Equilibrium Problems

15.17 For the system

$PCl_5(g) \rightleftharpoons PCl_3(g) + Cl_2(g)$ $K_c = 0.050$ at 250° C.

If 0.30 mol PCl_5 is placed in a 1.0-L container at this temperature, what are the equilibrium concentrations of all species?

Answers PCl_3 = .1 M Cl_2 = .1 M PCl_5 = .2 M

15.21 Consider the system

$2\ H_2S(g) + 3\ O_2(g)$ <-> $2\ H_2O(g) + 2\ SO_2(g)$

ΔH for the forward reaction is –1036 kJ. Predict whether the forward or reverse reaction will occur when the equilibrium is disturbed by

a. expanding the container at constant temperature

b. removing SO_2

c. raising the temperature

d. absorbing the water vapor

Answers a = left b = right c = left d. = right

15.40 A gaseous reaction mixture contains 0.30 mol SO_2, 0.16 mol Cl_2, and 0.50 mol SO_2Cl_2 in a 2.0-L container; $K_c = 0.011$ for $SO_2Cl_2(g)$ <-> $SO_2(g) + Cl_2(g)$

a. Is the system at equilibrium? Explain.

b. If it is not at equilibrium, in which direction will the system move to reach equilibrium?

Answers a. The system is not at equilibrium because Q is not equal to Kc.

b. The reaction will proceed to the left on the way to equilibrium because Q is greater than Kc and the product concentration needs to get smaller while the reactant concentration needs to get larger. Q was .048 – greater than .011

15.41 The commercial preparation of methanol, CH_3OH, is done at elevated temperatures with the reaction $CO(g) + 2\ H_2(g)$ <-> $CH_3OH(g)$ At a certain temperature, the K_c value is 7.3. In which direction will the system move to achieve equilibrium when the starting mixture contains

a. 0.80 M CO and 1.5 M H_2?

b. a gaseous mixture of 0.90 mol CH_3OH, 0.45 mol CO, and 0.45 mol H_2 in a 3.0-L container?

Answers a. Q = 0, so the reaction will proceed to the right in order to make more products and increase the ratio.

b. Q = 88.8 which is greater than 7.3, so the reaction will proceed to the left in order to decrease the ratio of products to reactants.

15.43 K_c is 2.6×10^8 at 825 K for the reaction $2\ H_2(g) + S_2(g)$ <-> $2\ H_2S(g)$

What is the equilibrium concentration of H_2S if those of H_2 and S_2 are 0.0020M and 0.0010M, respectively?

Answer 1.02 M

15.44 For the system $2\ HI(g)$ <-> $H_2(g) + I_2(g)$
$K_c = 0.016$ at 800 K. If, at 800 K [HI] = 0.20 M and $[H_2] = [I_2]$, calculate the equilibrium concentration of H_2.

Answer .025 M

15.45 For the equilibrium in Problem 15.44, 1.00 mol HI is placed in a 4.00-L flask at 800 K. What are the equilibrium concentrations of H_2, I_2, and HI?

Answer HI = .2 M H_2 = .025 M I_2 = .025 M

15.46 For the reaction

$2\ IBr(g)$ <-> $I_2(g) + Br_2(g)$
K_c is 2.5×10^{-3} at 25° C. Calculate the equilibrium concentration of each species in a 4.0-L vessel starting with

a. 0.60 mol IBr b. 0.30 mol I_2, 0.30 mol Br_2 c. 0.30 mol I_2, 0.30 mol Br_2, 0.30 mol IBr

Answers
a. .0068 M, .0068 M, and .136 M
b. IBr = .136 M, iodine = .007 M and bromine = .007 M
c. .IBr = .205 M, iodine = .01 M and bromine = .01 M

15.47 For the system
$CO(g) + Cl_2(g)$ <-> $COCl_2(g)$ $K_c = 3.0$. If 1.5 mol CO and 1.0 mol Cl_2 are put in a 5.0-L container, what are the equilibrium concentrations of all species?

Answers $CO(g) + Cl_2(g)$ <-> $COCl_2(g)$
.22 M .12 M .08 M

15.48 For the system
$PBr_3(g) + Br_2(g)$ <-> $PBr_5(g)$; $K_c = 0.250$
A starting mixture of 1.00 mol PBr_3 and 3.00 mol Br_2 is used in a 1.00-L container. What are the concentrations of all species at equilibrium?

Answers $PBr_3(g) + Br_2(g)$ <-> $PBr_5(g)$
.6 M 2.6 M .4 M

15.51 For the system

$N_2O_3(g)$ <-> $NO(g) + NO_2(g)$

ΔH is +39.7 kJ. Predict what effect each of the following changes will have on the position of the equilibrium:

a. decreasing the container size at constant temperature
b. adding NO
c. lowering the temperature
d. adding helium gas

Answers a = left b = left c = left d = no effect

15.52 Predict the direction in which each of the following equilibria will shift if the pressure on the system is reduced by expansion:

a. $SbCl_5(g) <-> SbCl_2(g) + Cl_2(g)$
b. $Ni(s) + 4\ CO(g) <-> Ni(CO)_4(g)$
c. $CO(g) + H_2O(g) <-> CO_2(g) + H_2(g)$

Answers a = right b = left c = no change

15.53 For the system

$$CH_4(g) + Cl_2(g) <-> CH_3Cl(g) + HCl(g)$$

$\Delta H = -99$ kJ for the forward reaction; K_c is 1×10^{18} at 25º C. Would you expect K_c to increase or decrease when the temperature rises? Explain.

Answer -- Kc should decrease.