Part 1: Calculating Equilibrium Constants

1. A mixture of H_2 and I_2 is allowed to react at 448°C. When equilibrium is established, the concentrations of the participants are found to be $[H_2]$ = 0.46 mol/L , $[I_2]$ = 0.39 mol/L and [HI] = 3.0 mol/L. calculate the value of Keq at 448°C from this data.
   a. Write a balanced chemical equation for this reaction
   b. Write the equilibrium expression, Keq
   c. Calculate the numerical value of Keq
   d. Assume that in the analysis of an equilibrium mixture of H_2 and I_2 at 448°C, the equilibrium concentrations of I_2 and H_2 are found to be 0.50 mol/L. What is the equilibrium concentration of HI?

2. Gaseous hydrogen iodide is placed in a closed container at 425°C, where it partially decomposes to hydrogen and iodine: $2\ HI_{(g)} \rightleftharpoons H_{2(g)} + I_{2(g)}$
   At equilibrium it was found that [HI] = 3.53×10^{-3} M ; $[H_2]$ 4.79×10^{-4} M ;
   $[I_2]$ 4.79×10^{-4} M. What is the value of Keq at this temperature?

3. At temperatures near 800°C, steam passed over hot coke (a form of carbon obtained from coal) reacts to form CO and H_2: $C_{(s)} + H_2O_{(g)} \rightleftharpoons CO_{(g)} + H_{2(g)}$
   The mixture of gases that results is an important industrial fuel called water gas. When equilibrium is achieved at 800°C, $[H_2]$ = 4.0×10^{-2} M ; [CO] = 4.0×10^{-2} M and $[H_2O]$ = 1.0×10^{-2} M. Calculate Keq at this temperature.

4. A sample of nitrosyl bromide, NOBr, decomposes according to the following equation:
   $2\ NOBr_{(g)} \rightleftharpoons 2\ NO_{(g)} + Br_{2(g)}$
   An equilibrium mixture in a 5.0 L vessel at 100°C contains 3.22 g NOBr, 3.08 g of NO, and 4.19 g of Br_2. Calculate Keq at this temperature.

Answers

1. c. Keq = 5.0×10^1
   d. [HI] = 3.5 M
2. Keq = 0.0184
3. Keq = 0.16
4. Keq = 0.064

Part 2: Predict the Direction of Equilibrium

1. At 448°C, Keq = 50.5 for the reaction of hydrogen gas with iodine gas to form hydrogen iodide gas. Predict how the reaction will proceed if the concentrations are as given below:
   $[H_2]$ = 0.150 M $[I_2]$ = 0.175 M   [HI] = 0.950 M

2. At 100°C, the equilibrium constant for the reaction $COCl_{2\,(g)} \rightleftharpoons CO_{(g)} + Cl_{2(g)}$ has the value of Keq = 2.19×10^{-10}. Are the following mixtures of $COCl_2$, CO, and Cl_2 at equilibrium? If not, indicate the direction that the reaction must proceed to achieve equilibrium
   a. $[COCl_2] = 5.00 \times 10^{-2}$ M $[CO] = 3.31 \times 10^{-2}$ M $[Cl_2] = 3.31 \times 10^{-2}$ M
   b. $[COCl_2] = 3.50 \times 10^{-3}$ M $[CO] = 1.11 \times 10^{-5}$ M $[Cl_2] = 3.25 \times 10^{-6}$ M
   c. $[COCl_2]$ = 1.45 M $[CO] = 1.56 \times 10^{-6}$ M $[Cl_2] = 1.56 \times 10^{-6}$ M

3. At 900°C, Keq = 0.0108 for the reaction
   $CaCO_{3\,(s)} \rightleftharpoons CaO_{(s)} + CO_{2(g)}$
   A mixture of $CaCO_3$, CaO and CO_2 is placed in a 10.0 L vessel at 900°C. For the following mixtures, will the amount of $CaCO_3$ increase, decrease or remain the same as the system approached equilibrium?
   a. 25.0 g $CaCO_3$ 25.0 g CaO   and 15.0 g CO_2
   b. 1.5 g $CaCO_3$ 15.0 g CaO   and 4.75 g CO_2
   c. 35.0 g $CaCO_3$ 20.5 g CaO   and 2.50 g CO_2

4. At a certain temperature Keq = 4 for the reaction
   $2\,HF_{(g)} \rightleftharpoons H_{2(g)} + F_{2(g)}$
   Predict the direction in which the equilibrium will shift, if any, when the following systems are introduced into a 5.0 L bulb.
   a. 3.0 mol HF   2.0 mol H_2 4.0 mol F_2
   b. 0.20 mol HF   0.50 mol H_2 0.60 mol F_2
   c. 0.30 mol HF   1.8 mol H_2 0.20 mol F_2

5. At a certain temperature, Keq = 125 for the reaction: $H_{2(g)} + I_{2(g)} \rightleftharpoons 2\,HI_{(g)}$.
   If 0.15 mol of HI, 0.034 mol of H_2 and 0.096 mol of I_2 are introduced into a 10 L vessel, will the reaction proceed to the reactant side or product side as the reaction attempts to reach equilibrium?

Answers

1. Q = 34.4 shifts to products/right
2. a) Q = 0.022 Left   b) Q = 1.03×10^{-8} Left   c) Q = 1.68×10^{-12} Right
3. a) mass increases   b) remains the same   c) mass decreases
4. a) Q = 0.89 to right/products   b) Q= 7.5 left/reactants   c) Q = 4 no shift
5. Q = 6.9 Eqm will shift to products

Part 3: Calculating Equilibrium Constants
(from initial concentrations)

1. When 0.40 mol of PCl_5 is heated in a 1L container, and equilibrium is established in which 0.25 mol of Cl_2 is present. The equation for the reaction is:
   $PCl_{5\,(g)} + 92.5\ kJ \rightleftharpoons PCl_{3(g)} + Cl_{2(g)}$
   a. What are the equilibrium concentration of all three components? Make a RICE table.
   b. What is the equilibrium constant for the reaction?

2. A 1.0 L reaction vessel contained 0.750 mol of CO and 0.275 mol of H_2O. After 1 hour, equilibrium was reached according to the equation:
   $CO_{(g)} + H_2O_{(g)} \rightleftharpoons CO_{2(g)} + H_{2(g)}$
   Analysis showed that 0.250 mol of CO_2 was present at equilibrium. What is Keq for the reaction?

3. A 5.0 L reaction vessel was initially filled with 6.00 mol of SO_2, 2.5 mol of NO_2 and 1.0 mol of SO_3. After equilibrium was established according to the equation
   $SO_{2(g)} + NO_{2(g)} \rightleftharpoons SO_{3(g)} + NO_{(g)}$
   the vessel was found to contain 3.0 mol of SO_3. What is the Keq for the reaction?

4. Consider the equilibrium $N_{2(g)} + 3\ H_{2(g)} \rightleftharpoons 2\ NO_{3(g)}$
   a. At a certain temperature 3.0 mol of N_2 and 2.0 mol of H_2 are introduced into a 5.0 L container. At equilibrium the concentration of NH_3 is 0.020 M. Calculate Keq for the reaction.
   b. At a different temperature, 6.0 mol of NH_3 was left. Calculate the Keq for the reaction at this temperature.

5. A mixture of 1.374 g of H_2 and 70.31 g of Br_2 is heated in a 2.00 L vessel at 700 K. These substances react as follows:
   $H_{2(g)} + Br_{2(g)} \rightleftharpoons 2\ HBr_{(g)}$
   At equilibrium, the vessel is found to contain 0.566 g of H_2. Calculate the Keq.

Answers

1. Keq = 0.42
2. Keq = 5.0
3. Keq = 3.0
4. a) Keq = 0.013 b) keq is undefined, rxn must go to completion
5. Keq = 64

Part 4: Using Keq to Find Concentrations

1. $2\ H_{2(g)} + S_{2(g)} \rightleftharpoons 2\ H_2S_{(g)}$ Keq = 7.5
   A certain amount of H_2S was added to a 2.0 L flask and allowed to come to equilibrium. At equilibrium, 0.072 mol of H_2 was found. How many moles of H_2S were originally added to the flask?

2. At a certain temperature, Keq = 49.5 for the reaction: $H_{2(g)} + I_{2(g)} \rightleftharpoons 2\ HI_{(g)}$
   If 0.250 mol of $H_{2(g)}$ and0.250 mol of $I_{2(g)}$ are placed in a 10.0 L vessel and permitted to react, what will be the concentrations of each substance at equilibrium?

3. The equilibrium constant for the reaction: $N_{2(g)} + 3\ H_{2(g)} \rightleftharpoons 2\ NH_{3(g)}$
   is 3.0 at a certain temperature. Enough $NH_{3(g)}$ was added to a 5.0 L container such that after equilibrium was established the container was found to contain 2.5 mol of $N_{2(g)}$. How many moles of NH_3 were originally introduced into the container?

4. At a certain temperature, Keq = 1.00 for the reaction: $N_2O_{2(g)} + H_{2(g)} \rightleftharpoons N_2O_{(g)} + H_2O_{(g)}$
   If 0.150 mol of N_2O and 0.250 mol of H_2O were introduced into a 1.00 bulb and allowed to come to equilibrium, what concentration of N_2O_2 was present at equilibrium?

5. Keq = 100 at a certain temperature for the reaction:
   $CH_{4(g)} + 2\ H_2S_{(g)} \rightleftharpoons CS_{2(g)} + 4\ H_{2(g)}$
   Some $CH_{4(g)}$ and H_2S were introduced into a 1.0 L bulb and at equilibrium 0.10 mol of CH_4 and 0.30 mol of H_2S were found. What was $[CS_2]$ at equilibrium?

6. Keq = 5.0 at a certain temperature for the reaction: $2\ SO_{2(g)} + O_{2(g)} \rightleftharpoons 2\ SO_{3(g)}$
   A certain amount of $SO_{3(g)}$ was placed in a 2.0 L reaction vessel. At equilibrium the vessel contained 0.30 mol of $O_{2(g)}$. What concentration of $SO_{3(g)}$ was originally placed in the vessel?

7. At 1285°C, the equilibrium constant for the reaction $Br_{2\ (g)} \rightleftharpoons 2\ Br_{(g)}$ is 1.04×10^{-3}. A 0.200 L vessel containing an equilibrium mixture of the gases has 0.245 g of $Br_{2(g)}$ in it. What is the mass of $Br_{(g)}$ in the vessel?

8. At 21.8°C, the equilibrium constant Keq = 1.2×10^{-4} for the following reaction:
   $NH_4HS_{(s)} \rightleftharpoons NH_{3(g)} + H_2S_{(g)}$
   Calculate the equilibrium concentrations of $NH_{3(g)}$ and $H_2S_{(g)}$ if a sample of solid $NH_4HS_{(s)}$ is placed in a closed vessel and allowed to decompose until equilibrium is reached.

Answers

1. Moles H_2S = 0.098 mol
2. [HI] = 0.039 M $[H_2] = [I_2] = 5.5 \times 10^{-3}$ M
3. $[NH_3]$= 3.25 M ∴ 16 mol NH_3
4. $[N_2O_2]$=0.0938 M
5. $[CS_2]$=0.32 M
6. $[SO_3]$= 0.56 M
7. 0.045 g Br
8. $[NH_3]=[H_2S]$=0.011 M

http://chemchurch.wikispaces.com/file/view/A.Calculating+Keq+Constants.pdf/260733496/A.Calculating%20Keq%20Constants.pdf