Exercise-1

✍ **Marked questions are recommended for Revision.**

PART - I : SUBJECTIVE QUESTIONS

Section (A) : Properties of equilibrium, active mass

A-1. In a reaction $A + B \rightleftharpoons C + D$ the rate constant of forward reaction & backward reaction is $k_f = 2 \times 10^{-4}$ M sec^{-1} and $k_b = 5 \times 10^{-5}$ M sec^{-1} then the equilibrium constant (k) for reaction is expressed as :

A-2.✍ What is the active mass of 5.6 litres of O_2 at S.T.P.?

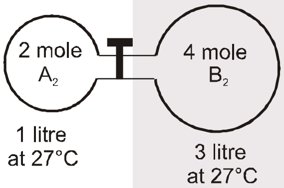
Section (B) : Homogeneous equilibrium : K_C in gaseous system

B-1.✍ A mixture of SO_3, SO_2 and O_2 gases is maintained at equilibrium in 10 litre flask at a temperature at which K_C for the reaction, $2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$ is 100 mol^{-1} litre. At equilibrium.
(a) If no. of mole of SO_3 and SO_2 in flask are same, how many mole of O_2 are present ?
(b) If no. of mole of SO_3 in flask are twice the no. of mole of SO_2, how many mole of O_2 are present ?

B-2. The equilibrium constant of the reaction, A_2 (g) + B_2 (g) $\rightleftharpoons$ 2 AB (g) at 100ºC is 16. Initially equal moles of A_2 & B_2 are taken in 2L container. Then find mole % of A_2 in equilibrium mixture.

B-3. For the reaction $3A(g) + B(g) \rightleftharpoons 2C(g)$ at a given temperature, $K_c = 9.0$. What must be the concentration of (C) at equlibrium, if a mixture of 2.0 mol each of A, B and C exist in equilibrium ?

B-4.✍



The gas A_2 in the left flask allowed to react with gas B_2 present in right flask as

$$A_2(g) + B_2(g) \rightleftharpoons 2AB(g) \;;\; K_c = 4 \text{ at } 27°C.$$

What is the concentration of AB when equilibrium is established?

Section (C) : Homogeneous equilibrium : K_P in gaseous system

C-1.✍ n mole each of $H_2O(g)$, $H_2(g)$ and $O_2(g)$ are mixed at a suitable high temperature to attain the equilibrium $2H_2O(g) \rightleftharpoons 2H_2(g) + O_2(g)$. If y mole of $H_2O(g)$ are the dissociated and the total pressure maintained is P, calculate the K_P.

C-2. The moles of N_2O_4 and NO_2 at equilirbrium are 1 and 2 respectively total pressure at equilibrium is 9 atm. Find K_P for the reaction $N_2O_4(g) \rightleftharpoons 2\,NO_2(g)$.

C-3.✍ 1 mole of N_2 and 3 moles of H_2 are placed in 1L vessel. Find the concentration of NH_3 at equilibrium, if the equilibrium constant (K_C) at 400 K is $\frac{4}{27}$ M^{-2}.

$$N_2\,(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$$

Section (D) : Relation between K_P and K_C

D-1. Calculate the expression for K_c and K_p if initially a moles of N_2 and b moles of H_2 is taken for the following reaction. $N_2\,(g) + 3H_2\,(g) \rightleftharpoons 2NH_3\,(g)$ $(\Delta n < 0)$(P, T, V given)

D-2.✍ 1 mole of a gas 'A' is taken in a vessel of volume 1L. It dissociates according to the reaction $A(g) \rightleftharpoons B(g) + C(g)$ at 27°C. Forward and backward reaction rate constants for the reaction are 1.5×10^{-2} and 3×10^{-2} respectively. Find the concentrations of A, B and C at equilibrium. Also find K_p and K_c.

D-3.✍ 0.15 mole of CO taken in a 2.5 litre flask is maintained at 500 K along with a catalyst so that the following reaction can take place;$CO(g) + 2H_2(g) \rightleftharpoons CH_3OH(g)$.

Hydrogen is introduced until the total pressure of the system is 8.2 atm at equilibrium and 0.08 mole of methanol is formed.Calculate :

(i) K_p & K_c ;

(ii) the final pressure if the same amount of CO and H_2 as before are used, but with no catalyst so that the reaction takes place on its own.

Section (E) : Reaction quotient and Its applications

E-1.✍ A mixture of 1.5 mol of N_2, 2 mole of H_2 and 8 mol of NH_3 is introduced into a 20 L reaction vessel at 500 K. At this temperature, the equilibrium constant, K_c for the reaction

$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$ is 1.7×10^2.

Is the reaction mixture at equilibrium? If not what is the direction of the net reaction?

E-2. At 460°C, $K_C = 81$ for the reaction, $SO_2(g) + NO_2(g) \rightleftharpoons NO(g) + SO_3(g)$

A mixture of these gases has the following concentrations of the reactants and products :

$[SO_2] = 0.04$ M $[NO_2] = 0.04$ M

$[NO] = 0.30$ M $[SO_3] = 0.3$ M

Is the system at equilibrium? If not, in which direction must the reaction proceed to reach equilibrium. What will be the molar concentrations of the four gases at equilibrium?

Section (F) : Properties of equilibrium Constant

F-1. Explain the effect of the following on the equilibrium constant.

(i) Concentrations of the reactants are doubled (ii) The reaction is reversed

(iii) Catalyst is added to the reaction (iv) Temperature is increased.

F-2. The equilibrium constant for the reactions $N_2 + O_2 \rightleftharpoons 2NO$ and $2NO + O_2 \rightleftharpoons 2NO_2$ are K_1 and K_2 respectively, then what will be the equilibrium constant for the reaction $N_2 + 2O_2 \rightleftharpoons 2NO_2$?

F-3.✍ Calculate the equilibrium constant for the reaction : $H_2(g) + CO_2(g) \rightleftharpoons H_2O(g) + CO(g)$

at 1395 K, if the equilibrium constants at 1395 K for the following are

$2H_2O(g) \rightleftharpoons 2H_2(g) + O_2(g)$ $K_1 = 2.1 \times 10^{-13}$

$2CO_2(g) \rightleftharpoons 2CO(g) + O_2(g)$ $K_2 = 1.4 \times 10^{-12}$.

Section (G) : Homogenuous Equilibrium (liquid system)

G-1.✍ The homogeneous reversible reaction, $C_2H_5OH(\ell) + CH_3COOH(\ell) \rightleftharpoons CH_3COOC_2H_5(\ell) + H_2O(\ell)$ is studied at various initial concentrations of the reactants at constant temperature. Calculate initial acid and alcohol moles.

	Moles of acid per litre (initial)	**Moles of alcohol per litre (initial)**	**Moles of ester per litre at equilibrium**
(i)	1	1	0.667
(ii)	X	X	8/3

Section (H) : Heterogenuous equilibrium

H-1.✍ Write the expressions for equilibrium constant K_C and K_P and classify in Homogeneous and Hetereogeneous equilibrium :

(i) $N_2O_4(g) \rightleftharpoons 2NO_2(g)$

(ii) $3Fe(s) + 4H_2O(g) \rightleftharpoons Fe_3O_4(s) + 4H_2(g)$

(iii) $NH_4HS(s) \rightleftharpoons NH_3(g) + H_2S(g)$

(iv) $CH_3COOH(\ell) + C_2H_5OH(\ell) \rightleftharpoons CH_3COOC_2H_5(\ell) + H_2O(\ell)$

(v) $MgCO_3(s) \rightleftharpoons MgO(s) + CO_2(g)$

(vi) $2H_2S(g) \rightleftharpoons 2H_2(g) + S_2(g)$

(vii) $SO_2(g) + NO_2(g) \rightleftharpoons SO_3(g) + NO(g)$

(viii) $NH_4NO_2(s) \rightleftharpoons N_2(g) + 2H_2O(\ell)$

H-2. For the reaction: $CaCO_3 \rightleftharpoons CaO(s) + CO_2(g)$; $K_p = 1$ atm at 927°C. If 20g of $CaCO_3$ were kept in a 10 litre vessel at 927°C, then calculate percentage of $CaCO_3$ remaining at equilibrium :

H-3. For the given reaction at equilibrium :

$$AgNO_3(s) \rightleftharpoons Ag(s) + NO_2(g) + \frac{1}{2}O_2(g)$$

If total pressure at equilibrium is P, then calculate K_P for the given reaction.

Section (I) : Degree of dissociation (α) and vapour density

I-1. N_2O_4 is 25% dissociated at 37°C and one atmosphere pressure. Calculate (i) K_P and (ii) the percentage dissociation at 0.1 atmosphere and 37°C.

I-2.✍ At temperature T, the compound AB_2 (g) dissociates according to the reaction; $2AB_2\,(g) \rightleftharpoons 2\,AB(g) + B_2(g)$.With a degree of dissociation *x*, which is small compared with unity.Deduce the expression for *x* in terms of the equilibrium constant, K_p and the total pressure, P.

I-3. Vapour density of the equilibrium mixture of NO_2 and N_2O_4 is found to be 38.33. For the equilibrium

$$N_2O_4(g) \rightleftharpoons 2NO_2(g).$$

Calculate :

(i) abnormal molecular weight. (ii) degree of dissociation.

(iii) percentage of NO_2 in the mixture. (iv) K_P for the reaction if total pressure is 2 atm.

I-4. When sulphur in the form of S_8(g) is heated at 900 K, the initial partial pressure of S_8(g) which was 1 atm falls by 29% at equilibrium. This is because of conversion of some S_8(g) to S_2(g). Find the K_p for reaction, $S_8\,(g) \rightleftharpoons 4S_2\,(g)$.

Section (J) : Thermodyanamics of equilibrium

J-1. For the reaction, $SO_2\,(g) + 1/2O_2(g) \rightleftharpoons SO_3(g)$

$\Delta H^o_{298} = -98.32$ kJ/mole, $\Delta S^o_{298} = -95.0$ J/mole-K. Find the K_p for this reaction at 298K. (Given that $10^{.27} = 1.86$)

J-2. From the following data :

(i) $H_2(g) + CO_2(g) \rightleftharpoons H_2O(g) + CO(g)$; $K_{2000K} = 4.4$

(ii) $2H_2O(g) \rightleftharpoons 2H_2(g) + O_2(g)$; $K_{2000K} = 5.31 \times 10^{-10}$

(iii) $2CO(g) + O_2(g) \rightleftharpoons 2CO_2(g)$; $K_{1000K} = 2.24 \times 10^{22}$

State whether the reaction (iii) is exothermic or endothermic?

Section (K) : Le-chatelier's principle

K-1. Which of the following reactions will get affected by increase of pressure ? Also mention, whether change will cause the reaction to go into the right or left direction ?

(i) $CH_4(g) + 2S_2(g) \rightleftharpoons CS_2(g) + 2H_2S(g)$

(ii) $CO_2(g) + C(s) \rightleftharpoons 2CO(g)$

(iii) $4NH_3(g) + 5O_2(g) \rightleftharpoons 4NO(g) + 6H_2O(g)$

(iv) $C_2H_4(g) + H_2(g) \rightleftharpoons C_2H_6(g)$

K-2. Using Le Chatelier's principle, predict the effect of

(i) decreasing the temperature and (ii) increasing the pressure on each of the following equilibria :

(a) $N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$ + Heat (b) $N_2(g) + O_2(g) \rightleftharpoons 2NO(g)$ + Heat

(c) $H_2O(g)$ + Heat $\rightleftharpoons H_2\,(g) + \frac{1}{2}\,O_2\,(g)$ (d) $2CO\,(g) + O_2\,(g) \rightleftharpoons 2CO_2\,(g)$ + Heat

K-3. The decomposition of solid ammonium carbamate, $(NH_4)(NH_2CO_2)$, to gaseous ammonia and carbon dioxide is an endothermic reaction.

$$(NH_4)(NH_2CO_2)\,(s) \rightleftharpoons 2NH_3\,(g) + CO_2(g)$$

(a) When solid $(NH_4)\,(NH_2CO_2)$ is introduced into an evacuated flask at 25°C, the total pressure of gas at equilibrium is 0.3 atm. What is the value of K_p at 25°C ?

(b) Given that the decomposition reaction is at equilibrium, how would the following changes affect the total quantity of NH_3 in the flask once equilibrium is re-established ?

(i)	Adding CO_2	(ii)	Adding $(NH_4)(NH_2CO_2)$
(iii)	Removing CO_2	(iv)	Increasing the total volume
(v)	Adding neon (at constant volume)	(vi)	Increasing the temperature.

K-4. Following equilibrium is established at temperature T.

$$\begin{array}{lccc} & A(g) \rightleftharpoons & B(g) + & C(g) \\ \text{at eq.} & 1M & 2M & 2M. \end{array}$$

If volume of the vessel is doubled then find the equilibrium concentration of each species.

(Given that : $\sqrt{40} = 6.324$)

Section (L) : Vapour pressure and Relative Humidity

L-1. Equilibrium constants is given (in atm) for the following reaction 0ºC :

$Na_2HPO_4.12H_2O(s) \rightleftharpoons Na_2HPO_4.7H_2O(s) + 5H_2O(g)$ $K_p = 2.43 \times 10^{-13}$

The vapour pressure of water at 0ºC is 4.56 torr.

At what relative humidities will $Na_2HPO_4.12H_2O(s)$ be efflorescent when exposed to air at 0ºC ?

L-2. Equilibrium constant for the following equilibrium is given at 0ºC.

$Na_2HPO_4.12H_2O(s) \rightleftharpoons Na_2HPO_4.7H_2O(s) + 5H_2O(g)$ $K_P = 31.25 \times 10^{-13}$

At equilibrium what will be partial pressure of water vapour :

Section (M) : Simultaneous equilibria

M-1. Two solid compounds A and B dissociate into gaseous products at 20°C as

(i) $A(s) \rightleftharpoons A'(g) + H_2S(g)$ (ii) $B(s) \rightleftharpoons B'(g) + H_2S(g)$

At 20°C pressure over excess solid A is 50 mm and that over excess solid B is 60 mm find :

(a) The dissociation constant of A and B

(b) Relative no. of moles of A′ and B′ in the vapour phase over a mixture of solid A and B.

(c) Show that the total pressure of the gas over the solid mixture would be 79.33 mm

M-2. When NO & NO_2 are mixed, the following equilibria readily obtained;

$2NO_2 \rightleftharpoons N_2O_4$ $K_p = 6.8\ atm^{-1}$

$NO + NO_2 \rightleftharpoons N_2O_3$ $K_p = ?$

In an experiment when NO & NO_2 are mixed in the ratio of 1 : 2, the total final pressure was 5.05 atm & the partial pressure of N_2O_4 was 1.7 atm. Calculate

(a) the equilibrium partial pressure of NO.

(b) K_p for $NO + NO_2 \rightleftharpoons N_2O_3$

PART - II : ONLY ONE OPTION CORRECT TYPE

Section (A) : Properties of equilibrium, active mass, homogeneous & heterogeneous equilibrium (theoritical)

A-1. A reversible reaction is one which

(A) Achieves equlibrium state (B) Proceeds in both directions

(C) Does not occurs at all (D) Both (A) and (B)

A-2. A chemical reaction is at equilibrium when

(A) Measurable properties becomes constant

(B) The rates of forward and backward reactions are equal

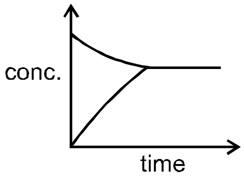
(C) Net rate of reaction is zero

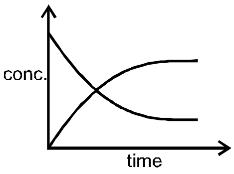
(D) All are correct

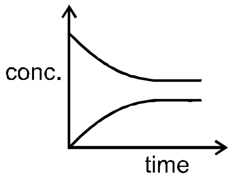
A-3. Molar concentration of 96 g of O_2 contained in a 2 litre vessel is :

(A) 16 mol/litre (B) 1.5 mol/litre (C) 4 mol/litre (D) 24 mol/litre

A-4. Find correct graph reagarding equlibrium state :

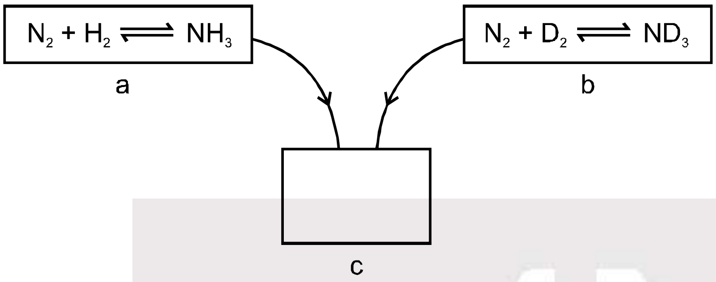
(A) 

(B) 

(C) 

(D) All of these

A-5.



Initially the reactions in the container a & b are at equilibrium when the products & reactants are put together in a container c then at the equilibrium the total number of different chemical species compounds are :

(A) 5 (B) 7 (C) 6 (D) 8

Section (B) : Homogeneous equilibrium : K_c in gaseous system

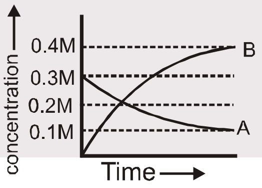
B-1. In a reversible reaction $A \underset{k_2}{\overset{k_1}{\rightleftharpoons}} B$, the initial concentration of A and B are a and b in moles per litre, k_1 and k_2 are rate constants for forward & backward reactions respectively and the equilibrium concentrations are (a – x) and (b + x) respectively; express x in terms of k_1, k_2, a and b.

(A) $\frac{k_1a - k_2b}{k_1 + k_2}$ (B) $\frac{k_1a - k_2b}{k_1 - k_2}$ (C) $\frac{k_1a - k_2b}{k_1 k_2}$ (D) $\frac{k_1a + k_2b}{k_1 + k_2}$

B-2. The reaction A(g) + B(g) $\rightleftharpoons$ C(g) + D(g) is studied in a one litre vessel at 250°C. The initial concentration of A was 3n and that of B was n. When equilibrium was attained, equilibrium concentration of C was found to the equal to the equilibrium concentration of B. What is the concentration of D at equilibrium?

(A) n/2 (B) (3n – 1/2) (C) (n – n/3) (D) n

B-3. The figure show the change in concentration of species A and B as a fuctional of time. The equilibrium constant K_C for the reaction A(g) $\rightleftharpoons$ 2B (g) is :



(A) $K_c > 1$ (B) $K_c < 1$ (C) $K_c = 1$ (D) data insufficient

B-4. $K_c = 9$ for the reaction, A + B $\rightleftharpoons$ C + D, If one mole of each A and B are taken, then amount of C in equilibrium is :

(A) 1 (B) 0.25 (C) 0.75 (D) None of these

B-5. The equilibrium $N_2(g) + O_2(g) \rightleftharpoons 2NO(g)$ is estabilished in a reaction vessel of 2.5 L capacity. The amounts of N_2 and O_2 taken at the start were respectively 2 moles and 4 moles. Half a mole of nitrogen has been used up at equilibrium. The molar concentration of nitric oxide is :

(A) 0.2 (B) 0.4 (C) 0.6 (D) 0.1

B-6. An equilibrium mixture for the reaction $2H_2S(g) \rightleftharpoons 2H_2(g) + S_2(g)$ had 1 mol of H_2S, 0.2 mol of H_2 and 0.8 mol of S_2 in a 2 litre flask. The value of K_C in mol lit^{-1} is :

(A) 0.08 (B) 0.016 (C) 0.004 (D) 0.160

Section (C) : Homogeneous equilibrium : K_P in gaseous system

C-1. What is the unit of K_P for the reaction ?

$$CS_2\ (g) + 4H_2\ (g) \rightleftharpoons CH_4\ (g) + 2H_2S\ (g)$$

(A) atm (B) atm^{-2} (C) atm^{2} (D) atm^{-1}

C-2.✍ N_2 and H_2 are taken in 1 : 3 molar ratio in a closed vessel to attained the following equilibrium $N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$. Find K_p for reaction at total pressure of 2P if P_{N_2} at equilibrium is $\frac{P}{3}$

(A) $\frac{1}{3P^2}$ (B) $\frac{4}{3P^2}$ (C) $\frac{4P^2}{3}$ (D) none

C-3.✍ The equilibrium constant, K_p for the reaction $2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$ is 4.0 atm^{-1} at 1000 K. What would be the partial pressure of O_2 if at equilibrium the moles of SO_2 and SO_3 are the same ?

(A) 16.0atm (B) 0.25 atm (C) 1 atm (D) 0.75 atm

C-4. For the reaction

$$A_2(g) + 2B_2(g) \rightleftharpoons 2C_2(g)$$

the partial pressure of A_2, B_2 at equilibrium are 0.80 atm and 0.40 atm respectively. The pressure of the system is 2.80 atm. The equilibrium constant K_p will be

(A) 20 (B) 5.0 (C) 0.02 (D) 0.2

C-5.✍ $PCl_5 \rightleftharpoons PCl_3 + Cl_2$ in the reversible reaction at equilibrium the moles of PCl_5, PCl_3 and Cl_2 are a, b and c respectively and total pressure is P then value of K_p is :

(A) $\frac{bc}{a}.RT$ (B) $\frac{b}{(a+b+c)}.P$ (C) $\frac{bc.P}{a\ (a+b+c)}$ (D) $\frac{c}{(a+b+c)}.P$

C-6.✍ A sample of pure NO_2 gas heated to 1000 K decomposes : $2NO_2(g) \rightleftharpoons 2NO(g) + O_2(g)$. The equilibrium constant K_P is 100 atm. Analysis shows that the partial pressure of O_2 is 0.25 atm. at equilibrium. The partial pressure of NO_2 at equilibrium is:

(A) 0.03 (B) 0.25 (C) 0.025 (D) 0.04

C-7. The reaction, $PCl_5 \rightleftharpoons PCl_3 + Cl_2$ is started in a five litre container by taking one mole of PCl_5. If 0.3 mole of PCl_5 is there at equilibrium, concentration of PCl_3 and K_C will respectively be :

(A) 0.14, $\frac{49}{150}$ (B) 0.12, $\frac{23}{100}$ (C) 0.07, $\frac{23}{100}$ (D) 20, $\frac{49}{150}$

Section (D) : Relation between K_P and K_C

D-1.✍ At 527ºC, the reaction given below has $K_C = 4$

$$NH_3\ (g) \rightleftharpoons \frac{1}{2}\ N_2(g) + \frac{3}{2}\ H_2(g)$$

What is the K_P for the reaction ?

(A) $16 \times (800\ R)^2$ (B) $\left(\frac{800\ R}{4}\right)^{-2}$ (C) $4 \times 800\ R$ (D) None of these

D-2. The value of K_p for the reaction, $2H_2O(g) + 2Cl_2(g) \rightleftharpoons 4HCl(g) + O_2(g)$ is 0.03 atm at 427º C, when the partial pressure are expressed in atmosphere then the value of K_C for the same reaction is :

(A) 5.23×10^{-4} (B) 7.34×10^{-4} (C) 3.2×10^{-3} (D) 5.43×10^{-5}

D-3.✍ $\log \frac{K_p}{K_c} + \log RT = 0$ is a relationship for the reaction :

(A) $PCl_5 \rightleftharpoons PCl_3 + Cl_2$ (B) $2SO_2 + O_2 \rightleftharpoons 2SO_3$

(C) $H_2 + I_2 \rightleftharpoons 2HI$ (D) $N_2 + 3H_2 \rightleftharpoons 2NH_3$

Section (E) : Reaction quotient and Its applications

E-1. 2 mole each of SO_3, CO, SO_2 and CO_2 is taken in a one lit. vessel. If K_C for

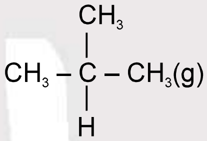
$$SO_3(g) + CO(g) \rightleftharpoons SO_2(g) + CO_2(g) \text{ is } 1/9 \text{ then}$$

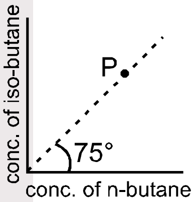
(A) total no. of moles at equilibrium are less than 8
(B) $n(SO_3) + n(CO_2) = 4$
(C) $[n(SO_2)/n(CO)] < 1$
(D) both (B) and (C).

E-2. A reaction mixture containing H_2, N_2 and NH_3 has partial pressure 2 atm, 1 atm and 3 atm respectively at 725 K. If the value of K_P for the reaction, $N_2 + 3H_2 \rightleftharpoons 2NH_3$ is 4.28×10^{-5} atm^{-2} at 725 K, in which direction the net reaction will go :

(A) Forward (B) Backward
(C) No net reaction (D) Direction of reaction cannot be predicted

E-3.

For the equilibium $CH_3–CH_2–CH_2–CH_3(g) \rightleftharpoons$  $CH_3-\underset{H}{\overset{CH_3}{\underset{|}{\overset{|}{C}}}}-CH_3(g)$ equilibrium constant is found to be 1.732 at 298 K. Now if in a vessel at 298 K, a mixture of these two gases be taken as represented by the point P in the figure, predict what will happen



(A) Immediately, above equilibrium will be setup
(B) Above reaction will go in the forward direction till it attains equilibrium
(C) Above reaction will go in the backward direction till it attains equilibrium
(D) Nothing can be said

E-4. The reaction quotient Q for $N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$ is given by $Q = \frac{[NH_3]^2}{[N_2][H_2]^3}$. The reaction will proceed in backward direction, when

(A) $Q = K_C$ (B) $Q < K_C$ (C) $Q > K_C$ (D) A = 0

E-5. For the reaction,

$2A + B \rightleftharpoons 3C$ at 298 K, $K_C = 49$

A 3L vessel contains 2, 1 and 3 moles of A, B and C respectively. The reaction at the same temperature

(A) must proceed in forward direction (B) must proceed in backward direction
(C) must be equilibrium (D) can not be predicted

E-6. When two reactants, A & B are mixed to give products C & D, the reaction quotient Q, at the initial stages of the reaction : **[JEE-2000, 1/35]**

(A) is zero (B) decrease with time
(C) is independent of time (D) increases with time

Section (F) : Properties of equilibrium Constant

F-1. At a certain temperature, the following reactions have the equilibrium constant as shown below :

$$S(s) + O_2(g) \rightleftharpoons SO_2(g);\ K_{c1} = 5 \times 10^{52}$$

$$2S(s) + 3O_2(g) \rightleftharpoons 2SO_3(g);\ K_{c2} = 10^{29}$$

What is the equilibrium constant K_c for the reaction at the same temperature ?

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$$

(A) 2.5×10^{76} (B) 4×10^{23} (C) 4×10^{-77} (D) None of these

F-2. The equilibrium constant of the reaction $SO_2(g) + \frac{1}{2}O_2(g)$ $SO_3(g) \rightleftharpoons$ is 4×10^{-3} atm$^{-1/2}$. The equilibrium constant of the reaction $2SO_3(g) \rightleftharpoons 2SO_2(g) + O_2(g)$ would be :

(A) 250 atm (B) 4×10^3 atm (C) 0.25×10^4 atm (D) 6.25×10^4 atm

F-3. Equilibrium constant for the reactions,

$2\,NO + O_2 \rightleftharpoons 2\,NO_2$ is K_{C_1} ;

$NO_2 + SO_2 \rightleftharpoons SO_3 + NO$ is K_{C_2} and

$2\,SO_3 \rightleftharpoons 2\,SO_2 + O_2$ is K_{C_3} then correct reaction is :

(A) $K_{C_3} = K_{C_1} \times K_{C_2}$
(B) $K_{C_3} \times K_{C_1} \times K^2_{C_2} = 1$
(A) $K_{C_3} = K_{C_1} \times K_{C_2} = 1$
(D) $K_{C_3} \times K^2_{C_1} \times K_{C_2} = 1$

Section (G) : Homogenuous Equilibrium (liquid system)

G-1. When alcohol (C_2H_5OH (ℓ)) and acetic acid (CH_3COOH (ℓ)) are mixed together in equimolar ratio at 27ºC , 33% of each is converted into ester. Then the K_C for the equilibrium

$C_2H_5OH(\ell) + CH_3COOH(\ell) \rightleftharpoons CH_3COOC_2H_5(\ell) + H_2O(\ell)$ is :

(A) 4 (B) 1/4 (C) 9 (D) 1/9

Section (H) : Heterogenuous equilibrium

H-1. What is the minimum mass of $CaCO_3$ (s), below which it decomposes completely, required to establish equilibrium in a 6.50 litre container for the reaction : $CaCO_3(s) \rightleftharpoons CaO(s) + CO_2(g)$; $K_c = 0.05$ mole/litre

(A) 32.5 g (B) 24.6 g (C) 40.9 g (D) 8.0 g

H-2. In the reaction $C(s) + CO_2(g) \rightleftharpoons 2CO(g)$, the equilibrium pressure is 12 atm. If 50% of CO_2 reacts then K_p will be :

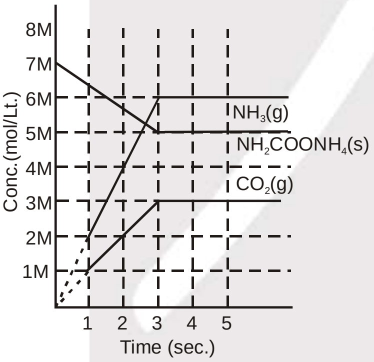
(A) 12 atm (B) 16 atm (C) 20 atm (D) 24 atm

H-3. Solid ammonium carbamate dissociate to give ammonia and carbon dioxide as follows

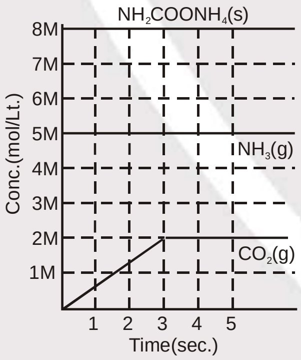
$NH_2COONH_4(s) \rightleftharpoons 2NH_3(g) + CO_2(g)$

which of the following graph correctly represents the equilibrium.

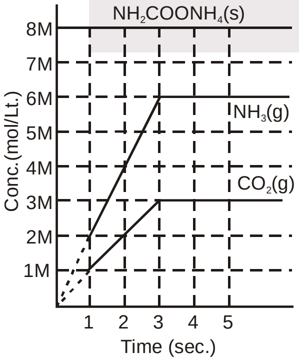
(A)



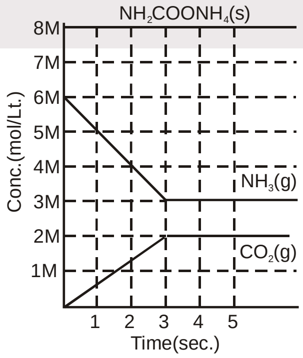
(B)



(C)



(D)



H-4. For $NH_4HS(s) \rightleftharpoons NH_3(g) + H_2S(g)$ reaction started only with $NH_4HS(s)$, the observed pressure for reaction mixture in equilibrium is 1.2 atm at 106°C. What is the value of K_p for the reaction ?

(A) 1.44 atm^2 (B) 0.36 atm^2 (C) 0.16 atm^2 (D) 3.6 atm^2

H-5. Consider the decomposition of solid NH_4HS in a flask containing $NH_3(g)$ at a pressure of 2 atm. What will be the partial pressure of $NH_3(g)$ and $H_2S(g)$ after the equilibrium has been attained?
K_P for the reaction is 3.

(A) p_{NH_3} = 6 atm, p_{H_2S} = ½ atm
(B) p_{NH_3} = 1.732 atm, p_{H_2S} = 1.732 atm
(C) p_{NH_3} = 3 atm, p_{H_2S} = 1 atm
(D) p_{NH_3} = 1 atm, p_{H_2S} = 3 atm

Section (I) : Degree of dissociation (α) and vapour density

I-1. For the dissociation reaction $N_2O_4(g) \rightleftharpoons 2NO_2(g)$, the degree of dissociation (α) in terms of K_p and total equilibrium pressure P is:

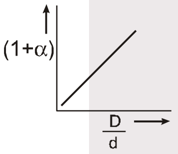
(A) $\alpha = \sqrt{\frac{4p+K_p}{K_p}}$
(B) $\alpha = \sqrt{\frac{K_p}{4p+K_p}}$
(C) $\alpha = \sqrt{\frac{K_p}{4p}}$
(D) None of these

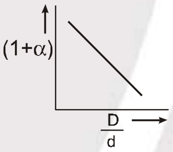
I-2. The degree of dissociation of SO_3 is α at equilibrium pressure P_0. K_p for $2SO_3(g) \rightleftharpoons 2SO_2(g) + O_2(g)$ is:

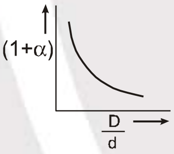
(A) $[(P_0\alpha^3)/2(1-\alpha)^3]$
(B) $[(P_0\alpha^3)/(2+\alpha)(1-\alpha)^2]$
(C) $[(P_0\alpha^2)/2(1-\alpha)^2]$
(D) None of these

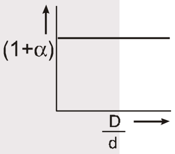
I-3. In the dissociation of N_2O_4 into NO_2, $(1 + \alpha)$ values with the vapour densities ratio $\left(\frac{D}{d}\right)$ is as given by :

[α-degree of dissociation, D-vapour density before dissociation, d-vapour density after dissociation]

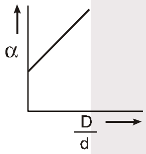
(A)


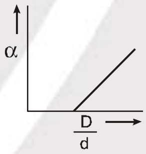
(B)


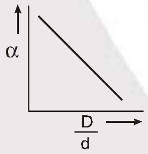
(C)


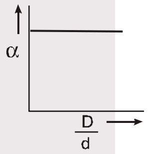
(D)


I-4. In the above question, α varies with $\frac{D}{d}$ according to :

(A)


(B)


(C)


(D)


I-5. For the reaction $N_2O_4(g) \rightleftharpoons 2NO_2(g)$, if percentage dissociation of N_2O_4 are 20%, 45%, 65% & 80%, then the sequence of observed vapour densities will be :

(A) $d_{20} > d_{45} > d_{65} > d_{80}$
(B) $d_{80} > d_{65} > d_{45} > d_{20}$
(C) $d_{20} = d_{45} = d_{65} = d_{80}$
(D) $(d_{20} = d_{45}) > (d_{65} = d_{80})$

I-6. The degree of dissociation of PCl_5 (α) obeying the equilibrium, $PCl_5 \rightleftharpoons PCl_3 + Cl_2$, is approximately related to the presure at equilibrium by (given α << 1) :

(A) $\alpha \propto P$
(B) $\alpha \propto \frac{1}{\sqrt{P}}$
(C) $\alpha \propto \frac{1}{P^2}$
(D) $\alpha \propto \frac{1}{P^4}$

I-7. At 727°C and 1.23 atm of total equilibrium pressure, SO_3 is partially dissociated into SO_2 and O_2 according to $SO_3(g) \rightleftharpoons SO_2(g) + 1/2O_2(g)$. The density of equilibrium mixture is 0.9 g/litre. The degree of dissociation is :

(A) 1/3
(B)2/3
(C) l/4
(D) 1/5.

I-8. Consider the following hypothetical equilibrium $2B(g) \rightleftharpoons B_2(g)$. If d is observed vapour density and D is theoretical vapour density, then degree of association (α) will be :

(A) $\alpha = 2\left(\frac{D-d}{d}\right)$
(B) $\alpha = \frac{2D-d}{D}$
(C) $\alpha = 2 - \frac{2D}{d}$
(D) $\alpha = \frac{2D}{D-d}$

I-9. The degree of dissociation is 0.5 at 800 K and 2 atm for the gaseous reaction $PCl_5 \rightleftharpoons PCl_3 + Cl_2$. Assuming ideal behaviour of all the gases.
Calculate the density of equilibrium mixture at 800 K and 2 atm.
(A) 4.232 g/L (B) 6.4 g/L (C) 8.4 g/L (D) 2.2 g/L

I-10. $SO_3(g) \rightleftharpoons SO_2(g) + \frac{1}{2} O_2(g)$
If observed vapour density of mixture at equilibrium is 35 then find out value of α
(A) 0.28 (B) 0.38 (C) 0.48 (D) 0.58

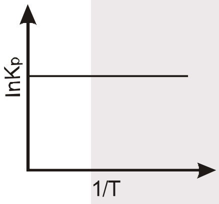
Section (J) : Thermodyanamics of equilibrium

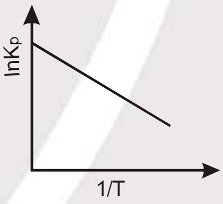
J-1. The correct relationship between free energy change in a reaction and the corresponding equilibrium constant K is
(A) $-\Delta G^o = RT \ln K$ (B) $\Delta G = RT \ln K$ (C) $-\Delta G = RT \ln K$ (D) $\Delta G^o = RT \ln K$

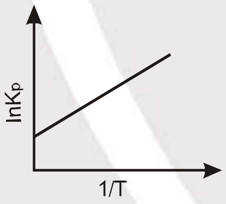
J-2. For the reaction $H_2(g) + I_2(g) \rightleftharpoons 2HI(g)$
$K_c = 66.9$ at 350°C and $K_c = 50.0$ at 448°C. The reaction has
(A) $\Delta H = +$ ve (B) $\Delta H = -$ ve
(C) $\Delta H =$ zero (D) ΔH sign can not be determined

J-3. The equilibrium constant for the reaction $Br_2 \rightleftharpoons 2Br$ at 500 K and 700 K are 1×10^{-10} and 1×10^{-5} respectively. The reaction is :
(A) Endothermic (B) Exothermic (C) Fast (D) Slow

J-4. An exothermic reaction is represented by the graph :

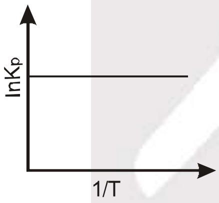
(A) 

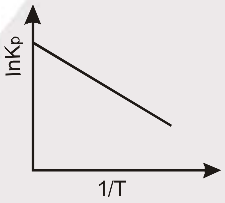
(B) 

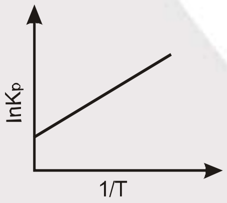
(C) 

(D) None of these

J-5. An endothermic reaction is represented by the graph :

(A) 

(B) 

(C) 

(D) None of these

J-6. The value of $\Delta G°$ for a reaction in aqueous phase having $K_c = 1$, would be :
(A) –RT (B) –1 (C) 0 (D) + RT

J-7. The effect of temperature on equilibrium constant is expressed as $(T_2 > T_1)$

$\log\frac{K_2}{K_1} = \frac{-\Delta H}{2.303}\left[\frac{1}{T_2}-\frac{1}{T_1}\right]$. For endothermic reaction false statement is

(A) $\left[\frac{1}{T_2}-\frac{1}{T_1}\right]$ = positive (B) ΔH = positive (C) $\log K_2 > \log K_1$ (D) $K_2 > K_1$

Section (K) : Le-chatelier's principle

K-1. For the reaction $CO(g) + H_2O(g) \rightleftharpoons CO_2(g) + H_2(g)$ at a given temperature the equilibrium amount of $CO_2(g)$ can be increased by :
(A) adding a suitable catalyst (B) adding an inert gas
(C) decreasing the volume of container (D) increasing the amount of CO(g)

K-2.✍ Given the following reaction at equilibrium $N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$. Some inert gas at constant pressure is added to the system. Predict which of the following facts will be affected.

(A) More $NH_3(g)$ is produced (B) Less $NH_3(g)$ is produced
(C) No affect on the equilibrium (D) K_p of the reaction is decreased

K-3. The equilibrium, $SO_2Cl_2(g) \rightleftharpoons SO_2(g) + Cl_2(g)$ is attained at 25°C in a closed container and an inert gas, helium, is introduced. Which of the following statement(s) is/are correct.

(A) Concentrations of SO_2, Cl_2 and SO_2Cl_2 are changed
(B) No effect on equilibrium
(C) Concentration of SO_2 is reduced
(D) K_p of reaction is increasing

K-4.✍ Densities of diamond and graphite are 3.5 and 2.3 g/mL.

$$C\text{ (diamond)} \rightleftharpoons C\text{ (graphite)} \qquad \Delta_rH = -1.9 \text{ kJ/mole}$$

favourable conditions for formation of diamond are

(A) high pressure and low temperature (B) low pressure and high temperature
(C) high pressure and high temperature (D) low pressure and low temperature

K-5. Introduction of inert gas (at the same temperature) will affect the equilibrium if :

(A) volume is constant and $\Delta n_g \neq 0$ (B) pressure is constant and $\Delta n_g \neq 0$
(C) volume is constant and $\Delta n_g = 0$ (D) pressure is constant and $\Delta n_g = 0$

K-6.✍ For an equilibrium $H_2O(s) \rightleftharpoons H_2O(\ell)$ which of the following statements is true.

(A) The pressure changes do not affect the equilibrium
(B) More of ice melts if pressure on the system is increased
(C) More of liquid freezes if pressure on the system is increased
(D) The degree of advancement of the reaction do not depend on pressure.

K-7. A reaction in equilibrium is represented by the following equation –
$2A(s) + 3B(g) \rightleftharpoons 3C(g) + D(g) + O_2$ if the pressure on the system is reduced to half of its original value

(A) The amounts of C and D decreases (B) The amounts of C and D increases
(C) The amount of B and D decreases (D) All the amounts remain constant

Section (L) : Vapour pressure and Relative Humidity

L-1. What is the relative humidity of air at 1 bar pressure and 313 K temperature if partial pressure of water in air is 19.355 mmHg.for any data use the table given below :

(in mmHg)	V.P. of H_2O	25.2	31.8	42.2	55.3	71.9	92.5
(in K)	Temp.	298	303	308	313	318	323

(A) 35% (B) 25% (C) 75% (D) 5%

L-2. (a) $CuSO_4.5H_2O(s) \rightleftharpoons CuSO_4.3H_2O\ (s) + 2H_2O\ (g)$ $K_P = 4 \times 10^{-4}$ atm^2
(b) $Na_2SO_4.10H_2O(s) \rightleftharpoons Na_2SO_4.5H_2O\ (s) + 5H_2O\ (g)$ $K_P = 2.43 \times 10^{-8}$ atm^5
(c) $Na_2S_2O_3.5H_2O(s) \rightleftharpoons Na_2S_2O_3.2H_2O\ (s) + 3H_2O\ (g)$ $K_P = 6.4 \times 10^{-5}$ atm^3

What is order of partial pressure of water vapours at equilibrium and relative humidity respectively.

(A) $c > b > a$ Partial pressure
$c > b > a$ Relative humidity
(B) $c < b < a$ Partial pressure
$c > b > a$ Relative humidity
(C) $a > c > b$ Partial pressure
$a > c > b$ Relative humidity
(D) $a > c > b$ Partial pressure
$a < c < b$ Relative humidity

L-3.✍ $CuSO_4.5H_2O(s) \rightleftharpoons CuSO_4.3H_2O(s) + 2H_2O(g)$ $K_P = 4 \times 10^{-4}$ atm^2
and vapour pressure of water is 22.4 torr at 298 K. Then find out realative humidity

(A) 74.46% (B) 78.46% (C) 67.85% (D) 70.46%

Section (M) : Simultaneous equilibria

M-1. The two equilibria, AB(aq) $\rightleftharpoons$ A^+(aq) + B^-(aq) and AB(aq) + B^-(aq) $\rightleftharpoons$ AB_2^-(aq) are simultaneously maintained in a solution with equilibrium constants, K_1 and K_2 respectively. The ratio of concentration of A^+ to AB_2^- in the solution is :
(A) directly proportional to the concentration of B^- (aq.).
(B) inversely proportional to the concentration of B^- (aq.).
(C) directly proportional to the square of the concentration of B^- (aq.).
(D) inversely proportional to the square of the concentration of B^- (aq.).

M-2. In the preceeding problem, if [A^+] and [AB_2^-] are y and x respectively, under equilibrium produced by adding the substance AB to the solvents, then K_1/K_2 is equal to

(A) $\frac{y}{x}(y-x)^2$ (B) $\frac{y^2(x+y)}{x}$ (C) $\frac{y^2(x+y)}{x}$ (D) $\frac{y}{x}(x-y)$

[**Note:** Use the information of the preceeding problem]

M-3. The reactions PCl_5(g) $\rightleftharpoons$ PCl_3(g) + Cl_2(g) and $COCl_2$(g) $\rightleftharpoons$ CO(g) + Cl_2(g) are simultaneously in equilibrium at constant volume. A few moles of CO(g) are introduced into the vessel. After some time, the new equilibrium concentration of
(A) PCl_5 will remain unchanged (B) Cl_2 will be greater
(C) PCl_5 will become less (D) PCl_5 will become greater

PART - III : MATCH THE COLUMN

1. Match the following : (Assume only reactants were present initially).

	Column-I		**Column-II**
(A)	$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$ (t = 300ºC)	(p)	$\Delta n_g > 0$
(B)	$PCl_5(g) \rightleftharpoons PCl_3(g) + Cl_2(g)$ (t = 50ºC)	(q)	$K_p < K_c$
(C)	$C(s) + H_2O(g) \rightleftharpoons CO(g) + H_2(g)$	(r)	K_p not defined
(D)	$CH_3COOH(\ell) + C_2H_3OH(\ell) \rightleftharpoons CH_3COOC_2H_5(\ell) + H_2O(\ell)$	(s)	$P_{initial} > P_{eq.}$

2. **Match the following :**

	Column-I **(Assume only reactant were present initially)**		**Column-II**
(A)	For the equilibrium $NH_4I(s) \rightleftharpoons NH_3(g) + HI(g)$, if pressure is increased at equilibrium	(p)	Forward shift
(B)	For the equilibrium $N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$, volume is increased at equilibrium	(q)	No shift in equilibrium
(C)	For the equilibrium $H_2O(g) + CO(g) \rightleftharpoons H_2(g) + CO_2(g)$, inert gas is added at constant pressure at equilibrium	(r)	Backward shift
(D)	For the equilibrium $PCl_5(g) \rightleftharpoons PCl_3(g) + Cl_2(g)$, Cl_2 is removed at equilibrium.	(s)	Final pressure is more than initial pressure

Exercise-2

✍ **Marked questions are recommended for Revision.**

PART - I : ONLY ONE OPTION CORRECT TYPE

1.✍ If K_1, K_2, K_3 are equilibrium constant for formation of AD, AD_2, AD_3 respectively as follows A + D $\rightleftharpoons$ AD, AD + D $\rightleftharpoons$ AD_2, AD_2 + D $\rightleftharpoons$ AD_3. Then equilibrium constant 'K' for A + 3D $\rightleftharpoons$ AD_3 is related as
(A) $K_1 + K_2 + K_3 = K$ (B) $\log K_1 + \log K_2 + \log K_3 = \log K$
(C) $K_1 + K_2 = K_3 + K$ (D) $\log K_1 + \log K_2 = \log K_3 + \log K$

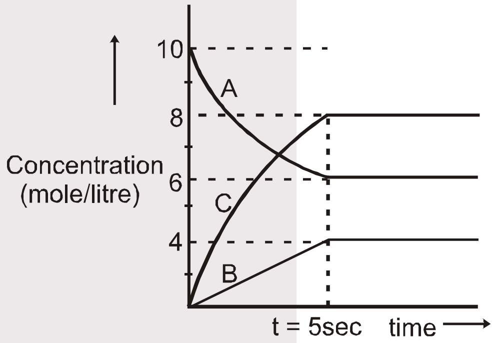
2.✍ A 10 litre box contains O_3 and O_2 at equilibrium at 2000 K. $K_P = 4 \times 10^{14}$ atm for $2O_3(g) \rightleftharpoons 3O_2(g)$. Assume that $P_{O_2} >> P_{O_3}$ and if total pressure is 8 atm, then partial pressure of O_3 will be :
(A) 8×10^{-5} atm (B) 11.3×10^{-7} atm (C) 9.71×10^{-6} atm (D) 9.71×10^{-2} atm

3. Sulfide ion in alkaline solution reacts with solid sulfur to form polysulfide ions having formulae S_2^{2-}, S_3^{2-}, S_4^{2-} and so on. $S(s) + S^{2-}(aq) \rightleftharpoons S_2^{2-}(aq)$ $K_1 = 12$ & $2S(s) + S^{2-}(aq) \rightleftharpoons S_3^{2-}(aq)$ $K_2 = 132$. What is the equilibrium constant for the formation of S_3^{2-} from S_2^{2-} and S?
(A) 11 (B) 12 (C) 132 (D) None of these

4.✍ If for $2A_2B(g) \rightleftharpoons 2A_2(g) + B_2(g)$, K_p = TOTAL PRESSURE (at equilibrium) and starting the dissociation from 4 mol of A_2B then :
(A) degree of dissociation of A_2B will be (2/3).
(B) total no. of moles at equilibrium will be (14/3).
(C) at equilibrium the no. of moles of A_2B are not equal to the no. of moles of B_2.
(D) at equilibrium the no. of moles of A_2B are equal to the no. of moles of A_2.

5.✍ Attainment of the equilibrium $A(g) \rightleftharpoons 2C(g) + B(g)$ gave the following graph. Find the correct option. (% dissociation = fraction dissociated × 100)

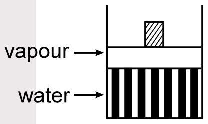
(A) At t = 5 sec equilibrium has been reached and $K_c = 128$ $(\text{mol/litre})^2$
(B) At t = 5 sec equilibrium has been reached and % dissociation of A is 60%
(C) At t = 5 sec equilibrium has been reached and % dissociation of A is 40%
(D) None of these



6. A 10 L container at 300 K contains CO_2 gas at pressure of 0.2 atm and an excess solid CaO (neglect the volume of solid CaO). The volume of container is now decreased by moving the movable piston fitted in the container. What will be the maximum volume of container when pressure of CO_2 attains its maximum value given that $CaCO_3(s) \rightleftharpoons CaO(s) + CO_2(g)$ $K_p = 0.800$ atm
(A) 5 L (B) 2.5 L (C) 1 L (D) The information is insufficient.

7.✍ In the system, $LaCl_3(s) + H_2O(g) + \text{heat} \rightleftharpoons LaClO(s) + 2HCl(g)$, equilibrium is established. More water vapour is added to restablish the equlibrium. The pressure of water vapour is doubled. The factor by which pressure of HCl is changed is:
(A) 2 (B) $\sqrt{2}$ (C) $\sqrt{3}$ (D) $\sqrt{5}$

8. Some quantity of water is contained in a container as shown in figure. As neon is added to this system at constant pressure, the amount of liquid water in the vessel
(A) increases (B) decreases
(C) remains same (D) changes unpredictably



9. The equilibrium constant for, $2H_2S(g) \rightleftharpoons 2H_2(g) + S_2(g)$ is 0.0118 at 1300 K while the heat of dissociation is 597.4 kJ. The standard equilibrium constant of the reaction at 1200 K is :
(A) 1.180×10^{-4} (B) 11.80 (C) 118.0
(D) cannot be calculated from given data

10. For reaction, assuming large volume of water.
$H_2O(\ell) \rightleftharpoons H_2O(g)$; at temp. T K Choose correct options :
(A) On introduction of an inert gas at constant temperature pressure in the container remains same at equilibrium.
(B) For this system % relative humidity always remains 100% at constant temperature at equilibrium
(C) If steam at temperature '2T' is passed into given system, after equilibrium is attained relative humidity changes.
(D) This is a special case of equilibrium where pressure of $H_2O(g)$ remains same always due to unique structural feature of H_2O.

11. In the Haber process for the industrial manufacturing of ammonia involving the reaction,
$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$ at 200 atm pressure in the presence of a catalyst, a temperature of about 500ºC is used. This is considered as optimum temperature for the process because
(A) yield is maximum at this temperature
(B) catalyst is active only at this temperature
(C) energy needed for the reaction is easily obtained at this temperature
(D) rate of the catalytic reaction is fast enough while the yield is also appreciable for this exothermic reaction at this temperature.

12.✍ Addition of water to which of the following equilibria causes it to shift in the backward direction?
(A) $CH_3NH_2\ (aq) + H_2O\ (\ell) \rightleftharpoons CH_3NH_3^{\oplus}\ (aq) + OH^-\ (aq)$
(B) $AgCl\ (s) \rightleftharpoons Ag^+\ (aq) + Cl^-\ (aq)$
(C) $HCN\ (aq) + H_2O\ (\ell) \rightleftharpoons H_3O^+\ (aq) + CN^-\ (aq)$
(D) $[Cr(dien)_2]^{3+}\ (aq) + 3H_2O\ (\ell) + 3Cl^-\ (aq) \rightleftharpoons [Cr\ (H_2O)_3Cl_3]\ (aq) + 2\ dien\ (aq)$

13. Consider the reactions
(i) $PCl_5(g) \rightleftharpoons PCl_3(g) + Cl_2(g)$ (ii) $N_2O_4(g) \rightleftharpoons 2NO_2(g)$
The addition of an inert gas at constant pressure
(A) will increase the dissociation of PCl_5 as well as N_2O_4
(B) observed molecular weight of PCl_5 increases at equilibrium.
(C) Concentration NO_2 increases at equilibrium.
(D) will not disturb the equilibrium of the reactions

14. An equilibrium mixture $[N_2(g) + O_2(g) \rightleftharpoons 2NO(g)]$ in a vessel of capacity 100 litre contain 1 mol N_2, 2 mol O_2 and 3 mol NO. Number of moles of O_2 to be added so that at new equilibrium the conc. of NO is found to be 0.04 mol/lit.:
(A) (101/18) (B) (101/9) (C) (202/9) (D) None of these.

15. $CaCl_2.6H_2O(s) \rightleftharpoons CaCl_2(s) + 6H_2O(g)\ K_p = 6.4 \times 10^{-17}\ atm^6$
Excess solid $CaCl_2.6H_2O$ & $CaCl_2$ are taken in a container containing some water vapours at a pressure of 1.14 torr at a particular temp.
(A) $CaCl_2(s)$ acts as drying agent under given condition.
(B) $CaCl_2(s)$ acts as hygroscopic substance given condition.
(C) $CaCl_2.6H_2O(s)$ acts as effluoroscent substance.
(D) Mass of $CaCl_2.6H_2O(s)$ increases dueto some reaction.

16.✍ $A(s) \rightleftharpoons B(g) + C(g)$ $K_P = 40\ atm^2$
$X(s) \rightleftharpoons B(g) + E(g)$
Above equilibrium is allowed to attain in a closed container and pressure of B was found to be 10 atm.
Calculate standard Gibb's free energy change for $X(s) \rightleftharpoons B(g) + E(g)$ at 300 K (take R = 2 cal/K/mol)
(A) 3.5 Kcal/mol (B) 3 Kcal/mol (C) 2.5 Kcal/mol (D) 2 Kcal/mol

PART - II : SINGLE AND DOUBLE VALUE INTEGER TYPE

1. How many of the following reactions are homogenous reversible reactions ?
(1) $CH_3COOH(\ell) + C_2H_5OH(\ell) \rightleftharpoons CH_3COOC_2H_5(\ell) + H_2O(\ell)$
(2) $H_2(g) + CO_2(g) \rightleftharpoons CO(g) + H_2O(g)$
(3) $CO(g) + Cl_2(g) \rightleftharpoons COCl_2(g)$
(4) $NH_4HS(s) \rightleftharpoons NH_3(g) + H_2S(g)$
(5) $CaCO_3(s) \rightleftharpoons CaO(s) + CO_2(g)$
(6) $N_2(g) + O_2(g) \rightleftharpoons 2NO(g)$
(7) $CO_2(g) + C(s) \rightleftharpoons 2CO(g)$
(8) $SO_2(g) + NO_2(g) \rightleftharpoons SO_3(g) + NO(g)$
(9) $NO(g) + \frac{1}{2}\ Br_2(\ell) \rightleftharpoons 2NOBr(g)$

2. $A(g) + B(g) \rightleftharpoons C(g) + D(g)$ above equilibrium is established by taking A & B in a closed container. Initial concentration of A is twice of the initial concentration of B. At equilibrium concentrations of B and C are equal. Then find the equilibrium constant for the reaction, $C(g) + D(g) \rightleftharpoons A(g) + B(g)$.

3.✍ If 0.5 mole H_2 is reacted with 0.5 mole I_2 in a ten-litre container at 444°C and at same temperature value of equilibrium constant K_C is 49, the ratio of [HI] and $[I_2]$ will be :

4. For the reaction, $N_2O_5(g) \rightleftharpoons 2NO_2(g) + 1/2\ O_2(g)$, calculate the mole fraction of $N_2O_5(g)$ decomposed at a constant volume & temperature, if the initial pressure is 600 mm Hg & the pressure at any time is 960 mm Hg. Assume ideal gas behaviour. If answer is x then report 10x.

5.✍ Consider the equilibrium

$$Ni(s) + 4CO(g) \rightleftharpoons Ni(CO)_4(g)\ ; \qquad K_p = 0.125\ atm^{-3}.$$

If equal number of moles of CO and $Ni(CO)_4$ (ideal gases) are mixed in a small container fitted with a piston, find the maximum total pressure (in atm) to which this mixture must be brought in order to just precipitate out metallic Ni ?

6.✍ K_p is 9 atm^2 for the reaction: $LiCl.3NH_3(s) \rightleftharpoons LiCl.NH_3(s) + 2NH_3(g)$ at 40°C. How many moles of ammonia must be added at this temperature to a 5 litre flask containing 0.1 mole of $LiCl.\ NH_3$ in order to completely convert the solid to $LiCl.3NH_3$? Multiply the obtained answer by 100. Round off the answer to the nearest integer.

7.✍ Consider the reaction, $2Cl_2(g) + 2H_2O(g) \rightleftharpoons 4HCl(g) + O_2(g)\ ;\ \Delta H^o = +113$ kJ

The four gases, Cl_2, H_2O, HCl and O_2, are mixed and the reaction is allowed to come to equilibrium. Each operation is to be considered separately. Temperature and volume are constant unless stated otherwise. Report the number of operations in the left column which lead to increase in the equilibrium value of the quantity in the right column.

(a) Increasing the volume of the container	Number of moles of H_2O
(b) Adding O_2	Number of moles of H_2O
(c) Adding O_2	Number of moles of HCl
(d) Decreasing the volume of the container	Number of moles of Cl_2
(e) Decreasing the volume of the container	Partial pressure of Cl_2
(f) Decreasing the volume of the container	K_C
(g) Raising the temperature	K_C
(h) Raising the temperature	Concentration of HCl
(i) Adding He	Number of moles of HCl
(j) Adding catalyst	Number of moles of HCl

8. For given simultaneous reaction :

$$X(s) \rightleftharpoons A(g) + B(s) + C(g) \qquad K_{P_1} = 500\ atm^2$$

$$Y(s) \rightleftharpoons D(g) + A(g) + E(s) \qquad K_{P_2} = 2000\ atm^2$$

If total pressure = x, then write your answer after dividing by 25.

9. For equilibrium $N_2O_4(g) \rightleftharpoons 2NO_2(g)$ the observed vapour density of N_2O_4 is 40 at 350 K. Calculate percentage dissociation of $N_2O_4(g)$ at 350K.

10. The vapour density of N_2O_4 at a certain temperature is 30.67. The % dissociation of N_2O_4 at this temperature is :

11.✍ Solid ammonium carbamate dissociates to give ammonia and carbon dioxide as follows:

$$NH_2COONH_4(s) \rightleftharpoons 2NH_3(g) + CO_2(g)$$

At equilibrium, ammonia is added such that partial pressures of NH_3 at new equilibrium equals the original total pressure (at previous equilibrium). If the ratio of the total pressures now to the original total pressure is a/b then report a + b.

PART - III : ONE OR MORE THAN ONE OPTIONS CORRECT TYPE

1. Which of the following is correct about the chemical equilibrium ?
(A) $(\Delta G)_{T,P} = 0$
(B) Equilibrium constant is independent of initial concentration of reactants
(C) Catalyst has no effect on equilibrium state
(D) Reaction stops at equilibrium

2. For a reaction $N_2 + 3H_2 \rightleftharpoons 2NH_3$, the value of K_C does not depends upon :
(A) Initial concentration of the reactants
(B) Pressure
(C) Temperature
(D) catalyst

3. Which of the following statement/s is/are correct :
(A) At equilibrium, vapour pressure of solution and refractive index of eq. mixture becomes constant.
(B) Equilibrium can be attained in both homogenous and heterogenous reaction.
(C) Approach to the equilibrium is fast in initial state but gradually it decreases.
(D) Equilibrium is dynamic in nature

4.✍ Equilibrium constant for following reactions respectively K_1, K_2 and K_3

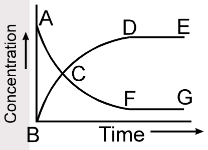
$N_2 + 3H_2 \rightleftharpoons 2NH_3$ K_1
$N_2 + O_2 \rightleftharpoons 2NO$ K_2
$H_2 + \frac{1}{2}O_2 \rightleftharpoons H_2O$ K_3
$2NH_3 + \frac{5}{2}O_2 \rightleftharpoons 2NO + 3H_2O$ K_4

Which of the following relation is correct.
(A) $K_1 = \frac{K_2 \times (K_3)^3}{K_4}$
(B) $K_4 = K_1 \times K_2/(K_3)^3$
(C) $K_2 = \frac{K_4 \times K_1}{(K_3)^3}$
(D) $K_4 = \frac{K_2 \times (K_3)^3}{K_1}$

5.✍ If $\log \frac{k_c}{k_p} - \log \frac{1}{RT} = 0$, then above is true for the following equilibrium reaction
(A) $NH_3(g) \rightleftharpoons \frac{1}{2}N_2(g) + \frac{3}{2}H_2(g)$
(B) $CaCO_3(s) \rightleftharpoons CaO(s) + CO_2(g)$
(C) $2NO_2(g) \rightleftharpoons N_2O_4(g)$
(D) $H_2(g) + I_2(g) \rightleftharpoons 2HI(g)$

6. The reaction for which, $K_P = K_C$ is satisfied
(A) $A(g) + 2B(g) \rightleftharpoons 3C(g)$
(B) $A(s) \rightleftharpoons B(g)$
(C) $2A(g) \rightleftharpoons B(g) + C(g)$
(D) $A(s) + B(g) \rightleftharpoons C(s) + 2D(g)$

7. $N_2O_4(g) \rightleftharpoons 2NO_2(g)$, $K_c = 4$. This reversible reaction is studied graphically as shown in figure. Select the correct statements.
(A) Reaction quotient has maximum value at point A
(B) Reaction proceeds left to right at a point when $[N_2O_4] = [NO_2] = 0.1$ M
(C) $K_c = Q$ when point D or F is reached :
(D) None of these



8.✍ If reaction $A + B \rightleftharpoons C + D$, take place in 5 liter close vessel, the rate constant of forward reaction is nine times of rate of backward reaction.
If initially one mole of each reactant present in the container, then find the correct option/s.
(A) $\frac{[C]}{[B]} = \frac{3}{1}$
(B) $\log K_P = \log K_C$
(C) $[D]_{eq} = 15 \times 10^{-2}$ mole L^{-1}
(D) $K_{eq} = 9$

9. Consider the following equilibrium $2AB(g) \rightleftharpoons A_2(g) + B_2(g)$
The vapour density of the equilibrium mixture does not depend upon
(A) Temperature
(B) Initial concentration
(C) Volume of contain
(D) Pressure of equilibrium mixture

10. Vapour density of equilibrium $PCl_5(g) \rightleftharpoons PCl_3(g) + Cl_2(g)$ is decreased by
(A) increasing temperature (B) decreasing pressure
(C) increasing pressure (D) decreasing temperature

11.✍ $CuSO_4.5H_2O(s) \rightleftharpoons CuSO_4(s) + 5H_2O(g)$; $K_p = 10^{-10}$ $(atm)^5$. 10^{-2} moles of $CuSO_4.5H_2O(s)$ is taken in a 2.5L container at 27°C then at equilibrium [Take : R = $\frac{1}{12}$ litre atm mol^{-1} K^{-1}]
(A) Moles of $CuSO_4.5H_2O$ left in the container is 9×10^{-3}
(B) Moles of $CuSO_4.5H_2O$ left in the container is 9.8×10^{-3}
(C) Moles of $CuSO_4$ left in the container is 10^{-3}
(D) Moles of $CuSO_4$ left in the container is 2×10^{-4}

12. $CuSO_4.5H_2O(s) \rightleftharpoons CuSO_4.3H_2O(s) + 2H_2O(g)$ $K_P = 0.4 \times 10^{-3}$ atm^2
Which of following statement are correct :
(A) $\Delta G^o = - RT \ln P_{H_2O}$ where P_{H_2O} = Partial pressure of H_2O at equilibrium.
(B) At vapour pressure of H_2O = 15.2 torr relative humidity of $CuSO_4.5H_2O$ is 100%.
(C) In presence of aqueous tension of 24 torr, $CuSO_4.5H_2O$ can not loss moisture.
(D) In presence of dry atmosphere in open container $CuSO_4.5H_2O$ will completely convert into $CuSO_4.3H_2O$

13. 1 mole each of $H_2(g)$ and $I_2(g)$ are introduced in a 1L evacuated vessel at 523K and equilibrium $H_2(g) + I_2(g) \rightleftharpoons 2HI(g)$ is established. The concentration of HI(g) at equilibrium :
(A) Changes on changing pressure.
(B) Changes on changing temperature.
(C) Changes on changing volume of the vessel.
(D) Is same even if only 2 mol of HI (g) were introduced in the vessel in the begining.
(E) Is same even when a platinum gauze is introduced to catalyse the reaction.

14. For the reaction : $PCl_5(g) \rightleftharpoons PCl_3(g) + Cl_2(g)$
The forward reaction at constant temperature is favoured by
(A) introducing chlorine gas at constant volume
(B) introducing an inert gas at constant pressure
(C) increasing the volume of the container
(D) introducing PCl_5 at constant volume

15.✍ Which of the following reaction will shift in forward direction. When the respective change is made at equilibrium :
(A) $N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$ increase in pressure at eq.
(B) $H_2O(s) \rightleftharpoons H_2O(\ell)$ addition of inert gas at constant volume
(C) $PCl_5(g) \rightleftharpoons PCl_3(g) + Cl_2(g)$ addition of inert gas at constant pressure
(D) $H_2 + I_2 \rightleftharpoons 2HI$ increase in temperature

16. $2CaSO_4(s) \rightleftharpoons 2CaO(s) + 2SO_2(g) + O_2(g)$, $\Delta H > 0$
Above equilibrium is established by taking some amount of $CaSO_4(s)$ in a closed container at 1600 K. Then which of the following may be correct option.
(A) moles of CaO(s) will increase with the increase in temperature
(B) If the volume of the container is doubled at equilibrium then partial pressure of $SO_2(g)$ will change at new equilibrium.
(C) If the volume of the container is halved partial pressure of $O_2(g)$ at new equilibrium will remain same
(D) If two moles of the He gas is added at constant pressure then the moles of CaO(s) will increase.
$2CaSO_4(s) \rightleftharpoons 2CaO(s) + 2SO_2(g) + O_2(g)$, $\Delta H > 0$

17. The dissociation of phosgene, which occurs according to the reaction
$COCl_2(g) \rightleftharpoons CO(g) + Cl_2(g)$
Is an endothermic process. Which of the following will increase the degree of dissociation of $COCl_2$?
(A) Adding Cl_2 to the system
(B) Adding helium to the system at constant pressure
(C) Decreasing the temperature of the system
(D) Reducing the total pressure

PART - IV : COMPREHENSION

Read the following passage carefully and answer the questions.

Comprehension # 1

Le chatelier's principle

If a system at equilibrium is subjected to a change of any one of the factors such as concentration, pressure or temperature, the system adjusts itself in such a way as to nulify the effect of that change.

Change of pressure : If a system in equilibrium consists of gases, then the concentrations of all the components can be altered by changing the pressure. To increase the pressure on the system, the volume has to be decreased proportionately. The total number of moles per unit volume will now be more and the equilibirum will shift in the direction in which there is decrease in number of moles i.e., towards the direction in which there can be decrease in pressure .

Effect of pressure on melting point : There are two types of solids :

(a) Solids whose volume decreases on melting, e.g., ice, diamond, carborundum, magnesium nitride and quartz.

Solid (higher volume) $\rightleftharpoons$ Liquid (lower volume)

The process of melting is facilitated at high pressure, thus melting point is lowered.

(b) Solids whose volume increase on melting, e.g., Fe, Cu, Ag, Au, etc.

Solid (lower volume) $\rightleftharpoons$ Liquid (higher volume)

In this case the process of melting become difficult at high pressure; thus melting point becomes high.

(c) **Solubility of substances :** When solid substance are dissolved in water, either heat is evolved (exothermic) or heat is absorbed (endothermic).

$KCl + aq \rightleftharpoons KCl(aq) - heat$

In such cases, solubility increase with increase in temperature. Consider the case of KOH; when this is dissolved, heat is evolved.

$KOH + aq \rightleftharpoons KOH(aq) + heat$

In such cases, solubility decrease with increase in temperature.

(d) **Solubility of gases in liquids :** When a gas dissolves in liquid, there is decrease in volume. Thus, increase of pressure will favour the dissolution of gas in liquid.

1. A gas 'X' when dissolved in water heat is evolved. Then solublity of 'X' will increase :

(A) Low pressure, high temperature
(B) Low pressure, low temperature
(C) high pressure, high temperature
(D) high pressure, low temperature

2. $Au(s) \rightleftharpoons Au(\ell)$

Above equilibrium is favoured at :

(A) High pressure low temperature
(B) High pressure high temperature
(C) Low pressure, high temperature
(D) Low pressure, low temperature

3.* For the reaction, $\frac{1}{2}N_2(g) + \frac{1}{2}O_2(g) \rightleftharpoons NO(g)$

If pressure is increased by reducing the volume of the container then :

(A) Total pressure at equilibrium will change.
(B) Concentration of all the component at equilibrium will change.
(C) Concentration of all the component at equilibrium will remain same
(D) Equilibrium will shift in the forward direction

Comprehension # 2

Effect of temperature on the equilibrium process is analysed by using the thermodynamics

From the thermodynamics relation

$\Delta G^o = -2.30\ RT \log k$ .... (1) ΔG^o : Standard free energy change

$\Delta G^o = \Delta H^o - T\Delta S^o$ .... (2) ΔH^o : Standard heat of the reaction.

From (1) & (2)

$-2.3\ RT \log k = \Delta H^o - T\Delta S^o$ ΔS^o : Standard entropy change

$$\Rightarrow \quad \log K = -\frac{\Delta H^o}{2.3RT} + \frac{\Delta S^o}{2.3\ R} \quad .... (3)$$

Clearly if a plot of log k vs 1/T is made then it is a straight line having slope = $\frac{-\Delta H^o}{2.3\ R}$

and Y intercept = $\frac{\Delta S^\circ}{2.3\ R}$

If at temp. T_1 equilibrium constant be k_1 and at temperature T_2 equilibrium constant be k_2 then :
The above equation reduces to:

$\Rightarrow$ $\log K_1 = -\frac{\Delta H^o}{2.3\ R\ T_1} + \frac{\Delta S^o}{2.3\ R}$ .... (4)

$\Rightarrow$ $\log K_2 = -\frac{\Delta H^o}{2.3\ R\ T_2} + \frac{\Delta S^o}{2.3\ R}$ .... (5)

Substracting (4) from (5) we get

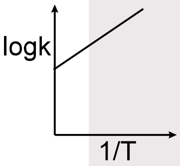
$$\Rightarrow \quad \log\frac{K_2}{K_1} = \frac{\Delta\ H^o}{2.30\ R}\left(\frac{1}{T_1} - \frac{1}{T_2}\right)$$

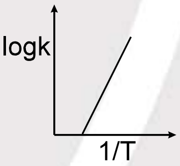
From the above relation we can conclude that the value of equilibrium constant increases with increase in temperature for endothermic reaction but value of equilibrium constant decreases with the increase in temperature for exothermic reaction.

4. If standard heat of dissociation of PCl_5 is 230 cal then slope of the graph of logk vs $\frac{1}{T}$ is :

(A) +50 (B) – 50 (C) 10 (D) None

5. For exothermic reaction if $\Delta S_0 < 0$ then the sketch of logk vs $\frac{1}{T}$ may be :

(A)


(B)


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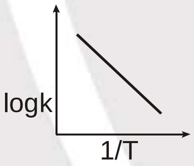
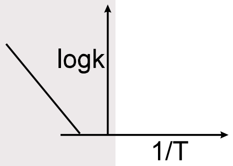


(D)


6. If for a particular reversible reaction $K_C = 57$ at 355ºC and $K_C = 69$ at 450ºC then :

(A) $\Delta H < 0$
(B) $\Delta H > 0$
(C) $\Delta H = 0$
(D) ΔH whose sign can't be determined

Comprehension # 3

Answer Q.7, Q.8 and Q.9 by appropriately matching the information given in the three columns of the following table.

Equilibrium is a state in which there are no observable changes as time goes by. When a chemical reaction has reached the equilibrium state, the concentrations of reactants and products remain constant over time and there are no visible changes in the system. However, there is much activity at the molecular level because reactant molecules continue to from product molecules while product molecules react to yield reactant molecules. If a change is applied to the system at equilibrium, then equilibrium will be shifted in that direction in which it can minimise the effect of change applied and the equilibrium is established again under new conditions.

Column-1		**Column-2**		**Column-3**	
(I)	$2NH_{3(g)} \rightleftharpoons N_{2(g)} + 3H_{2(g)}$	(i)	Homogeneous	(P)	If $\alpha = \frac{1}{2}$ & $P_{\text{total at equilibrium}} = 1$ atm, $K_P \leq 1$
(II)	$N_2O_{4(g)} \rightleftharpoons 2NO_{2(g)}$	(ii)	$K_P > K_C$ (T = 298k)	(Q)	On increasing temperature, yield of reaction increases
(III)	$2O_{3(g)} \rightleftharpoons 3O_{2(g)}$	(iii)	Degree of dissociation is not affected by pressure	(R)	On increasing pressure, vapour density of equilibrium mixture decreases
(IV)	$2HI_{(g)} \rightleftharpoons H_{2(g)} + I_{2(g)}$	(iv)	$M_{\text{theoritical}} \geq M_{\text{experimental}}$	(S)	Products are paramagnetic in nature

7.* Incorrect combination is
(A) (I) (i) (p) (B) (II) (ii) (Q) (C) (III) (iii) (Q) (D) (IV) (iv) (S)

8. Correct combination is
(A) (IV) (ii) (Q) (B) (III) (i) (S) (C) (II) (iv) (R) (D) (II) (iii) (S)

9.* Correct combination is
(A) (I) (iii) (R) (B) (II) (iv) (S) (C) (III) (iv) (Q) (D) (IV) (iii) (P)

Exercise-3

*** Marked Questions may have more than one correct option.**

PART - I : JEE (ADVANCED) / IIT-JEE PROBLEMS (PREVIOUS YEARS)

1. For a chemical reaction $3X(g) + Y(g) \rightleftharpoons X_3Y(g)$, the amount of X_3Y at equilibrium is affected by
(A) temperature and pressure (B) temperature only
(C) pressure only (D) temperature, pressure and catalyst **[JEE-1999, 2/80]**

2. For the reversible reaction, $N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3$ at 500°C, the value of K_P is 1.44×10^{-5} when partial pressure is measured in atmospheres. The corresponding value of K_C, with concentration in mole litre^{-1}, is **[JEE 2000, 1/35]**
(A) $\dfrac{1.44\times10^{-5}}{(0.082\times500)^{-2}}$ (B) $\dfrac{1.44\times10^{-5}}{(8.314\times773)^{-2}}$ (C) $\dfrac{1.44\times10^{-5}}{(0.082\times773)^{2}}$ (D) $\dfrac{1.44\times10^{-5}}{(0.082\times773)^{-2}}$

3. When two reactants, A & B are mixed to give products C & D, the reaction quotient Q, at the initial stages of the reaction. **[JEE-2000, 1/35]**
(A) is zero (B) decrease with time
(C) is independent of time (D) increases with time

4. At constant temperature, the equilibrium constant (K_P) for the decomposition reaction $N_2O_4 \rightleftharpoons 2NO_2$ is expressed by $K_P = \dfrac{(4x^2\ P)}{(1-x^2)}$, where P = pressure, x = extent of decomposition. Which one of the following statements is true? **[JEE 2001, 1/35]**
(A) K_P increases with increase of P (B) K_P increases with increase of x
(C) K_P increases with decrease of x (D) K_P remains constant with change in P and x

5. Consider the following equilibrium in a closed container **[JEE 2002, 3/90]**
$$N_2O_4(g) \rightleftharpoons 2NO_2(g)$$
At a fixed temperature, the volume of the reaction container is halved. For this change, which of the following statements holds true regarding the equilibrium constant (K_P) and degree of dissociation (α)?
(A) neither K_P nor α changes (B) both K_P and α change
(C) K_P changes, but α does not change (D) K_P does not change but α changes

6. The value of $\log_{10}K$ for a reaction $A \rightleftharpoons B$ is : (Given : $= \Delta_r H^\circ_{298K}$ -54.07 kJ mol^{-1}, $\Delta_r S^\circ_{298K} = 10$ JK^{-1} mol^{-1} and R = 8.314 JK^{-1} mol^{-1}; $2.303 \times 8.314 \times 298 = 5705$) **[JEE 2007, 3/162]**
(A) 5 (B) 10 (C) 95 (D) 100

7.* The thermal dissociation equilibrium of $CaCO_3(s)$ is studied under different conditions.
$CaCO_3(s) \rightleftharpoons CaO(s) + CO_2(g)$
For this equilibrium, the correct statement(s) is (are) : **[JEE(Advanced) 2013, 3/120]**
(A) ΔH is dependent on T
(B) K is independent of the initial amount of $CaCO_3$
(C) K is dependent on the pressure of CO_2 at a given T
(D) ΔH is independent of the catalyst, if any

Paragraph 1

Thermal decomposition of gaseous X_2 to gaseous X at 298 K takes place according to the following equation :

$$X_2(g) \rightleftharpoons 2X(g)$$

The standard reaction Gibbs energy, Δ_rG^o, of this reaction is positive. At the start of the reaction, there is one mole of X_2 and no X. As the reaction proceeds, the number of moles of X formed is given by β. Thus. $\beta_{equilibrium}$ is the number of moles of X formed at equilibrium. The reaction is carried out at a constant total pressure of 2 bar. Consider the gases to behave ideally. (Given : R = 0.083 L bar K^{-1} mol^{-1})

8. The equilibrium constant K_p for this reaction at 298 K, in terms of $\beta_{equilibrium}$, is **[JEE(Advanced) 2016, 3/124]**

(A) $\dfrac{8\beta^2_{equilibrium}}{2-\beta_{equilibrium}}$ (B) $\dfrac{8\beta^2_{equilibrium}}{4-\beta^2_{equilibrium}}$ (C) $\dfrac{4\beta^2_{equilibrium}}{2-\beta_{equilibrium}}$ (D) $\dfrac{4\beta^2_{equilibrium}}{4-\beta^2_{equilibrium}}$

9. The **INCORRECT** statement among the following, for this reaction, is **[JEE(Advanced) 2016, 3/124]**

(A) Decrease in the total pressure will result in formation of more moles of gaseous X
(B) At the start of the reaction, dissociation of gaseous X_2 takes place spontaneously
(C) $\beta_{equilibrium}$ = 0.7
(D) $K_C < 1$

PART - II : JEE (MAIN) / AIEEE PROBLEMS (PREVIOUS YEARS)

OFFLINE JEE-MAIN

1. Change in volume of the system does not alter the number of moles in which of the following equilibriums: **[AIEEE 2002, 3/225]**

(1) $N_2(g) + O_2(g) \rightleftharpoons 2NO(g)$ (2) $PCl_5(g) \rightleftharpoons PCl_3(g) + Cl_2(g)$
(3) $N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$ (4) $SO_2Cl_2(g) \rightleftharpoons SO_2(g) + Cl_2(g)$

2. In which of the following reactions, increase in the volume at constant temperature don't effect the number of moles of at equilibrium : **[AIEEE 2002, 3/225]**

(1) $2NH_3 \rightleftharpoons N_2 + 3H_2$ (2) $C(g) + (1/2)\, O_2(g) \rightleftharpoons CO\ (g)$
(3) $H_2\ (g) + O_2\ (g) \rightleftharpoons H_2O_2\ (g)$ (4) none of these.

3. For the reaction $CO\ (g) + (1/2)\ O_2\ (g) \rightleftharpoons CO_2\ (g)$, K_c/K_p is : **[AIEEE 2002, 3/225]**

(1) RT (2) $(RT)^{-1}$ (3) $(RT)^{-1/2}$ (4) $(RT)^{1/2}$

4. Consider the reaction equilibrium

$$2SO_2\,(g) + O_2\,(g) \rightleftharpoons 2SO_3\,(g)\ ;\ \Delta H° = -\,198\ kJ.$$

On the basis of Le Chatelier's principle, the condition favourable for the forward reaction is : **[AIEEE 2003, 3/225]**

(1) lowering of temperature as well as pressure
(2) increasing temperature as well as pressure
(3) lowering the temperature and increasing the pressure
(4) any value of temperature and pressure.

5. For the reaction equilibrium, $N_2O_4(g) \rightleftharpoons 2NO_2(g)$ the concentrations of N_2O_4 and NO_2 at equilibrium are 4.8×10^{-2} and 1.2×10^{-2} mol L^{-1} respectively. The value of K_c for the reaction is **[AIEEE 2003, 3/225]**

(1) 3.3×10^2 mol L^{-1} (2) 3×10^{-1} mol L^{-1} (3) 3×10^{-3} mol L^{-1} (4) 3×10^3 mol L^{-1}

6. What is the equilibrium constant expression for the reaction : **[AIEEE 2004, 3/225]**

$$P_4\,(s) + 5O_2\,(g) \rightleftharpoons P_4O_{10}\,(s)\ ?$$

(1) $K_C = [P_4O_{10}]/[P_4]\,[O_2]^5$ (2) $K_C = 1/[O_2]^5$
(3) $K_C = [O_2]^5$ (4) $K_C = [P_4O_{10}]\,/\,5[P_4]\,[O_2]$

7. For the reaction, $CO(g) + Cl_2\,(g) \rightleftharpoons COCl_2\,(g)$ then $K_p\,/\,K_c$ is equal to : **[AIEEE 2004, 3/225]**

(1) 1/RT (2) 1.0 (3) $\sqrt{RT}$ (4) RT

8. The equilibrium constant for the reaction, $N_2(g) + O_2(g) \rightleftharpoons 2NO(g)$ at temperature T is 4×10^{-4} . The value of K_c for the reaction, $NO(g) \rightleftharpoons \frac{1}{2} N_2(g) + \frac{1}{2} O_2(g)$ at the same temperature is :

[AIEEE 2004, 3/225 & JEE(Main) 2012, 4/120]

(1) 2.5×10^2 (2) 0.02 (3) 4×10^{-4} (4) 50

9. For the reaction, $2NO_2(g) \rightleftharpoons 2NO(g) + O_2(g)$,
($K_C = 1.8 \times 10^{-6}$ at 184°C)
(R = 0.0831 kJ/(mol.K))
When K_p and K_c are compared at 184°C it is found that : **[AIEEE 2005, 3/225]**
(1) Whether K_p is greater than, less than or equal to K_c depends upon the total gas pressure
(2) $K_p = K_c$
(3) K_p is less than K_c
(4) K_p is greater than K_c

10. The exothermic formation of ClF_3 is represented by the equation $Cl_2(g)+3F_2(g) \rightleftharpoons 2ClF_3(g);\Delta_rH = -329$ J which of the following will increase the quantity of ClF_3 in an equilibrium mixture of Cl_2, F_2 and ClF_3.

[AIEEE 2005, 3/225]

(1) Adding F_2 (2) Increasing the volume of container
(3) Removing Cl_2 (4) Increasing the temperature

11. An amount of solid NH_4HS is placed in a flask already containing ammonia gas at a certain temperature at 0.50 atm pressure. Ammonium hydrogen sulphide decomposes to yield NH_3 and H_2S gases in the flask. When the decomposition reaction reaches equilibrium, the total pressure in the flask rises to 0.84 atm? The equilibrium constant for NH_4HS decomposition at this temperature is : **[AIEEE 2005, 4½/225]**
(1) 0.11 (2) 0.17 (3) 0.18 (4) 0.30

12. Phosphorus pentachloride dissociates as follows in a closed reaction vessel.

$$PCl_5(g) \rightleftharpoons PCl_3(g) + Cl_2(g)$$

If total pressure at equilibrium of the reaction mixture is P and degree of dissociation of PCl_5 is x, the partial pressure of PCl_3 will be : **[AIEEE 2006, 3/165]**

(1) $\left(\frac{x}{x+1}\right)P$ (2) $\left(\frac{2x}{1-x}\right)P$ (3) $\left(\frac{x}{x+1}\right)P$ (4) $\left(\frac{x}{1-x}\right)P$

13. The equilibrium constant for the reaction, $SO_3(g) \rightleftharpoons SO_2(g) + \frac{1}{2}O_2(g)$ is $K_C = 4.9 \times 10^{-2}$. The value of K_C for the reaction $2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$ will be : **[AIEEE 2006, 3/165]**
(1) 416 (2) 2.40×10^{-3} (3) 9.8×10^{-2} (4) 4.9×10^{-2}

14. For the following three reactions a, b and c, equilibrium constants are given:
(a) $CO(g) + H_2O(g) \rightleftharpoons CO_2(g) + H_2(g)$; K_1
(b) $CH_4(g) + H_2O(g) \rightleftharpoons CO(g) + 3H_2(g)$; K_2
(c) $CH_4(g) + 2H_2O(g) \rightleftharpoons CO_2(g) + 4H_2(g)$; K_3
Which of the following relations is correct ? **[AIEEE 2008, 3/105]**
(1) $K_2 K_3 = K_1$ (2) $K_3 = K_1K_2$ (3) $K_3 K_2^3 = K_1^2$ (4) $K_1\sqrt{K_2} = K_3$

15. The equilibrium constants K_{p_1} and K_{p_2} for the reactions $X \rightleftharpoons 2Y$ and $Z \rightleftharpoons P + Q$, respectively are in the ratio of 1 : 9. If the degree of dissociation of X and Z be equal then the ratio of total pressures at these equilibria is **[AIEEE 2008, 3/105]**
(1) 1 : 1 (2) 1 : 3 (3) 1 : 9 (4) 1 : 36

16. A vessel at 1000 K contains CO_2 with a pressure of 0.5 atm. Some of the CO_2 is converted into CO on the addition of graphite. If the total pressure at equilibrium is 0.8 atm, the value of K is :

[AIEEE 2011, 4/120]

(1) 1.8 atm (2) 3 atm (3) 0.3 atm (4) 0.18

17. The equilibrium constant (K_c) for the reaction $N_2(g) + O_2(g) \rightleftharpoons 2NO(g)$ at temperature T is 4×10^{-4}. The value of K_c for the reaction $NO(g) \rightleftharpoons \frac{1}{2}N_2(g) + \frac{1}{2}O_2(g)$ at the same temperature is: **[AIEEE 2012, 4/120]**

(1) 0.02 (2) 2.5×10^2 (3) 4×10^{-4} (4) 50.0

18. For the reaction $SO_{2(g)} + \frac{1}{2}O_{2(g)} \rightleftharpoons SO_{3(g)}$, if $K_P = K_C(RT)^x$ where the symbols have usual meaning then the value of x is : (assuming ideality) **[JEE(Main) 2014, 4/120]**

(1) –1 (2) $-\frac{1}{2}$ (3) $\frac{1}{2}$ (4) 1

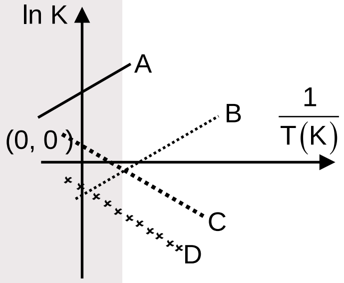
19. The standard Gibbs energy change at 300 K for the reaction $2A \rightleftharpoons B + C$ is 2494.2 J. At a given time, the composition of the reaction mixture is $[A] = \frac{1}{2}$, $[B] = 2$ and $[C] = \frac{1}{2}$. The reaction proceeds in the : [R = 8.314 J/K/mol, e = 2.718] **[JEE(Main) 2015, 4/120]**

(1) forward direction because $Q > K_C$ (2) reverse direction because $Q > K_C$
(3) forward direction because $Q < K_C$ (4) reverse direction because $Q < K_C$

20. The equilibrium constant at 298 K for a reaction $A + B \rightleftharpoons C + D$ is 100. If the initial concentration of all the four species were 1 M each, then equilibrium concentration of D (in mol L^{-1}) will be : **[JEE(Main) 2016, 4/120]**

(1) 0.818 (2) 1.818 (3) 1.182 (4) 0.182

21. Which of the following lines correctly show the temperature dependence of equilibrium constant, K, for an exothermic reaction ? **[JEE(Main) 2018, 4/120]**



(1) C and D
(2) A and D
(3) A and B
(4) B and C

ONLINE JEE-MAIN

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1. At a certain temperature, only 50% HI is dissociated into H_2 and I_2 at equilibrium. The equilibrium constant is: **[JEE(Main) 2014 Online (09-04-14), 4/120]**

$2HI_{(g)} \rightleftharpoons H_{2(g)} + I_{2(g)}$

(1) 1.0 (2) 3.0 (3) 0.5 (4) 0.25

2. What happens when an inert gas is added to an equilibrium keeping volume unchanged ? **[JEE(Main) 2014 Online (12-04-14), 4/120]**

(1) More product will form (2) Less product will form
(3) More reactant will form (4) Equilibrium will remain unchanged

3. For the decomposition of the compound, represented as $NH_2COONH_4(s) \rightleftharpoons 2NH_3(g) + CO_2(g)$ the $K_p = 2.9 \times 10^{-5}$ atm^3. If the reaction is started with 1 mol of the compound, the total pressure at equilibrium would be : **[JEE(Main) 2014 Online (19-04-14), 4/120]**

(1) 1.94×10^{-2} atm (2) 5.82×10^{-2} atm
(3) 7.66×10^{-2} atm (4) 38.8×10^{-2} atm

4. Gaseous N_2O_4 dissociates into gaseous NO_2 according to the reaction $N_2O_4(g) \rightleftharpoons 2NO_2(g)$ at 300 K and 1 atm pressure, the degree of dissociation of N_2O_4 is 0.2. If one mole of N_2O_4 gas is contained in a vessel, then the density of the equilibrium mixture is : **[JEE(Main) 2015 Online (10-04-15), 4/120]**

(1) 3.11 g/L (2) 4.56 g/L (3) 1.56 g/L (4) 6.22 g/L

5. The increase of pressure on ice $\rightleftharpoons$ water system at constant temperature will lead to :

[JEE(Main) 2015 Online (11-04-15), 4/120]

(1) a decrease in the entropy of the system (2) an increase in the Gibbs energy of the system
(3) no effect on the equilibrium (4) a shift of the equilibrium in the forward direction

6. A solid XY kept in an evacuated sealed container undergoes decomposition to form a mixture of gases X and Y at temperature T. The equilibrium pressure is 10 bar in this vessel. K_P for this reaction is :

[JEE(Main) 2016 Online (10-04-16), 4/120]

(1) 25 (2) 5 (3) 10 (4) 100

7. The following reaction occurs in the Blast Furnace where iron ore is reduced to iron metal :

$Fe_2O_3(s) + 3CO(g) \rightleftharpoons 2Fe(\ell) + 3CO_2(g)$

Using the Le Chatelier's principle, predict which one of the following will **not** disturb the equilibrium ?

[JEE(Main) 2017 Online (09-04-17), 4/120]

(1) Addition of Fe_2O_3 (2) Removal of CO_2 (3) Removal of CO (4) Addition of CO_2

8. In which of the following reactions, an increase in the volume of the container will favour the formation of products ? **[JEE(Main) 2018 Online (15-04-18), 4/120]**

(1) $4NH_3(g) + 5O_2(g) \rightleftharpoons 4NO(g) + 6H_2O(\ell)$ (2) $2NO_2(g) \rightleftharpoons 2NO(g) + O_2(g)$
(3) $3O_2(g) \rightleftharpoons 2O_3(g)$ (4) $H_2(g) + I_2(g) \rightleftharpoons 2HI(g)$

9. At a certain temperature in a 5 L vessel, 2 moles of carbon monoxide and 3 moles of chlorine were allowed to reach equilibrium according to the reaction,

$CO + Cl_2 \rightleftharpoons COCl_2$

At equilibrium if one mole of CO is present then equilibrium constant K_C for reaction is :

[JEE(Main) 2018 Online (15-04-18), 4/120]

(1) 2 (2) 2.5 (3) 3 (4) 4

10. At 320 K, a gas A_2 is 20 % dissociated to A(g). The standard free energy change at 320 K and 1 atm in J mol^{-1} is approximately : (R = 8.314 JK^{-1} mol^{-1} ; ln 2 = 0.693 ; ln 3 = 1.098)

[JEE(Main) 2018 Online (16-04-18), 4/120]

(1) 1844 (2) 2068 (3) 4281 (4) 4763

11. The gas phase reaction $2NO_2(g) \rightarrow N_2O_4(g)$ is an exothermic reaction. The decomposition of N_2O_4, in equilibrium mixture of $NO_2(g)$ and $N_2O_4(g)$, can be increased by :

[JEE(Main) 2018 Online (16-04-18), 4/120]

(1) addition of an inert gas at constant pressure. (2) lowering the temperature
(3) increasing the pressure (4) addition of an inert gas at constant volume.

12. Consider the following reversible chemical reactions :

$A_2(g) + B_2(g) \overset{K_1}{\rightleftharpoons} 2AB(g)$ ……(1)

$6AB(g) \overset{K_2}{\rightleftharpoons} 3A_2(g) + 3B_2(g)$ ……(2)

The relation between K_1 and K_2 is : **[JEE(Main) 2019 Online (09-01-19), 4/120]**

(1) $K_1K_2 = \frac{1}{3}$ (2) $K_2 = K_1^{-3}$ (3) $K_1K_2 = 3$ (4) $K_2 = K_1^{3}$

13. The values of K_P/K_C for the following reactions at 300 K are, respectively : (At 300 K, RT = 24.62 dm^3 atm mol^{-1})

$N_2(g) + O_2(g) \rightleftharpoons 2NO(g)$
$N_2O_4(g) \rightleftharpoons 2NO_2(g)$
$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$

[JEE(Main) 2019 Online (10-01-19), 4/120]

(1) 1,4.1 × 10^{-2} dm^{-3} atm^{-1} mol, 606 dm^6 atm^2mol^{-2}
(2) 1,24.62 dm^3 atm mol^{-1}, 1.65 × 10^{-3} dm^{-6} $atm^{-2}mol^2$
(3) 24.62 dm^3 atm mol^{-1} 606.0 dm^6 atm^2 mol^{-2}, 1.65 × 10^{-3} dm^{-6} atm^{-2} mol^2
(4) 1,24.62 dm^3 atm mol^{-1}, 606.0 dm^6 atm^2mol^{-2}

14. 5.1 g NH_4SH is introduced in 3.0 L evacuated flask at 327°C. 30% of the solid NH_4SH decomposed to NH_3 and H_2S as gases. The K_p of the reaction at 327°C is (R = 0.082 L atm $mol^{-1}K^{-1}$, molar mass of S = 32 g mol^{-1}, molar mass of N = 14 g mol^{-1}) **[JEE(Main) 2019 Online (10-01-19), 4/120]**

(1) 4.9×10^{-3} atm^2 (2) 0.242×10^{-4} atm^2 (3) 1×10^{-4} atm^2 (4) 0.242 atm^2

15. Consider the reaction, $N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$. The equilibrium constant of the above reaction is K_P. If pure ammonia is left to dissociate, the partial pressure of ammonia at equilibrium is given by (Assume that $p_{NH_3} \ll p_{total}$ at equilibrium) **[JEE(Main) 2019 Online (11-01-19), 4/120]**

(1) $\dfrac{3^{3/2}K_p^{1/2}P^2}{16}$ (2) $\dfrac{3^{3/2}K_p^{1/2}P^2}{4}$ (3) $\dfrac{K_p^{1/2}P^2}{4}$ (4) $\dfrac{K_p^{1/2}P^2}{16}$

16. In a chemical reaction, $A + 2B \overset{K}{\rightleftharpoons} 2C+D$, the initial concentration of B was 1.5 times of the concentration of A, but the equilibrium concentrations of A and B were found to be equal. The equilibrium constant (K) for the aforesaid chemical reaction is : **[JEE(Main) 2019 Online (12-01-19), 4/120]**

(1) 16 (2) 1 (3) 1/4 (4) 4

17. Two solids dissociate as follows

$A(s) \rightleftharpoons B(g) + C(g)$; $K_{P_1} = x \text{ atm}^2$

$D(s) \rightleftharpoons C(g) + E(g)$; $K_{P_2} = y \text{ atm}^2$

The total pressure when both the solids dissociate simultaneously is :

[JEE(Main) 2019 Online (12-01-19), 4/120]

(1) $\sqrt{x+y}$ atm (2) (x + y) atm (3) $x^2 + y^2$ atm (4) $2\left(\sqrt{x+y}\right)$ atm

Answers

EXERCISE - 1

PART - I

A-1. 4

A-2. 0.044 M.

B-1. (a) 0.1 (b) 0.4

B-2. $\frac{100\%}{6}$

B-3. 1/3M

B-4. 0.66

C-1. $\frac{P(n+y/2)(n+y)^2}{(3n+y/2)(n-y)^2}$

C-2. $K_P = 12$

C-3. $[NH_3] = 0.76$ M

D-1. $K_C = \frac{4x^2V^2}{(a-x)(b-3x)^3}$; $K_P = \frac{(a+b-2x)^2.4x^2}{P^2(a-x)(b-3x)^3}$

D-2. $[A]_{eq} = [B]_{eq} = [C]_{eq} = 1/2$ M, $K_p = 12.3$ atm, $K_c = 0.5$ M (unitless).

D-3. (i) $K_c = \frac{20000}{343} = 58.3\ mol^{-2}\ L^{2,}$ $K_P = \frac{58.3}{41\times 41} = 0.035\ atm^{-2}$ (ii) P = 8.2 atm

E-1. The reaction is $N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$

$$Q_c = \frac{[NH_3]^2}{[N_2][H_2]^3} = \frac{8\times 8\times 20\times 20}{\frac{3}{2}\times 2\times 2\times 2} = \frac{64}{3}\times 10^2$$

As $Q_c \neq K_c$, the reaction mixture is not in equilibrium.
As $Q_c > K_c$, the net reaction will be in the backward direction.

E-2. $[SO_2] = 0.034$ M ; $[NO_2] = 0.034$ M ; $[NO] = 0.306$ M ; $[SO_3] = 0.306$ M

F-1. (i) No change (ii) 1/k (iii) No change (iv) Change the equilibrium constant

F-2. For the required reaction, $K = K_1 \times K_2$.

F-3. 2.58

G-1. X = 4

H-1.

(i)	Homogeneous equilibrium	$K_C = \frac{[NO_2]^2}{[N_2O_4]}$	$K_P = \frac{(P_{NO_2})^2}{(P_{N_2O_4})}$
(ii)	Hetereogeneous equilibrium	$K_C = \frac{[H_2]^4}{[H_2O]^4}$	$K_P = \frac{(P_{H_2})^4}{(P_{H_2O})^4}$
(iii)	Hetereogeneous equilibrium	$K_C = [NH_3]\ [H_2S]$	$K_P = (P_{NH_3})\ (P_{H_2S})$
(iv)	Homogeneous equilibrium	$K_C = \frac{[CH_3COOC_2H_5]\ [H_2O]}{[CH_3COOH]\ [C_2H_5OH]}$	but K_P is not define for liquid system
(v)	Hetereogeneous equilibrium	$K_C = [CO_2]$	$K_P = (P_{CO_2})$
(vi)	Homogeneous equilibrium	$K_C = \frac{[H_2]^2\ [S_2]}{[H_2S]^2}$	$K_P = \frac{(P_{H_2})^2\ (P_{S_2})}{(P_{H_2S})^2}$
(vii)	Homogeneous equilibrium	$K_C = \frac{[SO_3]\ [NO]}{[SO_2][NO_2]}$	$K_P = \frac{(P_{SO_3})\ (P_{NO})}{(P_{SO_2})(P_{NO_2})}$
(viii)	Hetereogeneous equilibrium	$K_C = [N_2]$	$K_P = (P_{N_2})$

H-2. 50%

H-3. $K_P = \frac{2}{3^{3/2}}P^{3/2}$

I-1. (i) 0.266 atm (ii) 63.25% **I-2.** $x = \left[\frac{2\ K_P}{P}\right]^{1/3}$

I-3. (i) 76.66, (ii) 0.2, (iii) 33.33 %, (iv) 1/3 **I-4.** 2.55 atm^3 **J-1.** $K_P = 1.86 \times 10^{12}\ atm^{-1/2}$

J-2. ⇒ reaction (iii) is exothermic.

K-1. (i) unaffected; no shift (ii) affected; left direction. (iii) affected; left (iv) affected; right

K-2. (i) When decreasing temperature
(a) Forward (b) Forward (c) Backward (d) Forward
(ii) Increasing the pressure
(a) Forward (b) No change (c) Backward (d) Forward

K-3. (a) 4×10^{-3} (b) (i) decrease (ii) no change (iii) increase (iv) increase (v) no change (vi) increase

K-4. [A] = 0.34 M, [B] = 1.16 M, [C] = 1.16 M. **L-1.** below 50%

L-2. 5×10^{-3} atm. **M-1.** (a) $K_{p_1} = 625\ mm^2$, $K_{p_2} = 900\ mm^2$ (b) $\frac{25}{36}$

M-2. (a) 1.05 atm, (b) 3.43 atm^{-1}

PART – II

A-1. (D) **A-2.** (D) **A-3.** (B) **A-4.** (D) **A-5.** (D)

B-1. (A) **B-2.** (A) **B-3.** (A) **B-4.** (C) **B-5.** (B)

B-6. (B) **C-1.** (B) **C-2.** (B) **C-3.** (B) **C-4.** (A)

C-5. (C) **C-6.** (C) **C-7.** (A) **D-1.** (C) **D-2.** (A)

D-3. (B) **E-1.** (D) **E-2.** (B) **E-3.** (C) **E-4.** (C)

E-5. (A) **E-6.** (D) **F-1.** (C) **F-2.** (D) **F-3.** (B)

G-1. (B) **H-1.** (A) **H-2.** (B) **H-3.** (C) **H-4.** (B)

H-5. (C) **I-1.** (B) **I-2.** (B) **I-3.** (A) **I-4.** (B)

I-5. (A) **I-6.** (B) **I-7.** (B) **I-8.** (C) **I-9.** (A)

I-10. (A) **J-1.** (A) **J-2.** (B) **J-3.** (A) **J-4.** (C)

J-5. (B) **J-6.** (C) **J-7.** (A) **K-1.** (D) **K-2.** (B)

K-3. (B) **K-4.** (C) **K-5.** (B) **K-6.** (B) **K-7.** (B)

L-1. (A) **L-2.** (A) **L-3.** (C) **M-1.** (D) **M-2.** (A)

M-3. (C)

PART – III

1. (A - q, s) ; (B - p) ; (C - p) ; (D - r) **2.** (A - r) ; (B - r) ; (C - q) ; (D - p)

EXERCISE – 2

PART – I

1.	(B)	**2.**	(B)	**3.**	(A)	**4.**	(A)	**5.**	(C)
6.	(B)	**7.**	(B)	**8.**	(B)	**9.**	(A)	**10.**	(B)
11.	(D)	**12.**	(D)	**13.**	(A)	**14.**	(A)	**15.**	(C)
16.	(C)								

PART – II

1.	05	**2.**	3	**3.**	7	**4.**	4	**5.**	4
6.	78 mole	**7.**	5	**8.**	4	**9.**	15	**10.**	50
11.	58								

PART – III

1.	(ABC)	**2.**	(ABD)	**3.**	(ABCD)	**4.**	(ACD)	**5.**	(AB)
6.	(AC)	**7.**	(BC)	**8.**	(ABCD)	**9.**	(ABCD)	**10.**	(AB)
11.	(BD)	**12.**	(BCD)	**13.**	(ABCDE)	**14.**	(BCD)	**15.**	(ABC)
16.	(ACD)	**17.**	(BD)						

PART – IV

1.	(D)	**2.**	(C)	**3.***	(AB)	**4.**	(B)	**5.**	(B)
6.	(B)	**7.***	(CD)	**8.**	(B)	**9.***	(BD)		

EXERCISE – 3

PART - I

1.	(A)	**2.**	(D)	**3.**	(D)	**4.**	(D)	**5.**	(D)
6.	(B)	**7.***	(ABD)	**8.**	(B)	**9.**	(C)		

PART – II

OFFLINE JEE-MAIN

1.	(1)	**2.**	(4)	**3.**	(4)	**4.**	(3)	**5.**	(3)
6.	(2)	**7.**	(1)	**8.**	(4)	**9.**	(4)	**10.**	(1)
11.	(1)	**12.**	(1)	**13.**	(1)	**14.**	(2)	**15.**	(4)
16.	(1)	**17.**	(4)	**18.**	(2)	**19.**	(2)	**20.**	(2)
21.	(3)								

ONLINE JEE-MAIN

1.	(4)	**2.**	(4)	**3.**	(2)	**4.**	(1)	**5.**	(4)
6.	(1)	**7.**	(1)	**8.**	(2)	**9.**	(2)	**10.**	(4)
11.	(1)	**12.**	(2)	**13.**	(2)	**14.**	(4)	**15.**	(1)
16.	(4)	**17.**	(4)						