# SOLUTIONS

## Module - 2 / JEE-2022

| IN-CHAPTER EXERCISES | Chemistry | Chemical Equilibrium |
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### *EXERCISE-A*

**1.**

$$\begin{array}{lcccc} & 2SO_2(g) & +\ O_2(g) & \rightleftharpoons\ 2SO_3(g) & K_p = 3.4 \\ \underset{\text{(Partial P)}}{t=t} & 0.4 & 0.2 & 0.6 & \end{array}$$

$$Q_P = \frac{p_{SO_3}^2}{p_{SO_2}^2 \cdot p_{O_2}} = \frac{(0.6)^2}{(0.4)^2 \times 0.2} = 11.25 > K_p$$

$\Rightarrow$ Reaction is moving in backward direction.

**2.**

$$\begin{array}{lccc} & I_2(g) & \rightleftharpoons\ 2I(g) & K_p = 1.80 \times 10^{-10} \\ \underset{\text{(Partial P)}}{t=t} & 1 & 0.5\times10^{-6} & \end{array}$$

$$Q_p = \frac{p_I^2}{p_{I_2}} = \frac{(0.5\times10^{-6})^2}{1} = 2.5\times10^{-13}$$

As $Q_p < K_p$, reaction is moving in forward direction.

**3.** **(i)**

$$\begin{array}{lccc} & CaCO_3(s) & \rightleftharpoons\ CaO(s) & +\ CO_2(g) \\ \underset{\text{(moles)}}{t=0} & a & 0 & 0 \\ t=t_{eq} & a-x & x & x \end{array}$$

$$K_C = [CO_2] = \frac{x}{V} \quad [\because a_{CaCO_3} = a_{CaO} = 1]$$

$$K_P = p_{CO_2} = P$$

**(ii)** $H_2O(\ell) + CO_2(g) \rightleftharpoons H_2CO_3(aq.)$

$$K_C = \frac{[H_2CO_3]}{[CO_2]}$$

$$K_P = \frac{1}{p_{CO_2}} \quad [a_{H_2O(\ell)} = 1]$$

**(iii)**

$$\begin{array}{lccc} & 2NH_3(g) & \rightleftharpoons\ N_2(g) & +\ 3H_2(g) \\ \underset{\text{(moles)}}{t=0} & a & 0 & 0 \\ t=t_{eq} & a-2x & x & 3x \end{array}$$

$$K_C = \frac{[N_2][H_2]^3}{[NH_3]^2} = \frac{\frac{x}{V}\cdot\left(\frac{3x}{V}\right)^3}{\left(\frac{a-2x}{V}\right)^2} \ ; \ K_P = \frac{p_{N_2}\cdot p_{H_2}^3}{p_{NH_3}^2} = \frac{\left(\frac{x}{a+2x}\cdot P\right)\left(\frac{3x}{a+2x}\cdot P\right)^3}{\left(\frac{a-2x}{a+2x}\cdot P\right)^2}$$

**(iv)** $2HgO(s) \rightleftharpoons 2Hg(\ell) + O_2(g)$

$$K_C = [O_2] \qquad \left[\because a_{HgO} = a_{Hg} = 1\right]$$
$$K_P = p_{O_2}$$

**4.**

$$SO_2(g) + \frac{1}{2}O_2(g) \rightleftharpoons SO_3(g) \qquad K_P = 1.8$$
$$CO_2(g) \rightleftharpoons CO(g) + \frac{1}{2}O_2(g) \qquad K_P = 5 \times 10^{-10}$$
$$SO_2(g) + CO_2(g) \rightleftharpoons SO_3(g) + CO(g) \quad K_P = 1.8 \times 5 \times 10^{-10} = 9 \times 10^{-10}$$

**5.** $2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)\ K_C = ?$

$$\begin{array}{llll} & 2SO_3(g) & \rightleftharpoons 2SO_2(g) & + O_2(g) \\ \underset{\text{(moles)}}{t=0} & 3 & - & - \\ t = t_{eq} & 3-2x & 2x & x \end{array}$$

$\Rightarrow \quad [SO_3] = \dfrac{3-2x}{8}\ ;\ [SO_2] = \dfrac{2x}{8}\ ;\ [O_2] = \dfrac{x}{8}\ ;\ n_{O_2} = x = 0.6$

$$K_C = \frac{[SO_2]^2[O_2]}{[SO_3]^2} = \frac{1}{30}$$

$\Rightarrow \quad 2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g) \qquad K_C = 30$

**6.** $COCl_2(g) \rightleftharpoons CO(g) + Cl_2(g) \qquad K_P = 8 \times 10^{-8}$

$$\begin{array}{llll} \underset{\text{(moles)}}{t=0} & a & 0 & 0 \\ t = t_{eq} & a-x & x & x \end{array}$$

$$K_P = \frac{p_{CO} \cdot p_{Cl_2}}{p_{COCl_2}} = \frac{\left(\frac{x}{a+x}\cdot P\right)\left(\frac{x}{a+x}\cdot P\right)}{\left(\frac{a-x}{a+x}\cdot P\right)} \quad \Rightarrow \quad K_P = \frac{x^2P}{a^2-x^2} = \frac{\alpha^2 P}{1-\alpha^2}\left[\alpha = \frac{x}{a}\right]$$

Here, $K_P = 8 \times 10^{-8} << 1 \quad \Rightarrow \quad 1-\alpha^2 \approx 1 \quad \Rightarrow \quad 8 \times 10^{-8} = \alpha^2 \times 2 \quad \Rightarrow \quad \alpha = 2 \times 10^{-4} = 0.02\%$ [Check the approximation]

**7.** $N_2O_4(g) \rightleftharpoons 2NO_2(g)$

$$\begin{array}{lll} \underset{\text{(moles)}}{t=0} & a & 0 \\ t = t_{eq} & a - a\alpha & 2a\alpha \end{array}$$

$$K_p = \frac{p^2_{NO_2}}{p_{N_2O_4}} = \frac{\left(\frac{2a\alpha}{a+a\alpha}\cdot P\right)^2}{\frac{a-a\alpha}{a+a\alpha}P} = \frac{4\alpha^2P}{1-\alpha^2}$$

$K_p$ will remain same as T is const. $\Rightarrow \quad \dfrac{4\alpha_1^2 P_1}{1-\alpha_1^2} = \dfrac{4\alpha_2^2 P_2}{1-\alpha_2^2} \qquad [\alpha_1 = 0.2\ ; P_1 = 1.0\text{atm};\ P_2 = 0.2\text{atm}]$

$\Rightarrow \quad \alpha_2 = 0.41$

**8.(C)**

$$\begin{array}{lccc} & P_4(g) + & 6Cl_2(g) & \rightleftharpoons 4PCl_3(g) \\ \underset{(\text{moles})}{t=0} & a & a & 0 \\ t = t_{eq} & a-x & a-6x & 4x \end{array}$$

$$[Cl_2] = \frac{a-6x}{V} \quad ; \quad [PCl_3] = \frac{4x}{V} \quad ; \quad [P_4] = \frac{a-x}{V}$$

Clearly, $[Cl_2] < [P_4]$

**9.(D)** $A + 2B \rightleftharpoons C \;:\; K_{eq} = K_1$ ..... **(i)**

$C + D \rightleftharpoons 3A \;:\; K_{eq} = K_2$ ..... **(ii)**

Multiply (i) by 3 and add to (ii) to get : $6\,B + D \rightleftharpoons 2\,C$ $\qquad K_{eq} = K_3$

$\Rightarrow \quad K_{eq} = K_1^3 \,.\, K_2 = K_3$

**10.(B)** $N_2O_4(g) \rightleftharpoons 2NO_2(g) \qquad K_C = 4$

From graph, at point A, $Q = 0$

When $[N_2O_4] = [NO_2] = 0.1$ M

$\Rightarrow \quad Q = \dfrac{[NO_2]^2}{[N_2O_4]} = 0.1 < K_C \Rightarrow$ Reaction is moving in forward direction.

At point D or F, $[NO_2]$ and $[N_2O_4]$ is const. with time $\Rightarrow$ Achievement of chemical equilibrium.

**11.(B)** $N_2O_4$ at 300 K ; P = 1 atm

$\Rightarrow \quad N_2O_4$ at 600 K ; P = 2atm [P is proportional to T]

$$\begin{array}{lcc} & N_2O_4(g) & \rightleftharpoons 2NO_2(g) \\ \underset{(\text{Partial P})}{t=0} & P_0 & 0 \\ t = t_{eq} & P_0 - x & 2x \end{array}$$

$P_{Total} = P_0 - x + 2x = P_0 + x = 2.4$ atm $\left[\because \alpha = \dfrac{x}{P_0} = 0.2 \text{ and } P_0 = 2\text{atm}\right]$

**12.(C)** **(i)** $CaCO_3(s) \rightleftharpoons CaO(s) + CO_2(g)$

$$K_1 = p_{CO_2} = P = 1\text{atm}$$

**(ii)** $NH_4HS(s) \rightleftharpoons NH_3(g) + H_2S(g)$

$$K_2 = p_{NH_3} \cdot p_{H_2S} = \frac{P}{2} \cdot \frac{P}{2} = \frac{1}{4}$$

**(iii)** $NH_2COONH_4(s) \rightleftharpoons 2NH_3(g) + CO_2(g)$

$$K_3 = p_{NH_3}^2 \cdot p_{CO_2} = \left(\frac{2P}{3}\right)^2 \cdot \frac{P}{3} = \frac{4}{27} \qquad \Rightarrow \qquad K_1 > K_2 > K_3$$

**13.(A)** $FeO(s) + CO(g) \rightleftharpoons Fe(s) + CO_2(g)$

$$K_C = \frac{[CO_2]}{[CO]} = 5 \quad \Rightarrow \quad [CO_2] = 5 \times 0.025 = 0.125\text{ M}$$

**14.(C)** Large amount of Reactants and Small amount of products $\Rightarrow$ Reaction is not favorable in forward direction.

$$\Rightarrow \quad K_{eq} = \frac{k_f}{k_b} << 1 \quad \Rightarrow \quad k_f << k_b$$

**15.(D)** For a chemical reaction to be at equilibrium, $r_f = r_b$

**16.(AB)** A reaction at equilibrium, can be shifted only when $Q < K_{eq}$ or $Q > K_{eq}$.

**17.(ABCD)** Properties of equilibrium.

[**Note :** "Permanency" is a feature of equilibrium in the sense that whenever there is a change in the reaction conditions, reaction adjusts itself so as to attain a new equilibrium.]

**18.(A)**

$$\begin{array}{llll} & AB(g) & \rightleftharpoons A(g) & + B(g) \\ \underset{(\text{moles})}{t=0} & a & 0 & 0 \\ t = t_{eq} & a-x & x & x \end{array}$$

$$\Rightarrow \quad K_P = \frac{p_A \cdot p_B}{p_{AB}} = \frac{\left(\frac{x}{a+x}\cdot P\right)\left(\frac{x}{a+x}\cdot P\right)}{\left(\frac{a-x}{a+x}\cdot P\right)}$$

$$\Rightarrow \quad K_p = \frac{x^2 P}{a^2 - x^2} \text{ and } \alpha = \frac{x}{a} = \frac{1}{3} \quad \Rightarrow \quad P = 8\,K_P$$

**19.(D)** $K_{eq}$ depends only on T

**20.(D)**

$$\begin{array}{llll} & AB(g) & \rightleftharpoons A(g) & + B(g) \\ \underset{(\text{moles})}{t=0} & 1 & 0 & 0 \\ t = t_{eq} & 1-\alpha & \alpha & \alpha \end{array}$$

$$\Rightarrow \quad K_p = \frac{p_A \cdot p_B}{p_{AB}} = \frac{\left(\frac{\alpha}{1+\alpha}\cdot P\right)\left(\frac{\alpha}{1+\alpha}\cdot P\right)}{\frac{1-\alpha}{1+\alpha}\cdot P}$$

$$\Rightarrow \quad K_P = \frac{\alpha^2 P}{1-\alpha^2} = 4\,P\,(\text{given}) \Rightarrow \alpha = 0.9$$

**21.(ABC)** At initial stages of the reaction. Q = 0 but increases.
Also, initially increase in Q is high but its rate of increase decreases with time i.e. initially Q will increase rapidly but as the reaction proceeds , Q will change (increase) slowly and slowly.

**22.(C)**

$$\begin{array}{llll} & X + & Y & \rightleftharpoons 3Z \\ \underset{(\text{moles})}{\text{At eq.}} & 1 & 2 & 4 \end{array}$$

$$K_C = \frac{[Z]^3}{[X]\,[Y]} = \frac{\left(\frac{4}{3}\right)^3}{\frac{1}{3}\cdot\frac{2}{3}} = 10.67 < Q\,(=15) \quad \Rightarrow \quad \text{Reaction is moving in backward direction.}$$

## EXERCISE-B

**1.**

$$\begin{array}{lccc} & 2SO_2(g) + & O_2(g) \rightleftharpoons & 2SO_3(g) \\ \underset{\text{(Partial P)}}{t = t_{eq}} & 0.6 & 0.1 & 0.3 \end{array}$$

$$K_P = \frac{p^2_{SO_3}}{p^2_{SO_2} \cdot p_{O_2}} = \frac{(0.3)^2}{(0.6)^2 \times 0.1} = 2.5\,; \qquad K_P = \frac{p^2_{SO_3}}{P^2_{SO_2} \cdot p_{O_2}} = \frac{1}{p_{O_2}} \;[\because p_{SO_3} = p_{SO_2} \text{ (given)}]$$

$$\Rightarrow \quad p_{O_2} = \frac{1}{K_P} = 0.4$$

**2.**

$$\begin{array}{lccc} & PCl_5(g) \rightleftharpoons & PCl_3(g) + & Cl_2(g) \\ \underset{\text{(moles)}}{t = 0} & a & 0 & 0 \\ t = t_{eq} & a - x & x & x \end{array}$$

$$K_P = \frac{p_{PCl_3} \cdot p_{Cl_2}}{p_{PCl_5}} = \frac{\left[\frac{x}{a+x} \cdot P\right]\left[\frac{x}{a+x} \cdot P\right]}{\frac{a-x}{a+x} \cdot P} \quad \Rightarrow \quad K_P = \frac{x^2 P}{a^2 - x^2} = \frac{\alpha^2 P}{1 - \alpha^2} = 0.3 \left[\alpha = \frac{x}{a}\right] \quad \Rightarrow \quad \alpha = \sqrt{\frac{1}{6}}$$

$$\%\,Cl_2 = \frac{x}{a + x} = \frac{\alpha}{1 + \alpha} \times 100\% = 29.1\,\%$$ [**Note :** For a gaseous mixture, mole % = volume %]

**3.(B)** Yield$_{max}$ ≡ Amount of Product should be max.

$P\uparrow \Rightarrow$ Reaction will shift where $\Delta n_g < 0$.

Clearly, $2H_2(g) + O_2(g) \rightleftharpoons 2H_2O(g)\ ;\ \Delta n_g = -1$

**4.(C)** $H_2O(\ell) \rightleftharpoons H_2O(g)$

Increasing P, will shift the reaction in backward direction. ⇒ Increase in boiling point.

**5.(D)** All are facts. (Concept of Activation energy will be discussed in 12th class)

**6.(A)** $NH_2COONH_4(s) \rightleftharpoons 2NH_3(g) + CO_2(g)$

$Q = p^2_{NH_3} \cdot p_{CO_2} = 10^2 \times 30 = 3000 > K_P$

⇒ Reaction will shift in backward direction : $P_{Total} = p_{NH_3} + p_{CO_2} < 40$ atm at equilibrium.

**7.(C)**

$$\begin{array}{lcc} & N_2O_4(g) \rightleftharpoons & 2NO_2(g) \\ \underset{\text{(moles)}}{t = 0} & a & 0 \\ t = t_{eq} & a - a\alpha & 2a\alpha \end{array}$$

$$\frac{M_{mix,i}}{M_{min,f}} = \frac{n_f}{n_i} = \frac{d_i}{d_f} \quad \Rightarrow \quad \frac{1 + \alpha}{1} = \frac{92/2}{26} \Rightarrow \alpha = 0.76$$ [ **Note :** "Observed" means "Experimental"]

**8.(D)** $K_P$ changes only when T is changed.

**9.(C)** Addition of inert gas doesn't change $K_P$ and $K_C$.

**10.(C)** Ice $\rightleftharpoons$ water

This equlibrium is shifted in forward direction (melting) by the application of pressure.

**11.(C)** $PCl_5(g) \rightleftharpoons PCl_3(g) + Cl_2(g)$

Introducing inert gas at constant volume, doesn't shift equilibrium.

Introducing inert gas at constant P, shifts the reaction in a direction when $\Delta n_g > 0$.

**12.(ACD)** $P\uparrow \Rightarrow$ reaction shift where $\Delta n_g < 0$.

Check yourself for the reactions having $\Delta n_g < 0$ in forward direction.

**13.(A)** $N_2O_4(g) \rightleftharpoons 2NO_2(g)$

$$\left.\begin{array}{r} 500\,K : K_P = 1.7 \times 10^3 \\ \text{and } 600\,K : K_P = 1.78 \times 10^4 \end{array}\right\} \text{Endothermic reaction. } (\because\ K_P \text{ increases with temperature})$$

Increasing P will shift the reaction in backward direction.

**14.(B)** $K_{eq.}$ remains same even in the presence of catalyst.

**15.(D)** $C_2H_4(g) + H_2(g) \rightleftharpoons C_2H_6(g) \quad \Delta H = -32.7\ K\,cal.$

$[C_2H_4]$ can be increased by : removing $H_2$, adding $C_2H_6$, increasing T, decreasing P.

**16.(B)**