GAS PHASE EQUILIBRIUM
PRACTICE PROBLEMS

(1) Sulfuryl chloride, SO_2Cl_2 , is a highly reactive gaseous compound. When heated, it decomposes as follows:

$$SO_2Cl_{2\,(g)} \rightleftharpoons SO_{2\,(g)} + Cl_{2\,(g)}$$

This decomposition is endothermic. A sample of 3.509 grams of SO_2Cl_2 is placed in an evacuated 1.00 L bulb and the temperature is raised to 375 K.

a. What would be the pressure in atmospheres in the bulb if no dissociation of the SO_2Cl_2 occurred?

b. When the bulb has come to equilibrium at 375 K, the total pressure in the bulb is found to be 1.43 atmospheres. Calculate the partial pressures of SO_2, Cl_2, and SO_2Cl_2 at equilibrium at 375 K.

c. Give the expression for the equilibrium constant, K_c, for the decomposition of SO_2Cl_2. Calculate the value of the equilibrium constant at 375 K.

d. If the temperature were raised to 500 K, what effect would this have on the equilibrium constant? Explain your answer.

(2) At elevated temperatures, $SbCl_5$ gas decomposes into $SbCl_3$ gas and Cl_2 gas, as shown by the following equation:

$$SbCl_{5\,(g)} \rightleftharpoons SbCl_{3\,(g)} + Cl_{2\,(g)}$$

An 89.7 gram sample of $SbCl_5$ (molar mass 299.0) is placed in an evacuated 15.0 L container at 182 ^{O}C.

a. What is the concentration in moles per liter of $SbCl_5$ in the container before any decomposition occurs?

b. What is the pressure in atmospheres of $SbCl_5$ in the container before decomposition occurs?

c. If the $SbCl_5$ is 29.2 percent decomposed when equilibrium is established at 182 ^{O}C, calculate the value for both equilibrium constants, K_p and K_c, for the decomposition reaction.

d. In order to produce some $SbCl_5$, a 1.00 mole sample of $SbCl_3$ is first placed in an empty 2.00 liter container maintained at a temperature different for 182 ^{O}C. At this temperature K_c equals 0.117. How many moles of Cl_2 must be added to this container to reduce the number of moles of $SbCl_3$ to 0.700 moles at equilibrium?

(3) Consider the following equation:

$$H_{2\,(g)} + CO_{2\,(g)} \rightleftharpoons H_2O_{(g)} + CO_{(g)}$$

when $H_{2\,(g)}$ is mixed with $CO_{2\,(g)}$ at 2000 K, equilibrium is achieved according to the equation above. In one experiment, the following equilibrium concentrations were measured.

$[H_2]$ = 0.20 mol/L
$[CO_2]$ = 0.30 mol/L
$[H_2O]$ = $[CO]$ = 0.55 mol/L

a. What is the mole fraction of $CO_{(g)}$ in the equilibrium mixture?

b. Using the information above, write the equilibrium expression and calculate the value of K_C, the equilibrium constant for the reaction.

c. Calculate the value of K_P for this system.

d. When the system is cooled from 2000 K to a lower temperature, 30.0 % of the $CO_{(g)}$ is converted back to $CO_{2\,(g)}$. Calculate the value of K_C at this lower temperature.

e. In a different experiment, 0.50 moles of $H_{2\,(g)}$ is mixed with 0.50 moles of $CO_{2\,(g)}$ in a 3.0 L reaction vessel at 2000 K. Calculate the equilibrium concentration, in moles per liter, of $CO_{(g)}$ at this temperature.

(4) $$2\,H_2S_{(g)} \rightleftarrows 2\,H_{2\,(g)} + S_{2\,(g)}$$

When heated, hydrogen sulfide gas decomposes according to the equation above. A 3.40 gram sample of $H_2S_{(g)}$ is introduced into an evacuated 1.25 L container. The sealed container is heated to 483 K, and 3.72×10^{-2} moles of $S_{2\,(g)}$ are present at equilibrium.

a. Write the expression for the equilibrium constant, K_C, for the decomposition reaction represented above.

b. Calculate the equilibrium concentrations, in mol/L, of $H_{2\,(g)}$ and $H_2S_{(g)}$.

c. Calculate the value of the equilibrium constant, K_C, for the decomposition reaction at 483 K.

d. Calculate the partial pressure of $S_{2\,(g)}$ in the container at 483 K. Express your answer in atmospheres.

e. For the reaction: $H_{2\,(g)} + \frac{1}{2}\,S_{2\,(g)} \rightleftarrows H_2S_{(g)}$
at 483 K, calculate the value of the equilibrium constant, K_C.

(5) Solid sodium hydrogen carbonate (sodium bicarbonate), $NaHCO_3$, decomposes on heating according to the equation below:

$$2\ NaHCO_{3\,(s)} \rightleftharpoons Na_2CO_{3\,(s)} + H_2O_{(g)} + CO_{2\,(g)}$$

a. A sample of 100**.** grams of solid $NaHCO_3$ was placed in a previously evacuated rigid 5.00 L container and heated to 160 ^{O}C. Some of the original solid remained and the total pressure in the container was 7.76 atmospheres when equilibrium was reached. Calculate the number of moles of $H_2O_{(g)}$ present at equilibrium.

b. How many grams of the original solid remain in the container under the conditions described in part (a).

c. Write the equilibrium expression for the equilibrium constant, K_P, and calculate its value for the reaction under the conditions in part (a).

d. If 110**.** grams of solid $NaHCO_3$ had been placed in the 5.00 L container and heated to 160**.** ^{O}C, what would the total pressure have been at equilibrium?

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(1)
a. 0.800 atmospheres

b. SO_2Cl_2 : 0.170 atmospheres

SO_2 : 0.630 atmospheres

Cl_2 : 0.630 atmospheres

c. $K_C = \frac{[SO_2][Cl_2]}{[SO_2Cl_2]}$, $K_C = 7.58 \times 10^{-2}$

d. Since the reaction is endothermic, raising the temperature to 500 K will cause the equilibrium to shift toward the product side. This will increase the concentration of the products and decrease the concentration of the reactant, thus increasing the equilibrium constant.

(2)
a. 0.0200 *M*

b. 0.747 atmospheres

c. $K_P = 8.98 \times 10^{-2}$

$K_C = 2.40 \times 10^{-3}$

d. 0.100 moles Cl_2

(3)
a. $X_{CO} = 0.34$

b. $K_C = \frac{[H_2O][CO]}{[H_2][CO_2]}$, $K_C = 5.04$

c. $K_P = 5.04$

d. $K_C = 0.873$

e. $[CO]_{eq} = 0.115$

(4)
a. $K_c = \frac{[H_2]^2[S_2]}{[H_2S]^2}$

b. $[H_2] = 5.95 \times 10^{-2}$

$[H_2S] = 2.05 \times 10^{-2}$

c. $K_C = 0.251$

d. P = 1.18 atmospheres

d. $K_C = 0.631$

(5)
a. 0.546 moles

b. 8.27 grams $NaHCO_3$ remaining

c. $K_P = (P_{H2O})(P_{CO2})$

$K_P = 15.1$

d. The total pressure would remain at 7.76 atm. Since some solid remained when 100. g was used (and there had been no temperature change), then using 110 g would not affect the equilibrium.