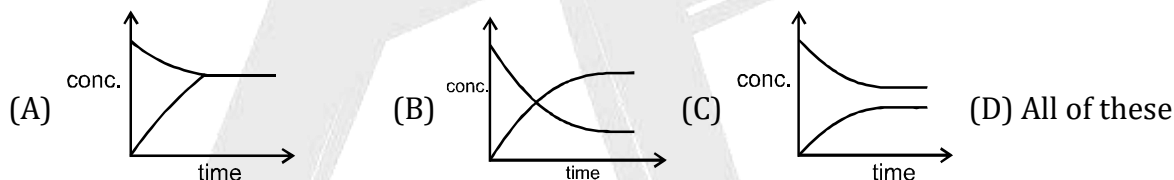


EXERCISE # O-I

Characteristics of Equilibrium State

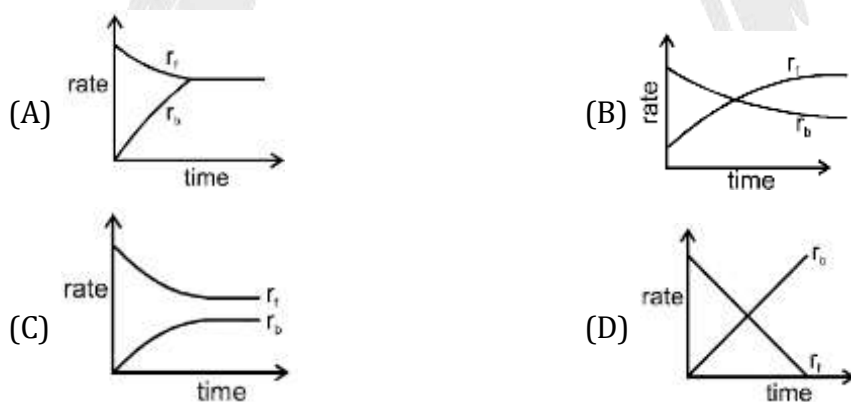
1. A chemical reaction is at equilibrium when
- (A) Reactants are completely transformed into products
 - (B) The rates of forward and backward reactions are equal
 - (C) Formation of products is minimised
 - (D) Equal amounts of reactants and products are present
2. Which of the following statement is incorrect :
- (A) At equilibrium, vapour pressure of solution and refractive index of equilibrium mixture becomes constant.
 - (B) Equilibrium can be attained in both homogenous and heterogeneous reaction.
 - (C) At equilibrium concentration of reactants and products becomes constant and equal.
 - (D) Equilibrium is dynamic in nature

3. Concentrations of reactants and products at equilibrium can be like :

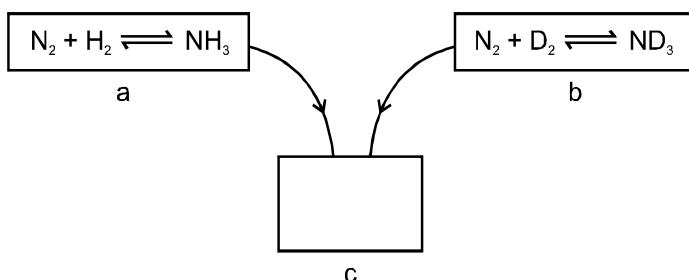


4. Rate of reaction curve for equilibrium can be like :

[r_f = rate of forward, r_b = rate of backward]



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 compounds are –



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

Characteristics of Equilibrium Constant

6. In a chemical equilibrium, the rate constant for the backward reaction is 2×10^{-4} and the equilibrium constant is 1.5. The rate constant for the forward reaction is:-
 (A) 2×10^{-3} (B) 5×10^{-4} (C) 3×10^{-4} (D) 9.0×10^{-4}
7. The equilibrium concentration of B $[(B)_e]$ for the reversible reaction $A \rightleftharpoons B$ can be evaluated by the expression :-
 (A) $K_c [A]_e^{-1}$ (B) $\frac{k_f}{k_b} [A]_e^{-1}$ (C) $k_f k_b^{-1} [A]_e$ (D) $k_f k_b [A]^{-1}$
8. For any reversible reaction if concentration of reactants increases then the equilibrium constant:-
 (A) will change depending on amount of concentration (B) remains same
 (C) will decrease (D) will increase
9. If some He gas is introduced into the equilibrium $PCl_{5(g)} \rightleftharpoons PCl_{3(g)} + Cl_{2(g)}$ at constant pressure and temperature then equilibrium constant of reaction:
 (A) Increase (B) Decrease (C) remains same (D) Nothing can be said
10. The equilibrium constant for the reaction : $N_2(g) + O_2(g) \rightleftharpoons 2NO(g)$ at 2000 K is 4×10^4 . In presence of a catalyst the equilibrium is established ten times faster at the same temperature. What is the value of equilibrium constant in presence of catalyst :
 (A) 40×10^4 (B) 4×10^{-4} (C) 4×10^4 (D) 2.5×10^{-5}

(Physical Chemistry)

CHEMICAL EQUILIBRIUM

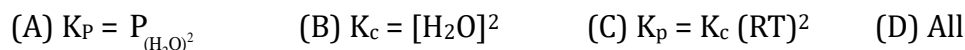
11. The equilibrium constant (K_c) for the reaction $2X(g) + 2Y(g) \longrightarrow 2Z(g)$ is given as :



12. For the reaction

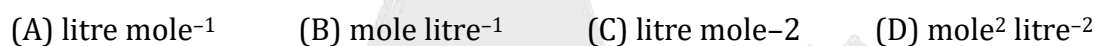


Which one is correct representation :-

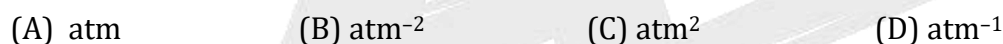
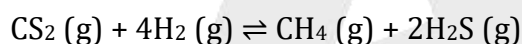


13. For hypothetical equilibrium, $4A(g) + 5B(g) \rightleftharpoons 4X(g) + 6Y(g)$

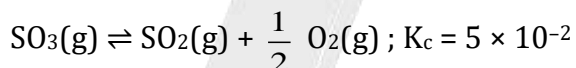
The unit of K_c will be :



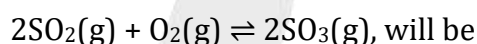
14. What is the unit of K_p for the reaction ?



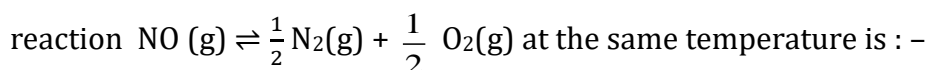
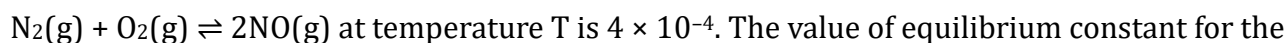
15. The equilibrium constant for the given reaction :



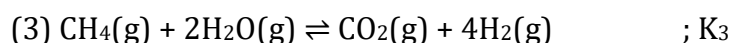
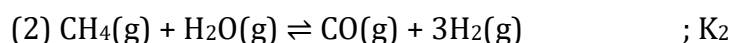
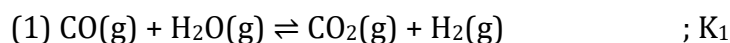
The value of K_c for the reaction



16. The equilibrium constant for the reaction ;



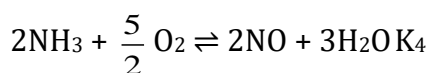
17. For the following three reactions 1, 2 and 3, equilibrium constants are given :



Which of the following relations is correct ?

- (A) $K_1 \sqrt{K_2} = K_3$ (B) $K_2 K_3 = K_1$ (C) $K_3 = K_1 K_2$ (D) $K_3 \cdot K_2^3 K_1^2$

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



Which of the following relation is incorrect.

- (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) $K_4 = \frac{K_2 \times (K_3)^3}{K_1}$

19. Sulfide ion in alkaline solution reacts with solid sulfur to form polysulfide ions having formulas S_2^{2-} , S_3^{2-} , S_4^{2-} and so on. The equilibrium constant for the formation of S_2^{2-} is 12 (K_1) & for the formation of S_3^{2-} is 132 (K_2), both from S and S^{2-} . 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

20. For which reaction is $K_p = K_c$:-

- (A) $2\text{NOCl} \rightleftharpoons 2\text{NO(g)} + \text{Cl}_2\text{(g)}$ (B) $\text{N}_2\text{(g)} + 3\text{H}_2\text{(g)} \rightleftharpoons 2\text{NH}_3\text{(g)}$
(C) $\text{H}_2\text{(g)} + \text{I}_2\text{(g)} \rightleftharpoons 2\text{HI(g)}$ (D) $2\text{SO}_2\text{(g)} + \text{O}_2\text{(g)} \rightleftharpoons 2\text{SO}_3\text{(g)}$

21. $\log \frac{K_p}{K_c} + \log RT = 0$ is true relationship for the following reaction :

- (A) $\text{PCl}_5 \rightleftharpoons \text{PCl}_3 + \text{Cl}_2$ (B) $2\text{SO}_2 + \text{O}_2 \rightleftharpoons 2\text{SO}_3$
(C) $\text{N}_2 + 3\text{H}_2 \rightleftharpoons 2\text{NH}_3$ (D) (B) and (C) both

22. For which reaction at 298 K, the value of $\frac{K_p}{K_c}$ will be maximum and minimum respectively :

- (a) $\text{N}_2\text{O}_4\text{(g)} \rightleftharpoons 2\text{NO}_2\text{(g)}$ (b) $2\text{SO}_2\text{(g)} + \text{O}_2\text{(g)} \rightleftharpoons 2\text{SO}_3\text{(g)}$
(c) $\text{X(g)} + \text{Y(g)} \rightleftharpoons 4\text{Z(g)}$ (d) $\text{A(g)} + 3\text{B(g)} \rightleftharpoons 7\text{C(g)}$
(A) d,c (B) d,b (C) c,b (D) d,a

23. For the following gases equilibrium. $\text{N}_2\text{O}_4(\text{g}) \rightleftharpoons 2\text{NO}_2(\text{g})$
 K_p is found to be equal to K_c . This is attained when temperature is
 (A) 0°C (B) 273 K (C) 1 K (D) 12.19 K

Application of Equilibrium Constant

24. When $K_c \gg 1$ for a chemical reaction,
 (A) the equilibrium would be achieved rapidly
 (B) the equilibrium would be achieved slowly
 (C) product concentrations would be much greater than reactant concentrations at equilibrium
 (D) reactant concentrations would be much greater than product concentrations at equilibrium.

25. Equilibrium constant of some reaction are given as under ;

- (a) $x \rightleftharpoons y$ $K = 10^{-1}$
 (b) $y \rightleftharpoons z$ $K = 2 \times 10^{-2}$
 (c) $P \rightleftharpoons Q$ $K = 3 \times 10^{-4}$
 (d) $R \rightleftharpoons S$ $K = 2 \times 10^{-3}$

Initial concentration of the reactants for each reaction was taken be equal :

Review the above reaction and indicate the reactions in which the reactants and products respectively were of highest concentration :

- (A) d, c (B) c, a (C) a, d (D) b, c

26. The reaction quotient Q for $\text{N}_2(\text{g}) + 3\text{H}_2(\text{g}) \rightleftharpoons 2\text{NH}_3(\text{g})$ is given by $Q = \frac{[\text{NH}_3]^2}{[\text{N}_2][\text{H}_2]^3}$. The

reaction will proceed in backward direction, when

- (A) $Q = K_c$ (B) $Q < K_c$ (C) $Q > K_c$ (D) $Q = 10$

27. 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, $\text{N}_2 + 3\text{H}_2 \rightleftharpoons 2\text{NH}_3$ is $4.28 \times 10^{-5} \text{ atm}^{-2}$ 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

Problems on K_c

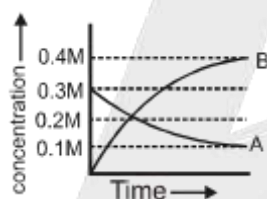
28. What should be the value of K_c for the reaction $2\text{SO}_2(\text{g}) + \text{O}_2(\text{g}) \rightleftharpoons 2\text{SO}_3(\text{g})$, if the amount are $\text{SO}_3 = 48 \text{ g}$, $\text{SO}_2 = 12.8 \text{ g}$ and $\text{O}_2 = 9.6 \text{ g}$ at equilibrium and the volume of the container is one litre?

(A) 64 (B) 30 (C) 42 (D) 8.5

29. A certain quantity of PCl_5 was heated in a 10 litre vessel at 250°C . At equilibrium the vessel contains 0.1 mole of PCl_5 0.20mole of PCl_3 and 0.2 mole of Cl_2 ; The equilibrium constant of the reaction $\text{PCl}_5(\text{g}) \rightleftharpoons \text{PCl}_3(\text{g}) + \text{Cl}_2(\text{g})$ is :

(A) 0.02 (B) 0.05 (C) 0.04 (D) 0.025

30. The figure show the change in concentration of species A and B as a function of time . The equilibrium constant K_c for the reaction $\text{A}(\text{g}) \rightleftharpoons 2\text{B}(\text{g})$ is :



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

31. For the reaction $\text{A} + 2\text{B} \rightleftharpoons 2\text{C} + \text{D}$, initial concentration of A is 'a' and that of B is 1.5 times that of A. Concentration of A and D are same at equilibrium. What should be the concentration of B at equilibrium?

(A) $\frac{a}{4}$ (B) $\frac{a}{2}$ (C) $\frac{3a}{4}$ (D) a

32. What is the minimum mass of $\text{CaCO}_3(\text{s})$ which is required to establish equilibrium in a 6.50 litre container for the reaction : $\text{CaCO}_3(\text{s}) \rightleftharpoons \text{CaO}(\text{s}) + \text{CO}_2(\text{g})$; $K_c = 0.05 \text{ mole/litre}$

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

33. $K_c = 9$ for the reaction, $\text{A} + \text{B} \rightleftharpoons \text{C} + \text{D}$, 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

(Physical Chemistry)

CHEMICAL EQUILIBRIUM

34. For the reaction $3A(g) + B(g) \rightleftharpoons 2C(g)$ at a given temperature, $K_c = 9.0$. What must be the volume of the flask, if a mixture of 2.0 mol each of A, B and C exist in equilibrium ?
 (A) 6L (B) 9L (C) 36 L (D) None of these
35. In the reaction $A(g) + 2B(g) \rightleftharpoons 2C(g)$, if 2 mole of A, 3.0 moles of B and 2.0 moles of C are placed in a 2L flask. If equilibrium concentration of C is 0.5 mole/L. The value of equilibrium constant (K_c) will be:
 (A) 0.073 (B) 0.147 (C) 0.05 (D) 0.026
36. The equilibrium constant for the reaction
 $A(g) + 2B(g) \rightleftharpoons C(g)$
 is $0.25 \text{ dm}^6 \text{ mol}^{-2}$. In a volume of 5 dm^3 , what amount of A must be mixed with 4 mol of B to yield 1 mol of C at equilibrium.
 (A) 3 moles (B) 24 moles (C) 26 moles (D) None of these
37. Equimolar concentrations of H_2 and I_2 are heated to equilibrium in a 2 litre flask. The forward and the backward rate constants are found to be equal, what percentage of initial concentration of H_2 has reacted at equilibrium for the reaction $H_2 + I_2 \rightleftharpoons 2HI$
 (A) 33 % (B) 66 % (C) 50 % (D) 40 % (E) 20 %
38. When alcohol ($C_2H_5OH(l)$) and acetic acid ($CH_3COOH(l)$) are mixed together in equimolar ratio at 27°C , 33% of each is converted into ester. Then the K_c for the equilibrium
 $C_2H_5OH(l) + CH_3COOH(l) \rightleftharpoons CH_3COOC_2H_5(l) + H_2O(l)$ is :
 (A) 4 (B) $1/4$ (C) 9 (D) $1/9$

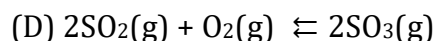
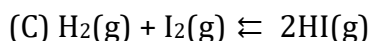
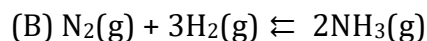
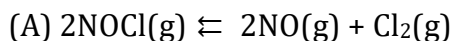
Problems on K_p

39. $PCl_5 \rightleftharpoons PCl_3 + Cl_2$ in the reversible reaction 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) $\frac{bc}{a} \cdot RT$ (B) $\frac{b}{(a+b+c)} \cdot P$ (C) $\frac{bc \cdot P}{a(a+b+c)}$ (D) $\frac{c}{(a+b+c)} \cdot P$
40. In the reaction, $PCl_5 \rightleftharpoons PCl_3 + Cl_2$, the amount of each PCl_5 , PCl_3 and Cl_2 is 2 mole at equilibrium and total pressure is 3 atmosphere. The value of K_p will be
 (A) 1.0 atm. (B) 3.0 atm. (C) 2.9 atm. (D) 6.0 atm.

41. The equilibrium constant, K_p for the reaction $2\text{SO}_2(\text{g}) + \text{O}_2(\text{g}) \rightleftharpoons 2\text{SO}_3(\text{g})$ is 4.0 atm^{-1} at 1000 K. What would be the partial pressure of O_2 if at equilibrium the amount of SO_2 and SO_3 is the same ?
 (A) 16.0 atm (B) 0.25 atm (C) 1 atm (D) 0.75 atm
42. For the reaction
 $\text{A}_2(\text{g}) + 2\text{B}_2 \rightleftharpoons 2\text{C}_2(\text{g})$
 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
43. A sample of pure NO_2 gas heated to 1000 K decomposes : $2\text{NO}_2(\text{g}) \rightleftharpoons 2\text{NO}(\text{g}) + \text{O}_2(\text{g})$. 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
44. On decomposition of NH_4HS , the following equilibrium is established :
 $\text{NH}_4\text{HS}(\text{s}) \rightleftharpoons \text{NH}_3(\text{g}) + \text{H}_2\text{S}(\text{g})$
 If the total pressure is P atm, then the equilibrium constant K_p is equal to
 (A) P atm (B) $P^2 \text{ atm}^2$ (C) $P^2 / 4 \text{ atm}^2$ (D) $2P$ atm
45. In the reaction $\text{C}(\text{s}) + \text{CO}_2(\text{g}) \rightleftharpoons 2\text{CO}(\text{g})$, 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
46. For $\text{NH}_4\text{HS}(\text{s}) \rightleftharpoons \text{NH}_3(\text{g}) + \text{H}_2\text{S}(\text{g})$ reaction started only with $\text{NH}_4\text{HS}(\text{s})$, the observed pressure for reaction mixture in equilibrium is 1.2 atm at 100°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
47. Consider the decomposition of solid NH_4HS in a flask containing $\text{NH}_3(\text{g})$ at a pressure of 2 atm. What will be the partial pressure of $\text{NH}_3(\text{g})$ and $\text{H}_2\text{S}(\text{g})$ after the equilibrium has been attained? K_p for the reaction is 3 atm^2 .
 (A) $p_{\text{NH}_3} = 4 \text{ atm}$, $p_{\text{H}_2\text{S}} = 2 \text{ atm}$ (B) $p_{\text{NH}_3} = 1.732 \text{ atm}$, $p_{\text{H}_2\text{S}} = 1.732 \text{ atm}$
 (C) $p_{\text{NH}_3} = 3 \text{ atm}$, $p_{\text{H}_2\text{S}} = 1 \text{ atm}$ (D) $p_{\text{NH}_3} = 1 \text{ atm}$, $p_{\text{H}_2\text{S}} = 1 \text{ atm}$

Relation Between K_p and K_c

48. For which reaction is $K_p = K_c$:-



49. For the following equilibrium $\text{N}_2\text{O}_{4\text{(g)}} \rightleftharpoons 2\text{NO}_{2\text{(g)}}$ K_p is found to be equal to K_c . This is attained when

(A) $T = 1\text{K}$

(B) $T = 12.18\text{ K}$

(C) $T = 27.3$

(D) $T = 273\text{ K}$

50. Reaction $\text{CO(g)} + \frac{1}{2}\text{O}_{2\text{(g)}} \rightleftharpoons \text{CO}_{2\text{(g)}}$. The value of $\frac{K_p}{K_c}$ is -

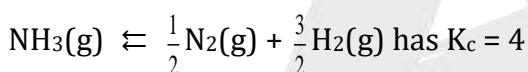
(A) $\frac{1}{RT}$

(B) \sqrt{RT}

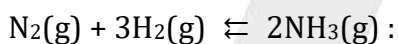
(C) $\frac{1}{\sqrt{RT}}$

(D) RT

51. At 527°C the reaction :



What is K_p for the reaction



(A) $16 \times (800\text{ R})^2$

(B) $\left(\frac{800\text{R}}{4}\right)^{-2}$

(C) $\left(\frac{527\text{R}}{4}\right)^2$

(D) None of these

Problems involving degree of dissociation, Average Molar Mass.

Degree of dissociation (α)

52. For the reaction : $\text{P} \rightleftharpoons \text{Q} + \text{R}$. Initially 2 moles of P are taken. Up to equilibrium 0.5 moles of P was dissociated. What would be the degree of dissociation :-

(A) 0.5

(B) 1

(C) 0.25

(D) 4.2

53. Two sample of HI, each of 5 gm. were taken separately into different vessels of volume 5 and 10 litres respectively at 27°C . The extent of dissociation of HI will be :

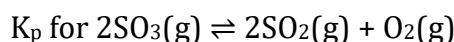
(A) More in 5 litre vessel

(B) More in 10 litre vessel

(C) Equal in both vessel

(D) None of these

54. The degree of dissociation of SO_3 is α at equilibrium pressure p^0 .



- (A) $\frac{p^0 \alpha^3}{2(1-\alpha)^3}$ (B) $\frac{p^0 \alpha^3}{(2+\alpha)(1-\alpha)^2}$ (C) $\frac{p^0 \alpha^2}{2(1-\alpha)^2}$ (D) None of these

55. For the reaction : $2\text{HI}(\text{g}) \rightleftharpoons \text{H}_2(\text{g}) + \text{I}_2(\text{g})$, the degree of dissociated (α) of $\text{HI}(\text{g})$ is related to equilibrium constant K_p by the expression

- (A) $\frac{2+2\sqrt{K_p}}{2}$ (B) $\sqrt{\frac{1+2K_p}{2}}$ (C) $\sqrt{\frac{2K_p}{1+2K_p}}$ (D) $\frac{2\sqrt{K_p}}{1+2\sqrt{K_p}}$

56. The degree of dissociation of PCl_5 (α) obeying the equilibrium, $\text{PCl}_5 \rightleftharpoons \text{PCl}_3 + \text{Cl}_2$, is approximately related to the pressure at equilibrium by (given $\alpha \ll 1$) :

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

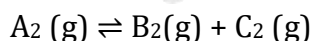
57. For the reaction $\text{N}_2\text{O}_4(\text{g}) \rightleftharpoons 2\text{NO}_2(\text{g})$, if percentage dissociation of N_2O_4 are 20%, 45%, 65% & 80%, then the sequence of observed vapour densities will be :

- (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) $(d_{20} = d_{45}) > (d_{65} = d_{80})$

58. The vapour density of N_2O_4 at a certain temperature is 30. What is the % dissociation of N_2O_4 at this temperature?

- (A) 53.3% (B) 106.6% (C) 26.7% (D) None

59. The equilibrium constant K_p (in atm) for the reaction is 9 at 7 atm and 300 K.



Calculate the average molar mass (in gm/mol) of an equilibrium mixture.

Given : Molar mass of A_2 , B_2 and C_2 are 70, 49 & 21 gm/mol respectively.

- (A) 50 (B) 45 (C) 40 (D) 37.5

60. The degree of dissociation is 0.5 at 800 K and 2 atm for the gaseous reaction



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

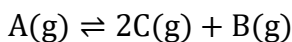
(Physical Chemistry)

CHEMICAL EQUILIBRIUM

61. At 727°C and 1.23 atm of total equilibrium pressure, SO_3 is partially dissociated into SO_2 and O_2 according to $\text{SO}_3(\text{g}) \rightleftharpoons \text{SO}_2(\text{g}) + 1/2\text{O}_2(\text{g})$. The density of equilibrium mixture is 0.9 g/litre. The degree of dissociation is:

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

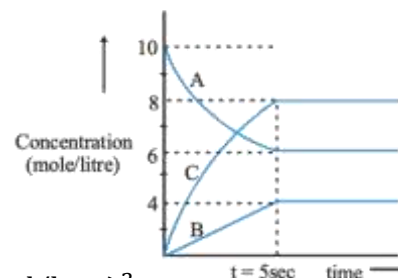
62. Attainment of the equilibrium



gave the following graph.

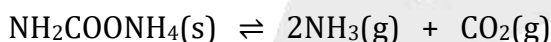
Find the correct option.

(% dissociation = fraction dissociated \times 100)

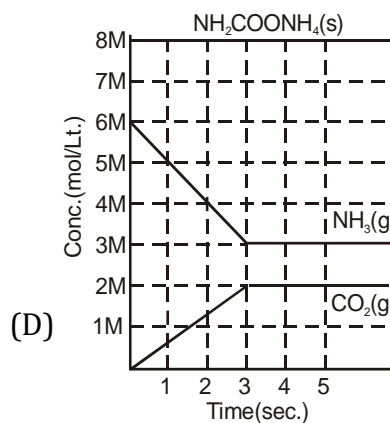
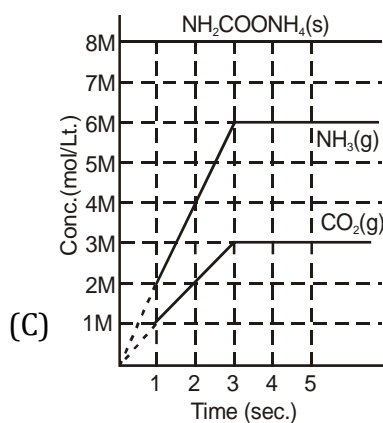
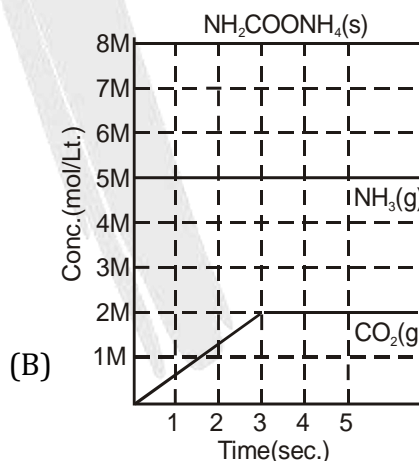
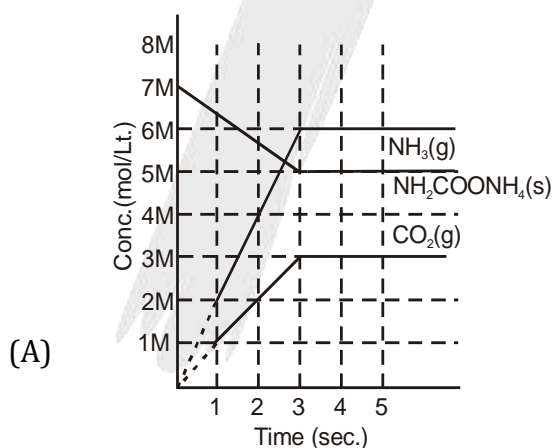


- (A) At $t = 5\text{sec}$ equilibrium has been reached and $K_e = 128(\text{mol/litre})^2$
 (B) At $t = 5\text{sec}$ equilibrium has been reached and % dissociation of A is 60%
 (C) At $t = 5\text{sec}$ equilibrium has been reached and % dissociation of A is 40%
 (D) None of these

63. Solid ammonium carbamate dissociates to give ammonia and carbon dioxide as follows



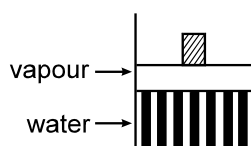
which of the following graph correctly represents the equilibrium.



Le-Chatelier's mix problems

64. The following reaction is at equilibrium in a closed vessel $\text{NH}_4\text{HS(s)} \rightleftharpoons \text{NH}_3\text{(g)} + \text{H}_2\text{S(g)}$ what is the effect of adding H_2S at constant volume :
- (A) Reaction moves forward (B) Reaction moves backward
(C) No change occurs (D) Change cannot be predicted
65. In an equilibrium system involving solids and gases, an increase in the amount of the solid reactant will
- (A) Increase the concentration of the gas product
(B) Decrease the concentration of the gas product
(C) Increase the concentration of all the product
(D) Not effect the concentration of the gas products
66. In which of the following reactions, increase in the pressure at constant temperature does not affect the moles at equilibrium :
- (A) $2\text{NH}_3\text{(g)} \rightleftharpoons \text{N}_2\text{(g)} + 3\text{H}_2\text{(g)}$ (B) $\text{C(g)} + \frac{1}{2} \text{O}_2\text{(g)} \rightleftharpoons \text{CO(g)}$
(C) $\text{H}_2\text{(g)} + \frac{1}{2} \text{O}_2\text{(g)} \rightleftharpoons \text{H}_2\text{O(g)}$ (D) $\text{H}_2\text{(g)} + \text{I}_2\text{(g)} \rightleftharpoons 2\text{HI(g)}$
67. $\text{Au(s)} \rightleftharpoons \text{Au(l)}$
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
68. For the reaction $\text{PCl}_5 \rightleftharpoons \text{PCl}_3 + \text{Cl}_2$, at constant temperature If the volume is increased 16 times the initial volume, the degree of dissociation for this reaction will becomes :-
- (A) 4 time (B) $\frac{1}{4}$ times (C) 2 time (D) $\frac{1}{2}$ times
69. What is the effect of the reduction of the volume of the system for the equilibrium $2\text{C(s)} + \text{O}_2\text{(g)} \rightleftharpoons 2\text{CO(g)}$?
- (A) The equilibrium will be shifted to the left by the increased pressure caused by the reduction in volume.
(B) The equilibrium will be shifted to the right by the decreased pressure caused by the reduction in volume.
(C) The equilibrium will be shifted to the left by the increased pressure caused by the increase in volume.

- (D) The equilibrium will be shifted to the right by the increased pressure caused by the reduction in volume.
70. For an equilibrium $\text{H}_2\text{O}(\text{s}) \rightleftharpoons \text{H}_2\text{O}(\text{l})$ 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
71. A gas 'X' when dissolved in water heat is evolved. Then solubility of 'X' will increase :
- (A) Low pressure, high temperature
 (B) Low pressure, low temperature
 (C) high pressure, high temperature
 (D) high pressure, low temperature
72. Consider the reactions
 (i) $\text{PCl}_5(\text{g}) \rightleftharpoons \text{PCl}_3(\text{g}) + \text{Cl}_2(\text{g})$
 (ii) $\text{N}_2\text{O}_4(\text{g}) \rightleftharpoons 2\text{NO}_2(\text{g})$
 The addition of an inert gas at constant volume
- (A) will increase the dissociation of PCl_5 as well as N_2O_4
 (B) will reduce the dissociation of PCl_5 as well as N_2O_4
 (C) will increase the dissociation of PCl_5 and step up the formation of NO_2
 (D) will not disturb the equilibrium of the reactions
73. The equilibrium $\text{SO}_2\text{Cl}_2(\text{g}) \rightleftharpoons \text{SO}_2(\text{g}) + \text{Cl}_2(\text{g})$ is attained at 25°C in a closed rigid container and an inert gas, helium is introduced. Which of the following statements is/are correct.
- (A) concentrations of SO_2 , Cl_2 and SO_2Cl_2 do not change
 (B) more chlorine is formed
 (C) concentration of SO_2 is reduced
 (D) more SO_2Cl_2 is formed
74. 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

75. Which of the following reaction will shift in backward direction. When the respective change is made at equilibrium:

- (A) $\text{N}_2(\text{g}) + 3\text{H}_2(\text{g}) \rightleftharpoons 2\text{NH}_3(\text{g})$ increase in pressure at eq.
 (B) $\text{H}_2\text{O}(\text{s}) \rightleftharpoons \text{H}_2\text{O}(\ell)$ addition of inert gas at constant volume
 (C) $\text{PCl}_5(\text{g}) \rightleftharpoons \text{PCl}_3(\text{g}) + \text{Cl}_2(\text{g})$ addition of inert gas at constant pressure
 (D) $\text{CO}_2(\text{g}) + \text{CaO}(\text{s}) \rightleftharpoons \text{CaCO}_3$ increase in temperature

76. The equilibrium $2\text{SO}_2(\text{g}) + \text{O}_2(\text{g}) \rightleftharpoons 2\text{SO}_3(\text{g})$ shifts forward if :-

- (A) A catalyst is used.
 (B) An adsorbent is used to remove SO_3 as soon as it is formed.
 (C) Small amounts of reactants are removed.
 (D) temperature is increased

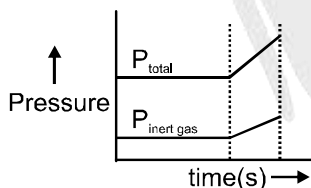
77. Densities of diamond and graphite are 3.5 and 2.3 gm/mL.

C (diamond) C (graphite) $\Delta_r H = -1.9 \text{ kJ/mole}$

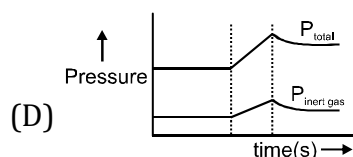
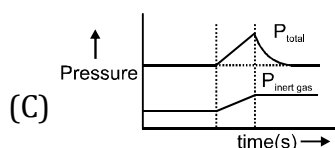
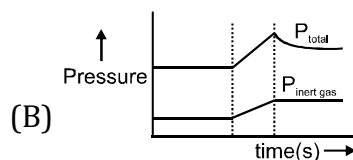
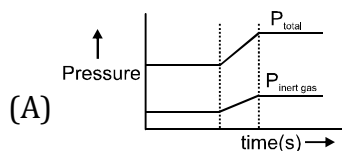
favourable conditions for formation of diamond are

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

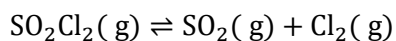
78. For a system at equilibrium some changes are made which is reported by a graph (shown below). Changes has been made at constant temperature.



Choose the correct options :



79. Sulfuryl chloride is in equilibrium with sulfur dioxide and chlorine gas:



A system with a volume of 1.00 L is in equilibrium at a certain temperature with $p(\text{SO}_2\text{Cl}_2) = 1.00$ bar and $p(\text{SO}_2) = p(\text{Cl}_2) = 0.10$ bar. By how much will the number of moles of SO_2Cl_2 at equilibrium change if the volume is reduced to 0.50 L?

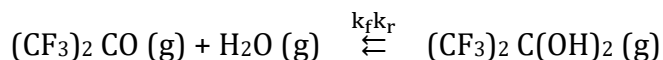
- (A) Increase 1-10%
(C) Decrease 1-10%

- (B) Increase 11 – 50%
(D) Decrease 11-50%

A

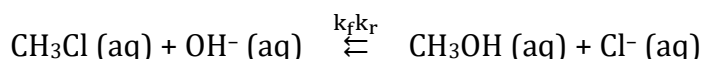
Characteristics of Equilibrium Constant

1. Consider the gas-phase hydration of hexafluoroacetone, $(\text{CF}_3)_2\text{CO}$:



At 76°C , the forward and reverse rate constants are $k_f = 0.15 \text{ M}^{-1} \text{ s}^{-1}$ and $k_r = 6 \times 10^{-4} \text{ s}^{-1}$. What is the value of the equilibrium constant K_c ?

2. Consider the reaction of chloromethane with OH^- in aqueous solution

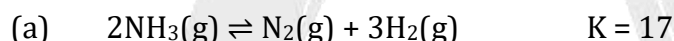


At 25°C , the rate constant for the forward reaction is $6 \times 10^{-6} \text{ M}^{-1} \text{ s}^{-1}$, and the equilibrium constant K_c is 1×10^{16} . Calculate the rate constant for the reverse reaction at 25°C .

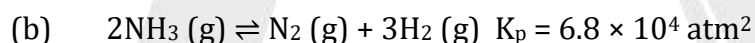
3. If $K_c = 0.5 \times 10^{-9}$ at 1000 K for the reaction $\text{N}_2 \text{ (g)} + \text{O}_2 \text{ (g)} \rightleftharpoons 2\text{NO (g)}$, what is K_c at 1000 K for the reaction $2\text{NO (g)} \rightleftharpoons \text{N}_2 \text{ (g)} + \text{O}_2 \text{ (g)}$?

Application of Equilibrium constant

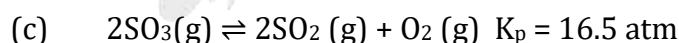
4. The initial concentrations or pressure of reactants and products are given for each of the following systems. Calculate the reaction quotient and determine the directions in which each system will shift to reach *equilibrium*.



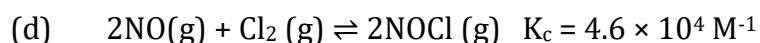
$$[\text{NH}_3] = 0.20 \text{ M} ; [\text{N}_2] = 1.00 \text{ M} ; [\text{H}_2] = 1.00 \text{ M}$$



$$\text{Initial pressure : } \text{NH}_3 = 3.0 \text{ atm} ; \text{N}_2 = 2.0 \text{ atm} ; \text{H}_2 = 1.0 \text{ atm}$$



$$\text{Initial pressure : } \text{SO}_3 = 1.0 \text{ atm} ; \text{SO}_2 = 1.0 \text{ atm} ; \text{O}_2 = 1.0 \text{ atm}$$



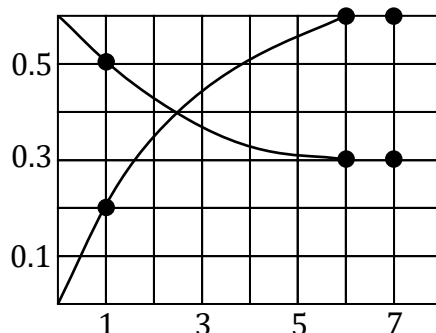
$$[\text{NO}] = 1.00 \text{ M} ; [\text{Cl}_2] = 1.00 \text{ M} ; [\text{NOCl}] = 0 \text{ M}$$

5. At 1400 K , $K_c = 2.5 \times 10^{-3}$ for the reaction $\text{CH}_4 \text{ (g)} + 2\text{H}_2\text{S} \rightleftharpoons \text{CS}_2(\text{g}) + 4\text{H}_2(\text{g})$. A 10.0 L reaction vessel at 1400 K contains 2.0 mol of CH_4 , 3.0 mol of CS_2 , 3.0 mol of H_2 and 4.0 mol of H_2S . Is the reaction mixture at equilibrium? If not, in which direction does the reaction proceed to reach equilibrium?

6. The first step in the industrial synthesis of hydrogen is the reaction of steam and methane to give water gas, a mixture of carbon monoxide and hydrogen.
- $$\text{H}_2\text{O}(\text{g}) + \text{CH}_4(\text{g}) \rightleftharpoons \text{CO}(\text{g}) + 3\text{H}_2(\text{g}) \quad K_c = 4.7 \text{ at } 1400 \text{ K}$$
- A mixture of reactants and product at 1400 K contains 0.03 M H_2O , 0.050 M CH_4 , 0.15 M CO , and 0.20 M H_2 . In which direction does the reaction proceed to reach equilibrium?
7. Which of the following reactions goes almost all the way to completion, and which proceeds hardly at all?
- (a) $\text{N}_2(\text{g}) + \text{O}_2(\text{g}) \rightleftharpoons 2\text{NO}(\text{g}); \quad K_c = 2.7 \times 10^{-18}$
- (b) $2\text{NO}(\text{g}) + \text{O}_2(\text{g}) \rightleftharpoons 2\text{NO}_2(\text{g}); \quad K_c = 6.0 \times 10^{13}$

Problems on K_c

8. An equilibrium mixture of PCl_5 , PCl_3 and Cl_2 at a certain temperature contains 0.5×10^{-3} M PCl_5 , 1.5×10^{-2} M PCl_3 , and 3×10^{-2} M Cl_2 . Calculate the equilibrium constant K_c for the reaction $\text{PCl}_5(\text{g}) \rightleftharpoons \text{PCl}_3(\text{g}) + \text{Cl}_2(\text{g})$.
9. An equilibrium mixture of N_2 , H_2 , and NH_3 at 700 K contains 0.036 M N_2 and 0.15 M H_2 . At this temperature, K_c for the reaction $\text{N}_2(\text{g}) + 3\text{H}_2(\text{g}) \rightleftharpoons 2\text{NH}_3(\text{g})$ is 0.29. What is the concentration of NH_3 ?
10. The value of K_c for the reaction $3\text{O}_2(\text{g}) \rightleftharpoons 2\text{O}_3(\text{g})$ is 8×10^{-55} at 25°C . Do you expect pure air at 25°C to contain much O_3 (ozone) when O_2 and O_3 are in equilibrium? If the equilibrium concentration of O_2 in air at 25°C is 8×10^{-3} M, what is the equilibrium concentration of O_3 ?
11. The progress of the reaction $\text{A} \rightleftharpoons n\text{B}$ with time, is presented in figure. Determine



- (i) the value of n .
- (ii) the equilibrium constant K .

12. 2 moles of A & 3 moles of B are mixed in 1 litre vessel and the reaction is carried at 400°C according to the equation; $A + B \rightleftharpoons 2C$. The equilibrium constant of the reaction is 4. Find the number of moles of C at equilibrium.
13. The air pollutant NO is produced in automobile engines from the high temperature reaction $N_2(g) + O_2(g) \rightleftharpoons 2NO(g)$; $K_c = 16$ at 2300 K. If the initial concentrations of N_2 and O_2 at 2300 K are both 1.5 M, what are the concentrations of NO, N_2 , and O_2 when the reaction mixture reaches equilibrium?
14. At a certain temperature, the reaction $PCl_5(g) \rightleftharpoons PCl_3(g) + Cl_2(g)$ has an equilibrium constant $K_c = 10^{-2}$. Calculate the equilibrium concentrations of PCl_5 , PCl_3 and Cl_2 if only PCl_5 is present initially, at a concentration of 0.1 M.
15. A sample of HI (9.6×10^{-3} mol) was placed in an empty 2.00 L container at 1000 K. After equilibrium was reached, the concentration of I_2 was 4×10^{-4} M. Calculate the value of K_c at 1000 K for the reaction $H_2(g) + I_2(g) \rightleftharpoons 2HI(g)$.
16. Following equilibrium is established at temperature T.
- $$A(g) \rightleftharpoons B(g) + C(g)$$
- at eq. 1M 2M 2M.
- If volume of the vessel is doubled then find the equilibrium concentration of each species.
(Given that : $\sqrt{40} = 6.324$)

Problems on K_p

17. At 90°C, the following equilibrium is established :
- $$H_2(g) + S(s) \rightleftharpoons H_2S(g) \quad K_p = 6.8 \times 10^{-2}$$
- If 0.2 mol of hydrogen and 1.0 mol of sulphur are heated to 90°C in a 1.0 litre vessel, what will be the partial pressure of H_2S at equilibrium?
18. The equilibrium constant for the reaction is 9 at 900°C $S_2(g) + C(s) \rightleftharpoons CS_2(g)$. Calculate the pressure of two gases at equilibrium, when initial 2 atm of S_2 and excess of $C(s)$ allowed to come to equilibrium.

19. At 700 K, $K_p = 0.2$ for the reaction $\text{ClF}_3(\text{g}) \rightleftharpoons \text{ClF}(\text{g}) + \text{F}_2(\text{g})$. Calculate the equilibrium partial pressure of ClF_3 , ClF , and F_2 if only ClF_3 is present initially, at a partial pressure of 0.150 atm.
20. A sample of $\text{CaCO}_3(\text{s})$ is introduced into a sealed container of volume 0.821 litre & heated to 1000K until equilibrium is reached. The equilibrium constant for the reaction $\text{CaCO}_3(\text{s}) \rightleftharpoons \text{CaO}(\text{s}) + \text{CO}_2(\text{g})$ is 4×10^{-2} atm at this temperature. Calculate the mass of CaO present at equilibrium.
21. 20.0 grams of $\text{CaCO}_3(\text{s})$ were placed in a closed vessel, heated & maintained at 727°C under equilibrium $\text{CaCO}_3(\text{s}) \rightleftharpoons \text{CaO}(\text{s}) + \text{CO}_2(\text{g})$ and it is found that 75% of CaCO_3 was decomposed. What is the value of K_p ? The volume of the container was 15 litres.
22. Equilibrium constant for the following equilibrium is given at 0°C .
 $\text{Na}_2\text{HPO}_4 \cdot 12\text{H}_2\text{O}(\text{s}) \rightleftharpoons \text{Na}_2\text{HPO}_4 \cdot 7\text{H}_2\text{O}(\text{s}) + 5\text{H}_2\text{O}(\text{g})$ $K_p = 31.25 \times 10^{-13}$
At equilibrium what will be partial pressure of water vapour :
23. Anhydrous calcium chloride is often used as a desiccant. In the presence of excess of CaCl_2 , the amount of the water taken up is governed by $K_p = 6.4 \times 10^{85}$ for the following reaction at room temperature, $\text{CaCl}_2(\text{s}) + 6\text{H}_2\text{O}(\text{g}) \rightleftharpoons \text{CaCl}_2 \cdot 6\text{H}_2\text{O}(\text{s})$. What is the equilibrium vapour pressure of water in a closed vessel that contains $\text{CaCl}_2(\text{s})$?

Relationship between K_p and K_c

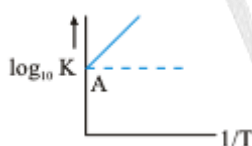
24. The vapour pressure of water at 27°C is 0.2463 atm. Calculate the values of K_p and K_c at 27°C for the equilibrium $\text{H}_2\text{O}(\text{l}) \rightleftharpoons \text{H}_2\text{O}(\text{g})$.
25. When 36.8g $\text{N}_2\text{O}_4(\text{g})$ is introduced into a 1.0-litre flask at 27°C . The following equilibrium reaction occurs :
 $\text{N}_2\text{O}_4(\text{g}) \rightleftharpoons 2\text{NO}_2(\text{g})$; $K_p = 0.1642$ atm.
(a) Calculate K_c of the equilibrium reaction.
(b) What are the number of moles of N_2O_4 and NO_2 at equilibrium?
(c) What is the total gas pressure in the flask at equilibrium?
(d) What is the percent dissociation of N_2O_4 ?

Problems involving degree of dissociation, Average Molecular Mass.

26. The degree of dissociation of N_2O_4 into NO_2 at 1.5 atmosphere and 40°C is 0.25. Calculate its K_p at 40°C . Also report degree of dissociation at 10 atmospheric pressures at same temperature.
27. At 46°C , K_p for the reaction $\text{N}_2\text{O}_4(\text{g}) \rightleftharpoons 2\text{NO}_2(\text{g})$ is 0.667 atm. Compute the percent dissociation of N_2O_4 at 46°C at a total pressure of 380 Torr.
28. $2\text{NOBr}(\text{g}) \rightleftharpoons 2\text{NO}(\text{g}) + \text{Br}_2(\text{g})$. If nitrosyl bromide (NOBr) is 33.33% dissociated at 25°C & a total pressure of 0.28 atm. Calculate K_p for the dissociation at this temperature.
29. At some temperature and under a pressure of 4 atm, PCl_5 is 10% dissociated. Calculate the pressure at which PCl_5 will be 20% dissociated, temperature remaining same.
30. The system $\text{N}_2\text{O}_4 \rightleftharpoons 2\text{NO}_2$ maintained in a closed vessel at 60°C & a pressure of 5 atm has an average (i.e. observed) molecular weight of 69, calculate K_p . At what pressure at the same temperature would the observed molecular weight be $(230/3)$?
31. PCl_5 dissociates according to the reaction $\text{PCl}_5 \rightleftharpoons \text{PCl}_3(\text{g}) + \text{Cl}_2(\text{g})$. At 523 K, $K_p = 1.78$ atm. Find the density of the equilibrium mixture at a total pressure of 1 atm.

Effect of Temperature

32. Variation of $\log_{10} K$ with $\frac{1}{T}$ is shown by the following graph in which straight line is at 45° , hence ΔH° is :



- (A) +4.606cal (B) -4.606cal (C) 2cal (D) -2cal

33. Listed in the table are forward and reverse rate constants for the reaction
 $2\text{NO}(\text{g}) \rightleftharpoons \text{N}_2(\text{g}) + \text{O}_2(\text{g})$

Temperature (K)	$k_f (\text{M}^{-1}\text{s}^{-1})$	$k_b (\text{M}^{-1}\text{s}^{-1})$
1400	0.29	1.1×10^{-6}
1500	1.3	1.4×10^{-5}

Is the reaction endothermic or exothermic?

34. From the following data :

- (i) $\text{H}_2(\text{g}) + \text{CO}_2(\text{g}) \rightleftharpoons \text{H}_2\text{O}(\text{g}) + \text{CO}(\text{g})$; $K_{2000\text{K}} = 4.4$
 (ii) $2\text{H}_2\text{O}(\text{g}) \rightleftharpoons 2\text{H}_2(\text{g}) + \text{O}_2(\text{g})$; $K_{2000\text{K}} = 5.31 \times 10^{-10}$
 (iii) $2\text{CO}(\text{g}) + \text{O}_2(\text{g}) \rightleftharpoons 2\text{CO}_2(\text{g})$; $K_{1000\text{K}} = 2.24 \times 10^{22}$

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

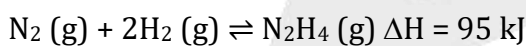
Le-Chatelier's mix problem

35. Using Le Chatelier's principle, predict the effect of

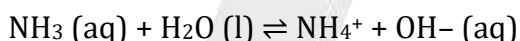
- (i) decreasing the temperature and
 (ii) increasing the pressure on each of the following equilibria :

- (A) $\text{N}_2(\text{g}) + 3\text{H}_2(\text{g}) \rightleftharpoons 2\text{NH}_3(\text{g}) + \text{Heat}$
 (B) $\text{N}_2(\text{g}) + \text{O}_2(\text{g}) \rightleftharpoons 2\text{NO}(\text{g}) + \text{Heat}$
 (C) $\text{H}_2\text{O}(\text{g}) + \text{Heat} \rightleftharpoons \text{H}_2(\text{g}) + \text{O}_2(\text{g})$
 (D) $2\text{CO}(\text{g}) + \text{O}_2(\text{g}) \rightleftharpoons 2\text{CO}_2(\text{g}) + \text{Heat}$

36. Suggest four ways in which the concentration of hydrazine, N_2H_4 , could be increased in an equilibrium described by the equation



37. Ammonia is a weak base that reacts with water according to the equation



Will any of the following increase the percent of ammonia that is converted to the ammonium ion in water?

- (a) Addition of NaOH. (b) Addition of HCl. (c) Addition of NH_4Cl .

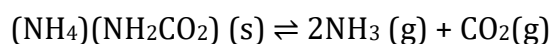
38. Consider the reaction, $2\text{Cl}_2(\text{g}) + 2\text{H}_2\text{O}(\text{g}) \rightleftharpoons 4\text{HCl}(\text{g}) + \text{O}_2(\text{g})$; $\Delta H^\circ = +113 \text{ kJ}$

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 |

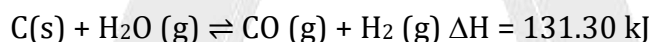
(f) Decreasing the volume of the container	K_c
(g) Raising the temperature	K_c
(h) Raising the temperature	Concentration of HCl
(i) Adding He	Number of moles of HCl
(j) Adding catalyst	Number of moles of HCl

39. The decomposition of solid ammonium carbamate, $(\text{NH}_4)(\text{NH}_2\text{CO}_2)$, to gaseous ammonia and carbon dioxide is an endothermic reaction.



- (a) When solid $(\text{NH}_4)(\text{NH}_2\text{CO}_2)$ 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 $(\text{NH}_4)(\text{NH}_2\text{CO}_2)$
 - (iii) Removing CO_2
 - (iv) Increasing the total volume
 - (v) Adding neon (at constant volume)
 - (vi) Increasing the temperature.

40. (a) Water gas, a mixture of H_2 and CO , is an important industrial fuel produced by the reaction of steam with red-hot coke, essentially pure carbon. Write the expression for the equilibrium constant for the reversible reaction.



- (b) Assume that equilibrium has been established and predict how the concentration of each reactant and product will differ at a new equilibrium if (1) more C is added. (2) H_2O is removed. (3) CO is added. (4) the pressure on the system is increased. (5) the temperature of the system is increased.

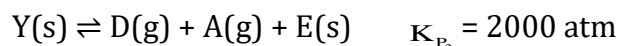
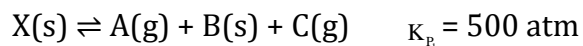
41. (a) Methanol, a liquid fuel that could possibly replace gasoline, can be prepared from water gas and additional hydrogen at high temperature and pressure in the presence of a suitable catalyst. Write the expression for the equilibrium constant for the reversible reaction.



- (b) Assume that equilibrium has been established and predict how the concentration of H_2 , CO and CH_3OH will differ at a new equilibrium if (1) more H_2 is added. (2) CO is removed. (3) CH_3OH is added. (4) the pressure on the system is increased. (5) the temperature of the system is increased. (6) more catalyst is added.

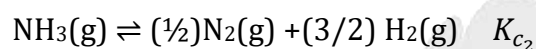
Simultaneous Equilibrium

42. For given simultaneous reaction :



Find total pressure at equilibrium containing both X(s) and Y(s)

43. $NH_4HS(s) \rightleftharpoons NH_3(g) + H_2S(g) \quad K_{c_1}$



2 mol $NH_4HS(s)$ is taken & 50% of this is dissociated till at equilibrium in 1 litre container. Find

$\frac{K_{c_2}^2}{K_{c_1}^6}$, if 0.25 moles of N_2 are found finally.

Should be K_c instead of K_p

44. When NO & NO_2 are mixed, the following equilibria readily obtained;



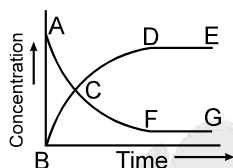
In an experiment when NO & NO_2 are mixed in the ratio of 1 : 2, the total final pressure was 5.05 atm & the partial pressure of N_2O_4 was 1.7 atm. Calculate

- (a) the equilibrium partial pressure of NO.
(b) K_p for $NO + NO_2 \rightleftharpoons N_2O_3$

EXERCISE # O-II

More than one may be correct

1. For a reaction $\text{N}_2 + 3\text{H}_2 \rightleftharpoons 2\text{NH}_3$, the value of K_c does not depend upon :-
 (a) Initial concentration of the reactants (b) Pressure
 (c) Temperature (d) Catalyst
2. $\text{N}_2\text{O}_4(\text{g}) \rightleftharpoons 2\text{NO}_2(\text{g})$, $K_c = 4$. This reversible reaction is studied graphically as shown in figure. Select the correct statement.



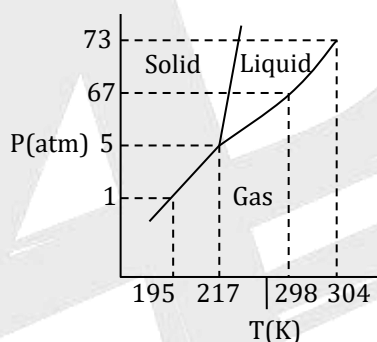
- (A) Reaction quotient has maximum value at point A
 (B) Reaction proceeds left to right at a point when $[\text{N}_2\text{O}_4] = [\text{NO}_2] = 0.1 \text{ M}$
 (C) $K_c = Q$ when point F is reached :
 (D) Point C represents state of equilibrium
3. 2 mole each of SO_3 , CO , SO_2 and CO_2 is taken in a one lit. vessel. If K_c for $\text{SO}_3(\text{g}) + \text{CO}(\text{g}) \rightleftharpoons \text{SO}_2(\text{g}) + \text{CO}_2(\text{g})$ is $1/9$ then
 (A) total no. of moles at equilibrium are less than 8
 (B) $n(\text{SO}_3) + n(\text{CO}_2) = 4$
 (C) $[n(\text{SO}_2)/n(\text{CO})] < 1$
 (D) $n(\text{SO}_3) + n(\text{SO}_2) = 2$
4. For the reaction $\text{PCl}_5(\text{g}) \rightleftharpoons \text{PCl}_3(\text{g}) + \text{Cl}_2(\text{g})$, the forward reaction at constant temperature is favoured by
 (A) introducing an inert gas at constant volume
 (B) introducing chlorine gas at constant volume
 (C) introducing an inert gas at constant pressure
 (D) introducing PCl_5 at constant volume.
5. When NaNO_3 is heated in a closed vessel, oxygen is liberated and NaNO_2 is left. At equilibrium
 (A) addition of NaNO_2 favours reverse reaction
 (B) addition of NaNO_3 favours forward reaction
 (C) increasing temperature favours forward reaction
 (D) increasing pressure favours reverse reaction

6. For the gas phase reaction, $\text{C}_2\text{H}_4 + \text{H}_2 \rightleftharpoons \text{C}_2\text{H}_6$ ($\Delta H = -32.7 \text{ kcal}$), carried out in a closed vessel, the equilibrium moles of C_2H_4 can be increased by
- (A) increasing the temperature (B) decreasing the pressure
(C) removing some H_2 (D) adding some C_2H_6
7. Decrease in the pressure for the following equilibria : $\text{H}_2\text{O}(\text{s}) \rightleftharpoons \text{H}_2\text{O}(\ell)$ result in the :
- (A) formation of more $\text{H}_2\text{O}(\text{s})$ (B) formation of more $\text{H}_2\text{O}(\ell)$
(C) increase in melting point of $\text{H}_2\text{O}(\text{s})$ (D) decrease in melting point of $\text{H}_2\text{O}(\text{s})$
8. $2\text{CaSO}_4(\text{s}) \rightleftharpoons 2\text{CaO}(\text{s}) + 2\text{SO}_2(\text{g}) + \text{O}_2(\text{g})$, $\Delta H > 0$
Above equilibrium is established by taking some amount of $\text{CaSO}_4(\text{s})$ in a closed container at 1600 K. Then which of the following may be incorrect option.
- (A) moles of $\text{CaO}(\text{s})$ will increase with the increase in temperature
(B) If the volume of the container is doubled at equilibrium, then partial pressure of $\text{SO}_2(\text{g})$ will change at new equilibrium.
(C) If the volume of the container is halved partial pressure of $\text{O}_2(\text{g})$ at new equilibrium will remain same
(D) If two moles of the He gas is added at constant pressure then the moles of $\text{CaO}(\text{s})$ will increase.
9. Following two equilibrium is simultaneously established in a container
- $$\text{PCl}_5(\text{g}) \rightleftharpoons \text{PCl}_3(\text{g}) + \text{Cl}_2(\text{g})$$
- $$\text{CO}(\text{g}) + \text{Cl}_2(\text{g}) \rightleftharpoons \text{COCl}_2(\text{g})$$
- If some $\text{Ni}(\text{s})$ is introduced in the container forming $\text{Ni}(\text{CO})_4(\text{g})$ then at new equilibrium
- (A) PCl_3 concentration will increase (B) PCl_3 concentration will decrease
(C) Cl_2 concentration will remain same (D) CO concentration will remain same
10. The equilibrium between, gaseous isomers A, B and C can be represented as
- | Reaction | Equilibrium constant |
|--|----------------------|
| $\text{A}(\text{g}) \rightleftharpoons \text{B}(\text{g})$: | $K_1 = ?$ |
| $\text{B}(\text{g}) \rightleftharpoons \text{C}(\text{g})$: | $K_2 = 0.4$ |
| $\text{C}(\text{g}) \rightleftharpoons \text{A}(\text{g})$: | $K_3 = 0.6$ |
- If one mole of A is taken in a closed vessel of volume 1 litre, then

- (A) $[A] + [B] + [C] = 1 \text{ M}$ at any time of the reactions
 (B) Concentration of C is $1/4.1 \text{ M}$ at the attainment equilibrium in all the reactions
 (C) The value of K is $\frac{1}{0.24}$
 (D) Isomer [A] is least stable

11. Consider the equilibrium $\text{HgO(s)} + 4\text{I}^- (\text{aq}) + \text{H}_2\text{O} (\ell) \rightarrow \text{HgI}_4^{2-} (\text{aq}) + 2\text{OH}^- (\text{aq})$, which changes will decrease the equilibrium concentration of HgI_4^{2-}
- (A) Addition of HI (s) (B) Addition of HgO (s)
 (C) Addition of $\text{H}_2\text{O} (\ell)$ (D) Addition of KOH (aq)

12. Phase diagram of CO_2 is shown as following



Based on above find the correct statement(s)

- (A) 298K is the normal boiling point of liquid CO_2
 (B) At 1 atm & 190 K CO_2 will exist as gas.
 (C) $\text{CO}_2(\text{s})$ will sublime above 195K under normal atmospheric pressure
 (D) Melting point & boiling point of CO_2 will increase on increasing pressure

Assertion Reason

13. **Statement-1** : Total number of moles in a closed system at new equilibrium is less than the old equilibrium if some amount of a substance is removed from a system (consider a reaction $\text{A(g)} \rightleftharpoons \text{B(g)}$) at equilibrium.
- Statement-2** : The number of moles of the substance which is removed, is partially compensated as the system reached to new equilibrium.
- (A) Statement-1 is true, statement-2 is true and statement-2 is correct explanation for statement-1.
 (B) Statement-1 is true, statement-2 is true and statement-2 is NOT the correct explanation for statement-1.

(C) Statement-1 is false, statement-2 is true.

(D) Statement-1 is true, statement-2 is false.

14. **Statement-1** : Ammonia at a pressure of 10 atm and CO_2 at a pressure of 20 atm are introduced into an evacuated chamber. If K_p for the reaction $\text{NH}_2\text{COONH}_4(\text{s}) \rightleftharpoons 2\text{NH}_3(\text{g}) + \text{CO}_2(\text{g})$ is 2020 atm^3 , the total pressure after a long time is less than 30 atm.

Statement-2 : Equilibrium can be attained from both directions.

- (A) Statement-1 is true, statement-2 is true and statement-2 is correct explanation for statement-1.
 (B) Statement-1 is true, statement-2 is true and statement-2 is NOT the correct explanation for statement-1.
 (C) Statement-1 is true, statement-2 is false.
 (D) Statement-1 is false, statement-2 is true.

Comprehension

Paragraph for Question Nos. 15 to 18

In a 7.0 L evacuated chamber, 0.50 mol H_2 and 0.50 mol I_2 react at 427°C .

$\text{H}_2(\text{g}) + \text{I}_2(\text{g}) \rightleftharpoons 2\text{HI}(\text{g})$. At the given temperature, $K_c = 49$ for the reaction.

15. What is the value of K_p ?
 (A) 7 (B) 39 (C) 24.5 (D) None
16. What is the total pressure (atm) in the chamber?
 (A) 83.14 (B) 831.4 (C) 8.21 (D) None
17. How many moles of the iodine remain unreacted at equilibrium?
 (A) 0.388 (B) 0.112 (C) 0.25 (D) 0.125
18. What is the partial pressure (atm) of HI in the equilibrium mixture?
 (A) 6.385 (B) 12.77 (C) 40.768 (D) 646.58

Paragraph for Question Nos. 19 to 20

Influence of pressure, temperature, concentration and addition of inert gas on a reversible chemical reaction in equilibrium can be explained by formulating the expression for equilibrium constant K_c or K_p for the equilibrium. On the other hand Le Chatelier principle can

be theoretically used to explain the effect of P, T or concentration on the physical or chemical equilibrium both.

19. For the reaction : $\text{PCl}_5 \rightleftharpoons \text{PCl}_3 + \text{Cl}_2$ increase of pressure shows :
- (A) An increase in degree of dissociation and a decrease in K_c
 (B) A decrease in degree of dissociation and a decrease in K_c
 (C) An increase in degree of dissociation but K_c remains constant
 (D) A decrease in degree of dissociation but K_c remains constant
20. For the reaction : $2\text{SO}_2 + \text{O}_2 \rightleftharpoons 2\text{SO}_3$; $\Delta H = -\text{ve}$, An increase in temperature shows :
- (A) More dissociation of SO_3 and a decrease in K_c
 (B) Less dissociation of SO_3 and an increase in K_c
 (C) More dissociation of SO_3 and an increase in K_c
 (D) Less dissociation of SO_3 and an decrease in K_c

Paragraph for Question Nos. 21 to 22

The two equilibria, $\text{AB}(\text{aq}) \rightleftharpoons \text{A}^+(\text{aq}) + \text{B}^-(\text{aq})$ and $\text{AB}(\text{aq}) + \text{B}^-(\text{aq}) \rightleftharpoons \text{AB}_2^-(\text{aq})$ are simultaneously maintained in a solution with equilibrium constants, K_1 and K_2 respectively.

21. 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.).
22. If $[\text{A}^+]$ and $[\text{AB}_2^-]$ 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) $\frac{y}{x}(x-y)$

Match the column

23. Column I

- (A) $K_P < K_C$
 (B) Introduction of inert gas at constant pressure will decrease the concentration of reactants
 (C) K°_P is dimensionless

Column II

- (P) $\text{N}_2 + 3\text{H}_2 \rightleftharpoons 2\text{NH}_3$
 (Q) $\text{PCl}_5(\text{g}) \rightleftharpoons \text{PCl}_3(\text{g}) + \text{Cl}_2(\text{g})$
 (R) $2\text{NO}_2(\text{g}) \rightleftharpoons \text{N}_2\text{O}_4(\text{g})$

(Physical Chemistry)

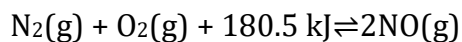
CHEMICAL EQUILIBRIUM

- (D) increase in temperature will shift equilibrium
to forward direction

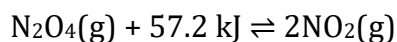
24. Column-I

(Reactions)

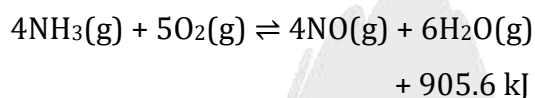
- (A) Oxidation of nitrogen



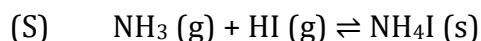
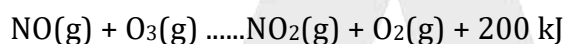
- (B) Dissociation of $\text{N}_2\text{O}_4(\text{g})$



- (C) Oxidation of $\text{NH}_3(\text{g})$



- (D) Formation of $\text{NO}_2(\text{g})$



Column-II

(Favourable conditions)

- (P) Addition of inert gas at
constant pressure

- (Q) Decrease in pressure

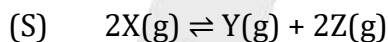
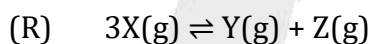
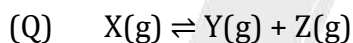
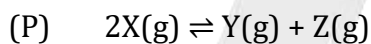
- (R) Decrease in temperature

- (S) Increase in temperature

Matching list type

25. Column-I

(Reaction)



Column-II

(If α is negligible w.r.t. 1, $V = 1$ litre)

(1) $\alpha = 2 \times \sqrt{K_c}$

(2) $\alpha = 3 \times \sqrt{K_c}$

(3) $\alpha = (2K_c)^{1/3}$

(4) $\alpha = \sqrt{K_c}$

Code:

	P	Q	R	S
(A)	4	1	3	2
(B)	2	4	1	3
(C)	1	4	2	3
(D)	2	3	1	4

EXERCISE # S-II

1. A mixture of hydrogen & iodine in the mole ratio 1.5 : 1 is maintained at 450° C. After the attainment of equilibrium $\text{H}_2(\text{g}) + \text{I}_2(\text{g}) \rightleftharpoons 2 \text{HI}(\text{g})$, it is found on analysis that the mole ratio of I_2 to HI is 1 : 18. Calculate the equilibrium constant and the number of moles of each species present under equilibrium, if initially, 127 grams of iodine were taken.
2. Solid Ammonium carbamate dissociates as: $\text{NH}_2 \text{COONH}_4 (\text{s}) \rightleftharpoons 2\text{NH}_3(\text{g}) + \text{CO}_2(\text{g})$.
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. Calculate the ratio of total pressure at new equilibrium to that of original total pressure.
3. For the reaction $\text{A}(\text{g}) + 2\text{B}(\text{g}) \rightleftharpoons \text{C}(\text{g}) + \text{D}(\text{g})$; $K_c = 10^{12}$.
If the initial moles of A, B, C and D are 0.5, 1, 0.5 and 3.5 moles respectively in a one liter vessel. What is the equilibrium concentration of B?
4. Consider the equilibrium
 $\text{Ni}(\text{s}) + 4\text{CO}(\text{g}) \rightleftharpoons \text{Ni}(\text{CO})_4(\text{g})$; $K_p = 0.125 \text{ atm}^{-3}$.
If equal number of moles of CO and $\text{Ni}(\text{CO})_4$ (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 ?
5. For the equilibrium $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}(\text{s}) \rightleftharpoons \text{CuSO}_4 \cdot 3\text{H}_2\text{O}(\text{s}) + 2\text{H}_2\text{O}(\text{g})$
 $K_p = 2.25 \times 10^{-4} \text{ atm}^2$ and vapour pressure of water is 22.8 Torr at 298 K.
 $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}(\text{s})$ is efflorescent (i.e., loses water) when relative humidity is :
6. Equilibrium constants are given (in atm) for the following reactions at 0° C:

$\text{SrCl}_2 \times 6\text{H}_2\text{O}(\text{s}) \rightleftharpoons \text{SrCl}_2 \times 2\text{H}_2\text{O}(\text{s}) + 4\text{H}_2\text{O}(\text{g})$	$K_p = 5 \times 10^{-12}$
$\text{Na}_2\text{HPO}_4 \cdot 12 \text{H}_2\text{O}(\text{s}) \rightleftharpoons \text{Na}_2\text{HPO}_4 \cdot 7 \text{H}_2\text{O}(\text{s}) + 5\text{H}_2\text{O}(\text{g})$	$K_p = 2.43 \times 10^{-13}$
$\text{Na}_2\text{SO}_4 \cdot 10 \text{H}_2\text{O}(\text{s}) \rightleftharpoons \text{Na}_2\text{SO}_4 (\text{s}) + 10 \text{H}_2\text{O} (\text{g})$	$K_p = 1.024 \times 10^{-27}$

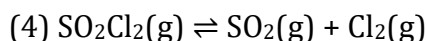
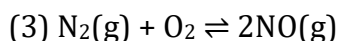
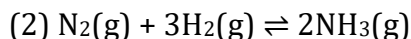
The vapor pressure of water at 0°C is 4.56 torr.
Out of $\text{SrCl}_2 \times 2\text{H}_2\text{O} (\text{s})$, $\text{Na}_2\text{HPO}_4 \cdot 7 \text{H}_2\text{O} (\text{s})$ and $\text{Na}_2\text{SO}_4 (\text{s})$,
Which is the most effective drying agent at 0°C?

7. Two solids X and Y dissociate into gaseous products at a certain temperature as follows:
 $X(s) \rightleftharpoons A(g) + C(g)$, and $Y(s) \rightleftharpoons B(g) + C(g)$. At a given temperature, pressure over excess solid X is 40 mm and total pressure over solid Y is 60 mm. When they are preset in separate containers. Calculate
- the values of K_p for two reactions (in mm)
 - the ratio of moles of A and B in the vapour state over a mixture of X and Y.
 - the total pressure of gases over a mixture of X and Y.
8. When 1 mole of A(g) is introduced in a closed rigid 1 litre vessel maintained at constant temperature the following equilibria are established.
- $$A(g) \rightleftharpoons B(g) + C(g) : K_{C_1}$$
- $$C(g) \rightleftharpoons D(g) + B(g) : K_{C_2}$$
- The pressure at equilibrium is twice the initial pressure. Calculate the value of $\frac{K_{C_2}}{K_{C_1}}$ if $\frac{[C]_{eq}}{[B]_{eq}} = \frac{1}{5}$
9. At certain temperature (T) for the gas phase reaction
 $2H_2O(g) + 2Cl_2(g) \rightleftharpoons 4HCl(g) + O_2(g)$ $K_p = 12 \times 10^8 \text{ atm}$
 If Cl_2 , HCl & O_2 are mixed in such a manner that the partial pressure of each is 2 atm and the mixture is brought into contact with excess of liquid water. What would be approximate partial pressure of Cl_2 when equilibrium is attained at temperature (T)?
[Given : Vapour pressure of water is 380 mm Hg at temperature (T)]
10. The value of K_p for the reaction at 27°C
 $Br_2(l) + Cl_2(g) \rightleftharpoons 2BrCl(g)$
 is '1 atm'. At equilibrium in a closed container partial pressure of $BrCl$ gas is 0.1 atm and at this temperature the vapour pressure of $Br_2(l)$ is also 0.1 atm. Then what will be minimum moles of $Br_2(l)$ to be added to 1 mole of Cl_2 , initially, to get above equilibrium situation ?

EXERCISE # (JEE-MAIN)

1. One of the following equilibrium is not affected by change in volume of the flask

[AIEEE-2002]



2. Reaction $\text{CO}(\text{g}) + \frac{1}{2} \text{O}_2(\text{g}) \rightleftharpoons \text{CO}_2(\text{g})$. The value of $\frac{K_p}{K_c}$ is -

[AIEEE-2002]

(1) $\frac{1}{RT}$

(B) \sqrt{RT}

(3) $\frac{1}{\sqrt{RT}}$

(4) RT

3. Consider the reaction equilibrium

[AIEEE-2003]



On the basis of Le-Chatelier's principle, the condition favourable for the forward reaction is -

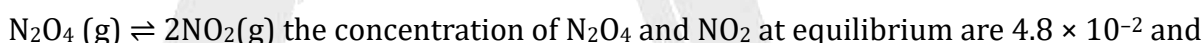
(1) Lowering the temperature and increasing the pressure

(2) Any value of temperature as well as pressure

(3) Lowering of temperature as well as pressure

(4) Increasing temperature as well as pressure

4. For the reaction equilibrium,

 $1.2 \times 10^{-2} \text{ mol L}^{-1}$ respectively. The value of K_c for the reaction is-

[AIEEE-2003]

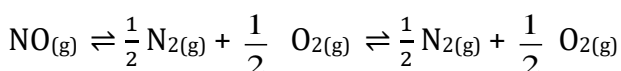
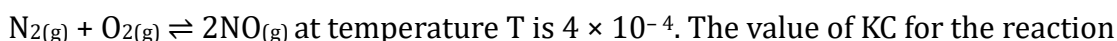
(1) $3 \times 10^{-3} \text{ mol L}^{-1}$

(2) $3 \times 10^3 \text{ mol L}^{-1}$

(3) $3.3 \times 10^2 \text{ mol L}^{-1}$

(4) $3 \times 10^{-1} \text{ mol L}^{-1}$

5. The equilibrium constant for the reaction



[AIEEE-2003]

(1) 2.5×10^2

(2) 50

(3) 4×10^{-4}

(4) 0.02

6. What is the equilibrium expression for the reaction $\text{P}_4(\text{s}) + 5\text{O}_2(\text{g}) \rightleftharpoons \text{P}_4\text{O}_{10}(\text{s})$? [AIEEE-2004]

(1) $K_c = [\text{P}_4\text{O}_{10}] / [\text{P}_4] [\text{O}_2]^5$

(2) $K_c = [\text{P}_4\text{O}_{10}] / 5 [\text{P}_4] [\text{O}_2]$

(3) $K_c = [\text{O}_2]^5$

(4) $K_c = 1 / [\text{O}_2]^5$

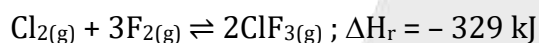
7. For the reaction $\text{CO}_{(g)} + \text{Cl}_{2(g)} \rightleftharpoons \text{COCl}_{2(g)}$ the $\frac{K_p}{K_c}$ is equal to – [AIEEE-2004]

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

8. For the reaction $2\text{NO}_{2(g)} \rightleftharpoons 2\text{NO}_{(g)} + \text{O}_{2(g)}$, ($K_c = 1.8 \times 10^{-6}$ at 184°C) ($R = 0.831 \text{ kJ}(\text{mol.K})$)
When K_p and K_c are compared at 184°C it is found that [AIEEE-2005]

- (1) K_p is less than K_c
(2) K_p is greater than K_c
(3) Whether K_p is greater than, less than or equal to K_c depends upon the total gas pressure
(4) $K_p = K_c$

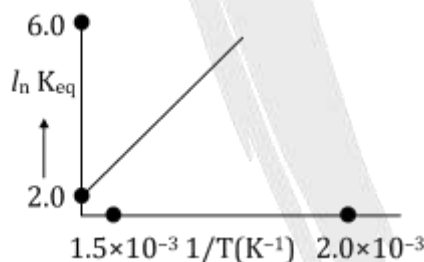
9. The exothermic formation of ClF_3 is represented by the equation [AIEEE-2005]



Which of the following will increase the quantity of ClF_3 in an equilibrium mixture of Cl_2 , F_2 and ClF_3 ?

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

10. A schematic plot of $\ln K_{eq}$ versus inverse of temperature for a reaction is shown below.
The reaction must be [AIEEE-2005]



- (1) endothermic
(2) exothermic
(3) highly spontaneous at ordinary temperature
(4) one with negligible enthalpy change

11. Phosphorus pentachloride dissociates as follows, in a closed reaction vessel,



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–

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

12. The equilibrium constant for the reaction $\text{SO}_3(\text{g}) \rightleftharpoons \text{SO}_2(\text{g}) + \frac{1}{2} \text{O}_2(\text{g})$ is $K_c = 4.9 \times 10^{-2}$.

The value of K_c for the reaction

[AIEEE-2006]

$2\text{SO}_2(\text{g}) + \text{O}_2(\text{g}) \rightleftharpoons 2\text{SO}_3(\text{g})$ will be

- (1) 2.40×10^{-3} (2) 9.8×10^{-2} (3) 4.9×10^{-2} (4) 416

13. The equilibrium constants K_{p1} and K_{p2} for the reaction $\text{X} \rightleftharpoons 2\text{Y}$ and $\text{Z} \rightleftharpoons \text{P} + \text{Q}$, respectively are in the ratio of 1 : 9. If the degree of dissociation of X and Z be equal then the ratio of total pressure at these equilibria is

[AIEEE-2008]

- (1) 1 : 36 (2) 1 : 1 (3) 1 : 3 (4) 1 : 9

14. 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]

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

15. The equilibrium constant (K_c) for the reaction $\text{N}_2(\text{g}) + \text{O}_2(\text{g}) \longrightarrow 2\text{NO}(\text{g})$ at temperature T is 4×10^{-4} . The value of K_c for the reaction, $\text{NO}(\text{g}) \longrightarrow \frac{1}{2}\text{N}_2(\text{g}) + \frac{1}{2}\text{O}_2(\text{g})$ at the same temperature is :

[AIEEE-2012]

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

16. The value of K_p for the equilibrium reaction $\text{N}_2\text{O}_4(\text{g}) \rightleftharpoons 2\text{NO}_2(\text{g})$ is 2. The percentage dissociation of $\text{N}_2\text{O}_4(\text{g})$ at a pressure of 0.5 atm is

[JEE-MAINS(online)-12]

- (1) 71 (2) 50 (3) 88 (4) 25

17. 8 mol of $\text{AB}_3(\text{g})$ are introduced into a 1.0 dm^3 vessel. If it dissociates as $2\text{AB}_3(\text{g}) \rightleftharpoons \text{A}_2(\text{g}) + 3\text{B}_2(\text{g})$ At equilibrium, 2 mol of A_2 are found to be present. The equilibrium constant of this reaction is :-

[JEE-MAINS(online)-12]

- (1) 36 (2) 3 (3) 27 (4) 2

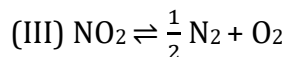
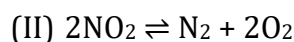
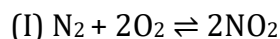
18. One mole of $\text{O}_2(\text{g})$ and two moles of $\text{SO}_2(\text{g})$ were heated in a closed vessel of one litre capacity at 1098 K. At equilibrium 1.6 moles of $\text{SO}_3(\text{g})$ were found. The equilibrium constant K_c of the reaction would be

[JEE-MAINS(online)-12]

- (1) 60 (2) 80 (3) 30 (4) 40

19. K_1 , K_2 and K_3 are the equilibrium constants of the following reactions (I), (II) and (III), respectively

[JEE-MAINS(online)-12]



The correct relation from the following is :

(1) $K_1 = \sqrt{K_2} = K_3$ (2) $K_1 = \frac{1}{K_2} = \frac{1}{K_3}$ (3) $K_1 = \frac{1}{K_2} = K_3$ (4) $K_1 = \frac{1}{K_2} = \frac{1}{(K_3)^2}$

20. In reaction $\text{A} + 2\text{B} \rightleftharpoons 2\text{C} + \text{D}$, initial concentration of B was 1.5 times of [A], but at equilibrium the concentrations of A and B became equal. The equilibrium constant for the reaction is :

[JEE-MAINS(online)-13]

(1) 4

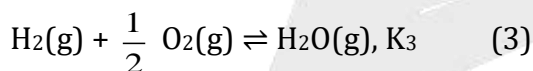
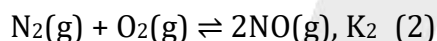
(2) 6

(3) 12

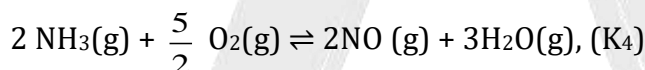
(4) 8

21. $\text{N}_2(\text{g}) + 3\text{H}_2(\text{g}) \rightleftharpoons 2\text{NH}_3(\text{g})$, K_1 (1)

[JEE-MAINS(online)-13]



The equation for the equilibrium constant of the reaction



in terms of K_1 , K_2 and K_3 is :

(1) $\frac{K_1 K_3^2}{K_2}$ (2) $\frac{K_2 K_3^3}{K_1}$ (C) $\frac{K_1 K_2}{K_3}$ (D) $K_1 K_2 K_3$

22. For the reaction $\text{SO}_2(\text{g}) + \frac{1}{2}\text{O}_2(\text{g}) \rightleftharpoons \text{SO}_3(\text{g})$, if $K_P = K_C (\text{RT})^x$ where the symbols have usual meaning then the value of x is : (assuming ideality)

[JEE-MAINS-14]

(1) $\frac{1}{2}$

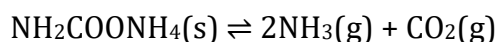
(2) 1

(3) -1

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

23. For the decomposition of the compound, represented as

[JEE-MAINS(online)-14]



the $K_P = 2.9 \times 10^{-5} \text{ atm}^3$.

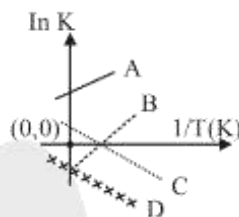
If the reaction is started with 1 mol of the compound, the total pressure at equilibrium would be

(1) $38.8 \times 10^{-2} \text{ atm}$ (2) $1.94 \times 10^{-2} \text{ atm}$ (3) $5.82 \times 10^{-2} \text{ atm}$ (4) $7.66 \times 10^{-2} \text{ atm}$

24. The equilibrium constants 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-MAINS-16]

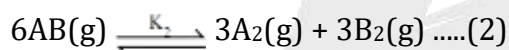
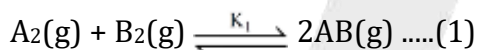
(1) 1.182 (2) 0.182 (3) 0.818 (4) 1.818

25. Which of the following lines correctly show the temperature dependence of equilibrium constant, K, for an exothermic reaction ? [JEE-MAINS-18]



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

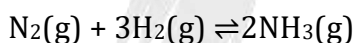
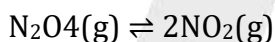
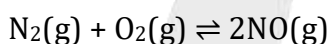
26. Consider the following reversible chemical reactions : [JEE-MAINS(Jan)-19]



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

27. The value of K_p/K_c for the following reactions at 300 K are, respectively :

(At 300 K, $RT = 24.62 \text{ dm}^3 \text{ atm mol}^{-1}$) [JEE-MAINS(Jan)-19]



(1) $24.62 \text{ dm}^3 \text{ atm mol}^{-1}$
 $606.0 \text{ dm}^6 \text{ atm}^2 \text{ mol}^{-2}$
 $1.65 \times 10^{-3} \text{ dm}^{-6} \text{ atm}^{-2} \text{ mol}^{-2}$
 (2) $1, 4.1 \times 10^{-2} \text{ dm}^{-3} \text{ atm}^{-1} \text{ mol}$,
 $606.0 \text{ dm}^6 \text{ atm}^2 \text{ mol}^{-2}$
 (3) $1, 24.62 \text{ dm}^3 \text{ atm mol}^{-1}$,
 $606.0 \text{ dm}^6 \text{ atm}^2 \text{ mol}^{-2}$,
 (4) $1, 24.62 \text{ dm}^3 \text{ atm mol}^{-1}$,
 $1.65 \times 10^{-3} \text{ dm}^{-6} \text{ atm}^{-2} \text{ mol}^2$.

(Physical Chemistry)

CHEMICAL EQUILIBRIUM

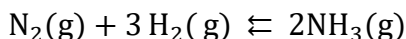
28. 5.1g NH_4SH is introduced in 3.0 L evacuated flask at 327°C . 30% of the solid NH_4SH decomposed to NH_3 and H_2S as gases. The K_p of the reaction at 327°C is ($R = 0.082 \text{ L atm mol}^{-1}\text{K}^{-1}$, Molar mass of S = 32 g mol^{-1} , molar mass of N = 14 g mol^{-1})

[JEE-MAINS(Jan)-19]

- (1) $0.242 \times 10^{-4} \text{ atm}^2$ (2) 0.242 atm^2 (3) $1 \times 10^{-4} \text{ atm}^2$ (4) $4.9 \times 10^{-3} \text{ atm}^2$

29. Consider the reaction,

[JEE-MAINS(Jan)-19]

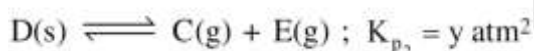
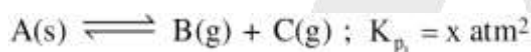


The equilibrium constant of the above reaction is K_p . If pure ammonia is left to dissociate, the partial pressure of ammonia at equilibrium is given by (Assume that $P_{\text{NH}_3} \ll P_{\text{total}}$ at equilibrium)

- (1) $\frac{3^{\frac{3}{2}} K_p^{\frac{1}{2}} P^2}{4}$ (2) $\frac{K_p^{\frac{1}{2}} P^2}{16}$ (3) $\frac{K_p^{\frac{1}{2}} P^2}{4}$ (4) $\frac{3^{\frac{3}{2}} K_p^{\frac{1}{2}} P^2}{16}$

30. Two solids dissociate as follows

[JEE-MAINS(Jan)-19]



The total pressure when both the solids dissociate simultaneously is :-

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

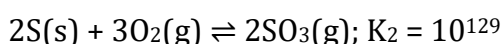
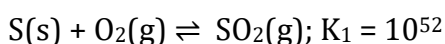
31. In a chemical reaction, $\text{A} + 2\text{B} \xrightleftharpoons{K} 2\text{C} + \text{D}$, the initial concentration of B was 1.5 times of the concentration of A, but the equilibrium concentrations of A and B were found to be equal. The equilibrium constant(K) for the aforesaid chemical reaction is :

[JEE-MAINS(Jan)-19]

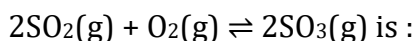
- (1) $\frac{1}{4}$ (2) 4 (3) 16 (4) 1

32. For the following reactions, equilibrium constants are given :

[JEE-MAINS(Apr.)-19]



The equilibrium constant for the reaction,



- (1) 10^{25} (2) 10^{154} (3) 10^{181} (4) 10^{77}

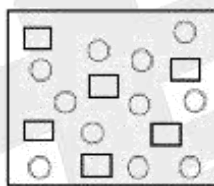
33. For the reaction, $2\text{SO}_2(\text{g}) + \text{O}_2(\text{g}) \rightleftharpoons 2\text{SO}_3(\text{g})$, $\Delta H = -57.2 \text{ kJ mol}^{-1}$ and $K_c = 1.7 \times 10^{16}$. Which of the following statement is INCORRECT ? [JEE-MAINS(Apr.)-19]

- (1) The equilibrium constant is large suggestive of reaction going to completion and so no catalyst is required.
- (2) The addition of inert gas at constant volume will not affect the equilibrium constant.
- (3) The equilibrium constant decreases as the temperature increases.
- (4) The equilibrium will shift in forward direction as the pressure increases.

34. In which one of the following equilibria, $K_p \neq K_c$? [JEE-MAINS(Apr.)-19]

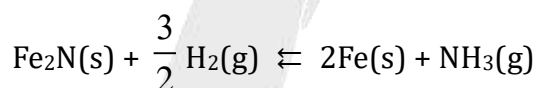
- (1) $2\text{HI}(\text{g}) \rightleftharpoons \text{H}_2(\text{g}) + \text{I}_2(\text{g})$
- (2) $\text{NO}_2(\text{g}) + \text{SO}_2(\text{g}) \rightleftharpoons \text{NO}(\text{g}) + \text{SO}_3(\text{g})$
- (3) $2\text{C}(\text{s}) + \text{O}_2(\text{g}) \rightleftharpoons 2\text{CO}(\text{g})$
- (4) $2\text{NO}(\text{g}) \rightleftharpoons \text{N}_2(\text{g}) + \text{O}_2(\text{g})$

35. In the figure shown below reactant A (represented by square) is in equilibrium with product B (represented by circle). The equilibrium constant is : [Jee Main, 2020]



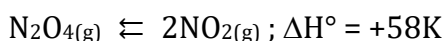
- (1) 4
- (2) 8
- (3) 1
- (4) 2

36. For the reaction [Jee Main, 2020]



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

37. Consider the following reaction: [Jee Main, 2020]



For each of the following cases (a, b), the direction in which the equilibrium shifts is:

- (a) Temperature is decreased
- (b) Pressure is increased by adding N_2 at constant T.
- (1) (a) towards product, (b) no change
- (2) (a) towards reactant, (b) no change
- (3) (a) towards product, (b) towards reactant
- (4) (a) towards reactant, (b) towards product

38. For the reaction; $A + B \rightleftharpoons 2C$

the value of equilibrium constant is 100 at 298 K. If the initial concentration of all the three species is 1 M each, then the equilibrium concentration of C is $x \times 10^{-1}$ M. The value of x is _____. (Nearest integer)

[JEE Main, July 2021]

39. At 1990 K and 1 atm pressure, there are equal number of Cl_2 molecules and Cl atoms in the reaction mixture. The value K_P for the reaction $\text{Cl}_2 \rightleftharpoons 2\text{Cl}_{(g)}$ under the above conditions is $x \times 10^{-1}$. The value of x is (Rounded off to the nearest integer)

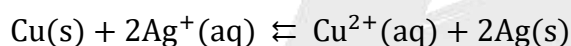
[JEE Main, Feb 2021]

40. When 5.1 g of solid NH_4HS is introduced into a two litre evacuated flask at 27°C , 20% of the solid decomposes into gaseous ammonia and hydrogen sulphide. The K_P for the reaction at 27°C is $x \times 10^{-2}$. The value of x is _____. (Integer answer)

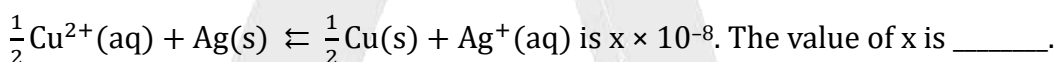
[Given $R = 0.082 \text{ L atm K}^{-1} \text{ mol}^{-1}$]

[JEE Main, August 2021]

41. At 298 K, the equilibrium constant is 2×10^{15} for the reaction:



The equilibrium constant for the reaction



(Nearest Integer)

[JEE Main, July 2022]

42. PCl_5 dissociates as



5 moles of PCl_5 are placed in a 200 litre vessel which contains 2 moles of N_2 and is maintained at 600 K. The equilibrium pressure is 2.46 atm. The equilibrium constant K_P for the dissociation of PCl_5 is $\underline{\hspace{2cm}} \times 10^{-3}$. (nearest integer)

(Given: $R = 0.082 \text{ L atm K}^{-1} \text{ mol}^{-1}$: Assume ideal gas behaviour)

[JEE Main, June 2022]

EXERCISE # (JEE-ADVANCED)

- The degree of dissociation is 0.4 at 400K & 1.0 atm for the gasoeus reaction $\text{PCl}_5 \rightleftharpoons \text{PCl}_3 + \text{Cl}_2(\text{g})$. Assuming ideal behaviour of all gases. Calculate the density of equilibrium mixture at 400K & 1.0 atm pressure. [JEE 1999]
- For the reversible reaction : [JEE 2000]
 $\text{N}_2(\text{g}) + 3\text{H}_2(\text{g}) \rightleftharpoons 2\text{NH}_3(\text{g})$ 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 mol L^{-1} is :
 (A) $1.44 \times 10^{-5} / (0.082 \times 500)^2$ (B) $1.44 \times 10^{-5} / (8.314 \times 773)^2$
 (C) $1.44 \times 10^{-5} / (0.082 \times 500)^2$ (D) $1.44 \times 10^{-5} / (0.082 \times 773)^{-2}$
- When two reactants A and B are mixed to give products C and D, the reaction quotient Q , at the initial stages of the reaction : [JEE 2000]
 (A) is zero (B) decrease with time
 (C) independent of time (D) increases with time
- When 3.06g of solid NH_4HS is introduced into a two litre evacuated flask at 27°C, 30% of the solid decomposes into gaseous ammonia and hydrogen sulphide. [JEE 2000]
 (i) Calculate K_c & K_p for the reaction at 27°C.
 (ii) What would happen to the equilibrium when more solid NH_4HS is introduced into the flask?
- At constant temperature, the equilibrium constant (K_p) for the decomposition reaction. $\text{N}_2\text{O}_4 \rightleftharpoons 2\text{NO}_2$ is expressed by $K_p = 4x^2P / (1 - x^2)$ where P is pressure, x is extent of decomposition. [JEE 2001]
 Which of the following statement is true ?
 (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 or x
- Consider the following equilibrium in a closed container : $\text{N}_2\text{O}_4(\text{g}) \rightleftharpoons 2\text{NO}_2(\text{g})$.
 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) : [JEE 2002]
 (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

7. If $\text{Ag}^+ + \text{NH}_3 \rightleftharpoons [\text{Ag}(\text{NH}_3)]^+$; $K_1 = 1.6 \times 10^3$ and $[\text{Ag}(\text{NH}_3)]^+ + \text{NH}_3 \rightleftharpoons [\text{Ag}(\text{NH}_3)_2]^+$; $K_2 = 6.8 \times 10^3$.
The formation constant of $[\text{Ag}(\text{NH}_3)_2]^+$ is :
(A) 6.08×10^{-6} (B) 6.8×10^{-6} (C) 1.6×10^3 (D) 1.088×10^7 [JEE 2006]
8. The thermal dissociation equilibrium of $\text{CaCO}_3(\text{s})$ is studied under different conditions.
 $\text{CaCO}_3(\text{s}) \rightleftharpoons \text{CaO}(\text{s}) + \text{CO}_2(\text{g})$ [JEE 2013]
For this equilibrium, the correct statement(s) is(are)
(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
9. For the reaction $\text{SO}_{2(\text{s})} + \frac{1}{2}\text{O}_{2(\text{g})} \rightleftharpoons \text{SO}_{3(\text{g})}$, if $K_p = K_c(\text{RT})^x$ where the symbols have usual meaning then the value of x is: (assuming ideality) ? [JEE Adv. 2014]
(A) $1/2$ (B) 1 (C) -1 (D) $-1/2$
10. For the following reaction, the equilibrium constant K_c at 298 K is 1.6×10^{17} .
 $\text{Fe}^{2+}(\text{aq}) + \text{S}^{2-}(\text{aq}) \rightleftharpoons \text{FeS}(\text{s})$ [JEE Advanced-2019]
When equal volumes of 0.06 M $\text{Fe}^{2+}(\text{aq})$ and 0.2 M $\text{S}^{2-}(\text{aq})$ solutions are mixed, the equilibrium concentration of $\text{Fe}^{2+}(\text{aq})$ is found to be $Y \times 10^{-17}$ M. The value of Y is_____

ANSWER KEY

EXERCISE O-I

- | | | | | | | |
|---------|---------|---------|---------|---------|---------|---------|
| 1. (B) | 2. (C) | 3. (D) | 4. (A) | 5. (A) | 6. (C) | 7. (C) |
| 8. (B) | 9. (C) | 10. (C) | 11. (C) | 12. (D) | 13. (B) | 14. (B) |
| 15. (A) | 16. (B) | 17. (C) | 18. (B) | 19. (A) | 20. (C) | 21. (B) |
| 22. (B) | 23. (D) | 24. (C) | 25. (B) | 26. (C) | 27. (B) | 28. (B) |
| 29. (C) | 30. (A) | 31. (D) | 32. (A) | 33. (C) | 34. (A) | 35. (D) |
| 36. (C) | 37. (A) | 38. (B) | 39. (C) | 40. (A) | 41. (B) | 42. (A) |
| 43. (C) | 44. (C) | 45. (B) | 46. (B) | 47. (C) | 48. (C) | 49. (B) |
| 50. (C) | 51. (D) | 52. (C) | 53. (C) | 54. (B) | 55. (D) | 56. (B) |
| 57. (A) | 58. (A) | 59. (C) | 60. (A) | 61. (B) | 62. (D) | 63. (C) |
| 64. (B) | 65. (D) | 66. (D) | 67. (C) | 68. (A) | 69. (A) | 70. (B) |
| 71. (D) | 72. (D) | 73. (A) | 74. (B) | 75. (D) | 76. (B) | 77. (C) |
| 78. (B) | 79. (A) | | | | | |

EXERCISE S-I

- | | | |
|--|--|--|
| 1. (250) | 2. (6×10^{-22}) | 3. 2×10^9 |
| 4. (a) backward, (b) forward, (c) forward, (d) forward | | |
| 5. The reaction is not an equilibrium because $Q_c > K_c$. The reaction will proceed from right to left to reach equilibrium | | |
| 6. Forward reaction. | | |
| 7. (a) very small extent (b) almost complete | | |
| 8. (0.9) | 9. 5.9×10^{-3} M | 10. No, 64×10^{-32} |
| 11. (i) 2; (ii) 1.2 mol/L | | 12. 2.4 mole |
| 13. $[\text{NO}] = 2\text{M}$, $[\text{N}_2] = [\text{O}_2] = 0.5\text{M}$ | | 14. $[\text{PCl}_3] = [\text{Cl}_2] = 0.027\text{ M}$, $[\text{PCl}_5] = 0.073$ |
| 15. $K_c = 100$ | | 16. $[\text{A}] = 0.34\text{ M}$, $[\text{B}] = 1.16\text{ M}$, $[\text{C}] = 1.16\text{ M}$ |
| 17. 0.379 atm | | 18. $P_{\text{CS}_2} = 1.8\text{ atm}$, $P_{\text{S}_2} = 0.2\text{ atm}$ |
| 19. $P_{\text{ClF}} = P_{\text{F}_2} = 0.1\text{ atm}$, $P_{\text{ClF}_3} = 0.05\text{ atm}$ | | 20. 22.4 g |
| 21. 0.821 atm | | 22. $5 \times 10^{-3}\text{ atm}$ |
| 23. $P = 5 \times 10^{-15}\text{ atm}$ | | 24. $K_p = 0.2463$ |
| 25. (a) $6.667 \times 10^{-3}\text{ mol L}^{-1}$; (b) $n(\text{N}_2\text{O}_4) = 0.374\text{ mol}$; $n(\text{NO}_2) = 0.052\text{ mol}$; (c) 10.49 atm (d) 6.44 % | | |
| 26. $K_p = 0.4$, $a \sim 0.1$ | 27. 50 % | 28. $K_p = 0.01\text{ atm}$ |
| 29. 0.97 atm | 30. $K_p = 2.5\text{ atm}$, $P = 15\text{ atm}$ | |
| 31. 2.7 g/lit | 32. (B) | |

33. k_r increase more than k_f , this means that E_a (reverse) is greater than E_a (forward). Hence exothermic reaction.
34. Exothermic
35. (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
36. Decreasing volume of container
 Increasing temperature
 Addition of N_2
 Addition of H_2
37. (2)
38. (a) decrease (b) increase (c) decrease (d) increase (e) increase (f) no change
 (g) increase (h) increase (i) no change (j) no change
39. (a) 4×10^{-3}
 (b) (i) decrease
 (ii) no change
 (iii) increase
 (iv) increase
 (v) no change
 (vi) increase
40. (a) $K = [CO][H_2]/[H_2O]$;
 (b) in each of the following cases the mass of carbon will change, but its concentration (activity) will not change.
 1. $[H_2O]$ no change, $[CO]$ no change, $[H_2]$ no change ;
 2. $[H_2O]$ decrease, $[CO]$ decrease, $[H_2]$ decrease ;
 3. $[H_2O]$ increase, $[CO]$ increase, $[H_2]$ decrease ;
 4. $[H_2O]$ increase, $[CO]$ increase, $[H_2]$ increase ;
 5. $[H_2O]$ decrease , $[CO]$ increase , $[H_2]$ increase
41. (a) $K = [CH_3OH]/[H_2]^2[CO]$,
 (b)
 1. $[H_2]$ increase, $[CO]$ decrease, $[CH_3OH]$ increase ;
 2. $[H_2]$ increase, $[CO]$ decrease, $[CH_3OH]$ decrease ;
 3. $[H_2]$ increase, $[CO]$ increase, $[CH_3OH]$ increase ;

4. $[H_2]$ increase, $[CO]$ increase, $[CH_3OH]$ increase ;
5. $[H_2]$ increase, $[CO]$ increase, $[CH_3OH]$ decrease ;
6. no change

42. 100

43. (27)

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

A

EXERCISE O-II

1. (ABD) 2. (BC) 3. (BCD) 4. (C, D) 5. (C, D)
6. (A, B, C, D) 7. (A, C) 8. (ACD) 9. (B) 10. (A, B, C, D)
11. (C, D) 12. (C, D) 13. (B) 14. (D) 15. (B)
16. (C) 17. (B) 18. (A) 19. (D) 20. (A)
21. (D) 22. (A) 23. (A)-P,R,S; (B)-P,Q,R,S; (C)-P,Q,R,S; (D)-Q;
24. (A)-S; (B)-P,Q,S; (C)-P,Q,R; (D)-R 25. (C)

EXERCISE S-II

1. $K_c=54$, $n_{HI}=0.9$ mol, $n_{I_2}=0.05$ mol, $n_{H_2}=0.3$ mol 2. 31/27 3. 2×10^{-4}
4. (4) 5. Less than 50 % 6. $SrCl_2 \times 2H_2O$
7. (a) 400mm², 900mm² (b) 4: 9, (c) 72.15 mm Hg
8. 4 9. 3.6×10^{-3} atm 10. $\frac{15}{6}$

JEE MAIN

1. (3) 2. (3) 3. (1) 4. (1) 5. (2) 6. (4) 7. (1)
8. (2) 9. (3) 10. (2) 11. (4) 12. (4) 13. (1) 14. (3)
15. (1) 16. (1) 17. (3) 18. (2) 19. (4) 20. (1) 21. (2)
22. (4) 23. (3) 24. (4) 25. (2) 26. (2) 27. (4) 28. (2)
29. (4) 30. (2) 31. (2) 32. (1) 33. (1) 34. (3) 35. (4)
36. (3) 37. (2) 38. (25) 39. (5) 40. (6) 41. (2) 42. (1107)

JEE ADVANCED

1. 4.54 g dm⁻³ 2. (D) 3. (D)
4. (i) $K_c=8.1 \times 10^{-5}$ mol² L²; $K_p=4.91 \times 10^{-2}$ atm² (ii) No effect;
5. (D)
6. (D)
7. (D)
8. (A, B, D)
9. (D)
10. 8.92 or 8.93

SOLUTION

EXERCISE O-I

3. At equilibrium conc. Becomes constant.

4. $r_f = r_b$

5. $\text{NH}_3, \text{ND}_3, \text{NH}_2\text{D}, \text{NHD}_2, \text{N}_2, \text{H}_2, \text{H-D}, \text{D}_2$

6. $K_{\text{eq}} = \frac{K_f}{K_b}$

7. $K_{\text{eq}} = \frac{[\text{B}]}{[\text{A}]}$

$$K_c = \frac{[\text{B}]_e}{[\text{A}]_e} = \frac{K_f}{K_b} \Rightarrow [\text{A}]_e = K_f K_b^{-1} [\text{B}]_e$$

13. $K_c = \left(\frac{\text{mol}}{\text{L}} \right)^{\Delta_{\text{ng}}}$
 $= \left(\frac{\text{mol}}{\text{L}} \right)^1 = \text{mol L}^{-1}$

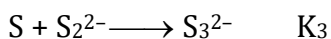
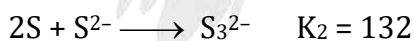
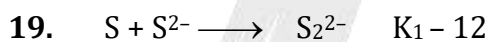
14. $K_p = (a/m)^{\Delta_{\text{ng}}}$

15. $K_2 = \frac{1}{K_1^2}$

16. $K_2 = \frac{1}{(K_1)^{\frac{1}{2}}}$

17. $K_3 = K_1 \times K_2$

(iii) = (i) + (ii)



(iii) = (ii) - (i)

$$K_3 = \frac{K_2}{K_1}$$

20. $K_p = K_c(RT)^{\Delta_{\text{ng}}}$

21. $\log \frac{K_p}{K_c} + \log RT = 0$

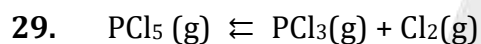
$$\frac{K_p}{K_c} = (RT)^{-1} \Rightarrow \Delta n_g = -1$$

22. $\frac{K_p}{K_c} = (RT)^{\Delta n_g}$

23. $K_p = K_c(RT)^1$

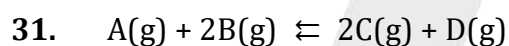
$$RT = 1 \quad T = \frac{1}{R} \text{ K}$$

28. $K_c = \frac{\left(\frac{48}{80}\right)^2}{\left(\frac{12.8}{64}\right)^2 \times \frac{9.6}{32}} = \frac{0.6 \times 0.6}{0.2 \times 0.2 \times 0.3} = 30$



n_{eq}	0.1	0.2	0.2
-----------------	-----	-----	-----

$$K_c = \frac{\frac{0.2}{10} \times \frac{0.2}{10}}{\frac{0.1}{10}} = 0.04$$

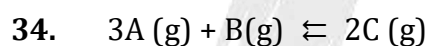


C_i	2a	3a	0	0
-------	----	----	---	---

C_{eq}	2a-x	3a-2x	2x	x
-----------------	------	-------	----	---

$$2a - x = x$$

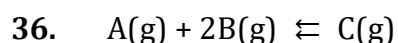
$$x = a$$



n_{eq}	2	2	2
-----------------	---	---	---

$$9 = \frac{2^2}{2^3 \times 2} \times \left(\frac{1}{V}\right)^{-2}$$

$$V^2 = 9 \times 2^2 \quad V = 6 \text{ L}$$



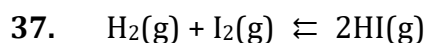
n_i	a	4	0
-------	---	---	---

n_{eq}	a-1	2	1
-----------------	-----	---	---

$$0.25 = \frac{\frac{1}{5}}{\frac{a-1}{5} \times \left(\frac{2}{5}\right)^2}$$

$$0.25 = \frac{1}{(a-1) \times 4} \times 25$$

$$a = 26$$

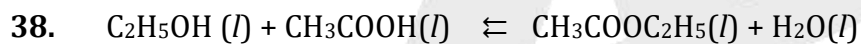


C_i	a	a	0
C_{eq}	$a-x$	$a-x$	$2x$

$$K_f = K_b \quad K_c = 1 \quad \frac{(2x)^2}{(a-x)(a-x)} = 1$$

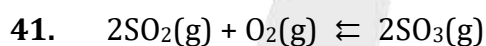
$$2x = a - x$$

$$x = \frac{a}{3}$$



n_i	a	a	0	0
n_{eq}	$\frac{2a}{3}$	$\frac{2a}{3}$	$\frac{a}{3}$	$\frac{a}{3}$

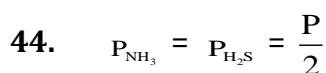
$$K_c = \frac{\frac{a}{3} \cdot \frac{a}{3}}{\frac{2a}{3} \cdot \frac{2a}{3}} = \frac{1}{4}$$



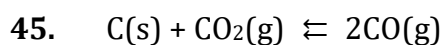
$$n_{\text{SO}_2} = n_{\text{SO}_3} \Rightarrow P_{\text{SO}_2} = P_{\text{SO}_3}$$

$$4 = \frac{P_{\text{SO}_3}^2}{P_{\text{SO}_2}^2 \times P_{\text{O}_2}}$$

$$P_{\text{O}_2} = \frac{1}{4}$$



$$K_p = \frac{P}{2} \cdot \frac{P}{2} = \frac{P^2}{4}$$

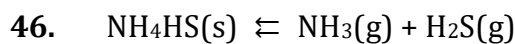


P_i	P	0
-------	-----	-----

$$P_{\text{eq}} = \frac{P}{2}$$

$$P_{\text{CO}_2} = 4 \text{ atm} \quad P_{\text{CO}} = 8 \text{ atm}$$

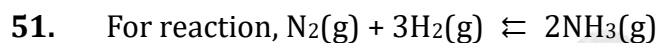
$$K_P = \frac{(8)^2}{4} = 16$$



$$0.6 \text{ atm} \quad 0.6 \text{ atm}$$

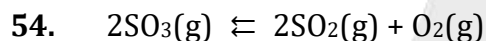
$$K_P = 0.6 \times 0.6$$

$$= 0.36 \text{ atm}^2$$



$$K_c = \left(\frac{1}{4}\right)^2$$

$$K_P = \frac{1}{16} (R \times 800)^{-2}$$



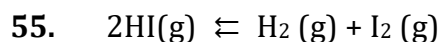
$$\begin{array}{ccc} \text{ni} & 1 & 0 \end{array}$$

$$\begin{array}{ccc} \text{neq} & 1-\alpha & \alpha \end{array}$$

$$K_P = \frac{\alpha^2 \cdot \frac{\alpha}{2}}{(1-\alpha)^2} \cdot \left(\frac{1}{1+\frac{\alpha}{2}}\right)^1$$

$$= \frac{\frac{\alpha^3}{2} \times 2}{(1-\alpha)^2 (2+\alpha)} \cdot P$$

$$K_P = \frac{\alpha^3}{(1-\alpha)^2 (2+\alpha)} \cdot P$$



$$\begin{array}{ccc} \text{neq} & 1-\alpha & \frac{\alpha}{2} \end{array}$$

$$K_P = \frac{\frac{\alpha}{2} \cdot \frac{\alpha}{2}}{(1-\alpha)^2} \cdot \left(\frac{P}{1}\right)^0$$

$$K_P = \frac{\alpha^2}{4(1-\alpha)^2}$$

56. $K_P = \frac{\alpha^2}{1-\alpha^2} \cdot P$

$$\frac{\alpha^2}{1-\alpha^2} \propto \frac{1}{P} \alpha \ll 1$$

$$\alpha \propto \frac{1}{\sqrt{P}}$$

58. $30 = \frac{46}{1+\alpha}$

$$\alpha = \frac{46}{30} - 1 = 0.533$$

59. $K_P = \frac{\alpha^2}{1-\alpha^2} \cdot P$

$$9 = \frac{\alpha^2}{1-\alpha^2} \cdot 7$$

$$7\alpha^2 = 9 - 9\alpha^2$$

$$16\alpha^2 = 9 \quad \alpha = \frac{3}{4} = 0.75$$

$$M_{\text{mix}} = \frac{70}{1+0.75} = \frac{70}{1.75} = 40$$

60. $M_{\text{mix}} = \frac{208.5}{1.5} = 139$

$$d_{\text{mix}} = \frac{PM_{\text{mix}}}{RT} = \frac{2 \times 139}{0.0821 \times 800}$$

$$= 4.23 \text{ g/L}$$

62. $A(s) \rightleftharpoons 2C(s) + B(g)$ at $t = 0$, $[A] = 10M$ from graph, $[A]_{\text{eq.}} = 10(1 - \alpha) = 8$, $[C] = 10(2\alpha) = 4$, $[B] = 10\alpha = 2$

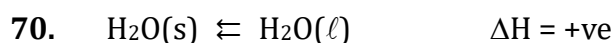
$$K_c = \frac{[C]^2[B]}{[A]} = \frac{4 \times 4 \times 2}{8} = 4 \text{ (mol/L)}^2$$



68. $\alpha \propto \frac{1}{\sqrt{P}}$

$$\frac{\alpha_1}{\alpha_2} = \sqrt{\frac{P_2}{P_1}}$$

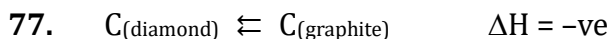
$$\frac{\alpha_1}{\alpha_2} = \sqrt{\frac{P/16}{P}} \Rightarrow \frac{\alpha_1}{\alpha_2} = \frac{1}{4}$$



d↓

d↑

high temperature and high pressure



d↑

d↓

High T and high pressure

79. The decrease in volume will lead to an increase in pressure. According to Le Chatelier's principle, the equilibrium is going to shift to the left side with less moles of gases as pressure increases. This is because the shift to fewer gas moles will reduce the pressure increase. First, let's find K_p using the equilibrium data.

$$K_p = \frac{(P_{\text{SO}_2})(P_{\text{Cl}_2})}{(P_{\text{SO}_2\text{Cl}_2})} = \frac{(0.10)(0.10)}{(1.00)} = 0.010$$

Now let's find Q_p . Since the volume was halved, all pressures are now doubled.

$$Q_p = \frac{(P_{\text{SO}_2})(P_{\text{Cl}_2})}{(P_{\text{SO}_2\text{Cl}_2})} = \frac{(0.20)(0.20)}{(2.00)} = 0.020$$

This confirms that the reaction must shift left. As the reaction reaches equilibrium, the pressure of SO_2Cl_2 will increase by some amount x . We see from the reaction that SO_2 and Cl_2 will decrease by the same amount. Thus, $K_p = \frac{(0.20-x)(0.20-x)}{(2.00+x)}$

We could solve this equation for x to find the final pressure of SO_2Cl_2 , but it would take time.

Instead, notice that $x > 0$ because by Le Chatelier's principle, SO_2Cl_2 must increase. Also notice that $x < 0.20$ because otherwise the partial pressures of SO_2 and Cl_2 would be negative. Therefore, the final SO_2Cl_2 is between 2.00 bar and 2.20 bar, which fits the range of an increase 1 – 10%. Thus, the answer is A. If we were to actually solve for x , we would get 0.06, meaning an increase of 3%.

EXERCISE S-I

1. $K_C = \frac{K_f}{K_b}$

2. $K_C = \frac{K_f}{K_b}$



$2NO \rightleftharpoons N_2(g) + O_2(g) \quad K_C = \frac{1}{0.5 \times 10^{-9}} = 2 \times 10^9$

4. (a) $Q_C = \frac{1 \times 1}{(0.2)^2} = \frac{1}{0.04} = 25$

$Q_C > K_C$, backward shift

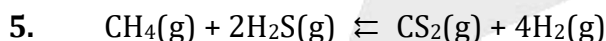
(b) $Q_P = \frac{2 \times (1)^2}{(3)^2} = \frac{2}{9}$

$Q_P < K_P$, forward shift

(c) $Q_P = \frac{1 \times 1}{1} =$

$Q_P < K_P$, forward shift

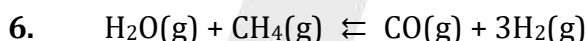
(d) Since initially only reactants are present, so reaction will shift to forward



3 4 3 3

$Q_C = \frac{0.3 \times (0.3)^4}{0.3 \times (0.4)^2}$

$= \frac{81 \times 10^4}{16 \times 10^{-2}} = \frac{81}{16} \times 10^{-2}$

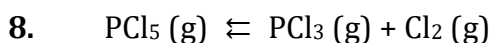


0.03 M 0.05 M 0.15 M 0.2 M

$Q_C = \frac{0.15 \times (0.2)^3}{0.03 \times 0.05} = 0.8$

$Q_C < K_C$, forward shift

7. (a) very small extent (b) almost complete



$C_{eq} \quad 0.5 \times 10^{-3} \quad 1.5 \times 10^{-2} \quad 3 \times 10^{-2}$

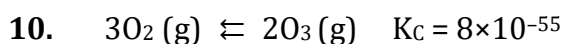
$K_C = \frac{1.5 \times 10^{-2} \times 3 \times 10^{-2}}{0.5 \times 10^{-3}} = 0.9$



0.036 M 0.15 M x

$$0.29 = \frac{x^2}{0.036 \times (0.15)^3}$$

$$x = 5.9 \times 10^{-3}$$



$$C_{eq} \quad 8 \times 10^{-3} \quad x$$

$$8 \times 10^{-55} = \frac{x^2}{(8 \times 10^{-3})^3}$$

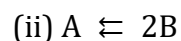
$$x^2 = 8 \times 10^{-55} \times (8)^3 \times 10^{-9}$$

$$x^2 = (8)^4 \times 10^{-64}$$

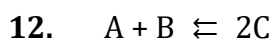
$$x = 64 \times 10^{-32}$$



$$\therefore n = 2$$



$$K = \frac{[B]^2}{[A]} = \frac{(0.6)^2}{0.3} = 1.2$$

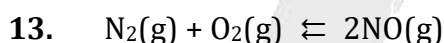


$$n_i \quad 2 \quad 3 \quad 0$$

$$n_{eq} \quad 2-x \quad 3-x \quad 2x$$

$$4 = \frac{4x^2}{(2-x)(3-x)}$$

$$x = 1.2$$



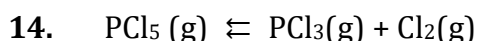
$$C_i \quad 1.5 \quad 1.5 \quad 0$$

$$C_{eq} \quad 1.5-x \quad 1.5-x \quad 2x$$

$$K_c = \frac{(2x)^2}{(1.5-x)(1.5-x)} = 16$$

$$\frac{2x}{(1.5-x)} = 4$$

$$x = 1$$

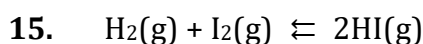


$$C_i \quad 0.1 \quad 0 \quad 0$$

$$C_{eq} \quad 0.1-x \quad x \quad x$$

$$\frac{x^2}{0.1-x} = 10^{-2}$$

$$x = 0.027$$

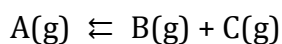


$$C_i \quad 0 \quad 0 \quad 4.8 \times 10^{-3}$$

$$C_{eq} \quad 0.4 \times 10^{-3} \quad 0.4 \times 10^{-3} \quad 4 \times 10^{-3}$$

$$K_C = \frac{(4 \times 10^{-3})^2}{0.4 \times 10^{-3} \times 0.4 \times 10^{-3}} = 100$$

16. $K_C = \frac{2 \times 2}{1} = 4$

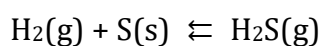


$$C_{eq} \quad 0.5 - x \quad 1 + x \quad 1 + x$$

$$\frac{(1 + x)^2}{0.5 - x} = 4$$

$$x = 0.16$$

17. $K_P = K_C$

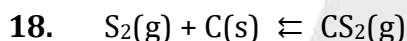


$$n_i \quad 0.2 \quad 1 \quad 0$$

$$n_{eq} \quad 0.2 - x \quad 1 - x \quad x$$

$$6.8 \times 10^{-2} = \frac{x}{0.2 - x}$$

$$x = 0.0127$$



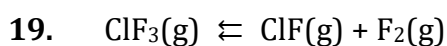
$$P_i \quad 2 \quad 0$$

$$P_{eq} \quad 2 - x \quad x$$

$$\frac{x}{2 - x} = 9$$

$$11x = 18$$

$$x = \frac{18}{11}$$

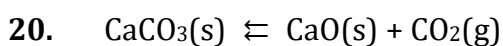


$$P_i \quad 0.15 \quad 0 \quad 0$$

$$P_{eq} \quad 0.15 - x \quad x \quad x$$

$$0.2 = \frac{x^2}{0.15 - x}$$

$$x = 0.01$$



$$K_P + P_{\text{CO}_2} = 4 \times 10^{-2}$$

$$n_{\text{CO}_2} = \frac{4 \times 10^{-2} \times 0.521}{0.0821 \times 1000}$$

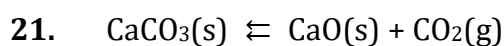
$$= 4 \times 10^{-4}$$

$$n_{\text{CaO}} = n_{\text{CO}_2} = 4 \times 10^{-4}$$

$$W_{\text{CaO}} = 4 \times 10^{-4} \times 56 \text{ g}$$

$$= 0.4 \times 56 \text{ g}$$

$$= 22.4 \text{ mg}$$



$$n_{\text{eq}} \quad 0.2 \times 0.75$$

$$K_P = P_{\text{CO}_2} = \frac{0.2 \times 0.75 \times 0.0821 \times 1000}{15}$$

$$K_P = 0.821$$

22. $K_P = (P_{\text{H}_2\text{O}})^2 = 2.25 \times 10^{-4}$

$$P_{\text{H}_2\text{O}} = 15 \times 10^{-3} = 1.5 \times 10^{-2}$$

$$\text{R.H.} = \frac{1.5 \times 10^{-2}}{22.8} \times 760 \times 100$$

$$= 50 \%$$

If $\text{RH} < 50\%$ reaction will shift forward

24. $K_P = P_{\text{H}_2\text{O}} = 0.2463$

$$K_P = K_C(RT)^2$$

$$K_C = \frac{0.2463}{0.0821 \times 300} = 0.01$$

25. $K_P = \frac{(0.1)^2}{1 - (0.1)^2} \times 4 = \frac{4}{99}$

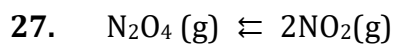
$$\frac{1/25}{1 - 1/25} \times P = \frac{4}{99}$$

$$P = \frac{96}{99} = 0.97 \text{ atm}$$

26. $K_P = \frac{4\alpha^2}{1 - \alpha^2} \cdot P$

$$\frac{4 \times \left(\frac{1}{4}\right)^2}{1 - \left(\frac{1}{4}\right)^2} \times 1.5 = \frac{4\alpha^2}{1 - \alpha^2} \times 10$$

$$\alpha = \frac{4 \times 0.01}{1 - 0.01} \times 10 = 0.4$$

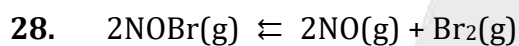


$$\frac{2}{3} = \frac{4\alpha^2}{1 - \alpha^2} \times \frac{1}{2}$$

$$\frac{\alpha^2}{1 - \alpha^2} = \frac{1}{3}$$

$$4\alpha^2 = 1$$

$$\alpha^2 = \frac{1}{4}$$



n_i	a	0	0
n_{eq}	$\frac{2a}{3}$	$\frac{a}{3}$	$\frac{a}{6}$
P_{eq}	0.16	0.8	0.4

$$K_P = \frac{(0.8)^2 \times 0.4}{(0.16)^2} = 0.1$$

29. $K_P = \frac{(0.1)^2}{1 - (0.1)^2} \times 4 = \frac{4}{99}$

$$\frac{1/25}{1 - 1/25} \times P = \frac{4}{99}$$

$$P = \frac{96}{99} = 0.97 \text{ atm}$$

30. $69 = \frac{9^2}{1 + \alpha}$

$$\alpha = \frac{1}{3}$$

$$K_P = \frac{4 \times 1/9}{1 - 1/9} \times 5 = \frac{4/9}{8/9} \times 5$$

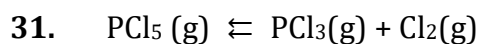
$$= \frac{20}{8} = 2.5$$

$$\frac{230}{3} = \frac{9^2}{1+\alpha}$$

$$\alpha = 0.2$$

$$\frac{20}{8} = \frac{\frac{1}{25} \times 4}{1 - \frac{1}{25}} \cdot P$$

$$P = 15 \text{ atm}$$



$$K_P = \frac{\alpha^2}{1-\alpha^2} \times P$$

$$0.178 = \frac{\alpha^2}{1-\alpha^2} \times 1$$

$$\alpha = 0.8$$

$$M_{\text{mix}} = \frac{208.5}{1.8} = 115.83$$

$$d = \frac{1 \times 115.83}{0.0821 \times 523} = 2.7 \text{ g/L}$$

32. Slope of plot $= \frac{-\Delta H^\circ}{2.303R} = 1$

$$\Rightarrow \Delta H^\circ = -2.303 \times 2 = -4.606 \text{ cal}$$

33. K_{eq} at 1400 K $= \frac{0.29}{1.1 \times 10^{-6}}$
 $= \frac{2.9}{1.1} \times 10^5$
 $= 2.6 \times 10^5$

$$K_{\text{eq}}$$
 at 1500 K $= \frac{1.3}{1.4 \times 10^{-5}}$
 $= \frac{1.3}{1.4} \times 10^5$
 $= 0.92 \times 10^5$

$$T \uparrow, K_{\text{eq}} \downarrow \quad e \times 0$$

34. K_{eq} at 2000 K

$$(iii) = -[2(i) + (ii)]$$

$$K = \frac{1}{(4.4)^2 \times 5.31 \times 10^{-10}}$$

$$= \frac{10^{10}}{(4.4)^2 \times 5.31}$$

K_{eq} at 1000 K

$$K = 2.24 \times 10^2$$

$$T \uparrow, K \downarrow \quad \times 0$$

35. On increasing temperature reaction will shift towards endothermic direction and on increasing pressure reaction will move towards lesser number of gaseous moles.

38. (a) Forward shift

No. of moles of H_2O will decrease

(b) Forward shift \Rightarrow moles of H_2O will decrease

(c) Forward shift \Rightarrow moles of HCl will increase

(d) Backward shift \Rightarrow moles of Cl_2 will increase

(e) Backward shift \Rightarrow partial pressure of each gas will increase

(f) No change

(g) $\Delta H > 0$, $T \uparrow$, $K_c \uparrow$

(h) $T \uparrow$, forward shift $[HCl] \uparrow$

(i) At constant volume – no change

41. (i) $2H_2(g) + CO(g) \rightleftharpoons CH_3OH(g)$

conc. \uparrow \downarrow \uparrow

(ii) conc. \uparrow \downarrow \downarrow

(iii) conc. \uparrow \uparrow \uparrow

(iv) conc. \uparrow \uparrow \uparrow

(v) conc. \uparrow \uparrow \downarrow

42. $X(s) \rightleftharpoons A(g) + B(s) + C(g)$

$$P_1 + P_2 \quad P_1$$

$Y(s) \rightleftharpoons D(g) + A(s) + E(s)$

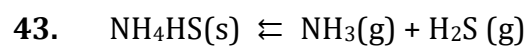
$$P_2 \quad P_2 + P_1$$

$$P_1 (P_1 + P_2) = 500$$

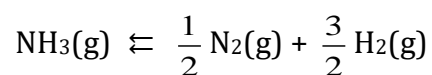
$$P_2 (P_1 + P_2) = 2000$$

$$P_1 + P_2 = 50$$

$$P_1 = 2 \times 50 = 100 \text{ atm}$$



$$1 - x \quad 1$$



$$1-x \quad \frac{x}{2} \quad \frac{3x}{2}$$

$$\frac{x}{2} = 0.25 \Rightarrow x = 0.5$$

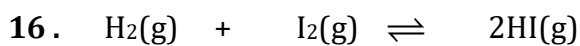
EXERCISE O-II

1. K_c depends only on temp

15. $K_P = K_C (RT)^{\Delta n_g}$

$$\Delta n_g = 0$$

$$K_P = 49$$



n_{eq}	$0.5-x$	$0.5-x$	$2x$
----------	---------	---------	------

$$\frac{(2x)^2}{(0.5-x)(0.5-x)} = 49$$

$$\frac{2x}{0.5-x} = 7$$

$$x = 0.38$$

$$P = \frac{1 \times 0.0821 \times 700}{7}$$

$$= 8.21 \text{ atm}$$

17. mole of I_2 , eq. = $0.5 - 0.38$
 $= .012$

18. $P_{HI} = \frac{2 \times 0.38 \times 0.0821 \times 700}{7}$

$$= 6.385 \text{ atm}$$

JEE MAINS

1. In this reaction the ratio of number of moles of reactants to products is same i.e., 2 : 2, hence change in volume will not alter the number of moles.
3. The conversion of SO_2 to SO_3 is an exothermic reaction, hence there is no need to increase the temperature. There is also a decrease in volume or moles in product side. Thus the reaction is favoured by low temperature and high pressure. (Le-Chatelier's principle).

4. $C_{[\text{N}_2\text{O}_4]} = 4.8 \times 10^{-2} \text{ mol L}^{-1}$, $C_{[\text{NO}_2]} = 1.2 \times 10^{-2} \text{ mol L}^{-1}$

$$K_c = \frac{[\text{NO}_2]^2}{[\text{N}_2\text{O}_4]} = \frac{1.2 \times 10^{-2} \times 1.2 \times 10^{-2}}{4.8 \times 10^{-2}} = 0.3 \times 10^{-2} = 3 \times 10^{-3} \text{ mol L}^{-1}$$

5. $\text{N}_2(\text{g}) + \text{O}_2(\text{g}) \rightleftharpoons 2\text{NO}(\text{g})$; $K_c = \frac{[\text{NO}]^2}{[\text{N}_2][\text{O}_2]} = 4 \times 10^{-4}$

$$\text{NO}(\text{g}) \rightleftharpoons \frac{1}{2} \text{N}_2(\text{g}) + \frac{1}{2} \text{O}_2(\text{g}) ; K_c = \frac{[\text{N}_2]^{1/2}[\text{O}_2]^{1/2}}{[\text{NO}]} = \frac{1}{\sqrt{K_c}} = \frac{1}{\sqrt{4 \times 10^{-4}}} = \frac{1}{2 \times 10^{-2}} = \frac{100}{2} = 50$$

7. $\text{CO}(\text{g}) + \text{Cl}_2(\text{g}) \rightleftharpoons \text{COCl}_2(\text{g})$

$$\Delta n = 1 - 2 = -1 ; K_p = K_c (RT)^{\Delta n} \quad \therefore \quad \frac{K_p}{K_c} = (RT)^{-1} = \frac{1}{RT}$$

8. $K_p = K_c (RT)^{\Delta n}$ $\Delta n = 3 - 2 = 1.$

$$K_p = K_c (0.0821 \times 457)^1. K_p > K_c.$$

9. $\text{Cl}_2(\text{g}) + 3\text{F}_2(\text{g}) \rightleftharpoons 2\text{ClF}_3(\text{g}) ; \quad \Delta H = -329 \text{ kJ. Favourable conditions:}$

(i) Decrease in temperature, (ii) Addition of reactants, (iii) Increase in pressure i.e., decrease in volume.

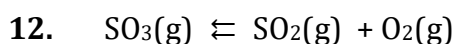
11. Given : $\text{PCl}_5(\text{g}) \rightleftharpoons \text{PCl}_3(\text{g}) + \text{Cl}_2(\text{g})$

$$t = 0 \quad 1 \quad 0 \quad 0$$

$$t_{\text{eq}} \quad 1-x \quad x \quad x$$

$$\text{Total number of moles} = 1 - x + x + x = 1 + x$$

$$\text{Thus partial pressure of } \text{PCl}_3 = \left(\frac{x}{1+x} \right) P.$$

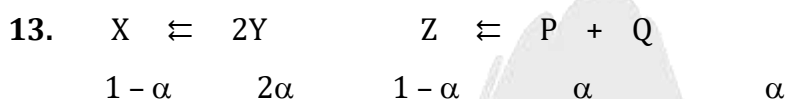


$$\frac{[\text{SO}_2][\text{O}_2]^{1/2}}{[\text{SO}_3]} = K_c = 4.9 \times 10^{-2} \quad \dots\dots\dots(\text{i})$$



$$\frac{[\text{SO}_3]}{[\text{SO}_2][\text{O}_2]^{1/2}} = K'_c = \frac{1}{4.9 \times 10^{-2}} \quad \text{For } 2\text{SO}_2(\text{g}) + \text{O}_2(\text{g}) \rightleftharpoons 2\text{SO}_3(\text{g})$$

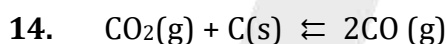
$$\frac{[\text{SO}_3]^2}{[\text{SO}_2]^2[\text{O}_2]} = K_c^2 = \frac{1}{4.9 \times 4.9 \times 10^{-4}} = \frac{10000}{24.01} = 416.49$$



$$K_{P_1} = \frac{\left(\frac{2\alpha}{1+\alpha} P_{T_1}\right)^2}{\left(\frac{1-\alpha}{1+\alpha} P_{T_1}\right)} \quad K_{P_2} = \frac{\left(\frac{\alpha}{1+\alpha} P_{T_2}\right) \left(\frac{\alpha}{1+\alpha} P_{T_2}\right)}{\left(\frac{1-\alpha}{1+\alpha} P_{T_2}\right)}$$

$$K_{P_1} = \frac{\left(\frac{2\alpha}{1+\alpha} P_{T_1}\right)^2}{\left(\frac{1-\alpha}{1+\alpha} P_{T_2}\right)} \times \frac{\left(\frac{1-\alpha}{1+\alpha} P_{T_2}\right)}{\left(\frac{\alpha}{1+\alpha} P_{T_2}\right) \left(\frac{\alpha}{1+\alpha} P_{T_2}\right)}$$

$$\frac{1}{9} = \frac{4P_{T_1}}{P_{T_2}} \quad ; \quad \frac{P_{T_1}}{P_{T_2}} = \frac{1}{36}$$



0.5 atm

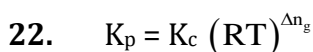
0.5-p \quad 2p

Total pressure = 0.5 - P + 2P = 0.8

P = 0.3

$$K_p = \frac{P_{\text{CO}}^2}{P_{\text{CO}_2}} = \frac{(2P)^2}{(0.5 - P)} = \frac{(0.6)^2}{(0.5 - 0.3)}$$

$K_p = 1.8$



$$\Delta n_g = -\frac{1}{2}$$

24. $A + B \rightleftharpoons C + D$

t = 0	1	1	1	1
t _{eq}	1-x	1-x	1+x	1+x

$$\Rightarrow \frac{(1+x)^2}{(1-x)^2} = 100 \Rightarrow \frac{1+x}{1-x} = 10$$

$$\Rightarrow 1+x = 10 - 10x \Rightarrow 11x = 9$$

$$\Rightarrow x = \frac{9}{11}$$

$$\Rightarrow [D] = 1 + \frac{9}{11}$$

$$\Rightarrow [D] = 1.818$$

25. $\ln K = \ln A - \frac{\Delta H}{R} \cdot \frac{1}{T}$

Reaction is exothermic (i.e. $\Delta H = -ve$) so slope of the curve between $\ln K$ and $\frac{1}{T}$ will be positive.

26. $K_1 = \frac{[AB]^2}{[A_2][B_2]} \dots (1)$

$K_2 = \frac{[A_2]^3[B_2]^3}{[AB]^6} \dots (2)$

$\Rightarrow K_2 = K_1^{-3}$

27. 1. $N_2 + O_2 \rightleftharpoons 2NO$

$\Delta_{ng} = 0$

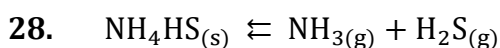
$K_p = K_c(RT)^{\Delta_{ng}}$

$\frac{K_p}{K_c} = 1$

2. $N_2O_4 \rightleftharpoons 2NO_2$

$\frac{K_p}{K_c} = (RT)^1 = 24.62$

3. $\frac{K_p}{K_c} = (RT)^{-2} = \frac{1}{(24.62)^2} = 1.62 \times 10^{-3}$

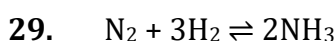


$$\text{Number of mole of given NH}_4\text{HS} = \frac{5.1}{51} = 0.1 \text{ mole}$$

$$\text{moles of NH}_3 \text{ formed} = \frac{0.1 \times 30}{100} = \text{moles of H}_2\text{S}$$

$$\text{pressure of NH}_3 = \frac{0.03 \times 0.0821 \times 600}{3} = \text{pressure of H}_2\text{S} = 0.492$$

$$\therefore K_p = P_{\text{NH}_3} \times P_{\text{H}_2\text{S}} = 0.492 \times 0.492 = 0.242 \text{ atm}^2$$



$$t = 0 \quad 0 \quad 0 \quad P$$

$$t_{\text{eq}} \quad P \quad 3p \quad x$$

$$K_p = \frac{x^2}{p \times (3p)^3}$$

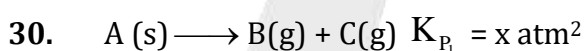
$$x = (K_p \times 27 p^4)^{1/2}$$

$$x = (27)^{1/2} K_p^{1/2} p^2$$

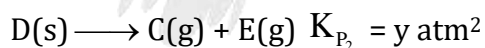
$$P_T = 4P$$

$$P = \frac{P_T}{4}$$

$$X = \frac{3^{3/2} K_p^{1/2} P_T^2}{16}$$



$$P_1 \quad P_1 + P_2$$



$$P_2 + P_1 \quad P_2$$

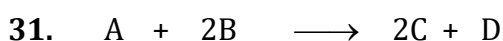
$$P_1 (P_1 + P_2) = x$$

$$P_2 (P_1 + P_2) = y$$

$$P_1 + P_2 = \sqrt{x + y}$$

$$\text{Total pressure} = 2 (P_1 + P_2)$$

$$= 2\sqrt{x + y} \text{ atm}$$



$$\text{Ci} \quad a \quad 1.5a \quad 0 \quad 0$$

$$C_{eq} \quad a-x \quad 1.5a-2x \quad 2x \quad x$$

$$[A]_{eq} = [B]_{eq}$$

$$a-x = 1.5a - 2x$$

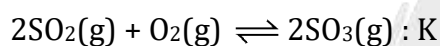
$$x = 0.5a$$

$$K_c = \frac{[C]^2 [D]}{[A] [B]^2} = \frac{a^2 \times 0.5a}{0.5a \times (0.5a)^2} = 4$$

32. Equation 1: $S(s) + \frac{1}{2} O_2(g) \rightleftharpoons SO_2(g) : K_1 = 10^{52}$

Equation 2 : $2S(s) + 3O_2(g) \rightleftharpoons 2SO_3(g) : K_2 = 10^{129}$

Equation 2 - 2 × Equation 1 gives,



$$\Rightarrow K = \frac{K_2}{(K_1)^2} = \frac{10^{129}}{10^{104}} = 10^{25}$$

33. On addition of catalyst value of equilibrium constant does not change.

34. As, $K_p = K_c (RT)^{\Delta n_g} \Rightarrow K_p \neq K_c$ if $\Delta n_g \neq 0$

1. $2HI(g) \rightleftharpoons H_2(g) + I_2(g), \Delta n_g = 0 \Rightarrow k_p = k_c$

2. $NO_2(g) + SO_2(g) \rightleftharpoons NO(g) + SO_3(g), \Delta n_g = 0 \Rightarrow k_p = k_c$

3. $2C(s) + O_2(g) \rightleftharpoons 2CO(g), \Delta n_g = 1 \Rightarrow k_p \neq k_c$

4. $2NO(g) \rightleftharpoons N_2(g) + O_2(g), \Delta n_g = 0 \Rightarrow k_p = k_c$

35. $A \rightarrow B$

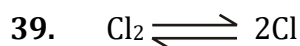
$$K = \frac{[B]}{[A]} = \frac{11}{6} = 2$$

36. $K_p = K_c(RT)^{\Delta n_g} \text{ \& } \Delta n_g = -\frac{1}{2}$

37. $N_2O_4(g) \rightleftharpoons 2NO_2(g) ; \Delta H = +58K$

(a) on decreasing temperature reaction equilibrium shift in the direction in which it is exothermic. Therefore in backward direction.

(b) Here pressure increases due to addition of N_2 gas, so there will be no effect.



Let mol of both of Cl_2 and Cl is x

$$P_{\text{Cl}} = \frac{x}{2x} \times 1 = \frac{1}{2}$$

$$P_{\text{Cl}_2} = \frac{x}{2x} \times 1 = \frac{1}{2}$$

$$K_p = \frac{\left(\frac{1}{2}\right)^2}{\frac{1}{2}} = \frac{1}{2} = 0.5 \Rightarrow 5 \times 10^{-1}$$

40. moles of NH_4HS initially taken = $\frac{5.1\text{g}}{51\text{g/mol}}$

41. $K'_{\text{eq}} = \frac{1}{\sqrt{K_{\text{eq}}}} = \frac{1}{\sqrt{2 \times 10^{15}}} = x \times 10^{-8}$

$$\Rightarrow \frac{1}{\sqrt{20}} \times \frac{1}{10^7} = x \times 10^{-8}$$

$$\Rightarrow \frac{1}{\sqrt{20}} \times 10^{-7} = x \times 10^{-8}$$

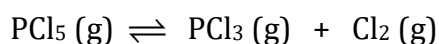
$$\frac{10}{\sqrt{20}} = x$$

$$\Rightarrow x = \frac{\sqrt{10}}{2} = \sqrt{5} = 2.236$$

$$= 2.24$$

42. Given : 2 mole of N_2 gas was present as inert gas.

Equilibrium pressure = 2.46 atm



$$t = 0 \quad \quad \quad 5 \quad \quad \quad 0 \quad \quad 0$$

$$t = \text{Eq}^n \quad \quad \quad 5 - x \quad \quad \quad x \quad \quad x$$

from ideal gas equation

$$PV = nRT$$

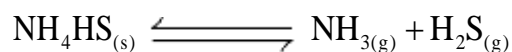
$$2.46 \times 200 = (5 - x + x + x + 2) \times 0.082 \times 600$$

$$x = 3$$

$$K_p = \frac{n_{\text{PCl}_3} \times n_{\text{Cl}_2}}{n_{\text{PCl}_5}} \times \left[\frac{P_{\text{total}}}{n_{\text{total}}} \right]$$

$$\frac{3 \times 3}{2} \times \frac{2.46}{10} = 1.107 = 1107 \times 10^{-3}$$

Volume of vessel = 2ℓ



$$t = 0 \quad 0.1 \text{ mol}$$

$$t = \infty \quad 0.1(1-0.2) \quad 0.1 \times 0.2 \quad 0.1 \times 0.2$$

⇒ partial pressure of each component

$$P = \frac{nRT}{V} = \frac{0.1 \times 0.2 \times 0.082 \times 300}{2}$$

$$= 0.246 \text{ atm}$$

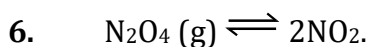
$$\Rightarrow K_p = P_{\text{NH}_3} \times P_{\text{H}_2\text{S}} = (0.246)^2 = 0.060516$$

$$= 6.05 \times 10^{-2}$$

$$\Rightarrow 6$$

EXERCISE - JEE ADVANCED

5. With change of pressure, x will change in such a way that K_p remains a constant.



moles $t=0$, 1 0

moles at eq. $1-\alpha$ 2α

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

Let total pressure at eq. = P .

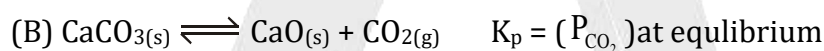
or $K_p = \frac{4\alpha^2}{1-\alpha^2} \times P.$

When volume is halved, P is double.

\therefore α will change as K_p is independent of pressure change.

8. (A) $\Delta H_2 - \Delta H_1 = C_{p(\text{rxn})} (T_2 - T_1)$

and C_p depends on temperature. Hence enthalpy also depends on temperature.



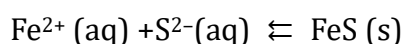
For a given reaction.

K_{eq} depends only on temperature.

(C) K_{eq} depends only on temperature.

(D) Enthalpy of reaction is independent of the catalyst. Catalyst generally changes activation energy.

9. Equal volumes of both the reactant are taken so, initial concentrations will be halved.



$t = 0$ 0.03M 0.1M

$t_{\text{eq.}}$ x 0.07M since K_c is very high

$$K_c = \frac{1}{[\text{Fe}^{2+}][\text{S}^{2-}]} = \frac{1}{x \times 0.07} = 1.6 \times 10^{17}$$

$$x = 8.928 \times 10^{-17}$$

So, $Y = 8.92$ (after truncate) or 8.93 (after round off).