

SOLUTIONS

Module - 2 / JEE-2022

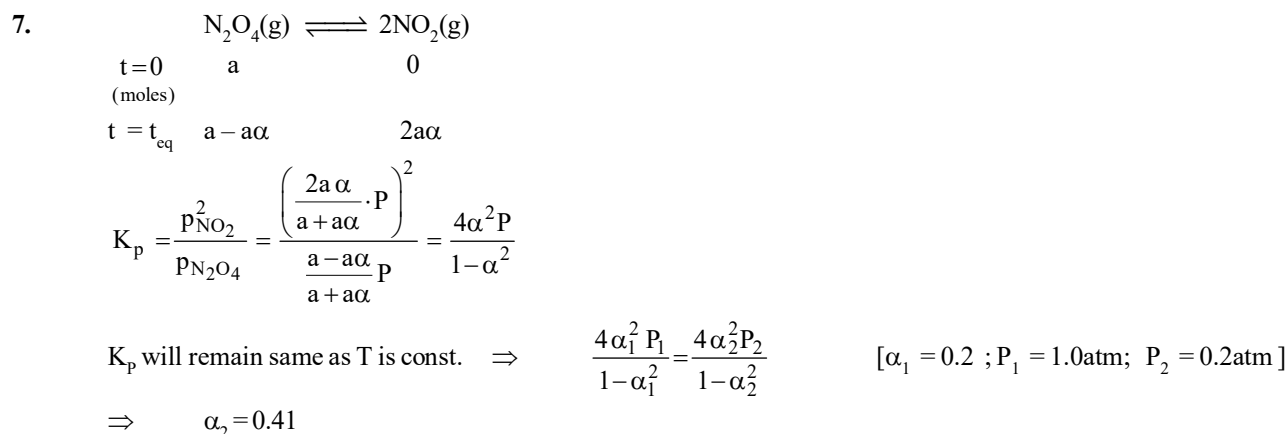
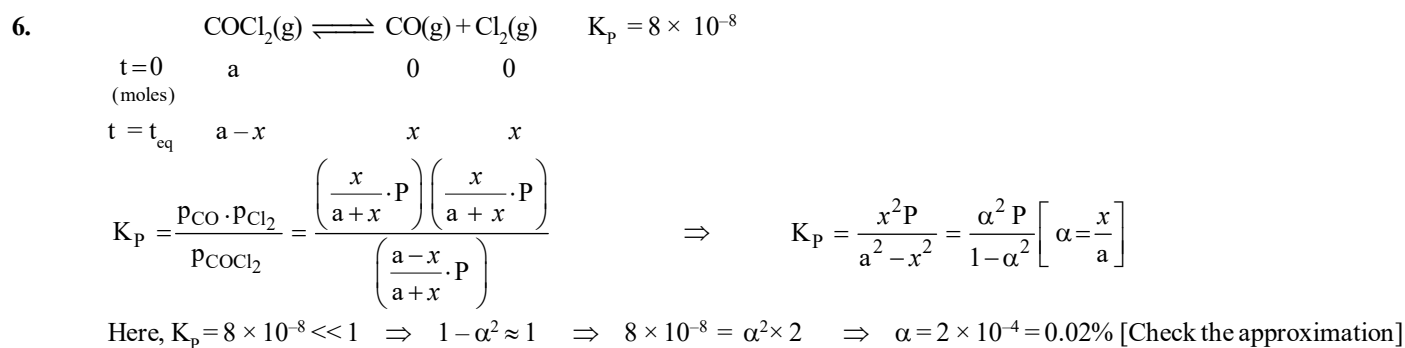
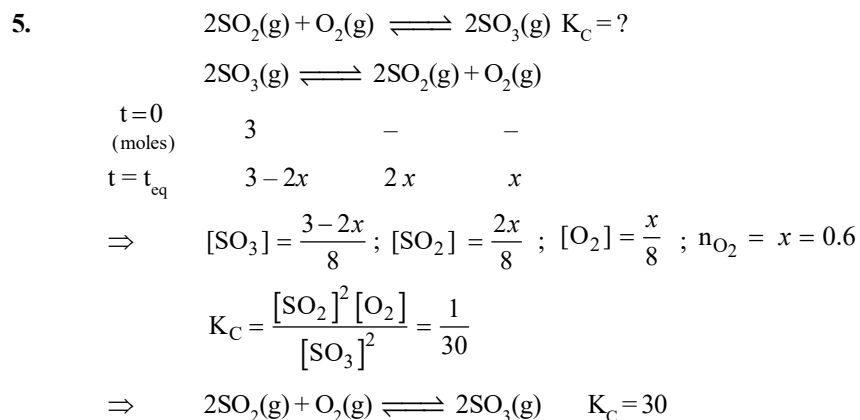
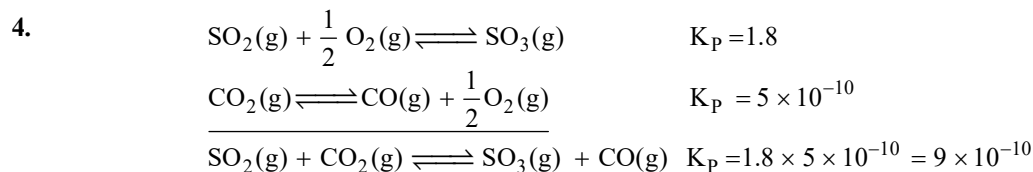
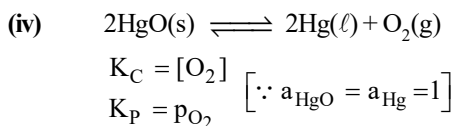
IN-CHAPTER EXERCISES

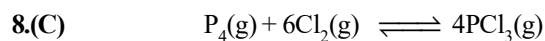
Chemistry

Chemical Equilibrium

EXERCISE-A

1. $2\text{SO}_2(\text{g}) + \text{O}_2(\text{g}) \rightleftharpoons 2\text{SO}_3(\text{g}) \quad K_p = 3.4$
- | | | | | |
|-------------|-----|-----|-----|--|
| $t = t$ | 0.4 | 0.2 | 0.6 | |
| (Partial P) | | | | |
- $$Q_p = \frac{p_{\text{SO}_3}^2}{p_{\text{SO}_2}^2 \cdot p_{\text{O}_2}} = \frac{(0.6)^2}{(0.4)^2 \times 0.2} = 11.25 > K_p \Rightarrow \text{Reaction is moving in backward direction.}$$
2. $\text{I}_2(\text{g}) \rightleftharpoons 2\text{I}(\text{g}) \quad K_p = 1.80 \times 10^{-10}$
- | | | | |
|-------------|---|----------------------|--|
| $t = t$ | 1 | 0.5×10^{-6} | |
| (Partial P) | | | |
- $$Q_p = \frac{p_{\text{I}}^2}{p_{\text{I}_2}} = \frac{(0.5 \times 10^{-6})^2}{1} = 2.5 \times 10^{-13} \quad \text{As } Q_p < K_p, \text{ reaction is moving in forward direction.}$$
3. (i) $\text{CaCO}_3(\text{s}) \rightleftharpoons \text{CaO}(\text{s}) + \text{CO}_2(\text{g})$
- | | | | |
|---------------------|---------|---|---|
| $t = 0$ | a | 0 | 0 |
| (moles) | | | |
| $t = t_{\text{eq}}$ | $a - x$ | x | x |
- $$K_c = [\text{CO}_2] = \frac{x}{V} \quad [\because a_{\text{CaCO}_3} = a_{\text{CaO}} = 1]$$
- $$K_p = p_{\text{CO}_2} = P$$
- (ii) $\text{H}_2\text{O}(\ell) + \text{CO}_2(\text{g}) \rightleftharpoons \text{H}_2\text{CO}_3(\text{aq.})$
- $$K_c = \frac{[\text{H}_2\text{CO}_3]}{[\text{CO}_2]}$$
- $$K_p = \frac{1}{p_{\text{CO}_2}} \quad [a_{\text{H}_2\text{O}(\ell)} = 1]$$
- (iii) $2\text{NH}_3(\text{g}) \rightleftharpoons \text{N}_2(\text{g}) + 3\text{H}_2(\text{g})$
- | | | | |
|---------------------|----------|---|----|
| $t = 0$ | a | 0 | 0 |
| (moles) | | | |
| $t = t_{\text{eq}}$ | $a - 2x$ | x | 3x |
- $$K_c = \frac{[\text{N}_2][\text{H}_2]^3}{[\text{NH}_3]^2} = \frac{\frac{x}{V} \cdot \left(\frac{3x}{V}\right)^3}{\left(\frac{a-2x}{V}\right)^2}; \quad K_p = \frac{p_{\text{N}_2} \cdot p_{\text{H}_2}^3}{p_{\text{NH}_3}^2} = \frac{\left(\frac{x}{a+2x} \cdot P\right) \left(\frac{3x}{a+2x} \cdot P\right)^3}{\left(\frac{a-2x}{a+2x} \cdot P\right)^2}$$



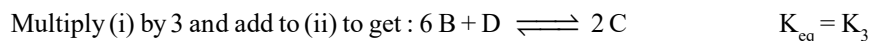
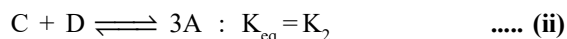
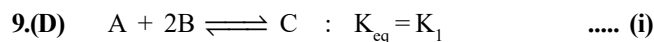


$$\begin{array}{cccc} t=0 & a & a & 0 \\ \text{(moles)} & & & \end{array}$$

$$t = t_{\text{eq}} \quad a-x \quad a-6x \quad 4x$$

$$[\text{Cl}_2] = \frac{a-6x}{V} ; [\text{PCl}_3] = \frac{4x}{V} ; [\text{P}_4] = \frac{a-x}{V}$$

$$\text{Clearly, } [\text{Cl}_2] < [\text{P}_4]$$



$$\Rightarrow K_{\text{eq}} = K_1^3 \cdot K_2 = K_3$$

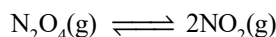
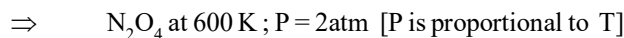
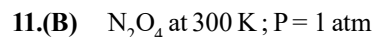


From graph, at point A, $Q = 0$

When $[\text{N}_2\text{O}_4] = [\text{NO}_2] = 0.1 \text{ M}$

$$\Rightarrow Q = \frac{[\text{NO}_2]^2}{[\text{N}_2\text{O}_4]} = 0.1 < K_C \Rightarrow \text{Reaction is moving in forward direction.}$$

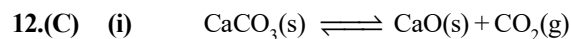
At point D or F, $[\text{NO}_2]$ and $[\text{N}_2\text{O}_4]$ is const. with time \Rightarrow Achievement of chemical equilibrium.



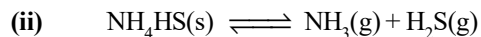
$$\begin{array}{ccc} t=0 & P_0 & 0 \\ \text{(Partial P)} & & \end{array}$$

$$t = t_{\text{eq}} \quad P_0 - x \quad 2x$$

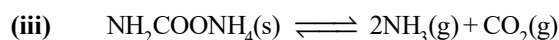
$$P_{\text{Total}} = P_0 - x + 2x = P_0 + x = 2.4 \text{ atm} \quad [\because \alpha = \frac{x}{P_0} = 0.2 \text{ and } P_0 = 2 \text{ atm}]$$



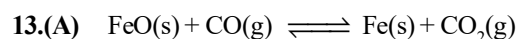
$$K_1 = p_{\text{CO}_2} = P = 1 \text{ atm}$$



$$K_2 = p_{\text{NH}_3} \cdot p_{\text{H}_2\text{S}} = \frac{P}{2} \cdot \frac{P}{2} = \frac{1}{4}$$



$$K_3 = p_{\text{NH}_3}^2 \cdot p_{\text{CO}_2} = \left(\frac{2P}{3}\right)^2 \cdot \frac{P}{3} = \frac{4}{27} \quad \Rightarrow \quad K_1 > K_2 > K_3$$



$$K_C = \frac{[\text{CO}_2]}{[\text{CO}]} = 5 \quad \Rightarrow \quad [\text{CO}_2] = 5 \times 0.025 = 0.125 \text{ M}$$

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

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

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) $AB(g) \rightleftharpoons A(g) + B(g)$

$$t=0 \quad a \quad 0 \quad 0$$

(moles)

$$t = t_{eq} \quad a-x \quad x \quad x$$

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

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

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

20.(D) $AB(g) \rightleftharpoons A(g) + B(g)$

$$t=0 \quad 1 \quad 0 \quad 0$$

(moles)

$$t = t_{eq} \quad 1-\alpha \quad \alpha \quad \alpha$$

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

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

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.

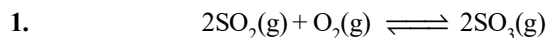
22.(C) $X + Y \rightleftharpoons 3 Z$

$$\text{At eq.} \quad 1 \quad 2 \quad 4$$

(moles)

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

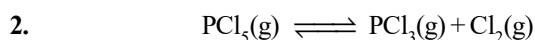
EXERCISE-B



$$\begin{array}{ccccc} t = t_{\text{eq}} & & & & \\ \text{(Partial P)} & 0.6 & 0.1 & 0.3 & \end{array}$$

$$K_P = \frac{p_{\text{SO}_3}^2}{p_{\text{SO}_2}^2 \cdot p_{\text{O}_2}} = \frac{(0.3)^2}{(0.6)^2 \times 0.1} = 2.5; \quad K_P = \frac{p_{\text{SO}_3}^2}{p_{\text{SO}_2}^2 \cdot p_{\text{O}_2}} = \frac{1}{p_{\text{O}_2}} [\because p_{\text{SO}_3} = p_{\text{SO}_2} \text{ (given)}]$$

$$\Rightarrow p_{\text{O}_2} = \frac{1}{K_P} = 0.4$$



$$\begin{array}{ccccc} t = 0 & & & & \\ \text{(moles)} & a & 0 & 0 & \end{array}$$

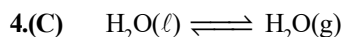
$$\begin{array}{ccccc} t = t_{\text{eq}} & a - x & x & x & \end{array}$$

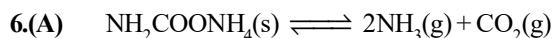
$$K_P = \frac{p_{\text{PCl}_3} \cdot p_{\text{Cl}_2}}{p_{\text{PCl}_5}} = \frac{\left[\frac{x}{a+x} \cdot P\right] \left[\frac{x}{a+x} \cdot P\right]}{\frac{a-x}{a+x} \cdot P} \Rightarrow K_P = \frac{x^2 P}{a^2 - x^2} = \frac{\alpha^2 P}{1 - \alpha^2} = 0.3 \left[\alpha = \frac{x}{a} \right] \Rightarrow \alpha = \sqrt{\frac{1}{6}}$$

$$\% \text{Cl}_2 = \frac{x}{a+x} = \frac{\alpha}{1+\alpha} \times 100\% = 29.1\% \quad [\text{Note : For a gaseous mixture, mole \% = volume \%}]$$

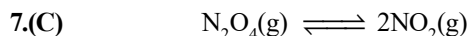
 3.(B) Yield_{max} \equiv Amount of Product should be max.

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

 Clearly, $2\text{H}_2(\text{g}) + \text{O}_2(\text{g}) \rightleftharpoons 2\text{H}_2\text{O}(\text{g})$; $\Delta n_g = -1$

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

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


$$Q = p_{\text{NH}_3}^2 \cdot p_{\text{CO}_2} = 10^2 \times 30 = 3000 > K_P$$

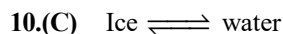
 \Rightarrow Reaction will shift in backward direction : $P_{\text{Total}} = p_{\text{NH}_3} + p_{\text{CO}_2} < 40 \text{ atm}$ at equilibrium.


$$\begin{array}{ccccc} t = 0 & & & & \\ \text{(moles)} & a & & 0 & \end{array}$$

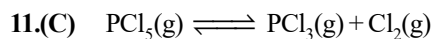
$$\begin{array}{ccccc} t = t_{\text{eq}} & a - a\alpha & & 2a\alpha & \end{array}$$

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

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

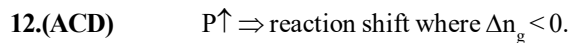
 9.(C) Addition of inert gas doesn't change K_P and K_C .


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

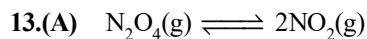


Introducing inert gas at constant volume, doesn't shift equilibrium.

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

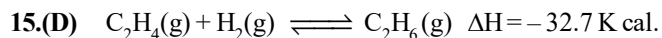
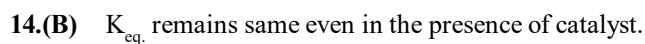


Check yourself for the reactions having $\Delta n_g < 0$ in forward direction.



500 K: $K_p = 1.7 \times 10^3$
and 600 K: $K_p = 1.78 \times 10^4$ } Endothermic reaction. ($\because K_p$ increases with temperature)

Increasing P will shift the reaction in backward direction.



$[\text{C}_2\text{H}_4]$ can be increased by : removing H_2 , adding C_2H_6 , increasing T, decreasing P.

