Class: XI Chemistry
Chapter 7: EQUILIBRIUM
Module 4 of 6

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Contents

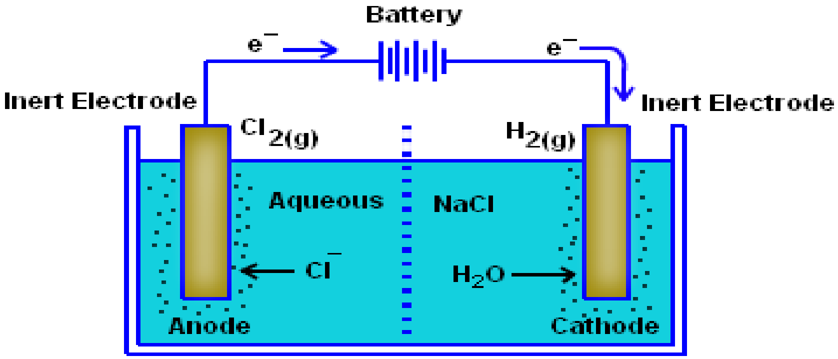
This module contains:

- ***Strong Electrolytes***
- ***Weak Electrolytes***
- ***Various Theories for Acids and Bases viz.***
  - ***Arrhenius theory,***
  - ***Bronsted-Lowry theory ,***
  - ***Lewis theory***

Electrolytes

- Substances which can conduct electricity in their aqueous solution due to ionization are known as **electrolytes**. The presence of ions in solution is responsible for the conduction and when the current passes through the wires, it shows the movement of free electrons through wire. This process of dissociation and flow of ions in aqueous solution of electrolyte is known as **electrolysis.**

Example: Electrolysis of sodium chloride in its aqueous solution gives sodium and chloride ion in solution.



Strong Electrolytes

- **Strong Electrolytes:**

“The electrolytes which ionise completely or near to completely are called strong electrolytes.”

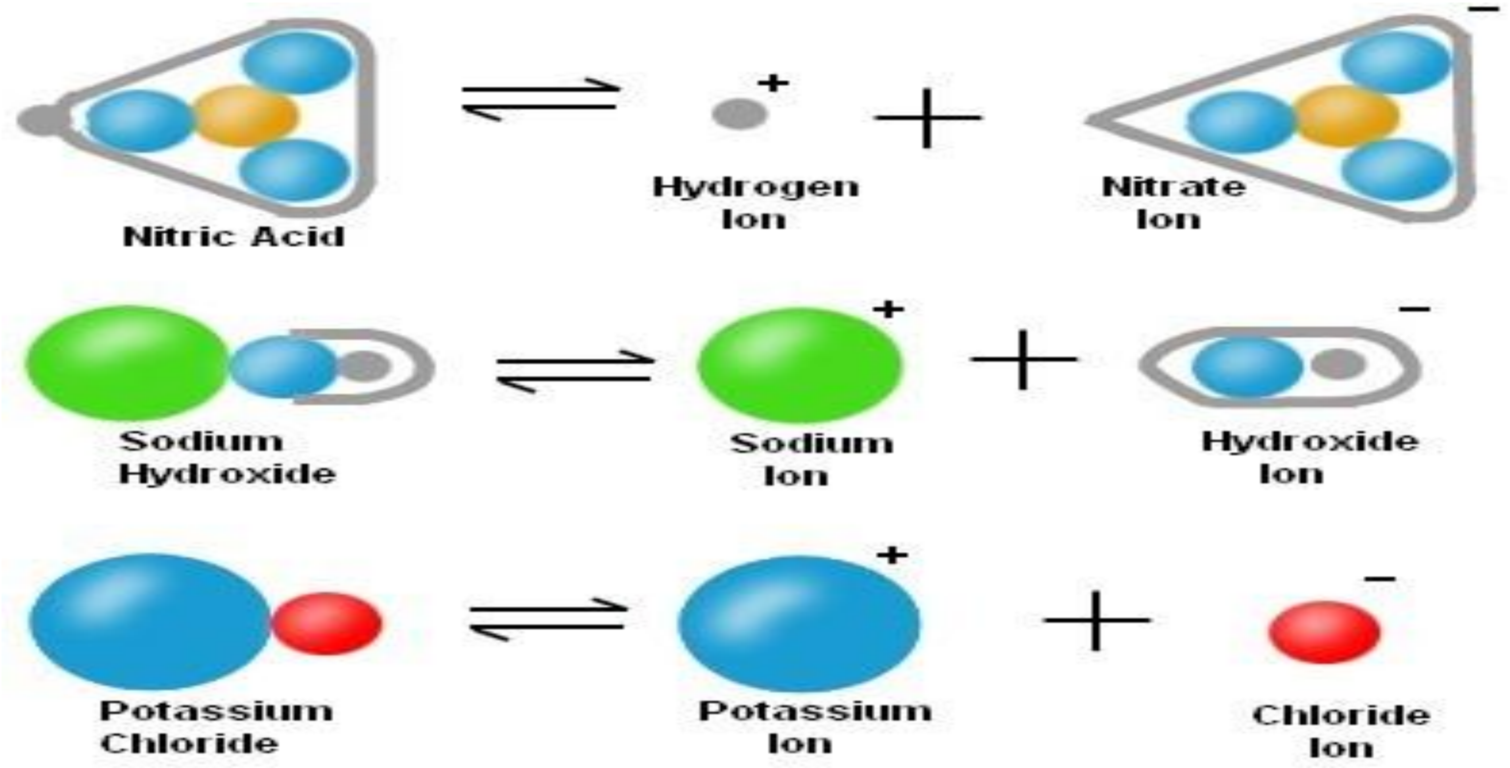
General Examples:

- ***Strong Acids.***
- ***Strong Bases***
- ***Salts***

Examples:

- **HCl, H_2SO_4, $NaOH$, KOH, $NaCl$, KBr, $AgCl$**

Examples of Strong Electrolytes



Strong electrolytes like salts are composed of oppositely charged ions. In solid state, these ions are held by strong electrostatic forces of attractions. When theses electrolytes are dissolved in water, the attraction forces between ions are highly weakened due to high dielectric constant of water.

Examples of Strong Electrolytes

Hydrochloric Acid	(HCl)
Nitric Acid	(HNO_3)
Sulphuric Acid	(H_2SO_4)
Hydro Bromic Acid	(HBr)
Hydro Iodic Acid	(HI)
Per Chloric Acid	($HClO_4$)
Acetic Acid	(CH_3COOH)
Carbonic Acid	(H_2CO_3)
Ammonia	(NH_3)
Lithium Hydroxide	($LiOH$)
Sodium Hydroxide	($NaOH$)
Potassium Hydroxide	(KOH)
Rubidium Hydroxide	($RbOH$)
Cesium Hydroxide	($CsOH$)
Calcium Hydroxide	($Ca(OH)_2$)
Strontium Hydroxide	($Sr(OH)_2$)
Barium Hydroxide	($Ba(OH)_2$)

Weak Electrolytes

Electrolytes which are weakly ionized in their aqueous solution are called as weak electrolytes.

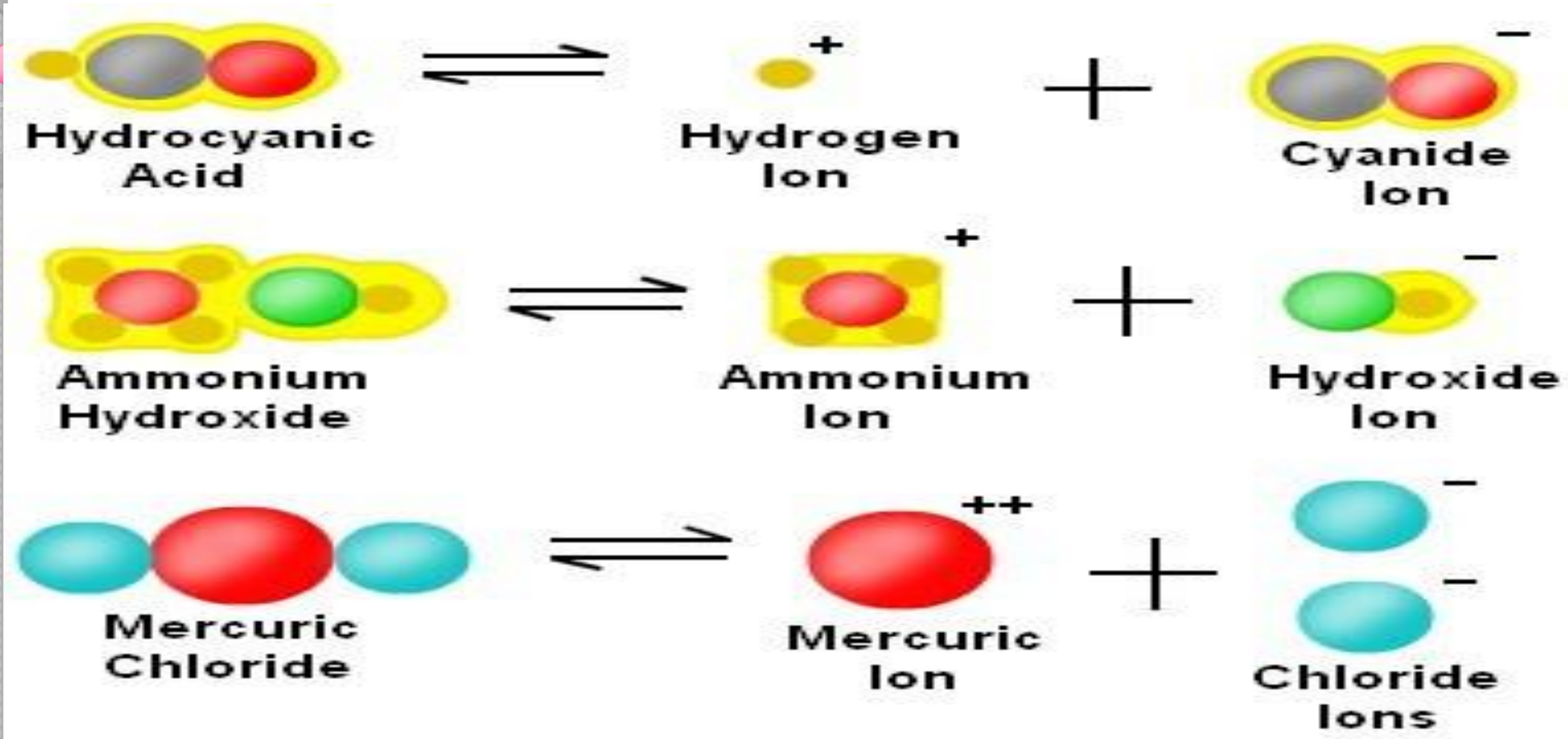
In the aqueous solution of weak electrolytes, the constituent ions are in equilibrium with un-dissociated molecules of electrolytes.

This type of equilibrium involving ions in aqueous solution is called ionic equilibrium.

The dissociation of weak electrolyte is represented by $\rightleftharpoons$

Example: $CH_3COOH + H_2O \rightleftharpoons H_3O^+ + CH_3COO^-$

Weak Electrolytes



Such type of equilibrium exists between ions and unionized molecule is called as ionic equilibrium. The fraction of molecules dissociates can be represented by using degree of dissociation.

Generally weak acids and weak bases are good examples of weak electrolytes.

List of Weak Electrolytes

S.No.	Weak electorate	Chemical formula
1	Acetic acid	CH_3COOH
2	Hydrocyanic acid	HCN
3	Ammonium hydroxide	NH_4OH
4	Ammonia	NH_3
5	Hydrofluoric acid	HF
6	Carbonic acid	H_2CO_3
7	Mercuric chloride	$HgCl_2$
8	Chromic acid	H_2CrO_4
9	Boric acid	H_2BO_3
10	Nitrous acid	HNO_2

Degree of Dissociation(α)

- *The degree of dissociation of an electrolyte is defined as a fraction of total number of moles of the electrolyte that dissociates into its ions when the equilibrium is attained. It is denoted by Alpha (α) and given as:*

$$\alpha = \frac{\text{Number of moles dissociated}}{\text{Total number of moles}}$$

Non-Electrolytes

- *Non-electrolytes are the substances which cannot conduct electricity in their aqueous solution due to the absence of ions. They are generally polar or non-polar covalent compounds which can dissolve in water as molecules instead of ions.*

As covalent compounds contain covalent bonds between bonded atoms, therefore cannot be ionized in their solution and exists in the form of molecule only.

Example, Sugar ($C_{12}H_{22}O_{11}$), alcohols are soluble in water but remain in molecular form only.

$$C_{12}H_{22}O_{11}(s) \rightarrow C_{12}H_{22}O_{11}(aq)$$

List of Non-Electrolytes

S.No	Non-electrolyte	Chemical formula
1	Sucrose	$C_{12}H_{22}O_{11}$
2	Glucose	$C_6H_{12}O_6$
3	Ethanol	C_3H_3OH
4	Methanol	CH_3OH
5	Carbon tetrachloride	CCl_4
6	Carbon disulphide	CS_2
7	Kerosene	Hydrocarbons
8	Chemically pure water	H_2O
9	Urea	NH_2CONH_2
10	Dichloromethane	CH_2Cl_2
11	Glycerol	$CH_2OH\text{-}CHOH\text{-}CH_2OH$
12	Methylsulfonylmethane (MSM)	$(CH_3)_2\ SO_2$
13	Carbon dioxide	CO_2
14	Oxygen	O_2
15	Sulphur dioxide	SO_2

Arrhenius Concept of Acids and Bases

Arrhenius Concept of Acid and Bases

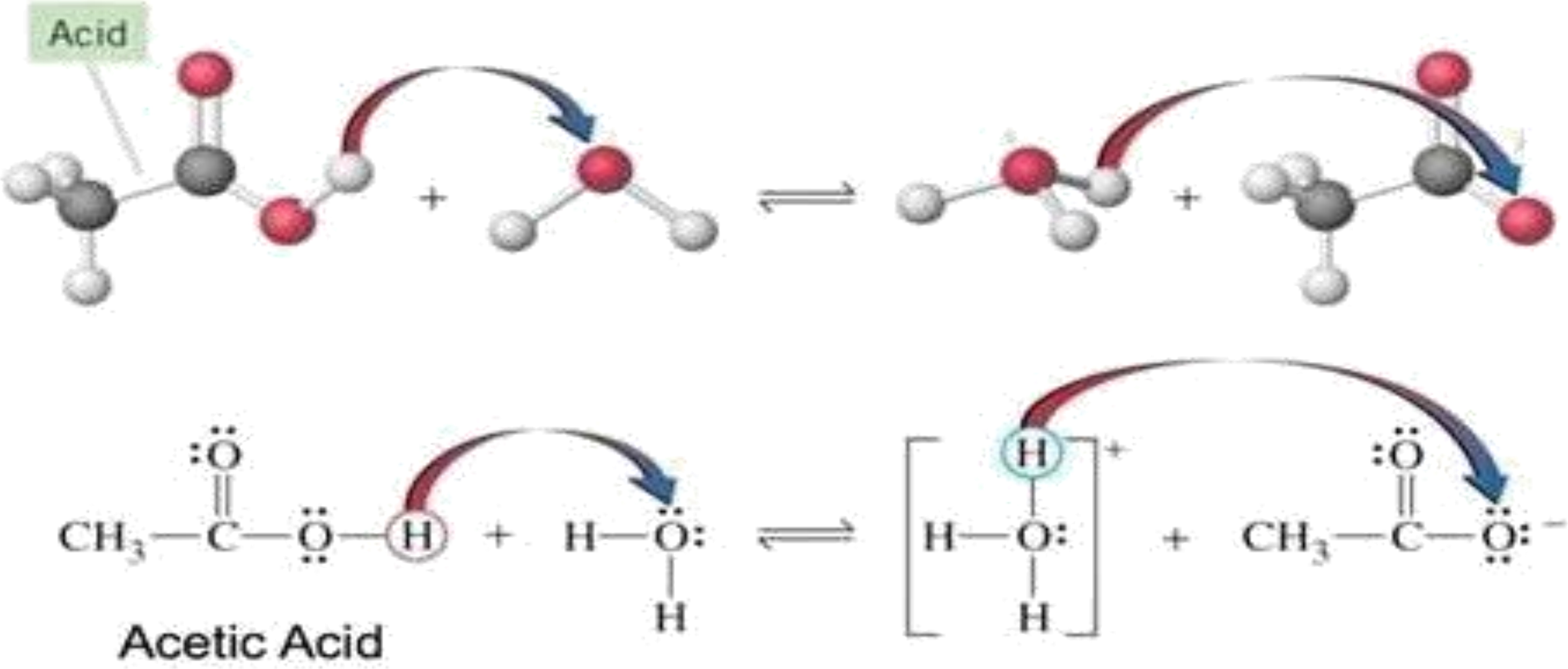
- *In 1884 the Swedish chemist Svante August Arrhenius (1859-1927) proposed that acids and bases can be defined in terms of the chemical species they form when they dissolve in water.*

Svante August Arrhenius(1859-1927)

Arrhenius was awarded the 1903 Nobel prize in Chemistry for proporsing that ionic compounds can divide into oppositely charged particle in solution.

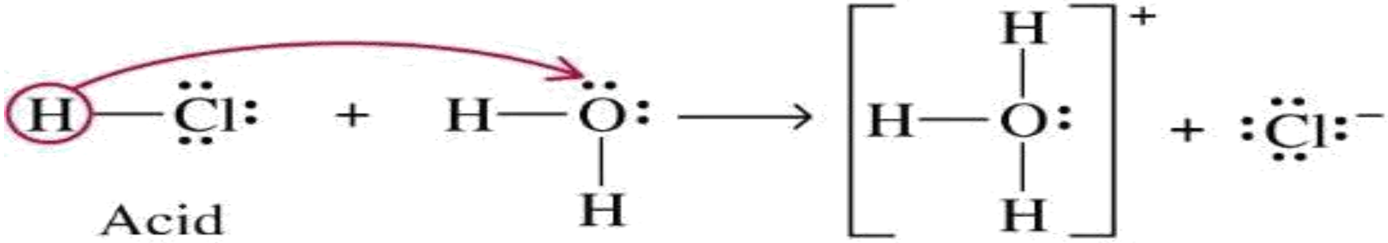
Arrhenius Concept of Acid and Bases

- **Arrhenius Acid:** According to Arrhenius theory, acid is a substance which has hydrogen atom and can be given in the form of hydrogen ion in aqueous solution. Such substances are called as Arrhenius acids. For example, when acetic acid (CH_3COOH) dissolves in water, it will form acetate ion (CH_3COO^-) and hydronium ion (H_3O^+).

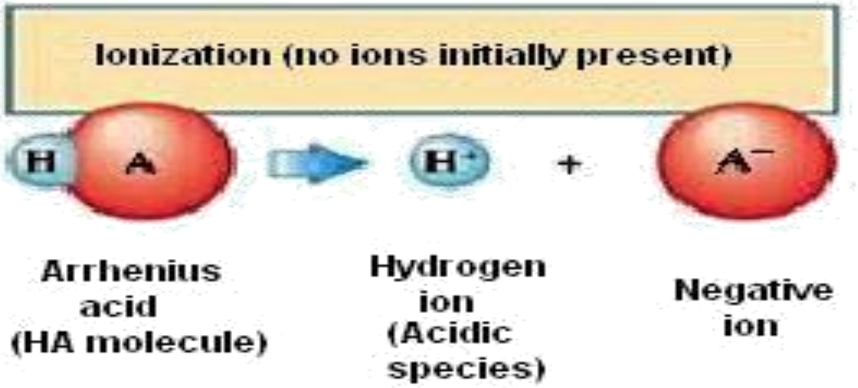


Arrhenius Concept of Acid and Bases

In the same way, HCl acts as Arrhenius acid in water and it converts to Cl^- ion by transferring hydrogen ion to water.



When Arrhenius acids are in pure state (not in solution) they are covalent compounds, that is, they do not contain H^+ ions. The ions are formed through an interaction between water and the acid when they are mixed. Ionization is the process in which individual positive and negative ions are produced from a molecular compound that is dissolved in solution.



Arrhenius Concept of Acid and Bases

STRENGTH OF ARRHENIUS ACIDS:

On the basis of ionization of acid , they can be classified into two types:

Strong acid: Those acids, which are completely ionized and give maximum number of proton (H^+) in a solution are known as strong acid. The value of acid dissociation constant or strong acids (K_a) is very high.

Hence, the strength of acid is directly proportional to the acid dissociation constant (K_a). <u>Example</u>: HCl, HNO_3, H_2SO_4 etc.

Weak acid: Those acids which are partially ionized i solution, like, acetic acid, hydrofluoric acid etc. are know as weak acids. The acid dissociation constant is less fo weak acids compared to strong acids.

<u>Example</u>: CH_3COOH, H_2CO_3, H_3PO_4 etc.

Arrhenius Concept of Acid and Bases

S.No.	Acid	Chemical formula	Ka
1	Per chlorate	HClO4	Very large
2	Hydrochloric	HI	Very large
3	Hydrophobic	HBr	Very large
4	Hydrochloric	HCl	Very large
5	Nitric	HNO_3	Very large
6	Sulfuric	H_2SO_4	Very large
7	Hydroponic ion	H_3O+	1.0
8	Ionic	HIO_3	1.7×10^{-1}
9	Oxalic	$H_2C_2O_4$	5.9×10^{-2}
10	Sulfurous	H_2SO_3	1.5×10^{-2}
11	Hydrogen sulfate ion	HSO_4	1.2×10^{-2}
12	PHOSPHORIC	H_3PO_4	7.5×10^{-3}
13	Citric	$H_3C_6H_5O_7$	7.1×10^{-4}
14	Nitrous	HNO_2	4.6×10^{-4}
15	Hydrofluoric	HF	3.5×10^{-4}
16	Formic	HCOOH	1.8×10^{-4}
17	Cenozoic	C_6H_5COOH	6.5×10^{-4}
18	Acetic	CH_3COOH	1.8×10^{-5}
19	Water	H_2O	1.0×10^{-14}

Arrhenius Concept of Acid and Bases

Arrhenius Base: An Arrhenius base is a hydroxide containing compound that produces hydroxide ions (OH- ions) in water. The basic species in Arrhenius theory is thus the hydroxide ion. For this reason Arrhenius bases are also called hydroxide bases.

Example:

- $NaOH(aq) \rightarrow Na^+ + OH^-$ produces OH^- in water.
- Some other examples of Arrhenius bases are KOH, $Ca(OH)_2$, NH_4OH etc.
- $KOH(aq) \rightarrow K^+ + OH^-$
- $NH_4OH(aq) \rightarrow NH_4^+ + OH^-$

Arrhenius Concept of Acid and Bases

STRENGTH OF ARRHENIUS BASES

On the basis of ionization of base, they can be classified into two types:
***Strong base**: Those bases, which when dissolved in water dissociate completely to give OH- ions are known as strong bases.*
The value of base dissociation constant or strong bases (Kb) is

very high. Hence, the strength of base is directly proportional to the base dissociation constant (Kb).

Example: NaOH, KOH etc**.**

***Weak base:** Those bases which are partially ionized in solution, are known as weak bases. The base dissociation constant is less for weak bases compared to strong bases.*
Example: NH_4OH, $Ca(OH)_2$, $Al(OH)_3$ etc.

Arrhenius Concept of Acid and Bases

STRENGTH OF ARRHENIUS BASES

Base	Formula	K_b
Ammonia	NH_3	4.75
Aniline	$C_6H_5NH_2$	9.37
Codeine	$C_{18}H_{21}O_3N$	6.05
Diethylamine	$(C_2H_5)_2NH$	4.51
Dimethylamine	$(CH_2)NH$	3.23
Ethylamine	$C_2H_5NH_2$	3.36
Hydrazine	N_2H_4	5.77
Hyroxylamine	$HONH_2$	9.04
Methylamine	CH_3NH_2	3.38
Morphine	$C_{17}H_{19}O_3N$	6.13
Piperidine	C_5H_5N	2.88
Pyridine	C_5H_5N	8.70
Quinoline	C_9H_7N	9.20
Triethanlamine	$C_6H_{15}O_3N$	6.24
Triethylamine	$(C_2H_5)_3N$	3.28
Trimethylamine	$(CH_3)_3N$	4.20

Arrhenius Concept of Acid and Bases

- **In Summary: As per Arrhenius Theory**

Acid:

Any substance that produces hydrogen ion (H^+) or hydronium ion (H_3O^+) when dissociating in water is ACID

Example:

$$HCl\ (aq) \longrightarrow H^+\ (aq) + Cl^-\ (aq)$$

$$HCl\ (aq) + H_2O\ (l) \longrightarrow H_3O^+(aq) + Cl^-\ (aq)$$

&

Base:

Any substance that produces hydroxide ions (OH^-) when dissociating in water is BASE.

Example:

$$NaOH\ (aq) \longrightarrow Na^+\ (aq) + OH^-(aq)$$

THE BRONSTED –LOWRY ACIDS AND BASES

THE BRONSTED –LOWRY ACIDS AND BASES

In 1923, J.N. Bronsted and T.M. Lowry independently developed the theory of proton donors and proton acceptors in acid-base reactions, coincidentally in the same region and during the same year. The main effect of the Bronsted-Lowry definition is to identify the proton (H^+) transfer occurring in the acid-base reaction. This is best illustrated in the following equation:

Bronsted

$$HA + Z \leftrightarrow A^- + HZ^+$$

Lowry

THE BRONSTED –LOWRY ACIDS AND BASES

In Bronsted-Lowry Theory:

Acid: Any substance that **can donate a proton, (H^+)** to other substance

Example:

$HNO_3\,(aq) + H_2O\,(l) \rightleftharpoons NO_3^-\,(aq) + H_3O^+\,(aq)$

$NH_4^+\,(aq) + H_2O\,(l) \rightleftharpoons NH_3\,(aq) + H_3O^+\,(aq)$

Base: Any substance that **can accept a proton** from other substance

Example:

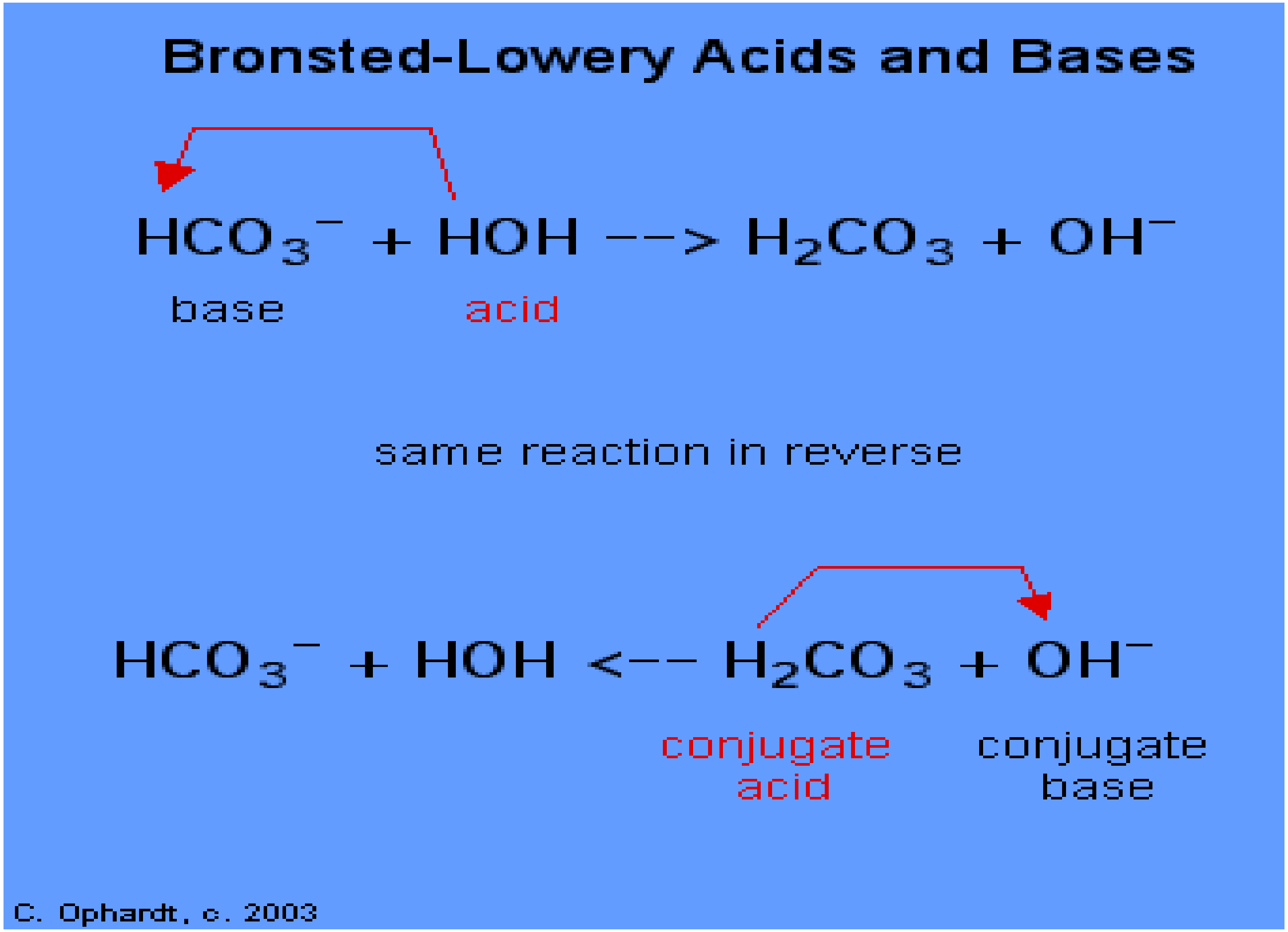
$NH_3\,(aq) + H_2O\,(l) \rightleftharpoons NH_4^+\,(aq) + OH^-\,(aq)$

$CO_3^{2-}\,(aq) + H_2O\,(l) \rightleftharpoons HCO_3^-\,(aq) + OH^-\,(aq)$

Note:

H_2O is able to act as an acid or a base : **AMPHOTERIC**

THE BRONSTED –LOWRY ACIDS AND BASES



Bronsted-Lowery Acids and Bases

$HCO_3^- + HOH \dashrightarrow H_2CO_3 + OH^-$

base acid

same reaction in reverse

$HCO_3^- + HOH \dashleftarrow H_2CO_3 + OH^-$

conjugate acid conjugate base

C. Ophardt, c. 2003

THE BRONSTED –LOWRY ACIDS AND BASES

Bronsted-Lowry Theory:Conjugate Acid-base Pairs

- **Conjugate base**
  - A species that remains when one proton has been removed from the Bronsted acid.
  - Or
  - **A base form the loss of proton by an acid called conjugate base of the acid.**
- **Conjugate acid**
  - A species that remains when one proton has been added to the Bronsted base.
  - **Or**
  - **An acid form the gain of proton by a base is called conjugate acid of the base.**

THE BRONSTED –LOWRY ACIDS AND BASES

- **CONJUGATE ACID-BASE PAIRS:** ***The acid-base pairs which are formed by loss or gain of a proton are called conjugate acid-base pairs. Eg:***

CONJUGATE PAIRS

$ACID_1$		$BASE_2$		$ACID_2$		$BASE_1$
HCl	+	H_2O	↔	H_3O^+	+	Cl^-
H_2O	+	NH_3	↔	NH_4^+	+	OH^-
HCl	+	NH_3	↔	NH_4^+	+	Cl^-

THE BRONSTED –LOWRY ACIDS AND BASES

ADVANTAGES OF BRONSTED -LOWRY CONCEPT:

- It is not limited to molecules but includes even the ionic species to act as acids or bases.
- It does not require aqueous medium to explain acidic or basic nature.
- It can explain the basic nature of ions or molecules having no OH^- ion. E.g. NH_3, Na_2CO_3 etc.

LIMITATIONS OF BRONSTED -LOWRY CONCEPT:

I. It could not explain the acidic and basic nature of compounds having no tendency to lose or gain H^+ ions. E.g: CO_2, SO_2, SO_3 etc.

II. It could not explain the basic nature of compounds having OH- ions. E.g. NaOH, $Ca(OH)_2$, KOH etc.

Lewis Theory for Acid and Bases

Lewis Theory for Acid and Bases

In 1923, ***G.N. Lewis*** *proposed a broader concept of acids and bases. This concept eliminated the necessity of the presence of hydrogen in an acid and this included many more substances as acids and bases.*

According to this concept, an acid is an electron pair acceptor while a base is an electron pair donor.

Lewis Theory for Acid and Bases

Acid: A substance that can accept a pair of electrons to form a covalent bond.

The species that can be Lewis acid are

- **Cations such as H^+, Fe^{2+}, Al^{3+}**
- **molecules with incomplete octet central atom such as BF_3, $BeCl_2$**
- **Molecules with central atom that can expand octet such as $PCl_{3\,,}$ SiF_{4},**
- **Molecules containing multiple bond such as CO_2, SO_2.**

Base: A substance that can donate a pair of electrons to form a covalent bond.

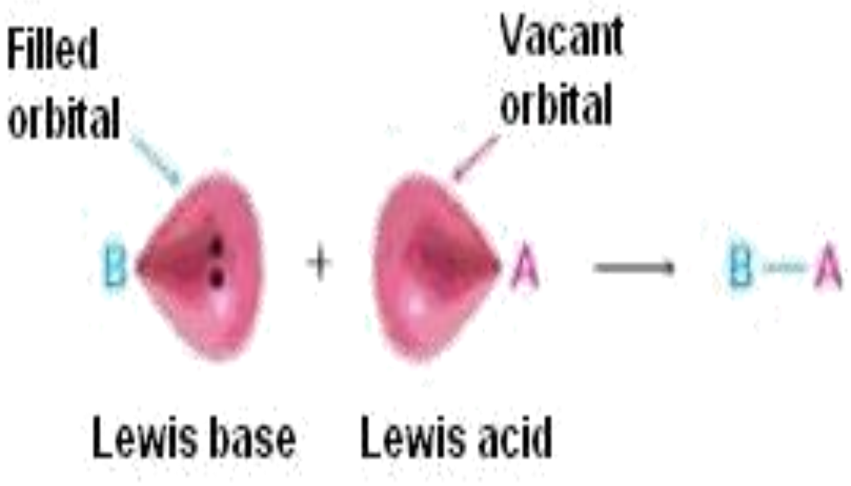
The species that can be Lewis base are

- **anions such as OH^-, CN^-, Cl^-**
- **molecules with lone pairs electrons at the central atom such as H_2O, NH_3, ROH**

Lewis Theory for Acid and Bases

- **Lewis Acid:** A Lewis acid is an electron pair acceptor. The accepted electron pair is shared between the acid and the base in the covalent bond**.** Thus, Lewis definition of acidity includes many species in addition to H+.

For example, various metal cations, such as Mg2+ and metal compounds such as AlCl3 are Lewis acids because they have vacant valence orbitals and can accept electron pairs from Lewis bases.



Lewis Theory for Acid and Bases

Type of Lewis Acids:

i. Molecules having a central atom with incomplete octet. E.g. BF_3, $AlCl_3$, $FeCl_3$.

ii. Simple cations. E.g. Ag^+, Cu^+, Fe^{3+}.

iii. Molecules having central atoms with empty d-orbitals. E.g. SiF_4, PCl_5.

iv. Molecules containing a multiple bond between two atoms of different electro negativities.

v. E.g. CO_2,SO_2.

Lewis Theory for Acid and Bases

Lewis Base: *The substance that donates the electron pair. The donated electron pair is shared between the acid and the base in the covalent bond.*

In a more general sense, most oxygen and nitrogen containing organic compounds can act as Lewis bases because they have pairs of electrons.

TYPES OF LEWIS BASES

- *Neutral molecules like NH_3, $R\text{-}NH_2$, etc.*
- *All negative ions like F^-, Cl^-, Br^-, I^-, OH^- etc.*

Lewis Theory for Acid and Bases

LIMITATIONS OF LEWIS CONCEPT

I. *The necessary requirement in Lewis concept is the formation of a coordinate bond between the acid and base. This is a slow process but in actual practice, acid-base reactions are extremely fast.*

II. *It does not explain the behavior of protonic acid such as HCl, H_2SO_4 etc.*

III. *The catalytic activity of an acid is due to H+ (aq.) ion. Since the presence of hydrogen is not an essential requirement for a Lewis acid, many Lewis acids will not have this property.*

Module 4 of 6 Ends…