VARUN

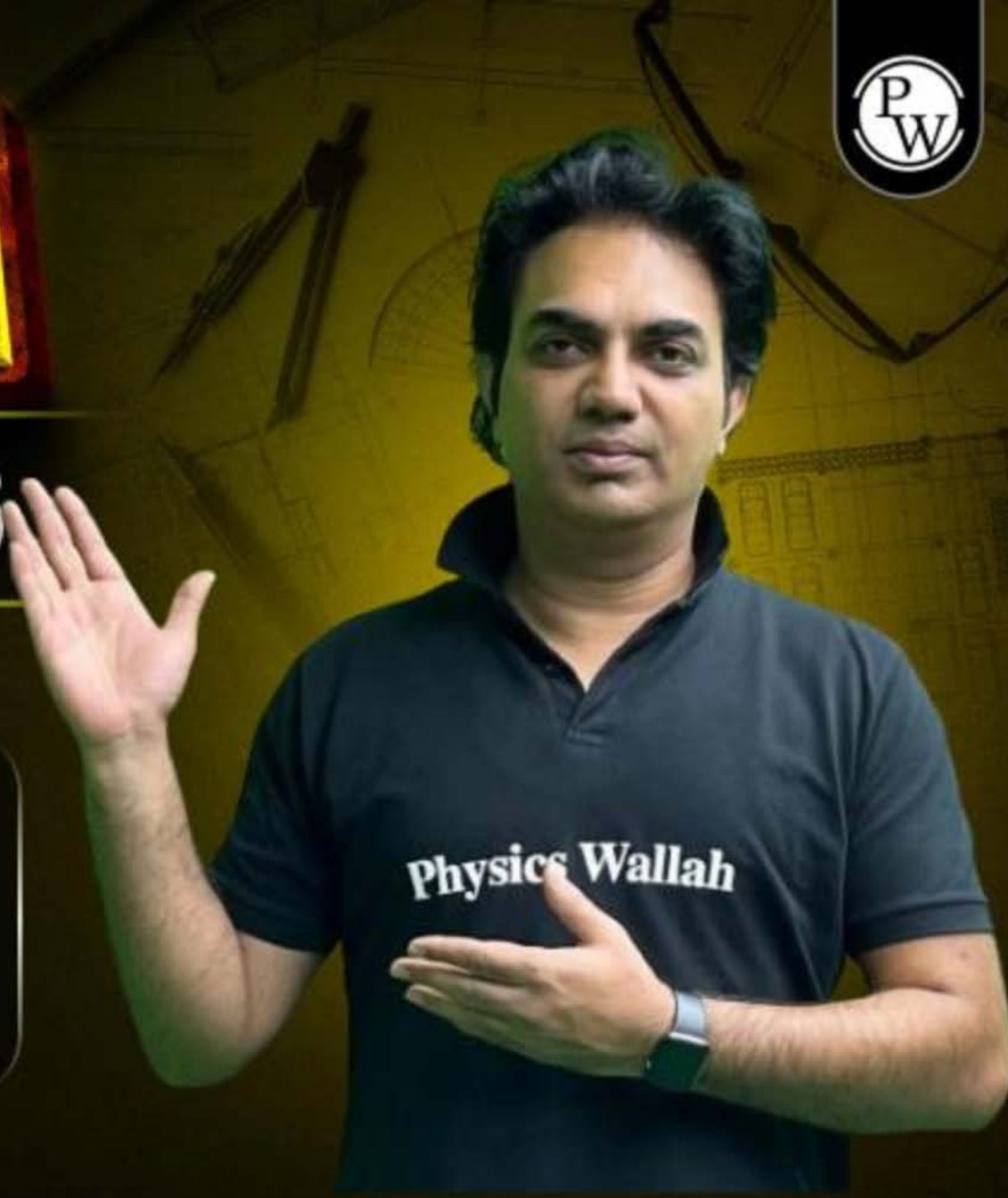
ADVANCE 2026

PHYSICAL CHEMISTRY

Lecture - 01

Chemical Equilibrium

FAISAL RAZAQ



Topics to be covered

1. Revision

JEE Adv. 2019

For the following reaction, the equilibrium constant K_c at 298 K is 1.6×10^{17}.

$Fe^{2+}(aq) + S^{2-}(aq) \rightleftharpoons FeS(s)$

When equal volumes of 0.06 M Fe^{2+} (aq) and 0.2 M S^{2-} (aq) solutions are mixed, the equilibrium concentration of Fe^{2+} (aq) is found to be $Y \times 10^{-17}$ M. The value of Y is

8.93.

	$Fe^{2+}_{(aq)}$	+	$S^{2-}_{(aq)}$	$\rightleftharpoons$	$FeS_{(s)}$
$t=0$	0.03		0.1		0
$t=t_{eq}$	$0.03-x$		$0.1-x$		x

$$K_c = \frac{1}{[Fe^{2+}]\ [S^{2-}]}$$

$$= \frac{1}{(0.03-x)(0.1-x)}$$

$$1.6 \times 10^{17} = \frac{1}{(0.03 - x)(0.1 - x)}$$

$$1.6 \times 10^{17} = \frac{1}{(y)(0.1 - 0.03)}$$

$$y = \frac{1}{1.6 \times 0.07 \times 10^{17}} M$$

$$= 8.93 \times 10^{-17} M$$

[Ans : 8.93]

JEE Adv. 2023

$A \rightleftharpoons P$	at T_1	at T_2	$K_{T_1} = 2$
6 0	[A] = 2 M	[A] = 4 M	
6-x x	[P] = 4 M	[P] = 2 M	$K_{T_2} = \frac{1}{2}$

In a one-litre flask, 6 moles of A undergoes the reaction $A\ (g) \leftrightharpoons P\ (g)$. The progress of product formation at two temperature (in Kelvin). T_1 and T_2, is shown in the figure.

If $T_1 = 2T_2$ and $(\Delta G^\circ_{2'} - \Delta G^\circ_{1'}) = RT_2 \ln x$, then the value of x is 8.
($\Delta G_{1'}$ and $\Delta G_{2'}$ are standard Gibb's free energy change for the reaction at temperature T_1 and T_2 respectively.)

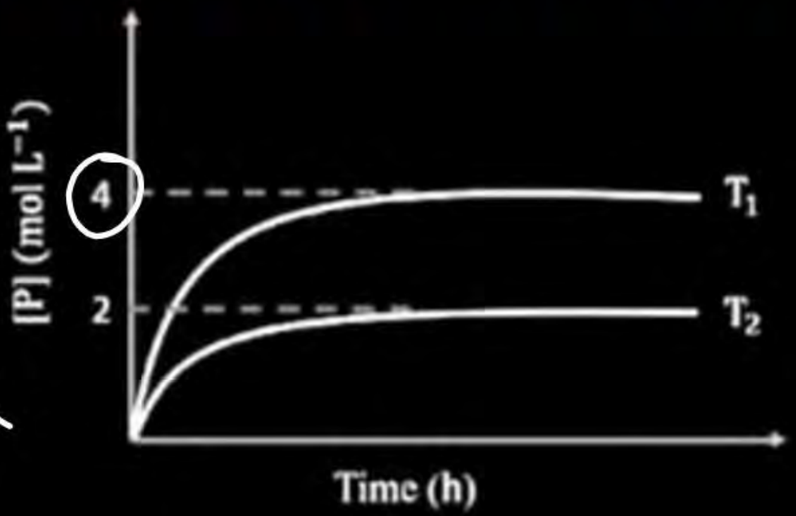
$\Delta G^\circ_1 = -RT_1 \ln 2$

$\Delta G^\circ_2 = -RT_2 \ln \frac{1}{2} = RT_2 \ln 2$

$\Delta G^\circ_2 - \Delta G^\circ_1 = R \ln 2 (T_2 + T_1)$

$= 3T_2 R \ln 2 = RT_2 \ln x$

$x = 2^3 = 8$



[Ans : 8]

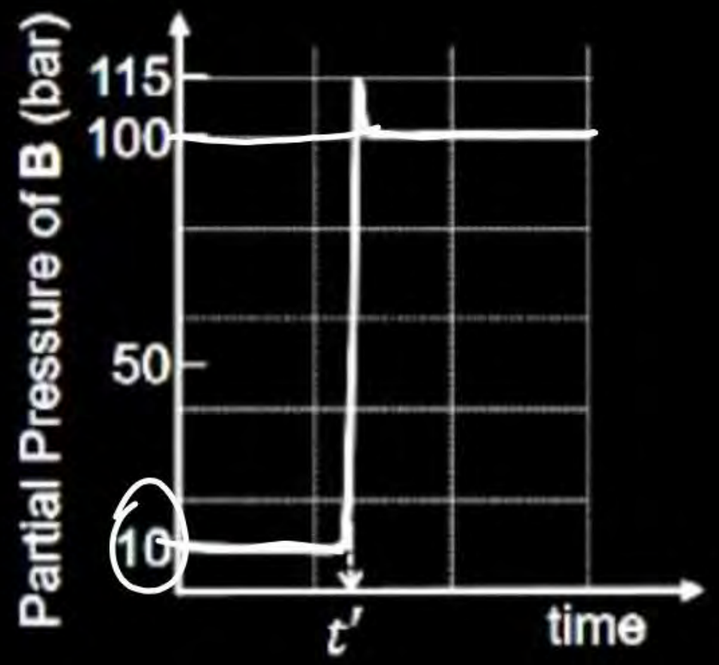
QUESTION

$K_{1000} = \frac{P_B}{P_A} = \frac{10}{1}$ | $K_{2000} = \frac{P_B}{P_A} = \frac{100}{1}$

Consider the reaction A ⇌ B at 1000 K. At time t', the temperature of the system was increased to 2000 K and the system was allowed to reach equilibrium. Throughout this experiment, the partial pressure of A was maintained at 1 bar. Given below is the plot of the partial pressure of B with time. What is the ratio of the standard Gibbs energy of the reaction at 1000 K to that at 2000 K ?

$$\frac{\Delta G^\circ_{1000K}}{\Delta G^\circ_{2000K}} = \frac{-R(1000)\ln 10}{-R(2000)\ln 100} = \frac{1}{4}$$

$$= 0.25$$



[Ans : 0.25]

QUESTION

$SrCl_2.2H_2O_{(s)} + 4H_2O_{(g)} \rightleftharpoons SrCl_2.6H_2O_{(s)}$

$K_p = \frac{1}{8.1 \times 10^{-7}}$

For the equilibrium $SrCl_2 \cdot 6H_2O(s) \rightleftharpoons SrCl_2 \cdot 2H_2O(s) + 4H_2O(g)$, $K_p = 8.1 \times 10^{-7}$ atm^4 at 27°C. If 1.642 L of air saturated with water vapour at 27°C is exposed to a large quantity of $SrCl_2 \cdot 2H_2O(s)$, then what mass of water vapour will be absorbed? Saturated vapour pressure of water at 27°C = 30.4 torr..

A 12 mg

B 6.67 mg

C 9 mg

D 48 mg

$30.4/760 = 0.04$ atm

$K_p = \frac{1}{P_{H_2O}^4} = \frac{1}{8.1 \times 10^{-7}} \Rightarrow P^{H_2O} = 0.03$ atm

Press drop $= 0.04 - 0.03 = 0.01$ atm

$0.01 \times 1.642 = \frac{W}{18} \times 0.0821 \times 300$

$W = (0.01 \times 1.642 \times 18)/0.0821 \times 300$

$= 0.012$ g

[Ans :A]

QUESTION

$K_p = \frac{P_{A_6}}{P_{A_2}^3} = \frac{x}{(2p-3x-y)^3} = 1.6$ $\quad (2p-3x-y)^3 = \frac{0.2}{1.6} = \frac{1}{8}$

The following equilibria are established on mixing two gases A_2 and C.

$3A_2(g) \rightleftharpoons A_6(g)$; $K_p = 1.6\ atm^{-2}$

$A_2(g) + C(g) \rightleftharpoons A_2C(g)$; $K_p =$ 'x' atm^{-1}

When $A_2(g)$ and C(g) are mixed in 2 : 1 molar ratio, the total pressure of gases at equilibrium is found to be 1.4 atm and partial pressure of $A_6(g)$, 0.2 atm. The value of '4x' is

6

$3A_{2(g)} \rightleftharpoons A_{6(g)}$

$2p-3x-y \qquad x$

$A_{2(g)} + C_{(g)} \rightleftharpoons A_2C_{(g)}$

$2p-3x-y \quad p-y \quad y$

$2p-3x-y = 0.5$

$2p-y = 1.1$ — (4)

$P_{A_2} + P_{A_6} + P_C + P_{A_2C} = 1.4$

$2p-3x-y+x+p-y+y = 1.4$

$3p-2x-y = 1.4$ — (1)

$P_{A_6} = x = 0.2$ — (2)

$3p-y = 1.8$ — (3)

$$2p - q = 1.1$$

$$3p - q = 1.8$$

$$p = 0.7$$

$$2p - q = 1.1$$

$$q = 2p - 1.1 = 0.3$$

$$K_2 = \frac{P_{A_2C}}{P_{A_2} \cdot P_C} = \frac{y}{(2p-3x-y)(p-y)}$$

$$= \frac{0.3}{(1.4-0.6-0.3)(0.7-0.3)}$$

$$= \frac{0.3}{0.5 \times 0.4} = \frac{3}{2} = 1.5$$

[Ans : 6]

QUESTION

The complexion of Fe^{2+} with the chelating agent dipyridyl has been studied kinetically in both the forward and reverse directions.

$$Fe^{2+} + 3\ dipy \leftrightharpoons [Fe\ (dipy)_3]^{2+}$$

For this reaction, the rates of forward and reverse reactions are $(1.45 \times 10^{13}\ M^{-3}\ s^{-1})$ $[Fe^{2+}][dipy]^3$ and $(1.22 \times 10^{-4}\ s^{-1})$ $[Fe\ (dipy)_3{}^{2+}]$, at What is the stability constant of the complex?

A 1.77×10^{9}

B 8.4×10^{-18}

C 1.18×10^{17}

D 5.65×10^{-10}

$$K = \frac{k_F}{k_b} = \frac{1.45 \times 10^{13}}{1.22 \times 10^{-4}}$$

$$= 1.18 \times 10^{17}$$

Ans: (C)

QUESTION

For dissociation of a gas N_2O_5 as $N_2O_5\ (g) \leftrightharpoons 2NO_2(g) + \frac{1}{2}O_2(g)$. The reaction is performed at constant temperature and volume. If D is the vapour density of equilibrium mixture, P_0 is initial pressure of $N_2O_5(g)$ and M is molecular mass of N_2O_5, then the correct information(s) at the equilibrium is /are

A The total pressure of gases at equilibrium is $\frac{P_o.M}{2D}$.

B The degree of dissociation of $N_2O_5(g)$ is $\frac{M-2D}{3D}$.

C The partial pressure of $N_2O_5(g)$ at equilibrium is $\frac{(5D-M).P_o}{3D}$

D The partial pressure of $O_2(g)$ at equilibrium is $\frac{(M-2D).P_o}{3D}$

$$1A_{n(g)} \rightleftharpoons \underline{n}A_{(g)}$$

$$\alpha = \frac{D - d}{d(\underline{n} - 1)}$$

$\underline{D}$ = V.D initial (Th.) $= \frac{M_{th}}{2}$

d = V.D at eqbm (obs) $= \frac{M_{obs}}{2}$

$$n = \frac{\text{gaseous moles of products}}{\text{gaseous mols of reactants}}$$

$$N_2O_5 \rightleftharpoons 2NO_2 + \frac{1}{2}O_2$$

(S) (g) (g)

P_0	0	0
$P_0(1-\alpha)$	$2P_0\alpha$	$\frac{P_0\alpha}{2}$

$$\alpha = \frac{\frac{M}{2} - D}{D\left(\frac{5}{2}-1\right)} = \frac{(M-2D)}{3D}$$

$$P_T = P_0(1-\alpha) + 2P_0\alpha + \frac{P_0\alpha}{2}$$

$$= P_0\left[1 + \frac{3\alpha}{2}\right]$$

$$= P_0\left[1 + \frac{3}{2}\left(\frac{M-2D}{3D}\right)\right] = \frac{P_0 M}{2D}$$

$$P_{N_2O_5} = X_{N_2O_5} \cdot P_T = P_0(1-\alpha)$$

$$= P_0\left[1 - \frac{M-2D}{3D}\right]$$

$$= P_0\left(\frac{5D-M}{3D}\right)$$

Ans: (A), (B), (C)

Comprehension

In a vessel, the equilibrium $N_2(g) + 3H_2(g) \leftrightharpoons 2NH_3(g)$ and $N_2(g) + 2H_2(g) \leftrightharpoons N_2H_4(g)$ are achieved simultaneously. Initially, the vessel constans N_2 and H_2 molar ratio of 9 : 13. The equilibrium pressure is $7P_o$ in which due to ammonia, the pressure is P_o and due to hydrogen, the pressure is $2P_o$.

QUESTION

The value of K_P for the reaction $N_2(g) + 3H_2(g) \leftrightharpoons 2NH_3(g)$ is

A $20\ P_o^2$

B $\frac{20\ P_o^2}{3}$

C $\frac{1}{20\ P_o^2}$

D $\frac{3}{20\ P_o^2}$

K, B₀

$$N_2 + 3H_2 \rightleftharpoons 2NH_3$$

$9P - x - y \quad 13P - 3x - 2y \quad 2x$

$$N_2 + 2H_2 \rightleftharpoons N_2H_4$$

$9P - x - y \quad 13P - 3x - 2y \quad y$

$P_T = 7P_0$

$P_{NH_3} = P_0$

$P_{H_2} = 2P_0$

$P_0 = 2x \Rightarrow x = P_0/2$

$13P - 3x - 2y = 2P_0$

$13P - 2y = 7P_0/2$ — (1)

$9P - x - y + 13P - 3x - 2y + 2x + y = 7P_0$

$22P - 2y = 8P_0$ — (2)

$$26P - 4y = 78_0$$

$$22P - 2y = 8P_0$$

$$18P = 9P_0$$

$$P = \frac{9}{18}P_0 = \frac{P_0}{2}$$

$$y = \left(\frac{3P_0}{2}\right)$$

$$x = \left(\frac{P_0}{2}\right)$$

$P_{NH_3} = P_0$; $P_{H_2} = 2P_0$,

$$P_{N_2} = 9P - x - y = \frac{9P_0}{2} - \frac{P_0}{2} - \frac{3P_0}{2} = \frac{5P_0}{2}$$

$$K_p = \frac{P_{NH_3}^2}{P_{N_2} \cdot P_{H_2}^3} = \frac{(P_0)^2}{\left(\frac{5P_0}{2}\right)(2P_0)^3}$$

$$= \frac{1}{20P_0^2}$$

Ans: (c)

Comprehension

In a vessel, the equilibrium $N_2(g) + 3H_2(g) \leftrightharpoons 2NH_3(g)$ and $N_2(g) + 2H_2(g) \leftrightharpoons N_2H_4(g)$ are achieved simultaneously. Initially, the vessel constans N_2 and H_2 molar ratio of 9 : 13. The equilibrium pressure is $7P_o$ in which due to ammonia, the pressure is P_o and due to hydrogen, the pressure is $2P_o$.

QUESTION

The value of KP for the reaction $N_2(g) + 2H_2(g) \leftrightharpoons N_2H_4(g)$ is

A $20\ P_o^2$

B $\frac{20\ P_o^2}{3}$

C $\frac{1}{20\ P_o^2}$

D $\frac{3}{20\ P_o^2}$

$$K_p = \frac{P_{N_2H_4}}{P_{N_2} \cdot P_{H_2}^2}$$

$$= \frac{(3P_0/2)}{(5P_0/2)(2P_0)^2}$$

$$= \frac{3}{20\ P_0^2}$$

Ans : (D)

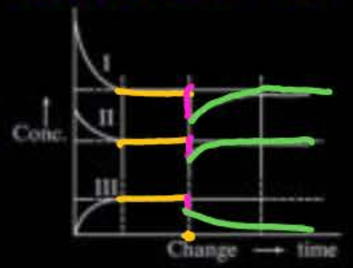
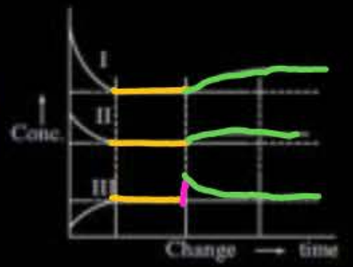
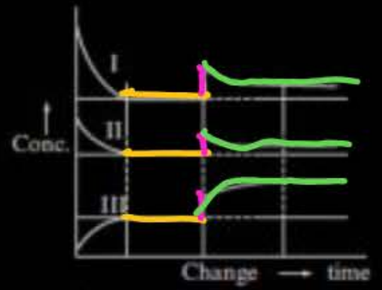
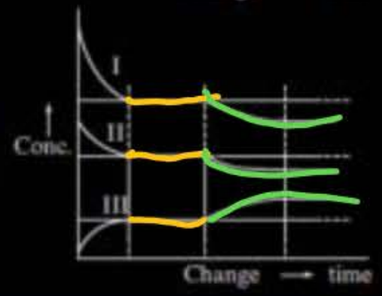
QUESTION

a b c

$Q = \frac{(\frac{c}{V})^2}{(\frac{a}{V})^4(\frac{b}{V})} = \frac{c^2}{a^4 b} \cdot V^3$

For an endothermic reaction : $4A(g) + B_2(g) \leftrightharpoons 2A_2B(g)$

(s, t)

Column – I		Column - II
(A) 		(P) Increase in temperatur
(B) 	R	(Q) Increase in pressure
(C) 	Q	(R) Addition of A_2B at equilibrium
(D) 	P	(S) Addition of inert gas at const Press.
		(T) Increase in volume

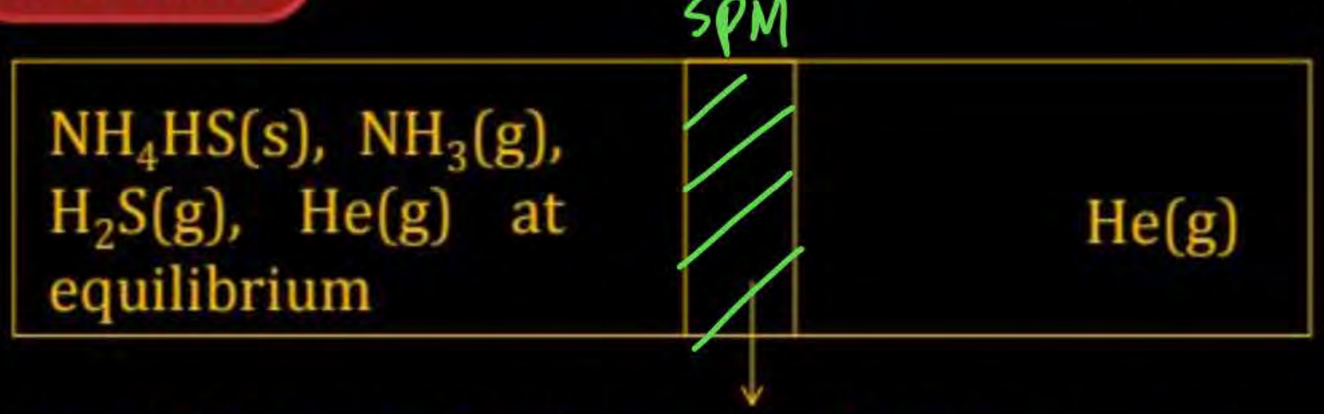
Ans: (A) S, T

(B) R

(C) Q

(D) P

QUESTION



Fixed SPM, which allows only He(g) to cross it.
The entire system is at equilibrium at 300 K. The volume of each chamber is 82.1 L. The total pressure in left chamber is 4 atm and in right chamber, 2 atm. $NH_3(g)$ and $H_2S(g)$ are obtained only from the dissociation of $NH_4HS(s)$. The value of K_P (in atm^2) for the reaction $NH_4HS(s) \rightleftharpoons 1\,NH_3(g) + 1\,H_2S(g)$ is

$$(P_{He})_{left} = (P_{He})_{right} = 2$$

$$P_{NH_3} + P_{H_2S} + P_{He} = 4$$

$$P_{NH_3} + P_{H_2S} = 4 - P_{He} = 4 - 2 = 2$$

P P $P_{NH_3} = P_{H_2S} = 1$ atm

$$K_p = P_{NH_3} \cdot P_{H_2S} = 1 \times 1 = 1 \text{ atm}^2$$

Ans: (1)

QUESTION

An amount of 5.0 moles each of 'A', 'B' and 'D' is added to a 1.0 L container.

$A(g) + B(g) \leftrightharpoons C(g)$; $K_C = 4 \times 10^{10} M^{-1}$

$A(g) + D(g) \leftrightharpoons E(g)$; $K_C = 10^{10}\ M^{-1}$

If at equilibrium, the moles of 'B' is 'x', then the value of '150x' is

A	+	B	⇌	C
$5-x-y$		$5-x$		x

A	+	D	⇌	E
$5-x-y$		$5-y$		y

$$4\times10^{10} = \frac{[C]}{[A][B]} = \frac{x}{(5-x-y)(5-x)} \quad -(1)$$

$$10^{10} = \frac{[E]}{[A][D]} = \frac{y}{(5-x-y)(5-y)}$$

Ans: (250)

$$d = \frac{P\,M_{avg}}{RT}$$

QUESTION

In a 10.0 L container, an equilibrium was established between SO_3, SO_2 and O_2 gases, by starting with SO_3 only. The density of equilibrium mixture was found to be 16 g/litre at a temperature of $\frac{900}{0.0821}$ K.

If the degree of dissociation of SO_3 is 40%, then the value of K_p (in atm) for the reaction $2SO_3(g) \leftrightharpoons 2SO_2(g) + O_2(g)$ is

$$M_{avg} = \sum M_i X_i$$

$2SO_3$	$\rightleftharpoons$	$2SO_2$	+	O_2
a		0		0
$a(1-\alpha)$		$a\alpha$		$a\alpha/2$
$0.6a$		$0.4a$		$0.2a$

$$M_{avg} = M_{SO_3} x_{SO_3} + M_{SO_2} x_{SO_2} + M_{O_2} x_{O_2}$$

$$= 80\left(\frac{0.6\,g}{1.2\,g}\right) + 64\left(\frac{0.4\,g}{1.2\,g}\right) + 32\left(\frac{0.2\,g}{1.2\,g}\right)$$

$$= \frac{48 + 25.6 + 6.4}{1.2} = \frac{80}{1.2}$$

$$d = \frac{P M_{avg}}{RT} \Rightarrow P = \frac{dRT}{M_{avg}} = \frac{16 \times \frac{900}{0.0821} \times 0.0821}{80/1.2}$$

$$= 216 \text{ atm}$$

$$K_p = \frac{P_{SO_2}^2 \cdot P_{O_2}}{P_{SO_3}^2} = \frac{\left(\frac{0.4x}{1.2x}\right)^2 \cdot \left(\frac{0.2x}{1.2x}\right)}{\left(\frac{0.6x}{1.2x}\right)^2}(216)$$

$$= \frac{\frac{1}{9} \times \frac{1}{6}}{\left(\frac{1}{2}\right)^2} \times 216 = \frac{4}{\frac{216 \times 4}{54}} = 16 \text{ atm}$$

Ans: (16)

QUESTION

In the system, $LaCl_3(s) + H_2O(g) + \text{heat} \leftrightharpoons LaClO(s) + 2HCl(g)$, equilibrium is established. More water vapour is added to disturb the equilibrium. If the pressure of water vapour at new equilibrium is double that of at initial equilibrium, the factor by which pressure of HCl is changed is

A 2 times

B $\sqrt{2}$ times

C $\frac{1}{\sqrt{2}}$ times

D 4 times

Ans : (B)

QUESTION

When $N_2O_5(g)$ is heated to 600 K, it dissociates as $N_2O_5(g) \leftrightharpoons N_2O_3(g) + O_2(g)$; $K_C = 2.5$ M. Simultaneously, $N_2O_3(g)$ decomposes as $N_2O_3(g) \leftrightharpoons N_2O(g) + O_2(g)$. When initially 4.0 moles of $N_2O_5(g)$ is taken in a 2.0 L flask and allowed to attain equilibrium, the equilibrium concentration of $O_2(g)$ is found to be 2.5 M. The equilibrium concentration of $N_2O(g)$ (in M) is

Ans: (1)

QUESTION

The minimum mass (in g) of $CaCO_3$ required to establish the equilibrium:
$CaCO_3(s) \rightleftharpoons CaO(s) + CO_2(g)$, $K_C = 0.05$ M at a certain temperature in a 1.0 L container is

Ans: (5)

QUESTION

The dissociation constant of PCl_5 is 8 atm at 273°C. What pressure (in atm) will be developed when 62.55 g of this substance is vaporized at 273°C in 4480 ml vessel originally full of chlorine gas at 0°C and 1 atm pressure?

Ans: (7)

QUESTION

The percent dissociation of $H_2S(g)$ if 0.1 mole of H_2S is kept in 0.4 L vessel at 1000 K for the reaction $2H_2S \rightleftharpoons 2H_2(g) + S_2(g)$; $K_C = 1.0 \times 10^{-6}$.

Ans: (2)

QUESTION

A reaction at 300 K with $\Delta G^\circ = -1743$ J consists of 3 moles of A(g), 6 moles of B(g) and 3 moles of C(g). If A, B and C are in equilibrium in 1 L container, then the reaction may be (In 2 = 0.7, R = 8.3 J/K-mol)

A $A + B \leftrightharpoons C$

B $A \leftrightharpoons B + 2C$

C $2A \leftrightharpoons B + C$

D $A + B \leftrightharpoons 2C$

Ans: (c)

QUESTION

The equilibrium $NH_4HS(s) \leftrightharpoons NH_3(g) + H_2S(g)$ is achieved at the equilibrium pressure of 'X' bar at TK. The value of $\Delta_r G°$ for the reaction is

A. $-RT \ln X$

B. $-2RT \ln X$

C. $-2RT (\ln X - \ln 2)$

D. $-2RT \ln (2X)$

Ans: (C)

QUESTION

The equilibrium constant for the reaction $CO(g) + H_2O(g) \leftrightharpoons CO_2(g) + H_2(g)$ is 3.0 at 500 K. In a 2.0 L vessel, 60 g of water gas [equimolar mixture of $CO(g)$ and $H_2(g)$] and 90 g steam is initially taken. What is the equilibrium concentration of $H_2(g)$?

A 1.75 M

B 3.5 M

C 1.5 M

D 0.75 M

QUESTION

Solid ammonium carbamate dissociates as:
$NH_2COONH_4(s) \rightleftharpoons 2NH_3(g) + CO_3(g)$. In a closed vessel, solid ammonium carbamate is in equilibrium with its dissociation products. At equilibrium ammonia is added such that the partial pressure of NH_3 at new equilibrium now equals the original total pressure. The ratio of total pressure at new equilibrium to that of original total pressure is

A 1 : 1

B 27 : 31

C 31 : 27

D 3 : 4

Ans: (C)

QUESTION

If for the equilibria $NH_2COONH_4(s) \leftrightharpoons N_2 + H_2 + CO + O_2$, the value of K_P at 800 K is $27 \times 2^{\lambda/2}$ and the equilibrium pressure is 22 atm. The value of λ is

A 21

B 22

C 11

D 12

Ans: (A)

QUESTION

An amount of 1 mole each of A and D is introduced in 1 L container. Simultaneously the following two equilibria are established.

$A \leftrightharpoons B + C : K_C = 10^6$ M and

$B + D \leftrightharpoons A: K_C = 10^{-6}$ M^{-1}

The equilibrium concentration of A will be

A 10^{-6} M

B 10^{-3} M

C 10^{-12} M

D 10^{-4} M

THANK YOU