AP Questions: Equilibrium

1977 D

For the system 2 $SO_2(g) + O_2(g) \leftrightarrow 2\ SO_3(g)$, ΔH is negative for the production of SO_3. Assume that one has an equilibrium mixture of these substances. Predict the effect of each of the following changes on the value of the equilibrium constant and on the number of moles of SO_3 present in the mixture at equilibrium. Briefly account for each of your predictions. (Assume that in each case all other factors remain constant.)

(a) Decreasing the volume of the system.

(b) Adding oxygen to the equilibrium mixture.

(c) Raising the temperature of the system.

1980 D

$NH_4Cl(s) \leftrightarrow NH_3(g) + HCl(g) \qquad \Delta H = +42.1$ kilocalories

Suppose the substances in the reaction above are at equilibrium at 600K in volume V and at pressure P. State whether the partial pressure of $NH_3(g)$ will have increased, decreased, or remained the same when equilibrium is reestablished after each of the following disturbances of the original system. Some solid NH_4Cl remains in the flask at all times. Justify each answer with a one-or-two sentence explanation.

(a) A small quantity of NH_4Cl is added.

(b) The temperature of the system is increased.

(c) The volume of the system is increased.

(d) A quantity of gaseous HCl is added.

(e) A quantity of gaseous NH_3 is added.

1981 A

Ammonium hydrogen sulfide is a crystalline solid that decomposes as follows:

$$NH_4HS(s) \leftrightarrow NH_3(g) + H_2S(g)$$

(a) Some solid NH_4HS is placed in an evacuated vessel at 25ºC. After equilibrium is attained, the total pressure inside the vessel is found to be 0.659 atmosphere. Some solid NH_4HS remains in the vessel at equilibrium. For this decomposition, write the expression for K_P and calculate its numerical value at 25ºC.

(b) Some extra NH_3 gas is injected into the vessel containing the sample described in part (a). When equilibrium is reestablished at 25ºC, the partial pressure of NH_3 in the vessel is twice the partial pressure of H_2S. Calculate the numerical value of the partial pressure of NH_3 and the partial pressure of H_2S in the vessel after the NH_3 has been added and the equilibrium has been reestablished.

(c) In a different experiment, NH_3 gas and H_2S gas are introduced into an empty 1.00 liter vessel at 25ºC. The initial partial pressure of each gas is 0.500 atmospheres. Calculate the number of moles of solid NH_4HS that is present when equilibrium is established.

1983 A

Sulfuryl chloride, SO_2Cl_2, is a highly reactive gaseous compound. When heated, it decomposes as follows: $SO_2Cl_{2(g)} \rightarrow SO_2(g) + Cl_2(g)$. This decomposition is endothermic. A sample of 3.509 grams of SO_2Cl_2 is placed in an evacuated 1.00 litre bulb and the temperature is raised to 375K.

(a) What would be the pressure in atmospheres in the bulb if no dissociation of the $SO_2Cl_{2(g)}$ occurred?

(b) When the system has come to equilibrium at 375K, 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 375K.

(c) Give the expression for the equilibrium constant (either K_p or K_c) for the decomposition of $SO_2Cl_{2(g)}$ at 375K. Calculate the value of the equilibrium constant you have given, and specify its units.

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

1988 A

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

(a) An 89.7 gram sample of $SbCl_5$ (molecular weight 299.0) is placed in an evacuated 15.0 litre container at 182ºC.

1. What is the concentration in moles per litre of $SbCl_5$ in the container before any decomposition occurs?
2. What is the pressure in atmospheres of $SbCl_5$ in the container before any decomposition occurs?

(b) If the $SbCl_5$ is 29.2 percent decomposed when equilibrium is established at 182ºC, calculate the value for either equilibrium constant K_p or K_c, for this decomposition reaction. Indicated whether you are calculating K_p or K_c.

(c) In order to produce some $SbCl_5$, a 1.00 mole sample of $SbCl_3$ is first placed in an empty 2.00 litre container maintained at a temperature different from 182ºC. 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 mole at equilibrium?

1988 D

$NH_4HS(s) \leftrightarrow NH_3(g) + H_2S(g)$ $\Delta H^\circ = +93$ kilojoules

The equilibrium above is established by placing solid NH_4HS in an evacuated container at 25ºC. At equilibrium, some solid NH_4HS remains in the container. Predict and explain each of the following.

(a) The effect on the equilibrium partial pressure of NH_3 gas when additional solid NH_4HS is introduced into the container

(b) The effect on the equilibrium partial pressure of NH_3 gas when additional solid H_2S is introduced into the container

(c) The effect on the mass of solid NH_4HS present when the volume of the container is decreased

(d) The effect on the mass of solid NH_4HS present when the temperature is increased.

1992 A

$$2\ NaHCO_3(s) \leftrightarrow Na_2CO_3(s) + H_2O(g) + CO_2(g)$$

Solid sodium hydrogen carbonate, $NaHCO_3$, decomposes on heating according to the equation above.

(a) A sample of 100. grams of solid $NaHCO_3$ was placed in a previously evacuated rigid 5.00-liter container and heated to 160ºC. 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 (a)?

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

(d) If 110. grams of solid $NaHCO_3$ had been placed in the 5.00-liter container and heated to 160ºC, what would the total pressure have been at equilibrium? Explain.

1995 A

$$CO_2(g) + H_2(g) \leftrightarrow H_2O(g) + CO(g)$$

When $H_2(g)$ is mixed with $CO_2(g)$ at 2,000 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 equilibrium concentrations given above, calculate the value of K_c, the equilibrium constant for the reaction.

(c) Determine K_p in terms of K_c for this system.

(d) When the system is cooled from 2,000 K to a lower temperature, 30.0 percent 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 mole of $H_2(g)$ is mixed with 0.50 mole of $CO_2(g)$ in a 3.0-liter reaction vessel at 2,000 K. Calculate the equilibrium concentration, in moles per liter, of $CO(g)$ at this temperature.

1998 D

$C(s) + H_2O(g) \leftrightarrow CO(g) + H_2(g)$ $\Delta H^o = +131 kJ$

A rigid container holds a mixture of graphite pellets ($C(s)$), $H_2O(g)$, $CO(g)$, and $H_2(g)$ at equilibrium. State whether the number of moles of $CO(g)$ in the container will increase, decrease, or remain the same after each of the following disturbances is applied to the original mixture. For each case, assume that all other variables remain constant except for the given disturbance. Explain each answer with a short statement.

(a) Additional $H_2(g)$ is added to the equilibrium mixture at constant volume.

(b) The temperature of the equilibrium mixture is increased at constant volume.

(c) The volume of the container is decreased at constant temperature.

(d) The graphite pellets are pulverized.

2000 A

1. $2\ H_2S(g) \rightarrow 2\ H_2(g) + S_2(g)$

When heated, hydrogen sulfide gas decomposes according to the equation above. A 3.40 g sample of $H_2S(g)$ is introduced into an evacuated rigid 1.25 L container. The sealed container is heated to 483 K, and 3.72×10^{-2} mol of $S_2(g)$ is present at equilibrium.

(a) Write the expression for the equilibrium constant, K_c, for the decomposition reaction represented above.

(b) Calculate the equilibrium concentration, in $mol \bullet L^{-1}$, of the following gases in the container at 483 K.

(i) $H_2(g)$

(ii) $H_2S(g)$

(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 equilibrium at 483 K.

(e) For the reaction $H_2(g) + \frac{1}{2} S_2(g) \rightarrow H_2S(g)$ at 483 K, calculate the value of the equilibrium constant, K_c.