25 0.205/7.25 2.10/7.25 3.15/7.25

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

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

$= 97.1$

$Q_p < K_p$
97.1 102

reaction going forward

8) 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:

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

What is the concentration of hydrogen at equilibrium? (*P12A*; ans: 0.0165M)

	CO	+ H_2O	⇌ CO_2	+ H_2
I	0.1mol/5L	0.1mol/5L	0	0
C	$-x$	$-x$	$+x$	$+x$.
E	$0.02-x$	$0.02-x$	x	x.

$$K_c = 23.2 = \frac{[CO_2][H_2O]}{[CO][H_2O]} = \frac{(x)(x)}{(0.02-x)(0.02-x)} = \frac{x^2}{(0.02-x)^2}$$

take square root of both: $4.82 = \frac{x}{0.02-x}$

$$\boxed{x = 0.0165M}$$

9) 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? (*P13A*; ans: 8.5×10^{-2}mol)

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

	CO	Cl_2	$COCl_2$
I	0.100/25L	0.200/25L	0
C	$-x$	$-x$	x
E	$(0.004-x)$	$(0.008-x)$	x.

$$K_c = 1.2 \times 10^3 = \frac{x}{(0.004-x)(0.008-x)} = \frac{x}{3.20 \times 10^{-5} - 0.01200x + x^2}$$

cross multiply:

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

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

divide all by 1.2×10^3 to make quadratic eq. easier.

$$x^2 - 1.28 \times 10^{-2} x + 3.2 \times 10^{-5} = 0.$$

(a = 1, b = 1.28×10^{-2}, c = 3.2×10^{-5})

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a} = \frac{1.28 \times 10^{-2} \pm \sqrt{(1.28 \times 10^{-2})^2 - 4(1)(3.2 \times 10^{-5})}}{2(1)}.$$

$x = 3.4 \times 10^{-3}$ M or 9.4×10^{-3} ← too large!

$$3.4 \times 10^{-3}\ \text{mol/L} \times 25L = \boxed{8.5 \times 10^{-2}\ \text{mol.}}$$

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

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

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.