

→  $K = \frac{1}{K_1} \times K_2 \times (K_3)^3 \rightarrow \frac{K_2(K_3)^3}{K_1}$

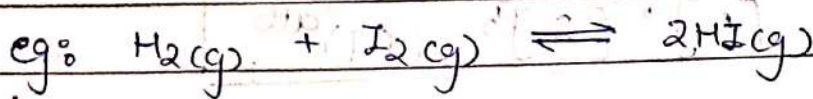
Q:5

### # Types of chemical equilibrium:

→ on the basis of physical state of reactant and product in equilibrium reaction.

#### (A.) Homogeneous equilibrium:

- when physical state of reactant and product are identical in chemical equilibrium is known as homogeneous equilibrium.



(B.) Heterogeneous equilibrium:

- when physical state of reactant and product differs in chemical equilibrium they are Heterogeneous equilibrium.



# Relation between  $K_C$  and  $K_P$ :

- for a general equilibrium reaction.



$$K_p = \frac{P_C^c \times P_D^d}{P_A^a \times P_B^b} \quad \text{--- eq(1)}$$

$P_A = [A]RT$

$P_B = [B]RT$

$P_C = [C]RT$

$P_D = [D]RT.$

} value in eq(1)

putting values in eq(1)

$$K_p = \frac{([C]RT)^c ([D]RT)^d}{([A]RT)^a ([B]RT)^b}$$

$$K_p = \frac{[C]^c [D]^d (RT)^{c+d}}{[A]^a [B]^b (RT)^{a+b}}$$

$$K_p = K_C (RT)^{(c+d)-(a+b)}$$

here:  $\Delta n_g$   
 $R = 0.082 \frac{\text{atm ltr}}{\text{mol} \cdot \text{K}}$

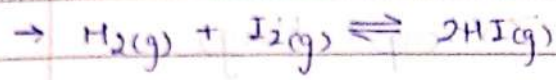
$$K_p = K_C RT^{\Delta n_g}$$

$T = \text{temp (K)}$

chemical equilibrium

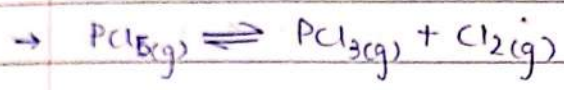
$\Delta n_g$

rel. b/w  $K_c$  &  $K_p$ .



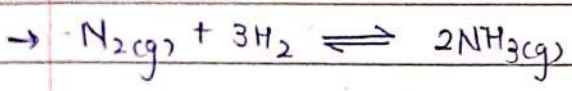
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$K_p = K_c$ .



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$K_p = K_c \cdot RT$   
 $[K_p > K_c]$

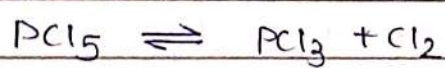


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$K_p = K_c (RT)^{-2}$   
 $[K_p < K_c]$

Q:6 find ratio of  $K_p / K_c$  at  $300^\circ K$  for following equili. rxns: (A)  $PCl_5(g) \rightleftharpoons PCl_3 + Cl_2(g)$  (B)  $N_2(g) + 3H_2 \rightleftharpoons 2NH_3$

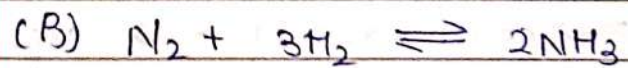
$\rightarrow$  (A)  $R = 0.0821$   $T = 300^\circ K$ .



$\frac{K_p}{K_c} = RT$

$\therefore \frac{K_p}{K_c} = \frac{0.0821 \times 300}{1}$

$\rightarrow 2463$



$\frac{K_p}{K_c} = \frac{1}{(RT)^2} \rightarrow$

\* NOTE:

1.) Homogeneous gaseous equilibrium =  $K_c$  and  $K_p$  both are applied.

2.) Homogeneous aqueous equilibrium = only  $K_c$  is applied not  $K_p$ .  
 $(K_c \checkmark K_p \times)$

\* NOTE:

3.) Heterogeneous equilibrium (solid & aq. sol.) = only  $K_c$  applies  
 $(s) + \dots \rightleftharpoons \dots + \dots$

4.) Heterogeneous equilibrium (solid & gas) = both  $K_c$  &  $K_p$  apply  
 $CaCO_3(s) \rightleftharpoons CO_2(g) + CaO(s)$

5.) Heterogeneous equilibrium (aqueous & gas) =  $K_{pc}$ .  
 here:  $K_{pc}$  = equilibrium const. in terms of partial pressure and concentration  
 $Zn(s) + 2H^+(aq) \rightleftharpoons Zn^{2+}(aq) + H_2(g)$

→ Homogeneous → (g) →  $K_c$  &  $K_p$   
 → (aq) →  $K_c$

→ Heterogeneous → (s+aq) →  $K_c$   
 → (s+g) →  $K_c$  and  $K_p$   
 → (s+g+aq+l) →  $K_{pc}$ .

# Significance of equilibrium constant: ( $K_{eq}$ )

- for a reversible equilibrium reaction the value of ' $K_{eq}$ ' gives information about the extent of reaction.

CASE:1 if ' $K_{eq} > 10^3$ '  
 → very high conversion of reactant (→) to product or very high extent of reaction.



CASE: II if  $K_{eq} < 10^{-3}$   
 → very low conversion of reactant ( $\rightarrow$ ) to product or very low extent of reaction.

CASE: III if  $10^{-3} < K_{eq} < 10^3$   
 → neither low nor high extent of reaction as it remains moderate for conversion of reactant ( $\rightarrow$ ) to product.

### # Reaction quotient (Q) and predicting direction of rxn:

- The reaction quotient is defined in the same way as equilibrium constant [with molar concentration to give  $Q_c$  or with partial pressure to give  $(Q_p)$ ] at any stage of reaction. For a general reaction:



$$Q_c = \frac{[C]^c [D]^d}{[A]^a [B]^b}$$

→ if  $\sigma_f = \sigma_b$  it means  $Q_c = K_c$   
 [reversible reaction in equill. condition]

→ if  $\sigma_f \neq \sigma_b$  (have 2 condition)

CASE: (A) - if  $Q_c < K_c$

→  $Q_c \downarrow$  product formation  $\downarrow$

→ to the product direction.

[reaction moved to product side.]

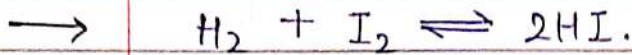
CASE: (B) - if  $Q_c > K_c$  (reversed rxn)

→  $K_c \downarrow$  product formation  $\uparrow$

→ to the reactant direction.

[reaction moved to reactant site]

Q:7 In the rxn  $H_2(g) + I_2(g) \rightleftharpoons 2HI(g)$ , molar conc. of all are 0.1 mol/L at 783 K. If value of  $K_c$  at 783K is 46. Find dir. of rxn.



$$Q_c \rightarrow \frac{[HI]^2}{[H_2][I_2]} \rightarrow \frac{[0.1]^2}{[0.1][0.1]} = \underline{\underline{1}}$$

$Q_c = 1.$

∴,  $Q_c < K_c$  here, dir. of rxn. is forward which means towards product side.

### # Degree of dissociation: ( $\alpha$ )

- degree of dissociation ( $\alpha$ ) =  $\frac{\text{consume mole or dissociated mole}}{\text{initial mole}}$

-  $\% - \alpha = \frac{\text{consume mole / dissociated mole}}{\text{initial mole}} \times 100$

### # calculation of $K_c$ and $K_p$

(A.)



Initial mole	a	0	(t=0)
mole at equi.	a-x	2x	
or	a- $\alpha a$	2 $\alpha a$	

∴,  $\alpha = \frac{x}{a}$

$x = \alpha a$

active mass (molecularity)  $\left(\frac{a-x}{v}\right)^2$  +  $\left(\frac{2x}{v}\right)$

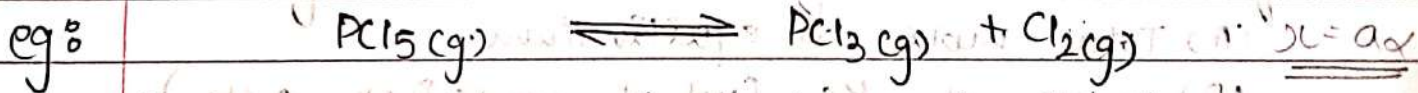
→ total mole at equilibrium =  $a-x+2x = \underline{a+x}$ .

mole fraction  $\frac{a-x}{a+x}$   $\frac{2x}{a+x}$

partial p.  $\left(\frac{a-x}{a+x}\right) P_T$   $\left(\frac{2x}{a+x}\right) P_T$

$K_c = \frac{[B]^2}{[A]} \rightarrow \frac{\left[\frac{2x}{v}\right]^2}{\left[\frac{a-x}{v}\right]}$  ∴  $P_T = P_{Total}$

$K_p = \frac{P_B^2}{P_A} \rightarrow \frac{\left[\left(\frac{2x}{a+x}\right) P_T\right]^2}{\left[\left(\frac{a-x}{a+x}\right) P_T\right]}$



initial mole:  $a$   $0$   $0$

mole at eq:  $a-x$   $x$   $x$

active m:  $\frac{a-x}{v}$   $\frac{x}{v}$   $\frac{x}{v}$

total mole at eq:  $a-x+x+x = \underline{a+x}$

partial p:  $\left(\frac{a-x}{a+x}\right) P_T$   $\left(\frac{x}{a+x}\right) P_T$   $\left(\frac{x}{a+x}\right) P_T$

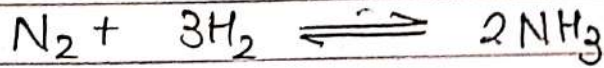
$K_c = \frac{\left[\frac{x}{v}\right] \left[\frac{x}{v}\right]}{\left[\frac{a-x}{v}\right]}$

$K_p = \frac{\left[\frac{x}{a+x}\right] \left[\frac{x}{a+x}\right] P_T}{\left[\frac{a-x}{a+x}\right] P_T}$

(conc)  $\left[\frac{a-x}{v}\right]$

$\left[\left(\frac{a-x}{a+x}\right) P_T\right]$

Q:8



initial mole:  $a$                        $3a$                        $0$   
 mole at eq:  $a-x$                        $3a-x$                        $2x$   
 active m:  $a-x/v$                        $3a-x/v$                        $2x/v$

Total mole at eq:  $a-x+3a-x+2x \rightarrow 4a$

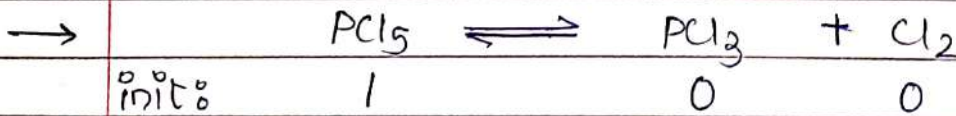
mole frac:  $\left(\frac{a-x}{4a}\right)$                        $\left(\frac{3a-x}{4a}\right)$                        $\left(\frac{2x}{4a}\right)$

partial p:  $\left[\frac{a-x}{4a}\right] PT$                        $\left[\frac{3a-x}{4a}\right] PT$                        $\left[\frac{2x}{4a}\right] PT$

$$K_c = \frac{[2x/v]}{[a-x/v][3a-x/v]}$$

$$K_p = \frac{[2x/4a] PT}{\left[\frac{a-x}{4a}\right] PT \left[\frac{3a-x}{4a}\right] PT}$$

Q:9 In a reaction:  $PCl_5(g) \rightleftharpoons PCl_3(g) + Cl_2(g)$   $\alpha$  is 30%.  
 if initial mole of  $PCl_5$  is 1 then find:  
 (A) Total mole at equilibrium.  
 (B) value of  $K_c$ . (vol. of container etc).  
 (C)



$$\% = \frac{\text{consum}}{\text{Pr.}} \times 100 \rightarrow 30 = \frac{\alpha \times 100}{1}$$

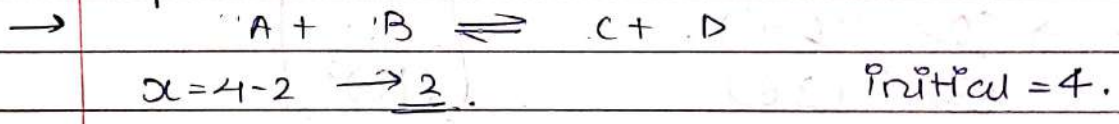
$$\alpha = 0.3$$

$$\begin{aligned} \therefore \text{total mole at eq} &= a + \alpha \\ &= 1 + 0.3 \\ &= 1.3 \end{aligned}$$

$$(B) K_c = \frac{\left[\frac{x}{V}\right] \left[\frac{x}{V}\right]}{\left[\frac{a-x}{V}\right]} \quad \begin{matrix} \text{initial} \\ \text{at } t \end{matrix} \quad \begin{matrix} \left[\frac{0.3}{2}\right] \\ \left[\frac{0.3}{2}\right] \end{matrix} \quad \begin{matrix} \left[\frac{1-0.3}{2}\right] \end{matrix}$$

$$\rightarrow \frac{0.09 \times 2}{4 \times 0.7} \rightarrow \frac{0.045}{0.7} = \frac{0.45}{7}$$

Q:10 4mole A mixed to 4mole B, when 2mole C formed at equilibrium, a/c to rxn  $A+B \rightleftharpoons C+D$ . Equilibrium constant is:



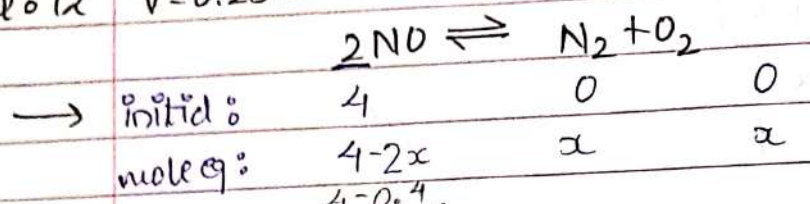
$$K_c = \frac{\left[\frac{x}{V}\right] \left[\frac{x}{V}\right]}{\left[\frac{a-x}{V}\right] \left[\frac{a-x}{V}\right]} \rightarrow \frac{[4]}{[2][2]} = [1]$$

initial m:	4(a)	4(a)	0	0
mole eq:	2(a-x)	2(a-x)	2(x)	2(x)

Q:11  $P \rightleftharpoons Q+R$  ini. mole of P = 2 to 0.5(x) of P. degree of dis?  
 $\rightarrow$  ini. m:      2      0      0  
 mole eq:      1.5(a-x)      0.5(x)      0.5(x).

$$\alpha = \frac{x}{a} \rightarrow \frac{0.5}{2} \rightarrow \frac{0.25}{1}$$

Q:12  $V=0.25 \text{ Ltr.}$   $4 \text{ mol NO}$   $\alpha=10\%$   $K_p=?$



$\alpha = \frac{2x}{4} \times 100$   $10 = \frac{2x}{4} \times 100$   $2x = \frac{200}{4}$

$1-0.4 = 3.6$

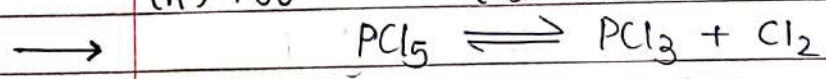
$\therefore \alpha = 0.2$

$K_p = \frac{[B][C]}{[A]^2} = \frac{(x)(x)}{(4-2x)^2}$  (Vol = const)

→  $\frac{(0.2)(0.2)}{(3.6)(3.6)} = \frac{10}{(18)^2}$

Q:13. 8gm mol of  $\text{PCl}_5$  heated in closed vessel of 10L capacity and 25% of its dissociates into  $\text{PCl}_3$  and  $\text{Cl}_2$  at the equilibrium then value of  $K_p$  equals to:

(A)  $P/30$       (B)  $P/15$       (C)  $2/3P$       (D)  $3/2P$



8gm molecule  $\rightarrow$  8 mole  $\alpha = 0.25$

initial:	8	0	0	$\alpha = 0.25$
mole eq:	$8-x$	$x$	$x$	$= 8 \times 0.25$
Total =	$8-x+x+x$			$= 2$
	$= 8+x$			$\rightarrow 10$

$K_p = P_T \left( \frac{n_{\text{PCl}_3}}{T_m} \right) \left( \frac{n_{\text{Cl}_2}}{T_m} \right) \times P_T = \left( \frac{2}{10} \right) \left( \frac{2}{10} \right) \times P_T$

$\left( \frac{n_{\text{PCl}_5}}{T_m} \right) \times P_T = \left( \frac{6}{10} \right)$

$= \frac{4^2}{10 \times 8} \times P_T = \frac{P}{15}$

Q:11  $K_c = \frac{1}{9}$ ;  $SO_3 + CO \rightleftharpoons CO_2 + SO_2$ ; In above reaction, 2 mole of each reactant and product taken in 1 litre vessel. Find out:

- (A) Total mole at equilibrium.
- (B) T. moles of  $SO_2$  and  $CO$ .
- (C) Value of

$\Rightarrow$

	$SO_3$	+	$CO$	$\rightleftharpoons$	$CO_2$	+	$SO_2$
Init <sup>o</sup>	2		2		2		2
fin <sup>o</sup>	$2-x$		$2-x$		$2+x$		$2+x$

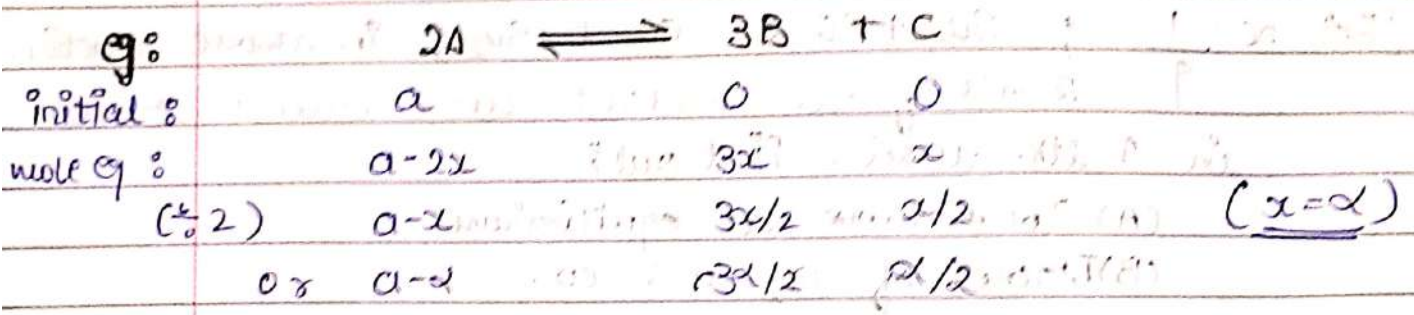
(A) Total mole =  $2-x + 2-x + 2+x + 2+x$   
 $= 8$  moles.

(B)  $K_c = \frac{[CO_2][SO_2]}{[CO][SO_3]} \rightarrow \frac{1}{9} = \frac{[2+x][2+x]}{[2-x][2-x]}$

$[2-x]^2 = (9)[2+x]^2$

$(1-x)^2 = 9(1+x)^2$        $(3)^2 = (2-x)^2$   
 $1-x = 3$        $3-x = -x$        $x = -1$   
 $-1 = x$

$\therefore$  T. mole  $SO_2 = 2 - (-1) = 3$        $CO = 2 - (-1) = 3$



NOTE: if initial mole (a) equals to one (1) the  $x$  is equal to consumed mole ( $x$ ).  
 $[ a = 1 \rightarrow x = x ]$

