Ch 12 EQUILIBRIUM CALCULATIONS

Name____________________

In solving the following problems
- write the equilibrium expression
- convert moles and litres to concentration
- omit the units for K_{eq} but write them for all other quantities

1. A closed container is found to have 0.45 M NO(g), 0.78 M O_2(g), and 0.26 M NO_2(g). Determine the equilibrium constant for the following equilibrium:

$$2NO(g) + O_2(g) \longleftrightarrow 2NO_2(g)$$

$$K_{eq} = \frac{[NO_2]^2}{[NO]^2[O_2]} \qquad K_{eq} = \frac{(.26)^2}{(0.45)^2(0.78)} = 0.43$$

2. A 1.00 L bulb holds 1.22 mol NH_3(g), 2.46 mol H_2(g), and 1.80 mol N_2(g). Calculate the K_{eq} for the following equilibrium:

$$N_2(g) + 3H_2(g) \longleftrightarrow 2NH_3(g)$$

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

$$K_{eq} = \frac{(1.22)^2}{(1.80)(2.46)^3} = 0.0555$$

$$[H_2] = \frac{2.46\text{ mol}}{1.00\text{ L}} = 2.46\text{ M}$$

$$[NH_3] = \frac{1.22\text{ mol}}{1.00\text{ L}} = 1.22\text{ M}$$

$$[N_2] = \frac{1.80\text{ mol}}{1.00\text{ L}} = 1.80\text{ M}$$

3. A 2.50 L container holds 1.65 moles PCl_5(g), 0.575 moles PCl_3(g), and 1.55 moles Cl_2(g). Calculate the K_{eq} for the following equilibrium:

$$PCl_5(g) \longleftrightarrow PCl_3(g) + Cl_2(g)$$

$$K_{eq} = \frac{[PCl_3][Cl_2]}{[PCl_5]}$$

$$K_{eq} = \frac{(0.230)(0.620)}{(0.660)} = 0.216$$

$$[PCl_5] = \frac{1.65\text{ mol}}{2.50\text{ L}} = 0.660\text{ M}$$

$$[PCl_3] = \frac{0.575\text{ mol}}{2.50\text{ L}} = 0.230\text{ M}$$

$$[Cl_2] = \frac{1.55\text{ mol}}{2.50\text{ L}} = 0.620\text{ M}$$

4. A 5.00 L container is found to hold 0.340 moles NO(g), 0.950 moles O_2(g), and 0.505 moles NO_2(g). Determine the equilibrium constant for the following equilibrium:

$$2NO(g) + O_2(g) \longleftrightarrow 2NO_2(g)$$

$$K_{eq} = \frac{[NO_2]^2}{[NO]^2[O_2]}$$

$$K_{eq} = \frac{(0.101)^2}{(0.0680)^2(0.190)} = 11.6$$

$$[NO_2] = \frac{0.505\text{ mol}}{5.00\text{ L}} = 0.101$$

$$[NO] = \frac{0.340\text{ mol}}{5.00\text{ L}} = 0.0680$$

$$[O_2] = \frac{0.950\text{ mol}}{5.00\text{ L}} = 0.190$$

10. A 1.00 L reaction vessel has 0.654 moles of NOCl(g) placed in it. After equilibrium is achieved according to the equation $2NOCl(g) \longleftrightarrow 2NO(g) + Cl_2(g)$, the concentration of $Cl_2(g)$ is found to be 0.168 M. Determine the K_{eq} for this reaction.

	[NOCl]	[NO]	[Cl2]
I	0.654	0.00	0.00
C	-0.336	+0.336	+0.168
E	0.318	0.336	0.168

2 : 2 : 1

$K_{eq} = \frac{[NO]^2[Cl_2]}{[NOCl]^2}$

$[NOCl] = \frac{0.654 \text{ mol}}{1.00 L} = 0.6$

$K_{eq} = \frac{0.336^2 (0.168)}{(0.318)^2} = 0.188$

11. When 1.42 mol $N_2(g)$ and 2.86 mol $H_2(g)$ are introduced to a 1.00 L container and allowed to reach equilibrium, 0.98 mol $N_2(g)$ are found. What is the K_{eq} for the equilibrium $N_2(g) + 3H_2(g) \longleftrightarrow 2NH_3(g)$?

	[N2]	[H2]	[NH3]
I	1.42	2.86	0.00
C	-0.44	-1.32	+0.88
E	0.98	1.54	0.88

1 : 3 : 2

1:3:2

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

$K_{eq} = \frac{(0.88)^2}{(0.98)(1.54)^3} = 0.22$

12. A bulb has 0.345 M CO(g) and 0.500 M $H_2O(g)$ placed in it. After 25 min, equilibrium has been reached according to the equation $CO(g) + H_2O(g) \longleftrightarrow CO_2(g) + H_2(g)$. Analysis shows the $[CO_2(g)]$ is now 0.122 M. Calculate K_{eq} for this equilibrium.

	[CO]	[H2O]	[CO2]	[H2]
I	0.345	0.500	0.00	0.00
C	-0.122	-0.122	+0.122	+0.122
E	0.223	0.378	0.122	0.122

$K_{eq} = \frac{[H_2][CO_2]}{[CO][H_2O]}$

$K_{eq} = \frac{(0.122)(0.122)}{(0.223)(0.378)} = 0.177$

13. A 4.00 L container was initially filled with 2.44 moles of $O_2(g)$ and 2.68 moles of $SO_2(g)$. At equilibrium, 1.32 moles of $SO_3(g)$ are found. Determine the K_{eq} for the equilibrium $2SO_2(g) + O_2(g) \longleftrightarrow 2SO_3(g)$.

	[SO2]	[O2]	[SO3]
I	0.670	0.610	0.00
C	-0.330	-0.165	+0.330
E	0.340	0.445	0.330

2 : 1 : 2

$K_{eq} = \frac{[SO_3]^2}{[SO_2]^2[O_2]}$

$[O_2] = \frac{2.44 \text{ mol}}{4.00 L} = 0.610$

$[SO_2] = \frac{2.68 \text{ mol}}{4.00 L} = 0.670$

$[SO_3] = \frac{1.32 \text{ mol}}{4.00 L} = $

$K_{eq} = \frac{(0.330)^2}{(0.340)^2 (0.445)} = 2.12$

18. The Keq for the equilibrium $2NO(g) + O_2(g)$ <-----> $2NO_2(g)$ is known to be 12.6 at a certain temperature. If, at this temperature, 2.46 mol NO(g), 1.23 mol $O_2(g)$, and 9.86 mol $NO_2(g)$ are introduced into a 1.00 L container, which way will the reaction proceed in order to achieve equilibrium?

$$K_{eq} = \frac{[NO_2]^2}{[NO]^2[O_2]}$$

Trial Keq (K_{trial}) $= \frac{(9.86)^2 \text{ products}}{(2.46)^2(1.23) \text{ reactants}} = 13.1 > K_{eq}$ (12.6)

This equilibrium proceeds left.

19. A 3.00 L container has 0.576 moles $NH_3(g)$, 0.843 moles $H_2(g)$, and 0.972 moles $N_2(g)$ added to it. As it approaches equilibrium according to $N_2(g) + 3H_2(g)$ <-----> $2NH_3(g)$, will the reaction proceed in the forward direction or the reverse direction? The K_{eq} for the reaction is 7.57.

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

Trial Keq $= \frac{(0.192)^2}{(0.324)(0.281)^3}$

$= 5.13 < 7.57$ Keq

shift to right

forward

$[NH_3] = \frac{0.576 \text{ mol}}{3.00 \text{ L}} = .192$ M

$[H_2] = \frac{0.843 \text{ mol}}{3.00 \text{ L}} = .281$ M

$[N_2] = \frac{0.972 \text{ mol}}{3.00 \text{ L}} = .324$ M

20. The K_{eq} for the reaction $CO(g) + H_2O(g)$ <-----> $CO_2(g) + H_2(g)$ is 1.24. If the initial conditions are: $[CO(g)] = 0.678$ M, $[H_2O(g)] = 0.456$ M, $[CO_2(g)] = 0.961$ M, and $[H_2(g)] = 0.543$ M, will the [CO(g)] increase or decrease as the reaction proceeds toward equilibrium?

$$K_{eq} = \frac{[CO_2][H_2]}{[CO][H_2O]}$$

Trial Keq $= \frac{(0.961)(0.543) \text{ P}}{(0.678)(0.456) \text{ r}} = 1.69 > 1.24$ Keq

shifts left ∴ [CO] increases

21. A 1.00 L bulb is injected with 0.87 mol $SO_2(g)$, 0.12 mol $O_2(g)$, and 0.59 mol $SO_3(g)$. As the reaction $2SO_3(g)$ <-----> $2SO_2(g) + O_2(g)$ proceeds towards equilibrium, will the $[O_2(g)]$ increase or decrease? The K_{eq} for the equilibrium is 0.41.

$$K_{eq} = \frac{[SO_2]^2[O_2]}{[SO_3]^2}$$

Trial Keq $= \frac{(0.87)^2(0.12) \text{ P}}{(0.59)^2 \text{ r}} = 0.26 < 0.41$ Keq

shifts right ∴ $[O_2]$ will increase