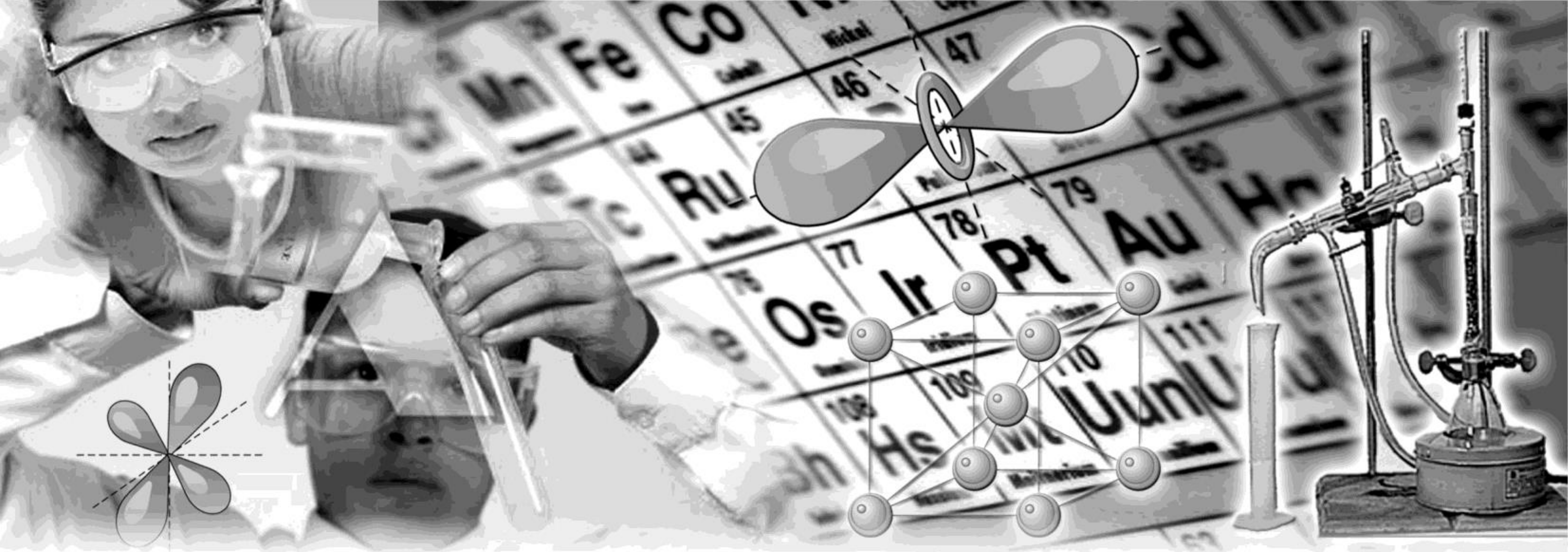


Chapter

8

Chemical Equilibrium

Whenever we hear the word Equilibrium immediately a picture arises in our mind an object under the influence of two opposing forces. For chemical reactions also this is true. A reaction also can exist in a state of equilibrium balancing forward and backward reactions.

Reversible and Irreversible reactions

A chemical reaction is said to have taken place when the concentration of reactants decreases, and the concentration of the products increases with time. The chemical reactions are classified on the basis of the extent to which they proceed, into the following two classes;

(1) **Reversible reactions :** Reaction in which entire amount of the reactants is not converted into products is termed as *reversible reaction.*

(i) ***Characteristics of reversible reactions***

(a) *These reactions can be started from either side*,

(b) *These reactions are never complete*,

(c) These reactions have a tendency to attain a state of equilibrium, in which Free energy change is zero ($\Delta G = 0$),

(d) This sign ($\rightleftharpoons$) represents the reversibility of the reaction,

(ii) ***Examples of reversible reactions***

(a) *Neutralisation between an acid and a base either of which or both are weak e.g.,*

$$CH_3COOH + NaOH \rightleftharpoons CH_3COONa + H_2O$$

(b) *Salt hydrolysis, e.g.,*

$$FeCl_3 + 3H_2O \rightleftharpoons Fe(OH)_3 + 3HCl$$

(c) *Thermal decomposition, e.g.,*

$$PCl_{5(g)} \rightleftharpoons PCl_{3(g)} + Cl_{2(g)} - Q$$

(d) *Esterification, e.g.,*

$$CH_3COOH + C_2H_5OH \rightleftharpoons CH_3COOC_2H_5 + H_2O$$

(e) *Evaporation of water in a closed vessel, e.g.,*

$$H_2O_{(l)} \rightleftharpoons H_2O_{(g)} - Q$$

(2) **Irreversible reactions :** Reaction in which entire amount of the reactants is converted into products is termed as *irreversible reaction.*

(i) ***Characteristics of irreversible reactions***

(a) These reactions proceed only in one direction (forward direction),

(b) These reactions can proceed to completion,

(c) In an irreversible reaction, $\Delta G < 0$,

(d) The arrow ($\rightarrow$) is placed between reactants and products,

(ii) ***Examples of irreversible reactions***

(a) *Neutralisation between strong acid and strong base e.g.,*

$$NaOH + HCl \rightarrow NaCl + H_2O + 13.7\ kcal$$

(b) *Double decomposition reactions or precipitation reactions e.g.,*

$$BaCl_{2(aq)} + H_2SO_{4(aq)} \rightarrow BaSO_{4(s)} \downarrow + 2HCl_{(aq)}$$

(c) *Thermal decomposition, e.g.,*

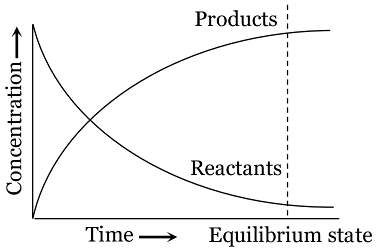
$$2KClO_{3(s)} \xrightarrow{MnO_2,\Delta} 2KCl_{(s)} + 3O_2 \uparrow$$

(d) *Redox reactions, e.g.,*

$$SnCl_{2(aq)} + 2FeCl_{3(aq)} \rightarrow SnCl_{4(aq)} + 2FeCl_{2(aq)}$$

Equilibrium and Its dynamic nature

*"**Equilibrium** is the state at which the concentration of reactants and products do not change with time. i.e. concentrations of reactants and products become constant."*



The important characteristics of equilibrium state are,

(1) Equilibrium state can be recognised by the constancy of certain measurable properties such as *pressure, density, colour, concentration* etc. by changing these conditions of the system, we can control the extent to which a reaction proceeds.

(2) Equilibrium state can only be achieved in *close vessel.*

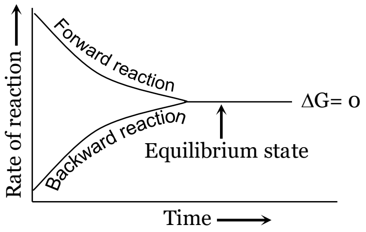
(3) Equilibrium state is *reversible* in nature.

(4) Equilibrium state is also *dynamic* in nature.

(5) At equilibrium state,

Rate of forward reaction = Rate of backward reaction

(6) At equilibrium state, $\Delta G = 0$, so that $\Delta H = T\Delta S$.



Law of mass action and Equilibrium constant

On the basis of observations of many equilibrium reactions, two Norwegian chemists ***Goldberg*** and ***Waage*** suggested (1864) a quantitative relationship between the rates of reactions and the concentration of the reacting substances. This relationship is known as *law of mass action.* It states that

"*The rate of a chemical reaction is directly proportional to the product of the molar concentrations of the reactants at a constant temperature at any given time.*"

The molar concentration *i.e. number of moles per litre* is also called *active mass*. It is expressed by enclosing the symbols of formulae of the substance in square brackets. For example, molar concentration of A is expressed as $[A]$.

Consider a simple reversible reaction

$aA + bB \rightleftharpoons cC + dD$ (At a certain temperature)

According to law of mass action

Rate of forward reaction $\propto [A]^a[B]^b = k_f[A]^a[B]^b$

Rate of backward reaction $\propto [C]^c[D]^d = k_b[C]^c[D]^d$

At equilibrium ,
Rate of forward reaction = Rate of backward reaction

$$k_f[A]^a[B]^b = k_b[C]^c[D]^d$$

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

Where, K_c is called equilibrium constant.

In terms of partial pressures, equilibrium constant is denoted by K_p and

$$K_p = \frac{P_C^c\ P_D^d}{P_A^a\ P_B^b}$$

In terms of mole fraction, equilibrium constant is denoted by K_x and

$$K_x = \frac{(X_C)^c\ (X_D)^d}{(X_A)^a\ (X_B)^b}$$

Relation between K_p, K_c and K_x

$$K_p = K_c(RT)^{\Delta n}$$

$$K_p = K_x(P)^{\Delta n}$$

Δn = number of moles of gaseous products – number of moles of gaseous reactants in chemical equation.

As a general rule, the concentration of pure solids and pure liquids are not included when writing an equilibrium equation.

Value of Δn	Relation between K_p and K_c	Units of K_p	Units of K_c
0	$K_p = K_c$	No unit	No unit
>0	$K_p > K_c$	$(atm)^{\Delta n}$	$(mole\ l^{-1})^{\Delta n}$
<0	$K_p < K_c$	$(atm)^{\Delta n}$	$(mole\ l^{-1})^{\Delta n}$

Characteristics of equilibrium constant

(1) *The value of equilibrium constant is independent of the original concentration of reactants.*

(2) *The equilibrium constant has a definite value for every reaction at a particular temperature.* However, it varies with change in temperature.

(3) *For a reversible reaction, the equilibrium constant for the forward reaction is inverse of the equilibrium constant for the backward reaction.*

$$\text{In general, } K_{\text{forward reaction}} = \frac{1}{K'_{\text{backward reaction}}}$$

(4) *The value of an equilibrium constant tells the extent to which a reaction proceeds in the forward or reverse direction.*

(5) *The equilibrium constant is independent of the presence of catalyst.*

(6) *The value of equilibrium constant changes with the change of temperature.* Thermodynamically, it can be shown that if K_1 and K_2 be the equilibrium constants of a reaction at absolute temperatures T_1 and T_2. If ΔH is the heat of reaction at constant volume, then

$$\log K_2 - \log K_1 = \frac{-\Delta H}{2.303\ R}\left[\frac{1}{T_2} - \frac{1}{T_1}\right] \text{ (Van't Hoff equation)}$$

The effect of temperature can be studied in the following three cases

(i) When $\Delta H = 0$ *i.e., neither heat is evolved nor absorbed*

$$\log K_2 - \log K_1 = 0 \text{ or } \log K_2 = \log K_1 \text{ or } K_2 = K_1$$

Thus, equilibrium constant remains the same at all temperatures.

(ii) When ΔH = +*ve i.e., heat is absorbed,* the reaction is *endothermic.* The temperature T_2 is higher than T_1.

$$\log K_2 - \log K_1 = +ve \text{ or } \log K_2 > \log K_1 \text{ or } K_2 > K_1$$

The value of equilibrium constant is higher at higher temperature in case of endothermic reactions.

(iii) When ΔH = – *ve, i.e., heat is evolved,* the reaction is *exothermic.* The temperature T_2 is higher than T_1.

$$\log K_2 - \log K_1 = -ve \text{ or } \log K_1 > \log K_2 \text{ or } K_1 > K_2$$

The value of equilibrium constant is lower at higher temperature in the case of exothermic reactions.

(7) *The value of the equilibrium constant depends upon the stoichiometry of the chemical equation.*

For the reaction

$$2SO_3(g) \rightleftharpoons 2SO_2(g) + O_2(g) \text{ and } SO_3(g) \rightleftharpoons SO_2(g) + 1/2O_2(g)$$

$$K = \frac{[SO_2]^2[O_2]}{[SO_3]^2} \text{ and } K' = \frac{[SO_2][O_2]^{1/2}}{[SO_3]}$$

$$K' = \sqrt{K} \text{ or } (K)^{1/2}$$

(i) Similarly, if a particular equation is multiplied by 2, the equilibrium constant for the new reaction (K') will be the square of the equilibrium constant (K) for the original reaction *i.e.,* $K' = K^2$

(ii) If the chemical equation for a particular reaction is written in two steps having equilibrium constants K_1 and K_2, then the equilibrium constants are related as $K = K_1 \times K_2$

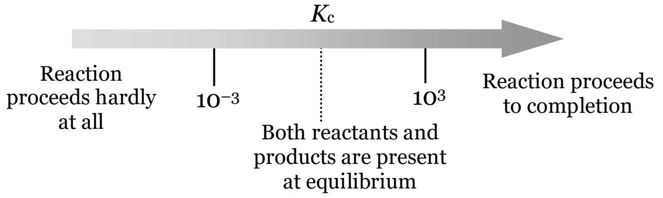
Applications of equilibrium constant

(1) Judging the extent of reaction

(i) If $K_c > 10^3$, products predominate over reactants. If K_c is very large, the reaction proceeds almost all the way to completion.

(ii) If $K_c < 10^{-3}$, reactants predominate over products. If K_c is very small, the reaction proceeds hardly at all.

(iii) If K_c is in the range 10^{-3} to 10^3, appreaciable concentration of both reactants and products are present.



(2) Predicting the direction of reaction : The concentration ratio, *i.e.*, ratio of the product of concentrations of products to that of reactants is also known as *concentration quotient* and is denoted by Q.

$$\text{Concentration quotient, } Q = \frac{[X][Y]}{[A][B]}.$$

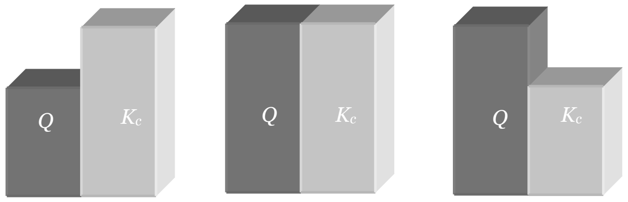
It may be noted that Q becomes equal to equilibrium constant (K) when the reaction is at the equilibrium state. At equilibrium, $Q = K = K_c = K_p$. Thus,

(i) If $Q > K$, the reaction will proceed in the direction of reactants (*reverse reaction*).

(ii) If $Q < K$, the reaction will proceed in the direction of the products (*forward reaction*).

(iii) If $Q = K$, the reaction mixture is already *at equilibrium.*

Thus, a reaction has a tendency to form products if $Q < K$ and to form reactants if $Q > K$.



Reactants → Products
$Q < K$
(Forward reaction)

Equilibrium
Q = K
(At

Reactants ← Products
$Q > K$
(Reverse reaction)

Fig. 8.1

Types of equilibria

The equilibrium between different chemical species present in the same or different phases is called chemical equilibrium. There are two types of chemical equilibrium.

(1) **Homogeneous equilibrium :** The equilibrium reactions in which all the reactants and the products are in the same phase are called *homogeneous equilibrium reactions.*

$$C_2H_5OH\,(l) + CH_3COOH\,(l) \rightleftharpoons CH_3COOC_2H_5\,(l) + H_2O(l)$$

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

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

(2) **Heterogeneous equilibrium :** The equilibrium reactions in which the reactants and the products are present in different phases are called *heterogeneous equilibrium reactions.*

$$2NaHCO_3\,(s) \rightleftharpoons Na_2CO_3\,(s) + CO_2\,(g) + H_2O(g)$$

$$Ca(OH)_2(s) + H_2O(l) \rightleftharpoons Ca^{2+}(aq) + 2OH^-\,(aq)$$

$$CaCO_3\,(s) \rightleftharpoons CaO\,(s) + CO_2\,(g)$$

$$H_2O(l) \rightleftharpoons H_2O(g)$$

Table : 8.1 Homogeneous equilibria and equations for equilibrium constant (Equilibrium pressure is *P atm* in a V L flask**)**

	$\Delta n = 0\,;\, K_p = K_c$	$\Delta n < 0\;;\; K_p < K_c$		$\Delta n > 0; K_p > K_c$
	$\underset{(g)}{H_2} + \underset{(g)}{I_2} \rightleftharpoons \underset{(g)}{2HI}$	$\underset{(g)}{N_2} + \underset{(g)}{3H_2} \rightleftharpoons \underset{(g)}{2NH_3}$	$\underset{(g)}{2SO_2} + \underset{(g)}{O_2} \rightleftharpoons \underset{(g)}{2SO_3}$	$\underset{(g)}{PCl_5} \rightleftharpoons \underset{(g)}{PCl_3} + \underset{(g)}{Cl_2}$
Initial mole	1 1 0	1 3 0	2 1 0	1 0 0
Mole at Equilibrium	$(1-x)$ $(1-x)$ $2x$	$(1-x)$ $(3-3x)$ $2x$	$(2-2x)$ $(1-x)$ $2x$	$(1-x)$ x x
Total mole at equilibrium	2	$(4-2x)$	$(3-x)$	$(1+x)$
Active masses	$\left(\frac{1-x}{V}\right)\left(\frac{1-x}{V}\right)\frac{2x}{V}$	$\left(\frac{1-x}{V}\right)3\left(\frac{1-x}{V}\right)\left(\frac{2x}{V}\right)$	$\left(\frac{2-2x}{V}\right)\left(\frac{1-x}{V}\right)\left(\frac{2x}{V}\right)$	$\left(\frac{1-x}{V}\right)\left(\frac{x}{V}\right)\left(\frac{x}{V}\right)$
Mole fraction	$\left(\frac{1-x}{2}\right)\left(\frac{1-x}{2}\right)\frac{2x}{2}$	$\frac{1-x}{2(2-x)}\;\frac{3}{2}\left(\frac{1-x}{2-x}\right)\frac{x}{(2-x)}$	$\left(\frac{2-2x}{3-x}\right)\left(\frac{1-x}{3-x}\right)\left(\frac{2x}{3-x}\right)$	$\left(\frac{1-x}{1+x}\right)\left(\frac{x}{1+x}\right)\left(\frac{x}{1+x}\right)$
Partial pressure	$p\left(\frac{1-x}{2}\right)p\left(\frac{1-x}{2}\right)p\left(\frac{2x}{2}\right)$	$P\left(\frac{1-x}{2(2-x)\_}\right)P\left(\frac{3(1-x)}{2(2-x)}\right)\frac{Px}{(2-x)}$	$P\left(\frac{2-2x}{3-x}\right)P\left(\frac{1-x}{3-x}\right)P\left(\frac{2x}{3-x}\right)$	$P\left(\frac{1-x}{1+x}\right)P\left(\frac{x}{1+x}\right)P\left(\frac{x}{1+x}\right)$
K_c	$\frac{4x^2}{(1-x)^2}$	$\frac{4x^2V^2}{27\,(1-x)^4}$	$\frac{x^2V}{(1-x)^3}$	$\frac{x^2}{(1-x)V}$
K_p	$\frac{4x^2}{(1-x)^2}$	$\frac{16x^2(2-x)^2}{27(1-x)^4P^2}$	$\frac{x^2(3-x)}{P(1-x)^3}$	$\frac{Px^2}{(1-x^2)}$

Table : 8.2 Heterogeneous equilibria and equation for equilibrium constant (Equilibrium pressure is P atm)

	$NH_4HS(s) \rightleftharpoons NH_3(g) + H_2S(g)$	$C(s) + CO_2(g) \rightleftharpoons 2CO(g)$	$NH_2CO_2NH_4(s) \rightleftharpoons 2NH_3(g) + CO_2(g)$
Initial mole	1 0 0	1 1 0	1 0 0
Mole at equilibrium	$(1-x)$ x x	$(1-x)$ $(1-x)$ $2x$	$(1-x)$ $2x$ x
Total moles at equilibrium (solid not included)	$2x$	$(1+x)$	$3x$
Mole fraction	$\frac{x}{2x} = \frac{1}{2}$ $\frac{1}{2}$	$\left(\frac{1-x}{1+x}\right)\left(\frac{2x}{1+x}\right)$	$\frac{2}{3}$ $\frac{1}{3}$
Partial pressure	$\frac{P}{2}$ $\frac{P}{2}$	$P\left(\frac{1-x}{1+x}\right)P\left(\frac{2x}{1+x}\right)$	$\frac{2P}{3}$ $\frac{P}{3}$
K_p	$\frac{P^2}{4}$	$\frac{4P\,x^2}{(1-x^2)}$	$\frac{4P^3}{27}$

Relationship between equilibrium constant and ΔG°

ΔG for a reaction under any condition is related with ΔG° by the relation, $\Delta G = \Delta G^\circ + 2.303\ RT \log Q$

Standard free energy change of a reaction and its equilibrium constant are related to each other at temperature T by the relation, $\Delta G^o = -2.303\ RT \log K$

For a general reaction $aA + bB \rightleftharpoons cC + dD$

$$K = \frac{(a_C)^c\,(a_D)^d}{(a_A)^a\,(a_B)^b}$$

Where a represent the activity of the reactants and products. It is unit less.

For pure solids and liquids: $a = 1$.

For gases: $a =$ pressure of gas in *atm*.

For components in solution: $a =$ molar concentration.

Le-Chatelier's principle

Le-Chatelier and Braun (1884), French chemists, made certain generalizations to explain the effect of changes in concentration, temperature or pressure on the state of system in equilibrium. When a system is subjected to a change in one of these factors, the equilibrium gets disturbed and the system readjusts itself until it returns to equilibrium. The generalization is known as ***Le-Chatelier's principle.*** It may be stated as :

"Change in any of the factors that determine the equilibrium conditions of a system will shift the equilibrium in such a manner to reduce or to counteract the effect of the change."

The principle is very helpful in predicting ***qualitatively*** the effect of change in concentration, pressure or temperature on a system in equilibrium.

Table : 8.3 The effect of varying conditions on the equilibrium $aA + bB \rightleftharpoons cC + dD$, $\Delta n = (c + d) - (a + b)$

Change imposed on the system in equilibrium	Equilibrium position moves	Equilibrium constant	Any other points
Conc. of *A* and/or *B* increased	To right	No change	No change
Conc. of *C* and /or *D* increased	To left	No change	No change
Pressure increased	To right if $(c+d) < (a+b)$, *i.e.* $\Delta n = -ve$ To left if $(c+d) > (a+b)$, *i.e.* $\Delta n = +ve$ No change if $(c+d) = (a+b)$, *i.e.* $\Delta n = 0$	No change No change No change	Very little effect, if any, on reactions in liquid solution.
Temperature increased	To left if $\Delta H = -ve$ (exothermic) To right if $\Delta H = +ve$ (endothermic)	Value decreased Value increased	Equilibrium achieved faster
Addition of catalyst	No change	No change	Equilibrium achieved faster

Application of Le-Chatelier's principle

The Le-Chateliers principle has a great significance for the chemical, physical systems and in every day life in a state of equilibrium.

(1) **Applications to the chemical equilibrium**

(i) ***Synthesis of ammonia (Haber's process)***

$$\underset{1\,vol}{N_2} + \underset{3\,vol}{3H_2} \rightleftharpoons \underset{2\,vol}{2NH_3} + 23\,kcal \text{ (exothermic)}$$

(a) High pressure $(\Delta n < 0)$

(b) Low temperature

(c) Excess of N_2 and H_2

(d) Removal of NH_3 favours forward reaction.

(ii) ***Formation of sulphur trioxide***

$$\underset{2\,vol}{2SO_2} + \underset{1\,vol}{O_2} \rightleftharpoons \underset{2\,vol}{2SO_3} + 45\,kcal \text{ (exothermic)}$$

(a) High pressure $(\Delta n < 0)$

(b) Low temperature

(c) Excess of SO_2 and O_2, favours the reaction in forward direction.

(iii) ***Synthesis of nitric oxide***

$$\underset{1\,vol}{N_2} + \underset{1\,vol}{O_2} \rightleftharpoons \underset{2\,vol}{2NO} - 43.2\,kcal \text{ (endothermic)}$$

(a) High temperature

(b) Excess of N_2 and O_2

(c) Since reaction takes place without change in volume *i.e.*, $\Delta n = 0$, pressure has no effect on equilibrium.

(iv) ***Formation of nitrogen dioxide***

$$\underset{2\,vol}{2NO} + \underset{1\,vol}{O_2} \rightleftharpoons \underset{2\,vol}{2NO_2} + 27.8\,Kcal$$

(a) High pressure

(b) Low temperature

(c) Excess of NO and O_2 favours the reaction in forward direction.

(v) ***Dissociation of phosphours pentachloride***

$$\underset{1\,vol}{PCl_5} \rightleftharpoons \underset{1\,vol}{PCl_3} + \underset{1\,vol}{Cl_2} - 15\,kcal$$

(a) Low pressure or high volume of the container, $\Delta n > 0$

(b) High temperature (c) Excess of PCl_5.

(2) **Applications to the physical equilibrium**

(i) ***Melting of ice*** *(Ice – water system)*

$$\underset{\text{(Greater Volume)}}{\text{Ice}} \rightleftharpoons \underset{\text{(Lesser Volume)}}{\text{Water}} - x\,kcal$$

(In this reaction volume is decreased from 1.09 *c.c.* to 1.01 *c.c. per gm.*)

(a) At high temperature more water is formed as it absorbs heat.

(b) At high pressure more water is formed as it is accompanied by decrease in volume.

(c) At higher pressure, melting point of ice is lowered, while boiling point of water is increased.

(ii) ***Melting of sulphur*** : $S_{(s)} \rightleftharpoons S_{(l)} - x\,kcal$

(This reaction accompanies increase in volume.)

(a) At high temperature, more liquid sulphur is formed.

(b) At higher pressure, less sulphur will melt as melting increases volume.

(c) At higher pressure, melting point of sulphur is increased.

(iii) ***Boiling of water*** *(water- water vapour system)*

$$\underset{\text{(Low volume)}}{\text{Water}} \rightleftharpoons \underset{\text{(Higher volume)}}{\text{Water Vapours}} - x\,kcal$$

(It is accompanied by absorption of heat and increase in volume.)

(a) At high temperature more vapours are formed.

(b) At higher pressure, vapours will be converted to liquid as it decreases volume.

(c) At higher pressure, boiling point of water is increased (principle of pressure cooker).

(iv) ***Solubility of salts*** : If solubility of a salt is accompanied by absorption of heat, its solubility increases with rise in temperature; e.g., NH_4Cl, K_2SO_4, KNO_3 etc.

$$KNO_{3(s)} + (aq) \longrightarrow KNO_{3(aq)} - x\ kcal$$

On the other hand if it is accompanied by evolution of heat, solubility decreases with increase in temperature; e.g., $CaCl_2$, $Ca(OH)_2$, $NaOH$, KOH etc.

$$Ca(OH)_{2(s)} + (aq) \longrightarrow Ca(OH)_{2(aq)} + x\ kcal$$

Relation between vapour density and Degree of dissociation

In the following reversible chemical equation.

$$A \rightleftharpoons yB$$

Initial mol 1 0

At equilibrium (1–x) yx x = degree of dissociation

Number of moles of A and B at equilibrium $= 1 - x + yx = 1 + x(y-1)$

If initial volume of 1 mole of A is V, then volume of equilibrium mixture of A and B is, $= [1 + x(y-1)]V$

Molar density before dissociation,

$$D = \frac{\text{molecular weight}}{\text{volume}} = \frac{m}{V}$$

Molar density after dissociation,

$$d = \frac{m}{[1 + x(y-1)]V}\ ;\ \frac{D}{d} = [1 + x(y-1)]\ ;\ x = \frac{D-d}{d(y-1)}$$

y is the number of moles of products from one mole of reactant. $\frac{D}{d}$ is also called ***Van't Hoff factor.***

In terms of molecular mass, $x = \frac{M - m}{(y-1)m}$

Where $M =$ Initial molecular mass,

$m =$ molecular mass at equilibrium

Thus for the equilibria

(I) $PCl_{5(g)} \rightleftharpoons PCl_{3(g)} + Cl_{2(g)}, y = 2$

(II) $N_2O_{4(g)} \rightleftharpoons 2NO_{2(g)}, y = 2$

(III) $2NO_2 \rightleftharpoons N_2O_4, y = \frac{1}{2}$

$\therefore\ x = \frac{D-d}{d}$ (for I and II) and $x = \frac{2(d-D)}{d}$ (for III)

Also $D \times 2 =$ Molecular weight (theoretical value)

$d \times 2 =$ Molecular weight (abnormal value) of the mixture.

Tips & Tricks

- Pure ice can be made to melt at a temperature slightly below 0°C by increasing the pressure. As the water so obtained on melting is below 0°C, it refreezes when pressure is reduced. It is called regelation of ice.
- Increase in external pressure always increases the boiling point and vice-versa.
- If the reaction is multipled by 2, the equilibrium constant is squared.
- When a bottle of coca or beer is opened, the pressure is decreased and dissolved CO_2 gas escapes out with a fizze.
- Increase in pressure favours melting of ice into water
- Flash evaporation is a technique generally used for concentrating certain aqueous solutions which cannot be concentrated by normal boiling.
- Freeze drying is a technique where water is made to sublime off at a temperature below 0°C.

Ordinary Thinking

Objective Questions

Reversible and Irreversible reaction

1. A reversible reaction is one which **[MP PET 1986]**

(a) Proceeds in one direction

(b) Proceeds in both directions

(c) Proceeds spontaneously

(d) All the statements are wrong

2. Which of the following is a characteristic of a reversible reaction **[AFMC 1993]**

(a) Number of moles of reactants and products are equal

(b) It can be influenced by a catalyst

(c) It can never proceed to completion

(d) None of the above

3. The reaction $CaCO_3 \rightleftharpoons CaO + CO_2(g)$ goes to completion in lime kiln because **[MP PMT/PET 1988; CPMT 1990]**

(a) Of the high temperature

(b) CaO is more stable than $CaCO_3$

(c) CaO is not dissociated

(d) CO_2 escapes continuously

4. In the given reaction $N_2 + O_2 \rightleftharpoons 2NO$, equilibrium means that

(a) Concentration of reactants is changing where as concentration of products is constant

(b) Concentration of all substances is constant

(c) Concentration of reactants is constant where as concentration of products is changing

(d) Concentration of all substances is changing

5. Which of the following reactions is reversible **[MADT Bihar 1980]**

(a) $H_2 + I_2 \longrightarrow 2HI$

(b) $H_2SO_4 + Ba(OH)_2 \longrightarrow BaSO_4 + 2H_2O$

(c) $NaCl + AgNO_3 \longrightarrow NaNO_3 + AgCl$

(d) $Fe + S \longrightarrow FeS$

6. All reactions which have chemical disintegration **[MP PMT 1990]**

(a) Is reversible

(b) Is reversible and endothermic

(c) Is exothermic

(d) Is reversible or irreversible and endothermic or exothermic

7. Amongst the following chemical reactions the irreversible reaction is **[MP PMT 1999]**

(a) $H_2 + I_2 \rightleftharpoons HI$

(b) $AgNO_3 + NaCl \rightleftharpoons AgCl + NaNO_3$

(c) $CaCO_3 \rightleftharpoons CaO + CO_2$

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

Equilibrium state

1. In any chemical reaction, equilibrium is supposed to be establish when

[CPMT 1974, 80, 89; EAMCET 1975, 77, 79; MP PMT 1990; NCERT 1980; MP PET 1995]

(a) Mutual opposite reactions undergo

(b) Concentration of reactants and resulting products are equal

(c) Velocity of mutual reactions become equal

(d) The temperature of mutual opposite reactions become equal

2. Which of the following conditions represents an equilibrium

(a) Freezing of ice in a open vessel, temperature of ice is constant

(b) Few drops of water is present along with air in a balloon, temperature of balloon is constant

(c) Water is boiling in an open vessel over stove, temperature of water is constant

(d) All the statements (a), (b) and (c) are correct for the equilibrium

3. When rate of forward reaction becomes equal to backward reaction, this state is termed as

[NCERT 1975, 80; CPMT 1973, 74, 77]

(a) Chemical equilibrium (b) Reversible state

(c) Equilibrium (d) All of these

4. In chemical reaction $A \rightleftharpoons B$, the system will be known in equilibrium when **[MP PMT 1990; NCERT 1977]**

(a) A completely changes to B

(b) 50% of A changes to B

(c) The rate of change of A to B and B to A on both the sides are same

(d) Only 10% of A changes to B

5. A chemical reaction is at equilibrium when

[NCERT 1975; CPMT 1974; MP PMT 1996; KCET 1993; IIT 1978; Manipal MEE 1995; Pb. PMT 2002]

(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

6. In the chemical reaction $N_2 + 3H_2 \rightleftharpoons 2NH_3$ at equilibrium point, state whether **[NCERT 1977]**

(a) Equal volumes of N_2 and H_2 are reacting

(b) Equal masses of N_2 and H_2 are reacting

(c) The reaction has stopped

(d) The same amount of ammonia is formed as is decomposed into N_2 and H_2

7. For the reaction $PCl_3(g) + Cl_2(g) \rightleftharpoons PCl_5(g)$ the position of equilibrium can be shifted to the right by **[MP PMT 2004]**

(a) Increasing the temperature

(b) Doubling the volume

(c) Addition of Cl_2 at constant volume

(d) Addition of equimolar quantities of PCl_3 and PCl_5

8. If a system is at equilibrium the rate of forward to the reverse reaction is **[UPSEAT 2004]**

(a) Less (b) Equal

(c) High (d) At equilibrium

9. Chemical equilibrium is dynamic in nature because

[IIT 1977]

(a) Equilibrium is maintained rapidly

(b) The concentration of reactants and products become same at equilibrium

(c) The concentration of reactants and products are constant but different

(d) Both forward and backward reactions occur at all times with same speed

10. The number of gram molecules of a substance present in unit volume is termed as **[MP PMT 1993]**

(a) Activity (b) Normal solution

(c) Molar concentration (d) Active mass

Law of mass action

1. According to law of mass action rate of a chemical reaction is proportional to **[AFMC 2005]**

(a) Concentration of reactants

(b) Molar concentration of reactants

(c) Concentration of products

(d) Molar concentration of products

2. In a reaction the rate of reaction is proportional to its active mass, this statement is known as **[IIT 1979]**

(a) Law of mass action

(b) Le-chatelier principle

(c) Faraday law of electrolysis

(d) Law of constant proportion

3. The active mass of 64 gm of HI in a two litre flask would be

[CPMT 1979]

(a) 2 (b) 1

(c) 5 (d) 0.25

4. Under a given set of experimental conditions, with increase in the concentration of the reactants, the rate of a chemical reaction

(a) Decreases

(b) Increases

(c) Remains unaltered

(d) First decreases and then increases

5. The law of mass action was enunciated by **[MP PMT 1995]**

(a) Guldberg and Waage (b) Bodenstein
(c) Birthelot (d) Graham

6. Theory of 'active mass' indicates that the rate of chemical reaction is directly proportional to the **[MP PET 1990]**

(a) Equilibrium constant
(b) Properties of reactants
(c) Volume of apparatus
(d) Concentration of reactants

7. The rate at which substances react depends on their **[MP PMT 1997]**

(a) Atomic weight (b) Molecular weight
(c) Equivalent weight (d) Active mass

8. Which is false **[AMU 1999]**

(a) The greater the concentration of the substances involved in a reaction, the lower the speed of the reaction
(b) The point of dynamic equilibrium is reached when the reaction rate in one direction just balances the reaction rate in the opposite direction
(c) The dissociation of weak electrolyte is a reversible reaction
(d) The presence of free ions facilitates chemical changes

9. Chemical equations convey quantitative information on the **[Orissa JEE 2002]**

(a) Type of atoms/molecules taking part in the reaction
(b) Number of atoms/molecules of the reactants and products involved in the reaction
(c) Relative number of moles of reactants and products involved in the reaction
(d) Quantity of reactant consumed and quantity of product formed

10. In the thermal decomposition of potassium chlorate given as $2KClO_3 \longrightarrow 2KCl + 3O_2$, law of mass action **[MADT Bihar 1983]**

(a) Cannot be applied
(b) Can be applied
(c) Can be applied at low temperature
(d) Can be applied at high temp. and pressure

Law of equilibrium and Equilibrium constant

1. For the system $3A + 2B \rightleftharpoons C$, the expression for equilibrium constant is **[NCERT 1981; CPMT 1989; MP PMT 1990; RPMT 1999; Pb. PMT 2002; Pb. CET 2002]**

(a) $\frac{[3A][2B]}{C}$ (b) $\frac{[C]}{[3A][2B]}$
(c) $\frac{[A]^3[B]^2}{[C]}$ (d) $\frac{[C]}{[A]^3[B]^2}$

2. In the reversible reaction $A + B \rightleftharpoons C + D$, the concentration of each *C* and *D* at equilibrium was 0.8 mole/litre, then the equilibrium constant K_c will be **[MP PET 1986]**

(a) 6.4 (b) 0.64
(c) 1.6 (d) 16.0

3. 4 moles of A are mixed with 4 moles of B. At equilibrium for the reaction $A + B \rightleftharpoons C + D$, 2 moles of *C* and *D* are formed. The equilibrium constant for the reaction will be **[CPMT 1992]**

(a) $\frac{1}{4}$ (b) $\frac{1}{2}$
(c) 1 (d) 4

4. On a given condition, the equilibrium concentration of HI, H_2 and I_2 are 0.80, 0.10 and 0.10 mole/litre. The equilibrium constant for the reaction $H_2 + I_2 \rightleftharpoons 2HI$ will be **[MP PET 1986]**

(a) 64 (b) 12
(c) 8 (d) 0.8

5. In which of the following, the reaction proceeds towards completion **[MNR 1990]**

(a) $K = 10^3$ (b) $K = 10^{-2}$
(c) $K = 10$ (d) $K = 1$

6. A reversible chemical reaction having two reactants in equilibrium. If the concentrations of the reactants are doubled, then the equilibrium constant will **[CPMT 1982, 90; MP PMT 1990,2004; MNR 1992; UPSEAT 2002; KCET 1999; Pb. CET 2004]**

(a) Also be doubled (b) Be halved
(c) Become one-fourth (d) Remain the same

7. The equilibrium constant in a reversible reaction at a given temperature **[AIIMS 1982]**

(a) Depends on the initial concentration of the reactants
(b) Depends on the concentration of the products at equilibrium
(c) Does not depend on the initial concentrations
(d) It is not characteristic of the reaction

8. Pure ammonia is placed in a vessel at temperature where its dissociation constant (α) is appreciable. At equilibrium **[IIT 1984; Kurukshetra CEE 1998]**

(a) K_p does not change significantly with pressure
(b) α does not change with pressure
(c) Concentration of NH_3 does not change with pressure
(d) Concentration of H_2 is less than that of N_2

9. For the system $A(g)+2B(g) \rightleftharpoons C(g)$, the equilibrium concentrations are (A) 0.06 *mole/litre* (B) 0.12 *mole/litre* (C) 0.216 *mole/litre*. The K_{eq} for the reaction is

[CPMT 1983]

(a) 250 (b) 416

(c) 4×10^{-3} (d) 125

10. The equilibrium constant for the given reaction $H_2+I_2 \rightleftharpoons 2HI$ is correctly given by expression

[CPMT 1984]

(a) $K_c=\frac{[H_2][I_2]}{[HI]}$ (b) $K_c=\frac{[H_2][I_2]}{[2HI]}$

(c) $K_c=\frac{[H_2][I_2]}{[HI]^2}$ (d) $K_c=\frac{[HI]^2}{[H_2][I_2]}$

11. Partial pressures of *A, B, C* and *D* on the basis of gaseous system $A+2B \rightleftharpoons C+3D$ are A = 0.20; B = 0.10; C = 0.30 and D = 0.50 atm. The numerical value of equilibrium constant is

(a) 11.25 (b) 18.75

(c) 5 (d) 3.75

12. For the reaction $A+2B \rightleftharpoons C$, the expression for equilibrium constant is

[MNR 1987; MP PMT 1999; UPSEAT 2002]

(a) $\frac{[A][B]^2}{[C]}$ (b) $\frac{[A][B]}{[C]}$

(c) $\frac{[C]}{[A][B]^2}$ (d) $\frac{[C]}{2[B][A]}$

13. 2 moles of PCl_5 were heated in a closed vessel of 2 litre capacity. At equilibrium, 40% of PCl_5 is dissociated into PCl_3 and Cl_2. The value of equilibrium constant is

[MP PMT 1989; RPMT 2000; UPSEAT 2004; Kerala CET 2005]

(a) 0.266 (b) 0.53

(c) 2.66 (d) 5.3

14. For which of the following reactions does the equilibrium constant depend on the units of concentration

[AIIMS 1983]

(a) $NO_{(g)} \rightleftharpoons \frac{1}{2}N_{2(g)}+\frac{1}{2}O_{2(g)}$

(b) $Zn_{(s)}+Cu^{2+}_{(aq)} \rightleftharpoons Cu_{(s)}+Zn^{2+}_{(aq)}$

(c) $C_2H_5OH_{(l)}+CH_3COOH_{(l)} \rightleftharpoons CH_3COOC_2H_{5(l)}+H_2O_{(l)}$ (Reaction carried in an inert solvent)

(d) $COCl_{2(g)} \rightleftharpoons CO_{(g)}+Cl_{2(g)}$

15. Unit of equilibrium constant for the reversible reaction $H_2+I_2 \rightleftharpoons 2HI$ is

(a) $mol^{-1}\ litre$ (b) $mol^{-2}\ litre$

(c) $mol\ litre^{-1}$ (d) None of these

16. The decomposition of N_2O_4 to NO_2 is carried out at $280\,K$ in chloroform. When equilibrium has been established, 0.2 mol of N_2O_4 and 2×10^{-3} mol of NO_2 are present in 2 litre solution. The equilibrium constant for reaction $N_2O_4 \rightleftharpoons 2NO_2$ is **[AIIMS 1984]**

(a) 1×10^{-2} (b) 2×10^{-3}

(c) 1×10^{-5} (d) 2×10^{-5}

17. Concentration of a gas is expressed in the following terms in the calculation of equilibrium constant **[EAMCET 1982]**

(a) No. of molecules per litre

[CPMT 1987]

(b) No. of grams per litre

(c) No. of gram equivalent per litre

(d) No. of molecules equivalent per litre

18. The unit of equilibrium constant K for the reaction $A+B \rightleftharpoons C$ would be **[CPMT 1987]**

(a) $mol\ litre^{-1}$ (b) $litre\ mol^{-1}$

(c) $mol\ litre$ (d) Dimensionless

19. In a reaction $A+B \rightleftharpoons C+D$, the concentrations of *A, B, C* and *D* (in moles/litre) are 0.5, 0.8, 0.4 and 1.0 respectively. The equilibrium constant is **[BHU 1981]**

(a) 0.1 (b) 1.0

(c) 10 (d) ∞

20. In a chemical equilibrium $A+B \rightleftharpoons C+D$, when one mole each of the two reactants are mixed, 0.6 mole each of the products are formed. The equilibrium constant calculated is

[CBSE PMT 1989]

(a) 1 (b) 0.36

(c) 2.25 (d) 4/9

21. For the reaction $N_{2(g)}+3H_{2(g)} \rightleftharpoons 2NH_{3(g)}$, the correct expression of equilibrium constant K is

[CPMT 1984, 2000]

(a) $K=\frac{[NH_3]^2}{[N_2][H_2]^3}$ (b) $K=\frac{[N_2][H_2]^3}{[NH_3]^2}$

(c) $K=\frac{2[NH_3]}{[N_2]\times3[H_2]}$ (d) $K=\frac{[N_2]\times3[H_2]}{2[NH_3]}$

22. The suitable expression for the equilibrium constant of the reaction $2NO_{(g)}+Cl_{2(g)} \rightleftharpoons 2NOCl_{(g)}$ is

[CPMT 1983, 87]

(a) $K_c=\frac{[2NOCl]}{[2NO][Cl_2]}$ (b) $K_c=\frac{[NOCl]^2}{[NO]^2[Cl_2]}$

(c) $K_c = \frac{[NOCl]^2}{[NO][Cl_2]^2}$ (d) $K_c = \frac{[NOCl]^2}{[NO]^2[Cl_2]^2}$

23. $A + B \rightleftharpoons C + D$. If finally the concentration of A and B are both equal but at equilibrium concentration of D will be twice of that of A then what will be the equilibrium constant of reaction. **[BHU 2005]**

(a) 4 / 9 (b) 9 / 4

(c) 1 / 9 (d) 4

24. If in the reaction $N_2O_4 = 2NO_2, \alpha$ is that part of N_2O_4 which dissociates, then the number of moles at equilibrium will be **[MP PET 1990; MH CET 2001; KCET 2005]**

(a) 3 (b) 1

(c) $(1-\alpha)^2$ (d) $(1+\alpha)$

25. In the gas phase reaction, $C_2H_4 + H_2 \rightleftharpoons C_2H_6$, the equilibrium constant can be expressed in units of

[CBSE PMT 1992; Pb. PMT 1999]

(a) $litre^{-1}\ mole^{-1}$ (b) $litre\, mole^{-1}$

(c) $mole^{2}\ litre^{-2}$ (d) $mole\ litre^{-1}$

26. For the reaction $2SO_2 + O_2 \rightleftharpoons 2SO_3$, the units of K_c are

[CPMT 1990]

(a) $litre\, mole^{-1}$ (b) $mol\ litre^{-1}$

(c) $(mol\ litre^{-1})^2$ (d) $(litre\ mole^{-1})^2$

27. A quantity of PCl_5 was heated in a 10 litre vessel at 250^oC; $PCl_5(g) \rightleftharpoons PCl_3(g) + Cl_2(g)$. At equilibrium the vessel contains 0.1 mole of PCl_5 0.20 mole of PCl_3 and 0.2 mole of Cl_2. The equilibrium constant of the reaction is

[KCET 1993, 2001; MP PMT 2003]

(a) 0.02 (b) 0.05

(c) 0.04 (d) 0.025

28. A mixture of 0.3 mole of H_2 and 0.3 mole of I_2 is allowed to react in a 10 *litre* evacuated flask at 500^oC. The reaction is $H_2 + I_2 \rightleftharpoons 2HI$, the K is found to be 64. The amount of unreacted I_2 at equilibrium is **[KCET 1990]**

(a) 0.15 mole (b) 0.06 mole

(c) 0.03 mole (d) 0.2 mole

29. In a chemical equilibrium, the rate constant of the backward reaction is 7.5×10^{-4} and the equilibrium constant is 1.5. So the rate constant of the forward reaction is **[KCET 1989]**

(a) 5×10^{-4} (b) 2×10^{-3}

(c) 1.125×10^{-3} (d) 9.0×10^{-4}

30. 28 *g* of N_2 and 6 *g* of H_2 were kept at 400^oC in 1 *litre* vessel, the equilibrium mixture contained $27.54\,g$ of NH_3. The approximate value of K_c for the above reaction can be (in $mole^{-2}\ litre^{2}$) **[CBSE PMT 199**

(a) 75 (b) 50

(c) 25 (d) 100

31. The equilibrium concentration of X, Y and YX_2 are 4, 2 and 2 moles respectively for the equilibrium $2X + Y \rightleftharpoons YX_2$. The value of K_c is **[EAMCET 19**

(a) 0.625 (b) 0.0625

(c) 6.25 (d) 0.00625

32. An amount of solid NH_4HS is placed in a flask already containing ammonia gas at a certain temperature and 0.50 *atm*. pressure. Ammonium hydrogen sulphide decomposes to yield NH_3 and H_2S gases in the flask. When the decomposition reaction reaches equilibrium, the total pressure in the flask rises to 0.84 *atm*. The equilibrium constant for NH_4HS decomposition at this temperature is

[AIEEE 2005]

(a) 0.30 (b) 0.18

(c) 0.17 (d) 0.11

33. In the reaction $A + 2B \rightleftharpoons 2C$, if 2 moles of A, 3.0 moles of B and 2.0 moles of C are placed in a 2.0 l flask and the equilibrium concentration of C is 0.5 mole/l. The equilibrium constant (K_c) for the reaction is **[KCET 1996]**

(a) 0.073 (b) 0.147

(c) 0.05 (d) 0.026

34. In a $500\,ml$ capacity vessel CO and Cl_2 are mixed to form $COCl_2$. At equilibrium, it contains 0.2 moles of $COCl_2$ and 0.1 mole of each of CO and CO_2. The equilibrium constant K_c for the reaction $CO + Cl_2 \rightleftharpoons COCl_2$ is

[CBSE PMT 1998]

(a) 5 (b) 10

(c) 15 (d) 20

35. A reaction is $A + B \rightarrow C + D$. Initially we start with equal concentration of A and B. At equilibrium we find the moles of C is two times of A. What is the equilibrium constant of the reaction **[BHU 1998; KCET 2**

(a) 4 (b) 2

(c) $1/4$ (d) $1/2$

36. 4.5 moles each of hydrogen and iodine heated in a sealed ten litre vessel. At equilibrium, 3 moles of HI were found. The equilibrium constant for $H_2(g) + I_2(g)$

[EAMCET 1998]

(a) 1 (b) 10

(c) 5 (d) 0.33

37. An equilibrium mixture of the reaction $2H_2S(g) \rightleftharpoons 2H_2(g) + S_2(g)$ had 0.5 mole H_2S, 0.10

mole H_2 and 0.4 mole S_2 in one litre vessel. The value of equilibrium constant (K) in *mole litre*$^{-1}$ is

[AIIMS 1998; IIT 1992; AFMC 1999; UPSEAT 2001]

(a) 0.004 (b) 0.008

(c) 0.016 (d) 0.160

38. At 3000 K the equilibrium pressures of CO_2, CO and O_2 are 0.6,0.4 and 0.2 atmospheres respectively. K_p for the reaction, $2CO_2 \rightleftharpoons 2CO + O_2$ is **[JIPMER 1999]**

(a) 0.089 (b) 0.0533

(c) 0.133 (d) 0.177

39. The rate constant for forward and backward reactions of hydrolysis of ester are 1.1×10^{-2} and 1.5×10^{-3} per minute respectively. Equilibrium constant for the reaction is

$CH_3COOC_2H_5 + H_2O \rightleftharpoons CH_3COOH + C_2H_5OH$

[AIIMS 1999]

(a) 4.33 (b) 5.33

(c) 6.33 (d) 7.33

40. At a certain temp. $2HI \rightleftharpoons H_2 + I_2$ Only 50% HI is dissociated at equilibrium. The equilibrium constant is

[DCE 1999]

(a) 0.25 (b) 1.0

(c) 3.0 (d) 0.50

41. When 3 mole of A and 1 mole of B are mixed in 1 *litre* vessel the following reaction takes place $A_{(g)} + B_{(g)} \rightleftharpoons 2C_{(g)}$. 1.5 moles of C are formed. The equilibrium constant for the reaction is **[MP PMT 2000]**

(a) 0.12 (b) 0.25

(c) 0.50 (d) 4.0

42. A 1 M solution of glucose reaches dissociation equilibrium according to equation given below $6HCHO \rightleftharpoons C_6H_{12}O_6$. What is the concentration of $HCHO$ at equilibrium if equilibrium constant is 6×10^{22} **[MP PMT 2000]**

(a) $1.6 \times 10^{-8} M$ (b) $3.2 \times 10^{-6} M$

(c) $3.2 \times 10^{-4} M$ (d) $1.6 \times 10^{-4} M$

43. Equilibrium concentration of HI, I_2 and H_2 is $0.7, 0.1$ and $0.1 M$ respectively. The equilibrium constant for the reaction $I_2 + H_2 \rightleftharpoons 2HI$ is

(a) 36 (b) 49

(c) 0.49 (d) 0.36

44. For the equilibrium $N_2 + 3H_2 \rightleftharpoons 2NH_3, K_c$ at 1000K is 2.37×10^{-3}. If at equilibrium $[N_2] = 2M, [H_2] = 3M$, the concentration of NH_3 is **[JIPMER 2000]**

(a) 0.00358 M (b) 0.0358 M

(c) 0.358 M (d) 3.58 M

45. In the reaction, $A + B \rightleftharpoons 2C$, at equilibrium, the concentration of A and B is $0.20\ mol\ l^{-1}$ each and that of C was found to be $0.60\ mol\ l^{-1}$. The equilibrium constant of the reaction is

(a) 2.4 (b) 18

(c) 4.8 (d) 9

46. 15 moles of H_2 and 5.2 moles of I_2 are mixed and allowed to attain equilibrium at 500^oC. At equilibrium, the concentration of HI is found to be 10 moles. The equilbrium constant for the formation of HI is

[KCET 2005]

(a) 50 (b) 15

(c) 100 (d) 25

47. In a chemical reaction equilibrium is established when

[MP PET 2001]

(a) Opposing reaction ceases

(b) Concentration of reactants and products are equal

(c) Velocity of opposing reaction is the same as that of forward reaction

(d) Reaction ceases to generate heat

48. For the reaction $H_2 + I_2 = 2HI$, the equilibrium concentration of H_2, I_2 and HI are 8.0, 3.0 and 28.0 *mol per litre* respectively, the equilibrium constant of the reaction is

[BHU 2000; CBSE PMT 2001]

(a) 30.66 (b) 32.66

(c) 34.66 (d) 36.66

49. Change in volume of the system does not alter the number of moles in which of the following equilibrium

[AIEEE 2002]

(a) $N_{2(g)} + O_{2(g)} \rightleftharpoons 2NO_{(g)}$

(b) $PCl_{5(g)} \rightleftharpoons PCl_{3(g)} + Cl_{2(g)}$

(c) $N_{2(g)} + 3H_{2(g)} \rightleftharpoons 2NH_{3(g)}$

(d) $SO_2Cl_{2(g)} \rightleftharpoons SO_{2(g)} + Cl_{2(g)}$

50. The rate of forward reaction is two times that of reverse reaction at a given temperature and identical concentration. $K_{\text{equilibrium}}$ is **[KCET 2002]**

(a) 2.5 (b) 2.0

(c) 0.5 **[JIPMER 2000]** (d) 1.5

51. Write the equilibrium constant K for

$CH_3COOH + H_2O = H_3O^+ + CH_3COO^-$

[Kerala (Med.) 2002]

(a) $K = \dfrac{[H_3O^+][H_2O]}{[CH_3COO^-][CH_3COOH]}$

(b) $K = \dfrac{[H_3O^+][CH_3COO^-]}{[H_2O][CH_3COOH]}$

(c) $K = \dfrac{[H_3O^+][H_2O]}{[CH_3COOH][CH_3COO^-]}$

[MH CET 2000]

(d) $K = \dfrac{[H_2O][CH_3COO^-]}{[H_2O][CH_3COOH]}$

52. The equilibrium constant (K_c) for the reaction $\mathrm{HA + B \rightleftharpoons BH^+ + A^-}$ is 100. If the rate constant for the forward reaction is $10^{5,}$ then rate constant for the backward reaction is **[CBSE PMT 2002]**

(a) 10^7 (b) 10^3

(c) 10^{-3} (d) 10^{-5}

53. 9.2 *grams* of $N_2O_{4(g)}$ is taken in a closed one litre vessel and heated till the following equilibrium is reached $N_2O_{4(g)} \rightleftharpoons 2NO_{2(g)}$.

At equilibrium, 50% $N_2O_{4(g)}$ is dissociated. What is the equilibrium constant (in *mol litre*$^{-1}$) (Molecular weight of $N_2O_4 = 92$) **[MP PET 2003]**

(a) 0.1 (b) 0.4

(c) 0.2 (d) 2

54. Two moles of NH_3 when put into a previously evacuated vessel (one *litre*), partially dissociate into N_2 and H_2. If at equilibrium one mole of NH_3 is present, the equilibrium constant is

(a) 3/4 $mol^2\ litre^{-2}$ (b) 27/64 $mol^2\ litre^{-2}$

(c) 27/32 $mol^2\ litre^{-2}$ (d) 27/1 $mol^2\ litre^{-2}$

55. In a reaction, reactant '*A*' decomposes 10% in 1 *hour*, 20% on 2 *hour* and 30% in 3 *hour*. The unit of rate constant of this reaction is

(a) sec^{-1} (b) $mol\ litre^{-1}\ sec^{-1}$

(c) $litre\ mol^{-1}\ sec^{-1}$ (d) $litre^2\ mol^{-2}\ sec^{-1}$

56. In the reaction $PCl_{5(g)} \rightleftharpoons PCl_{3(g)} + Cl_{2(g)}$.

The equilibrium concentrations of PCl_5 and PCl_3 are 0.4 and 0.2 *mole/litre* respectively. If the value of K_c is 0.5 what is the concentration of Cl_2 in *moles/litre* **[EAMCET 2003]**

(a) 2.0 (b) 1.5

(c) 1.0 (d) 0.5

57. In Haber process 30 *litres* of dihydrogen and 30 *litres* of dinitrogen were taken for reaction which yielded only 50% of the expected product. What will be the composition of gaseous mixture under the aforesaid condition in the end **[CBSE PMT 2003]**

(a) 20 *litres* ammonia, 25 *litres* nitrogen, 15 *litres* hydrogen

(b) 20 *litres* ammonia, 20 *litres* nitrogen, 20 *litres* hydrogen

(c) 10 *litres* ammonia, 25 *litres* nitrogen, 15 *litres* hydrogen

(d) 20 *litres* ammonia, 10 *litres* nitrogen, 30 *litres* hydrogen

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

(a) $3.3 \times 10^2\ mol\ litre^{-1}$ (b) $3 \times 10^{-1}\ mol\ litre^{-1}$

(c) $3 \times 10^{-3}\ mol\ litre^{-1}$ (d) $3 \times 10^3\ mol\ litre^{-1}$

59. 3.2 moles of hydrogen iodide were heated in a sealed bulb at 444^oC till the equilibrium state was reached. Its degree of dissociation at this temperature was found to be 22%. The number of moles of hydrogen iodide present at equilibrium are **[BHU 1982]**

(a) 2.496 (b) 1.87

(c) 2 (d) 4

60. 56 *g* of nitrogen and 8 *g* hydrogen gas are heated in a closed vessel. At equilibrium 34 *g* of ammonia are present. The equilibrium number of moles of nitrogen, hydrogen and ammonia are respectively **[KCET 2004]**

(a) 1,2,2 (b) 2,2,1

(c) 1,1,2 (d) 2,1,2

61. The reaction, $2SO_{2(g)} + O_{2(g)} \rightleftharpoons 2SO_{3(g)}$ is carried out in a $1\,dm^3$ vessel and $2\,dm^3$ vessel separately. The ratio of the reaction velocities will be **[KCET 2004]**

(a) $1:8$ **[MP PET 2003]** (b) $1:4$

(c) $4:1$ (d) $8:1$

62. The compound *A* and *B* are mixed in equimolar proportion to form the products, $A + B \rightleftharpoons C + D$. At equilibrium, one third of *A* and *B* are consumed. The equilibrium constant for the **[MP PET 2003]** reaction is **[KCET 2004]**

(a) 0.5 (b) 4.0

(c) 2.5 (d) 0.25

63. Calculate the partial pressure of carbon monoxide from the following

$CaCO_{3(s)} \xrightarrow{\Delta} CaO_{(s)} + CO_2 \uparrow$; $K_p = 8 \times 10^{-2}$

$CO_{2(g)} + C_{(s)} \rightarrow 2CO_{(g)}$; $K_p = 2$ **[Orissa JEE 2004]**

(a) 0.2 (b) 0.4

(c) 1.6 (d) 4

64. The equilibrium constant for the reaction $N_{2(g)} + O_{2(g)} \rightleftharpoons 2NO_{(g)}$ at temperature *T* is 4×10^{-4}. The value of K_c for the reaction $NO_{(g)} \rightleftharpoons \frac{1}{2}N_{2(g)} + \frac{1}{2}O_{2(g)}$ at the same temperature is **[AIEEE 2004]**

(a) 4×10^{-4} (b) 50

(c) 2.5×10^2 (d) 0.02

65. What is the equilibrium expression for the reaction $P_{4(s)} + 5O_{2(g)} \rightleftharpoons P_4O_{10(s)}$

(a) $K_c = [O_2]^5$ (b) $K_c = [P_4O_{10}]/5[P_4][O_2]$

(c) $K_c = [P_4O_{10}]/[P_4][O_2]^5$ (d) $K_c = 1/[O_2]^5$

66. In the reaction, $H_2 + I_2 \rightleftharpoons 2HI$. In a 2 litre flask 0.4 moles of each H_2 and I_2 are taken. At equilibrium 0.5 moles of HI are formed. What will be the value of equilibrium constant, K_c

(a) 20.2 (b) 25.4

(c) 0.284 (d) 11.1

67. Ammonia carbonate when heated to 200°C gives a mixture of NH_3 and CO_2 vapour with a density of 13.0. What is the degree of dissociation of ammonium carbonate

[Kerala PMT 2004]

(a) $3/2$ (b) $1/2$

(c) 2 (d) 1

(e) $5/2$

68. 2 mol of N_2 is mixed with 6 mol of H_2 in a closed vessel of one litre capacity. If 50% of N_2 is converted into NH_3 at equilibrium, the value of K_c for the reaction $N_{2(g)} + 3H_{2(g)} \rightleftharpoons 2NH_{3(g)}$ is

(a) $4/27$ (b) $27/4$

(c) $1/27$ (d) 24

(e) 9

69. For a reaction $H_2 + I_2 \rightleftharpoons 2HI$ at 721K, the value of equilibrium constant is 50. If 0.5 mols each of H_2 and I_2 is added to the system the value of equilibrium constant will be

[DCE 2004]

(a) 40 (b) 60

(c) 50 (d) 30

70. What is the effect of halving the pressure by doubling the volume on the following system at 500°C

$H_{2(g)} + I_{2(g)} \rightleftharpoons 2HI_{(g)}$ **[UPSEAT 2004]**

(a) Shift to product side

(b) Shift to product formation

(c) Liquefaction of HI

(d) No effect

71. When $NaNO_3$ is heated in a closed vessel, O_2 is liberated and $NaNO_2$ is left behind. At equilibrium

[IIT 1986; Roorkee 1995]

(a) Addition of $NaNO_3$ favours forward reaction

(b) Addition of $NaNO_2$ favours reverse reaction

(c) Increasing pressure favours reverse reaction

(d) Increasing temperature favours forward reaction

72. For the reaction : $H_{2(g)} + CO_{2(g)} \rightleftharpoons CO_{(g)} + H_2O_{(g)}$, if the initial concentration of $[H_2] = [CO_2]$ and x moles/litre of hydrogen is consumed at equilibrium, the correct expression of K_p is **[Orissa JEE 2005]**

(a) $\frac{x^2}{(1-x)^2}$ **[CPMT 2004]** (b) $\frac{(1+x)^2}{(1-x)^2}$

(c) $\frac{x^2}{(2+x)^2}$ (d) $\frac{x^2}{1-x^2}$

73. 0.6 mole of NH_3 in a reaction vessel of 2dm^3 capacity was brought to equilibrium. The vessel was then found to contain 0.15 mole of H_2 formed by the reaction

$2NH_{3(g)} = N_{2(g)} + 3H_{2(g)}$

Which of the following statements is true **[KCET 1999]**

(a) 0.15 mole of the original NH_3 had dissociated at equilibrium

(b) 0.55 mole of ammonia is left in the vessel

(c) At equilibrium the vessel contained 0.45 mole of N_2 **[Kerala PMT 2004]**

(d) The concentration of NH_3 at equilibrium is 0.25 mole per dm^3

74. 5 moles of SO_2 and 5 moles of O_2 are allowed to react to form SO_3 in a closed vessel. At the equilibrium stage 60% of SO_2 is used up. The total number of moles of SO_2, O_2 and SO_3 in the vessel now is **[KCET 2001]**

(a) 10.0 (b) 8.5

(c) 10.5 (d) 3.9

K_p & K_c Relationship and Characteristics of K

1. In which of the following reaction, the value of K_p will be equal to K_c **[MP PMT 1995]**

(a) $H_2 + I_2 \rightleftharpoons 2HI$ (b) $PCl_5 \rightleftharpoons PCl_3 + Cl_2$

(c) $2NH_3 \rightleftharpoons N_2 + 3H_2$ (d) $2SO_2 + O_2 \rightleftharpoons 2SO_3$

2. Equilibrium constants K_1 and K_2 for the following equilibria

$$NO(g) + \frac{1}{2}O_2 \overset{K_1}{\rightleftharpoons} NO_2(g)$$

and $2NO_2(g) \overset{K_2}{\rightleftharpoons} 2NO(g) + O_2(g)$ are related as

[CBSE PMT 2005]

(a) $K_2 = \frac{1}{K_1}$ (b) $K_2 = K_1^2$

(c) $K_2 = \frac{K_1}{2}$ (d) $K_2 = \frac{1}{K_1^2}$

3. For the reaction $PCl_3(g) + Cl_2(g) \rightleftharpoons PCl_5(g)$ at $250\,^oC$, the value of K_c is 26, then the value of K_p on the same temperature will be **[MNR 1990; MP PET**

(a) 0.61 (b) 0.57

(c) 0.83 (d) 0.46

4. The relation between equilibrium constant K_p and K_c is

[IIT 1994; MP PMT 1994; CPMT 1997; AMU 2000; RPMT 2000, 02;MP PET 2002; Kerala PMT 2002]

(a) $K_c = K_p(RT)^{\Delta n}$ (b) $K_p = K_c(RT)^{\Delta n}$

(c) $K_p = \left(\frac{K_c}{RT}\right)^{\Delta n}$ (d) $K_p - K_c = (RT)^{\Delta n}$

5. $CH_3COOH_{(l)} + C_2H_5OH_{(l)} \rightleftharpoons CH_3COOC_2H_{5(l)} + H_2O_{(l)}$

In the above reaction, one mole of each of acetic acid and alcohol are heated in the presence of little conc. H_2SO_4. On equilibrium being attained

[CPMT 1985; MP PET 1992]

(a) 1 mole of ethyl acetate is formed

(b) 2 mole of ethyl acetate are formed

(c) 1/2 moles of ethyl acetate is formed

(d) 2/3 moles of ethyl acetate is formed

6. If the equilibrium constant of the reaction $2HI \rightleftharpoons H_2 + I_2$ is 0.25, then the equilibrium constant of the reaction $H_2 + I_2 \rightleftharpoons 2HI$ would be**[MP PMT 1989, 95]**

(a) 1.0 (b) 2.0

(c) 3.0 (d) 4.0

7. For $N_2 + 3H_2 \rightleftharpoons 2NH_3 +$ heat

[CPMT 1990; MP PMT 1997; RPMT 1999; MP PET 2000; KCET 2001]

(a) $K_p = K_c(RT)$ (b) $K_p = K_c(RT)$

(c) $K_p = K_c(RT)^{-2}$ (d) $K_p = K_c(RT)^{-1}$

8. In the reaction $N_2(g) + 3H_2 \rightleftharpoons 2NH_3(g)$, the value of the equilibrium constant depends on

[CPMT 1990; AIIMS 1991; MP PET 1996]

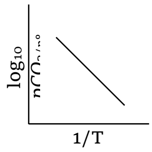
(a) Volume of the reaction vessel

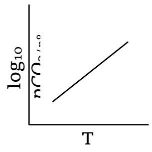
(b) Total pressure of the system

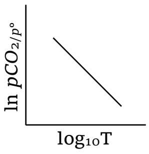
(c) The initial concentration of nitrogen and hydrogen

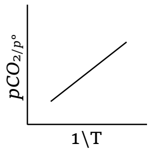
(d) The temperature

9. For the chemical equilibrium, $CaCO_3(s) \rightleftharpoons CaO(s) + CO_2(g), \Delta H_r^{\circ}$ can be determined from which one of the following plots **[AIIMS 2005]**

(a) 

(b) 

(c) 

(d) 

10. In which of the following equilibria, the value of K_p is less than K_c **[MP PMT 1993]**

(a) $H_2 + I_2 \rightleftharpoons 2HI$

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

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

(d) $CO + H_2O \rightleftharpoons CO_2 + H_2$

11. Two gaseous equilibria $SO_{2(g)} + \frac{1}{2}O_{2(g)} \rightleftharpoons SO_{3(g)}$ and $2SO_{3(g)} \rightleftharpoons 2SO_{2(g)} + O_{2(g)}$ have equilibrium constants K_1 and K_2 respectively at $298\,K$. Which of the following relationships between K_1 and K_2 is correct

[CPMT 1988; CBSE PMT 1989; MP PET 1993, 95; RPMT 1999; MP PMT 2001]

(a) $K_1 = K_2$ (b) $K_2 = K_1^2$

(c) $K_2 = \frac{1}{K_1^2}$ (d) $K_2 = \frac{1}{K_1}$

12. $H_2 + I_2 \rightleftharpoons 2HI$

In the above equilibrium system if the concentration of the reactants at $25^{\circ}C$ is increased, the value of K_c will

[BHU 1979; CPMT 1990; CBSE PMT 1990]

(a) Increase

(b) Decrease

(c) Remains the same

(d) Depends on the nature of the reactants

13. At a given temperature, the equilibrium constant for reaction $PCl_5(g) \rightleftharpoons PCl_3(g) + Cl_2(g)$ is 2.4×10^{-3}. At the same temperature, the equilibrium constant for reaction $PCl_3(g) + Cl_2(g) \rightleftharpoons PCl_5(g)$ is**[KCET 199**

(a) 2.4×10^{-3} (b) -2.4×10^{-3}

(c) 4.2×10^{2} (d) 4.8×10^{-2}

14. For the reaction $C(s) + CO_2(g) \rightleftharpoons 2CO(g)$, the partial pressure of CO_2 and CO are 2.0 and 4.0 *atm* respectively at equilibrium. The K_p for the reaction is **[Roorkee 1990]**

(a) 0.5 (b) 4.0

(c) 8.0 (d) 32.0

15. K for the synthesis of HI is 50. K for dissociation of HI is **[Roorkee 1990]**

(a) 50 (b) 5

(c) 0.2 (d) 0.02

16. In which one of the following gaseous equilibria K_p is less than K_c **[EAMCET 1989; MP PET 1994; Pb. PMT 2000; KCET 2001; CBSE PMT 2002]**

(a) $N_2O_4 \rightleftharpoons 2NO_2$ (b) $2HI \rightleftharpoons H_2 + I_2$

(c) $2SO_2 + O_2 \rightleftharpoons 2SO_3$ (d) $N_2 + O_2 \rightleftharpoons 2NO$

17. For which of the following reactions $K_p = K_c$

[KCET 1991; IIT 1991; EAMCET 1992; AIIMS 1996; KCET 2000; AMU 2000]

(a) $2NOCl(g) \rightleftharpoons 2NO(g) + Cl_2(g)$

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

(c) $H_2(g) + Cl_2(g) \rightleftharpoons 2HCl(g)$

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

18. For the reaction $H_2(g) + I_2(g) \rightleftharpoons 2HI(g)$ at $721K$ the value of equilibrium constant (K_c) is 50. When the equilibrium concentration of both is $0.5\,M$, the value of K_p under the same conditions will be

[CBSE PMT 1990]

(a) 0.002 (b) 0.2

(c) 50.0 (d) $50/RT$

19. In which of the following reaction $K_p > K_c$ **[AFMC 1995]**

(a) $N_2 + 3H_2 \rightleftharpoons 2NH_3$ (b) $H_2 + I_2 \rightleftharpoons 2HI$

(c) $PCl_3 + Cl_2 \rightleftharpoons PCl_5$ (d) $2SO_3 \rightleftharpoons O_2 + 2SO_2$

20. For the reaction $PCl_5(g) \rightleftharpoons PCl_3(g) + Cl_2(g)$

[MP PET 1996]

(a) $K_p = K_c$ (b) $K_p = K_c(RT)^{-1}$

(c) $K_p = K_c(RT)$ (d) $K_p = K_c(RT)^2$

21. The equilibrium constant of the reaction $H_2(g) + I_2(g) \rightleftharpoons 2HI(g)$ is 64. If the volume of the container is reduced to one fourth of its original volume, the value of the equilibrium constant will be **[MP PET 1996]**

(a) 16 (b) 32

(c) 64 (d) 128

22. For the following gaseous reaction $H_2 + I_2 \rightleftharpoons 2HI$, the equilibrium constant **[MP PMT 1996; MP PET/PMT 1998]**

(a) $K_p > K_c$ (b) $K_p < K_c$

(c) $K_p = K_c$ (d) $K_p = 1/K_c$

23. For the reaction

$2NO_{2(g)} \rightleftharpoons 2NO_{(g)} + O_{2(g)}$

$(K_c = 1.8 \times 10^{-6}$ at $184\,°C)$

$(R = 0.0831\,kJ/(mol.K))$

When K_p and K_c are compared at 184°C it is found that

[AIEEE 2005]

(a) K_p is greater than K_c

(b) K_p is less than K_c

(c) $K_p = K_e$

(d) Whether K_p is greater than, less than or equal to K_c depends upon the total gas pressure

24. In equilibrium $CH_3COOH + H_2O \rightleftharpoons CH_3COO + H_3^+O$ The equilibrium constant may change when

(a) CH_3COO^- are added (b) CH_3COOH is added

(c) Catalyst is added (d) Mixture is heated

25. For reaction $2NOCl(g) \rightleftharpoons 2NO(g) + Cl_2(g)$, K_C at 427°C is $3 \times 10^{-6}\,L\,mol^{-1}$. The value of K_P is nearly **[AIIMS**

(a) 7.50×10^{-5} (b) 2.50×10^{-5}

(c) 2.50×10^{-4} (d) 1.75×10^{-4}

26. For which one of the following reactions $K_p = K_c$

[MP PET 1997]

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

(c) $PCl_5 \rightleftharpoons PCl_3 + Cl_2$ (d) $2SO_3 \rightleftharpoons 2SO_2 + O_2$

27. The equilibrium constant for the reversible reaction, $N_2 + 3H_2 \rightleftharpoons 2NH_3$ is K and for the reaction $\frac{1}{2}N_2 + \frac{3}{2}H_2 \rightleftharpoons NH_3$ the equilibrium constant is K'. K and K' will be related as

(a) $K = K'$ (b) $K' = \sqrt{K}$

(c) $K = \sqrt{K'}$ (d) $K \times K' = 1$

28. The equilibrium constant (K_p) for the reaction $PCl_5(g) \rightarrow PCl_3(g) + Cl_2(g)$ is 16. If the volume of the container is reduced to one half its original volume, the value of K_p for the reaction at the same temperature will be

[KCET 1996]

(a) 32 (b) 64

(c) 16 (d) 4

29. $2NO_2 \rightleftharpoons 2NO + O_2;\ K = 1.6 \times 10^{-12}$

$NO + \frac{1}{2}O_2 \rightleftharpoons NO_2 K' = ?$ **[CPMT 1996]**

(a) $K' = \frac{1}{K^2}$ (b) $K' = \frac{1}{K}$

(c) $K' = \frac{1}{\sqrt{K}}$ (d) None of these

30. The value of K_p for the following reaction $2H_2S(g) \rightleftharpoons 2H_2(g) + S_2(g)$ is 1.2×10^{-2} at $106.5^o C$. The value of K_c for this reaction is

[EAMCET 1997; AIIMS 1999; AFMC 2000; KCET 2001]

(a) 1.2×10^{-2} (b) $< 1.2 \times 10^{-2}$

(c) 83 (d) $> 1.2 \times 10^{-2}$

31. Which statement for equilibrium constant is true for the reaction $A + B \rightleftharpoons C$ **[CPMT 1997]**

(a) Not changes with temperature

(b) Changes when catalyst is added

(c) Increases with temperature

(d) Changes with temperature

32. The equilibrium constant for the reaction $N_2 + 3H_2 \rightleftharpoons 2NH_3$ is K, then the equilibrium constant for the equilibrium $NH_3 \rightleftharpoons \frac{1}{2}N_2 + \frac{3}{2}H_2$ is **[CBSE PMT 1996; UPSEAT 2001]**

(a) $1/K$ (b) $1/K^2$

(c) $\sqrt{K}$ (d) $\frac{1}{\sqrt{K}}$

33. Which of the following statements regarding a chemical equilibrium is wrong

(a) An equilibrium can be shifted by altering the temperature or pressure

(b) An equilibrium is dynamic

(c) The same state of equilibrium is reached whether one starts with the reactants or the products

(d) The forward reaction is favoured by the addition of a catalyst

34. The reaction between N_2 and H_2 to form ammonia has $K_c = 6 \times 10^{-2}$ at the temperature 500°*C*. The numerical value of K_p for this reaction is **[UPSEAT 1999]**

(a) 1.5×10^{-5} (b) 1.5×10^{5}

(c) 1.5×10^{-6} (d) 1.5×10^{6}

35. For the gaseous phase reaction

$2NO \rightleftharpoons N_2 + O_2 \quad \Delta H^\circ = +43.5 \ kcal\,mol^{-1}$

Which statement is correct

(a) *K* varies with addition of *NO*

(b) *K* decrease as temperature decreases

(c) *K* Increases as temperature decreases

(d) *K* is independent of temperature

36. For the reversible reaction,

$N_{2(g)} + 3H_{2(g)} \rightleftharpoons 2NH_{3(g)}$

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 mole *litre*$^{-1}$, is **[IIT Screening 2000; Pb. CET 2004]**

(a) $1.44 \times 10^{-5} / (0.082 \times 500)^{-2}$

(b) $1.44 \times 10^{-5} / (8.314 \times 773)^{-2}$

(c) $1.44 \times 10^{-5} / (0.082 \times 773)^{2}$

(d) $1.44 \times 10^{-5} / (0.082 \times 773)^{-2}$

37. A chemical reaction is catalyzed by a catalyst *X*. Hence *X* **[AIIMS 2000]**

(a) Reduces enthalpy of the reaction

(b) Decreases rate constant of the reaction

(c) Increases activation energy of the reaction

(d) Does not affect equilibrium constant of reaction

38. At 490°*C*, the equilibrium constant for the synthesis of *HI* is 50, the value of *K* for the dissociation of *HI* will be **[KCET 2000]**

(a) 20.0 (b) 2.0

(c) 0.2 (d) 0.02

39. In which of the following case K_p is less than K_c **[AFMC 1997; Pb. PMT 2000]**

(a) $H_2 + Cl_2 \rightleftharpoons 2HCl$ (b) $2SO_2 + O_2 \rightleftharpoons 2SO_3$

(c) $N_2 + O_2 \rightleftharpoons 2NO$ (d) $PCl_5 \rightleftharpoons PCl_3 + Cl_2$

40. $CaCO_{3(s)} \rightleftharpoons CaO_{(s)} + CO_{2(g)}$ **[JIPMER 1999]** which of the following expression is correct **[MH CET 2000]**

(a) $K_P = (P_{CaO} + P_{CO_2} / P_{CaCO_3})$

(b) $K_P = P_{CO_2}$

(c) $K_P \times (P_{CaO} \times P_{CO_2}).P_{CaCO_3}$

(d) $\frac{K_p[CaO][CO_2]}{[CaCO_3]}$

41. If K_c is the equilibrium constant for the formation of NH_3, the dissociation constant of ammonia under the same temperature will be **[DPMT 2001]**

(a) K_c (b) $\sqrt{K_c}$

(c) K_c^2 (d) $1/K_c$

42. 3.2 moles of hydrogen iodide were heated in a scaled bulb at 444°C till the equilibrium was reached. The degree of dissociation of *HI* at this **[MH CET 1999]** temperature was found to be 22%. The number of moles of hydrogen iodide present at equilibrium are **[MH CET 2001]**

(a) 1.87 (b) 2.496

(c) 4.00 (d) 2.00

43. The K_c for $H_{2(g)} + I_{2(g)} \rightleftharpoons 2HI_{(g)}$ is 64. If the volume of the container is reduced to one-half of its original volume, the value of the equilibrium constant will be **[JIPMER 2001]**

(a) + 28 (b) 64

(c) 32 (d) 16

44. A reversible reaction $H_2 + Cl_2 \rightleftharpoons 2HCl$ is carries out in one litre flask. If the same reaction is carried out in two litre flask, the equilibrium constant will be **[JIPMER 2001]**

(a) Decreased (b) Doubled

(c) Halved (d) Same

45. For the reaction

$2NO_{2(g)} \rightleftharpoons 2NO_{(g)} + O_{2(g)}, K_c = 1.8 \times 10^{-6}$ at 185°*C*. At 185°*C* the K_c for $NO_{(g)} + \frac{1}{2}O_{2(g)} \rightleftharpoons NO_{2(g)}$ is **[JIPMER 2001]**

(a) 1.95×10^{-3} (b) 1.95×10^{3}

(c) 7.5×10^{2} (d) 0.9×10^{6}

46. If for $H_{2(g)}+\frac{1}{2}S_{2(S)} \rightleftharpoons H_2S_{(g)}$ and

$H_{2(g)}+Br_{2(g)} \rightleftharpoons 2HBr_{(g)}$

The equilibrium constants are K_1 and K_2 respectively, the reaction

$Br_{2(g)}+H_2S_{(g)} \rightleftharpoons 2HBr_{(g)}+\frac{1}{2}S_{2(S)}$ would have equilibrium constant **[MP PMT 2001]**

(a) $K_1 \times K_2$ (b) K_1/K_2

(c) K_2/K_1 (d) K_2^2/K_1

47. Some solid NH_4HS is placed in a flask containing 0.5 *atm* of NH_3, what would be pressures of NH_3 and H_2S when equilibrium is reached

$NH_4HS_{(g)} \rightleftharpoons NH_{3(g)}+H_2S_{(g)}$, $K_p=0.11$ **[UPSEAT 2001]**

(a) 6.65 *atm* (b) 0.665 *atm*

(c) 0.0665 *atm* (d) 66.5 *atm*

48. In which of the following reactions, increase in the volume at constant temperature don't affect the number of moles at equilibrium.

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

(b) $C_{(g)}+\frac{1}{2}O_{2(g)} \rightarrow CO_{(g)}$

(c) $H_{2(g)}+O_{2(g)} \rightarrow H_2O_{2(g)}$

(d) None of these

49. A chemical reaction was carried out at 300 *K* and 280 *K*. The rate constants were found to be K_1 and K_2 respectively. The energy of activation is 1.157×10^4 *cal mole*$^{-1}$ and $R=1.987$ *cal*. Then

(a) $K_2 \approx 0.25K_1$ (b) $K_2 \approx 0.5K_1$

(c) $K_2 \approx 4K_1$ (d) $K_2 \approx 2K_1$

50. Δn, the change in the number of moles for the reaction,

$C_{12}H_{22}O_{11(s)}+12O_{2(g)} \rightleftharpoons 12CO_{2(g)}+11H_2O_{(l)}$

at 25°*C* is **[Pb. PMT 2002]**

(a) 0 (b) 2

(c) 4 (d) – 1

51. Value of K_p in the reaction

$MgCO_{3(s)} \rightleftharpoons MgO_{(s)}+CO_{2(g)}$ is

[CBSE PMT 2000; RPMT 2002]

(a) $K_P=P_{CO2}$

(b) $K_P=Pco_2\times\frac{Pco_2\times P_{MgO}}{P_{MgCO_3}}$

(c) $K_P=\frac{Pco_2\times P_{MgO}}{P_{MgCO_3}}$

(d) $K_P=\frac{P_{MgCO_3}}{P_{CO_2}\times P_{MgO}}$

52. For $N_2+3H_2 \rightleftharpoons 2NH_3$ equilibrium constant is k then equilibrium constant for $2N_2+6H_2 \rightleftharpoons 4NH_3$ is

[RPMT 2002]

(a) $\sqrt{k}$ (b) k^2

(c) $k/2$ (d) $\sqrt{k+1}$

53. For the reaction, $PCl_{3(g)}+Cl_{2(g)} \rightleftharpoons PCl_{5(g)}$, the value of K_c at 250°*C* is 26. The value of K_p at this temperature will be

[UPSEAT 1999, 2000, 02]

(a) 0.61 (b) 0.57

(c) 0.83 (d) 0.46

54. A tenfold increase in pressure on the reaction $N_{2(g)}+3H_{2(g)} \rightleftharpoons 2NH_{3(g)}$ at equilibrium, makes K_p

[MP PET 2003]

(a) Unchanged (b) Two times

(c) Four times (d) Ten times

55. If equilibrium constant for reaction $2AB \rightleftharpoons A_2+B_2$, is 49, then the equilibrium constant for reaction $AB \rightleftharpoons \frac{1}{2}A_2+\frac{1}{2}B_2$, will be

[EAMCET 1998; MP PMT 2003]

(a) 7 **[AIEEE 2002]** (b) 20

(c) 49 (d) 21

56. In the manufacture of ammonia by Haber's process,

$N_{2(g)}+3H_2 \rightleftharpoons 2NH_{3(g)}+92.3kJ$,

which of the following conditions is unfavourable

[KCET 2004]

(a) Increasing the temperature

(b) Increasing the pressure **[KCET 2002]**

(c) Reducing the temperature

(d) Removing ammonia as it is formed

57. The chemical equilibrium of a reversible reaction is not influenced by **[KCET 2004]**

(a) Pressure

(b) Catalyst

(c) Concentration of the reactants

(d) Temperature

58. Of the following which change will shift the reaction towards the product

$I_2(g) \rightleftharpoons 2I(g), \Delta H_r^0(298\,K)=+150\ kJ$ **[AIIMS 2004]**

(a) Increase in concentration of l

(b) Decrease in concentration of I_2

(c) Increase in temperature

(d) Increase in total pressure

59. For the reaction, $CO_{(g)}+Cl_{2(g)} \rightleftharpoons COCl_{2(g)}$ the K_p/K_c is equal to **[AIEEE 2004]**

(a) $\sqrt{RT}$ (b) RT

(c) $1/RT$ (d) 1.0

60. Consider the following reversible reaction at equilibrium, $2H_2O_{(g)} \rightleftharpoons 2H_{2(g)}+O_{2(g)}$; $\Delta H=241.7\,kJ$

Which one of the following changes in conditions will lead to maximum decomposition of $H_2O_{(g)}$ **[Kerala PMT**

(a) Increasing both temperature and pressure
(b) Decreasing temperature and increasing pressure
(c) Increasing temperature and decreasing pressure
(d) Increasing temperature at constant pressure

61. For reaction, $2A(g) \rightleftharpoons 3C(g) + D(s)$, the value of K_c will be equal to **[Pb. CET 2003]**

(a) $K_p(RT)$
(b) K_p / RT
(c) $= K_p$
(d) None of these

62. In the reaction, $A_2(g) + 4B_2(g) \rightleftharpoons 2AB_4(g)$

$\Delta H < 0$ the formation of AB_4 is will be favoured at

[IIT Screening 1990; MP PET 2004]

(a) Low temperature, high pressure
(b) High temperature, low pressure
(c) Low temperature, low pressure
(d) High temperature, high pressure

63. The formation of SO_3 takes place according to the following reaction, $2SO_2 + O_2 \rightleftharpoons 2SO_3$; $\Delta H = -45.2\ kcal$

The formation of SO_3 is favoured by**[UPSEAT 2004]**

(a) Increasing in temperature
(b) Removal of oxygen
(c) Increase of volume
(d) Increasing of pressure

64. What is the effect of increasing pressure on the dissociation of PCl_5 according to the equation

$PCl_{5(g)} \rightleftharpoons PCl_{3(g)} + Cl_{2(g)} - x\ cal$ **[UPSEAT 2004]**

(a) Dissociation decreases
(b) Dissociation increases
(c) Dissociation does not change
(d) None of these

65. If equilibrium constants of reaction, $N_2 + O_2 \rightleftharpoons 2NO$ is K_1 and $\frac{1}{2}N_2 + \frac{1}{2}O_2 \rightleftharpoons NO$ is K_2, then**[BHU 2004]**

(a) $K_1 = K_2$
(b) $K_2 = \sqrt{K_1}$
(c) $K_1 = 2K_2$
(d) $K_1 = \frac{1}{2}K_2$

66. For the following reaction in gaseous phase $CO + \frac{1}{2}O_2 \rightarrow CO_2$; K_p / K_c is **[DCE 2002]**

(a) $(RT)^{1/2}$
(b) $(RT)^{-1/2}$
(c) (RT)
(d) $(RT)^{-1}$

67. For the reaction $N_{2(g)} + O_{2(g)} \rightleftharpoons 2NO_{(g)}$, the value of K_c at 800^oC is 0.1. When the equilibrium concentrations of both the reactants is 0.5 mol, what is the value of K_p at the same temperature **[KCET 2005]**

(a) 0.5
(b) 0.1
(c) 0.01
(d) 0.025

68. $A_{(g)} + 3B_{(g)} \rightleftharpoons 4C_{(g)}$. Starting concentration of A is equal to B, equilibrium concentration of A and C are same. $K_c =$

[Kerala CET 2005]

(a) 0.08
(b) 0.8
(c) 8
(d) 80
(e) 1/8

69. $NH_4COONH_{2(s)} \rightleftharpoons 2NH_{3(g)} + CO_{2(g)}$ if equilibrium pressure is 3 atm for the above reaction K_p for the reaction is

(a) 4
(b) 27
(c) 4/27
(d) 1/27

Activation energy, Standard free energy and Degree of dissociation and Vapour density

1. The vapour density of completely dissociated NH_4Cl would be **[NCERT 1974]**

(a) Slight less than half that of NH_4Cl
(b) Half that of NH_4Cl
(c) Double that of NH_4Cl
(d) Determined by the amount of solid NH_4Cl in the experiment

2. In an equilibrium reaction for which $\Delta G^0 = 0$, the equilibrium constant $K =$

(a) 0
(b) 1
(c) 2
(d) 10

3. For a system in equilibrium $\Delta G = 0$ under conditions of constant **[KCET 1992, 2005]**

(a) Temperature and pressure
(b) Temperature and volume
(c) Energy and volume
(d) Pressure and volume

4. A reaction attains equilibrium when the free energy change accompanying it is **[KCET 1989]**

(a) Positive and large
(b) Zero
(c) Negative and large
(d) Negative and small

5. $\Delta G^0(HI, g) \cong +1.7\,kJ$. What is the equilibrium constant at 25^oC for $2HI(g) \leftrightarrows H_2(g) + I_2(g)$ **[KCET 1992]**

(a) 24.0
(b) 3.9
(c) 2.0
(d) 0.5

6. The standard state gibbs free energy change for the given isomerization reaction *cis*-2-pentene $\rightleftharpoons$ trans –2 -pentene is $-3.67\,kJ/mol$ at $400\,K$. If more trans-2-pentene is added to the reaction vessel, then

[CBSE PMT 1995; BHU 1999; AFMC 2000]

(a) More *cis* –2–pentene is formed

(b) Equilibrium is shifted in the forward direction

(c) Equilibrium remains unaffected

(d) Additional *trans*–2–pentene is formed

7. In a reversible reaction, the catalyst **[KCET 2003]**

(a) Increases the activation energy of the backward reaction

(b) Increases the activation energy of the forward reaction

(c) Decreases the activation energy of both, forward and backward reaction

(d) Decreases the activation energy of forward reaction

8. For the reaction $H_2(g)+I_2(g) \rightleftharpoons 2HI(g)$, the equilibrium constant changes with

[IIT 1981; MNR 1983, 85; NCERT 1984; MP PMT 1987, 97; MP PET/PMT 1988; CPMT 1976, 90; UPSEAT 2000]

(a) Total pressure

(b) Catalyst

(c) The amounts of H_2 and I_2 taken

(d) Temperature

9. Calculate ΔG° for conversion of oxygen to ozone $3/2\, O_2(g) \rightarrow O_3(g)$ at 298 *K,* if K_p for this conversion is 2.47×10^{-29} **[DPMT 2004]**

(a) $163\ kJ\ mol^{-1}$ (b) $2.4 \times 10^2\ kJ\ mol^{-1}$

(c) $1.63\ kJ\ mol^{-1}$ (d) $2.38 \times 10^6\ kJ\ mol^{-1}$

Le-Chaterlier principle and It's application

1. When in any system at equilibrium state pressure, temperature and concentration is changed then the equilibria shifted to such a direction which neutralize the effect of change. This is known as

[MP PMT/PET 1988; DPMT 1985]

(a) First law of thermodynamics

(b) Le-chatelier's principle

(c) Ostwald's rule

(d) Hess's law of constant heat summation

2. $N_2 + O_2 \rightleftharpoons 2NO - Q\,cals$

In the above reaction which is the essential condition for the higher production of NO **[CPMT 1971, 89; MP PMT 1985]**

(a) High temperature (b) High pressure

(c) Low temperature (d) Low pressure

3. A reversible reaction is in equilibrium. If a factor is changed which affect it, then

(a) The speed of forward and backward reaction increases

(b) The speed of forward and backward reaction decreases

(c) Only the speed of that reaction increases which nullifies the factor causing increase of speed

(d) No difference

4. Which of the following reactions proceed at low pressure

[MP PET 1985; CPMT 1984; MP PMT 1995; RPMT 1997]

(a) $N_2 + 3H_2 \rightleftharpoons 2NH_3$ (b) $H_2 + I_2 \rightleftharpoons 2HI$

(c) $PCl_5 \rightleftharpoons PCl_3 + Cl_2$ (d) $N_2 + O_2 \rightleftharpoons 2NO$

5. Le-chatelier principle is applicable

(a) Both for physical and chemical equilibrium

(b) Only for chemical equilibrium

(c) Only for physical equilibrium

(d) Neither for (b) nor for (c)

6. In the following reversible reaction

$2SO_2 + O_2 \rightleftharpoons 2SO_3 + Q\ Cal$

Most suitable condition for the higher production of SO_3 is

[NCERT 1974; DPMT 1983, 89; IIT 1981; MP PET 1992; MP PMT 1990, 91, 94, 99; CPMT 1973, 77, 84, 89, 94, 99]

(a) High temperature and high pressure

(b) High temperature and low pressure

(c) Low temperature and high pressure

(d) Low temperature and low pressure

7. When the pressure is applied over system *ice* $\rightleftharpoons$ *water* what will happen ?

[MP PMT 1990; CPMT 1983; NCERT 1978; DPMT 2002]

(a) More water will form

(b) More ice will form

(c) There will be no effect over equilibrium

(d) Water will decompose in H_2 and O_2

8. The reaction $A + B \rightleftharpoons C + D + heat$ has reached equilibrium. The reaction may be made to proceed forward by

[IIT 1978]

(a) Adding more C

(b) Adding more D

(c) Decreasing the temperature

(d) Increasing the temperature

9. On the velocity in a reversible reaction, the correct explanation of the effect of catalyst is**[MP PMT 198**

(a) It provides a new reaction path of low activation energy

(b) It increases the kinetic energy of reacting molecules

(c) It displaces the equilibrium state on right side

(d) It decreases the velocity of backward reaction

10. Select the correct statement from the following **[MP PMT 1985]**

(a) Equilibrium constant changes with addition of catalyst

(b) Catalyst increases the rate of forward reaction

(c) The ratio of mixture at equilibrium is not changed by catalyst

(d) Catalyst are active only in solution

11. According to Le-chatelier principle, if heat is given to solid-liquid system, then **[MNR 1990]**

(a) Quantity of solid will reduce

(b) Quantity of liquid will reduce

(c) Increase in temperature

(d) Decrease in temperature

12. In the reaction $A(g)+2B(g) \rightleftharpoons C(g)+QkJ$, greater product will be obtained **or** the forward reaction is favoured by

[MNR 1988; MP PMT 1989, 97]

(a) At high temperature and high pressure

(b) At high temperature and low pressure

(c) At low temperature and high pressure

(d) At low temperature and low pressure

13. Following gaseous reaction is undergoing in a vessel $C_2H_4+H_2 \rightleftharpoons C_2H_6$; $\Delta H=-32.7\,Kcal$

Which will increase the equilibrium concentration of C_2H_6

[IIT 1984; MP PET/PMT 1988; MADT Bihar 1995]

(a) Increase of temperature

(b) By reducing temperature

(c) By removing some hydrogen

(d) By adding some C_2H_6

14. The effect of increasing the pressure on the equilibrium $2A+3B \rightleftharpoons 3A+2B$ is**[EAMCET 1980; MP PMT 1991]**

(a) Forward reaction is favoured

(b) Backward reaction is favoured

(c) No effect

(d) None of the above

15. For the equilibrium $2NO_2(g) \rightleftharpoons N_2O_4(g) \;+14.6\,kcal$ the increase in temperature would **[CPMT 1974, 78]**

(a) Favour the formation of N_2O_4

(b) Favour the decomposition of N_2O_4

(c) Not alter the equilibrium

(d) Stop the reaction

16. Which of the following factors will favour the reverse reaction in a chemical equilibrium **[AIIMS 1982]**

(a) Increase in the concentration of one of the reactants

(b) Removal of at least one of the product at regular time intervals

(c) Increase in the concentration of one or more products

(d) None of these

17. In the formation of SO_3 by contact process, the conditions used are **[CPMT 1984]**

(a) Catalyst, optimum temperature and higher concentration of reactants

(b) Catalyst, optimum temperature and lower concentration of reactants

(c) Catalyst, high temperature and higher concentration of reactants

(d) Catalyst, low temperature and lower concentration of reactants

18. Given reaction is $2X_{(gas)}+Y_{(gas)} \rightleftharpoons 2Z_{(gas)}+80\,kcal$

Which combination of pressure and temperature gives the highest yield of Z at equilibrium

(a) 1000 atm and $500\,^oC$

(b) 500 atm and $500\,^oC$

(c) 1000 atm and $100\,^oC$

(d) 500 atm and $100\,^oC$

19. Consider the reaction $HCN_{(aq)} \rightleftharpoons H^+_{(aq)}+CN^-_{(aq)}$. At equilibrium, the addition of $CN^-_{(aq)}$ would**[NCERT 1979]**

(a) Reduce $HCN_{(aq)}$ concentration

(b) Decrease the $H^+_{(aq)}$ ion concentration

(c) Increase the equilibrium constant

(d) Decrease the equilibrium constant

20. In the gaseous equilibrium H_2X_2+ heat $\rightleftharpoons 2HX$, the formation of HX will be favoured by**[CPMT 1977]**

(a) High pressure and low temperature

(b) High temperature and low pressure

(c) Low temperature and low pressure

(d) High temperature and high pressure

21. Raising the temperature of an equilibrium system **[MP PMT 1987]**

(a) Favours the exothermic reaction only

(b) Favours the endothermic reaction only

(c) Favours both the exothermic and endothermic reactions

(d) Favours neither the exothermic nor endothermic reactions

22. Reaction in which yield of product will increase with increase in pressure is

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

(b) $H_2O_{(g)}+CO_{(g)} \rightleftharpoons CO_{2(g)}+H_{2(g)}$

(c) $H_2O_{(g)}+C_{(s)} \rightleftharpoons CO_{(g)}+H_{2(g)}$

(d) $CO_{(g)}+3H_{2(g)} \rightleftharpoons CH_{4(g)}+H_2O_{(g)}$

23. In reaction $N_{2(g)}+3H_{2(g)} \rightleftharpoons 2NH_{3(g)}; \Delta H=-93.6\,kJ$, the yield of ammonia does not increase when **[CPMT 1988]**

(a) Pressure is increased

(b) Temperature is lowered

(c) Pressure is lowered

(d) Volume of the reaction vessel is decreased

24. The equilibrium which remains uneffected by change in pressure of the reactants is

[CPMT 1987; KCET 1991; EAMCET 1992; MP PET 1992, 95; MP PMT 1999]

(a) $N_{2(g)}+O_{2(g)} \rightleftharpoons 2NO_{(g)}$

(b) $2SO_{2(g)}+O_{2(g)} \rightleftharpoons 2SO_{3(g)}$

(c) $2O_{3(g)} \rightleftharpoons 3O_{2(g)}$

(d) $2NO_{2(g)} \rightleftharpoons N_2O_{4(g)}$

25. The endothermic reaction $(M+N \leftrightarrows P)$ is allowed to attain an equilibrium at 25^o. Formation of P can be increased by **[BHU 1981]**

(a) Raising temperature

(b) Lowering temperature

(c) Keeping temperature constant

(d) Decreasing the concentration of M and N

26. According to Le-chatelier's principle, an increase in the temperature of the following reaction will

$N_2+O_2 \rightleftharpoons 2NO-43,200\,kcal$ **[MP PMT 1985, 93]**

(a) Increase the yield of NO

(b) Decrease the yield of NO

(c) Not effect the yield of NO

(d) Not help the reaction to proceed in forward direction

27. In the manufacture of NH_3 by Haber's process, the condition which would give maximum yield is

$N_2+3H_2 \rightleftharpoons 2NH_3+Q\,kcal$

[NCERT 1978; EAMCET 1980; MNR 1987; AFMC 1999; CPMT 1983, 84, 86, 94; MP PMT 1999]

(a) High temperature, high pressure and high concentrations of the reactants

(b) High temperature, low pressure and low concentrations of the reactants

(c) Low temperature and high pressure

(d) Low temperature, low pressure and low concentration of H_2

28. Suppose the reaction $PCl_{5(s)} \rightleftharpoons PCl_{3(s)}+Cl_{2(g)}$ is in a closed vessel at equilibrium stage. What is the effect on equilibrium concentration of $Cl_{2(g)}$ by adding PCl_5 at constant temperature **[MP PMT 1992]**

(a) Decreases

(b) Increases

(c) Unaffected

(d) Cannot be described without the value of K_p

29. In which of the following equilibrium reactions, the equilibrium would shift to the right, if total pressure is increased **[KCET 1993]**

(a) $N_2+3H_2 \rightleftharpoons 2NH_3$ (b) $H_2+I_2 \rightleftharpoons 2HI$

(c) $H_2+Cl_2 \rightleftharpoons 2HCl$ (d) $N_2O_4 \rightleftharpoons 2NO$

30. In which of the following gaseous equilibrium an increase in pressure will increase the yield of the products

[EAMCET 1988]

(a) $2HI \rightleftharpoons H_2+I_2$ (b) $2SO_2+O_2 \rightleftharpoons 2SO_3$

(c) $H_2+Br_2 \rightleftharpoons 2HBr$ (d) $H_2O+CO \rightleftharpoons H_2+CO_2$

31. In the reaction $A(g)+B(g) \rightleftharpoons C(g)$, the backward reaction is favoured by **[EAMCET 1986]**

(a) Decrease of pressure (b) Increase of pressure

(c) Either of the two (d) None of the two

32. The formation of NO_2 in the reaction $2NO+O_2 \rightleftharpoons 2NO_2$ + heat is favoured by

[Rookee Qualifying 1998]

(a) Low pressure (b) High pressure

(c) Low temperature (d) Reduction in the mass of

33. For the reaction $PCl_5(g) \rightleftharpoons PCl_3(g)+Cl_2(g)$, the forward reaction at constant temperature is favoured by

[IIT 1991; AMU 2001]

(a) Introducing an inert gas at constant volume

(b) Introducing chlorine gas at constant volume

(c) Introducing an inert gas at constant pressure

(d) Decreasing the volume of the container

34. Which of the following conditions is favourable for the production of ammonia by Haber's process **[MP PET**

(a) High concentration of reactants

(b) Low temperature and high pressure

(c) Continuous removal of ammonia

(d) All of these

35. According to Le-chatelier's principle, which of the following factors influence a chemical system **[MP PMT 199**

(a) Concentration only

(b) Pressure only

(c) Temperature only

(d) Concentration, pressure and temperature

36. If pressure increases then its effect on given equilibrium $C(s)+H_2O(g) \rightleftharpoons CO(g)+H_2(g)$ it is satisfied in

[BCECE 2005]

(a) Forward direction (b) Backward direction

(c) No effect (d) None of these

37. The exothermic formation of ClF_3 is represented by the equation

$Cl_{2(g)} + 3F_{2(g)} \rightleftharpoons 2ClF_{3(g)}$; $\Delta H = -329\ kJ$

Which of the following will increase the quantity of ClF_3 in an equilibrium mixture of Cl_2, F_2 and ClF_3 **[AIEEE 2005]**

(a) Increasing the temperature

(b) Removing Cl_2

(c) Increasing the volume of the container

(d) Adding F_2

38. What would happen to a reversible reaction at equilibrium when an inert gas is added while the pressure remains unchanged

(a) More of the product will be formed

(b) Less of the product will be formed

(c) More of the reactants will be formed

(d) It remains unaffected

39. Formation of SO_3 takes place according to the reaction $2SO_2 + O_2 \leftrightarrows 2SO_3; \Delta H = -45.2\,kcal$

Which of the following factors favours the formation of SO_3

[MP PET/PMT 1998]

(a) Increase in temperature

(b) Increase in pressure

(c) Removal of oxygen

(d) Increase in volume

40. For the chemical reaction $3X(g) + Y(g) \rightleftharpoons X_3Y(g)$, the amount of X_3Y at equilibrium is affected by **[IIT 1999]**

(a) Temperature and pressure

(b) Temperature only

(c) Pressure only

(d) Temperature, pressure and catalyst

41. In $N_2 + 3H_2 \rightleftharpoons 2NH_3$ reversible reaction, increase in pressure will favour **[DPMT 1996]**

(a) Reaction in forward direction

(b) Reaction in reverse direction

(c) Will not exert any effect

(d) In backward and forward direction equally

42. In the reaction $N_2 + 3H_2 \rightarrow 2NH_3$, the product increases on

(a) Increasing temperature

(b) Increasing pressure

(c) Increasing temperature and pressure both

(d) Decreasing temperature and pressure both

(e) None of these

43. In which of the following system, doubling the volume of the container cause a shift to the right **[AIIMS 1996]**

(a) $H_2(g) + Cl_2(g) = 2HCl(g)$

(b) $2CO(g) + O_2(g) = 2CO_2(g)$

(c) $N_2(g) + 3H_2(g) = 2NH_3(g)$

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

44. Which of the following information can be obtained on the basis of Le-chatelier's principle

[AIIMS 1998; Pb. PMT 1999; BHU 2000; DPMT 2004]

(a) Entropy change in a reaction

(b) Dissociation constant of a weak acid

(c) Equilibrium constant of a chemical reaction

(d) Shift in equilibrium position on changing value of a constant

45. The equilibrium $2SO_{2(g)} + O_{2(g)} \rightleftharpoons 2SO_{3(g)}$ shifts forward if **[MP PMT 1997]**

[CPMT 1988]

(a) A catalyst is used

(b) An adsorbent is used to remove SO_3 as soon as it is formed

(c) Low pressure

(d) Small amounts of reactants are used

46. The equilibrium $SO_2Cl_{2(g)} \rightleftharpoons SO_{2(g)} + Cl_{2(g)}$ is attained at 25°C in a closed container and an inert gas helium is introduced which of the following statement is correct

[MP PMT 2000]

(a) More chlorine is formed

(b) Concentration of SO_2 is reduced

(c) More SO_2Cl_2 is formed

(d) Concentration of SO_2Cl_2, SO_2 and Cl_2 does not change

47. Which of the following equilibria will shift to right side on increasing the temperature **[MP PMT 2000]**

(a) $CO_{(g)} + H_2O_{(g)} \rightleftharpoons CO_{2(g)} + H_{2(g)}$

(b) $2SO_{2(g)} + O_{2(g)} \rightleftharpoons 2SO_{3(g)}$

(c) $H_2O_{(g)} \rightleftharpoons H_{2(g)} + \frac{1}{2}(O_2)_{(g)}$

(d) $4HCl_{(g)} + O_{2(g)} \rightleftharpoons 2H_2O_{(g)} + 2Cl_{2(g)}$

48. Sodium sulphate dissolves in water with evolution of heat. Consider a saturated solution of sodium sulphate. If the temperature is raised, then according to Le-Chatelier principle

(a) More solid will dissolve

(b) Some solid will precipitate out from the solution

[Bihar MEE 1996]

(c) The solution will become supersaturated

(d) Solution concentration will remain unchanged

49. Consider the equilibrium $N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$; ΔH = – 93.6 KJ. The maximum yield of ammonia is obtained by

[UPSEAT 1999; AMU 2000]

(a) Decrease of temp. and increase of pressure

(b) Increase of temp. and decrease of pressure

(c) Decrease of both the temp. and pressure

(d) Increase of both the temp. and pressure

50. In the equilibrium $AB \rightleftharpoons A + B$; if the equilibrium concentration of A is doubled, the equilibrium concentration of *B* would become: **[AMU 2000]**

(a) Twice (b) Half

(c) 1/4th (d) 1/8th

51. Le-Chatelier's principle is applicable only to a **[MP PET/PMT 1988; KCET 1999; AFMC 2000; Pb. CET 2002]**

(a) System in equilibrium (b)Irreversible reaction

(c) Homogeneous reaction (d)Heterogeneous reaction

52. In a vessel containing SO_3, SO_2 and O_2 at equilibrium, some helium gas is introduced so that the total pressure increases while temperature and volume remain constant. According to Le–Chatelier principle the dissociation of SO_3 **[UPSEAT 2000]**

(a) Increases (b) Decreases

(c) Remains unaltered (d) Changes unpredictably

53. $H_{2(g)} + I_{2(g)} \rightleftharpoons 2HI_{(g)}$ $\Delta H = +q\,cal$, then formation of *HI*: **[AMU 2000]**

(a) Is favoured by lowering the temperature

(b) Is favoured by increasing the pressure

(c) Is unaffected by change in pressure

(d) Is unaffected by change in temperature

54. In which of the following equilibrium systems is the rate of the backward reaction favoured by increase of pressure **[KCET 2001]**

(a) $PCl_5 \rightleftharpoons PCl_3 + Cl_2$ (b) $2SO_2 + O_2 \rightleftharpoons 2SO_3$

(c) $N_2 + 3H_2 \rightleftharpoons 2NH_3$ (d) $N_2 + O_2 \rightleftharpoons 2NO$

55. Which of the following equilibrium is not shifted by increase in the pressure

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

(b) $N_{2(g)} + 3H_{2(g)} \rightleftharpoons 2NH_{3(g)}$

(c) $2CO_{(g)} + O_{2(g)} \rightleftharpoons 2CO_{2(g)}$

(d) $2C_{(S)} + O_{2(g)} \rightleftharpoons 2CO_{(g)}$

56. According to Le–Chatelier's principal adding heat to a solid and liquid in equilibrium with endothermic nature will cause the **[JIPMER 2000; MP PET 2001]**

(a) Temperature to rise

(b) Temperature to fall

(c) Amount of solid to decrease

(d) Amount of liquid to decrease

57. On addition of an inert gas at constant volume to the reaction $N_2 + 3H_2 \rightleftharpoons 2NH_3$ at equilibrium **[Pb. PMT 2001]**

(a) The reaction remains unaffected

(b) Forward reaction is favoured

(c) The reaction halts

(d) Backward reaction is favoured

58. Le-Chatelier principle is not applicable to **[MH CET 2001]**

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

(b) $Fe_{(S)} + S_{(S)} \rightleftharpoons FeS_{(S)}$

(c) $N_{2(g)} + 3H_{2(g)} \rightleftharpoons 2NH_{3(g)}$

(d) $N_{2(g)} + O_{2(g)} \rightleftharpoons 2NO_{(g)}$

59. For the reaction: *A* + *B* + *Q* $\rightleftharpoons$ *C* + *D*, if the temperature is increased, then concentration of the products will **[AFMC 2001]**

(a) Increase (b) Decrease

(c) Remain same (d) Become Zero

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

In this reaction when pressure increases, the reaction direction **[RPMT 2002]**

(a) Does not change (b) Forward

(c) Backward (d) Decrease

61. The rate of reaction of which of the following is not affected by pressure **[MP PMT 2002]**

(a) $PCl_3 + Cl_2 \rightleftharpoons PCl_5$ (b) $N_2 + 3H_2 \rightleftharpoons 2NH_3$

(c) $N_2 + O_2 \rightleftharpoons 2NO$ (d) $2SO_2 + O_2 \rightleftharpoons 2SO_3$

62. In the equilibrium $N_2 + 3H_2 \rightleftharpoons 2NH_3$ + 22 *kcal*, the formation of ammonia is favoured by **[MP PET 2000, 02]**

(a) Increasing the pressure

(b) Increasing the temperature

(c) Decreasing the pressure

(d) Adding ammonia

63. **[MP PMT 2001]** The reaction $2SO_2 + O_2 \rightleftharpoons 2SO_3$; ΔH = – *ve* is favoured by **[CPMT 2002; Pb. PMT 2001]**

(a) Low temperature, low pressure

(b) Low temperature, high pressure

(c) High temperature, high pressure

(d) High temperature, low pressure

64. Which of the following will favour the reverse reaction in a chemical equilibrium **[Kerala (Med.) 2002]**

(a) Increasing the concentration of the reactants

(b) Removal of at least one of the products at regular intervals

(c) Increasing the concentration of one or more of the products

(d) Increasing the pressure

(e) None of these

65. Under what conditions of temperature and pressure the formation of atomic hydrogen from molecular hydrogen will be favoured most **[UPSEAT 2000, 01, 02]**

(a) High temperature and high pressure
(b) Low temperature and low pressure
(c) High temperature and low pressure
(d) Low temperature and high pressure

66. The formation of nitric oxide by contact process $N_2 + O_2 \rightleftharpoons 2NO.$ ΔH = 43.200 *kcal* is favoured by **[AMU 2002]**

(a) Low temperature and low pressure
(b) Low temperature and high pressure
(c) High temperature and high pressure
(d) High temperature and excess reactants concentration

67. The chemical reaction: $BaO_{2(S)} \rightleftharpoons BaO_{(s)} + O_{2(g)}$, ΔH = + *ve*. In equilibrium condition, pressure of O_2 depends upon

[CBSE PMT 2002]

(a) Increase mass of *BaO*
(b) Increase mass of BaO_2
(c) Increase in temperature
(d) Increase mass of BaO_2 and *BaO* both

68. The yield of product in the reaction

$A_{2(g)} + 2B_{(g)} \rightleftharpoons C_{(g)} + Q.kJ.$ would be high at

[UPSEAT 2002]

(a) High temperature and high pressure
(b) High temperature and low pressure
(c) Low temperature and high pressure
(d) Low temperature and low pressure

69. Which reaction is not effected by change in pressure

[UPSEAT 2003]

(a) $H_2 + I_2 \rightleftharpoons 2HI$ (b) $2C + O_2 \rightleftharpoons 2CO$
(c) $N_2 + 3H_2 \rightleftharpoons 2NH_3$ (d) $PCl_5 \rightleftharpoons PCl_3 + Cl_2$

70. The gaseous reaction $A + B \rightleftharpoons 2C + D; + Q$ is most favoured at **[Karnataka CET 2003]**

(a) Low temperature and high pressure
(b) High temperature and high pressure
(c) High temperature and low pressure
(d) Low temperature and low pressure

71. For a reaction if $K_p > K_c$, the forward reaction is favoured by **[RPET 2003]**

(a) Low pressure (b) High pressure
(c) High temperature (d) Low temperature

72. $A_{2(g)} + B_{2(g)} \rightleftharpoons 2AB_{(g)}$; $\Delta H = +ve$ **[BHU 2003]**

(a) Unaffected by pressure
(b) It occurs at 1000 pressure
(c) It occurs at high temperature
(d) It occurs at high pressure and high temperature

73. Consider the reaction equilibrium,
$2SO_{2(g)} + O_{2(g)} \rightleftharpoons 2SO_{3(g)}$; $\Delta H° = -198 kJ$. On the basis of Le-Chatelier's principle, the condition favourable for the forward reaction is

(a) Lowering of temperature as well as pressure
(b) Increasing temperature as well as pressure
(c) Lowering the temperature and increasing the pressure
(d) Any value of temperature and pressure

Critical Thinking

Objective Questions

1. If dissociation for reaction, $PCl_5 \rightleftharpoons PCl_3 + Cl_2$

Is 20% at 1 *atm*. pressure. Calculate K_c

[Kerala (Med.) 2003]

(a) 0.04 (b) 0.05
(c) 0.07 (d) 0.06

2. Ammonia under a pressure of 15 *atm* at 27°*C* is heated to 347°*C* in a closed vessel in the presence of a catalyst. Under the conditions, NH_3 is partially decomposed according to the equation, $2NH_3 \rightleftharpoons N_2 + 3H_2$.The vessel is such that the volume remains effectively constant where as pressure increases to 50 *atm*. Calculate the percentage of NH_3 actually decomposed. **[IIT 1981; MNR 19**

(a) 65% (b) 61.3%
(c) 62.5% (d) 64%

3. K_p for the following reaction at 700 *K* is 1.3×10^{-3} atm$^{-1.}$ The K_c at same temperature for the reaction $2SO_2 + O_2 \square 2SO_3$ will be **[AIIMS 2001]**

(a) 1.1×10^{-2} (b) 3.1×10^{-2}
(c) 5.2×10^{-2} (d) 7.4×10^{-2}

4. For the reaction $2NO_{2(g)} \rightleftharpoons 2NO_{(g)} + O_{2(g)}$

$K_c = 1.8 \times 10^{-6}$ at 185°*C*. At 185°*C*, the value of K_c for the reaction $NO_{(g)} + \frac{1}{2}O_{2(g)} \rightleftharpoons NO_{2(g)}$ is **[UPSEAT 2000]**

(a) 0.9×10^6 (b) 7.5×10^2
(c) 1.95×10^{-3} (d) 1.95×10^3

5. $2SO_3 \rightleftharpoons 2SO_2 + O_2$. If $K_c = 100, \alpha = 1$, half of the reaction is completed, the concentration of SO_3 and SO_2 are equal, the concentration of O_2 is **[CPMT 1996**

(a) $0.001\,M$ (b) $\frac{1}{2}SO_2$
(c) 2 times of SO_2 (d) Data incomplete

6. At 700 K, the equilibrium constant K_p for the reaction $2SO_{3(g)} \rightleftharpoons 2SO_{2(g)} + O_{2(g)}$ is 1.80×10^{-3} and kP_a is 14, (R = 8.314 $Jk^{-1}\ mol^{-1}$). The numerical value in moles per litre of K_c for this reaction at the same temperature will be

[AFMC 2001]

(a) 3.09×10^{-7} *mol-litre* (b) 5.07×10^{-8} *mol-litre*

(c) 8.18×10^{-9} *mol-litre* (d) 9.24×10^{-10} *mol-litre*

7. 0.1 mole of $N_2O_{4(g)}$ was sealed in a tube under one atmospheric conditions at 25°C. Calculate the number of moles of $NO_{2(g)}$ present, if the equilibrium $N_2O_{4(g)} \rightleftharpoons 2NO_{2(g)}$ $(K_p = 0.14)$ is reached after some time

[UPSEAT 2001]

(a) 1.8×10^2 (b) 2.8×10^2

(c) 0.034 (d) 2.8×10^{-2}

8. The partial pressures of CH_3OH, CO and H_2 in the equilibrium mixture for the reaction

$$CO + 2H_2 \rightleftharpoons CH_3OH$$

at 427°C are 2.0, 1.0 and 0.1 *atm* respectively. The value of K_P for the decomposition of CH_3OH to CO and H_2 is

[Roorkee 1999]

(a) $1 \times 10^2\ atm$ (b) $2 \times 10^2\ atm^{-1}$

(c) $50\ atm^2$ (d) $5 \times 10^{-3}\ atm^2$

9. One mole of a compound *AB* reacts with one mole of a compound *CD* according to the equation

$AB + CD \rightleftharpoons AD + CB$.

When equilibrium had been established it was found that $\frac{3}{4}$ mole each of reactant *AB* and *CD* had been converted to *AD* and *CB*. There is no change in volume. The equilibrium constant for the reaction is **[Kerala (Med.) 2003]**

(a) $\frac{9}{16}$ (b) $\frac{1}{9}$

(c) $\frac{16}{9}$ (d) 9

10. For the reaction $CO(g) + H_2O(g) \rightleftharpoons CO_2(g) + H_2(g)$ at a given temperature, the equilibrium amount of $CO_2(g)$ can be increased by **[IIT 1998]**

(a) Adding a suitable catalyst

(b) Adding an inert gas

(c) Decreasing the volume of the container

(d) Increasing the amount $CO(g)$

11. At constant temperature, the equilibrium constant (K_P) for the decomposition reaction $N_2O_4 \rightleftharpoons 2NO_2$ is expressed by $K_P = \frac{(4x^2P)}{(1-x^2)}$, where $P =$ pressure, $x =$ extent of decomposition. Which one of the following statements is true

[IIT Screening 2001]

(a) K_P increases with increase of P

(b) K_P increases with increase of x

(c) K_P increases with decrease of x

(d) K_P remains constant with change in P and x

AR Assertion & Reason

For AIIMS Aspirants

Read the assertion and reason carefully to mark the correct option out of the options given below :

(a) *If both assertion and reason are true and the reason is the correct explanation of the assertion.*
(b) *If both assertion and reason are true but reason is not the correct explanation of the assertion.*
(c) *If assertion is true but reason is false.*
(d) *If the assertion and reason both are false.*
(e) *If assertion is false but reason is true.*

1. Assertion : The equilibrium constant is fixed and is the characteristic of any given chemical reaction at a specified temperature.

Reason : The composition of the final equilibrium mixture at a particular temperature depends upon the starting amount of reactants. **[AIIMS 2000]**

2. Assertion : $K_p = K_c$ for all reaction.

Reason : At constant temperature, the pressure of the gas is proportional to its concentration.

3. Assertion : The equilibrium constant for the reaction

$$CaSO_4.5H_2O(s) \rightleftharpoons CaSO_4.3H_2O(s) + 2H_2O(g)$$

is $K_C = \frac{[CaSO_4.3H_2O][H_2O]^2}{[CaSO_4.5H_2O]}$

Reason : Equilibrium constant is the ratio of the product of molar concentration of the substances produced to the product of the molar concentrations of reactants with each concentrations term raised to the power equal to the respective stoichiometric constant.

4. Assertion : On cooling a freezing mixture, colour of the mixture turns to pink from deep blue for a reaction. $Co(H_2O)_6^{2+}{}_{(aq)} + 4Cl^-{}_{(aq)} \rightleftharpoons CoCl_4^{2-}{}_{(aq)} + 6H_2O_{(l)}$.

Reason : Reaction is endothermic so on cooling, the reaction moves to backward direction.

5. Assertion : If Q_c (reaction quotient) $< K_C$ (equilibrium constant) reaction moves in direction of reactants.

Reason : Reaction quotient is defined in the same way as equilibrium constant at any stage of he reaction.

6. Assertion : $NaCl$ solution can be purified by passage of hydrogen chloride through brine.

Reason : This type of purification is based on Le-Chaterlier's principle.

7. Assertion : According to Le-Chatelier's principle addition of heat to an equilibrium solid $\rightleftharpoons$ liquid results in decrease in the amount of solid.

Reason : Reaction is endothermic, so on heating forward reaction is favoured.

8. Assertion : Equilibrium constant has meaning only when the corresponding balanced chemical equation is given.

Reason : Its value changes for the new equation obtained by multiplying or dividing the original equation by a number.

9. Assertion : Equilibrium constant for the reverse reaction is the inverse of the equilibrium constant for the reaction in the forward direction.

Reason : Equilibrium constant depends upon the way in which the reaction is written.

10. Assertion : The value of K gives us a relative idea about the extent to which a reaction proceeds.

Reason : The value of K is independent of the stochiometry of reactants and products at the point of equilibrium.

11. Assertion : Catalyst affects the final state of the equilibrium.

Reason : It enables the system to attain a new equilibrium state by complexing with the reagents.

12. Assertion : For the reaction, $2NH_3(g) \rightleftharpoons N_2(g) + 3H_2(g)$, the unit of K_p will be atm.

Reason : Unit of K_p is $(atm)^{\Delta n}$.

13. Assertion : Effect of temperature of K_c or K_p depends on enthalpy change.

Reason : Increase in temperature shifts the equilibrium in exothermic direction and decrease in temperature shifts the equilibrium position in endothermic direction.

14. Assertion : For a gaseous reaction, $xA + yB \rightleftharpoons lC + mD, K_p = K_C$.

Reason : Concentration of gaseous reactant is taken to be unity.

15. Assertion : Ice $\rightleftharpoons$ water, if pressure is applied water will evaporate.

Reason : Increase of pressure pushes the equilibrium towards the side in which number of gaseous mole decreases.

16. Assertion : $SO_2(g) + \frac{1}{2}O_2(g) \rightleftharpoons SO_3(g) +$ heat.

Forward reaction is favoured at high temperature and low pressure.

Reason : Reaction is exothermic.

17. Assertion : For a reaction $H_2(g) + I_2(g) \rightleftharpoons 2HI(g)$ if the volume of vessel is reduced to half of its original volume, equilibrium constant will be doubled.

Reason : According to Le-Chatelier principle, reaction shifts in a direction that tends to undo the effect of the stress.

Answers

Reversible and Irreversible reaction

1	b	2	c	3	d	4	b	5	a
6	d	7	b						

Equilibrium state

1	c	2	b	3	a	4	c	5	b
6	d	7	c	8	b	9	cd	10	cd

Law of mass action

1	b	2	a	3	d	4	b	5	a
6	d	7	d	8	a	9	c	10	a

Law of equilibrium and Equilibrium constant

1	d	2	d	3	c	4	a	5	a
6	d	7	c	8	a	9	a	10	d
11	b	12	c	13	a	14	d	15	d
16	c	17	a	18	b	19	b	20	c
21	a	22	b	23	d	24	d	25	b
26	a	27	c	28	b	29	c	30	a
31	b	32	d	33	c	34	b	35	a
36	a	37	c	38	a	39	d	40	a
41	d	42	d	43	b	44	c	45	d
46	a	47	c	48	b	49	a	50	b
51	b	52	b	53	c	54	d	55	b
56	c	57	c	58	c	59	a	60	c
61	d	62	d	63	b	64	b	65	d
66	d	67	d	68	a	69	c	70	d
71	abcd	72	a	73	d	74	b		

K_p & K_c Relationship and Characteristics of K

1	a	2	d	3	a	4	b	5	d
6	d	7	c	8	d	9	a	10	b
11	c	12	c	13	c	14	c	15	d
16	c	17	c	18	c	19	d	20	c
21	c	22	c	23	a	24	d	25	d
26	b	27	b	28	c	29	c	30	b
31	d	32	d	33	d	34	a	35	b
36	d	37	d	38	d	39	b	40	b
41	d	42	b	43	b	44	d	45	c
46	c	47	b	48	d	49	a	50	a
51	a	52	b	53	a	54	a	55	a
56	a	57	b	58	c	59	c	60	c
61	b	62	a	63	d	64	a	65	b
66	b	67	b	68	c	69	b		

Activation energy, Standard free energy and Degree of dissociation and Vapour density

1	b	2	b	3	a	4	b	5	d
6	a	7	c	8	d	9	a		

Le-Chaterlier principle and It's application

1	b	2	a	3	c	4	c	5	a
6	c	7	a	8	c	9	a	10	c
11	a	12	c	13	b	14	c	15	b
16	c	17	a	18	c	19	b	20	b
21	b	22	d	23	c	24	a	25	a
26	a	27	c	28	b	29	a	30	b
31	a	32	b,c	33	c	34	d	35	d
36	b	37	d	38	d	39	b	40	a
41	a	42	b	43	d	44	d	45	b
46	d	47	c	48	b	49	a	50	b
51	a	52	b	53	c	54	a	55	a
56	c	57	a	58	b	59	a	60	a
61	c	62	a	63	b	64	c	65	c
66	d	67	a	68	c	69	a	70	d
71	a	72	a	73	c				

Critical Thinking Questions

1	b	2	b	3	d	4	b	5	d
6	a	7	c	8	d	9	d	10	d
11	d								

Assertion & Reason

1	c	2	e	3	e	4	a	5	e
6	c	7	b	8	a	9	a	10	c
11	d	12	e	13	c	14	d	15	e
16	e	17	e						

Answers and Solutions

Reversible and Irreversible reaction

1. (b) Reversible reaction always attains equilibrium which proceeds both sides and never go for completion.

2. (c) In a reversible reaction some amount of the reactants remains unconverted into products.

3. (d) In lime klin CO_2 escaping regularly so reaction proceeds in forward direction.

7. (b) The reaction is not reversible.

Equilibrium state

1. (c) When rate of forward reaction is equal to the rate of backward reaction then equilibrium is supposed to be established.

2. (b) Equilibrium can be achieved only in closed vessel.

4. (c) When rate of forward reaction is equal to rate of backward reaction the reaction is said to be in equilibrium.

6. (d) At equilibrium rate of forward reaction is equal to the rate of backward reaction.

7. (c) According to Le-chatelier principle when concentration of reactant increases, the equilibrium shift in favour of forward reaction.

8. (b) At equilibrium, the rate of forward & backward reaction become equal.

Law of mass action

1. (b) According to law of mass-action, “at a given temperature, the rate of a reaction at a particular instant is proportional to the product of the active masses of the reactants at that instant raised to powers which are numerically equal to the numbers of their respective molecules in the stoichiometric equation describing the reaction”.

3. (d) $[HI] = \dfrac{64\,gm}{128 \times 2\,litre} = 0.25$

Active mass is the concentration in *moles/litre.*

8. (a) As we increase the concentration of substance, then speed of the reaction increases.

9. (c) Chemical reaction quantitatively depend on the reactant and product molecule.

Law of equilibrium and Equilibrium constant

1. (d) Equilibrium constant for the reaction , 3A + 2B $\rightleftharpoons$ C is

$$K = \frac{[C]}{[A]^3[B]^2}\,.$$

2. (d) Suppose 1 mole of A and B each taken then 0.8 *mole/litre* of C and D each formed remaining concentration of A and B will be (1 – 0.8) = 0.2 *mole/litre* each.

$$Kc = \frac{[C]\,[D]}{[A]\,[B]} = \frac{0.8 \times 0.8}{0.2 \times 0.2} = 16.0$$

3. (c) $A + B \rightleftharpoons C + D$

Initial conc. 4, 4 0 0

After T time conc. (4-2) (4-2) 2 2

Equilibrium constant = $\dfrac{[C]\,[D]}{[A]\,[B]} = \dfrac{2 \times 2}{2 \times 2} = 1$

4. (a) $H_2 + I_2 \rightleftharpoons 2HI$; $[HI]$ = 0.80, $[H_2] = 0.10$, $[I_2] = 0.10$

$$K_c = \frac{[HI]^2}{[H_2]\,[I_2]} = \frac{0.80 \times 0.80}{0.10 \times 0.10} = 64$$

5. (a) Those reaction which have more value of K proceeds towards completion.

6. (d) K_c is a characteristic constant for the given reaction.

7. (c) Equilibrium constant is independent of original concentration of reactant.

8. (a) K_p is constant and does not change with pressure.

9. (a) For reaction $A + 2B \rightleftharpoons C$

$$K = \frac{[C]}{[A]\,[B]^2} = \frac{0.216}{0.06 \times 0.12 \times 0.12} = 250\,.$$

11. (b) $A + 2B \rightleftharpoons C + 3D$

$$K = \frac{[pC]\,[pD]^3}{[pA]\,[pB]^2} = \frac{0.30 \times 0.50 \times 0.50 \times 0.50}{0.20 \times 0.10 \times 0.10} = 18.75$$

13. (a)

$$\begin{array}{ccc} PCl_5 & \rightleftharpoons PCl_3 + & Cl_2 \\ 2 & 0 & 0 \\ \dfrac{2 \times 60}{100} & \dfrac{2 \times 40}{100} & \dfrac{2 \times 40}{100} \end{array}$$

Volume of container = 2 *litre*.

$$K_c = \frac{\dfrac{2 \times 40}{100 \times 2} \times \dfrac{2 \times 40}{100 \times 2}}{\dfrac{2 \times 60}{100 \times 2}} = 0.266\,.$$

14. (d) Δn = 1 for this change

So the equilibrium constant depends on the unit of concentration.

15. (d) Unit of $K_p = (atm)^{\Delta n}$

Unit of $K_c = (mole\,/\,litre)^{\Delta n}$

$= [mole\,/\,litre]^0 = 0$

16. (c) $K = \frac{[NO_2]^2}{[N_2O_4]} = \frac{\left[2 \times \frac{10^{-3}}{2}\right]^2}{\left[\frac{.2}{2}\right]} = \frac{10^{-6}}{10^{-1}} = 10^{-5}$.

19. (b) For $A + B \rightleftharpoons C + D$

$$K = \frac{[C]\,[D]}{[A]\,[B]} = \frac{0.4 \times 1}{0.5 \times 0.8} = 1.$$

20. (c) $A + B \rightleftharpoons C + D$

Initial 1 1 0 0

remaining at equilibrium 0.4 0.4 0.6 0.6

$$K = \frac{[C]\,[D]}{[A]\,[B]} = \frac{0.6 \times 0.6}{0.4 \times 0.4} = \frac{36}{16} = 2.25.$$

21. (a) $K = \frac{[NH_3]^2}{[N_2]\,[H_2]^3}$

23. (d) $A + B \rightleftharpoons C + D$

x x 0 0

$2x$ $2x$

$$K_c = \frac{[C][D]}{[A][B]} = \frac{2x\,.\,2x}{x\,.\,x} = 4$$

24. (d) $N_2O_4 \rightleftharpoons 2NO_2$

1 0

$(1-\alpha)$ 2α

total mole at equilibrium $= (1-\alpha) + 2\alpha = 1 + \alpha$

25. (b) $K = \frac{[C_2H_6]}{[C_2H_4]\,[H_2]} = \frac{[mole\ /\ litre]}{[mole\ /\ litre]\,[mole\ /\ litre]}$

= *litre/mole*. or litre mole^{-1}.

27. (c) $K_c = \frac{[PCl_3]\,[Cl_2]}{[PCl_5]} = \frac{\frac{0.2}{10} \times \frac{0.2}{10}}{[0.1/10]} = 0.04$.

28. (b) $K_c = \frac{[HI]^2}{[H_2]\,[I_2]}$; $64 = \frac{x^2}{0.03 \times 0.03}$

$x^2 = 64 \times 9 \times 10^{-4}$

$x = 8 \times 3 \times 10^{-2} = 0.24$

x is the amount of HI at equilibrium amount of I_2 at equilibrium will be

$0.30 - 0.24 = 0.06$

29. (c) $K_c = \frac{K_f}{K_b}$

$K_f = K_c \times K_b = 1.5 \times 7.5 \times 10^{-4} = 1.125 \times 10^{-3}$

30. (a) $N_2 + 3H_2 \rightleftharpoons 2NH_3$

Initial conc. 1 3 0

at equilibrium 1-0.81 3-2.43 1.62

0.19 0.57

No. of moles of $N_2 = \frac{28}{28} = 1$ *mole*

No. of moles of $H_2 = \frac{6}{2} = 3$ *mole*

No. of moles of $NH_3 = \frac{27.54}{17} = 1.62$ *mole*

$$K_c = \frac{[NH_3]^2}{[N_2]\,[H_2]^3} = \frac{[1.62]^2}{[0.19]\,[0.57]^3} = 75$$

31. (b) $K_c = \frac{[YX_2]}{[X]^2[Y]} = \frac{2}{4 \times 4 \times 2} = \frac{1}{16} = 0.0625$.

32. (d) $NH_4HS \rightleftharpoons NH_{3(g)} + H_2S_{(g)}$

a 0.5atm

a − x 0.5+x x

Total pressure $= 0.5 + 2x = 0.84$

i.e., $x = 0.17$

$K_p = P_{NH_3}.P_{H_2S} = (0.67).(0.17) = 0.1139$

33. (c) $A + 2B \rightleftharpoons 2C$

Initial conc. 2 3 2

at eqm. 2.5 4 1

Molar $\frac{2.5}{2} = 1.25$ $\frac{4}{2} = 2$ $\frac{1}{2} = 0.5$

$$K = \frac{[0.5]^2}{[1.25] \times [2]^2} = 0.05$$

34. (b) $CO + Cl_2 \rightleftharpoons COCl_2$

$[CO] = \frac{0.1}{0.5}$, $[Cl_2] = \frac{0.1}{0.5}$, $[COCl_2] = \frac{0.2}{0.5}$

$$= \frac{[COCl_2]}{[CO]\,[Cl_2]} = 0\,\frac{\frac{0.2}{0.5}}{\frac{0.1}{0.5} \times \frac{0.1}{0.5}} = \frac{2}{5} \times 25 = 10$$

35. (a) $A + B \rightleftharpoons C + D$

at equilibrium a a $2a$ $2a$

$$K = \frac{2a \times 2a}{a \times a} = 4$$

36. (a) $H_2 + I_2 \rightleftharpoons 2HI$

Initial conc. 4.5 4.5 0

x x $2x$

from question $2x = 3$

$$x = \frac{3}{2} = 1.5$$

So conc. at eqm. $4.5 - 1.5$ of H_2

$= 4.5 - 1.5$ of I_2 and 3 of HI

$$K = \frac{[HI]^2}{[I_2]\,[H_2]} = \frac{3 \times 3}{3 \times 3} = 1.$$

37. (c) $K = \frac{[H_2]^2[S_2]}{[H_2S]^2} = \frac{[0.10]^2[0.4]}{[0.5]^2} = 0.016$

38. (a) $K_p = \frac{[P_{CO}]^2[P_{O_2}]}{[P_{CO_2}]^2} = \frac{[0.4]^2 \times [0.2]}{[0.6]^2} = 0.0888$.

39. (d) $K_f = 1.1 \times 10^{-2}$; $K_b = 1.5 \times 10^{-3}$

$$K_c = \frac{K_f}{K_b} = \frac{1.1 \times 10^{-2}}{1.5 \times 10^{-3}} = 7.33.$$

40. (a) $\underset{\substack{100\\50}}{2HI} \rightleftharpoons \underset{\substack{0\\25}}{H_2} + \underset{\substack{0\\25}}{I_2}$

$$\frac{[H_2]\,[I_2]}{[HI]^2} = \frac{25 \times 25}{50 \times 50} = 0.25\ .$$

41. (d) $\underset{(3-0.75)}{A} + \underset{(1-0.75)}{B} \rightarrow \underset{1.5}{2C}$

$$K = \frac{[C]^2}{[A]\,[B]} = \frac{(1.5)^2}{2.25 \times 0.25} = \frac{2.25}{2.25 \times 0.25} = 4.0\ .$$

42. (d) $6HCHO \underset{}{\overset{K_2}{\rightleftharpoons}} C_6H_{12}O_6$ forward reaction

$C_6H_{12}O_6 \overset{K_1}{\rightleftharpoons} 6HCHO$ backward reaction

$$K_2 = \left[\frac{1}{K_1}\right]^{1/6} ;\ K_2 = \left[\frac{1}{6 \times 10^{22}}\right]^{1/6}$$

$K_2 = 1.6 \times 10^{-4}\ M$

43. (b) $K_c = \dfrac{[HI]^2}{[H_2]\,[I_2]} = \dfrac{[0.7]^2}{[0.1]\,[0.1]} = 49$

44. (c) $K_c = \dfrac{[NH_3]^2}{[N_2]\,[H_2]^3}$

$$2.37 \times 10^{-3} = \frac{x^2}{[2]\,[3]^3} = x^2 = 0.12798$$

$x = 0.358\ M.$

45. (d) $A + B \rightleftharpoons 2C$

$$K_c = \frac{[C]^2}{[A]\,[B]} = \frac{[0.6]^2}{[0.2]\,[0.2]} = 9$$

46. (a) $H_2 \quad + \quad I_2 \quad \rightleftharpoons \quad 2HI$

15 5.2 0

(15-5) (5.2-5) 10

$$K_C = \frac{[HI]^2}{[H_2][I_2]} = \frac{10 \times 10}{10 \times 0.2} = 50$$

47. (c) Rate of backward reaction = Rate of forward reaction

48. (b) $K_c = \dfrac{[HI]^2}{[H_2]\,[I_2]} = \dfrac{(28)^2}{8 \times 3} = 32.66$

49. (a) $N_{2(g)} + O_{2(g)} \rightleftharpoons 2NO_{(g)}$; $\quad \Delta n = 2 - 2 = 0$

50. (b) The rate of forward reaction is two times that of reverse reaction at a given temperature and identical concentration $K_{\text{equilibrium}}$ is 2 because the reaction is reversible. So $K = \dfrac{K_1}{K_2} = \dfrac{2}{1} = 2$.

52. (b) $K_c = \dfrac{K_f}{K_b}\ \therefore K_b = \dfrac{K_f}{K_c} = \dfrac{10^5}{100} = 10^3$

53. (c) $K_c = \dfrac{[NO_2]^2}{[N_2O_4]} = \dfrac{4 \times (0.05)^2}{0.05} = 4 \times 0.05 = 0.2$

54. (d) $\underset{\substack{\text{initial}\\ \text{at.equil.}}}{} \underset{\substack{2\\1}}{2NH_3} \rightleftharpoons \underset{\substack{0\\1}}{N_2} + \underset{\substack{0\\3}}{3H_2}$; $K \dfrac{[N_2][H_2]^3}{[NH_3]^2} = \dfrac{1 \times 3^3}{1} = 27$

56. (c) $K_c = \dfrac{[PCl_3]\,[Cl_2]}{[PCl_5]} = \dfrac{0.2 \times x}{0.4} = 0.5$, $x = 1$

57. (c) $N_2 + 3H_2 \rightleftharpoons 2NH_3$

30 30 0

30-x 30-3x 2x

2x = 10 ; $x = \dfrac{10}{2} = 5$

$N_2 = 30 - 5 = 25$ *litre*

$H_2 = 30 - 3 \times 5 = 15$ *litre*

$NH_3 = 2 \times 5 = 10$ *litre*

58. (c)

$$K = \frac{[NO_2]^2}{[N_2O_4]} = \frac{[1.2 \times 10^{-2}]^2}{[4.8 \times 10^{-2}]} = 0.3 \times 10^{-2} = 3 \times 10^{-3}$$

59. (a) $\dfrac{22}{100} \times 3.2 = 0.704$

$\therefore$ at equil. moles of HI =3.2–0.704 = 2.496

60. (c) $N_2 + 3H_2 \rightleftharpoons 2NH_3$ ..... (i)

at $t = 0$ $56\ gm$ $8\ gm$ $0\ gm$

= $2\,mole$ $4\,mole$ $0\,mole$

at equilibrium $2 - 1$ $4 - 3$ $34\ gm$

$= 1\,mole$ = $1\,mole$ = $2\,mole$

According to eq. (i) 2 mole of ammonia are present & to produce 2 mole of NH_3, we need 1 mole of N_2 and 3 mole of H_2 hence $2 - 1 = 1$ mole of N_2 and $4 - 3 = 1$ mole of H_2 are present at equilibrium in vessel.

61. (d) $2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$

For $1dm^3$ $R = k[SO_2]^2[O_2]$

$$R = K\left[\frac{1}{T}\right]^2\left[\frac{1}{1}\right] = 1$$

For $2dm^3$ $R = K\left[\dfrac{1}{2}\right]^2\left[\dfrac{1}{2}\right] = \dfrac{1}{8}$

So, the ratio is 8 : 1

62. (d) $K = \dfrac{[C][D]}{[A][B]} = \dfrac{\frac{1}{3} \times \frac{1}{3}}{\frac{2}{3} \times \frac{2}{3}} = \dfrac{1}{4} = 0.25$

So, $K = 0.25$

63. (b) Given, $CaCO_3(s) \xrightarrow{\Delta} CaO(s) + CO_2(g)\uparrow$

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

$$Kp_2 = \frac{[pCO]^2}{[pCO_2]}\ ;\quad pCO = \sqrt{[Kp_1 \times Kp_2]}$$

$$pCO = \sqrt{[8 \times 10^{-2} \times 2]} = \sqrt{16 \times 10^{-2}} = 4 \times 10^{-1} = 0.4$$

64. (b) $N_2(g) + O_2(g) \rightleftharpoons 2NO(g)$

$$Kc = \frac{[NO]^2}{[N_2][O_2]} = 4 \times 10^{-4}$$

⇌

$$NO_2 \rightleftharpoons \frac{1}{2}N_2(g)+\frac{1}{2}O_2(g)$$

$$K_c' = \frac{[N_2]^{1/2}[O_2]^{1/2}}{[NO]} = \frac{1}{\sqrt{Kc}} = \frac{1}{\sqrt{4\times10^{-4}}}$$

$$= \frac{1}{2\times10^{-2}} = \frac{100}{2} = 50$$

65. (d) $P_4(s)+5O_2(g) \rightleftharpoons P_4O_{10}(s)$

$$K_c = \frac{[P_4O_{10}(s)]}{[P_4(s)][O_2(g)]^5}$$

We know that concentration of a solid component is always taken as unity $K_c = \frac{1}{[O_2]^5}$

66. (d)

$$\begin{array}{ccccc} H_2 & + & I_2 & \rightleftharpoons & 2HI \\ 0.4 & & 0.4 & & 0.50 \\ 0.4-0.25 = 0.15 & & 0.4-0.25 = 0.15/2 & & 0.50/2 \end{array}$$

$$K_c = \frac{[HI]^2}{[H_2][I_2]} = \frac{\left[\frac{0.5}{2}\right]^2}{\left[\frac{0.15}{2}\right]\left[\frac{0.15}{2}\right]} = \frac{0.5\times0.5}{0.15\times0.15} = 11.11$$

67. (d) $NH_2COONH_4 \rightleftharpoons 2NH_3+CO_2$

$\alpha = \frac{D-d}{(n-1)d}$ where D is the density (initial)

$$D = \frac{mol.wt}{2} = \frac{78}{2} = 39$$

$n =$ no. of product = 3 $d =$ final density

$\alpha = \frac{39-13}{(3-1)13} = 1$, so $\alpha = 1$

68. (a) $\underset{(a-x)}{\overset{a}{N_2}} + \underset{(b-3x)}{\overset{b}{3H_2}} \rightleftharpoons \underset{(2x)}{\overset{0}{2NH_3}}$

50% Dissociation of N_2 take place so,

At equilibrium $\frac{2\times50}{100} = 1$; value of $x = 1$

$K_c = \frac{[2]^2}{[1][3]^3} = \frac{4}{27}$ so, $K_c = \frac{4}{27}$

69. (c) The equilibrium constant does not change when concentration of reactant is changed as the concentration of product also get changed accordingly.

70. (d) We know that $PV = nRT$

P become $\frac{1}{2}P$ & V bcome $2V$ so,

$$\frac{1}{2}P\times2V = PV = nRT$$

So there is no effect in equation.

71. (abcd)All options are true for that equilibrium.

72. (a)

	$H_{2(g)}$	$+CO_{2(g)}$	$\rightleftharpoons CO_{(g)}$	$+H_2O_{(l)}$
Initial conc.	1	1	0	0
At equili	$(1-x)$	$(1-x)$	x	x

$$K_p = \frac{p_{CO}\cdot p_{H_2O}}{p_{H_2}\cdot p_{CO_2}} = \frac{x.x}{(1-x)(1-x)} = \frac{x^2}{(1-x)^2}$$

K_p & K_c Relationship and Characteristics of K

1. (a) $n_p = n_r$ then $K_p = K_c$

where n_p = no. of moles of product

n_r = no. of moles of reactant.

2. (d) $K_1 = \frac{[NO_2]}{[NO][O_2]^{1/2}}$; $K_2 = \frac{[NO]^2[O_2]}{[NO_2]^2}$

$$\Rightarrow \frac{[NO_2]^2}{[NO]^2[O_2]} = \frac{1}{K_2} \Rightarrow \frac{[NO_2]}{[NO][O_2]^{1/2}} = \frac{1}{\sqrt{K_2}}$$

$$\Rightarrow K_1 = \frac{1}{\sqrt{K_2}};\ K_2 = \frac{1}{K_1^2}.$$

3. (a) $K_p = K_c(RT)^{\Delta n} = 26\,(0.0821\times523)^{-1} = 0.61$.

$\Delta n_g = 1-2 = -1$

5. (d) In presence of little H_2SO_4 (as catalyst) about 2/3 mole of each of CH_3COOH and C_2H_5OH react to form 2/3 mole of the product at equilibrium.

6. (d) K_1 for reaction $2HI \rightleftharpoons H_2+I_2$ is 0.25 K_2 for reaction $H_2+I_2 \rightleftharpoons$ $2HI$ will be

$$K_2 = \frac{1}{K_1} = \frac{1}{0.25} = 4$$

Because IInd reaction is reverse of Ist.

9. (a) For the reaction,

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

$K_p = P_{CO_2}$ and $K_C = [CO_2]$

($\because$ $[CaCO_3] = 1$ and $[CaO] = 1$ for solids]

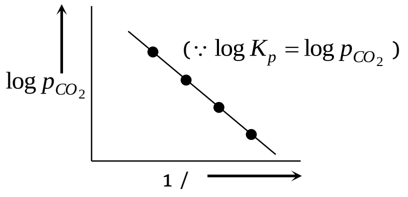
According to Arrhenius equation we have

$K = Ae^{-\Delta H^\circ_r/RT}$

Taking logarithm, we have

$$\log K_p = \log A - \frac{\Delta H_r^o}{RT(2.303)}$$

This is an equation of straight line. When log K_p is plotted against 1 / T. we get a straight line.



The intercept of this line = log A, slope = $-\Delta H^\circ_r$ / 2.303 R

Knowing the value of slope from the plot and universal gas constant R, ΔH_r^o can be calculated.

(Equation of straight line : $Y = mx + C$. Here,

$$\underset{Y}{\log K_p} = \underset{m}{-\frac{\Delta H_r^o}{2.303 R}}\underset{x}{\left(\frac{1}{T}\right)} + \underset{C}{\log A}$$

10. (b) $K_p = K_c(RT)^{\Delta n}$; When $\Delta n = 2-(2+1) = -1$, *i.e.* negative, $K_p < K_c$.

11. (c) $K_1 = \frac{[SO_3]}{[SO_2]\,[O_2]^{1/2}}$ and $K_2 = \frac{[SO_2]^2[O_2]}{[SO_3]^2}$; $K_2 = \frac{1}{K_1^2}$.

13. (c) Reaction is reversed. Hence

$$K = \frac{1}{(2.4\times 10^{-3})} = 4.2\times 10^2$$

14. (c) $K_p = \frac{[P_{co}]^2}{[P_{CO_2}]} = \frac{4\times 4}{2} = 8$.

15. (d) K_{c_1} for $H_2 + I_2 \rightleftharpoons 2HI$ is 50

K_{c_2} for $2HI \rightleftharpoons H_2 + I_2$

$$K_{c_2} = \frac{1}{K_{c_1}} = \frac{1}{50} = 0.02$$

16. (c) $K_p = K_c(RT)^{\Delta n}$

$\Delta n = -1$ for reaction $2SO_2 + O_2 \rightleftharpoons 2SO_3$

So for this reaction K_p is less than K_c.

17. (c) $K_p = K_c(RT)^{\Delta n}$; $\Delta n = 2-2 = 0$

18. (c) For the reaction $H_2 + I_2 \rightleftharpoons 2HI$

$\Delta n = 0$

So $K_p = K_c$ $\therefore$ 50.0

19. (d) For reaction $2SO_3 \rightleftharpoons O_2 + 2SO_2$

Δn is + *ve* so K_p is more than K_c.

By $K_p = K_c(RT)^{\Delta n}$

20. (c) Δn =2-1=1

$K_p = K_c(RT)$

21. (c) For this reaction there is no change in equilibrium constant by change of volume.

22. (c) If Δn =0 then $K_p = K_c$

23. (a) $k_p = k_c(RT)^{\Delta n}$

$\Delta n = 3-2 = 1$; $k_p > k_c$.

24. (d) Equilibrium constant depends upon temperature.

25. (d) $2NOCl_{(g)} = 2NO_{(g)} + Cl_{2(g)}$

$K_p = K_C\,(RT)^{\Delta n}$

$K_p = 3\times 10^{-6}\,(0.0821\times 700) = 172.41\times 10^{-6}$

$= 1.72\times 10^{-4}$

27. (b) $K' = K^n$; Hence $n = \frac{1}{2}$

$\therefore K' = K^{1/2} = \sqrt{K}$

29. (c) $2NO_2 \rightleftharpoons 2NO + O_2$ ......(i)

$K = 1.6\times 10^{-12}$

$NO + \frac{1}{2}O_2 \rightleftharpoons NO_2$ ......(ii)

Reaction (ii) is half of reaction (i)

$K = \frac{[NO]^2[O_2]}{[NO_2]^2}$ ......(i)

$K' = \frac{[NO_2]}{[NO]\,[O_2]^{1/2}}$ ......(ii)

On multiplying (i) and (ii)

$$K\times K' = \frac{[NO]^2[O_2]}{[NO_2]^2}\times\frac{[NO_2]}{[NO]\,[O_2]^{1/2}} = \frac{[NO]\,[O_2]^{1/2}}{[NO_2]} = \frac{1}{K'}$$

$$K\times K' = \frac{1}{K'};\quad K = \frac{1}{K'^2};\quad K' = \frac{1}{\sqrt{K}}.$$

30. (b) $K_p = K_c(RT)^{\Delta n}$; $\Delta n = 1$

So K_c will be less than K_p.

32. (d) K_1 for $N_2 + 3H_2 \rightleftharpoons 2NH_3$

K_2 for $NH_3 \rightleftharpoons \frac{1}{2}N_2 + \frac{3}{2}H_2$

$$K_1\times K_2 = \frac{[NH_3]^2}{[N_2]\,[H_2]^3}\times\frac{[N_2]^{1/2}[H_2]^{3/2}}{[NH_3]}$$

$$K_1\times K_2 = \frac{1}{K_2};\quad K_2 = \frac{1}{\sqrt{K_1}}$$

34. (a) $K_p = K_c(RT)^{\Delta n}$; $\Delta n = 2-4 = -2$

$K_p = 6\times 10^{-2}\times(0.0812\times 773)^{-2}$

$$K_p = \frac{6\times 10^{-2}}{(0.0812\times 773)^2} = 1.5\times 10^{-5}.$$

35. (b) $2.303\log\frac{K_2}{K_1} = \frac{\Delta H}{R}\,\frac{[T_2 - T_1]}{T_1\times T_2}$

ΔH =+ve for the reaction

36. (d) $N_2 + \underset{4}{3H_2} \rightleftharpoons \underset{2}{2NH_3}$

Δn = 2 – 4 = – 2

$K_p = K_c[RT]^{\Delta n}$; $K_p = K_c[RT]^{-2}$

$$K_c = \frac{K_p}{[RT]^{-2}} = \frac{1.44\times 10^{-5}}{[0.082\times 773]^{-2}}$$

37. (d) Catalyst does not affect equilibrium constant.

38. (d) K for dissociation of HI =?

$H_2 + I_2 \rightleftharpoons 2HI$

$K_a = 50$, $K_b = \frac{1}{50} = 0.02$

39. (b) $2\underset{3}{SO_2} + O_2 \rightleftharpoons 2\underset{2}{SO_3}$ for this reaction

$\Delta n = -1$; $\therefore K_c > K_p$

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

$K_p = P_{CO_2}$

Solid molecule does not have partial pressure so in calculation of K_p only P_{CO_2} is applicable.

41. (d) $NH_3 \rightleftharpoons \frac{1}{2}N_2 + \frac{3}{2}H_2$

$K_c = \frac{[N_2]^{1/2}[H_2]^{3/2}}{NH_3}$ and $\frac{1}{2}N_2 + \frac{3}{2}H_2 \rightleftharpoons NH_3$

$K_c = \frac{[NH_3]}{[N_2]^{1/2}[H_2]^{3/2}}$

So for dissociation $= \frac{1}{K_c}$

42. (b) Given $x = \frac{22}{100}$ and $a = 3.2$

$\therefore [HI]$ at equilibrium $= 3.2\left[1 - \frac{22}{100}\right] = 2.496$

43. (b) K_c does not depend upon initial concentration of reactants or product.

44. (d) K_p and K_c are characteristic for a given reaction if $\Delta n = 0$ then there is no change.

45. (c) $K_{c_1} = \frac{[NO]^2[O_2]}{[NO_2]^2} = 1.8 \times 10^{-6} \Rightarrow K_{c_2} = \frac{[NO_2]}{[NO]\,[O_2]^{1/2}}$

$K_{c_1} = \frac{1}{K_{c_2}^2}$; $1.8 \times 10^{-6} = \frac{1}{K_{c_2}^{\;2}} \Rightarrow K_{c_2} = 7.5 \times 10^2$

46. (c) $K_1 = \frac{[H_2S]}{[H_2]\,[S_2]^{1/2}}$; $K_2 = \frac{[HBr]^2}{[H_2]\,[Br_2]}$

$K_3 = \frac{[HBr]^2 \times [S_2]^{1/2}}{[Br_2] \times [H_2S]}$; $\frac{K_2}{K_1} = K_3$

47. (b) $K_p = \frac{p^2}{4}; 0.11 = \frac{p^2}{4} \Rightarrow p^2 = 0.44$

or $p = \sqrt{0.44} = 0.66444 \approx 0.665\ atm$

50. (a) $C_{12}H_{22}O_{11(s)} + 12O_{2(g)} \rightarrow 12CO_{2(g)} + 11H_2O$

$\Delta n = 12 - 12 = 0$

51. (a) In this reaction gaseous molecule count

$MgCO_3 \rightarrow MgO_{(s)} + CO_{2(g)}$

$K_p = P_{CO_2}$

53. (a) $K_p = K_c[RT]^{\Delta n}; \Delta n = -1, K_c = 26$

$R = 0.0812, T = 250 + 273 = 523K$

$K_p = 26[0.0812 \times 523]^{-1} = 0.605 \approx 0.61$

55. (a) $2AB \rightleftharpoons A_2 + B_2$

$K_c = \frac{[A_2][B_2]}{[AB]^2}$

For reaction $AB \rightleftharpoons \frac{1}{2}A_2 + \frac{1}{2}B_2$

$K_c^{'} = \frac{[A_2]^{1/2}[B_2]^{1/2}}{[AB]}$; $K_c^{'} = \sqrt{K_c} = \sqrt{49} = 7$.

56. (a) For this reaction Δn is negative & ΔH is positive so it take forward by decrease in temperature.

57. (b) Chemical equilibrium of reversible reaction is not influenced by catalyst. It is affected by pressure, temperature & concentration of reactant.

58. (c) ΔH is positive so it will shift toward the product by increase in temperature.

59. (c) $CO(g) + Cl_2(g) \rightleftharpoons COCl_2(g)$

$\Delta n = 1 - 2 = -1$

$K_p = K_c[RT]^{\Delta n}$; $\therefore \frac{K_p}{K_c} = [RT]^{-1} = \frac{1}{RT}$

60. (c) ΔH is positive so reaction move forward by increase in temperature & value of $\Delta n = 3 - 2 = +1$ is positive so it forward with decrease in pressure.

61. (b) $2A(g) \qquad 3C(g) + D(s)$

For this reaction, $\Delta n_g = 3 - 2 = 1$

$\therefore K_p = K_c[RT]^1$ or $\frac{K_p}{K_c} = RT$ or $K_c = \frac{K_p}{RT}$

62. (a) According to Le-Chatelier principle exothermic reaction is forwarded by low temperature, in forward direction number of moles is less, hence pressure is high.

63. (d) In this reaction ΔH is negative so reaction move forward by decrease in temperature while value of $\Delta n = 2 - 3 = -1$ *i.e.*, negative so the reaction move forward by increase in pressure.

64. (a) $PCl_5(g) \rightleftharpoons PCl_3(g) + Cl_2(g)$

For this reaction $\Delta n = 2 - 1 = 1$

Value of Δn is positive so the dissociation of PCl_5 take forward by decrease in pressure & by increase in pressure the dissociation of PCl_5 decrease.

65. (b) $N_2 + O_2 \rightleftharpoons 2NO$ .....(i)

$\frac{1}{2}N_2 + \frac{1}{2}O_2 \rightleftharpoons NO$ ......(ii)

For equation number (i)

$K_1 = \frac{[NO]^2}{[N_2][O_2]}$ ..... (iii)

For equation number (ii)

$$K_2 = \frac{[NO]}{[N_2]^{1/2}[O_2]^{1/2}} \qquad \text{...... (iv)}$$

From equation (iii) & (iv) it is clear that

$K_2 = (K_1)^{1/2} = \sqrt{K_1}$; Hence, $K_2 = \sqrt{K_1}$

66. (b) $K_p = K_c[RT]^{\Delta n_g}$

$\Delta n_g = 1 - 1.5 = -0.5$

$K_p = K_c[RT]^{-1/2} \quad \therefore \frac{K_p}{K_c} = [RT]^{-1/2}$

67. (b) $N_{2(g)} + O_{2(g)} \rightleftharpoons 2NO_{(g)}$

$K_c = 0.1, K_p = K_c(RT)^{\Delta n}$

$\Delta n = 0, K_p = K_c = 0.1$

68. (c)

$$\begin{array}{ccccc} A & + & 3B & \rightleftharpoons & 4C \\ a & & b & & 0 \\ (a-x) & & (b-3x) & & 4x \end{array}$$

$$K_C = \frac{[C]^4}{[A][B]^3} = \frac{4x.4x.4x.4x}{(a-x)(b-3x)}$$

Given $a = b, a - x = 4x \Rightarrow a = 5x = b$

$$K_C = \frac{4x.4x.4x.4x}{(5x-x)(5x-3x)} = \frac{4x.4x.4x.4x}{4x.2x.2x.2x} = 8 .$$

69. (b) Equilibrium pressure = 3atm

$NH_4COONH_{2(s)} \rightleftharpoons 2NH_{3(g)} + CO_{2(g)}$

$K_p = p^2_{NH_3}.p_{CO_2} = 3^2.3 = 27$

Activation energy, Standard free energy and Degree of dissociation and Vapour density

1. (b) $\frac{\text{Normal molecular weight}}{\text{experiment al molecular wt.}} = 1 + \alpha$

$NH_4Cl \rightleftharpoons NH_3 + HCl$

$\because \alpha = 1 \; \therefore$ Experimental Molecular wt $= \frac{\text{nor.mol.wt.}}{2}$

2. (b) If $\Delta G^o = 0$

$\Delta G^o = -2.303 \; RT \; \log K_p$

$\log K_p = 0 \qquad (\because \log 1 = 0)$

$K_p = 1$.

5. (d) $\Delta G^o = -2.303 \times 8.314 \times 10^{-3} \times 298 \; \log K_p$

$1.7 = -2.303 \times 8.314 \times 10^{-3} \times 298 \times \log K_p$

$K_p = 0.5$

6. (a) Equilibrium shifts backward by Le-chatelier's principle.

7. (c) Decreases the activation energy of both forward and backward reaction.

8. (d) Equilibrium constant changes with temperature, pressure and the concentration of either reactant or product.

9. (a) As we know that, $\Delta G^o = -2.303 RT \log K_p$

Therefore, $\Delta G^o = -2.303 \times (8.314) \times (298)$

$(\log 2.47 \times 10^{-29})$

$\Delta G^o = 16{,}3000 \; J \, mol^{-1} = 163 \; KJ \, mol^{-1}$

Le-Chaterlier principle and It's application

2. (a) $N_2 + O_2 \rightleftharpoons 2NO$; Q cal

The above reaction is endothermic so for higher production of NO, and the temperature should be high.

4. (c) At low pressure, reaction proceeds where volume is increasing. This is the favourable condition for the reaction. $PCl_5 \rightleftharpoons PCl_3 + Cl_2$.

6. (c) Reaction is exothermic and volume is decreasing from left to right so for higher production of SO_3 there should be low temperature and high pressure.

7. (a) $\underset{\text{more volume}}{\text{Ice}} \rightleftharpoons \underset{\text{less volume}}{\text{Water}}$

On increasing pressure, equilibrium shifts forward.

8. (c) Exothermic reaction is favoured by low temperature to proceed in forward direction.

9. (a) Effect of catalyst is that it attains equilibrium quickly by providing a new reaction path of low activation energy. It does not alter the state of equilibrium.

11. (a) On increasing temperature equilibrium will shift in forward direction due to decrease in intermolecular forces of solid.

12. (c) Both Δn and ΔH are negative. Hence, high pressure and low temperature will forward reaction.

13. (b) Exothermic reaction, favoured by low temperature.

14. (c) $\Delta n = 0$, No effect of pressure.

15. (b) The reaction is endothermic in reverse direction and hence increase in temperature will favour reverse reaction.

16. (c) A reaction is in equilibrium it will shift in reverse or backward direction when we increase the concentration of one or more product (from Le chatelier's principle).

17. (a) According to Le chatelier's principle.

18. (c) The reaction takes place with a reduction in number of moles (volume) and is exothermic. So high pressure and low temperature with favour the reaction in forward direction

19. (b) At equilibrium, the addition of $(CN)^-$ would decrease the (H^+) ion concentration to produce more and more HCN to nullified the increase of $CN^-{}_{aq}$.

20. (b) $H_2X_2 + \text{heat} \rightleftharpoons 2HX$.

Reaction is endothermic and volume increasing in forward direction so according to Le chatelier's principle for formation of HX, Temperature of the reaction should be high and pressure should be low.

21. (b) According to Le chatelier's principle.

22. (d) In reaction $CO + 3H_2 \rightleftharpoons CH_4 + H_2O$

Volume is decreasing in forward direction so on increasing pressure the yield of product will increase.

25. (a) In endothermic reaction rate of forward reaction can be increased by raising temperature.

26. (a) Being endothermic, the forward reaction is favoured by high temperature.

27. (c) According to Le chatelier's principle.

28. (b) On adding more PCl_5, equilibrium shifts forward.

29. (a) According to Le chatelier's principle.

30. (b) Increase in pressure causes the equilibrium to shift in that direction in which no. of moles (volume) is less.

32. (b,c) According to Le-chatelier's principle.

37. (d) By increasing the amount of F_2 in the reaction the amount of ClF_3 increases.

39. (b) According to Le chatelier's principle when we increase pressure reaction proceeds in that direction where volume is decreasing.

40. (a) Factors affecting equilibrium are pressure, temperature and concentration of product or reactant.

42. (b) According to Le chatelier's principle.

43. (d) Increase in volume, *i.e.*, decrease in pressure shifts the equilibrium in the direction in which number of moles increases (Δn positive)

46. (d) At constant volume. Three is no change in concentration (closed container).

47. (c) $H_2O(g) \rightleftharpoons H_{2(g)} + \frac{1}{2}O_{2(g)}$

In this reaction volume is increasing in the forward reaction. So on increasing temperature reaction will proceed in forward direction.

48. (b) When temperature increases precipitation of sodium sulphate takes place. Because reaction is exothermic so reverse reaction will take place.

49. (a) For high yield of ammonia low temperature, high pressure and high concentration of the reactant molecule.

53. (c) Since $\Delta n = 0$.

54. (a) The rate of backward reaction favoured by increase of pressure in the reaction as Δn is positive

$PCl_5 \rightleftharpoons PCl_3 + Cl_2$

55. (a) $H_{2(g)} \underset{2}{+} I_{2(g)} \rightleftharpoons 2\underset{2}{H}I$

$\Delta n = 0\ ;\ \because\ K_c = K_p$

56. (c) Solid + liquid $\rightleftharpoons$ Solution ΔH =+ve

Increase in temperature favours forward reaction.

57. (a) Addition of an inert gas of constant volume condition to an equilibrium has no effect.

58. (b) Le chatelier principle is not applicable to solid-solid equilibrium.

59. (a) $A + \underset{2}{B} + Q \rightleftharpoons C \underset{2}{+} D$

The reaction is endothermic so on increase temperature concentration of product will increase.

60. (a) In that type of reaction the state of equilibrium is not effected by change in volume (hence pressure) of the reaction mixture.

61. (c) $N_2 + O_2 \rightleftharpoons 2NO\ ;\ \Delta n = 0$

65. (c) High temperature and low pressure.

66. (d) High temperature and excess concentration of the reactant concentration.

68. (c) Low temperature and high pressure.

69. (a) $H_2 + I_2 \rightleftharpoons 2HI \Rightarrow \Delta n = 2 - 2 = 0$.

70. (d) Low temperature and low pressure.

73. (c) It is an exothermic reaction hence low temperature and increasing pressure will favour forward reaction

Critical Thinking Questions

1. (b) $K_c = \frac{[PCl_3][Cl_2]}{[PCl_5]} = \frac{\left[\frac{20}{100}\right]\times\left[\frac{20}{100}\right]}{\left[\frac{80}{100}\right]}$

$= \frac{0.2\times 0.2}{0.8} = \frac{0.04}{0.8} = 0.05$

2. (b) $2NH_3 \rightleftharpoons N_2 + 3H_2$

Initial mole a 0 0

Mole at equilibrium $(a-2x)$ x $3x$

Initial pressure of NH_3 of a mole = 15 atm at 27^oC

The pressure of 'a' mole of $NH_3 = p$ atm at 347^oC

$\therefore \frac{15}{300} = \frac{p}{620}$

$\therefore p = 31$ atm

At constant volume and at 347^oC, mole $\propto$ pressure

$a \propto 31$ (before equilibrium)

$\therefore a + 2x \propto 50$ (after equilibrium)

$\therefore \frac{a+2x}{a} = \frac{50}{31}$

$\therefore x = \frac{19}{62}a$

$\therefore$ % of NH_3 decomposed $= \frac{2x}{a}\times 100$

$= \frac{2\times 19a}{62\times a}\times 100 = 61.33\%$

3. (d) $K_p = K_c(RT)^{\Delta n}$ R = Gas constant

$K_c = \frac{K_p}{(RT)^{\Delta n}} = \frac{1.3\times 10^{-3}}{(0.0821\times 700)^{-1}} = 7.4\times 10^{-2}$

4. (b) Reaction is reversed and halved.

$K = \sqrt{1/1.8\times 10^{-6}} = 7.5\times 10^{2}$

5. (d) Conc. is not known so we can't calculate.

6. (a) $\underset{2}{2SO_3} \rightleftharpoons \underset{3}{2SO_2} + O_2$

$\Delta n = 3 - 2 = +1$; $K_p = 1.80\times 10^{-3}$

$[RT]^{\Delta n} = (8.314\times 700)^1$

$K_c = \frac{K_p}{(RT)^{\Delta n}} = \frac{1.8\times 10^{-3}}{(8.314\times 700)^1}$

$= 3.09\times 10^{-7}$ *mole-litre.*

7. (c) $\underset{0.1}{N_2O_4} \rightleftharpoons \underset{0}{2NO_2}$

(.1-α) 2α

∵ P ∝ 0.1

If V and T are constant (P∝0.1+ α)

$P = (0.1+\alpha)/0.1$

$K_p = \frac{[2\alpha]^2}{[0.1-\alpha]}\times\left[\frac{P}{0.1+\alpha}\right]$ or $K_p = \frac{40\alpha^2}{[0.1-\alpha]} = 0.14$

$\alpha = 0.017$

$NO_2 = 0.017\times 2 = 0.034$ *mole*

8. (d) $CH_3OH \rightarrow CO + 2H_2$

$\frac{[H_2]^2[CO]}{[CH_3OH]} = \frac{0.1\times 0.1\times 1}{2} = \frac{0.01}{2} = \frac{10\times 10^{-3}}{2}$

$= 5\times 10^{-3}$.

9. (d) $AB + CD \rightleftharpoons AD + CD$

mole at $t=0$ 1 1 0 0

Mole at equilibrium $\left(1-\frac{3}{4}\right)$ $\left(1-\frac{3}{4}\right)$ $\rightleftharpoons$ $\left(\frac{3}{4}\right)$ $\left(\frac{3}{4}\right)$

0.25 0.25 ⇌ 0.75 0.75

$K_c = \frac{0.75\times 0.75}{0.25\times 0.25} = \frac{0.5625}{0.0625} = 9$

10. (d) According to Le-chatelier's principle.

11. (d) K_p (equilibrium constant) is independent of pressure and concentration.

Assertion & Reason

2. (e) Assertion is false but reason is true.

$K_p \neq K_c$ for all reaction.

$K_p = K_c(RT)^{\Delta n}$

$\Delta n =$ number of moles of products – number of moles of reactants in the balanced chemical equation.

So, if for a reaction $\Delta n = 0$. Then $K_p = K_c$

3. (e) Assertion is false but reason is true.

$K_c = [H_2O]^2$, because concentration of solids is taken to be unity.

4. (a) Both assertion and reason are true and reason is the correct explanation of assertion.

$CO(H_2O)_6^{2+}$ (Pink) while $CoCl_4^{2-}$ (blue). So, on Cooling because of Le-chatelier's principle the reaction tries to over come the effect of temperature.

5. (e) Assertion is false but reason is true.

$aA + bB \rightleftharpoons cC + dD$, $Qc = \frac{[C]^c[D]^d}{[A]^a[B]^b}$

If $Q_c > K_c$, reaction will proceed in the direction of reactants.

If $Q_c < K_c$, reaction will move in direction of products.

If $Q_c = K_c$, the reaction mixture is already at equilibrium.

6. (c) Assertion is true but reason is false. This is based on common ion effect.

$NaCl \rightleftharpoons Na^+ + Cl^-$; $HCl \rightleftharpoons H^+ + Cl^-$

Concentration of Cl^- ions increases due to ionisation of HCl which increases the ionic product $[Na^+][Cl^-]$. This result in the precipitation of pure $NaCl$.

7. (b) Both assertion and reason are true and reason is not the correct explanation of assertion, solid+heat $\rightleftharpoons$ liquid, so on heating forward reactions is favoured and amount of solid will decrease.

8. (a) $aA + bB \rightleftharpoons cC + dD$

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

For $2aA + 2bB \rightleftharpoons 2cC + 2dD$

$$K_C = \frac{[C]^{2c}[D]^{2d}}{[A]^{2a}[B]^{2b}}.$$

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

$$K_C = \frac{[HI]^2}{[H_2][I_2]}$$

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

$$K_C = \frac{[H_2][I_2]}{[HI]^2} = \frac{1}{K_C}.$$

10. (c) The value of K depends on the stoichiometry of reactants and products at the point of equilibrium. For *e.g.,* if the reaction is multiplied by 2, the equilibrium constant is squared.

11. (d) Catalyst does not affect the final state of the equilibrium. It enables the system to attain equilibrium state earlier by providing an alternative path which involve lower energy of activation.

12. (e) $K_p = \frac{p^3_{H_2} \times p_{N_2}}{p_{NH_3}} = \frac{(atm)^3(atm)}{(atm)^2} = (atm)^2$

or $\Delta n = 4 - 2 = 2$.

Unit of K_p for given reaction $= (atm)^2$.

13. (c) According to Le-Chatelier's principle endothermic reaction favours increase in temperature. However exothermic reaction favours decrease in temperature.

14. (d) $K_p = K_c(RT)^{\Delta n}$; where $\Delta n = (l+m) - (x+y)$

Concentration of solids and liquids is taken to be unity.

15. (e) Increase in pressure favours melting of ice into water because at higher pressure melting point of ice is lowered.

16. (e) As assertion is exothermic, low temperature favours forward reaction. High pressure favours forward reaction as it is accompanied by decrease in the number of moles.

17. (e) There is no change in number of gas molecules. Therefore the expression for K is independent of volume. Hence K will remain same.

Chemical Equilibrium

SET Self Evaluation Test - 8

1. One mole of SO_3 was placed in a litre reaction vessel at a certain temperature. The following equilibrium was established $2SO_3 \rightleftharpoons 2SO_2 + O_2$

At equilibrium 0.6 moles of SO_2 were formed. The equilibrium constant of the reaction will be **[MP PMT 1991]**

(a) 0.36 (b) 0.45
(c) 0.54 (d) 0.675

2. For the following homogeneous gas reaction $4NH_3 + 5O_2 \rightleftharpoons 4NO + 6H_2O$, the equilibrium constant K_c has the dimension of **[CPMT 1990; MP PET/PMT 1998]**

(a) $Conc^{+10}$ (b) $Conc^{+1}$
(c) $Conc^{-1}$ (d) It is dimensionless

3. Consider the imaginary equilibrium

$$4A + 5B \rightleftharpoons 4X + 6Y$$

The equilibrium constant K_c has the unit **[RPMT 2000]**

(a) Mole^2 *litre*$^{-2}$ (b) *Litre* mole^{-1}
(c) Mole *litre*$^{-1}$ (d) *Litre*^{2} mole^{-2}

4. For the reaction $CO(g) + 2H_2(g) \rightleftharpoons CH_3OH(g)$, true condition is

(a) $K_p = K_c$ (b) $K_p > K_c$
(c) $K_p < K_c$ (d) $K_c = 0$ but $K_p \neq 0$

5. For the reaction $CO(g) + \frac{1}{2}O_2(g) \rightleftharpoons CO_2(g)$; $\frac{K_p}{K_c}$ is equivalent to **[MP PET/PMT 1998; AIEEE 2002]**

(a) 1 (b) RT
(c) $\frac{1}{\sqrt{RT}}$ (d) $(RT)^{1/2}$

6. $\underset{(g)}{2N_2O_5} \rightarrow \underset{(g)}{4NO_2} + \underset{(g)}{O_2}$ what is the ratio of the rate of decomposition of N_2O_5 to rate of formation of NO_2 **[DCE 2003]**

(a) $1:2$ (b) $2:1$
(c) $1:4$ (d) $4:1$

7. The reaction quotient (Q) for the reaction

$$N_{2(g)} + 3H_{2(g)} \rightleftharpoons 2NH_{3(g)}$$

is given by $Q = \frac{[NH_3]^2}{[N_2][H_2]^3}$. The reaction will proceed from right to left is **[CBSE PMT 2003]**

(a) $Q = 0$ (b) $Q = K_c$
(c) $Q < K_c$ (d) $Q > K_c$

Where K_c is the equilibrium constant

8. In the thermal dissociation of PCl_5, the partial pressure in the gaseous equilibrium mixture is 1.0 atmosphere when half of PCl_5 is found to dissociate. The equilibrium constant of the reaction (K_p) in atmosphere is **[JIPMER 2002]**

(a) 0.25 (b) 0.50
(c) 1.00 (d) 0.3

9. HI was heated in a closed tube at 440^oC till equilibrium is obtained. At this temperature 22% of HI was dissociated. The equilibrium constant for this dissociation will be

[MP PET 1988, 92; MNR 1987; UPSEAT 2000]

(a) 0.282 (b) 0.0796
(c) 0.0199 (d) 1.99

10. The following equilibrium exists in aqueous solution $CH_3COOH \rightleftharpoons CH_3COO^- + H^+$. If dilute HCl is added without a change in temperature, then the **[MNR 1987]**

(a) Concentration of CH_3COO^- will increase
(b) Concentration of CH_3COO^- will decrease
(c) Equilibrium constant will increase
(d) Equilibrium constant will decrease

11. Which of the following is not favourable for SO_3 formation

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g); \Delta H = -45.0\,kcal$$

[IIT 1984; MP PET 1997]

(a) High pressure
(b) High temperature
(c) Decreasing SO_3 concentration
(d) Increasing reactant concentration

12. 120 *gm* of urea are present in 5 *litre* solution, the active mass of urea is **[MP PMT 1994]**

(a) 0.2 (b) 0.06
(c) 0.4 (d) 0.08

13. For the system $2A(g) + B(g) \rightleftharpoons 3C(g)$, the expression for equilibrium constant K is **[NCERT 1973; DCE 1999]**

(a) $\frac{[2A]\times[B]}{[3C]}$ (b) $\frac{[A]^2\times[B]}{[C]^3}$
(c) $\frac{[3C]}{[2A]\times[B]}$ (d) $\frac{[C]^3}{[A]^2\times[B]}$

14. If concentration of reactants is increased by 'x', then K becomes **[AFMC 1997]**

(a) $\ln(K/x)$ (b) K/x
(c) $K + x$ (d) K

AS Answers and Solutions

(SET -8)

1. (d) $\underset{(1-0.6)}{2SO_3} \rightleftharpoons \underset{(0.6)}{2SO_2} + \underset{(0.3)}{O_2}$

$$K_c = \frac{[SO_2]^2[O_2]}{[SO_3]} = \frac{0.6 \times 0.6 \times 0.3}{0.4 \times 0.4} = 0.675 \ .$$

2. (b) K has the units of $(\text{conc.})^{\Delta n}$, where $\Delta n = 10 - 9 = +1$

3. (c) Unit of $K_c =$ (unit of concentration)$^{\Delta n}$

$= (mole\ litre^{-1})^{\Delta n}$

$\Delta n = 10 - 9 = 1$

$\therefore\ K_c = mol\ Litre^{-1}$.

4. (c) When $n_r > n_p$ then $K_p < K_c$

where n_r = no. of moles of reactant

n_p = no. of moles of product.

5. (c) For $CO + \frac{1}{2}O_2 \rightleftharpoons CO_2$

$$K_p = K_c(RT)^{1-1\frac{1}{2}} = K_c(RT)^{-\frac{1}{2}}\ ;\ \frac{K_p}{K_c} = \sqrt{\frac{1}{RT}}$$

6. (b) $2N_2O_5 \rightarrow HNO_2 + O_2$

Rate of decomposition of N_2O_5

$$= -\frac{1}{2}.\frac{K[N_2O_5]}{dt}$$

Rate of formation of $NO_2 = \frac{1}{4}.\frac{d[NO_2]}{dt}$

$\therefore$ Ratio = 2 : 1

7. (d) If $Q > K_c$ reaction will proceed right to left to decrease concentration of product.

8. (d) $PCl_5 \rightleftharpoons PCl_3 + Cl_2$

Initial conc. 1 0 0

At equilibrium 0.5 0.5 0.5

$$K_p = \frac{Px^2}{(1-x^2)} = \frac{1 \times 0.5 \times 0.5}{[1-(0.5)^2]} = \frac{0.5 \times 0.5}{0.75} = \frac{1}{3} = 0.3$$

9. (c) $2HI \rightleftharpoons H_2 + I_2$

Initial conc. 2 *moles* 0 0

at equilibrium $\frac{22}{100} \times 2$ 0.22 0.22

$= 2 - 0.44 = 1.56$

$$K = \frac{[H_2]\,[I_2]}{[HI]^2} = \frac{0.22 \times 0.22}{[1.56]^2} = 0.0199\ .$$

10. (b) When adding HCl in CH_3COOH solution the concentration of H^+ is increased. So reaction is proceed in reverse direction and the concentration of CH_3COO^- is decreased.

11. (b) The reaction is exothermic so high temperature will favour backward reaction.

12. (c) Active mass $= \frac{moles}{litre}$

$$= \frac{\text{wt. in } gm/\text{molecular wt.}}{V \text{ in } litre} = \frac{120/60}{5} = \frac{2}{5} = .4$$

13. (d) $K = \frac{[C]^3}{[A]^2[B]}$.

14. (d) There is no effect of change in concentration on equilibrium constant.

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