Week 1 Step-Up Session

1. A reaction used in the production of gaseous fuels from coal, which is mainly carbon, is:

$$C(s) + H_2O(g) \rightleftharpoons CO(g) + H_2(g) \quad K_c = 0.403 \text{ at } 900 \text{ K}$$

A 5.20-kg sample of graphite and 125 g of water were placed into a 10.0-L container and heated to 900 K. What are the equilibrium concentrations?

$$5.20 \times 10^3 \text{ g C} \times \frac{1 \text{ mol C}}{12.011 \text{ g}} = 433. \text{ mol C}$$

$$125 \text{ g } H_2O \times \frac{1 \text{ mol } H_2O}{18.016 \text{ g}} = 6.94 \text{ mol } H_2O$$

$$\text{conc: } \frac{n}{V} = \frac{6.94 \text{ mol } H_2O}{10.0 \text{ L}} = 0.694 \text{ mol}\cdot L^{-1}$$

	$C(s)$	$H_2O(g)$	$\longrightarrow$	$CO(g)$	$H_2(g)$
I		0.694		0	0
C		$-x$		$+x$	$+x$
E		$0.694-x$		x	x

$$K_c = \frac{[CO][H_2]}{[H_2O]} = \frac{(x)(x)}{0.694-x} = 0.403$$

$$x^2 = 0.403(0.694-x)$$

$$x = +0.364, \ -0.766$$

$x = 0.364$ M $= [CO] = [H_2O]$

$[H_2O] = 0.694 - 0.364 = 0.330$ M

2. The two air pollutants SO_2 and NO_2 can react in the atmosphere as follows:

$SO_2(g) + NO_2(g) \rightleftharpoons SO_3(g) + NO(g)$ ↓

Predict the effect of the following changes to the amount of NO when the reaction above has come to equilibrium in a stainless steel bulb equipped with entrants for chemicals.

a. The amount of NO_2 is increased. ↑

b. The SO_3 is removed by condensation. ↑

c. The pressure is tripled by pumping in helium. ∅

↑

3. At 25℃, $K_c = 1.93$ for the reaction $N_2O_4 (g) \rightleftharpoons 2 NO_2 (g)$.
   a. If 0.020 mol of N_2O_4 and 0.010 mol of NO_2 are placed in a 2.00-L reaction vessel and the reaction is allowed to reach equilibrium, what are the equilibrium concentrations of N_2O_4 and NO_2?

$$Q = \frac{[NO_2]^2}{[N_2O_4]} = \frac{[0.010/2]^2}{[0.020/2]} = 2.5 \times 10^{-3}$$

	N_2O_4	$2NO_2$
I	$0.020/2 = 0.010$	$0.010/2 = 0.0050$
C	$-x$	$+2x$
E	$0.010 - x$	$0.0050 + 2x$

$$K_c = 1.93 = \frac{(0.0050 + 2x)^2}{(0.010 - x)}$$

$$x = 9.69 \times 10^{-3} \ mol.L^{-1}$$

$$[N_2O_4] = 3.1 \times 10^{-4} \ M$$

$$[NO_2] = 2.44 \times 10^{-2} \ M$$

   b. If additional NO_2 is added to the flask how will this change affect the concentration of N_2O_4?

$$\uparrow \ N_2O_4 \rightleftharpoons 2NO_2 \ \uparrow$$

$\uparrow$

4. The equilibrium constant $K_c = 0.56$ for the reaction PCl_3 (g) + Cl_2 (g) ⇌ PCl_5 (g) at 250. °C. On analysis, 1.50 mol PCl_5, 3.00 mol PCl_3, and 0.500 mol Cl_2 were found to be present in a 0.500 L reaction vessel at 250. °C.
   Is the reaction at equilibrium? If not, in which direction does it tend to proceed?

$$[PCl_5] = \frac{1.50 \text{ mol}}{0.500 \text{ L}} = 3.00 \text{ M} \qquad [PCl_3] = \frac{3.00 \text{ mol}}{0.500 \text{ L}} = 6.00 \text{M}$$

$$[Cl_2] = \frac{0.500 \text{ mol}}{0.500 \text{ L}} = 1.00 \text{ M}$$

$$Q = \frac{[PCl_5]}{[PCl_3][Cl_2]} = \frac{(3.00)}{(6.00)(1.00)} = 0.500$$

$Q \neq K$ not at equilibrium

$Q < K$ rxn proceeds to form products

5. The following reaction is at equilibrium: NH_3 (g) + O_2 (g) ⇌ H_2O (g) + N_2 (g).

$4NH_3 (g) + 3O_2 (g) \rightarrow 6H_2O (g) + 2N_2 (g)$

$PV = nRT$

How will the equilibrium shift if:

a. The volume is increased.

v ↑ shift right

P ↓ ↑ moles gas

b. Four moles of Helium gas is added.

∅

c. A lit match is placed inside the container.

$NH_3 + O_2 \rightleftharpoons H_2O + N_2$

↓

←

Stuff to Know

equilibrium constant: an expression that describes the relationship between the amount of products and reactants at equilibrium

@ equilibrium: FORWARD RATE = REVERSE

$$X \rightleftharpoons Y$$

SOLVING FOR K

$$N_{2(g)} + H_{2(g)} \rightleftharpoons NH_{3(g)}$$

1) Balance rxn

$$N_{2(g)} + 3H_{2(g)} \rightleftharpoons 2NH_{3(g)}$$

$$K = \frac{[\text{products}]}{[\text{reactants}]}$$

$$= \frac{[NH_3]^2}{[N_2][H_2]^3}$$

$$K_{rev} = \frac{1}{K_{forward}} = \frac{[N_2][H_2]^3}{[NH_3]^2}$$

What does K tell you?

Stability

$K > 10^3$ — products are more stable; forward rxn is favored

$K = 1$ — neither forward or reverse is more stable

$K < 10^{-3}$ — reactants are more stable; reverse reaction is favored

$$\longrightarrow$$

$$\text{reactants} \rightleftharpoons \text{products}$$

$$\longleftarrow$$

$$K_{concentrations} = \frac{[\text{product}]^{\text{coefficient}}}{[\text{reactant}]^{\text{coefficient}}}$$

$$K_P = \frac{(P_{\text{products}})^{\text{coefficients}}}{(P_{\text{reactants}})^{\text{coefficients}}}$$

$$P = \frac{nRT}{V}$$

$$\text{concentration} = \frac{n}{V} = \frac{P}{RT}$$

n = moles

T = temperature (K)

V = volume (L)

R = universal gas constant

What doesn't go in the equilibrium constant K?

1) pure solids — NO CONC., NOT POSSIBLE

2) PURE LIQUIDS — so much, any change insignificant

↑ H_2O

Reaction quotient (Q) = tells the product : reactant ratio at any point in rxn

→ tell you if it's at equilibrium

$Q < K$: forward rxn is favored

$Q > K$: reverse rxn is favored

$Q = K$: equilibrium

In an experiment, 2.0 mmol Cl_2 (g) was sealed into a rxn vessel of volume 2.0 L and heated to 1000. K. Calculate K.

$$[Cl_2(g) \rightleftharpoons 2\,Cl(g)]$$

$$[K = 1.2 \times 10^{-7} \text{ @ } 1000\text{ K}]$$

$$K = \frac{[Cl]^2}{[Cl_2]}$$

2.0×10^{-3} mol / 2.0 L =

	Cl_2	$\longrightarrow$	2 Cl
I	1.0×10^{-3} M		0
C	$-x$		$+2x$
E	$1.0 \times 10^{-3} - x$		$2x$

$$K = 1.2 \times 10^{-7} = \frac{(2x)^2}{(1.00 \times 10^{-3} - x)}$$

$$1.2 \times 10^{-7} = \frac{(2x)^2}{(1.00 \times 10^{-3} - x)}$$

$$1.2\times10^{-7}(1.00\times10^{-3}-x) = (2x)^2$$

$$1.2\times10^{-10} - (1.2\times10^{-7})x = 4x^2$$

$$4x^2 + (1.2\times10^{-7})x - (1.2\times10^{-10}) = 0$$

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

$$= \frac{-1.2\times10^{-7} \pm \sqrt{(1.2\times10^{-7})^2 - 4(4)(1.2\times10^{-10})}}{2(4)}$$

$$= 5.5\times10^{-6}$$