

Part 1: Calculating Equilibrium Constants

- 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 $[\text{H}_2] = 0.46 \text{ mol/L}$, $[\text{I}_2] = 0.39 \text{ mol/L}$ and $[\text{HI}] = 3.0 \text{ mol/L}$. Calculate the value of K_{eq} at 448°C from this data.
 - Write a balanced chemical equation for this reaction
 - Write the equilibrium expression, K_{eq}
 - Calculate the numerical value of K_{eq}
 - 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 ?
- Gaseous hydrogen iodide is placed in a closed container at 425°C , where it partially decomposes to hydrogen and iodine: $2 \text{HI}_{(\text{g})} \rightleftharpoons \text{H}_{2(\text{g})} + \text{I}_{2(\text{g})}$
At equilibrium it was found that $[\text{HI}] = 3.53 \times 10^{-3} \text{ M}$; $[\text{H}_2] = 4.79 \times 10^{-4} \text{ M}$; $[\text{I}_2] = 4.79 \times 10^{-4} \text{ M}$. What is the value of K_{eq} at this temperature?
- At temperatures near 800°C , steam passed over hot coke (a form of carbon obtained from coal) reacts to form CO and H_2 : $\text{C}_{(\text{s})} + \text{H}_2\text{O}_{(\text{g})} \rightleftharpoons \text{CO}_{(\text{g})} + \text{H}_{2(\text{g})}$
The mixture of gases that results is an important industrial fuel called water gas. When equilibrium is achieved at 800°C , $[\text{H}_2] = 4.0 \times 10^{-2} \text{ M}$; $[\text{CO}] = 4.0 \times 10^{-2} \text{ M}$ and $[\text{H}_2\text{O}] = 1.0 \times 10^{-2} \text{ M}$. Calculate K_{eq} at this temperature.
- A sample of nitrosyl bromide, NOBr , decomposes according to the following equation:
 $2 \text{NOBr}_{(\text{g})} \rightleftharpoons 2 \text{NO}_{(\text{g})} + \text{Br}_{2(\text{g})}$
An equilibrium mixture in a 5.0 L vessel at 100°C contains 3.22 g NOBr , 3.08 g NO , and 4.19 g of Br_2 . Calculate K_{eq} at this temperature.

Answers

- $K_{\text{eq}} = 5.0 \times 10^1$
 - $[\text{HI}] = 3.5 \text{ M}$
- $K_{\text{eq}} = 0.0184$
- $K_{\text{eq}} = 0.16$
- $K_{\text{eq}} = 0.064$

Part 2: Predict the Direction of Equilibrium

1. At 448°C, $K_{eq} = 50.5$ 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:

$$[H_2] = 0.150 \text{ M} \quad [I_2] = 0.175 \text{ M} \quad [HI] = 0.950 \text{ M}$$

2. At 100°C, the equilibrium constant for the reaction $COCl_2(g) \rightleftharpoons CO(g) + Cl_2(g)$ has the value of $K_{eq} = 2.19 \times 10^{-10}$. 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. $[COCl_2] = 5.00 \times 10^{-2} \text{ M}$ $[CO] = 3.31 \times 10^{-2} \text{ M}$ $[Cl_2] = 3.31 \times 10^{-2} \text{ M}$

b. $[COCl_2] = 3.50 \times 10^{-3} \text{ M}$ $[CO] = 1.11 \times 10^{-5} \text{ M}$ $[Cl_2] = 3.25 \times 10^{-6} \text{ M}$

c. $[COCl_2] = 1.45 \text{ M}$ $[CO] = 1.56 \times 10^{-6} \text{ M}$ $[Cl_2] = 1.56 \times 10^{-6} \text{ M}$

3. At 900°C, $K_{eq} = 0.0108$ for the reaction



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 $K_{eq} = 4$ for the reaction



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, $K_{eq} = 125$ 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) $Q = 1.03 \times 10^{-8}$ Left c) $Q = 1.68 \times 10^{-12}$ Right

3. a) mass increases b) remains the same c) mass decreases

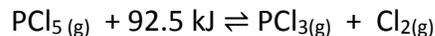
4. a) $Q = 0.89$ to right/products b) $Q = 7.5$ left/reactants c) $Q = 4$ no shift

5. $Q = 6.9$ Eqm will shift to products

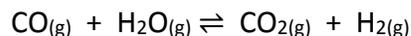
Part 3: Calculating Equilibrium Constants

(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:

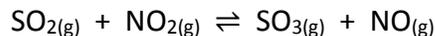


- What are the equilibrium concentration of all three components? Make a RICE table.
 - What is the equilibrium constant for the reaction?
2. A 1.0 L reaction vessel contained 0.750 mol of CO and 0.275 mol of H_2O . After 1 hour, equilibrium was reached according to the equation:



Analysis showed that 0.250 mol of CO_2 was present at equilibrium. What is K_{eq} for the reaction?

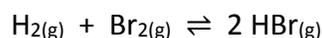
3. A 5.0 L reaction vessel was initially filled with 6.00 mol of SO_2 , 2.5 mol of NO_2 and 1.0 mol of SO_3 . After equilibrium was established according to the equation



the vessel was found to contain 3.0 mol of SO_3 . What is the K_{eq} for the reaction?

4. Consider the equilibrium $\text{N}_2(\text{g}) + 3 \text{H}_2(\text{g}) \rightleftharpoons 2 \text{NH}_3(\text{g})$

- 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 K_{eq} for the reaction.
 - At a different temperature, 6.0 mol of NH_3 was left. Calculate the K_{eq} 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:

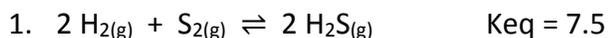


At equilibrium, the vessel is found to contain 0.566 g of H_2 . Calculate the K_{eq} .

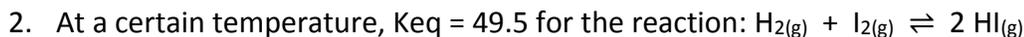
Answers

- $K_{\text{eq}} = 0.42$
- $K_{\text{eq}} = 5.0$
- $K_{\text{eq}} = 3.0$
- a) $K_{\text{eq}} = 0.013$ b) K_{eq} is undefined, rxn must go to completion
- $K_{\text{eq}} = 64$

Part 4: Using Keq to Find Concentrations



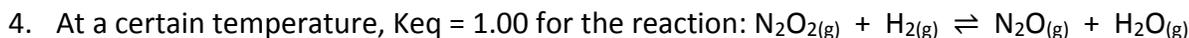
A certain amount of H_2S was added to a 2.0 L flask and allowed to come to equilibrium. At equilibrium, 0.072 mol of H_2 was found. How many moles of H_2S were originally added to the flask?



If 0.250 mol of $\text{H}_{2(g)}$ and 0.250 mol of $\text{I}_{2(g)}$ are placed in a 10.0 L vessel and permitted to react, what will be the concentrations of each substance at equilibrium?

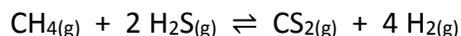


is 3.0 at a certain temperature. Enough $\text{NH}_{3(g)}$ was added to a 5.0 L container such that after equilibrium was established the container was found to contain 2.5 mol of $\text{N}_{2(g)}$. How many moles of NH_3 were originally introduced into the container?



If 0.150 mol of N_2O and 0.250 mol of H_2O were introduced into a 1.00 L bulb and allowed to come to equilibrium, what concentration of N_2O_2 was present at equilibrium?

5. $K_{eq} = 100$ at a certain temperature for the reaction:



Some $\text{CH}_{4(g)}$ 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 $[\text{CS}_2]$ at equilibrium?



A certain amount of $\text{SO}_{3(g)}$ was placed in a 2.0 L reaction vessel. At equilibrium the vessel contained 0.30 mol of $\text{O}_{2(g)}$. What concentration of $\text{SO}_{3(g)}$ was originally placed in the vessel?

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

8. At 21.8°C , the equilibrium constant $K_{eq} = 1.2 \times 10^{-4}$ for the following reaction:



Calculate the equilibrium concentrations of $\text{NH}_{3(g)}$ and $\text{H}_2\text{S}_{(g)}$ if a sample of solid $\text{NH}_4\text{HS}_{(s)}$ is placed in a closed vessel and allowed to decompose until equilibrium is reached.

Answers

1. Moles $\text{H}_2\text{S} = 0.098$ mol

2. $[\text{HI}] = 0.039$ M $[\text{H}_2] = [\text{I}_2] = 5.5 \times 10^{-3}$ M

3. $[\text{NH}_3] = 3.25$ M $\therefore 16$ mol NH_3

4. $[\text{N}_2\text{O}_2] = 0.0938$ M

5. $[\text{CS}_2] = 0.32$ M

6. $[\text{SO}_3] = 0.56$ M

7. 0.045 g Br

8. $[\text{NH}_3] = [\text{H}_2\text{S}] = 0.011$ M

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