Acids, Bases and Salts

Acid

An acid is a compound which when dissolved in water yields hydronium ions (H_3O^+) as the only positively charged ions.

Examples: $HCl \rightleftharpoons H^+ + Cl^-$

$H^+ + H_2O \rightleftharpoons H_3O^+$

Hydrogen ion Hydronium ion

Classification of Acids

1. Depending on sources

Organic acid: Acids which are usually obtained from plants are called organic acids. They contain carbon and hydrogen atoms.

Examples:

Organic Acids	Occurrence
Acetic acid	Vinegar
Citric acid	Citrus fruits (oranges, lemons)

Inorganic (Mineral) acids: Acids which are obtained from minerals are known as inorganic acids.

Examples:

Inorganic Acids	Chemical Formulae
Hydrochloric acid	HCl
Sulphuric acid	H_2SO_4
Nitric acid	HNO_3

2. Depending on strength

(a) Strength of an acid: The strength of an acid depends on the concentration of the hydronium ions (H_3O^+) present in the aqueous solution of an acid.

i. **Strong acids:** A strong acid vigorously ionises in aqueous solution, thereby producing a high concentration of hydronium ions (H_3O^+).
Examples: HNO_3, HCl, H_2SO_4

ii. **Weak acids:** Weak acids ionise only partially in aqueous solution to produce ions and molecules.
Examples: H_2CO_3, CH_3COOH, HCOOH

3. Depending on basicity

Basicity of an acid: The number of hydronium ions (H_3O^+) which can be produced by the ionisation of one molecule of that acid in aqueous solution.

i. **Monobasic acids:** Acids which on ionisation in water produce one hydronium ion (H_3O^+) per molecule of the acid are known as monobasic acids.
Example: $HCl + H_2O \rightleftharpoons H_3O^+ + Cl^-$ [Basicity = 1]

ii. **Dibasic acids:** Acids which on ionisation in water produce two hydronium ions (H_3O^+) per molecule of the acid are known as dibasic acids.
Examples: $H_2SO_4 + H_2O \rightleftharpoons H_3O^+ + HSO_4^-$

$HSO_4^- + H_2O \rightleftharpoons H_3O^+ + SO_4^{2-}$ [Basicity = 2]

iii. **Tribasic acids:** Acids which on ionisation in water produce three hydronium ions (H_3O^+) per molecule of the acid are known as tribasic acids.

Examples: $H_3PO_4 + H_2O \rightleftharpoons H_3O^+ + H_2PO_4^-$

$H_2PO_4^- + H_2O \rightleftharpoons H_3O^+ + HPO_4^{2-}$

$HPO_4^{2-} \rightleftharpoons H_3O^+ + PO_4^{3-}$ [Basicity = 3]

4. Depending on concentration

The concentration of an acid means the amount of acid present in a definite amount of its aqueous solution.

i. **Concentrated acid:** An acid which contains a very small amount of water or no water is called a concentrated acid.

ii. **Dilute acid:** An acid which contains far more amount of water than its own mass is known as a dilute acid.

5. Depending on molecular composition

i. **Hydracids:** Acids which contain hydrogen, a non-metallic element and no oxygen are called hydracids. Examples: HCl, H_2S, HBr, HI

ii. **Oxyacids:** Acids which contain oxygen, hydrogen and a non-metallic element are called oxyacids. Examples: H_2SO_4, HNO_3, H_2CO_3

Preparation of Acids

1. By synthesis

$H_2 + Cl_2 \rightarrow 2HCl$

2. By the action of water on non-metallic or acidic oxides

$SO_3 + H_2O \rightarrow H_2SO_4$

$N_2O_5 + H_2O \rightarrow 2HNO_3$

3. By oxidation of non-metals

$S + 6HNO_3 \rightarrow H_2SO_4 + 2H_2O + 6NO_2$

$P + H_3PO_4 \rightarrow H_3PO_4 + H_2O + 5O_2$

4. By displacement

$NaCl + H_2SO_4 \rightarrow NaHSO_4 + HCl$

$NaNO_3 + H_2SO_4 \rightarrow NaHSO_4 + HNO_3$

Properties of Acids

Physical properties

i. Sour in taste in aqueous solution.

ii. Turns blue litmus red.

iii. Some acids are solids and some are liquids at room temperature.

iv. All strong mineral acids have corrosive action on the skin and cause painful burns.

v. They are electrolytes, i.e. they conduct electricity in the aqueous state.

Chemical Properties

1. **Reaction with active metals**
   $Mg + 2HCl \rightarrow MgCl_2 + H_2$

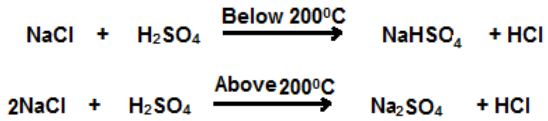
2. **Reaction with bases - Neutralisation**
   $NaOH + H_2SO_4 \rightarrow NaNO_3 + H_2O$

3. **Reaction with carbonates and bicarbonates**
   $CaCO_3 + 2HCl \rightarrow CaCl_2 + H_2O + CO_2$

4. **Reaction with sulphites and bisulphites**
   $CaSO_3 + 2HCl \rightarrow CaCl_2 + H_2O + SO_2$
   $NaHSO_3 + HCl \rightarrow NaCl + H_2O + SO_2$

5. **Reaction with sulphides**
   $ZnS + 2HCl \rightarrow ZnCl_2 + H_2S$

6. **Reaction with chlorides**



7. **Reaction with nitrates**
   $Pb(NO_3)_2 + 2HCl \rightarrow PbCl_2 + 2HNO_3$

Uses of Some Acids

Acid	Use
Boric acid	Eye wash/antiseptic
Citric acid	Food preservation
Oxalic acid	Ink stain remover
Carbonic acid	Flavoured drinks

Bases

A base is either a metallic oxide or a metallic hydroxide or ammonium hydroxide which reacts with hydronium ions of an acid to form salt and water only.

Basic Oxide

A basic oxide is a metallic oxide which contains the ion O^{2-} and reacts with an acid to form salt and water.

Alkalis

An alkali is a basic hydroxide which when dissolved in water produces hydroxyl (OH^-) ions as the only negatively charged ions.

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

Note: All alkalis are bases, but all bases are not alkalis.

Classification of Bases

1. **On the basis of strength**
   i. **Strong base:** It undergoes almost complete ionisation in aqueous solution to produce a high concentration of OH^- ions.
   Example: $NaOH_{(aq)} \rightleftharpoons Na^+_{(aq)} + OH^-_{(aq)}$
   ii. **Weak base:** It undergoes only partial ionisation in aqueous solution to produce a low concentration of OH^- in solution.
   Example: $NH_4OH_{(aq)} \rightleftharpoons NH^+_{(aq)} + OH^-_{(aq)}$

2. **On the basis of acidity**
   a. Acidity of a base: The number of hydroxyl ions (OH^-) which can be produced per molecule of the base in aqueous solution.
   i. **Monoacidic base:** Bases which dissociate in aqueous solution to produce one hydroxyl ion (OH^-) per molecule of the base are called monoacidic bases.
   Example: $NaOH \rightleftharpoons Na^+ + OH^-$ [Acidity = 1]
   ii. **Diacidic base:** Bases which dissociate in aqueous solution to produce two hydroxyl ions (OH^-) per molecule of the base are called diacidic bases.
   Example: $Ca(OH)_2 \rightleftharpoons Ca^{2+} + 2OH^-$ [Acidity = 2]
   iii. **Triacidic base:** Bases which dissociate in aqueous solution to produce three hydroxyl ions (OH^-) per molecule of the base are called triacidic bases.
   Example: $Al(OH)_3 \rightleftharpoons Al^{3+} + 3OH^-$ [Acidity = 3]
   iv. By oxidation of non-metals
   $S + 6HNO_3 \xrightarrow{\text{Boiling}} H_2SO_4 + 2H_2O + 6NO_2$

3. **On the basis of composition**
   Concentrated alkali: It is an alkali with a relatively high percentage of alkali in its aqueous solution.
   Dilute alkali: It is an alkali with a relatively low percentage of alkali in its aqueous solution.

Preparation of Bases

i. From Metals
$2Mg + O_2 \longrightarrow 2MgO$

ii. By action of water or steam on reactive metals
$2Na + 2H_2O \longrightarrow 2NaOH + H_2$

iii. By the action of water on soluble metallic oxides
$Na_2O + H_2O \longrightarrow 2NaOH$

iv. By double decomposition
$FeCl_3 + 3NaOH \longrightarrow Fe(OH)_3 + 3NaCl$

v. By the action of oxygen on metal sulphides
$2ZnS + 3O_2 \longrightarrow 2ZnO + 2SO_2$

vi. By decomposition of salts
$CaCO_3 \longrightarrow CaO + CO_2$

Properties of Bases

Physical properties

1. They have sharp and bitter taste.
2. They change red litmus blue.
3. Soapy substances, i.e. they are slippery to touch.
4. They are strong electrolytes.
5. They show mild corrosive action on the skin.

Chemical properties

1. **Reaction with carbon dioxide**

   $2NaOH + CO_2 \longrightarrow Na_2CO_3 + H_2O$

2. **Reaction with acids - Neutralisation**

   $Ca(OH)_2 + 2HCl \longrightarrow CaCl_2 + 2H_2O$

3. **Reaction with metallic salts**

   $CuSO_4 + 2NH_4OH \longrightarrow (NH_4)_2SO_4 + Cu(OH)_2$

Uses of Some Bases

Base	Use
Sodium hydroxide	Manufacture of soaps
Potassium hydroxide	Manufacture of salts and soaps In batteries
Magnesium hydroxide	An antacid
Magnesia	In making refractory bricks

pH Value

It represents the strength of acids and alkalis expressed in terms of hydrogen ion concentration.

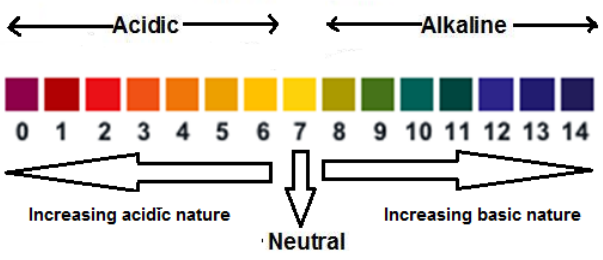
pH of Solution

pH of a solution is the negative logarithm to the base 10 of the hydrogen ion concentration expressed in mole per litre.

$pH = -\log_{10}(H^+)$

pH Scale

It is a scale showing the relative strength of acids and alkalis.
The normal pH scale ranges from 0 to 14 as shown below.



Indicators

They are complex substances which acquire separate colours in acidic and basic media.

Types of Indicators

a. **Acid–base indicators:** Common acid–base indicators such as litmus, methyl orange and phenolphthalein can distinguish between acid and basic solutions, but they cannot determine the strength of the solution.
b. **Universal indicator:** A universal indicator is a mixture of organic dyes which gives a definite colour change over a wide range of pH.

Salts

A salt is a compound formed by the partial or total replacement of the ionisable hydrogen atoms of an acid by a metallic ion or an ammonium ion.

Classification of Salts

1. **Normal salts:** The salts formed by the complete replacement of the replaceable hydrogen ion of an acid molecule by a basic radical.
   Example:
   $HCl + NaOH \longrightarrow NaCl + H_2O$
2. **Acid salts**: The salts formed by partial replacement of the replaceable hydrogen ion of an acid molecule by a basic radical.
   Example:
   $NaOH + H_2SO_4 \longrightarrow NaHSO_4 + H_2O$
3. **Basic salts:** The salts formed by the partial replacement of the hydroxyl group of a di- or tri-acidic base by an acidic radical.
   Example:
   $Mg(OH)_2 + HCl \longrightarrow Mg(OH)Cl + H_2O$
4. **Double salts**: The salts formed by the union of two simple salts which dissolve in water and crystallise.
   Example:
   Potash alum: $K_2SO_4 . Al_2(SO_4)_3 . 24H_2O$
5. **Mixed salts:** Mixed salts are those salts which contain more than one basic or acidic radical.
   Example:
   Sodium potassium carbonate $NaKCO_3$
6. **Complex salts:** Complex salts are those salts which on dissociation give one simple ion and one complex ion.
   Example:
   $Na[Ag(CN)_2] \rightleftharpoons Na^+ + [Ag(CN)_2]^-$

Preparation of Soluble Salts

Method	Reaction
1. Direct combination	Metal + Non-metal $\longrightarrow$ Salt $2Na + Cl_2 \longrightarrow 2NaCl$
2. Simple displacement	Active metal + Acid $\longrightarrow$ Salt + Hydrogen $Zn + H_2SO_4 \longrightarrow ZnSO_4 + H_2$
3. Decomposition a. Decomposition of bicarbonates b. Decomposition of carbonates c. Decomposition of chlorides d. Decomposition of nitrates	$NaHCO_3 + HCl \longrightarrow NaCl + H_2O + CO_2$ $CuCO_3 + 2HCl \longrightarrow 2CuCl_2 + H_2O + CO_2$ $NaCl + H_2SO_4 \xrightarrow{\text{Below } 200^0C} NaHSO_4 + HCl$ $KNO_3 + H_2SO_4 \xrightarrow{\text{Below } 200^0C} KHSO_4 + HNO_3$
4. Neutralisation	$HNO_3 + NaOH \longrightarrow NaNO_3 + H_2O$

Preparation of Insoluble Salts

1. By direct combination
   Reaction: $Pb + S \longrightarrow PbS$
2. By combination of an acidic oxide with a basic oxide
   Reaction: $SO_2 + CaO \longrightarrow CaSO_3$
3. Double decomposition
   Reactions: $BaCl_2 + H_2SO_4 \longrightarrow BaSO_4 + 2HCl$

Laboratory Preparation of some Normal and Acid Salts

1. Iron (III) chloride or anhydrous ferric chloride

It is prepared by passing dry chlorine gas over heated iron.

$Fe + Cl_2 \longrightarrow FeCl_3$

2. Copper (II) sulphate

It is prepared by the reaction of copper oxide, copper hydroxides or copper carbonates with dilute sulphuric acid.

$CuO + H_2SO_4 \longrightarrow CuSO_4 + H_2O$

$Cu(OH)_2 + H_2SO_4 \longrightarrow CuSO_4 + 2H_2O$

$CuCO_3 + H_2SO_4 \longrightarrow CuSO_4 + H_2O$

$CuSO_4 + 5H_2O \longrightarrow CuSO_4.5H_2O$

3. Zinc sulphate and iron (II) sulphate

It is prepared by the reaction of metals with dilute sulphuric acid.

$Zn + H_2SO_4 \longrightarrow ZnSO_4 + H_2O$

$ZnSO_4 + 7H_2O \longrightarrow FeSO_4.7H_2O$

4. Lead chloride

It is prepared by adding either dilute hydrochloric acid or sodium chloride solution to a solution of lead nitrate.

$Pb(NO_3)_2 + 2HCl \longrightarrow PbCl_2 + 2HNO_3$

5. Calcium carbonate

It is prepared by adding sodium carbonate solution to a hot solution of calcium chloride.

$CaCl_2 + Na_2CO_3 \longrightarrow CaCO_3 + 2NaCl$

6. Sodium bicarbonate

It is prepared by passing excess of carbon dioxide gas through a saturated solution of sodium carbonate.

$Na_2CO_3 + CO_2 + H_2O \longrightarrow 2\ NaHCO_3$

7. Neutralisation

It is the process by which H^+ ions of an acid react completely with the $[OH^-]$ ions of a base to give salt and water only.

Example: HCl (Acid) + NaOH (Base) $\longrightarrow$ NaCl (Salt) + H_2O (water)

Water of Crystallisation

It is the amount of water molecules which enter into loose chemical combination with one molecule of the substance on crystallisation from its aqueous solution.

Hydrated Salt

The salts which contain a definite number of water molecules as water of crystallisation are called hydrated salts.

Examples: $Na_2CO_3.10H_2O$ (washing soda), $CuSO_4.5H_2O$ (blue vitriol)

Anhydrous Salt

A salt which does not contain any water of crystallisation is called an anhydrous salt.

Examples: NaCl, $NaNO_3$, $Pb(NO_3)_2$

Deliquescence

Water soluble salts which on exposure to the atmosphere absorb moisture from the atmosphere, dissolve in the same and change into a solution. The phenomenon is called deliquescence and the salts deliquescent.

Examples: $CaCl_2$, $MgCl_2$, $ZnCl_2$

Efflorescence

Crystalline hydrated salts which on exposure to the atmosphere lose their water of crystallisation partly or completely and change into a powder. This phenomenon is called efflorescent and the salts efflorescent.

Examples: $CuSO_4.5H_2O$, $MgSO_4.7H_2O$, $Na_2CO_3.10H_2O$