CHEMISTRY

Acids, Bases and Salts

Introduction to Acids, Bases and Salts
Classification of matter

On the basis of
a) composition - elements, compounds and mixtures
b) state - solids, liquids and gases
c) solubility - suspensions, colloids and solutions

Types of mixtures - homogeneous and heterogeneous
Types of compounds - covalent and ionic

What Is an Acid and a Base?

Ionisable and non-ionisable compounds

An ionisable compound when dissolved in water or in its molten state, dissociates into ions almost entirely. Example: NaCl, HCl, KOH, etc.
A non-ionisable compound does not dissociate into ions when dissolved in water or in its molten state. Example: glucose, acetone, etc.

Arrhenius theory of acids and bases

Arrhenius acid - when dissolved in water, dissociates to give $H^+(aq)$ or H_3O^+ ion.
Arrhenius base - when dissolved in water, dissociates to give OH^- ion.

Examples

Acids

- Hydrochloric acid (HCl)
- Sulphuric acid (H_2SO_4)
- Nitric acid (HNO_3)

Bases

- Sodium hydroxide (NaOH)
- Potassium hydroxide (KOH)
- Calcium hydroxide $(Ca(OH)_2)$

Bronsted Lowry theory

A Bronsted acid is a $H^+(aq)$ ion donor.
A Bronsted base is a $H^+(aq)$ ion acceptor.

Example
In the reaction: $HCl(aq) + NH_3(aq) \rightarrow NH_4^+(aq) + Cl^-(aq)$
HCl - Bronsted acid and Cl^- - its conjugate acid
NH_3 - Bronsted base and NH_4^+ - its conjugate acid

Physical test

Given are two possible physical tests to identify an acid or a base.

a. Taste

An acid tastes sour whereas a base tastes bitter.
The method of taste is not advised as an acid or a base could be contaminated or corrosive.

b. Effect on indicators by acids and bases

An indicator is a chemical substance which shows a change in its physical properties, mainly colour or odour when brought in contact with an acid or a base.
Below mentioned are commonly used indicators and the different colours they exhibit:

a) Litmus
In neutral solution - purple
In acidic solution - red
In basic solution - blue

Litmus is also available as strips of paper in two variants - red litmus and blue litmus.
An acid turns a moist blue litmus paper to red.
A base turns a moist red litmus paper to blue.

b) Methyl orange
In neutral solution - orange
In acidic solution - red
In basic solution - yellow

c) Phenolphthalein
In neutral solution - colourless
In acidic solution - remains colourless
In basic solution - pink

Acid Base Reactions

Reaction of Acids & Bases with Metals

Acids react with metals to produce salt by displacing hydrogen.

For Example:

i. When dilute sulphuric acid reacts with the metal zinc, zinc sulphate is formed with the evolution of hydrogen gas.

$Zn + H_2SO_4 \rightarrow ZnSO_4 + H_2$

ii. Zinc is the only metal which reacts with sodium hydroxide to form sodium zincate with the release of hydrogen gas.

$Zn + 2NaOH \rightarrow Na_2ZnO_2 + H_2$

Reaction of Metal Carbonates & Bicarbonates with Acids

Acids react with metal carbonates or bicarbonates to form salt and water with the evolution of carbon dioxide gas.

For Example:

i. Hydrochloric acid reacts with sodium carbonate to form sodium chloride and water with the release of carbon dioxide gas.

$Na_2CO_{3(s)} + 2\ HCl_{(aq)} \rightarrow 2NaCl_{(aq)} + CO_{2(g)} + H_2O_{(l)}$

ii. Similarly, sodium bicarbonate also reacts with hydrochloric acid to form sodium chloride and water with the release of carbon dioxide gas.

$NaHCO_{3(s)} + HCl_{(aq)} \rightarrow NaCl_{(aq)} + CO_{2(g)} + H_2O_{(l)}$

Neutralisation

The reaction between an acid and a base to form salt and water is called a neutralisation reaction.

For example:

Hydrochloric acid reacts with sodium hydroxide to form sodium chloride and water.

$HCl + NaOH \rightarrow NaCl + H_2O$

Reaction of Metallic Oxides with Acids

Acids react with metallic oxides to form salt and water.

For Example:

Copper oxide (II), a black metal oxide reacts with dilute hydrochloric acid to form a blue-green coloured copper chloride (II) solution.

$CuO + 2HCl \rightarrow CuCl_{2(aq)} + H_2O$

Reaction of Non-Metallic Oxides with Base

Bases react with non-metallic oxides to form salt and water.

For Example:

Calcium hydroxide reacts with non-metallic oxides like carbon dioxide to form calcium carbonate salt and water.

$Ca(OH)_2 + CO_2 \rightarrow CaCO_3 + H_2O$

Acids and Bases in Water

Acids

An acid is a substance which dissociates (or ionises) when dissolved in water to release hydrogen ions.

For Example:

An aqueous solution of hydrochloric acid dissociates to form hydrogen ions. Since hydrogen ions do not exist as H^+ in solution, they combine with polar water molecules to form hydronium ions [H_3O^+].

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

$H^+ + H_2O \rightarrow H_3O^+$

The presence of hydrogen ions [H^+] in hydrochloric acid solution makes it behave like an acid.

Bases

A base is a substance which dissolves in water to produce hydroxide ions [OH- ions].

Bases which are soluble in water are called alkalis.

For Example:

Sodium hydroxide dissolves in water to produce hydroxide and sodium ions.

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

The presence of hydroxide ions [OH^-] in sodium hydroxide solution makes it behave like a base.

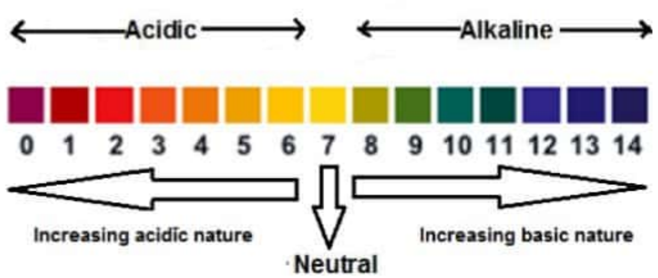
pH Scale

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

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

p H = 7 - Neutral	$[H^+] = [OH^-]$
pH less than 7 - Acidic	$[H^+]$ more than $[OH^-]$
pH more than 7 - Basic	$[OH^-]$ more than $[H^+]$

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



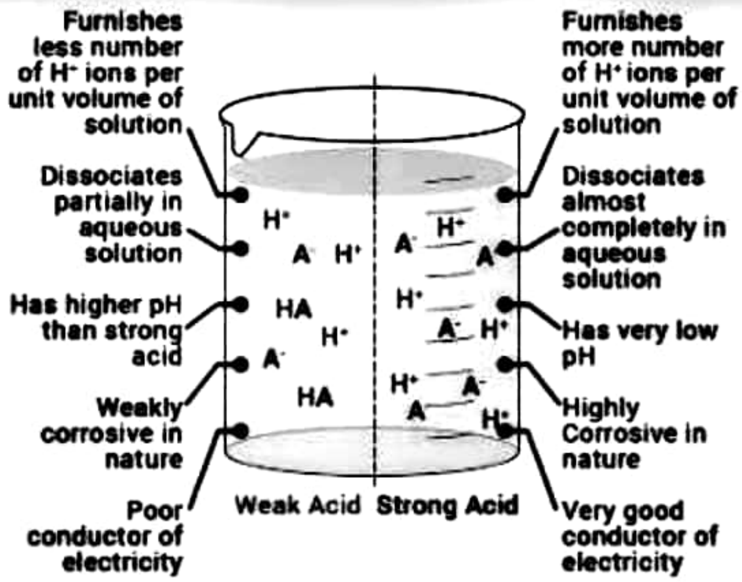
Dilution

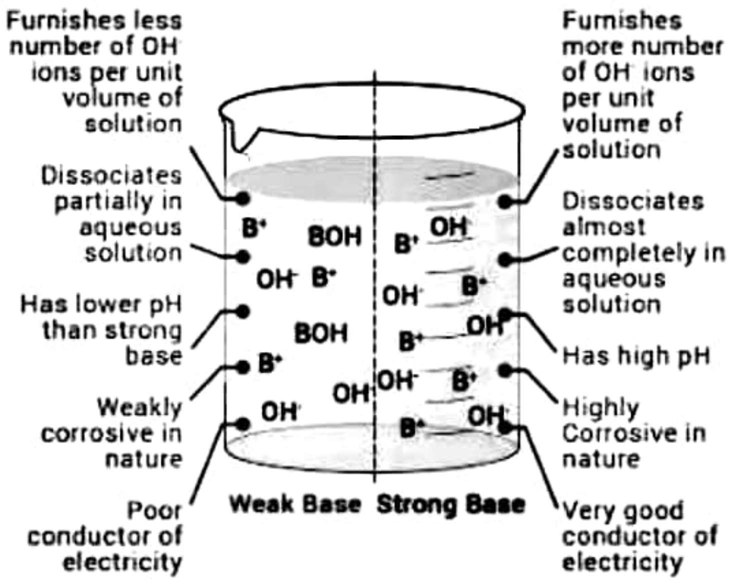
Dilution is the process of reducing the concentration of a solution by adding more solvent (usually water) to it.
It is a highly exothermic process.
To dilute an acid, the acid must be added to water and not the other way round.

Strength of acids and bases

Strong acid or base: When all molecules of given amount of an acid or a base dissociate completely in water to furnish their respective ions, $H^{+}(aq)$ for acid and $OH^{-}(aq)$ for base).

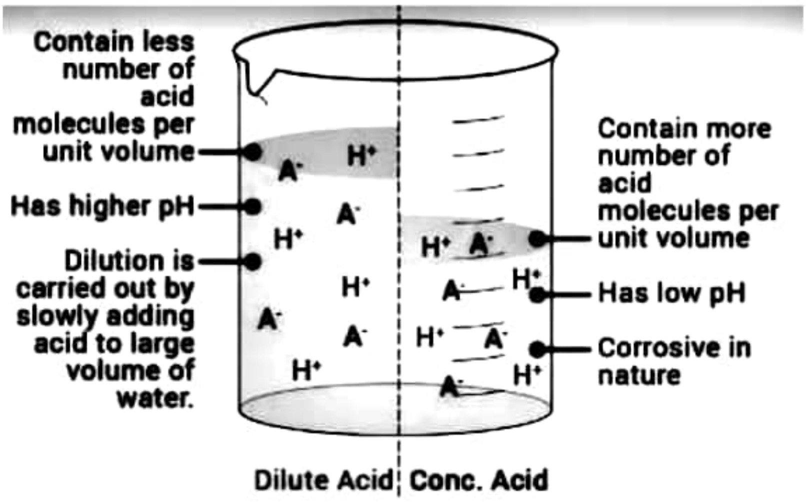
Weak acid or base: When only a few of the molecules of given amount of an acid or a base dissociate in water to furnish their respective ions, $H^{+}(aq)$ for acid and $OH^{-}(aq)$ for base).

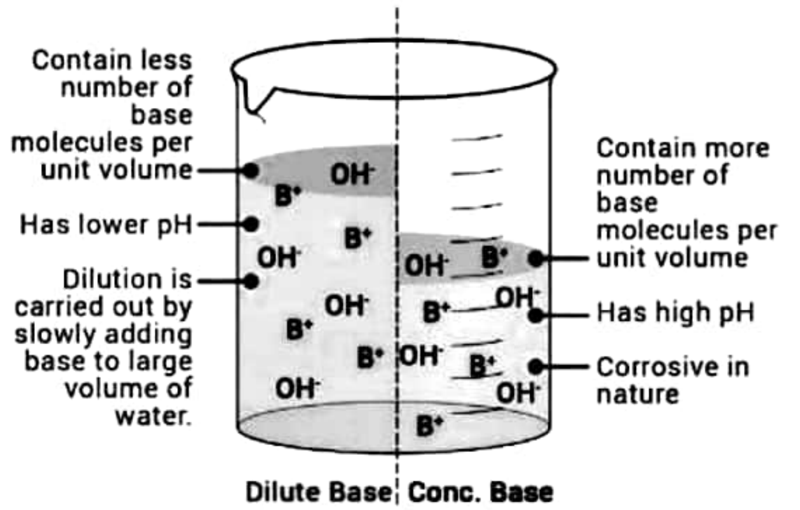




Dilute acid: contains less number of $H^{+}(aq)$ ions per unit volume.

Concentrated acid: contains more number of $H^{+}(aq)$ ions per unit volume.


Contain less number of acid molecules per unit volume
Has higher pH
Dilution is carried out by slowly adding acid to large volume of water.
Contain more number of acid molecules per unit volume
Has low pH
Corrosive in nature
Dilute Acid
Conc. Acid


Contain less number of base molecules per unit volume
Has lower pH
Dilution is carried out by slowly adding base to large volume of water.
Contain more number of base molecules per unit volume
Has high pH
Corrosive in nature
Dilute Base
Conc. Base

Universal Indicator

In case of a colourless liquid, the accurate pH can be obtained by adding a universal indicator.
It is a mixture of several indicators and shows different colours at different concentration of hydrogen ions in a solution.

For Example:

i. A universal indicator produces green colour in a neutral solution, pH = 7.
ii. The colour changes from blue to violet as pH increases from 7 to 14.
iii. The colour changes from yellow to pink and then to red as pH decreases from 7 to 1.

Importance of pH in everyday life

pH change and survival of animals

- Our body works well within a narrow pH range of 7.0 to 7.8.
- When the pH of rain water is less than 5.6, it is known as acid rain.
- When this acid rain flows into rivers, it lowers the pH of the river water making the survival of aquatic life difficult.

pH in our digestive system

- Our stomach produces hydrochloric acid which helps in the digestion of food without harming the stomach.
- Sometimes excess acid is produced in the stomach which causes indigestion.
- To get rid of this pain, bases called antacids are used.
- Antacids are a group of mild bases which react with the excess acid and neutralise it.
- Commonly used antacids are magnesium hydroxide [$Mg(OH)_2$] & sodium bicarbonate[$NaHCO_3$]

pH change - Cause of tooth decay

- Tooth decay starts when the pH in the mouth falls below 5.5.
- Tooth enamel is made up of calcium phosphate which is the hardest substance in the body.
- It is insoluble in water but gets corroded when the pH in the mouth falls below 5.5.
- The bacteria present in the mouth produce acids due to the degradation of sugar and food particles after eating.
- Hence, to prevent tooth decay, the mouth should be rinsed after eating food and toothpastes which are basic should be used cleaning teeth to neutralise the excess acid.

More about Salts

Salts having same positive ions (or same negative ions) are said to belong to a family of salts.

pH of Salts

- Salts of strong acid and a strong base are neutral, with a pH value of 7.
  For Example: NaCl, Na_2SO_4
- Salts of strong acid and weak base are acidic, with a pH value less than 7.
  For Example: Ammonium chloride solution has pH value of 6.
- Salts of weak acid and strong base are basic, with a pH value more than 7.
  For Example: Sodium carbonate solution has a pH value of 9.

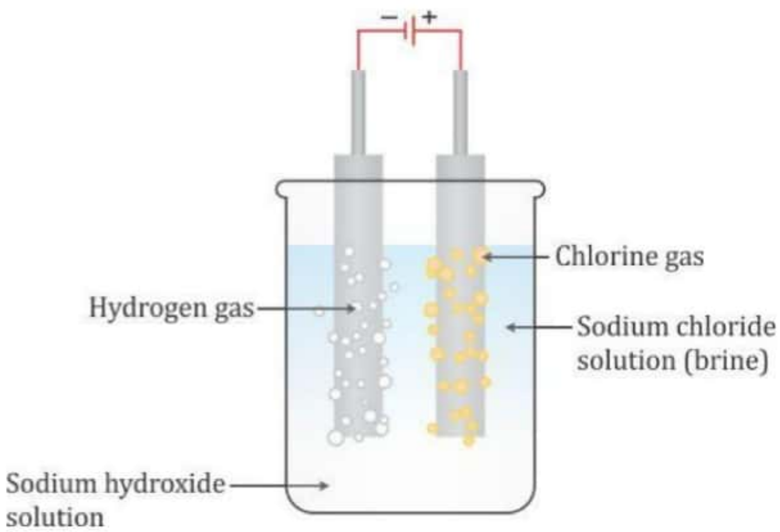
Common Salt

- Chemical name: Sodium chloride
- Common salt is a neutral salt and can be prepared in the laboratory by the reaction of sodium hydroxide and hydrochloric acid.
  $NaOH_{(aq)} + HCl_{(aq)} \rightarrow NaCl_{(aq)} + H_2O_{(aq)}$
- It is an important raw material for products of daily use such as NaOH, baking soda, washing soda and bleaching powder.

Sodium Hydroxide

- Sodium hydroxide is produced by the electrolysis of an aqueous solution of sodium chloride (called brine).
- The process is called the chlor-alkali process because of the products formed, i.e. 'chlor' for chlorine and 'alkali' for sodium hydroxide.

$$2NaCl_{(aq)} + 2H_2O_{(aq)} \rightarrow 2NaOH_{(aq)} + H_{2(g)} + Cl_{2(g)}$$



Bleaching Powder

- Bleaching powder is manufactured from chlorine gas.
- It is produced by the action of chlorine on dry slaked lime [$Ca(OH)_2$].
  $Ca(OH)_2 + Cl_2 \rightarrow CaOCl_2 + H_2O$
- It is represented as $CaOCl_2$

Uses

- For bleaching cotton and linen in the textile industry and for bleaching wood pulp in the paper industry.
- Used for disinfecting drinking water to make it free of germs.

Baking Soda

- Chemical formula: $NaHCO_3$
- It is produced on a large scale by treating cold and concentrated solution of sodium chloride (brine) with ammonia and carbon dioxide.
  $NaCl + H_2O + CO_2 + NH_3 \rightarrow NH_4Cl + NaHCO_3$
- On heating, it decomposes to give sodium carbonate with the evolution of carbon dioxide.
  $2NaHCO_3 \xrightarrow{Heat} Na_2CO_3 + H_2O + CO_2$

Uses

- Used as an antacid to treat acidity of the stomach.
- Used to make baking powder, which is used in preparation of cakes, breads, etc.
- Used in soda-acid fire extinguishers.

Washing Soda

- Chemical formula: $Na_2CO_3.10H_2O$
- Sodium hydrogen carbonate, on heating decomposes to give sodium carbonate with the release of hydrogen gas. Re-crystallisation of sodium carbonate produces washing soda.
  $2NaHCO_3 \xrightarrow{Heat} Na_2CO_3 + H_2O + CO_2$
  $Na_2CO_3 + 10H_2O \longrightarrow Na_2CO_3.10H_2O$

Uses

- Used in glass, soap and paper industries.
- Employed in the manufacture of sodium compounds such as borax.

Water Of Crystallisation

- Water molecules which form a part of the structure of a crystal are called water of crystallisation.
- The salts which contain water of crystallisation are called hydrated salts.
- Every hydrated salt has a fixed number of molecules of crystallisation in its one formula unit.
  For Example: $CuSO_4.5H_2O$, $Na_2CO_3.10H_2O$, $CaSO_4.5H_2O$, and $FeSO_4.7H_2O$
- Copper sulphate crystals ($CuSO_4.5H_2O$) are blue in colour, and on heating strongly they lose all the water of crystallisation and form anhydrous copper sulphate, which is white. On adding water to anhydrous copper sulphate, it gets hydrated and turns blue.
  $CuSO_4.5H_2O \xrightarrow{Heat} CuSO_4 + 5H_2O$
  $CuSO_4 + 5H_2O \longrightarrow CuSO_4.5H_2O$

Plaster of Paris

Plaster of Paris is prepared by heating gypsum at 373 K. On heating, it loses water molecules and becomes calcium sulphate hemihydrate ($CaSO_4.1/2\ H_2O$) which is called Plaster of Paris.

$$\underset{\text{Gypsum}}{CaSO_4.2H_2O} \xrightarrow{\text{Heat}} \underset{\text{Plaster of Paris}}{CaSO_4.\tfrac{1}{2}H_2O} + 1\tfrac{1}{2}H_2O$$

Uses

- Used in hospitals as plaster for supporting fractured bones in the right position.
- Used as a fire-proofing material.