Q:4 $N_2 + 3H_2 \rightleftharpoons 2NH_3$ K_1 $1/K_1$

$N_2 + O_2 \rightleftharpoons 2NO$ K_2 (K_2)

$H_2 + \frac{1}{2}O_2 \rightleftharpoons H_2O$ K_3 $(K_3)^3$

find K for $2NH_3 + \frac{5}{2}O_2 \rightleftharpoons 2NO + 3H_2O$.

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

Q:5

Types of chemical equilibrium:

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

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(A.) Homogeneous equilibrium:

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

eg: $H_2(g) + I_2(g) \rightleftharpoons 2HI(g)$

(B.) Heterogeneous equilibrium:

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

eg: $CaCO_{3(s)} \rightleftharpoons CaO_{(s)} + CO_{2(g)}$

Relation between KC and KP:

- for a general equilibrium reaction.

$$aA + bB \rightleftharpoons cC + dD.$$

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

$$\left.\begin{matrix} P_A = [A]RT & & P_B = [B]RT \\ & P_C = [C]RT & & P_D = [D]RT. \end{matrix}\right\} \text{value in eq(1)}$$

putting values in eq(1)

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

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

$$Kp = KC \ (RT)^{(c+d)-(a+b)}$$

here: Δng

$R = 0.082 \ \frac{atm \ lit}{mol \cdot K}$,

$T = temp \ (K)$.

$$\boxed{Kp = KC \ RT^{\Delta ng}.}$$

chemical equilibrium	Δn_g	rel. b/w Kc & Kp.
→ $H_{2(g)} + I_{2(g)} \rightleftharpoons 2HI_{(g)}$	0	$K_p = K_c$.
→ $PCl_{5(g)} \rightleftharpoons PCl_{3(g)} + Cl_{2(g)}$	1	$K_p = K_c \cdot RT$. $[K_p > K_c]$
→ $N_{2(g)} + 3H_2 \rightleftharpoons 2NH_{3(g)}$	-2	$K_p = K_c (RT)^{-2}$ $[K_p < K_c]$

Q:6 find ratio of KP / KC at 300°K for following equili. rxn: (A) $PCl_{5(g)} \rightleftharpoons PCl_3 + Cl_{2(g)}$ (B) $N_{2(g)} + 3H_2 \rightleftharpoons 2NH_3$

→ (A) R = 0.0821. T = 300°K.

$PCl_5 \rightleftharpoons PCl_3 + Cl_2$ $\qquad \frac{K_p}{K_c} = RT$

$\therefore \frac{KP}{KC} = \frac{0.0821 \times 300}{1000} \longrightarrow \underline{\underline{2463}}$

(B) $N_2 + 3H_2 \rightleftharpoons 2NH_3$

$\frac{KP}{KC} = \frac{1}{(RT)^2} \longrightarrow$

* **NOTE:**

1.) Homogeneous gaseous equilibrium = KC and Kp both are applied.

2.) Homogeneous aqueous equilibrium = only KC is applied not Kp. (KC ✓ Kp ✗)

* **NOTE:**

3.) Heterogeneous equilibrium (solid & aquoes) = only Kc applies

$(s) + \quad) \rightleftharpoons \quad +$

4.) Heterogeneous equilibrium (solid & gas) = both Kc Kp apply

$CaCO_{3(s)} \rightleftharpoons CO_{2(g)} + CaO_{(s)}$

5.) Heterogeneous equilibrium (aqueous & gas) = Kpc.

here: Kpc = equilibrium const. in terms of partial pressure and concentration

$Zn_{(s)} + 2H^{+}_{(aq)} \rightleftharpoons Zn^{+2}_{(aq)} + H_{2(g)}$

→ Homogeneous ⟹ (g) → Kc Kp
⟹ (aq) → Kc

→ Heterogeneous ⟹ (s+aq) → Kc
⟹ (s+g) → Kc and Kp
⟹ (s+g+aq+l) → Kpc.

Significance of equilibrium constant: (Keq)

- for a reversible equilibrium reaction the value of 'Keq' gives information about the extent of reaction.

CASE:1 if '$Keq > 10^3$'
→ 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 (→) 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 (→) 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 Qc or with partial pressure to give (Qp)] at any stage of reaction. For a general reaction:

$$aA + bB \rightleftharpoons cC + dD$$

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

→ if $r_f = r_b$ it means $Q_c = K_c$
[reversible reaction in equili. condition]

→ if $r_f \neq r_b$ (have 2 condition)

CASE : (A) :- if $Q_c < K_c$
→ Qc↓ product formation↓
→ to the product direction.
[reaction moved to product side.]

CASE : (B) :- if $Q_c > K_c$ (reversed rxn)
→ Kc↓ product formation↑
→ 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 Kc at 783K is 46. Find dir. of rxn.

→ $H_2 + I_2 \rightleftharpoons 2HI$.

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

$$Q_c = 1.$$

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

Degree of dissociation: (α).

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

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

Calculation of Kc and Kp:

(A.) $A \rightleftharpoons 2B$:

	A	2B	
initial mole	a	0	$(t=0)$
mole at equi.	$a-x$	$2x$	
Or	$a-a\alpha$	$2a\alpha$	

∴ $\boxed{\alpha = \frac{x}{a}}$ $\boxed{x = \alpha a}$.

active mass (molarity)	$\left(\frac{a-x}{V}\right)$	$\left(\frac{2x}{V}\right)$

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

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

$$K_c = \frac{[B]^2}{[A]} \longrightarrow \frac{[2x/V]^2}{[a-x/V]}$$

∵ $P_T = P$ Total.

$$K_p = \frac{P_B^{\,2}}{P_A} \longrightarrow \frac{[(2x/a+x)\,P_T]^2}{[(a-x/a+x)\,P_T]}$$

eg: $PCl_{5(g)} \rightleftharpoons PCl_{3(g)} + Cl_{2(g)}$ ∵ $\underline{\underline{x = a\alpha}}$

	PCl_5	PCl_3	Cl_2
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: $a-\cancel{x}+\cancel{x}+x$ = $\underline{a+x}$

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

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

(molarity)
(conc)

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

Q:8 $N_2 + 3H_2 \rightleftharpoons 2NH_3$

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

$$Kc = \frac{[2x/v]}{\left[\frac{a-x}{v}\right]\left[\frac{3a-x}{v}\right]} \qquad Kp = \frac{[2x/4a]\,PT}{\left[\frac{a-x}{4a}\right]PT\left[\frac{3a-x}{4a}\right]PT}$$

Q:9 In a reaction: $PCl_{5(g)} \rightleftharpoons PCl_{3(g)} + Cl_{2(g)}$ α is 30%. if initial mole of PCl_5 is 1 then find:

(A) Total mole at equilibrium.

(B) value of Kc. (vol. of container 2 ltr).

(C)

→ $PCl_5 \rightleftharpoons PCl_3 + Cl_2$

init: 1 0 0

$$\% = \frac{\text{consum}}{\text{ini.}} \times 100 \longrightarrow 3\cancel{0} = \frac{x}{1} \times 10\cancel{0}$$

$$\underline{x = 0.3}$$

$\therefore$ total mole at equili $= a+x$

$= 1+0.3.$

$= \underline{1.3}$

$$(B)\ K_c = \frac{\left[\frac{x}{v}\right]\left[\frac{x}{v}\right]}{\left[\frac{a-x}{v}\right]} \qquad \frac{\left[\frac{0.3}{2}\right]\left[\frac{0.3}{2}\right]}{\left[\frac{1-0.3}{2}\right]}$$

$$\longrightarrow \frac{0.09 \times \cancel{2}}{\underset{2}{\cancel{4}} \times 0.7} \rightarrow \frac{0.\cancel{0}45}{\cancel{0}.7} = \boxed{\frac{0.45}{7}}$$

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

→ $A + B \rightleftharpoons C + D$

$x = 4-2 \longrightarrow \underline{2}$. Initial = 4.

$$K_c = \frac{\left[x/\cancel{v}\right]\left[x/\cancel{v}\right]}{\left[a-x/\cancel{v}\right]\left[a-x/\cancel{v}\right]} \longrightarrow \frac{[\cancel{4}]}{[\cancel{2}][\cancel{2}]} \qquad \boxed{1}$$

	A	B	C	D
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?

→			
ini. m:	2	0	0
mole eq:	1.5 (a−x)	0.5 (x)	0.5 (x).

$$\alpha = \frac{x}{a} \longrightarrow \frac{0.5}{2} \longrightarrow \boxed{0.25}$$

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

$$2NO \rightleftharpoons N_2 + O_2$$

→ initial: 4 0 0

mole eq: $4-2x$ x x

$4-0.4$
$= 3.6$

$\alpha = \frac{2x}{a} \times 100$

$\cancel{10} = \frac{2x}{\cancel{4}_{2}} \times \cancel{100}^{5}$ $\cancel{2}x = \frac{\cancel{4}^{2}}{10 \times \cancel{2}}$

$\therefore, \boxed{x = 0.2}$

$\therefore, K_p = \frac{[B][C]}{[A]^2}$ $\frac{(x)(x)}{(a-2x)^2}$ (vol = cut)

$\longrightarrow \frac{(\cancel{0.2})(\cancel{0.2})}{(\cancel{3.6})_{18}(\cancel{3.6})_{18}} = \boxed{\frac{1}{(18)^2}}$

Q: 13. 8gm mol of PCl_5 heated in closed vessel of 10L capacity and 25% of its dissociates into PCl_3 and Cl_2 at the equilibrium then value of Kp equals to:

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

$$\longrightarrow PCl_5 \rightleftharpoons PCl_3 + Cl_2$$

8gm molecule → 8 mole $\alpha = 0.25$

initial: 8 0 0 $x = \cancel{\alpha}$

mole eq: $8-x$ x x $= 8 \times 0.25$

$= 2$

Total $= 8 - \cancel{x} + x + x$

$= 8 + x \longrightarrow 10.$

$K_p = \frac{P_T\left(\frac{n_{PCl_3}}{T_m}\right)\left(\frac{n_{Cl_2}}{T_m}\right)\cancel{P_T}}{\left(\frac{n_{PCl_5}}{T_m}\right)\cancel{P_T}} = \frac{\left(\frac{2}{10}\right)\left(\frac{2}{10}\right) \times P_T.}{\left(\frac{6}{10}\right)}$

$= \frac{\cancel{4}^{3} \times \cancel{10} \times P_T}{\cancel{100}\ \cancel{6}_{21.5}}$ $\boxed{= \frac{P}{15}}$

Q:14 $\boxed{K_C = \frac{1}{9}}$; $SO_3 + CO \rightleftharpoons CO_2 + SO_2$; 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

$\Rightarrow$ $SO_3 + CO \rightleftharpoons CO_2 + SO_2$.

	SO_3	CO	CO_2	SO_2
Ini:	2	2	2	2
fin:	$2-x$	$2-x$	$2+x$	$2+x$

(A) Total mole $= 2-\cancel{x}+2-\cancel{x}+2+\cancel{x}+2+\cancel{x}$

$= \underline{8 \text{ moles}}$.

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

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

$\dfrac{1}{(3)^2} = \dfrac{[2+x]}{[2-x]^2}$ $\therefore$ $(3)^2 = (2-x)^2$

$3-2x = -x$ $\boxed{x = -1}$

$(1)^2 (2+x)^2$

$1-2 = x$

$-1 = x$

$\therefore$ T mole $SO_2 = 2-(-1)$
$= \underline{3}$

$CO = 2-(-1)$
$= \underline{3}$.

eg:	$2A \rightleftharpoons$	$3B$	$+ C$	
initial:	a	0	0	
mole eq:	$a-2x$	$3x$	x	
$(\div 2)$	$a-x$	$3x/2$	$x/2$	$(\underline{x=\alpha})$
or	$a-\alpha$	$3\alpha/2$	$\alpha/2$	

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

Q:15 $A + B \rightleftharpoons C + D$

$\longrightarrow$