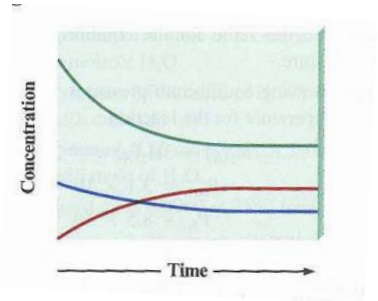
Chapter 13 Questions

Sections 13.1, 13.2(a) & 13.4

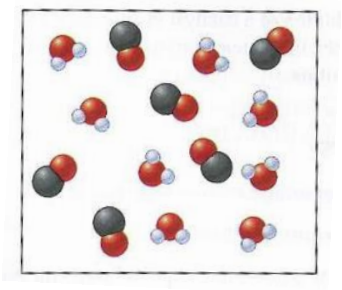
1) Explain what is incorrect about the following statements:
a) At equilibrium, no more reactants are transformed into products.
b) At equilibrium, there are equal amounts of reactants and products.

2) The following diagram represents the amounts of N_2, H_2 and NH_3 in a synthesis reaction of NH_3:



a) Describe which line represents which substance in the graph and why.
b) When is equilibrium reached? How do you know?

3) Consider the following reaction:
H_2O (g) + CO (g) <==> H_2 (g) + CO_2 (g) K = 2.0
Some molecules of H_2O and CO are placed in a 1.0 L container as shown below:



When equilibrium is reached, how many molecules of H_2O, CO, H_2 and CO_2 are present? Do this problem by trial and error: if two molecules of CO react will equilibrium be established? How about three molecules of CO?

4) At equilibrium, the amount of reactants and the amount of products are not the same. What is the same at equilibrium?

5) Write the expression for K_c for the following reactions. In each case, indicate whether the reaction is homogeneous or heterogeneous.
a) 3 NO (g) <==> N_2O (g) + NO_2 (g)
b) CH_4 (g) + 2 H_2S (g) <==> CS_2 (g) + 4 H_2 (g)
c) $Ni(CO)_4$ (g) <==> Ni (s) + 4 CO (g)
d) Fe_2O_3 (g) + 3 H_2 (g) <==> 2 Fe (s) + 3 H_2O (g)
e) 2 N_2O_5 (g) <==> 4 NO_2 (g) + O_2 (g)
f) Ti (s) + 2 Cl_2 (g) <==> $TiCl_4$ (l)
g) 2 $KClO_3$ (s) <==> 2 KCl (s) + 3 O_2 (g)
h) 2 C_2H_4 (g) + 2 H_2O (l) <==> 2 C_2H_6 (g) + O_2 (g)
i) N_2 (g) + O_2 (g) + Br_2 (g) <==> 2 NOBr (g)
j) 4 Hg (l) + O_2 (g) <==> 2 Hg_2O (s)
k) SnO_2 (s) + 2 CO (g) <==> Sn (s) + 2 CO_2 (g)

6) When the following reactions come to equilibrium, does the equilibrium mixture contain mostly reactants or mostly products?
a) N_2 (g) + O_2 (g) <==> 2 NO (g) $K_c = 1.5 \times 10^{-10}$
b) 2 SO_2 (g) + O_2 (g) <==> 2 SO_3 (g) $K_c = 2.5 \times 10^{9}$

7) Which of the following reactions lies to the right, favoring the formation of products, and which lies to the left, favoring the formation of reactants?
a) 2 NO (g) + O_2 (g) <==> 2 NO_2 (g) $K_c = 5.0 \times 10^{12}$
b) 2 HBr (g) <==> H_2 (g) + Br_2 (g) $K_c = 5.8 \times 10^{-18}$

Section 13.2(b)

8) Gaseous hydrogen iodide is placed in a closed container at 425 ^oC, where it is partially decomposed to hydrogen and iodine. At equilibrium, it is found that $[HI] = 3.53 \times 10^{-3}$ M, $[H_2] = 4.79 \times 10^{-4}$ M and $[I_2] = 4.79 \times 10^{-4}$ M. What is the value of K_c at this temperature?

9) Methanol is produced by the following reaction: CO (g) + 2 H_2 (g) <==> CH_3OH (g). An equilibrium mixture in a 2.00 L vessel is found to contain 0.0406 mol CH_3OH, 0.170 mol CO and 0.302 mol H_2 at 500 K. Calculate K_c at this temperature.

10) At 1285 ^oC, the K_c for the reaction

Br_2 (g) <==> 2 Br (g)

is 1.04×10^{-3}. A 0.200 L flask containg an equilibrium mixture contains 0.245 g of Br_2. What is the mass of Br (g) in the flask?

11) At 100 ^oC, $K_c = 0.078$ for the following reaction:

SO_2Cl_2 (g) <==> SO_2 (g) + Cl_2 (g)

In an equilibrium mixture of the three gases, the concentrations of SO_2Cl_2 and SO_2 are 0.108 M and 0.052 M, respectively. What is the $[Cl_2]$ in the equilibrium mixture?

12) At 700 ^{O}C, the reaction

$2\ H_2\ (g) + S_2\ (g) \Longleftrightarrow 2\ H_2S\ (g)$

has a $K_C = 1.08 \times 10^7$. At equilibrium, a 10.0 L flask of the reaction contains 4.20 moles of product. If the moles of hydrogen is triple the moles of sulfur, how many moles of each are in the container?

13) At equilibrium, a 4.0 L reaction flask, holding the reaction of

$Ti\ (s) + 2\ Cl_2\ (g) \Longleftrightarrow TiCl_4\ (l)$

contains 1.40 g of Ti (s), 0.45 g of Cl_2 (g) and 0.65 g of $TiCl_4$ (s). What is the K_c for the reaction?

Section 13.3

14) Write K_p expressions for each of the reactions in question 5. Be careful of the heterogeneous reactions.

15) At 500 K the following equilibrium is established: $2\ NO\ (g) + Cl_2\ (g) \Longleftrightarrow 2\ NOCl\ (g)$. An equilibrium mixture of three gases has partial pressures of 0.095 atm, 0.171 atm and 0.28 atm for NO, Cl_2, and NOCl respectively.
a) Calculate K_p for this reaction at 500 K.
b) Calculate the K_c for this reaction at 500 K.

16) At 700 ^{O}C, $K_c = 20.4$ for the reaction

$SO_2\ (g) + \frac{1}{2}\ O_2\ (g) \Longleftrightarrow SO_3\ (g)$

a) What is the value for K_c for the reaction

$SO_3\ (g) \Longleftrightarrow SO_2\ (g) + \frac{1}{2}\ O_2\ (g)$?

b) What is the value of K_p for the original reaction?

17) At 900 K, the following reaction has $K_p = 0.345$:

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

In an equilibrium mixture the partial pressures of SO_2 and O_2 are 0.165 atm and 0.755 atm, respectively. What is the equilibrium partial pressure of SO_3 in the mixture?

18) Dimercury (I) sulfide decomposes at 273 K in the following reaction:

$2\ Hg_2O\ (s) \Longleftrightarrow 4\ Hg\ (l) + O_2\ (g)$

4.50 g of dimercury (I) sulfide is placed in an evacuated chamber (pressure = 0 atm), and the reaction occurs and reaches equilibrium. At equilibrium, the amounts of 3.43 g of mercury and the gas pressure is 0.191 atm.
a) What is the K_p of the reaction?
b) What is the K_c of the reaction?

Section 13.5

19a) How does a reaction quotient differ from an equilibrium constant?
b) If Q<K, in which direction will a reaction proceed in order to reach equilibrium?
c) What condition must be satisfied so that the Q=K?
d) At the start of a certain reaction, only reactants are present. No products have been formed. What is the value of Q at this point in the reaction?

20) The Kc =1.9 for the reaction $C(s) + CO_2\ (g) \Longleftrightarrow 2\ CO\ (g)$
If 2.9 g of C, 3.1 g of CO_2 and 5.2 g of CO are injected into a 1.0 L flask, will the reaction make more product or more reactant?

21) At 450 ^{O}C the $K_p = 4.51 \times 10^{-5}$ for the equilibrium:

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

For each of the mixtures listed here, indicate whether the mixture is at equilibrium. If it is not at equilibrium, indicate the direction (toward products or toward reactants) in which the mixture must shift to achieve equilibrium.
a) 105 atm NH_3, 35 atm N_2 and 495 atm H_2
b) 35 atm NH_3, 595 atm H_2 and no N_2
c) 26 atm NH_3, 42 atm H_2 and 202 atm N_2
d) 105 atm NH_3, 5.0 atm N_2 and 55 atm H_2

22) A mixture of 0.100 mol of NO, 0.050 mol of H_2 and 0.10 mol of H_2O is placed in a 1.0 L vessel. The following equilibrium is established at 298 K:

$2\ NO\ (g) + 2\ H_2\ (g) \Longleftrightarrow N_2\ (g) + 2\ H_2O\ (g)$.

At equilibrium [NO] = 0.062 M.
a) Calculate the concentrations of H_2, N_2 and H_2O.
b) Calculate K_c.
c) Calculate K_p.

23) A mixture of 0.0457 mol of NO and .0379 mol of Cl_2 is placed in a 5.00 L flask at 500 K. The chemical reaction of

$2\ NO\ (g) + Cl_2\ (g) \Longleftrightarrow 2\ NOCl\ (g)$

occurs and creates 0.0341 mol of NOCl.
a) Calculate the initial partial pressures of each reactant.
b) Calculate the equilibrium partial pressures of all three materials.
c) Calculate K_p.
d) Calculate K_c.

24) Consider the reaction:
$4\ NH_3\ (g) + 5\ O_2\ (g) \Longleftrightarrow 4\ NO\ (g) + 6\ H_2O\ (g)$
If 10.0 g of each reactant (and no products) are placed in the 10.0 L reaction flask and at equilibrium there is 5.6 g of NO present, what is the K_c for the reaction?

Section 13.6

25) At 400 K, $K_c = 7.0$ for the equilibrium
$Br_2\ (g) + Cl_2\ (g) \Longleftrightarrow 2\ BrCl\ (g)$
If 0.30 mol of Br_2 and 0.30 mol Cl_2 are introduced into a 1.0 L container at 400 K, what will be the equilibrium concentration of BrCl?

26) For the reaction $I_2\ (g) + Br_2\ (g) \Longleftrightarrow 2\ IBr\ (g)$, $K_c = 280$ at 150 ^oC. Suppose that 0.500 mol IBr in a 1.00 L flask is allowed to reach equilibrium at 150 ^oC. What are the equilibrium concentrations of all materials in the flask?

27) When 1.50 mol CO_2 and 1.50 mol of H_2 are placed in a 3.00 L container at 395 ^oC, the following reaction occurs:
$CO_2\ (g) + H_2\ (g) \Longleftrightarrow CO\ (g) + H_2O\ (g)$, Kc = 0.802
What are the concentrations of each substance in the equilibrium mixture?

28) Solid NH_4SH is introduced into an evacuated flask at 297 K. The following reaction takes place: $NH_4SH\ (s) \Longleftrightarrow NH_3\ (g) + H_2S\ (g)$
At equilibrium, the total pressure of gas is 0.614 atm. What is the K_p for this equilibrium at 297 K.

29) At 2000 ^oC, the equilibrium constant for the reaction
$2\ NO\ (g) \Longleftrightarrow N_2\ (g) + O_2\ (g)$
Is $K_c = 2400$. If the initial concentration of NO is 0.175 M, what are the final concentrations of all three materials?

30) At 80 ^oC, $K_p = 0.0542$ for the reaction
$PH_3BCl_3\ (s) \Longleftrightarrow PH_3\ (g) + BCl_3\ (g)$
a) Calculate the equilibrium pressures of PH_3 and BCl_3 if a solid sample of PH_3BCl_3 is placed in a 2.50 L flask.
b) Calculate the grams of PH_3BCl_3 placed in the tank.

Section 13.7

31) If equilibrium were established for the reaction:
$4\ NH_3\ (g) + 5\ O_2\ (g) \Longleftrightarrow 4\ NO\ (g) + 6\ H_2O\ (g)$
What affect would each of the following changes have on the equilibrium?
a) increase the amount NH_3
b) adding Ar, an inert gas, to the container
c) removing NO from the container
d) adding water vapor to the container
e) moving the equilibrium to a larger container
f) increasing the oxygen in the container

32) Consider the following equilibrium, for which $\Delta H < 0$: $2\ SO_2\ (g) + O_2\ (g) \Longleftrightarrow 2\ SO_3\ (g)$
How will each of the following affect an equilibrium mixture of the three gases?
a) O_2 (g) is added to the system
b) The reaction mixture is heated
c) The volume of the reaction vessel is doubled
d) A catalyst is added to the mixture
e) The total pressure of the system is increased by adding a noble gas
f) SO_3 (g) is removed from the system

33) For the following reaction, $\Delta H^o = 2816$ kJ
$6\ CO_2\ (g) + 6\ H_2O\ (l) \Longleftrightarrow C_6H_{12}O_6\ (s) + 6\ O_2\ (g)$
How is the equilibrium yield of $C_6H_{12}O_6$ affected by:
a) increasing P_{CO2}
b) increasing temperature
c) removing CO_2
d) decreasing total pressure
e) removing part of the $C_6H_{12}O_6$
f) adding a catalyst

34) How do the following changes affect the value of the equilibrium constant for an exothermic reaction?
a) removal of reactant or product
b) decrease in volume
c) decrease in the temperature
d) addition of a catalyst

Review

1) Determine the molar mass of a gas that has the following data: mass = 0.931 g, volume = 495 mL, pressure = 105 kPa, temperature = 83.0 ^{O}C.

2) 450 mL of 0.525 M sodium chloride is added to 235 mL of 0.640 M lead (II) nitrate. How many grams of precipitate are made by the reaction?

3) Write the net ionic equations for the following reactions:
a) the reaction of solid magnesium with aqueous hydrobromic acid
b) solid calcium chloride is placed in a solution of silver nitrate
c) aqueous nickel chloride is poured on top of a piece of gold metal

4a) How many grams of $Cu(NO_3)_2 \bullet 3H_2O$ are needed to make 50.0 mL of a 0.750 M solution?
b) Describe how to dilute the above solution to 100 mL of 0.145 M solution.

5) Rubidium has two naturally occurring isotopes: Rb-85 (atomic mass = 84.9118 amu, abundance = 72.15%) and Rb-87 (atomic mass = 86.9092 amu, abundance = 27.85%). Calculate the atomic weight of rubidium.

6) Monosodium glutamate (MSG),a flavor enhancer in certain foods, contains 13.60% Na, 35.51% C, 4.77% H, 8.29% N, and 37.85% O, and has a molar mass of 169 g/mol. What is the empirical formula and molecular formula for MSG?

7) Hydrogen gas is produced when zinc reacts with sulfuric acid. If 159 mL of hydrogen is produced at 24 ^{O}C and a barometric pressure of 738 torr, how many grams of zinc were consumed?