

# Equilibrium

## Check Point - 1

- (a) :  $K_p = \frac{P_C}{P_A \times P_B} = \frac{1}{P^2} = \text{atm}^{-2}$
- (a) : (a) is correct because concentrations of  $\text{H}_2$  and  $\text{N}_2$  decrease while that of  $\text{NH}_3$  increases with time and after equilibrium, all of them remain constant.
- (c) :  $K = \frac{[\text{CO}_2]^2}{[\text{N}_2\text{O}_4]} = \frac{(2 \times 10^{-3} / 2)^2}{(0.2 / 2)} = \frac{10^{-6}}{10^{-1}} = 10^{-5}$
- (b) :  $\text{XY}_2 \rightleftharpoons \text{XY} + \text{Y}$   

mol	400	0	0
eqm.	$400 - x$	$x$	$x$
tot. pressure	$= 600 + p$		
	$= 800$		
Actual vol.	400	200	200

or  $p = 200 \text{ mm Hg}$   
 $K = \frac{200 \times 200}{400} = 100$

- (c) : Partial pressure of I atoms ( $p_I$ )  
 $= \frac{40}{100} \times 10^5 \text{ Pa} = 0.40 \times 10^5 \text{ Pa}$   
 Partial pressure of  $\text{I}_2$  ( $p_{\text{I}_2}$ )  
 $= \frac{60}{100} \times 10^5 \text{ Pa} = 0.60 \times 10^5 \text{ Pa}$   
 $K_p = \frac{p^2}{p_{\text{I}_2}} = \frac{(0.4 \times 10^5)^2}{0.60 \times 10^5} = 2.66 \times 10^4$
- (d) :  $\text{A}_2 + 3\text{B}_2 \rightleftharpoons 2\text{AB}_3$ ;  $K_1 = x \text{ mol}^{-2} \text{ L}^2$  ... (i)  
 $\text{AB}_3 \rightleftharpoons \frac{1}{2}\text{A}_2 + \frac{3}{2}\text{B}_2$ ;  $K_2 = y \text{ mol L}^{-1}$  ... (ii)

Equation (ii) is obtained by reversing equation (i) and then dividing by 2.

$$\therefore K_2 = \frac{1}{\sqrt{K_1}} \Rightarrow y = \frac{1}{\sqrt{x}} = x^{-1/2}$$

- (b) : For reaction (i),  
 $P_{\text{A}_2} = P_{\text{B}_2} = 8 \times 10^{-2}$  (given)  
 For reaction (ii),

$$K_2 = \frac{P_{\text{CO}}^2}{P_{\text{CO}_2}} = 2 \text{ (given)}$$

$$\therefore 2 = \frac{P_{\text{CO}}^2}{8 \times 10^{-3}} \quad \text{or, } P_{\text{CO}} = 0.4$$

- (c) :  $K_c = \frac{[\text{PCl}_3][\text{Cl}_2]}{[\text{PCl}_5]}$  i.e.,  $0.5 = \frac{0.2 \times [\text{Cl}_2]}{0.4}$   
 or,  $[\text{Cl}_2] = 1.0 \text{ mol L}^{-1}$

- (b) : Active mass = molar concentration =  $n/V$   
 From  $PV = nRT$ ,  $\frac{n}{V} = \frac{P}{RT}$
- (a)

## Check Point - 2

- (b)
- (a) : Equilibrium shifts backward.
- (d) : At constant volume, there is no change in concentrations.
- (c) :  $n_p = n_g$ . Pressure has no effect.
- (c) : As  $n_p < n_g$  higher the pressure, greater will be yield of Z. As reaction is exothermic in the forward direction, lower the temperature, greater is the yield of Z.
- (c) : The given reaction is endothermic. So, on increasing temperature, it will shift in the forward direction.
- (c) :  $\text{Ice} \rightleftharpoons \text{Water}$   
 More vol.    less vol.

On applying pressure, equilibrium shifts to the side in which volume is less.

- (c) : The reaction proceeds from right to left when  $Q_c > K_c$ , so, that  $Q_c$  tends to decrease to become equal to  $K_c$ .
- (a) : Change in volume, changes the molar concentration. In (a),  $n_p = n_g$ . Change in volume will not alter the number of moles in this case.
- (b) : For a hypothetical reaction



$$Q_c = \frac{[\text{C}][\text{D}]}{[\text{A}][\text{B}]} \quad Q_c \text{ increases}$$

## Check Point - 3

- (b) :  $\text{pH} = \frac{\text{p}K_1 + \text{p}K_2}{2} = \frac{2.15 + 7.80}{2} = 4.975$
- (c) :  $\text{pOH} = 14 - \text{pH} = 14 - 8.26 = 5.74$   
 $5.74 = \text{p}K_b + \log \frac{[\text{NH}_4^+]}{[\text{NH}_3]} = 4.74 + \log \frac{[\text{NH}_4^+]}{0.1}$   
 $[\text{NH}_4^+] = 1 \text{ mol L}^{-1}$   
 $[(\text{NH}_4)_2\text{SO}_4] = \frac{1}{2} = 0.5 \text{ mol L}^{-1}$

- (c) :  $\text{N}_2\text{O}_{4(g)} \rightleftharpoons 2\text{NO}_{2(g)}$   

$t = 0$	1	0
eqm.	$1 - \alpha$	$2\alpha$

Total number of moles at equilibrium =  $1 - \alpha + 2\alpha = 1 + \alpha$

$$K_p = \frac{P_{\text{NO}_2}^2}{P_{\text{N}_2\text{O}_4}} = \frac{\left(\frac{2\alpha}{1+\alpha}P\right)^2}{\left(\frac{1-\alpha}{1+\alpha}P\right)}$$

$$K_p = \frac{4\alpha^2 P}{(1+\alpha)(1-\alpha)} = \frac{4\alpha^2 P}{1-\alpha^2}$$

$$4\alpha^2 P = K_p(1-\alpha^2) \quad 4\alpha^2 P + \alpha^2 K_p = K_p$$

# 19 Chemical Equilibrium Answer Key

**Charles E. Mortimer**



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