TEXTBOOK QUESTIONS SOLVED

Question 1. A liquid is in equilibrium with its vapours in a sealed container at a fixed temperature. The volume of the container is suddenly increased,
(i) What is the initial effect of the change on the vapour pressure?
(ii) How do the rates of evaporation and condensation change initially?
(iii) What happens when equilibrium is restored finally and what will be the final vapour pressure?
Answer:
(i) On increasing the volume of the container, the vapour pressure will initially decrease because the same amount of vapours are now distributed over a larger space.
(ii) On increasing the volume of the container, the rate of evaporation will increase initially because now more space is available. Since the amount of the vapours per unit volume decrease on increasing the volume, therefore, the rate of condensation will decrease initially.
(iii) Finally, equilibrium will be restored when the rates of the forward and backward processes become equal. However, the vapour pressure will remain unchanged because it depends upon the temperature and not upon the volume of the container.

Question 2. What is K_c for the following reaction in state of equilibrium?

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$$

Given: $[SO_2] = 0.6\ M$; $[O_2] = 0.82\ M$; and $[SO_3] = 1.90\ M$

Answer:

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$$

$$K_c = \frac{[SO_3]^2}{[SO_2]^2[O_2]} = \frac{(1.9\ M)\times(1.9\ M)}{(0.6\ M)\times(0.6\ M)\times(0.82\ M)}$$

$$= 12.229\ M^{-1} = \mathbf{12.229\ L\ mol^{-1}}$$

Question 3.

At a certain temperature and total pressure of 10^5 Pa, iodine vapours contain 40% by volume of iodine atoms in the equilibrium $I_2(g) \rightleftharpoons 2I\,(g)$. Calculate K_p for the equilibrium.

Answer:

According to available data:

Total pressure of equilibrium mixture $= 10^5$ Pa

Partial pressure of iodine atoms $(I) = \frac{40}{100}\times(10^5\ \text{Pa}) = 0.4\times10^5$ Pa

Partial pressure of iodine molecules $(I_2) = \frac{60}{100}\times(10^5\ \text{Pa}) = 0.6\times10^5$ Pa

$$\underset{(0.6\times10^5\,\text{Pa})}{I_2\,(g)} \rightleftharpoons \underset{(0.4\times10^5\,\text{Pa})}{2I\,(g)}$$

$$K_p = \frac{p_{I}^2}{p_{I_2}} = \frac{(0.4\times10^5\text{Pa})^2}{(0.6\times10^5\text{Pa})} = \mathbf{2.67\times10^4\ Pa}$$

Question 4. Write the expression for the equilibrium constant for each of the following reactions

(i) $2NOCl(g) \rightleftharpoons 2NO(g) + Cl_2(g)$

(ii) $2Cu(NO_3)_2(s) \rightleftharpoons 2CuO(s) + 4NO_2(g) + O_2(g)$

(iii) $CH_3COOC_2H_5(aq) + H_2O(l) \rightleftharpoons CH_3COOH(aq) + C_2H_5OH(aq)$

(iv) $Fe^{3+}(aq) + 3OH^-(aq) \rightleftharpoons Fe(OH)_3(s)$

(v) $I_2(s) + 5F_2(g) \rightleftharpoons 2IF_5(l)$

Answer:

(i) $$K_c = \frac{[NO(g)]^2[Cl_2(g)]}{[NOCl(g)]^2}$$

(ii) $$K_c = \frac{[CuO(g)]^2[NO_2(g)]^4[O_2(g)]}{[Cu(NO_3)_2(s)]^2} = [NO_2(g)]^4[O_2(g)]$$

(iii) $$K_c = \frac{[CH_3COOH(aq)][C_2H_5OH(aq)]}{[CH_3COOC_2H_5(aq)][H_2O(l)]}$$

$$= \frac{[CH_3COOH(aq)][C_2H_5OH(aq)]}{[CH_3COOC_2H_5(aq)]}$$

(iv) $$K_c = \frac{[Fe(OH)_3(s)]}{[Fe^{3+}(aq)][OH^-(aq)]^3} = \frac{1}{[Fe^{3+}(aq)][OH^-(aq)]^3}$$

(v) $$K_c = \frac{[IF_5(l)]^2}{[I_2(s)][F_2(g)]^5} = \frac{[IF_5(l)]^2}{[F_2(g)]^5}$$

Question 5. Find the value of K_c for each of the following equilibria from the value of K

(a) $2NOCl(g) \rightleftharpoons 2NO(g) + Cl_2(g)$; $K_p = 1.8 \times 10^{-2}$ atm at 500 K

(b) $CaCO_3(s) \rightleftharpoons CaO(s) + CO_2(g)$; $K_p = 167$ atm at 1073 K.

Answer:

K_p and K_c are related to each other as $K_p = K_c(RT)^{\Delta ng}$

The value of K_c can be calculated as follows:

(a) $2NOCl(g) \rightleftharpoons 2NO(g) + Cl_2$

$K_p = 1.8 \times 10^{-2}$ atm,

$\Delta^{ng} = 3 - 2 = 1$; $R = 0.0821$ litre atm K^{-1} mol^{-1} ; $T = 500$ K

$$\therefore \quad K_c = \frac{K_p}{(RT)^{\Delta ng}} = \frac{(1.8\times10^{-2}\text{ atm})}{(0.0821\text{ L atm K}^{-1}\text{ mol}^{-1}\times 500\text{ K})^1}$$

$= \mathbf{4.4 \times 10^{-4}\ mol\ L^{-1}}$

(b) $CaCO_3(s) \rightleftharpoons CaO(s) + CO_2(g)$

$K_p = 167$ atm, $\Delta^{ng} = 1$

$R = 0.0821$ liter atm K^{-1} mol^{-1} ; $T = 1073$ K

$$K_c = \frac{K_p}{(RT)^{\Delta ng}} = \frac{(167\text{ atm})}{(0.0821\text{ L atm K}^{-1}\text{ mol}^{-1}\times 1073\text{ K})^1}$$

$= \mathbf{1.9\ mol\ L^{-1}}$

Question 6. For the following equilibrium, K =6.3 x 10^{14} at 1000 K. $NO(g)+O_3 \rightarrow NO_2(g) + O_2(g)$ Both the forward and reverse reactions in the equilibrium are elementary bimolecular reactions. What is K_c for the reverse reaction ?

Answer:

For the reverse reaction $$K_c = \frac{1}{K_c} = \frac{1}{6.3\times10^{14}} = \mathbf{1.59 \times 10^{-15}}.$$

Question 7. Explain why pure liquids and solids can be ignored while writing the value of equilibrium constants.

Answer: This is because molar concentration of a pine solid or liquid is independent of the amount present.

$$\text{Molar concentration} = \frac{\text{No. of moles}}{\text{volume}} \times \frac{\text{Mass}}{\text{volume}} \times \text{Density}$$

Since density of pure liquid or solid is fixed and molar mass is also fixed. Therefore molar concentration are constant.

Question 8. Reaction between nitrogen and oxygen takes place as follows:

$$2N_2 (g) + O_2 (g) \rightleftharpoons 2N_2O(g)$$

If a mixture of 0.482 mol of N_2 and 0.933 mol of O_2 is placed in a reaction vessel of volume 10 L and allowed to form N_2O at a temperature for which K_c - 2.0×10^{-37}, determine the composition of the equilibrium mixture.

Answer: Let x moles of $N_2(g)$ take part in the reaction. According to the equation, x/2 moles of O_2 (g) will react to form x moles of $N_2O(g)$. The molar concentration per litre of different species before the reaction and at the equilibrium point is:

	$2N_2(g)$	+ $O_2(g)$	$\rightleftharpoons 2N_2O(g)$
Initial mole/litre:	$\frac{0.482}{10}$	$\frac{0.933}{10}$	Zero
Mole/litre at eqm. point:	$\frac{0.482-x}{10}$	$\frac{0.933-\frac{x}{2}}{10}$	$\frac{x}{10}$

The value of equilibrium constant (2.0×10^{-37}) is extremely small. This means that only small amounts of reactants have reacted. Therefore, is extremely small and can be omitted as far as the reactants are concerned.

Applying Law of Chemical Equilibrium $K_c = \frac{[N_2O(g)]^2}{[N_2(g)]^2[O_2(g)]}$

$$2.0 \times 10^{-37} = \frac{\left(\frac{x}{10}\right)^2}{\left(\frac{0.482}{10}\right)^2 \times \left(\frac{0.933}{10}\right)} = \frac{0.01\,x^2}{2.1676 \times 10^{-4}}$$

$$x^2 = 43.352 \times 10^{-40} \quad \text{or} \quad x = 6.6 \times 10^{-20}$$

As x is extremely small, it can be neglected.

Thus, in the equilibrium mixture

Molar conc. of N_2 = **0.0482 mol L^{-1}**

Molar conc. of O_2 = **0.0933 mol L^{-1}**

Molar conc. of N_2O = $0.1 \times x = 0.1 \times 6.6 \times 10^{-20}$ mol L^{-1}

= **6.6×10^{-21} mol L^{-1}**

Question 9. Nitric oxide reacts with bromine and gives nitrosyl bromide as per reaction given below:

$$2NO (g) + Br_2 (g) \rightleftharpoons 2NOBr(g)$$

When 0.087 mole of NO and 0.0437 mole of Br_2 are mixed in a closed container at constant temperature, 0.0518 mole of NOB_r is obtained at equilibrium. Determine the compositions of the equilibrium mixture.

Answer: The balanced chemical equation for the reaction is:

According to the equation, 2 moles of NO (g) react with 1 mole of Br_2 (g) to form 2 moles of NOB_r (g). The composition of the equilibrium mixture can be calculated as follows:

No. of moles of NOB_r (g) formed at equilibrium = 0.0518 mol (given)

No. of moles of NO (g) taking part in reaction = 0.0518 mol

No. of moles of NO (g) left at equilibrium = 0.087 - 0.0518 = 0.0352 mol

No. of moles of Br_2 (g) taking part in reaction = 1/2 x 0.0518 = 0.0259 mol

No. of moles of Br_2 (g) left at equilibrium = 0.0437 - 0.0259 = 0.0178 mol

The initial molar concentration and equilibrium molar concentration of different species may be represented as:

$2NO (g) + Br_2(g) \rightarrow 2NOB_r(g)$

Initial moles 0.087 0.0437 0

Moles at eqm. point: 0.0352 0.0178 0.0518

Question 10.

At 450 K, $K_p = 2.0 \times 10^{10}$ bar^{-1} for the equilibrium reaction:

$$2SO_2\,(g) + O_2\,(g) \rightleftharpoons 2SO_3\,(g)$$

What is K_c at this temperature?

Answer:

$$K_p = K_c\,(RT)^{\Delta ng} \text{ or } K_c = \frac{K_p}{(RT)^{\Delta ng}} = K_p\,(RT)^{-\Delta ng}$$

$K_p = 2.0 \times 10^{10}$ bar^{-1} ; R = 0.083 L bar K^{-1} mol^{-1} ; T = 450 K; $\Delta^{ng} = 2 - 3 = -1$

$K_c = (2.0 \times 10^{10}\ \text{bar}^{-1}) \times [(0.083\ \text{L bar K}^{-1}\ \text{mol}^{-1}) \times (450\ \text{K})]^{-(-1)}$

$= 7.47 \times 10^{11}$ mol^{-1} **L = 7.47 × 10^{11} M^{-1}**

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