Chemical Equilibrium

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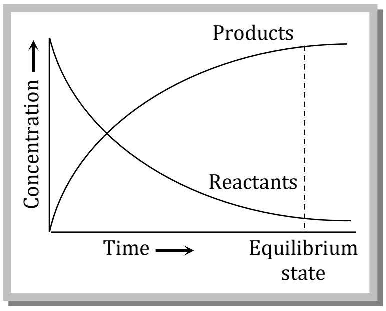
Whenever we hear the word Equilibrium immediately a picture arises in our mind an object under the influence of two opposing forces. For chemical reactions also this is true. A reaction also can exist in a state of equilibrium balancing forward and backward reactions.

8.1 Equilibrium and its dynamic nature

(1) **Definition :** *"**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."*



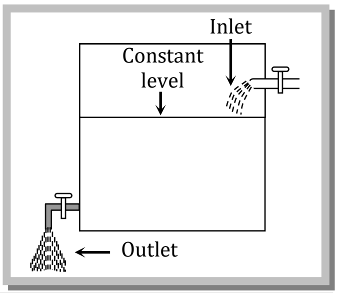
(2) **Characteristics :** Following are the important characteristics of equilibrium state,

(i) 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.

(ii) Equilibrium state can only be achieved in ***close vessel***, but if the process is carried out in an open vessel equilibrium state cannot be attained because in an open vessel, the reverse process will not take place.

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

(iv) Equilibrium state is also ***dynamic*** in nature. Dynamic means *moving* and at a microscopic level, the system is in motion. The dynamic state of equilibrium can be compared to water tank having an inlet and outlet. Water in tank can remain at the same level if the rate of flow of water from inlet (compared to rate of forward reaction) is made equal to the rate of flow of water from outlet (compared to rate of backward reaction). Thus, the water level in the tank remains constant, though both the inlet and outlet of water are working all the time.

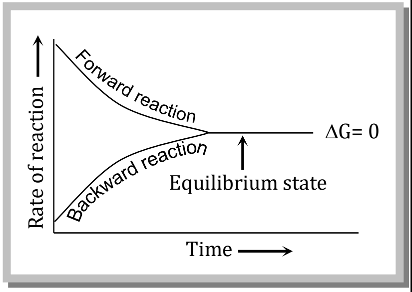


(v) At equilibrium state,

Rate of forward reaction = Rate of backward reaction

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

(3) **Types :** Equilibrium in a system implies the existence of the following types of equilibria simultaneously,



(i) ***Thermal equilibrium*** **:** There is no flow of heat from one part to another *i.e. T = constant.*

(ii) ***Mechanical equilibrium*** **:** There is no flow of matter from one part to another *i.e. P = constant.*

(iii) ***Physical equilibrium*** **:** There is the substance exist in three states: solid, liquid and gaseous.

(iv) ***Chemical equilibrium*** **:** There is no change in composition of any part of the system with time.

8.2 Physical equilibrium

The physical equilibrium is a state of equilibrium between the same chemical species in different phases (solid, liquid and gaseous). The various equilibria which can exist in any physical system are,

Solid	$\rightleftharpoons$	Liquid
Liquid	$\rightleftharpoons$	Vapour
Solid	$\rightleftharpoons$	Gas(vapour)

Solid	$\rightleftharpoons$	Saturated solution of solid in a liquid
Gas(vapour)	$\rightleftharpoons$	Saturated solution of gas in a liquid

(1) **Solid-liquid equilibrium**

Rate of transfer of molecules from ice to water = Rate of transfer of molecules from water to ice

Rate of melting of ice = Rate of freezing of water

Free energy change and solid-liquid equilibrium in water : *For ice-water system free energy change* (ΔG), at 273 *K*, and one atmosphere pressure is zero *i.e.*, $\Delta G = 0$; Ice $\rightleftharpoons$ Water; $H_2O(s) \rightleftharpoons H_2O(l)$

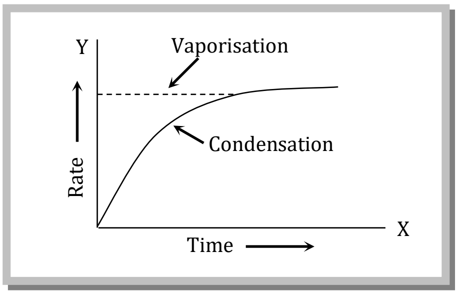
(i) At temperature higher than 273 *K*, and 1 *atm* pressure, $\Delta G < 0$. Thus, the process in the forward direction would become favourable and ice will melt to give more water.

(ii) At temperature less than 273 *K*, and 1 *atm* pressure, $\Delta G > 0$. Thus, the reverse reaction will become favourable, and more ice will be formed from liquid water.

(2) **Liquid-vapour equilibrium :** A liquid placed in an open container disappears completely. After some time vapours of the liquid held in an open container can escape out to the atmosphere. Thus, when vapour of liquid exists in equilibrium with the liquid, then

Rate of vaporisation = Rate of condensation,

$$H_2O(l) \rightleftharpoons H_2O(v)$$



Conditions necessary for a liquid-vapour equilibrium

(i) The system must be a closed system *i.e.*, the amount of matter in the system must remain constant.

(ii) The system must be at a constant temperature.

(iii) The visible properties of the system should not change with time.

(3) **Solid-vapour equilibrium :** Certain solid substances on heating get converted directly into vapour without passing through the liquid phase. This process is called ***sublimation.*** The vapour when cooled, gives back the solid, it is called ***disposition***.

Solid $\rightleftharpoons$ Vapour

The substances which undergo sublimation are camphor, iodine, ammonium chloride etc.

For *exampie*, Ammonium chloride when heated sublimes.

$$NH_4Cl(s) \underset{\text{cool}}{\overset{\text{heat}}{\rightleftharpoons}} NH_4Cl(v)$$

(4) **Equilibrium between a solid and its solution :** When a saturated solution is in contact with the solid solute, there exists a dynamic equilibrium between the solid and the solution phase.

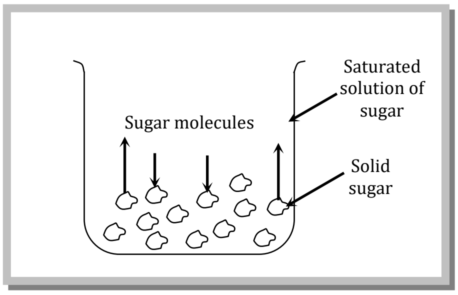
Solid substance $\rightleftharpoons$ Solution of the substance

Example : Sugar and sugar solution. In a saturated solution, a dynamic equilibrium is established between dissolved sugar and solid sugar.

Sugar (s) $\rightleftharpoons$ Sugar (aq)

At the equilibrium state, the number of sugar molecules going into the solution from the solid sugar is equal to the number of molecules precipitating out from the solution, *i.e.*, at equilibrium,

Rate of dissolution of solid sugar = Rate of precipitation of sugar from the solution.



(5) **Equilibrium between a gas and its solution in a liquid :** Gases dissolve in liquids. The solubility of a gas in any liquid depends upon the,

(i) Nature of the gas and liquid.

(ii) Temperature of the liquid.

(iii) Pressure of the gas over the surface of the solution.

Henry's law : *"At a certain temperature, the mass of a gas which dissolves in a definite volume of a liquid is proportional to the pressure of the gas in equilibrium with the solution."*

$m \propto P$ or $m = KP$; (where K is the proportionality constant)

Thus, at a constant temperature, the ratio of the molar concentration of the gas in the solution and into the atmosphere is constant.

Limitations of Henry's law

- Henry's law is applicable to ideal gases only. Henry's law should be applied only at low pressures because real gases behave like ideal gases at low pressures.
- Henry's law is not applicable to gases which react chemically with the solvent.
- Henry's law will not apply to the solution of gases like ammonia (NH_3) and hydrogen chloride (HCl) in water because these gases react chemically with water.

Note : ☐ *A chilled soda water bottle fizzes out when opened because, soda water is a solution of carbon dioxide gas, $CO_2(g)$ in water at high pressure. As soon as the bottle is opened under normal atmospheric conditions, the dissolved gas escapes out to reach a new equilibrium state, so that the pressure of the gas inside the bottle becomes equal to the atmospheric pressure. At low pressure, the solubility of the gas in water decreases.*

8.3 Chemical equilibrium

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.*

Example : (i) $C_2H_5OH\,(l) + CH_3COOH\,(l) \rightleftharpoons \underbrace{CH_3COOC_2H_5\,(l) + H_2O(l)}_{\text{liquidphase}}$

(ii) $N_2(g) + 3H_2(g) \rightleftharpoons \underbrace{2NH_3(g)}_{\text{gas phase}}$

(iii) $2SO_2(g) + O_2(g) \rightleftharpoons \underbrace{2SO_3(g)}_{\text{gas phase}}$

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

Example : (i) $CaCO_3(s) \rightleftharpoons CaO(s) + CO_2(g)$

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

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

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

Note : ☐ *The equilibrium expression for heterogeneous reactions does not include the concentrations of pure solids because their concentrations remain constant.*

8.4 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 :** Reactions in which only a part of the total amount of reactants is converted into products are termed as *reversible reactions.*

(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,

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

(e) Free energy change in a reversible reaction is zero ($\Delta G = 0$),

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

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

$$CH_3COOH + Na\,OH \rightleftharpoons CH_3COONa + H_2O$$

(b) *Salt hydrolysis, e.g.,* $Fe\,Cl_3 + 3H_2O \rightleftharpoons Fe(OH)_3 + 6HCl$

(c) *Thermal decomposition, e.g.,* $PCl_{5(g)} \rightleftharpoons PCl_{3(g)} + Cl_{2(g)} - Q$

$$CaCO_{3(s)} \rightleftharpoons CaO_{(s)} + CO_{2(g)} \ ; \ 2HI_{(g)} \rightleftharpoons H_{2(g)} + I_{2\ (g)}$$

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

(f) *Other reactions, e.g.,* $N_{2(g)} + 3H_{2(g)} \rightleftharpoons 2NH_{3(g)} + Q$; $2SO_{2(g)} + O_{2(g)} \rightleftharpoons 2SO_{3(g)} + Q$

(2) **Irreversible reactions :** Reactions in which the entire amounts of the reactants are converted into products are termed as *irreversible reactions*.

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

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

(b) These reactions can proceed to completion,

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

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

(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.*

$$BaCl_{2(aq)} + H_2SO_{4(aq)} \rightarrow BaSO_{4(s)} \downarrow + 2HCl_{(aq)};\ AgNO_{3(aq)} + NaCl_{(aq)} \rightarrow AgCl_{(g)} \downarrow + NaNO_{3(aq)}$$

(c) *Thermal decomposition, e.g.* $2KClO_{3(s)} \xrightarrow{MnO_2,\Delta} 2KCl_{(s)} + 3O_2 \uparrow$

$$2Pb(NO_3)_2 \xrightarrow{\text{heat}} 2PbO + 4NO_2 + O_2 \uparrow;\ NH_4NO_2 \xrightarrow{heat} N_2 \uparrow + 2H_2O \uparrow$$

(d) *Redox reactions, e.g.,* $SnCl_{2(aq)} + 2FeCl_{3(aq)} \rightarrow SnCl_{4(aq)} + 2FeCl_{2(aq)}$

(e) *Other reactions, e.g.,* $NaCl + H_2SO_4 \rightarrow NaHSO_4 + HCl \uparrow$

8.5 Law of mass action

On the basis of observations of many equilibrium reactions, two Norwegian chemists ***Guldberg*** 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 $[A]$.

Let us consider a simple reaction between the species A and B : $A + B \rightarrow$ Products

According to law of mass action, rate of reaction, $r \propto [A]\ [B] = k\ [A]\ [B]$

Where $[A]$ and $[B]$ are the molar concentrations of the reactants A and B respectively, k is a constant of proportionality for the forward reaction and is known as *rate constant*. The rate constant is also called *velocity constant.* Now, if the concentration of each of the reactants involved in the reaction is unity, *i.e.*, $[A] = [B] = 1$, then, rate of reaction, $r = k \times 1 \times 1$ or $r = k$

Thus, the rate constant of a reaction at a given temperature may be defined as "*the rate of the reaction when the concentration of each of the reactants is unity.*"

For a general reaction, $aA + bB + cC \rightarrow$ Products

The law of mass action may be written as : Rate of reaction, $r = k[A]^a[B]^b[C]^c$

Thus, the law of mass action may be restated as, "*The rate of a chemical reaction at any particular temperature is proportional to the product of the molar concentrations of reactants with each concentration term raised to the power equal to the number of molecules of the respective reactants taking part in the reaction.*"

The number of molecules of a reactant taking part in a reaction is also called its ***stoichiometric coefficient***. For example, a, b and c…. in the above equation are called stoichiometric coefficients of A, B and C…. respectively.

8.6 Equilibrium constant

(1) **Equilibrium constant in terms of law of mass action :** The law of mass action may be applied to a reversible reaction to derive a mathematical expression for equilibrium constant known as ***law of chemical equilibrium***.

Let us consider a simple reversible reaction, $A + B \rightleftharpoons X + Y$ in which an equilibrium exists between the reactants (A and B) and the products (X and Y). The forward reaction is,

$$A + B \rightarrow X + Y$$

According to law of mass action,

$$\textit{Rate of forward reaction} \propto [A][B] = k_f[A][B]$$

Where k_f is the rate constant for the forward reaction and $[A]$ and $[B]$ are molar concentrations of reactants A and B respectively.

Similarly, the backward reaction is ; $X + Y \rightarrow A + B$

$$\textit{Rate of backward reaction} \propto [X][Y] = k_b[X][Y]$$

Where k_b is the rate constant for the backward reaction and $[X]$ and $[Y]$ are molar concentrations of products X and Y respectively.

At equilibrium, the rates of two opposing reactions become equal. Therefore, at equilibrium,

$$\textit{Rate of forward reaction = Rate of backward reaction}$$

$$k_f[A][B] = k_b[X][Y]$$

$$\boxed{\frac{k_f}{k_b} = \frac{[X][Y]}{[A][B]} \quad \text{or} \quad K = \frac{[X][Y]}{[A][B]}}$$

The combined constant K, which is equal to k_f / k_b is called ***equilibrium constant*** and has a constant value for a reaction at a given temperature. The above equation is known as ***law of chemical equilibrium***.

For a general reaction of the type : $aA + bB \rightleftharpoons cC + dD$

The equilibrium constant may be represented as : $K = \dfrac{[C]^c[D]^d}{[A]^a[B]^b}$

where the exponents *a*, *b*, *c* and *d* have the same values as those in the balanced chemical equation. Thus, ***the equilibrium constant*** may be defined as,

"The ratio between the products of molar concentrations of the products to that of the molar concentrations of the reactants with each concentration term raised to a power equal to its stoichiometric coefficient in the balanced chemical equation at a constant temperature."

(2) Characteristics of equilibrium constant

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

For example, the equilibrium constant for the reaction,

$$Fe^{3+}(aq) + SCN^{-}(aq) = FeSCN^{2+}(aq);\quad K = \frac{[FeSCN^{2+}]}{[Fe^{3+}][SCN^{-}]} = 138.0\,L mol^{-1} \text{ (at 298 } K\text{)}$$

Whatever may be the initial concentrations of the reactants, Fe^{3+} and SCN^{-} ions, the value of *K* comes out to be 138.0 $L\,mol^{-1}$ at 298 *K*.

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

For example, the equilibrium constant for the reaction between hydrogen and iodine to form hydrogen iodide is 48 at 717 *K*.

$$H_2(g) + I_2(g) = 2HI(g);\quad K = \frac{[HI]^2}{[H_2][I_2]} = 48$$

For this reaction, the value of *K* is fixed as long as the temperature remains constant.

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

For example, if equilibrium constant, *K*, for the reaction of combination between hydrogen and iodine at 717 *K* is 48

$$H_2(g) + I_2(g) \rightleftharpoons 2HI(g);\quad K' = \frac{[HI]^2}{[H_2][I_2]} = 48$$

Then, the equilibrium constant for the decomposition of hydrogen iodide is the inverse of the above equilibrium constant.

$$2HI(g) \rightleftharpoons H_2(g) + I_2(g);\quad K = \frac{[H_2][I_2]}{[HI]^2} = \frac{1}{K'} = \frac{1}{48} = 0.02$$

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

(iv) *The value of an equilibrium constant tells the extent to which a reaction proceeds in the forward or reverse direction*. If value of *K* is large, the reaction proceeds to a greater extent in the forward direction and if it is small, the reverse reaction proceeds to a large extent and the progress in the forward direction is small.

(v) *The equilibrium constant is independent of the presence of catalyst.* This is so because the catalyst affects the rates of forward and backward reactions equally.

(vi) *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

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

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

(a) 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.

(b) 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.

(c) 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.

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

Examples :

(a) If the equation (having equilibrium constant *K*) is divided by 2, then the equilibrium constant for the new equation is the square root of *K i.e.* $\sqrt{K}$. For example, the thermal dissociation of SO_3 can be represented in two ways as follows,

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

$$K = \frac{[SO_2]^2[O_2]}{[SO_3]^2} \text{ and } K' = \frac{[SO_2][O_2]^{1/2}}{[SO_3]}; \quad \boxed{K' = \sqrt{K} \text{ or } (K)^{1/2}}$$

(b) 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.*, $\boxed{K' = K^2}$

(c) 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 $\boxed{K = K_1 \times K_2}$

For example, the reaction $N_2(g) + 2O_2(g) \rightleftharpoons 2NO_2(g)$ with equilibrium constant (*K*) can be written in two steps :

$N_2(g) + O_2(g) \rightleftharpoons 2NO\,(g)$; (Equilibrium constant = K_1)

$2NO(g) + O_2(g) \rightleftharpoons 2NO_2(g)$; (Equilibrium constant = K_2)

Now, $K_1 = \dfrac{[NO]^2}{[N_2][O_2]}$ and $K_2 = \dfrac{[NO_2]^2}{[NO]^2[O_2]}$

Therefore, $K_1 \times K_2 = \dfrac{[NO]^2}{[N_2][O_2]} \times \dfrac{[NO_2]^2}{[NO]^2[O_2]} = \dfrac{[NO_2]^2}{[N_2][O_2]^2} = K$

(3) **Types of equilibrium constant :** Generally two types of equilibrium constants are used,

(i) $\boldsymbol{K_c}$ → It is used when the various species are generally expressed in terms of *moles/litre* or in terms of molar concentrations.

(ii) $\boldsymbol{K_p}$ → It is used when in gaseous reactions, the concentration of gases expressed in terms of their partial pressures.

K_p is not always equal to K_c. K_p and K_c are related by the following expression, $\boxed{K_p = K_c(RT)^{\Delta n}}$

where, *R* = Gas constant = 0.0831 $bar dm^3\ mol^{-1}\ k^{-1}$; *T* = Temperature in Kelvin

Δ*n* = number of moles of gaseous products – number of moles of gaseous reactants in chemical equation

(4) **Unit of equilibrium constant :** Equilibrium constant *K* has no units *i.e.*, dimensionless if the total number of moles of the products is exactly equal to the total number of moles of reactants. On the other hand if the number of mioles of products and reactants are not equal, *K* has specific units.

Units of K_p and K_c and the value of Δn

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	$K_p < K_c$	$(atm)^{\Delta n}$	$(mole\ l^{-1})^{\Delta n}$

(5) **Applications of equilibrium constant :** Knowing the value of the equilibrium constant for a chemical reaction is important in many ways. For example, it judge the extent of the reaction and predict the direction of the reaction.

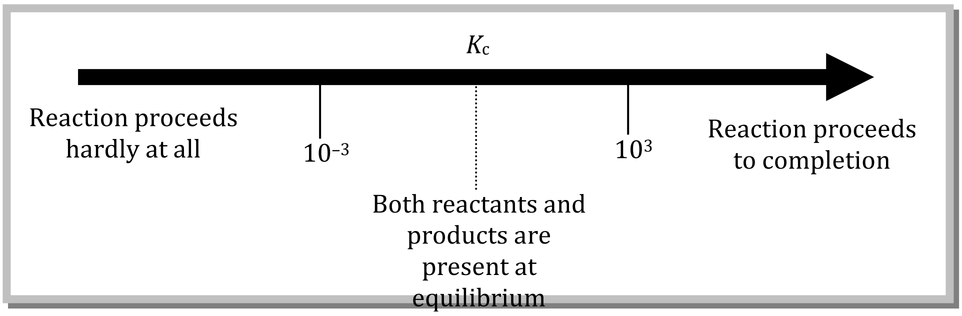
(i) ***Judging the extent of reaction***

We can make the following generalisations concerning the composition of equilibrium mixture.

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

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

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



(ii) ***Reaction quotient and 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***.

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

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,

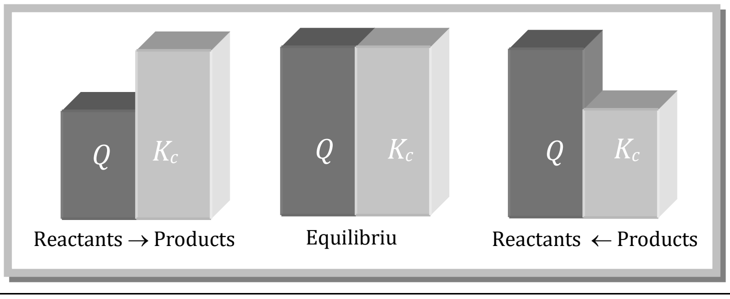
(a) If $Q > K$, the reaction will proceed in the direction of reactants (*reverse reaction*).

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

(c) 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 $Q > K$.

This has also been shown in figure,



(6) **Calculation of equilibrium constant :** We have studied in the characteristics of the equilibrium constant that its value does not depend upon the original concentrations of the reactants and products involved in the reaction. However, its value depends upon their concentrations at the equilibrium point. Thus, if the equilibrium concentrations of the species taking part in the reaction be known, then the value of the equilibrium constant and *vice versa* can be calculated.

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*) 2*x*	(1–*x*) (3–3*x*) 2*x*	(2–2*x*) (1–*x*) 2*x*	(1–*x*) *x* *x*
Total mole at equilibrium	2	(4 – 2*x*)	(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	$\frac{4x^2}{(1-x)^2}$	$\frac{16x^2(2-x)^2}{27(1-x)^4P^2}$	$\frac{x^2(3-x)}{P(1-x)^3}$	$\frac{Px^2}{(1-x^2)}$

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*) 2*x*	(1–*x*) 2*x* *x*
Total moles at equilibrium (solid not included)	2*x*	(1+*x*)	3*x*
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	$\frac{P^2}{4}$	$\frac{4P^2x^2}{(1-x^2)}$	$\frac{4P^3}{27}$

(7) **Equilibrium constant and standard free energy change :** Standard free energy change of a reaction and its equilibrium constant are related to each other at temperature *T* by the following relation,

$$\boxed{\Delta G^o = -2.303\ RT \log K}$$

when, $\Delta G^o = -ve$, the value of equilibrium constant will be large positive quantity and

when, $\Delta G^o = +ve$, the value of equilibrium constant is less than 1 *i.e.*, low concentration of products at equilibrium state.

Examples based on Equilibrium constant, K_p & K_c and $\Delta G^o = -2.303\ RT \log K$

Example : 1 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

Solution: (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.

$$K_c = \frac{[C][D]}{[A][B]} = \frac{0.8 \times 0.8}{0.2 \times 0.2} = 16.0$$

Example : 2 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

Solution: (a) For reaction $A + 2B \rightleftharpoons C$; $K_{eq} = \frac{[C]}{[A][B]^2} = \frac{0.216}{0.06 \times 0.12 \times 0.12} = 250$

Example : 3 Molar concentration of O_2 is 96 *gm*, it contained in 2 *litre* vessel, active mass will be

(a) 16 *mole/litre* (b) 1.5 *mole/litre* (c) 4 *mole/litre* (d) 24 *mole/litre*

Solution: (b) Active mass $= \frac{\frac{\text{weight}}{\text{M.wt.}}}{\text{Volume}} = \frac{\text{weight}}{\text{M.wt.} \times \text{Volume}} = \frac{96}{32 \times 2} = \frac{3}{2} = 1.5\ mol\ /\ litre$

Example : 4 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]**

(a) 0.266 (b) 0.53 (c) 2.66 (d) 5.3

Solution: (a) At start, $\underset{2}{PCl_5} \rightleftharpoons \underset{0}{PCl_3} + \underset{0}{Cl_2}$

At equilibrium. $\frac{2 \times 60}{100}$ $\frac{2 \times 40}{100}$ $\frac{2 \times 40}{100}$

Volume of cantainer = 2 litre

$$\therefore\ K_c = \frac{\frac{2 \times 40}{100 \times 2} \times \frac{2 \times 40}{100 \times 2}}{\frac{2 \times 60}{100 \times 2}} = 0.266$$

Example : 5 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 $500^o C$. The reaction is $H_2 + I_2 \rightleftharpoons 2HI$ the K_c 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*

Solution: (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

$0.30 - 0.24 = 0.06\ mole$

Example : 6 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,

$CH_3COOC_2H_5 + H_2O \rightleftharpoons CH_3COOH + C_2H_5OH$ is **[AIIMS 1999]**

(a) 4.33 (b) 5.33 (c) 6.33 (d) 7.33

Solution: (d) $K_f = 1.1 \times 10^{-2},\ K_b = 1.5 \times 10^{-3};\ K_c = \frac{K_f}{K_b} = \frac{1.1 \times 10^{-2}}{1.5 \times 10^{-3}} = 7.33$

Example : 7 For the reaction $PCl_3(g) + Cl_2(g) \rightleftharpoons PCl_5$ at $250^o C$, the value of K_c is 26, then the value of K_p on the same temperature will be **[MNR 1990; MP PET 2001]**

(a) 0.61 (b) 0.57 (c) 0.83 (d) 0.46

Solution: (a) $\Delta n_g = 1 - 2 = -1$

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

Since $R = 0.0821$ *litre atm* k^{-1} mol^{-1}, $T = 250^oC = 250 + 273 = 523$ $K_p = 26(0.0821 \times 523)^{-1} = 0.61$

Example : 8 If K_p for reaction $A_{(g)} + 2B_{(g)} \rightleftharpoons 3C_{(g)} + D_{(g)}$ is 0.05 *atm* at 1000K its K_c in term of R will be **[CBSE PMT 1989]**

(a) $\frac{5 \times 10^{-4}}{R}$ (b) $\frac{5}{R}$ (c) $\frac{5 \times 10^{-5}}{R}$ (d) None of these

Solution: (c) $K_p = K_c(RT)^{\Delta n} \Rightarrow 5 \times 10^{-2} = K_c(R \times 1000)^1 \Rightarrow K_c = \frac{5 \times 10^{-5}}{R}$

Example : 9 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

Solution: (d) K_c for the IInd reaction is reverse of Ist for reaction $2HI \rightleftharpoons H_2 + I_2$ is $0.25\ K'_c$ for reaction, $H_2 + I_2 \rightleftharpoons 2HI$ will be $K'_c = \frac{1}{K_c} = \frac{1}{0.25} = 4$.

Example : 10 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 **[MP PMT 2003; EAMCET 1998]**

(a) 7 (b) 20 (c) 49 (d) 21

Solution: (a) $2AB \rightleftharpoons A_2 + B_2$

$$K_c = \frac{[A_2][B_2]}{[AB]^2} = 49$$

For reaction $AB \rightleftharpoons \frac{1}{2}A_2 + \frac{1}{2}B_2$

$$K_c' = \frac{[A_2]^{1/2}[B_2]^{1/2}}{[AB]}$$

$$K_c' = \sqrt{K_c} = \sqrt{49} = 7$$

Example : 11 For the reaction $2NO_{2(g)} \rightleftharpoons 2NO_{(g)} + O_{2(g)}$ $K_c = 1.8 \times 10^{-6}$ at $185^o C$. At $185^o C$, 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

Solution: (b) Reaction is reversed and halved.

$$\therefore\ K_c' = \frac{1}{\sqrt{K_c}};\quad K_c' = \frac{1}{\sqrt{1.8 \times 10^{-6}}} = 7.5 \times 10^2$$

Example : 12 In an equilibrium reaction for which $\Delta G^0 = 0$ the equilibrium constant K_p should be **[BHU 1987]**

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

Solution: (b) If $\Delta G^0 = 0$ and $\Delta G^0 = -2.303\,RT\,\log K_p$

$\log K_p = 0$, $K_p = 1$

Example : 13 ΔG^0 for $HI_{(g)} \cong +1.7 kJ/mole$ what is the equilibrium constant at $25^o C$ for $2HI_{(g)} \rightleftharpoons H_{2(g)} + I_{2(g)}$ **[KCET 1992]**

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

Solution: (d) $\Delta G^0 = -2.303\,RT\,\log K_p = -2.303 \times 8.314 \times 10^{-3} \times 298\ \log K_p$

$1.7 = -2.303 \times 8.314 \times 10^{-3} \times 298\ \log K_p$

$K_p = 0.5$

Example : 14 It is found that the equilibrium constant increases by a factor of four when the temperature is increased from $25^o C$ to $40^o C$. The value of ΔH^o is

(a) $25.46\,kJ\,mol^{-1}$ (b) $171.67\,kJ\,mol^{-1}$ (c) $89.43\,kJ\,mol^{-1}$ (d) $71.67\,kJ\,mol^{-1}$

Solution: (d) Using the equation,

$$\log \frac{(K_p)_{40^o C}}{(K_p)_{25^o C}} = \frac{\Delta H}{2.303\,R}\left(\frac{1}{T_1} - \frac{1}{T_2}\right),$$

we get $\log 4 = \frac{\Delta H}{2.303 \times 8.314}\left(\frac{1}{273 + 25} - \frac{1}{273 + 40}\right)$

$\therefore\ \Delta H = 71.67\,kJ\,mol^{-1}$

Example : 15 K_c for the reaction $A(g) + B(g) \rightleftharpoons 2C(g)$ is 3.0 at $400K$. In an experiment "*a*" *mol* of *A* is mixed with 3 *mol* of *B* in a 1-*L* vessel. At equilibrium 3 *mol* of *C* is formed. The value of '*a*' will be,

(a) 4.5 *mol* (b) 9.5 *mol* (c) 2.5 *mol* (d) 3.5 *mol*

Solution: (d)

$$\underset{\substack{a \\ a-x}}{A(g)} + \underset{\substack{3 \\ 3-x}}{B(g)} \rightleftharpoons \underset{\substack{0 \\ 2x}}{2C(g)}$$

From the equation, $2x = 3 \Rightarrow x = 1.5$

$$K_c = \frac{4x^2}{(a-x)(b-x)};\ 3 = \frac{4 \times (1.5)^2}{(a-1.5)(3-1.5)};\ 3 = \frac{4 \times 2.25}{(a-1.5)(1.5)} \Rightarrow a = 3.5$$

Example : 16 For the reaction $AB(g) \rightleftharpoons A(g) + B(g), AB$ is 33% dissociated at a total pressure of *P*. Then

(a) $P = K_p$ (b) $P = 4K_p$ (c) $P = 3K_p$ (d) $p = 8K_p$

Solution: (d)

$$\begin{array}{ccc} AB(g) & \rightleftharpoons & A(g) + B(g) \\ 1 & & 0 \quad\quad 0 \\ -1/3 & & +1/3 \quad +1/3 \\ 2/3 & & 1/3 \quad\quad 1/3 \end{array}$$

$$(\Sigma n)_{eq/m} = \frac{2}{3} + \frac{1}{3} + \frac{1}{3} = \frac{4}{3}$$

$$K_p = \frac{P_A P_B}{P_{AB}} = \frac{\frac{1/3}{4/3}P \frac{1/3}{4/3}P}{\frac{2/3}{4/3}P} = \frac{1}{8}P$$

$$P = 8K_p$$

Example : 17 The total pressure observed at equilibrium in the dissociation of solid ammonium carbamate at a certain temperature is 2.0 *atm*. The equilibrium constant K_p is

(a) 4.185 (b) 1.185 (c) 2.276 (d) 1.072

Solution: (b)

$$NH_4COONH_2(s) \rightleftharpoons \underset{\frac{2}{3}P}{2NH_3(g)} + \underset{\frac{1}{3}P}{CO_2(g)}$$

$$K_p = P_{NH_3}^2 P_{CO_2} = \left(\frac{2}{3}P\right)^2 \left(\frac{1}{3}P\right) = \frac{4}{27}P^3 = \frac{4}{27} \times (2)^3 = 1.185$$

Example : 18 At the equilibrium of the reaction $N_2O_4(g) \rightleftharpoons 2NO_2(g)$, the observed molar mass of N_2O_4 is 77.70 *g*. The percentage dissociation of N_2O_4 is

(a) 28.4 (b) 46.7 (c) 22.4 (d) 18.4

Solution: (d) $\alpha = \frac{M_{Th} - M_{obs}}{M_{obs}(n-1)}$; Molar mass of $N_2O_4 = 92\, g\, mol^{-1}$

Here, *n* = 2; $\alpha = \frac{92.00 - 77.70}{77.70(2-1)} = 0.184 = 18.4\%$

Example : 19 In the equilibrium $H_2O(g) \rightleftharpoons H_2(g) + \frac{1}{2}O_2(g)$, the extent of dissociation of water when *p* = 1 *atm* and $K = 2.08 \times 10^{-3}$ is approximately

(a) 2% (b) 0.2% (c) 20% (d) 1%

Solution: (a) For the equilibrium $H_2O(g) \rightarrow H_2(g) + \frac{1}{2}O_2(g)$

$$K_p = \frac{\alpha^{3/2} P^{1/2}}{\sqrt{2}} \quad P = 1\, atm$$

$$\alpha = (\sqrt{2}.K_p)^{2/3} = 0.0205 \approx 2\%$$

8.7 Factors which Change the State of Equilibrium : 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 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. *This is applicable to all physical and chemical equilibria*.

(1) **Effect of change of concentration** : According to Le-Chatelier's principle, "*If concentration of one or all the reactant species is increased, the equilibrium shifts in the forward direction and more of the products are formed.* Alternatively, *if the concentration of one or all the product species is increased, the equilibrium shifts in the backward direction forming more reactants."*

Thus,

Increase in concentration of any of the reactants $\xrightarrow[\text{equilibrium to}]{\text{Shifts the}}$ **Forward direction**

Increase in concentration of any of the products $\xrightarrow[\text{equilibrium to}]{\text{Shifts the}}$ **Backward direction**

(2) **Effect of change of temperature** : According to Le-Chatelier's principle, *"If the temperature of the system at equilibrium is increased (heat is supplied), the equilibrium will shift in the direction in which the added heat is absorbed. In other words, the equilibrium will shift in the direction of* ***endothermic reaction*** *with increase in temperature. Alternatively, the decrease in temperature will shift the equilibrium towards the direction in which heat is produced and, therefore, will favour* ***exothermic reaction.****"*

Thus,

Increase in temperature $\xrightarrow[\text{in the direction of}]{\text{Shifts the equilibrium}}$ **Endothermic reaction**

Decrease in temperature $\xrightarrow[\text{in the direction of}]{\text{Shifts the equilibrium}}$ **Exothermic reaction**

(3) **Effect of change of pressure** : Pressure has hardly effect on the reactions carried in solids and liquids. However, it does influence the equilibrium state of the reactions that are carried in the gases. The effect of pressure depends upon the number of moles of the reactants and products involved in a particular reaction. According to Le-Chatelier's principle, *"Increase in pressure shifts the equilibrium in the direction of decreasing gaseous moles. Alternatively, decrease in pressure shifts the equilibrium in the direction of increasing gaseous moles and pressure has no effect if the gaseous reactants and products have equal moles."*

Thus,

Increase in pressure $\xrightarrow[\text{in the direction of}]{\text{Shifts the equilibrium}}$ **Decreasing gaseous moles**

Decrease in pressure $\xrightarrow[\text{in the direction of}]{\text{Shifts the equilibrium}}$ **Increasing gaseous moles**

(4) **Effect of volume change** : We know that increase in pressure means decrease in volume, so the effect of change of volume will be exactly reverse to that of pressure. Thus, "*decreasing the volume of a mixture of gases at equilibrium shifts the equilibrium in the direction of decreasing gaseous moles while increasing the volume shifts the equilibrium in the direction of increasing gaseous moles."*

Thus,

Increase in volume $\xrightarrow[\text{in the direction of}]{\text{Shifts the equilibrium}}$ **Increasing gaseous moles**

Decrease in volume $\xrightarrow[\text{in the direction of}]{\text{Shifts the equilibrium}}$ **Decreasing gaseous moles**

(5) **Effect of catalyst** : Catalyst has no effect on equilibrium. This is because, catalyst favours the rate of forward and backward reactions equally. Therefore, the ratio of the forward to reverse rates remains same and no net change occurs in the relative amount of reactants and products present at equilibrium. Thus, a **catalyst does not affect the position of the equilibrium**. It simply helps to achieve the equilibrium quickly. It may also be noted that a catalyst has no effect on the equilibrium composition of a reaction mixture.

Thus, **Catalyst does not shift the equilibrium in any direction**

(6) **Effect of addition of inert gas** : The addition of an inert gas (like helium, neon, etc.) has the following effects on the equilibrium depending upon the conditions :

(i) ***Addition of an inert gas at constant volume*** **:** When an inert gas is added to the equilibrium system at constant volume, then the total pressure will increase. But the concentrations of the reactants and products (ratio of their moles to the volume of the container) will not change. Hence, under these conditions, *there will be no effect on the equilibrium.*

(ii) ***Addition of an inert gas at constant pressure :*** When an inert gas is added to the equilibrium system at constant pressure, then the volume will increase. As a result, the number of moles per unit volume of various reactants and products will decrease. Hence, *the equilibrium will shift in a direction in which there is increase in number of moles of gases.*

Thus,

Addition of an inert gas $\xrightarrow{V = constant}$ **No effect on the equilibrium.**

Addition of an inert gas $\xrightarrow[\text{Shifts the equilibrium in the direction of}]{P = constant}$ **Increasing gaseous moles.**

8.8 Applications 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. Let us discuss in brief a few applications.

(1) **Applications to the chemical equilibrium** : With the help of this principle, most favourable conditions for a particular reaction can be predicted.

(i) ***Synthesis of ammonia*** *(Haber's process)*: $\underset{1\,vol}{N_2} + \underset{3\,vol}{3H_2} \rightleftharpoons \underset{2\,vol}{2NH_3} + 23kcal$ (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*** **:** $\underset{2\,vol}{2SO_2} + \underset{1\,vol}{O_2} \rightleftharpoons \underset{2\,vol}{2SO_3} + 45\ kcal$ (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*** **:** $\underset{1\,vol}{N_2} + \underset{1\,vol}{O_2} \rightleftharpoons \underset{2\,vol}{2NO} - 43.2\ kcal$ (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** : Le-Chatelier's principle is applicable to the physical equilibrium in the following manner;

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

(3) **Application in every day life** : We have studied the application of the Le-Chatelier's principle to some equilibria involved in the physical and chemical systems. In addition to these, the principle is also useful to explain certain observations which we come across in every day life. A few out of them are discussed below,

(i) ***Clothes dry quicker in a windy day*** **:** When wet clothes are spread on a stand, the water evaporates and the surrounding air tends to get saturated thus hampering the process of drying. On a windy day when breeze blows, the nearby wet air is replaced by dry air which helps the process of evaporation further. Thus, clothes dry quicker when there is a breeze.

(ii) ***We sweat more on a humid day*** **:** The explanation is the same as given above. In a humid day, the air is already saturated with water vapours. This means that the water that comes out of the pores of the body as sweat does not vaporise. This will result in greater sweating in a humid day.

(iii) ***Carriage of oxygen by haemoglobin in blood*** **:** The haemoglobin (*Hb*) in red corpuscles of our blood carries oxygen to the tissues. This involves the equilibrium, $Hb(s) + O_2(g) \rightleftharpoons HbO_2(s)$

The blood that is in equilibrium with the oxygen of the air in the lungs finds a situation in the tissues where the partial pressure of oxygen is low. According to Le-Chatelier's principle, the equilibrium shifts towards the left so that some of the oxyhaemoglobin changes to haemoglobin giving up the oxygen. When the blood returns to the lungs, the partial pressure of the oxygen is higher and the equilibrium favours the formation of more oxyhaemoglobin.

(iv) ***Removal of carbon dioxide from the tissues by blood*** **:** Blood removes CO_2 from the tissues. The equilibrium is, $CO_2(g) + H_2O(l) \rightleftharpoons H_2CO_3(aq) \rightleftharpoons H^+(aq) + HCO_3^-(aq)$

Carbon dioxide dissolves in the blood in the tissues since the partial pressure of CO_2 is high. However in the lungs, where the partial pressure of CO_2 is low, it is released from the blood.

(v) ***Sweet substances cause tooth decay*** **:** Tooth enamel consists of an insoluble substance called hydroxyapatite, $Ca_5(PO_4)_3OH$. The dissolution of this substance from the teeth is called *demineralization* and its formation is called *remineralization*. Even with the healthy teeth, there is an equilibrium in the mouth as

$$Ca_5(PO_4)_3OH(s) \underset{endothermic}{\overset{exothermic}{\rightleftharpoons}} 5Ca^{2+}(aq) + 3PO_4^{3-}(aq) + OH^-(aq)$$

When sugar substances are taken, sugar is absorbed on teeth and gets fermented to give H^+ ions. The H^+ ions produced distrub the equilibrium by combining with OH^- to form water and with PO_4^{3-} to form HPO_4^{2-}. Removal of products cause the equilibrium to shift towards right and therefore, $Ca_5(PO_4)_3OH$ dissolves causing tooth decay.

8.9 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, $\boxed{D = \dfrac{molecular\ weight}{volume} = \dfrac{m}{V}}$

Molar density after dissociation, $d = \dfrac{m}{[1 + x(y-1)]V}$; $\dfrac{D}{d} = [1 + x(y-1)]$; $x = \dfrac{D-d}{d(y-1)}$

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

In terms of molecular mass,

$x = \dfrac{M-m}{(y-1)m}$; 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) $2NO_2 \rightleftharpoons N_2O_4, y = \dfrac{1}{2}$

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

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

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

Assignment

Level-1

1. A reversible reaction is one which

(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

(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. In a reversible reaction both side rate of reactions are

(a) Same (b) Different (c) One side more (d) Not definite

4. Which of the following reactions is reversible

(a) $H_2 + I_2 \rightarrow 2HI$ (b) $H_2SO_4 + Ba(OH)_2 \rightarrow BaSO_4 + 2H_2O$

(c) $NaCl + AgNO_3 \rightarrow NaNO_3 + AgCl$ (d) $Fe + S \rightarrow FeS$

5. Which one is reversible process

(a) Melting of ice at $10^o C$ (b) Mixing of two gases by diffusion

(c) Evaporation of water at $100^o C$ and 1 atm pressure (d) None of these

6. All reactions which have chemical disintegration

(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

(a) $H_2 + I_2 \rightarrow 2HI$ (b) $AgNO_3 + NaCl \rightarrow AgCl + NaNO_3$

(c) $CaCO_3 \rightarrow CaO + CO_2$ (d) $O_2 + 2SO_2 \rightarrow 2SO_3$

8. The reaction, $3Fe(s) + 4H_2O \rightleftharpoons Fe_3O_4(s) + 4H_2(g)$ is reversible if it carried out

(a) At constant pressure (b) At constant temperature (c) In an open vessel (d) In a closed vessel

9. Amongst the following chemical reactions the reversible reaction is

(a) $FeCl_3 + 3H_2O \rightarrow Fe(OH)_3 + 6HCl$ (b) $NaCl + H_2SO_4 \rightarrow NaHSO_4 + HCl \uparrow$

(c) (a) and (b) both (d) None of these

Level-2

10. An example of reversible reaction is

(a) $AgNO_3(aq.) + HCl(aq.) \rightarrow AgCl(s) + HNO_3(aq.)$ (b) $NaOH + CH_3COOH \rightarrow CH_3COONa + H_2O$

(c) $2Na + 2H_2O \rightarrow 2NaOH + H_2$ (d) $Pb(NO_3)_2 + 2NaI \rightarrow PbI_2 + 2NaNO_3$

11. The given reaction, $AgNO_3 + NaCl \rightarrow AgCl + NaNO_3$ is irreversible because

(a) $NaCl$ is sparingly soluble in water (b) $AgNO_3$ and $NaCl$ are completely ionised

(c) $AgCl$ is slightly soluble in water (d) None of these

12. Which is incorrect for a reversible reaction

(a) The reaction is never completed

(b) The reactants are present in the initial stage but after that reactants and products are always present in the reaction mixture

(c) At equilibrium only products are present

(d) When the reaction is carried out in closed space it attains equilibrium state after suitable time.

13. What is the direction of a reversible reaction when one of the products of the reaction removed

(a) Forward direction (b) Backward direction (c) The reaction stops (d) All of these

14. The reaction which proceeds in the forward direction is

(a) $SnCl_4 + Hg_2Cl_2 \rightarrow SnCl_2 + 2HgCl_2$ (b) $NH_4Cl + NaOH \rightarrow H_2O + NH_3 + NaCl$

(c) $Mn^{2+} + 2H_2O + Cl_2 \rightarrow MnO_2 + 4H^+ + 2Cl^-$ (d) $S_4O_6^{--} + 2I^- \rightarrow 2S_2O_3^{2-} + I_2$

Level-1

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

(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 becomes equal

16. For reversible reaction $A \rightleftharpoons B$, what is true

(a) $\frac{d[A]}{dt} = \frac{d[B]}{dt}$ (b) $\frac{dx}{dt} = \frac{K_p}{K_c}$ (c) $\frac{d[A]}{d[B]} = K$ (d) None of these

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

(a) Chemical equilibrium (b) Reversible state (c) Equilibrium (d) All of these

18. In chemical reaction $A \rightleftharpoons B$, the system will be known in equilibrium when

(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 change to B

19. Select the correct statement from the following

(a) Equilibrium constant changes with addition of catalyst
(b) Catalyst increases the rate of forward reaction
(c) The ratio of mixture at equilibrium does not change by catalyst
(d) Catalyst are active only in solution

20. A chemical reaction is at equilibrium when

(a) Reactants are completely transformed into products
(b) The rates of forward and backward reactions are equal
(c) Formation of products is minimised
(d) Equal amounts of reactants and products are present

21. In the chemical reaction $N_2 + 3H_2 \rightleftharpoons 2NH_3$ at equilibrium point

(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

22. What would happen to a reversible reaction at equilibrium when an inert gas is added while the volume 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

23. 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

24. In a chemical reaction equilibrium is established when

(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

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

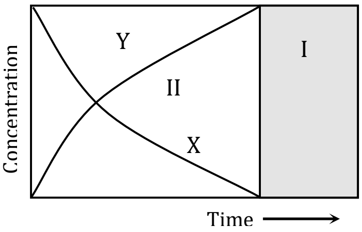
(a) Concentration of reactants is changing where as concentration of products is constant
(b) Concentration of all substances is constant
(c) Concentration of reactants is constant where as concentration of products is changing
(d) Concentration of all substance is changing

26 Study of the equilibrium of the type $CO_2(g) + H_2(g) \square CO(g) + H_2O(g)$ is concerned with the

(a) Macroscopic behaviour of mixture (b) Microscopic behaviour of mixture

(c) Both (a) and (b) (d) None of these.

27. Variation of the concentration of the reactant (X) and the product (Y) is shown in the fig. Select the correct statement

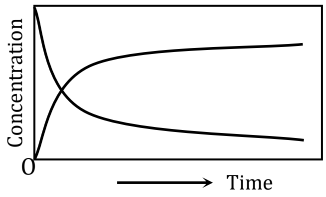


(a) I and II both are kinetic regions (b) I and II both are equilibrium region

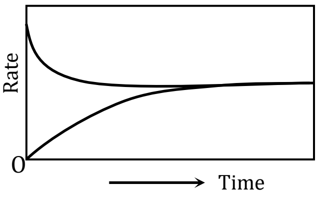
(c) I is equilibrium and II is kinetic region (d) I is kinetic and II is equilibrium region

28. In the following reaction $PCl_5 \rightleftharpoons PCl_3 + Cl_2$ study is made graphically till equilibrium is attained. Following graphs were taken: Correct graphs are

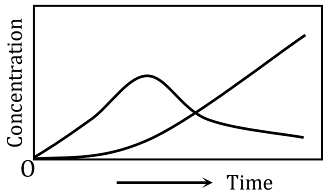
I:



II:



III:



(a) I, II, III (b) II, III (c) I, III (d) I.II

29. When a burner on a gas stove is operating at one setting, the size of the flame does not change, $CH_4 + 2O_2 \longrightarrow CO_2 + 2H_2O$. It is due to

(a) That on equilibrium among CH_4, O_2, CO_2 and H_2O is established

(b) That products escape continuously as well as reactants are added continuously.

(c) That CO_2, CH_4 and O_2 are gases

(d) That pressure is decreased.

Level-2

30. 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 a open vessel over stove, temperature of water is constant

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

31. Chemical equilibrium is dynamic in nature because

(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 as

32. One dm^3 of $2M$ ethanoic acid is mixed with one dm^3 of $3M$ ethanol to form an ester, $CH_3COOH + C_2H_5OH \rightarrow CH_3COOC_2H_5 + H_2O$. The decrease in the initial rate if each solution is diluted with an equal volume of water would be

(a) 2 times (b) 4 times (c) 0.25 times (d) 0.5 times

33. 3.2 moles of hydrogen iodide were heated in a sealed bulb at 444°C till the equilibrium was reached. The degree of dissociation of HI at this temperature was found to be 22%. The number of moles of hydrogen iodide present at equilibrium are

(a) 1.87 (b) 2.496 (c) 4.00 (d) 2.00

34. For the reaction $2N_2O_4 \rightarrow 4NO_2$ given that $\frac{-d}{dt}(N_2O_4) = K$ and $\frac{d}{dt}(NO_2) = K'$, then

(a) $K' = 2K$ (b) $K' = K$ (c) $2K' = K$ (d) None of these

35. Which is false

(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

36. **Assertion** (*A*): The equilibrium constant is fixed and is the characteristic of any given chemical reaction at a specified temperature.

Reason (*R*): The composition of the final equilibrium mixture at a particular temperature depends upon the starting amount of reactants.

(a) Both *A* and *R* are true and *R* is a correct explanation of *A*

(b) Both *A* and *R* are true but *R* is not a correct explanation of *A*

(c) *A* is true but *R* is false

(d) Both *A* and *R* are false

(e) *A* is false but *R* is true

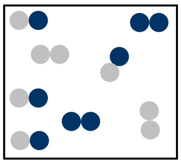
37. For a reaction of the type $aA + bB \rightleftharpoons$ Products, the $\frac{d[A]}{dt}$ is equal to....

(a) $-\frac{d[B]}{dt}$ (b) $-\frac{1}{b} \times \frac{d[B]}{dt}$ (c) $-\frac{a}{b} \times \frac{d[B]}{dt}$ (d) $-\frac{b}{a} \times \frac{d[B]}{dt}$

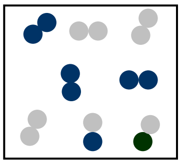
38. Which one of the following equation is correct for the reaction : $N_{2(g)} + 3H_{2(g)} \rightleftharpoons 2NH_{3(g)}$

(a) $\frac{3d[H_2]}{dt} = \frac{2d[N_2]}{dt}$ (b) $\frac{2d[N_2]}{dt} = \frac{1}{3}\frac{d[H_2]}{dt}$ (c) $\frac{2d[NH_3]}{dt} = \frac{-3d[H_2]}{dt}$ (d) $\frac{3d[NH_3]}{dt} = \frac{-2d[H_2]}{dt}$

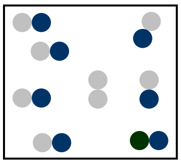
39. The reaction $A_2 + B_2$ □ $2AB$ has an equilibrium constant $K_c = 4$. The following pictures represent reaction mixtures that contain A_2 (●●) molecules, B_2 (●●) molecules and AB (●●) molecules



I



II



III

In which case (*s*) system is in equilibrium

(a) I (b) I, II (c) II, III (d) I, II, III

40. A reaction reaches a state of chemical equilibrium only when

(a) The reactants and the products are reacting

(b) The concentrations of the reactants and products become equal

(c) The products react together at the same rate at which they are formad

(d) All the reactants and the products are in the same state of matter

Level-1

41. The active mass of a reactant is

(a) Its gram molecular weight (b) Its equivalent weight (c) Per litre number of moles (d) None of these

42. In a reaction the rate of reaction is proportional to its active mass, this statement is known as

(a) Law of mass action (b) Le- chatelier principle (c) Faraday law of electrolysis (d) Law of constant proportion

43. The law of mass action was enunciated by

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

44. Theory of 'active mass' indicates that the rate of chemical reaction is directly proportional to the

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

45. 240*g* of urea is present in 10 litre solution the active mass of urea will be

(a) 0.2 mol/litre (b) 0.06 mol/litre (c) 0.4 mol/litre (d) 0.08 mol/litre

46. According to law of mass action, for the reaction $2A + B \longrightarrow$ products

(a) Rate = $K[A][B]$ (b) Rate = $K[A]^2[B]$ (c) Rate = $K[A][B]^2$ (d) Rate = $K[A]^{1/2}[B]$

47. According to law of mass action, the rate of a reaction is directly proportional to

(a) Molarities of the reactants (b) Normalities of the reactants
(c) Molalities of the reactants (d) Mole fractions of the reactants

48. The number of gram molecules of substance present in unit volume is termed as

(a) Activity (b) Normal solution (c) Molar concentration (d) Active mass

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

(a) 2 (b) 1 (c) 5 (d) 0.25

50. The thermal decomposition of potassium chlorate given as $2KClO_3 \rightarrow 2KCl + 3O_2$, law of mass action

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

51. 120 *gm* of urea are present in 5 litre solution, the active mass of urea is

(a) 0.2 (b) 0.06 (c) 0.4 (d) 0.08

52. Active mass is given as, {If *f* = activity coefficient & C_M= Molarity}

(a) $a = f\ C_M$ (b) $a = r\ C_M$
(c) Amount of substance per unit Volume (d) Number of *g mol per* 100 *litre*

53. Unit of active mass is

(a) $\frac{M}{litre}$ (b) *M. litre* (c) *M. litre*$^{-2}$ (d) None of these

Level-1

54. For the system $3A + 2B \rightleftharpoons C$, the expression for equilibrium constant is

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

55. $A + B \rightleftharpoons AB$ (in gaseous state) is a reversible reaction. It appears in equilibrium that 0.4 mole of *AB* is formed when *A* and *B* each are taken one mole. How much percentage of *A* changes to *AB*

(a) 20 (b) 40 (c) 60 (d) 4

56. Concentration of a gas is expressed in the following terms in the calculation of equilibrium constant

(a) Number of molecules per litre (b) Number of grams per litre
(c) Number of gram equivalent per litre (d) Number of molecules equivalent per litre

57. In the reversible reaction $A + B \rightleftharpoons C + D$ the concentration of each *C* and *D* at equilibrium is 0.4 mole/litre and concentration of A and B is 0.6 mol/litre, then the equilibrium constant *K* will be

(a) $\frac{4}{9}$ (b) $\frac{2}{9}$ (c) $\frac{3}{9}$ (d) None of these

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

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

59. For the system $2A(g) + B(g) \rightleftharpoons 3C(g)$. The expression for equilibrium constant *K* is

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

60. At a constant temperature when the concentration of a reactant is increased, then the equilibrium constant

(a) Increases (b) Decreases

(c) Remains unaffected
(d) First increases and then decreases

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

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

62. The unit of equilibrium constant K for the reaction $A + B \rightleftharpoons C$ would be

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

63. The equilibrium constant for the reaction $P_2 \rightleftharpoons 2P$ at $500K$ and $700K$ are 1×10^{-10} and 1×10^{-5} respectively. Given reaction will be

(a) Fast
(b) Slow
(c) Endothermic
(d) Exothermic

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

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

65. One mole of ethyl alcohol was treated with one mole of acetic acid at $25^o C$. Two-third of the acid changes into ester at equilibrium. The equilibrium constant for the reaction will be

(a) 1
(b) 2
(c) 3
(d) 4

66. A quantity of PCl_5 was heated in a 10 *litre* vessel as $250^o C$; $PCl_{5(g)} \rightleftharpoons PCl_{3(g)} + Cl_{2(g)}$. 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

(a) 0.02
(b) 0.05
(c) 0.04
(d) 0.025

67. $2SO_3 \rightleftharpoons 2SO_2 + O_2$ in equation 2 mole SO_3 is taken in 10 litre flask its degree of dissociation is 10%. Find out the value of K_c

(a) 1.2×10^{-4}
(b) 10^{-4}
(c) 10^{-2}
(d) 0.1

68. 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

(a) 16
(b) 32
(c) 64
(d) 128

69. For the following chemical reaction $2X + Y \rightleftharpoons Z$ the expression of equilibrium constant will be

(a) $K = \frac{[X]^2[Y]}{[Z]}$
(b) $K = \frac{[X][Y]^2}{[Z]}$
(c) $K = \frac{[Z]}{[X]^2[Y]}$
(d) $K = \frac{[Z]}{[X][Y]^2}$

70. Value of K_p in the reaction $MgCO_{3(s)}\ MgO_{(s)} + CO_{2(g)}$ is

(a) $K_p = P_{CO_2}$
(b) $K_p = P_{CO_2} \times \frac{P_{CO_2} \times P_{MgO}}{P_{MgCO_3}}$
(c) $K_p = \frac{P_{CO_2} \times P_{MgO}}{P_{MgCO_3}}$
(d) $K_p = \frac{P_{MgCO_3}}{P_{CO_2} \times P_{MgO}}$

71. 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

(a) 0.004
(b) 0.008
(c) 0.016
(d) 0.160

72. 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 is formed at equilibrium . The equilibrium constant for the reaction is

(a) 0.12
(b) 0.25
(c) 0.50
(d) 4.0

73. At $490^o C$, the equilibrium constant for the synthesis of HI is 50, the value of K for the dissociation of HI will be:

(a) 20.0
(b) 2.0
(c) 0.2
(d) 0.02

74. For the reaction $H_2 + I_2 \rightleftharpoons 2HI$, the equilibrium concentration of H_2, I_2 and HI are 8.0, 3.0 and 28.0 *mol per liter* respectively, the equilibrium constant of the reaction is

(a) 30.66
(b) 32.66
(c) 34.66
(d) 36.66

75. Write the equilibrium constant for the reaction, $CH_3COOH + H_2O \square H_3O^+ + CH_3COO^-$

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

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

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

(e) None of these

76. 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

(a) 0.25 (b) 0.50 (c) 1.00 (d) 0.3

77. 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 $N_2O_4 = 92$)

(a) 0.1 (b) 0.4 (c) 0.2 (d) 2

78. 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) $27/16\ mol^2\ litre^{-2}$

79. In the reaction $CH_3COOH + H_2O \rightleftharpoons CH_3COO^- + H_3O^+$. The equilibrium constant may change when

(a) CH_3COO^- is added (b) CH_3COOH is added (c) Catalyst is added (d) Mixture is heated

80. A chemical reaction is catalyzed by a catalyst *X*. Hence *X*

(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

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

(a) Volume of the reaction vessel

(b) Total pressure of the system

(c) The initial concentration of nitrogen and hydrogen

(d) The temperature

82. Which statement for equilibrium constant is true for the reaction $A + B \rightleftharpoons C$

(a) Not changes with temperature

(b) Changes when catalyst is added

(c) Increases with temperature

(d) Changes with temperature

83. The equilibrium constant in a reversible reaction at a given temperature

(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

84. The equilibrium constant (K_c) for the reaction $HA + B \rightleftharpoons BH^+ + A^-$ is 100. If the rate constant for the forward reaction is 10^5, then rate constant for the backward reaction is

(a) 10^7 (b) 10^3 (c) 10^{-3} (d) 10^{-5}

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

(a) Unchanged (b) Two times (c) Four times (d) Ten times

Level-2

86. 4 moles of *A* are mixed with 4 moles of *B*. At equilibrium for the reaction *A* + *B* ⇌ *C* + *D*, 2 moles of *C* and *D* are formed. The equilibrium constant for the reaction will be

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

87. *HI* was heated in a closed tube at $440^{o}C$ till equilibrium is obtained. At this temperature 22% of *HI* was dissociated. The equilibrium constant for this dissociation will be

(a) 0.282 (b) 0.0796 (c) 0.0199 (d) 1.99

88. A reversible chemical reaction having two reactants in equilibrium. If the concentrations of the reactants are doubled, then the equilibrium constant will

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

89. The equilibrium constant *K,* for the given reaction $2HI(g) \rightleftharpoons H_2(g) + I_2(g)$ at room temperature is 2.85 *K* and that at 698 *K* is 1.4×10^{-2} . Hence the reason that *HI* exists as a stable compound at room temperature is

(a) It decomposes so slowly that equilibrium is not readily achieved

(b) The bond *HI* has a large covalent contribution

(c) The standard free energy of the dissociation reaction at room temperature is – 0.62 *kcal*

(d) It is uncatalytic reaction

90. 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

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

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

92. 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

(a) 1×10^{-2} (b) 2×10^{-3} (c) 1×10^{-5} (d) 2×10^{-5}

93. 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

(a) 0.1 (b) 1.0 (c) 10 (d) ∞

94. 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

(a) 1 (b) 0.36 (c) 2.25 (d) 4/9

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

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

96. $H_2 + I_2 \rightleftharpoons 2HI.$ In this equilibrium system if the concentration of the reactants at $25^{o}C$ is increased, the value of K_c will

(a) Increase (b) Decrease

(c) Remains the same (d) Depends on the nature of the reactants

97. 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

(a) 2.4×10^{-3} (b) -2.4×10^{-3} (c) 4.2×10^{2} (d) 4.8×10^{2}

98. 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

(a) 0.5 (b) 4.0 (c) 8.0 (d) 32.0

99. An equilibrium mixture for the reaction $2H_2S(g) \rightleftharpoons 2H_2(g)+S_2(g)$ had 1 mole of H_2S, 0.2 mole of H_2 and 0.8 mole of S_2 in a 2 *litre* flask. The value of K_c in mole $litre^{-1}$ is

(a) 0.004 (b) 0.080 (c) 0.016 (d) 0.160

100. 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

(a) 5×10^{-4} (b) 2×10^{-3} (c) 1.125×10^{-3} (d) 9.0×10^{-4}

101. 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 $mole^{-2}\,litre^2$)

(a) 75 (b) 50 (c) 25 (d) 100

102. 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

(a) 0.625 (b) 0.0625 (c) 6.25 (d) 0.00625

103. At a certain temperature and a total pressure of 1 atmosphere dinitrogen tetraoxide (N_2O_4) 50% dissociated. The value of K_p at that temperature will be

(a) 0.75 atmosphere (b) 6.75 atmosphere (c) 2.00 atmosphere (d) 1.33 atmosphere

104. In the reaction $PCl_5 \rightleftharpoons PCl_3+Cl_2$. 4 moles of PCl_5 are taken in a two litre flask. At equilibrium flask contain 0.4 moles of chlorine. Its equilibrium constant will be

(a) 0.011 (b) 0.022 (c) 0.044 (d) 0.001

105. 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

(a) 32 (b) 64 (c) 16 (d) 4

106. In the reaction *A* + 2*B* ⇌ 2*C*, 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

(a) 0.073 (b) 0.147 (c) 0.33 (d) 0.026

107. $2SO_3 \rightleftharpoons 2SO_2+O_2$. 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

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

108. 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 Cl_2. The equilibrium constant K_c for the reaction $CO+Cl_2 \rightleftharpoons COCl_2$ is

(a) 5 (b) 10 (c) 15 (d) 20

109. 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

(a) 4 (b) 2 (c) 1/4 (d) 1/2

110. If concentration of reactants is increased by '*x*' then *K* becomes

(a) In (*K*/*x*) (b) *K*/*x* (c) *K*+*x* (d) *K*

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

(a) 1 (b) 10 (c) 5 (d) 0.33

112. For a reversible reaction, if concentrations of the reactants are doubled, then equilibrium

(a) Is halved (b) Is doubled (c) Remains same (d) Becomes 1/4th

113. At a certain temperature $2HI \rightleftharpoons H_2+I_2$ only 50% *HI* is dissociated at equilibrium. The equilibrium constant is

(a) 0.25 (b) 1.0 (c) 3.0 (d) 0.50

114. For the gaseous phase reaction $2NO \rightleftharpoons N_2+O_2$ $\Delta H^0=-43.5\,kcal\,mol^{-1}$. 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

115. For the reversible reaction, $N_{2(g)} + 3H_{2(g)} \rightleftharpoons 2NH_{3(g)}$ at 500^oC, 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

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

116. 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}

(a) $1.6 \times 10^{-8}\, M$ (b) $3.2 \times 10^{-6}\, M$ (c) $3.2 \times 10^{-4}\, M$ (d) $1.6 \times 10^{-4}\, M$

117. 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

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

(a) 0.00358 *M* (b) 0.0358 *M* (c) 0.358 *M* (d) 3.58 *M*

119. In the equilibrium $AB \rightleftharpoons A + B$; if the equilibrium concentration of *A* is doubled, the equilibrium concentration of *B* would become

(a) Twice (b) Half (c) 1/4th (d) 1/8th

120. In the reaction *A*+*B* ⇌ 2*C*, 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

121. 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

(a) 10.0 (b) 8.5 (c) 10.5 (d) 3.9

122. 10 dm^3 of N_2 gas and 10 dm^3 of gas *X* at the same temperature and pressure contain the same number of molecules. The gas *X* is

(a) *NO* (b) H_2 (c) CO_2 or *CO* (d) All of these

123. 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

(a) 28 (b) 64 (c) 32 (d) 16

124. 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

(a) Decreased (b) Doubled (c) Halved (d) Same

125. 0.1 mole of $N_2O_{4(g)}$ was sealed in a tube under atmospheric conditions at 25^oC. 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

(a) 1.8×10^2 (b) 2.8×10^2 (c) 0.034 (d) 2.8×10^{-2}

126. NH_3 is heated at 15 atm from 27^oC to 347^oC assuming volume constant. The new pressure becoming 50 atm at equilibrium of the reaction $2NH_3 \square N_2 + 3H_2$: calculate. % of mole of NH_3 actually decomposed

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

127. The rate of forward reaction is two times that of reverse reaction at a given temperature and identical concentration. $K_{\text{equiilibrium}}$ is

(a) 2.5 (b) 2.0 (c) 0.5 (d) 1.5

128. In a reversible reaction two substances are in equilibrium. If the concentration of each one is doubled, the equilibrium constant will be

(a) Reduced to half its original value (b) Reduced to one fourth of its original value

(c) Doubled (d) Constant

129. 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*

(a) 2.0 (b) 1.5 (c) 1.0 (d) 0.5

130. One mole of a compound *AB* reacts with one mole of a compound *CD* according to the equation *AB* + *CD* ⇌ *AD* + *CB* Whom 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

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

131. 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

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

132. $CaCO_{3(s)} \rightleftharpoons CaO_{(s)} + CO_{2(g)}$ which of the following expression is correct

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

133. For the gas phase reaction $2NO = N_2 + O_2 : \Delta H^0 = -43.5\,kcal\,mol^{-1}$ which one of the statements below is true for $N_{2(g)} + O_{2(g)} = 2NO_{(g)}$

(a) *K* is independent of *T* (b) *K* increases as *T* decreases

(c) *K* decreases as *T* decreases (d) *K* varies with addition of *NO*

134. 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

(a) 0.36 (b) 0.45 (c) 0.54 (d) 0.67

135. The equilibrium constant for the reaction $CaSO_4.5H_2O(s) \square CaSO_4.3H_2O(s) + 2H_2O(g)$ is equal to

(a) $\frac{[CaSO_4.3H_2O][H_2O]^2}{[CaSO_4.5H_2O]}$ (b) $\frac{[CaSO_4.3H_2O]}{[CaSO_4.5H_2O]}$ (c) $[H_2O]^2$ (d) H_2O

136. 1 mole of hydrogen and 2 moles of iodine are taken initially in a 2 liltre vessel. The number of moles of hydrogen at equilibrium is 0.2. Then the number of moles of iodine and hydrogen iodide at equilibrium are

(a) 1.2, 1.6 (b) 1.8, 1.0 (c) 0.4, 2.4 (d) 0.8, 2.0

137. 1 mole of N_2 and 2 moles of H_2 are allowed to react in a 1 dm^3 vessel. At equilibrium 0.8 mole of NH_3 is formed. The concentration of H_2 in the vessel is

(a) 0.6 mole (b) 0.8 mole (c) 0.2 mole (d) 0.4 mole

138. If concentrations of N_2, H_2 and NH_3 are 1, 2 and 3 respectively. Their concentration at equilibrium will be

$N_2 \quad + \quad 3H_2 \quad \square \quad 2NH_3$

(a) $(1-x) \quad (2-3x) \quad 2x$

(b) $\left(1-\frac{x}{3}\right) \quad (2-x) \quad \frac{2x}{3}$

(c) $(1-x) \quad (2-x) \quad (3+x)$

(d) $(1-x) \quad (2-3x) \quad (3+2x)$

139. When 3 moles of ethyl alcohol are mixed with 3 moles of acetic acid, 2 moles of ester are formed at equilibrium according to the equation $CH_3COOH(l) + C_2H_5OH(l) \square CH_3COOC_2H_5(l) + H_2O(l)$. The value of the equilibrium constant for the reaction is

(a) 4 (b) 2/9 (c) 2 (d) 4/9

140. In a reaction, $A+2B \rightleftharpoons 2C$, 2.0 mole of '*A*', 3.0 mole of 'B' and 2.0 mole of '*C*' are placed in a 2.0 L flask and equilibrium concentration of '*C*' is 0.5 mole/L. The equilibrium constant (K) for the reaction is

(a) 0.073 (b) 0.147 (c) 0.05 (d) 0.026

141. In a reaction $A+B \rightleftharpoons C+D$, the initial concentrations of A and B were 0.9 $mol.\ dm^{-3}$ each. At equilibrium the concentration of D was found to be 0.6 mole dm^{-3}. What is the value of equilibrium constant for the reaction

(a) 8 (b) 4 (c) 9 (d) 3

142. At a given temperature, the equilibrium constant for the reactions $NO(g)+\frac{1}{2}O_2(g) \rightleftharpoons NO_2(g)$ and $2NO_2(g) \rightleftharpoons 2NO(g)+O_2(g)$ are K_1 and K_2 respectively. If K_1 is 4×10^{-3}, then K_2 will be

(a) 8×10^{-3} (b) 16×10^{-3} (c) 6.25×10^{4} (d) 6.25×10^{6}

143. If the equilibrium constant for the reaction $2AB \rightleftharpoons A_2+B_2$ is 49. What is the value of equilibrium constant for $AB \rightleftharpoons \frac{1}{2}A_2+\frac{1}{2}B_2$

(a) 49 (b) 2401 (c) 7 (d) 0.02

144. For a hypothetical reaction $A(g)+B(g) \rightleftharpoons X(g)+Y(g)$ occurring in a single step, the specific rate constants are 2.0×10^{-2} and 5.0×10^{3} respectively for the forward and the backward reactions. The equilibrium constant is

(a) 4.0×10^{-4} (b) 2.5×10^{-6} (c) 2.5×10^{5} (d) 4.0×10^{-6}

145. For the reaction, $2NO_2(g) \rightleftharpoons 2NO(g)+O_2(g)$ $K_c=1.8\times10^{-6}$ at 185° C, the value of K_c for the reaction, $NO+\frac{1}{2}O_2 \rightleftharpoons NO_2$ is

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

146. Equilibrium concentration of HI, I_2 and H_2 is 0.7, 0.1, and 0.1 moles/litres. Calculate equilibrium constant for the reaction

$I_2+H_2 \rightleftharpoons 2HI$

(a) 0.36 (b) 36 (c) 49 (d) 0.49

147. Equilibrium constant K_p for the following equilibrium is $CO_2(g)+C(s) \rightleftharpoons 2CO(g)$

(a) $K_p=\frac{p^2{}_{CO}}{p_{CO_2}p_C}$ (b) $K_p=\frac{2p_{CO}}{p_{CO_2}p_C}$ (c) $K_p=\frac{p^2{}_{CO}}{p_{CO_2}}$ (d) $K_p=\frac{\sqrt{p_{CO}}}{p_{CO_2}}$

148. The equilibrium constant K_c for the reaction of H_2 with I_2 is 57.0 at 700 K, $H_2(g)+I_2(g) \underset{k_b}{\overset{k_f}{\rightleftharpoons}} 2HI$; $K_c=57$ at 700 K

Select correct statement

(a) Rate constant k_f for the formation of HI is smaller than that of rate constant k_b of the dissociation of HI

(b) $k_f > k_b$

(c) Addition of catalyst increases value of K_c

(d) Addition of catalyst decreases value of K_c

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

(a) 16.0 atm (b) 0.25 atm (c) 1 atm (d) 0.75 atm

150. The equilibrium constants for the reaction $H_3BO_3+\text{glycerine} \rightleftharpoons (H_3BO_3.\text{glycerine})$ is 0.90. Glycerine present per liter of 0.1 M H_3BO_3 to convert 60% of H_3BO_3 into $(H_3BO_3.\text{glycerine})$ is

(a) 0.167 M (b) 1.73 M (c) 0.0167 M (d) 10.67 M

151. Select the reaction for which the equilibrium constant is written as $[MX_3]^2 = K[MX_2]^2[X_2]$

(a) $MX_3 \rightleftharpoons MX_2 + \frac{1}{2}X_2$ (b) $2MX_3 \rightleftharpoons 2MX_2 + X_2$ (c) $2MX_2 + X_2 \rightleftharpoons 2MX_3$ (d) $MX_2 + \frac{1}{2}X_2 \rightleftharpoons MX_3$

152. K_1 and K_2 are equilibrium constant for reactions (i) and (i)

$N_2(g) + O_2(g) \rightleftharpoons 2NO(g)$ ....(i)

$NO(g) \rightleftharpoons \frac{1}{2}N_2(g) + \frac{1}{2}O_2(g)$ ....(ii)

Then,

(a) $K_1 = \left(\frac{1}{K_2}\right)^2$ (b) $K_1 = K_2^2$ (c) $K_1 = \frac{1}{K_2}$ (d) $K_1 = (K_2)^o$

153. The value of equilibrium constant for an endothermic reaction

(a) Increases with increases of temperature
(b) Decreases with increases of temperature
(c) Is independent of temperature
(d) Sufficient information is not available to answer the questions.

Level-1

154. 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 $K_p \neq 0$

155. The relation between equilibrium constant K_p and K_c is

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

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

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

157. In which of the following equilibria, the value of K_p is less than K_c

(a) $H_2 + I_2 \rightleftharpoons 2HI$ (b) $N_2 + 3H_2 \rightleftharpoons 2NH_3$ (c) $N_2 + O_2 \rightleftharpoons 2NO$ (d) $CO + H_2O \rightleftharpoons CO_2 + H_2$

158. In which one of the following gaseous equilibria K_p is less than K_c

(a) $N_2O_4 \rightleftharpoons 2NO_2$ (b) $2HI \rightleftharpoons H_2 + I_2$ (c) $2SO_2 + O_2 \rightleftharpoons 2SO_3$ (d) $N_2 + O_2 \rightleftharpoons 2NO$

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

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

160. For the reaction $PCl_{5\,(g)} \rightleftharpoons PCl_{3(g)} + Cl_{2(g)}$

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

161. For the following gaseous reaction $H_2 + I_2 \rightleftharpoons 2HI$, the equilibrium constant

(a) $K_p > K_c$ (b) $K_p < K_c$ (c) $K_p = K_c$ (d) $K_p = 1/K_c$

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

(a) $N_2 + 3H_2 \rightleftharpoons 2NH_3$ (b) $N_2 + O_2 \rightleftharpoons 2NO$ (c) $PCl_5 \rightleftharpoons PCl_3 + Cl_2$ (d) $2SO_3 \rightleftharpoons 2SO_2 + O_2$

163. In which of the following case K_p is less than K_c

(a) $PCl_5 \rightleftharpoons PCl_3 + Cl_2$ (b) $H_2 + Cl_2 \rightleftharpoons 2HCl$ (c) $2SO_2 + O_2 \rightleftharpoons 2SO_3$ (d) All of these

164. Consider the imaginary equilibrium

$4A + 5B \rightleftharpoons 4X + 6Y$

The equilibrium constant K_c has the unit

(a) $Mole^2\ litre^{-2}$ (b) $Litre\ mole^{-1}$ (c) $Mole\ litre^{-1}$ (d) $Litre^2\ mole^{-2}$

165. At $700K$, the equilibrium constant K_p for the reaction $2SO_{3(g)} \rightleftharpoons 2SO_{2(g)} + O_{2(g)}$ is 1.80×10^{-13} 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

(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*

166. 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 $25^o C$ is

(a) 0 (b) 2 (c) 4 (d) –1

167. The correct relation between K_p and K_c for the reaction $aX + bY \rightleftharpoons bZ + aW$ is

(a) $K_p = K_c(RT)^{a+b}$ (b) $K_p = \frac{K_c}{(a+b)^2}$ (c) $K_p = K_c(RT)$ (d) $K_p = K_c$

168. For the reaction $H_{2(g)} + I_{2(g)} \rightleftharpoons 2HI_{(g)}$, the equilibrium constant changes with

(a) Total pressure (b) Catalyst

(c) The amounts of H_2 and I_2 taken (d) Temperature

169. Consider the equilibrium reactions

$H_3PO_4 \xrightleftharpoons{K_1} H^+ + H_2PO_4^-$

$H_2PO_4^- \xrightleftharpoons{K_2} H^+ + HPO_4^{-2}$

$HPO_4^{-2} \xrightleftharpoons{K_3} H^+ + PO_4^{-3}$

The equilibrium constant *K* for the following dissociation

$H_3PO_4 \rightleftharpoons 3H^+ + PO_4^{-3}$ is

(a) K_1 / K_2K_3 (b) K_1, K_2, K_3 (c) K_2 / K_1K_3 (d) $K_1 + K_2 + K_3$

170. For the reaction $2NH_3 \rightleftharpoons N_{2(g)} + 3H_{2(g)}$ the unit of K_p will be

(a) atm (b) $(atm)^3$ (c) $(atm)^{-2}$ (d) $(atm)^2$

171. In an exothermic reaction, a $10^o C$ rise in temperature will

(a) Decrease the value of equilibrium constant (b) Double the value of K_c

(c) Not produce any change in K_c (d) Produce some increase in K_c

172. For the homogeneous gas reaction, $4NH_3 + 5O_2 \rightleftharpoons 4NO + 6H_2O$, the equilibrium constant K_c has the dimension of

(a) conc $^{+10}$ (b) conc $^{+1}$ (c) conc $^{-1}$ (d) It is dimensionless

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

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

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

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

175. 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

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

176. 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) $K \times K' = 1$

177. $2NO_2 \rightleftharpoons 2NO + O_2;\ K = 1.6 \times 10^{-12},\ NO + \frac{1}{2}O_2 \rightleftharpoons NO_2;\ K' = ?$

(a) $K' = \frac{1}{K^2}$ (b) $K' = \frac{1}{K}$ (c) $K' = \frac{1}{\sqrt{K}}$ (d) None of these

178. If K_c is the equilibrium constant for the formation of NH_3. the dissociation constant of ammonia under the same temperature will be

(a) K_c (b) $\sqrt{K_c}$ (c) K_c^2 (d) $1/K_c$

179. 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

(a) $K_1 \times K_2$ (b) K_1/K_2 (c) $K_2/\ K_1$ (d) $K_2^2/\ K_1$

180. 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. Then

(a) $K_2 = 0.25K_1$ (b) $K_2 = 0.5K_1$ (c) $K_2 = 4K_1$ (d) $K_2 = 2K_1$

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

(a) $\sqrt{K}$ (b) K^2 (c) $K/2$ (d) $\sqrt{K+1}$

182. For exothermic reactions equilibrium constant decreases with

(a) Rise in temperature (b) Decreases in pressure (c) Decreases in volume (d) None of these

183. 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

(a) $1/K$ (b) $1/K^2$ (c) $\sqrt{K}$ (d) $\sqrt{1/K}$

Level-1

184. 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

(a) 0.002 (b) 0.2 (c) 50.0 (d) $50/RT$

185. In which of the following reaction $K_p > K_c$

(a) $N_2 + 3H_2 \rightleftharpoons 2NH_3$ (b) $H_2 + I_2 \rightleftharpoons 2HI$ (c) $PCl_3 + Cl_2 \rightleftharpoons PCl_5$ (d) $2SO_3 \rightleftharpoons O_2 + 2SO_2$

186. 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 $1065\,^oC$. The value of K_c for this reaction is

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

187. The reaction between N_2 and H_2 to form ammonia has $K_c = 6 \times 10^{-2}$ at the temperature 500^oC. The numerical value of K_p for this reaction is

(a) 1.5×10^{-5} (b) 1.5×10^{5} (c) 1.5×10^{-6} (d) 1.5×10^{6}

188. K_p for the following reaction at $700K$ is $1.3 \times 10^{-3}\ atm^{-1}$. The K_c at same temperature for the reaction $2SO_2 + O_2 \rightleftharpoons 2SO_3$ will be

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

189. For a reaction if $K_p > K_c$, the forward reaction is favoured by

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

190. If dissociation for reaction $PCl_5 \rightleftharpoons PCl_3 + Cl_2$. Is 20% at 1 *atm* pressure. Calculate K_p

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

191. If K_P for a reaction, $A(g)+2B(g)\rightleftharpoons 3C(g)+D(g)$ is 0.05 atm at 1000 K. Its K_c in terms of R will be

(a) $20000\,R$ (b) $0.02\,R$ (c) $5\times10^{-5}\,R$ (d) $\frac{5\times10^{-5}}{R}$

192. For reaction $PCl_3(g)+Cl_2(g)\rightleftharpoons PCl_5(g)$, the value of K_c at 250^oC is 26. The value of K_P at this temperature will be

(a) 0.61 (b) 0.83 (c) 0.57 (d) 0.46

193. K_C for the reaction $N_2(g)+O_2(g)\rightleftharpoons 2NO(g)$ at 300 K is 4.0×10^{-6}. K_P for the above reaction will be $(R = 2\text{ cal mol}^{-1}K^{-1})$

(a) 2.4×10^{-3} (b) 4×10^{-6} (c) $4\times10^{-6}(RT)^2$ (d) 16×10^{-12}

194. For the following equilibrium, $N_2O_4(g)\rightleftharpoons 2NO_2(g)$, K_P is found to be equal to K_C. This is attained when

(a) $T=1K$ (b) $T=12.18K$ (c) $T=27.3K$ (d) $T=273K$

195. Naphthalene, a white solid used to make mothballs, has a vapour pressure of 0.10 *mm Hg* at 27^oC. Hence, K_P and K_C for the equilibrium are $C_{10}H_8(g)\rightleftharpoons C_{10}H_8(g)$

(a) 0.10, 0.10 (b) 0.10, 4.1×10^{-3} (c) $1.32\times10^{-4}, 5.34\times10^{-6}$ (d) $5.34\times10^{-6}, 1.32\times10^{-4}$

196. For the following gaseous equilibria *X, Y* and *Z* at 300 K

$X:\ 2SO_2+O_2\rightleftharpoons 2SO_3$

$Y:\ PCl_5\rightleftharpoons PCl_3+Cl_2$

$Z:\ 2HI\rightleftharpoons H_2+I_2$

ratio of K_P and K_C in the increasing order is

(a) $X = Y = Z$ (b) $X<Y<Z$ (c) $X<Z<Y$ (d) $Z<Y<X$

197. For the reaction, $CO(g)+\frac{1}{2}O_2(g)\rightleftharpoons CO_2(g)$, K_P/K_c is

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

198. *A* and *B* are gaseous substances which react reversibly to give two gaseous substances *C* and *D,* accompanied by the liberation of heat. When the reaction reaches equilibrium, it is observed that $K_P = K_C$. The equilibrium cannot be disturbed by

(a) Adding *A* (b) Adding *D* (c) Raising the temperature (d) Increasing the pressure.

199. When pressure is applied to the equilibrium system, ice ⇌ Water, which of the following phenomenon will happen

(a) More ice will be formed (b) Water will evaporate

(c) More water will be-formed (d) Equilibrium will not be disturbed

Level-1

200. On the velocity in a reversible reaction, the correct explanation of the effect of catalyst is

(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

201. If in the reaction $N_2O_4 = 2NO_2$, α is that part of N_2O_4 which dissociates, then the number of molecules at equilibrium will be

(a) 3 (b) 1 (c) $(1-\alpha)^2$ (d) $(1+\alpha)$

202. In a reversible reaction, the catalyst

(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

203. A reaction attains equilibrium when the free energy change accompanying it is

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

204. The vapour density of completely dissociated NH_4Cl would be

(a) Slight less than half that of NH_4Cl

(b) Half that of NH_4Cl molecule

(c) Double that of NH_4Cl

(d) Determined by the amount of solid NH_4Cl in the experiment

205. A liquid is in equilibrium with its vapour at its boiling point. The molecules in the two phases have equal

(a) Potential energy (b) Kinetic energy (c) Vander Waal's forces (d) Total energy

Level-2

206. The vapour density of N_2O_4 at a certain temperature is 30. What is the percentage dissociation of N_2O_4 at this temperature

(a) 53.3% (b) 106.6% (c) 26.7% (d) None of these

207. Vapour density of PCl_5 is 104.16 but when heated to 230^oC its vapour density is reduced to 62. The degree of dissociation of PCl_5 at this temperature will be

(a) 6.8% (b) 68% (c) 46% (d) 64%

208. At equilibrium, if $K_p = 1$ then

(a) $\Delta G^o = 0$ (b) $\Delta G^o > 1$ (c) $\Delta G^o < 1$ (d) None of these

209. For a system in equilibrium $\Delta G = 0$ under conditions of constant

(a) T and P (b) T and V (c) E and V (d) P and V

210. In a flask colourless N_2O_4 is in equilibrium with brown coloured NO_2. At equilibrium, when the flask is heated at 100^oC the brown colour deepens and on cooling it be comes less coloured. The change in enthalpy ΔH for the system is

(a) Negative (b) Positive (c) Zero (d) Undefined

211. For an endothermic reaction where ΔH represents the enthalpy of the reaction in *kJ/mol* the minimum value for energy of activation will be

(a) Less than ΔH (b) Zero (c) More than ΔH (d) Equal to ΔH

212. Starting with 1 mole of N_2O_4, if α is the degree of dissociation of N_2O_4 for the reaction, $N_2O_4 \rightleftharpoons 2NO_2$

then at equilibrium the total number of moles of N_2O_4 and NO_2 present is

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

213. The degree of dissociation of dinitrogen tetroxide $N_2O_4(g) \rightarrow 2NO_2(g)$ at temperature *T* and total pressure *P* is α. Which one of the following is the correct expression for the equilibrium constant (K_P) at this temperature.

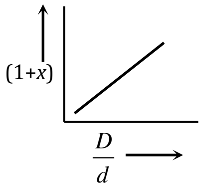
(a) $2\alpha/(1-\alpha^2)$ (b) $\alpha^2P/(1-\alpha)$ (c) $4\alpha^2/(1-\alpha^2)$ (d) $4\alpha^2P/(1-\alpha^2)$

214. 2.2 moles of phosphorus pentachloride were taken in a closed vessel and dissociated into phosphorus trichloride and chlorine. At equilibrium, the total number of moles of the reactant and the products was 2.53. The degree of dissociation is

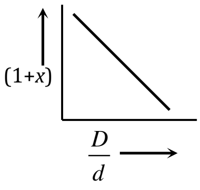
(a) 0.33 (b) 0.165 (c) 0.15 (d) 0.30

215. In the dissociation of N_2O_4 into NO_2, $(1+x)$ values with the vapour densities ratio $\left(\frac{D}{d}\right)$ as given by

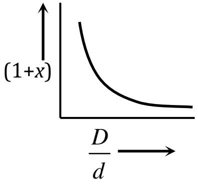
(a)



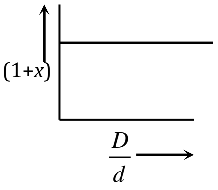
(b)



(c)

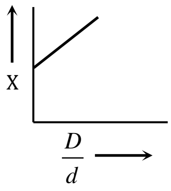


(d)

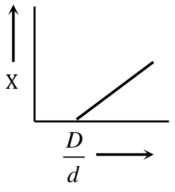


216. In the above question, x varies with $\frac{D}{d}$ according to

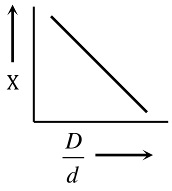
(a)



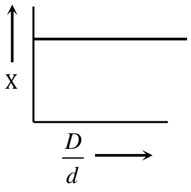
(b)



(c)



(d)



217. For a very small extent of dissociation of PCl_5 into PCl_3 and Cl_2 is a gaseous phase reaction then degree of dissociation *x*

(a) $x \propto P$ (b) $x \propto \frac{1}{P}$ (c) $x \propto \sqrt{P}$ (d) $x \propto \sqrt{\frac{1}{P}}$

218. For a reaction $nA \rightleftharpoons A_n$, degree of dissociation when *A* trimerises is

(a) $2\left(\frac{d-D}{d}\right)$ (b) $\frac{3}{2}\left(\frac{d-D}{d}\right)$ (c) $\frac{4}{3}\left(\frac{d-D}{d}\right)$ (d) $2\left(\frac{D-d}{d}\right)$

219. For the reaction $N_2O_4 \rightleftharpoons 2NO_2$, if degrees of dissociation of N_2O_4 are 25%, 50%, 75% and 100%, the gradation of observed vapour densities is

(a) $d_1 > d_2 > d_3 > d_4$ (b) $d_4 > d_3 > d_2 > d_1$ (c) $d_1 = d_2 = d_3 = d_4$ (d) None of these

220. The equation $\alpha = \frac{D-d}{(n-1)d}$ is correctly matched for

(a) $A \rightleftharpoons nB/2 + nC/3$ (b) $A \rightleftharpoons nB/3 + (2n/3)C$ (c) $A \longrightarrow (n/2)B + (n/4)C$ (d) $A \rightleftharpoons (n/2)B + C$

221. For the reaction $N_2 + O_2 \rightleftharpoons 2NO$ equilibrium constant $K_c = 2$. Degrees of dissociation of N_2 and O_2 are

(a) $\frac{1}{1+\sqrt{2}}, \frac{1}{1-\sqrt{2}}$ (b) $\frac{1}{1-\sqrt{2}}, \frac{1}{1+\sqrt{2}}$ (c) Both are $\frac{1}{1+\sqrt{2}}$ (d) $\frac{2}{1+\sqrt{2}}, \frac{2}{1-\sqrt{2}}$

Level-1

222. $N_2 + O_2 \rightleftharpoons 2NO - Q\ cal$, In the above reaction which is the essential condition for the higher production of *NO*

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

223. Which of the following is not favourable for SO_3 formation $2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$; $\Delta H = -45.0\ kcal$

(a) High pressure (b) High temperature

(c) Decreasing SO_3 concentration (d) Increasing reactant concentration

224. Which of the following reactions proceeds at low pressure

(a) $N_2 + 3H_2 \rightleftharpoons 2NH_3$ (b) $H_2 + I_2 \rightleftharpoons 2HI$ (c) $PCl_5 \rightleftharpoons PCl_3 + Cl_2$ (d) $N_2 + O_2 \rightleftharpoons 2NO$

225. 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)

226. 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

(a) High temperature and high pressure (b) High temperature and low pressure

(c) Low temperature and high pressure (d) Low temperature and low pressure

227. When the pressure is applied over system ice $\rightleftharpoons$ water; what will happen

(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

228. In the reaction $A(g) + 2B(g) \rightleftharpoons C(g) + Q\ kJ$. greater product will be obtained or the forward reaction is favoured by

(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

229. The reaction $CaCO_3 \rightleftharpoons CaO + CO_2(g)$ goes to completion in lime kiln because

(a) Of the high temperature (b) *CaO* is more stable than $CaCO_3$

(c) *CaO* is not dissociated (d) CO_2 escapes continuously

230. In the gaseous equilibrium $H_2X_2 + \text{heat} \rightleftharpoons 2HX$, the formation of *HX* will be favoured by

(a) High pressure and low temperature (b) High temperature and low pressure

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

231. Reaction in which yield of product will increases 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) $CO_{(g)} + 3H_{2(g)} \rightleftharpoons CH_{4(g)} + H_2O_{(g)}$

232. 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

(a) Pressure is increased (b) Temperature is lowered

(c) Pressure is lowered (d) Volume of the reaction vessel is decreased

233. Which of the following conditions is favourable for the production of ammonia by Haber's process

(a) High concentration of reactants (b) Low temperature and high pressure

(c) Continuous removal of ammonia (d) All the above

234. According to Le - Chatelier's principle, which of the following factors influence a chemical system

(a) Concentration only (b) Pressure only

(c) Temperature only (d) Concentration, pressure and temperature

235. Which of the following changes would decrease the dissociation of PCl_5 in the reaction $PCl_5 \rightleftharpoons PCl_3 + Cl_2$

(a) Decrease in pressure (b) Increase in pressure

(c) Addition of an inert gas at constant volume (d) Addition of an inert gas at constant pressure

236. Formation of SO_3 takes place according to the reaction $2SO_2 + O_2 \rightleftharpoons 2SO_3$; $\Delta H = -45.2$ *kcal*. Which of the following factors favours the formation of SO_3

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

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

(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

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

(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

239. 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

(c) The solution will become super saturated (d) Solution concentration will remain unchanged

240. Le-chatelier's principle is applicable only to a

(a) System in equilibrium (b) Irreversible reaction (c) Homogeneous reaction (d) Heterogeneous reaction

241. $H_{2(g)} + I_{2(g)} \rightleftharpoons 2HI_{(g)}$ $\Delta H = +q$ *cal*, then formation of *HI*

(a) Is favoured by lowering the temperature (b) Is favoured by increasing the temperature

(c) Is unaffected by change in pressure (d) Is unaffected by change in temperature

242. 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) $2C_{(s)} + O_{2(g)} \rightleftharpoons 2CO_{(g)}$

243. According to Le - chatelier's principle adding heat to a solid and liquid in equilibrium with endothermic nature will cause the

(a) Temperature to rise (b) Temperature to fall

(c) Amount of solid to decrease (d) Amount of liquid to decrease

244. A solute is soluble in two immiscible liquids which are present in mixture. The concentration of the solute in upper layer of mixture will be

(a) Same as in the lower layer (b) Less than in the lower layer

(c) More than in the lower layer (d) In fixed ratio with that in the lower layer

245. In the equilibrium $N_2 + 3H_2 \rightleftharpoons 2NH_3 + 22\,kcal$, the formation of ammonia is favoured by

(a) Increasing the pressure (b) Increasing the temperature (c) Decreasing the pressure (d) Adding ammonia

246. Under what conditions of temperature and pressure the formation of atomic hydrogen from molecular hydrogen will be favoured most

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

247. The formation of nitric oxide by contact process $N_2 + O_2 \rightleftharpoons 2NO.$ ΔH = 43.20 $kcal$ is favoured by

(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

248. Consider the reaction equilibrium, $2SO_{2(g)} + O_{2(g)} \rightleftharpoons 2SO_{3(g)}$; $\Delta H^0 = -198\ kJ$. 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

249. Which statement is correct about Henry's law

(a) The amount of gas dissolved per unit volume of solvent is directly proportional to pressure of gas
(b) The volume of gas dissolved per unit volume of solvent is independent of pressure of gas
(c) The law is valid only when the gas dissolved neither dissociates nor associates in solvent
(d) All are correct

250. Le - chatelier's principle is valid for

(a) Formation of moles
(b) Rectification of dilute alcohol
(c) Manufacture of H_2SO_4 by contact process
(d) Manufacture of acid by vinegar process

251. Le - chatelier's principle suggests

(a) If system in equilibrium is subjected to a change of concentration, pressure or temperature, the equilibrium shifts in the direction that tends to under the effect of change
(b) Applicable to all types of dynamic equilibrium
(c) Given to study the effect of state variables on the equilibrium
(d) All are correct

252. Solubility of gas in liquid increases on

(a) Increasing the pressure
(b) Decreasing the pressure
(c) Addition of catalyst
(d) Increasing the temperature

253. The gaseous reaction $A + B \rightleftharpoons 2C + D; + Q$ is most favoured at

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

254. Raising the temperature of an equilibrium system

(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

255. The equilibrium $2SO_{2(g)} + O_{2(g)} \rightleftharpoons 2SO_{3(g)}$ shifts forward, if

(a) A catalyst is used
(b) An Adsorbent is used to remove SO_3 as soon as it is formed
(c) Large amounts of reactants are used
(d) Small amounts of reactants are used

256. Raising the temperature of a reversible chemical reaction

(a) Favours the forward rate only
(b) Favours the backward rate only
(c) Favours both the forward and backward rates
(d) Favours neither the forward nor backward rates

257. For the endothermic reaction $2A_{(g)} + B_{(g)} \rightleftharpoons D_{(g)}$, high yields of D will be obtained by having

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

258. According to Le - chatelier's principle, an increase in the temperature of the following reaction $N_2 + O_2 \rightleftharpoons 2NO - 43{,}200\ cal$

(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

259. A reversible reaction is in equilibrium. If a factor is changed which effect 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 nullified the factor causes increases of speed

(d) No difference

260. The effect of increasing the pressure on the equilibrium $2A + 3B \rightleftharpoons 3A + 2B$ is

(a) Forward reaction is favoured

(b) Backward reaction is favoured

(c) No effect

(d) None of the above

261. Which of the following equilibria will shift to right side on increasing the temperature

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

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

(a) Adding more C

(b) Adding more D

(c) Decreasing the temperature

(d) Increasing the temperature

263. For the gas phase reaction $C_2H_4 + H_2 \rightleftharpoons C_2H_6$, $\Delta H = -137\,kJmol^{-}$ carried out in a closed vessel, the equilibrium concentration of C_2H_4 can be increased by

(a) Increasing the temperature

(b) Decreasing the pressure

(c) Removing some C_2H_6

(d) Adding some H_2

264. In which of the following equilibrium systems is the rate of the backward reaction favoured by increase of pressure

(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) $N_2 + O_2 \rightleftharpoons 2NO$

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

(a) Introducing an inert gas at constant volume

(b) Introducing chlorine gas at constant volume

(c) Introducing an inert gas at constant pressure

(d) Decreasing the volume of the container

266. NO_2 (brown colour gas) exists in equilibrium with N_2O_4 (colourless gas) as given by chemical equation, $2NO_2 \rightleftharpoons N_2O_4$

Mixture is slightly brown due to existence of NO_2. If pressure is increased

(a) Colour intensity is increased

(b) Colour intensity is decreased

(c) Colour intensity first increases and then decreases

(d) No change in colour intensity

267. Following equilibrium is disturbed by $CaCO_3(s) \rightleftharpoons CaO(s) + CO_2(g)$

(a) Addition of $CaCO_3$

(b) Addition of CaO

(c) Addition of CO_2

(d) All of these

268. Which factor will shift the following equilibrium in forward direction

$AgCl(s) \rightleftharpoons Ag^+(aq) + Cl^-(aq)$

(a) Addition of $NH_3(aq)$

(b) Addition of $AgNO_3(aq)$

(c) Addition of $NaCl(aq)$

(d) Addition of $AgCl(s)$

269. In the manufacturing of H_2SO_4 with following equilibrium

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

reaction proceeds in the forward direction if

(a) Some SO_2 is added

(b) Some SO_3 is added

(c) Some SO_2 is removed

(d) Some O_2 is removed

Level-1

270. For the equilibrium $2NO_2(g) \rightleftharpoons N_2O_4(G) + 14.6\,kcal$, the increase in temperature would

(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

271. In the formation of SO_3 by contact process, the conditions used are

(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, lower temperature and lower concentration of reactants

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

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

(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

273. The equilibrium which remains unaffected by change in pressure of the reactants is

(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) $2NO_{2(g)} \rightleftharpoons N_2O_4$

274. 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

(a) Increases (b) Decreases (c) Remains unaltered (d) Changes unpredictably

275. The endothermic reaction ($M + N \rightleftharpoons P$) is allowed to attain an equilibrium at $25^o C$. Formation of P can be increased by

(a) Raising temperature (b) Lowering temperature

(c) Keeping temperature constant (d) Decreasing the concentration of M and N

276. In which of the following equilibrium reactions, the equilibrium would shift to the right, if total pressure is increased

(a) $N_2 + 3H_2 \rightleftharpoons 2NH_3$ (b) $H_2 + I_2 \rightleftharpoons 2HI$ (c) $H_2 + Cl_2 \rightleftharpoons 2HCl$ (d) $N_2O_4 \rightleftharpoons 2NO$

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

(a) $2HI \rightleftharpoons H_2 + I_2$ (b) $2SO_2 + O_2 \rightleftharpoons 2SO_3$ (c) $H_2 + Br_2 \rightleftharpoons 2HBr$ (d) $H_2O + CO \rightleftharpoons H_2 + CO_2$

278. In the reaction $A(g) + B(g) \rightleftharpoons C(g)$, the backward reaction is favoured by

(a) Decrease of pressure (b) Increase of pressure (c) Either of the two (d) None of the two

279. In the reaction $A_2(g) + 4B_2(g) \rightleftharpoons 2AB_4(g)$, $\Delta H < 0$ the formation of $AB_4(g)$ will be favoured at

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

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

280. For the chemical reaction, $3X(g) + Y(g) \rightleftharpoons X_3Y(g)$ the amount of X_3Y at equilibrium is affected by

(a) Temperature and pressure (b) Temperature only

(c) Pressure only (d) Temperature, pressure and catalyst

281. In $N_2 + 3H_2 \rightleftharpoons 2NH_3$ reversible reaction, increase in pressure will favour

(a) Reaction in forward direction (b) Reaction in reverse direction

(c) Will not exert any effect (d) In backward and forward direction equally

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

(a) Low pressure (b) High pressure

(c) Low temperature (d) Reduction in the mass of O_2

283. If a mixture containing 3 moles of hydrogen and 1 mole of nitrogen is converted completely into ammonia, the ratio of initial and final volumes at the same temperature and pressure would be

(a) 2 : 1 (b) 1 : 2 (c) 3 : 1 (d) 1 : 3

284. Formation of ammonia is represented by the equation, $N_2 + 3H_2 \rightleftharpoons 2NH_3$. If 100 cm^3 of nitrogen gas is used, what is the volume of ammonia produced at S.T.P

(a) 100 cm^3 (b) 200 cm^3 (c) 400 cm^3 (d) 300 cm^3

285. 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, $2NH_{3(g)} \rightleftharpoons N_{2(g)} + 3H_{2(g)}$; which of the following statements is true

(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

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

286. Consider the equilibrium, $N_{2(g)} + 3H_{2(g)} \rightleftharpoons 2NH_{3(g)}$; $\Delta H = -93.6$ *kJ*. The maximum yield of ammonia is obtained by

(a) Decrease of temperature and increase of pressure

(b) Increase of temperature and decrease of pressure

(c) Decrease of both the temperature and pressure

(d) Increase of both the temperature and pressure

287. 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

(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 of *P* and *x*

288. Le - chatelier principle is not applicable to

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

289. For the reaction : $A + B + Q \rightleftharpoons C + D$, if the temperature is increased, then concentration of the products will

(a) Increase (b) Decrease (c) Remain same (d) Become zero

290. Change in volume of the system does not alter the number of moles in which of the following equilibria

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

291. In which of the following reactions, increase in the volume at constant temperature don't effect 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

292. The yield of product in the reaction $A_{2(g)} + 2B_{(g)} \rightleftharpoons C_{(g)} + Q\,kJ.$ would be high at

(a) High temperature and high pressure (b) High temperature and low pressure

(c) Low temperature and high pressure (d) Low temperature and low pressure

293. Which reaction is not affected by change in pressure

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

294. $A_{2(g)} + 2B_{(g)} \rightleftharpoons 2AB_{(g)}$; $\Delta H = +ve$

(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

295. 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

(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

296. Which of the following factors will favour the reverse reaction in a chemical equilibrium

(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

297. In the reversible reaction of type $A + B \rightleftharpoons AB$, in general

(a) Neither of the reactions will be endothermic

(b) Both the reactions will be exothermic

(c) The combination reaction will be endothermic and the dissociation reaction will be exothermic

(d) The combination reaction will be exothermic and the dissociation reaction will be endothermic

298. In which of the following system, doubling the volume of the container cause a shift to the right

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

299. For the reaction $CO(g) + H_2O(g) \rightleftharpoons CO_2(g) + H_2(g)$ at a given temperature, the equilibrium amount of $CO_2(g)$ can be increased by

(a) Adding a suitable catalyst (b) Adding an inert gas

(c) Decreasing the volume of the container (d) Increasing the amount $CO(g)$

300. In the reaction $4NH_3(g) + 5O_2(g) \rightarrow 4NO(g) + 6H_2O_{(l)}$ when a mole of ammonia and 1 mole of O_2 are made to react to completion

(a) 1.0 mole of H_2O is produced (b) 1.0 mole of NO will be produced

(c) All the oxygen will be consumed (d) All the ammonia will be consumed

301. On addition of an inert gas at constant volume to the reaction $N_2 + 3H_2 \rightleftharpoons 2NH_3$ at equilibrium

(a) The reaction remains unaffected (b) Forward reaction is favoured

(c) The reaction halts (d) Backward reaction is favoured

302. 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

(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

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

(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

304. Consider the reaction $HCN_{(aq)} \rightleftharpoons H^+_{(aq)} + CN^-_{(aq)}$. At equilibrium, the addition $CN^-_{(aq)}$ would

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

(c) Increase the equilibrium constant (d) Decrease the equilibrium constant

305. The chemical reaction : $BaO_{2(s)} \rightleftharpoons BaO_{(s)} + O_{2(g)}$ $\Delta H = +ve.$ in equilibrium condition, pressure of O_2 depends upon

(a) Increase mass of BaO (b) Increase mass of BaO_2

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

306. The following equilibrium exists in aqueous solution $CH_3COOH \rightleftharpoons CH_3COO^- + H^+$. If dilute HCl is added without change in temperature than the

(a) Concentration of CH_3COO^- will increase (b) Concentration of CH_3COO^- will decrease

(c) Equilibrium constant will increase (d) Equilibrium constant will decrease

307. Following gaseous reaction is undergoing in a vessel $C_2H_4 + H_2 \rightleftharpoons C_2H_6$; ΔH = – 32.7 *kcal*. What will increase the equilibrium concentration of C_2H_6

(a) Increase of temperature

(b) By reducing temperature

(c) By removing some hydrogen

(d) By adding some C_2H_6

308. Pure ammonia is placed in a vessel at temperature where its dissociation constant (α) is appreciable. At equilibrium

(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

309. A system in equilibrium is described by the gaseous phase equation

Heat + $SO_2Cl_2 \rightleftharpoons SO_2 + Cl_2$

Which of the following statement is true

(a) Addition of Cl_2 will shift the equilibrium towards right and temperature is raised

(b) Addition of Cl_2 will shift the equilibrium towards left and temperature is raised

(c) Withdrawl of Cl_2 and SO_2 will shift the equilibrium towards left and temperature is raised

(d) Withdrawl of SO_2 and Cl_2 will shift the equilibrium towards left and temperature is lowered.

310. Consider the general hypothetical reaction

$A(s) \rightleftharpoons 2B(g) + 3C(g)$

If the concentration of *C* at equilibrium is doubled, then after the equilibrium is re-established, the concentration of *B* will be

(a) Two times the original value

(b) One half of its original value

(c) $\frac{1}{2\sqrt{2}}$ times the original value

(d) $2\sqrt{2}$ times the original value

311. Consider the water gas equilibrium reaction

$C(s) + H_2O(g) \rightleftharpoons CO(g) + H_2(g)$

Which of the following statement is true at equilibrium

(a) If the amount of $C(s)$ is increased, less water would be formed

(b) If the amount of $C(s)$ is increased, more CO and H_2 would be formed

(c) If the pressure on the system is increased by halving the volume, more water would be formed

(d) If the pressure on the system is increased by halving the volume, more CO and H_2 would be formed.

312. The equilibrium

$P_4(g) + 6Cl_2(g) \rightleftharpoons 4PCl_3(g)$

is attained by mixing equal moles of P_4 and Cl_2 in an evacuated vessel. Then at equilibrium

(a) $[Cl_2] > [PCl_3]$

(b) $[Cl_2] > [P_4]$

(c) $[P_4] > [Cl_2]$

(d) $[PCl_3] > [P_4]$

Level-1

313. Le-chatelier's principle is applicable

(a) At reaction equilibria

(b) At reaction unequilibria

(c) At dissociation of electrolyte

(d) None of these

314. 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

(a) First law of thermodynamics

(b) Le-chatelier's principle

(c) Ostwald's rule
(d) Hess's law of constant heat summation

315. 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

(a) Decreases
(b) Increases
(c) Unaffected
(d) Cannot be described without the value of K_p

316. The rate at which substances react depends on their

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

317. Chemical equations convey quantitative information on the

(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 informed

318. The variation of equilibrium constant with temperature is called

(a) Van't Hoff isotherm
(b) Kirchhoff's equation
(c) Van't Hoff isochore
(d) None of these

319. The effect of temperature on equilibrium constant was first studied by

(a) Arrhenius
(b) Van't Hoff
(c) Lewis
(d) Vander Waal's

320. In the case of gaseous homogeneous reaction, the active mass of the reactant is obtained by the expression

(a) $\frac{PV}{RT}$
(b) $\frac{P}{RT}$
(c) $\frac{RT}{P}$
(d) $\frac{n}{V}RT$

ANSWERSHEET

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
b	c	a	a	c	d	b	d	a	b	c	c	a	b	c	a	d	c	c	b
21	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**31**	**32**	**33**	**34**	**35**	**36**	**37**	**38**	**39**	**40**
d	d	d	c	b	a	c	d	b	b	c	b	b	a	a	c	c	d	a	c
41	**42**	**43**	**44**	**45**	**46**	**47**	**48**	**49**	**50**	**51**	**52**	**53**	**54**	**55**	**56**	**57**	**58**	**59**	**60**
c	a	a	d	c	b	a	c,d	d	a	c	a	a	d	b	a	a	a	d	c
61	**62**	**63**	**64**	**65**	**66**	**67**	**68**	**69**	**70**	**71**	**72**	**73**	**74**	**75**	**76**	**77**	**78**	**79**	**80**
d	b	c	a	d	c	a	c	c	a	c	d	d	b	b	d	c	a	d	d
81	**82**	**83**	**84**	**85**	**86**	**87**	**88**	**89**	**90**	**91**	**92**	**93**	**94**	**95**	**96**	**97**	**98**	**99**	**100**
d	d	c	b	a	c	c	d	b	b	d	c	b	c	b	c	c	c	c	c
101	**102**	**103**	**104**	**105**	**106**	**107**	**108**	**109**	**110**	**111**	**112**	**113**	**114**	**115**	**116**	**117**	**118**	**119**	**120**
a	b	d	b	a	c	d	b	a	d	a	c	a	c	d	d	b	c	d	d
121	**122**	**123**	**124**	**125**	**126**	**127**	**128**	**129**	**130**	**131**	**132**	**133**	**134**	**135**	**136**	**137**	**138**	**139**	**140**
b	a	b	d	c	b	b	d	c	d	c	b	c	d	c	a	b	d	a	c
141	**142**	**143**	**144**	**145**	**146**	**147**	**148**	**149**	**150**	**151**	**152**	**153**	**154**	**155**	**156**	**157**	**158**	**159**	**160**
b	c	c	d	b	c	c	b	b	b	c	a	a	c	b	c	b	c	c	c
161	**162**	**163**	**164**	**165**	**166**	**167**	**168**	**169**	**170**	**171**	**172**	**173**	**174**	**175**	**176**	**177**	**178**	**179**	**180**
c	b	c	c	a	a	d	d	b	d	a	b	b	a	c	b	c	d	c	a
181	**182**	**183**	**184**	**185**	**186**	**187**	**188**	**189**	**190**	**191**	**192**	**193**	**194**	**195**	**196**	**197**	**198**	**199**	**200**
b	a	d	c	d	b	a	d	a	a	d	a	b	b	c	c	c	d	c	a
201	**202**	**203**	**204**	**205**	**206**	**207**	**208**	**209**	**210**	**211**	**212**	**213**	**214**	**215**	**216**	**217**	**218**	**219**	**220**
d	c	b	b	b	a	b	a	a	b	c	d	d	c	d	b	d	b	a	b
221	**222**	**223**	**224**	**225**	**226**	**227**	**228**	**229**	**230**	**231**	**232**	**233**	**234**	**235**	**236**	**237**	**238**	**239**	**240**
c	a	b	c	a	c	a	c	d	b	d	c	d	d	b	b	d	d	b	a
241	**242**	**243**	**244**	**245**	**246**	**247**	**248**	**249**	**250**	**251**	**252**	**253**	**254**	**255**	**256**	**257**	**258**	**259**	**260**
b	a	c	d	a	c	d	c	d	c	d	a	d	b	b,c	c	c	a	c	c
261	**262**	**263**	**264**	**265**	**266**	**267**	**268**	**269**	**270**	**271**	**272**	**273**	**274**	**275**	**276**	**277**	**278**	**279**	**280**
c	c	a,b	a	c	b	c	d	a	b	a	d	a	c	a	a	b	a	a	a
281	**282**	**283**	**284**	**285**	**286**	**287**	**288**	**289**	**290**	**291**	**292**	**293**	**294**	**295**	**296**	**297**	**298**	**299**	**300**
a	b,c	a	b	d	a	d	b	a	a	d	c	a	d	c	c	d	d	d	c
301	**302**	**303**	**304**	**305**	**306**	**307**	**308**	**309**	**310**	**311**	**312**	**313**	**314**	**315**	**316**	**317**	**318**	**319**	**320**
a	a	abcd	b	c	b	b	a	b	c	c	c	a	b	b	d	c	c	b	b