AP CHEMISTRY

TOPIC 6: EQUILIBRIUM, PART C

Day 66:

- Heterogeneous Equilibria
- Applications of the Equilibrium Constant
- Reaction Quotient
- Calculating Equilibrium Pressures

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1. The equilibrium constant is 0.0900 M^{-2} at 25^0C for the reaction:

$$3\ H_{2\ (g)}\ +\ N_{2\ (g)}\ \leftrightarrow\ 2\ NH_{3\ (g)}$$

For which of the following sets of conditions is the system at equilibrium (Show all work)? For those which are not at equilibrium, in which direction will the system shift?

a) a 1.0-L flask contains 1.0 mol of NH_3, 1.0 mol N_2, and 0.10 mol H_2.

Answers:

$$Q\ =\ \frac{[\ NH_3\ ]^2}{[\ H_2\ ]^3[\ N_2\ ]}\ =\ \frac{\left(\frac{1.0\ mol}{L}\right)^2}{\left(\frac{0.10\ mol}{L}\right)^3\left(\frac{1.0\ mol}{L}\right)}\ =\ 1.0\times10^3\ \frac{L^2}{mol^2}$$

$Q\ >\ K$ Shift to the Left to form Reactants

b) a 2.0-L flask contains 0.84 mol of NH_3, 0.80 mol N_2, and 0.98 mol H_2.

Answers:

$$Q\ =\ \frac{[\ NH_3\ ]^2}{[\ H_2\ ]^3[\ N_2\ ]}\ =\ \frac{\left(\frac{0.84\ mol}{2\ L}\right)^2}{\left(\frac{0.98\ mol}{2\ L}\right)^3\left(\frac{0.80\ mol}{2\ L}\right)}\ =\ 3.8\ \frac{L^2}{mol^2}$$

$Q\ >\ K$ Shift to the Left to form Reactants

c) a 3.0-L flask contains 0.25 mol of NH_3, 0.56 mol N_2, and 0.0010 mol H_2.

Answers:

$$Q\ =\ \frac{[\ NH_3\ ]^2}{[\ H_2\ ]^3[\ N_2\ ]}\ =\ \frac{\left(\frac{0.25\ mol}{3\ L}\right)^2}{\left(\frac{0.0010\ mol}{3\ L}\right)^3\left(\frac{0.56\ mol}{3\ L}\right)}\ =\ 1.0\times10^9\ \frac{L^2}{mol^2}$$

$Q\ >\ K$ Shift to the Left to form Reactants

d) P_{H_2} = 1.33 atm, P_{N_2} = 2.10 atm, P_{NH_3} = 0.25 atm (K_p is 13.35 atm^{-2} at 25^0C for the reaction)

Answers:

$$Q\ =\ \frac{\left(P_{NH_3}\right)^2}{\left(P_{H_2}\right)^3\left(P_{N_2}\right)}\ =\ \frac{\left(0.25\ atm\right)^2}{\left(1.33\ atm\right)^3\left(2.10\ atm\right)}\ =\ 0.013\ \frac{1}{atm^2}$$

$Q\ <\ K$ Shift to the Right to form Reactants

e) P_{H_2} = 200. torr, P_{N_2} = 49.8 torr, P_{NH_3} = 21.0 torr (K_p is 13.35 atm^{-2} at 25^0C for the reaction)

Answers:

$$Q\ =\ \frac{\left(P_{NH_3}\right)^2}{\left(P_{H_2}\right)^3\left(P_{N_2}\right)}\ =\ \frac{\left(\frac{21.0\ torr}{}\times\frac{1\ atm}{760\ torr}\right)^2}{\left(\frac{200.\ torr}{}\times\frac{1\ atm}{760\ torr}\right)^3\left(\frac{49.8\ torr}{}\times\frac{1\ atm}{760\ torr}\right)}\ =\ 0.639\ \frac{1}{atm^2}$$

$Q\ <\ K$ Shift to the Right to form Products

2. The equilibrium constant for the reaction

$$H_{2\,(g)} + F_{2\,(g)} \leftrightarrow 2\,HF_{(g)}$$

has the value 2.1 x 10^3 at a particular temperature. When the system is analyzed at equilibrium at this temperature, the concentrations of $H_{2\,(g)}$ and $F_{2\,(g)}$ are both found to be 0.0021 *M*. What is the concentration of $HF_{(g)}$ in the equilibrium system under these conditions?

Answers:

$$K = \frac{\left[\ HF\ \right]^2}{\left[\ H_2\ \right]\left[\ F_2\ \right]} = 2.1\times10^3 \ ; \ \left[\ HF\ \right]^2 = \left(2.1\times10^3\right)\left[\ H_2\ \right]\left[\ F_2\ \right]$$

$$\left[HF\right]^2 = \left(\ 2.1\times10^3\ \right)\left(0.0021\ \frac{mol}{L}\right)\left(0.0021\ \frac{mol}{L}\right) = 9.261\times10^{-3}\ \frac{mol^2}{L^2}$$

$$\sqrt{\left[HF\right]^2} = \sqrt{9.261\times10^{-3}\ \frac{mol^2}{L^2}}$$

$$\left[HF\right] = 0.096\ \frac{mol}{L}$$

3. The reaction

$$H_{2\,(g)} + I_{2\,(g)} \leftrightarrow 2\,HI_{(g)}$$

has a K_p = 45.9 at 763 K. A particular equilibrium mixture at that temperature contains gaseous HI at a partial pressure of 4.00 atm and hydrogen gas at a partial pressure of 0.200 atm. What is the partial pressure of I_2?

Answers:

$$K_p = \frac{\left(P_{HI}\right)^2}{\left(\ P_{H_2}\ \right)\left(\ P_{I_2}\ \right)} = 45.9 \ ; \ K_p = \frac{\left(P_{HI}\right)^2}{\left(\ P_{H_2}\ \right)\left(\ P_{I_2}\ \right)}$$

$$P_{I_2} = \frac{\left(P_{HI}\right)^2}{\left(\ K_p\ \right)\left(\ P_{H_2}\ \right)} = \frac{\left(\ 4.00\ atm\ \right)^2}{\left(\ 45.9\ \right)\left(\ 0.200\ atm\ \right)} = 1.74\ atm$$