VMC Vidyamandir Classes SINCE 1986

IIT JEE | MEDICAL | FOUNDATION

# Ionic equilibrium

**Ionic equilibrium** → Equilibrium established b/w undissociated molecule and dissociated ions is K/a ionic equilibrium.

$$AB_{(aq)} \rightleftharpoons A^+_{(aq)} + B^-_{(aq)}$$

so eq. established b/w AB, $A^+$, $B^-$ is termed as Ionic equilibrium

**classification of substances on the basis of ionisation** →

(1) **Electrolytes** → The substances which can dissociate into cations and anions in their aq. sol$^n$ are K/a electrolytes.
They are capable of conducting electricity in aq. sol$^n$.

Ex. NaCl, HCl, $CaCl_2$, $MgCl_2$, $CH_3COONa$, NaOH etc.

(2) **Non electrolytes** → The substances which cannot dissociate into ions in aq. sol$^n$ are K/a non electrolytes.
They are not capable of conducting electricity in aq. sol$^n$.

Ex. $C_6H_{12}O_6$ (glucose), $C_{12}H_{22}O_{11}$ (sucrose), $NH_2CONH_2$ (urea) etc.

## Classification of electrolytes →

(1) **Strong electrolytes** → The substances which can ionize completely (100%) in aq. $sol^n$.

* $\alpha = 1$
* Ionization of strong electrolytes is irreversible $Rx^n$.

Ex. (i) **All strong acids** → HCl, HBr, HI, $HNO_3$, $H_2SO_4$, $HClO_4$ etc.

$$HCl_{(aq)} \longrightarrow H^+_{(aq)} + Cl^-_{(aq)}$$

$$H_2SO_{4\,(aq)} \longrightarrow 2H^+_{(aq)} + SO_4^{2-}{}_{(aq)}$$

$$HClO_{4\,(aq)} \longrightarrow H^+_{(aq)} + ClO_4^-{}_{(aq)}$$

Perchloric acid

(ii) **All strong bases** → NaOH, KOH, RbOH, CsOH, $Ba(OH)_2$, $Sr(OH)_2$ etc.

$$NaOH_{(aq)} \longrightarrow Na^+_{(aq)} + OH^-_{(aq)}$$

$$Ba(OH)_{2\,(aq)} \longrightarrow Ba^{2+}_{(aq)} + 2\,OH^-_{(aq)}$$

(iii) All soluble salts — $NaCl$, $KCl$, $KNO_3$, $CH_3COONa$, $NH_4Cl$, $CH_3COONH_4$, $NH_4CN$ etc.

$$NaCl_{(aq)} \longrightarrow Na^+_{(aq)} + Cl^-_{(aq)}$$

$$CH_3COONa_{(aq)} \longrightarrow CH_3COO^-_{(aq)} + Na^+_{(aq)}$$

$$NH_4Cl_{(aq)} \longrightarrow NH_4^+_{(aq)} + Cl^-_{(aq)}$$

(2) Weak electrolytes $\longrightarrow$ The substances which ionise partially in aq. $sol^n$.

* $\alpha < 1$
* Ionisation $Rx^n$ of weak electrolytes is reversible $Rx^n$.

Ex. (i) All weak acids — $HCN$, $H_3PO_4$, $H_3PO_3$, $H_3PO_2$, $CH_3COOH$, $H_2S$, $H_2SO_3$, $H_2CO_3$, $HCOOH$, $C_6H_5COOH$, $H_2C_2O_4$, $HF$ etc.

$$HCN_{(aq)} \rightleftharpoons H^+_{(aq)} + CN^-_{(aq)}$$

$$H_3PO_{4\,(aq)} \rightleftharpoons 3H^+_{(aq)} + PO_4^{3-}{}_{(aq)}$$

$$H_3PO_{3(aq)} \rightleftharpoons 2H^+_{(aq)} + HPO_3^{2-}$$

$$H_3PO_{2(aq)} \rightleftharpoons H^+_{(aq)} + H_2PO^-_{2(aq)}$$

$$CH_3COOH_{(aq)} \rightleftharpoons CH_3COO^-_{(aq)} + H^+_{(aq)}$$

$$H_2CO_{3(aq)} \rightleftharpoons 2H^+_{(aq)} + CO^{2-}_{3(aq)}$$

$$C_6H_5COOH_{(aq)} \rightleftharpoons H^+_{(aq)} + C_6H_5COO^-_{(aq)}$$

Benzoic acid

(ii) All weak bases → Ex. $NH_4OH$, $NH_3$, $LiOH$, $Mg(OH)_2$, $Fe(OH)_3$ etc.

(iii) All sparingly soluble substances —

Ex. $AgCl$, $PbCl_2$, $Pb(OH)_2$, $ZnCl_2$ etc.

(iv) $H_2O$ is weak electrolyte.

## Classification of acid and base →

### (1) Arrhenius theory →

Acid → Substances which can produce $H^+$ ions in aq. sol$^n$.

Base → Substances which can produce

$OH^-$ ions in aq. solⁿ.

**Ex.**

$$HCl_{(aq)} \longrightarrow H^+_{(aq)} + Cl^-_{(aq)}$$

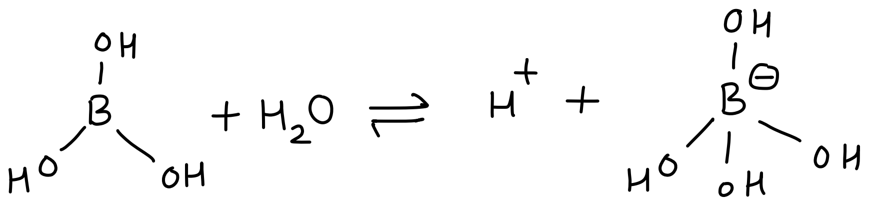
A.A.

$$H_2SO_{4\,(aq)} \longrightarrow 2H^+_{(aq)} + SO_4^{2-}{}_{(aq)}$$

A.A.

$$CH_3COOH_{(aq)} \rightleftharpoons CH_3COO^-_{(aq)} + H^+_{(aq)}$$

A.A.



(Boric acid) or $[B(OH)_4]^-$

A.A.

$$KOH_{(aq)} \longrightarrow K^+_{(aq)} + OH^-_{(aq)}$$

A.B.

$$NH_4OH_{(aq)} \rightleftharpoons NH_4^+{}_{(aq)} + OH^-_{(aq)}$$

A.B.

$$NH_3 + H_2O \rightleftharpoons NH_4^+ + OH^-$$

A.B.

## (2) Lewis theory (Electronic concept) —

Lewis acid = lone pair acceptor

Lewis base = lone pair donor

### Exa. of lewis acid —

Cations → $H^+$, $Na^+$, $K^+$, $Mg^{2+}$ etc.

Species having Incomplete octet → $BeF_2$, $BeCl_2$, $AlCl_3$, $BF_3$, $BCl_3$, $BBr_3$, $BI_3$ etc.

Species Capable to expand octet → $SiF_4$, $PCl_5$, $SF_6$, $IF_7$ etc.

Species having Polar π-bond → $CO_2$, $SO_2$, $SO_3$ etc

$O=C=O$

Transition metal ion/atom → $Ag^+$, $Cu^{2+}$, Fe, Ni etc.

Diatomic molecules having vacant Molecular orbitals → $F_2$, $Cl_2$, $Br_2$, $I_2$ etc.

### Exa. of Lewis base →

All anions → $H^-$, $OH^-$, $CN^-$, $O^{2-}$, $HS^-$, $NH_2^-$, $NH^{2-}$, $N^{3-}$ etc.

Neutral molecules in which octet of central atom is complete and having $lp\ e^-$ for donation.

<u>Ex.</u> $H_2\ddot{O}:$ , $R-\ddot{\underset{..}{O}}H$ , $R-\ddot{\underset{..}{O}}-R$ , $\ddot{N}H_3$ , $R-\ddot{N}H_2$ ,

$R-\ddot{N}H-R$ , $R-\dot{N}(R)-R$ etc.

## (3) Bronsted-lowry theory (protonic concept) →

Bronsted acid = Proton donor

Bronsted base = Proton acceptor.

* This concept can be used in aq. phase, non aq. phase, gas phase.

<u>Ex.</u>

$$\underset{\substack{\text{Proton donor}\\(B.A.)}}{HX} + \underset{\substack{\text{Proton acceptor}\\(B.B.)}}{H_2O} \rightleftharpoons X^- + H_3O^+$$

$$\underset{\substack{\text{Proton acceptor}\\(B.B.)}}{X^-} + \underset{\substack{\text{Proton donor}\\(B.A.)}}{H_2O} \rightleftharpoons HX + OH^-$$

$$HC_2O_4^- + NH_3 \rightleftharpoons NH_4^+ + C_2O_4^{2-}$$

$HC_2O_4^-$: Proton donor (B.A.)

$NH_3$: Proton acceptor (B.B.)

$$HS^- + NH_3 \rightleftharpoons H_2S + NH_2^-$$

$HS^-$: Proton acceptor (B.B.)

$NH_3$: Proton donor (B.A.)

The substances which can act as both (bronsted acid and bronsted base) are known as amphiprotic substances.

$H_2O$ (A.P.S.)

$$H_2O \xrightarrow{H^+} H_3O^+$$

$$H_2O \xrightarrow{-H^+} OH^-$$

$NH_3$ (A.P.S.)

$$NH_3 \xrightarrow{H^+} NH_4^+$$

$$NH_3 \xrightarrow{-H^+} NH_2^-$$

$O^{2-}$ only (B.B.)

$$O^{2-} \xrightarrow{H^+} OH^-$$

$$O^{2-} \xrightarrow{-H^+} \times$$

$H_2PO_4^-$ (A.P.S.)

$$H_2PO_4^- \xrightarrow{H^+} H_3PO_4$$

$$H_2PO_4^- \xrightarrow{-H^+} HPO_4^{2-}$$

$HPO_4^{2-}$ (A.P.S.)

$HPO_4^{2-} \xrightarrow{H^+} H_2PO_4^-$

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

$PO_4^{3-}$ only (B.B.)

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

$PO_4^{3-} \xrightarrow{-H^+} \times$

$H_2PO_3^-$ (A.P.S.)

$H_2PO_3^- \xrightarrow{H^+} H_3PO_3$

$H_2PO_3^- \xrightarrow{-H^+} HPO_3^{2-}$

$HPO_3^{2-}$ only (B.B.)

$HPO_3^{2-} \xrightarrow{H^+} H_2PO_3^-$

$HPO_3^{2-} \xrightarrow{-H^+} \cancel{PO_3^{3-}}$

$H_2PO_2^-$ only (B.B.)

$H_2PO_2^- \xrightarrow{H^+} H_3PO_2$

$H_2PO_2^- \xrightarrow{-H^+} \cancel{HPO_2^{2-}}$

$$\underbrace{H_3BO_3 + H_2O}_{\text{Neither bronsted acid nor bronsted base}} \rightleftharpoons H^+ + [B(OH)_4]^-$$

$[Al(H_2O)_6]^{3+}$ only (B.A.)

$[Al(H_2O)_6]^{3+} \xrightarrow{H^+} \times$

$[Al(H_2O)_6]^{3+} \xrightarrow{-H^+} [Al(H_2O)_5(OH)]^{2+}$

## Conjugate acid - base Pair →

$$\text{Acid} \xrightarrow{-H^+} \text{conjugate base}$$

$$\text{Base} \xrightarrow{H^+} \text{conjugate acid}$$

**Ex.**

$$\underset{(B.B.)}{C_2O_4^{2-}} + \underset{(B.A.)}{NH_3} \rightleftharpoons \underset{\text{(Conjugate acid)}}{HC_2O_4^-} + \underset{\text{(Conjugate base)}}{NH_2^-}$$

$$\underset{(B.A.)}{HSO_4^-} + \underset{(B.B.)}{H_2O} \rightleftharpoons \underset{(C.B.)}{SO_4^{2-}} + \underset{(C.A.)}{H_3O^+}$$

**Q.** Which of the following Pair is conjugate acid-base Pair ?

(A) $(HC_2O_4^-, H_2C_2O_4)$ (B) $(HS^-, S^{2-})$

(C) $(HCN, CN^-)$ (D) $(H_2SO_4, SO_4^{2-})$

(E) $(HS^-, Cl^-)$ (F) $(H_2O, H_3O^+)$

**Soln →**

$$\underset{\text{base}}{HC_2O_4^-} \xrightarrow{H^+} \underset{(C.A.)}{H_2C_2O_4}$$

$$\underset{\text{acid}}{HS^-} \xrightarrow{-H^+} \underset{(C.B.)}{S^{2-}}$$

$$HCN \xrightarrow{-H^+} CN^-$$

acid          (C.B.)

$$H_2SO_4 \xrightarrow{-2H^+} SO_4^{2-}$$

$$HS^- \longrightarrow Cl^-$$

$$H_2O \xrightarrow{H^+} H_3O^+$$

base          (C.A.)

## (4) On the basis of no. of transfer of $H^+$ or $OH^-$ ions $\longrightarrow$

**Acid**

**Monobasic acid or Monoprotic acid**

$HCl$, $HBr$, $HI$, $HClO_4$, $HNO_3$, $HCN$, $H_3PO_2$, $H_3BO_3$, $CH_3COOH$, $HCOOH$, $C_6H_5COOH$, $HNO_2$

**Dibasic acid or Diprotic acid**

$H_2SO_4$, $H_3PO_3$, $H_2SO_3$, $H_2S_2O_8$, $H_2S$, $H_2S_2O_7$, $H_2C_2O_4$, $H_2CO_3$

**tribasic or triprotic acid**

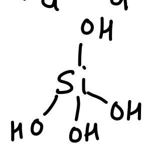
$H_3PO_4$

**Tetra basic or Tetra protic**

$H_4P_2O_7$

$H_4P_2O_8$

$H_4SiO_4$




Silicic acid

Base

- Monoacidic base
  - $LiOH$, $NaOH$, $KOH$, $RbOH$, $CsOH$, $NH_3$, $NH_4OH$ etc.
- Diacidic base
  - $Mg(OH)_2$
  - $Ba(OH)_2$
  - $Sr(OH)_2$
  - $Ca(OH)_2$
- Triacidic base
  - $Fe(OH)_3$

**13.** Morphine $(C_{17}H_{19}NO_3)$, which is used medically to relieve pain is a base. What is its conjugate acid?

**(A)** $C_{17}H_{18}NO_3^+$ **(B)** $C_{17}H_{18}NO_3$ **(C)** $C_{17}H_{20}NO_3^-$ **(D)** $C_{17}H_{20}NO_3^+$

$$\underset{\text{base}}{C_{17}H_{19}NO_3} \xrightarrow{H^+} \underset{(C.A.)}{C_{17}H_{20}NO_3^+}$$

2. Three reactions involving $H_2PO_4^-$ are given below :

I. $H_3PO_4 + H_2O \longrightarrow H_3O^+ + H_2PO_4^-$

II. $H_2PO_4^- + H_2O \longrightarrow HPO_4^{2-} + H_3O^+$

III. $H_2PO_4^- + OH^- \longrightarrow H_3PO_4 + O^{2-}$

In which of the above does $H_2PO_4^-$ act as an acid ?

(A) II only (B) I and II (C) III only (D) I only

62. Conjugate base of $HO_2^-$ is :

(A) $O_2^-$ (B) $H_2O_2$ (C) $O_2^{2-}$ (D) $O_2^+$

$$\underset{\text{acid}}{HO_2^-} \xrightarrow{-H^+} \underset{\text{(C.B.)}}{O_2^{2-}}$$

74. In the reaction, $I_2 + I^- \longrightarrow I_3^-$ the Lewis base is :

(A) $I_2$ (B) $I^-$ (C) $I_3^-$ (D) None of these

$$\underset{\text{(L.A.)}}{I_2} + \underset{\text{(L.B.)}}{I^-} \longrightarrow \underset{\text{(Salt)}}{I_3^-}$$

2. Species acting as both Bronsted acid and base is: **(1992)**

(A) $HSO_4^-$ (B) $Na_2CO_3$ (C) $NH_3$ (D) $OH^-$

$HSO_4^- \xrightarrow{H^+} H_2SO_4$

$HSO_4^- \xrightarrow[-H^+]{} SO_4^{2-}$

$Na_2CO_3 \longrightarrow$ only B.B

$NH_3 \xrightarrow{H^+} NH_4^+$

$NH_3 \xrightarrow[-H^+]{} NH_2^-$

$OH^- \xrightarrow{H^+} H_2O$

$OH^- \xrightarrow[-H^+]{} O^{2-}$

**9.** Aluminium chloride ($AlCl_3$) is a Lewis acid because it can donate electrons. (True/False) **(1982)**

False

$AlCl_3 \longrightarrow$ Lewis acid (lp $e^-$ acceptor)

**83.** Which is Bronsted lowry acid as well as Arrhenius acid.

**(A)** $H_2$ **(B)** $HCO_3^-$ **(C)** $NH_3$ **(D)** $NH_2^-$

$\underset{(A.B.)}{NH_3} + H_2O \longrightarrow NH_4^+ + OH^-$

$\underset{(A.B.)}{NH_2^-} + H_2O \longrightarrow NH_3 + OH^-$

$NH_3, NH_2^- \longrightarrow$ A.P.S.

$\underset{\begin{pmatrix}A.A.\\B.A.\end{pmatrix}}{HCO_3^-} + H_2O \longrightarrow CO_3^{2-} + H_3O^+$