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

Reactions of acids and bases

a) Reaction of acids and bases with metals

Acid + active metal → salt + hydrogen + heat
$2HCl + Mg \rightarrow MgCl_2 + H_2(\uparrow)$
Base + metal → salt + hydrogen + heat
$2NaOH + Zn \rightarrow Na_2ZnO_2 + H_2(\uparrow)$

A more reactive metal displaces the less reactive metal from its base.
$2Na + Mg(OH)_2 \rightarrow 2NaOH + Mg$

b) Reaction of acids with metal carbonates and bicarbonates

Acid + metal carbonate or bicarbonate → salt + water + carbon dioxide.
$2HCl + CaCO_3 \rightarrow CaCl_2 + H_2O + CO_2$
$H_2SO_4 + Mg(HCO_3)_2 \rightarrow MgSO_4 + 2H_2O + 2CO_2$
Effervescence indicates liberation of CO_2 gas.

c) Neutralisation reaction

1. Reaction of metal oxides and hydroxides with acids
Metal oxides or metal hydroxides are basic in nature.
Acid + base → salt + water + heat
$H_2SO_4 + MgO \rightarrow MgSO_4 + H_2O$
$2HCl + Mg(OH)_2 \rightarrow MgCl_2 + 2H_2O$

2. Reaction of non-metal oxides with bases

Non-metal oxides are acidic in nature
Base + Non-metal oxide → salt + water + heat
$2NaOH + CO_2 \rightarrow Na_2CO_3 + H_2O$

Water

Acids and bases in water

When added to water, acids and bases dissociate into their respective ions and help in conducting electricity.

Difference between a base and an alkali

Base-

Bases undergo neutralisation reaction with acids.

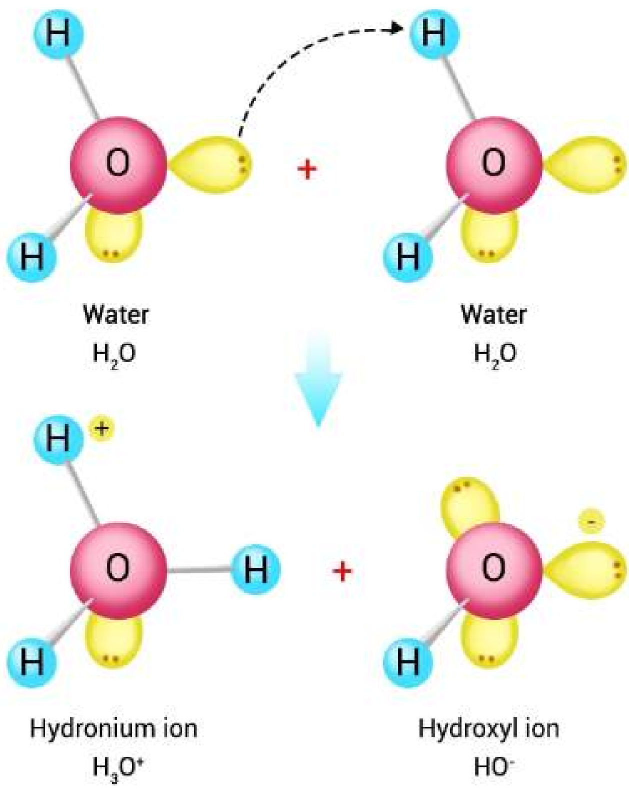
- They are comprised of metal oxides, metal hydroxides, metal carbonates and metal bicarbonates.
- Most of them are insoluble in water.

Alkali -

- An alkali is an aqueous solution of a base, (mainly metallic hydroxides).
- It dissolves in water and dissociates to give OH^- ion.
- All alkalis are bases, but not all bases are alkalis.

Hydronium ion

Hydronium ion is formed when a hydrogen ion accepts a lone pair of electrons from the oxygen atom of a water molecule, forming a coordinate covalent bond.



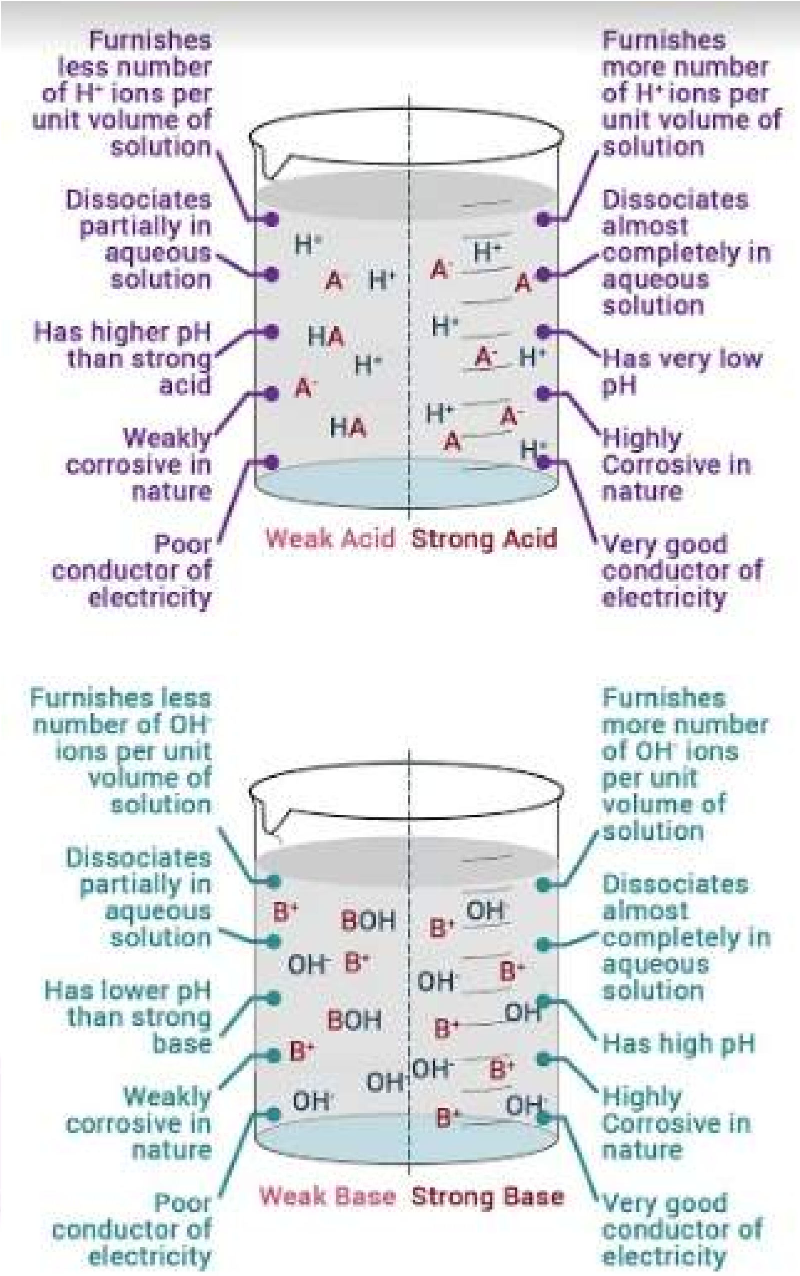
Formation of a hydronium ion

Dilution

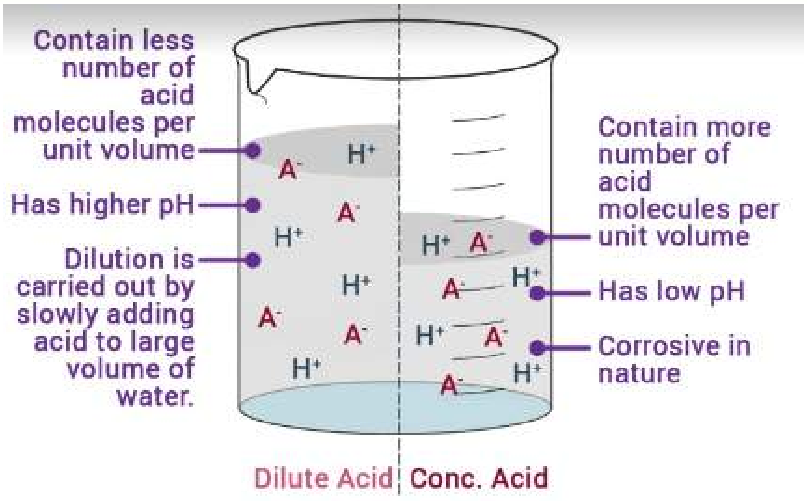
Dilution is the process of reducing the concentration of a solution by adding more solvent (usually water) to it.
It is a highly exothermic process.
To dilute an acid, the acid must be added to water and not the other way round.

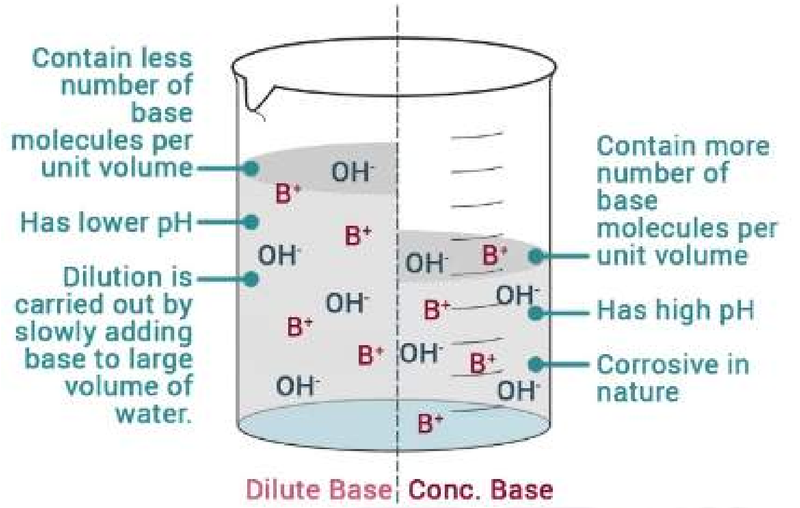
Strength of acids and bases

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.





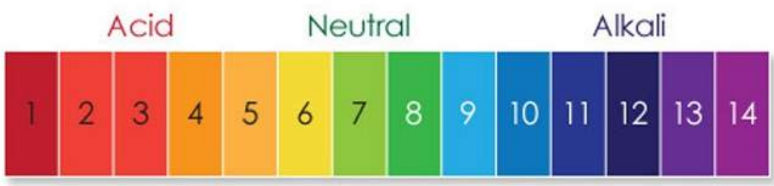
Universal indicator

A universal indicator has pH range from 0 to 14 that indicates the acidity or alkalinity of a solution.
A neutral solution has pH=7

pH

$$pH = -log_{10}[H^+]$$

In pure water, $[H^+] = [OH^-] = 10^{-7}$ mol/L. Hence, the pH of pure water is 7.
The pH scale ranges from 0 to 14.
If pH < 7 - acidic solution
If pH > 7- basic solution



pH scale

Importance of pH in everyday life

1. pH sensitivity of plants and animals

Plants and animals are sensitive to pH. Crucial life processes such as digestion of food, functions of enzymes and hormones happen at a certain pH value.

2. pH of a soil

The pH of a soil optimal for the growth of plants or crops is 6.5 to 7.0.

3. pH in the digestive system

The process of digestion happens at a specific pH in our stomach which is 1.5 - 4.
The pH of the interaction of enzymes, while food is being digested, is influenced by HCl in our stomach.

4. pH in tooth decay

Tooth decay happens when the teeth are exposed to an acidic environment of pH 5.5 and below.

5. pH of self-defense by animals and plants

Acidic substances are used by animals and plants as a self-defense mechanism. For example, bee and plants like nettle secrete a highly acidic substance for self-defense. These secreted acidic substances have a specific pH.

Manufacture of Acids and Bases

Manufacture of acids and bases

a) Non-metal oxide + water → acid
$SO_2(g) + H_2O(l) \rightarrow H_2SO_3(aq)$
$SO_3(g) + H_2O(l) \rightarrow H_2SO_4(aq)$
$4NO_2(g) + 2H_2O(l) + O_2(g) \rightarrow 4HNO_3(aq)$
Non-metal oxides are thus referred to as acid anhydrides.

b) Hydrogen + halogen → acid
$H_2(g) + Cl_2(g) \rightarrow 2HCl(g)$
$HCl(g) + H_2O(l) \rightarrow HCl(aq)$

c) Metallic salt + conc. sulphuric acid → salt + more volatile acid
$2NaCl(aq) + H_2SO_4(aq) \rightarrow Na_2SO_4(aq) + 2HCl(aq)$
$2KNO_3(aq) + H_2SO_4(aq) \rightarrow K_2SO_4(aq) + 2HNO_3(aq)$

d) Metal + oxygen → metallic oxide (base)
$4Na(s) + O_2(g) \rightarrow 2Na_2O(s)$
$2Mg(s) + O_2(g) \rightarrow 2MgO(s)$

e) Metal + water → base or alkali + hydrogen
Zn(s) + $H_2O(steam)$ → ZnO(s)+ H_2(g)

f) Few metallic oxides + water → alkali
$Na_2O(s) + H_2O(l) \rightarrow 2NaOH(aq)$

g) Ammonia + water → ammonium hydroxide
$NH_3(g) + H_2O(l) \rightarrow NH_4OH(aq)$

Salts

Salts

A salt is a combination of an anion of an acid and a cation of a base.
Examples - $KCl, NaNO_3, CaSO_4, etc.$
Salts are usually prepared by neutralisation reaction of an acid and a base.

Common salt

Sodium Chloride (NaCl) is referred to as common salt because it's used all over the world for cooking.

Family of salts

Salts having the same cation or anion belong to the same family. For example, NaCl, KCl, LiCl.

pH of salts

A salt of a strong acid and a strong base will be neutral in nature. pH = 7 (approx.).
A salt of a weak acid and a strong base will be basic in nature. pH > 7.
A salt of a strong acid and a weak base will be acidic in nature. pH < 7.
The pH of a salt of a weak acid and a weak base is determined by conducting a pH test.

Preparation of Sodium hydroxide

Chemical formula - NaOH
Also known as - caustic soda
Preparation (Chlor-alkali process):
Electrolysis of brine (solution of common salt, NaCl) is carried out.

At anode: Cl_2 is released
At cathode: H_2 is released
Sodium hydroxide remains in the solution.

Bleaching powder

Chemical formula - Ca(OCl)Cl or $CaOCl_2$
Preparation - $Ca(OH)_2(aq) + Cl_2(g) \rightarrow CaOCl_2(aq) + H_2O(l)$
On interaction with water - bleaching powder releases chlorine which is responsible for bleaching action.

Baking soda

Chemical name - Sodium hydrogen carbonate
Chemical formula - $NaHCO_3$
Preparation (Solvay process) -
a. Limestone is heated: $CaCO_3 \rightarrow CaO + CO_2$
b. CO_2 is passed through a concentrated solution of sodium chloride and ammonia:
$NaCl(aq) + NH_3(g) + CO_2(g) + H_2O(l) \rightarrow NaHCO_3(aq) + NH_4Cl(aq)$

Uses:
1. Textile industry
2. Paper industry
3. Disinfectant

Washing soda

Chemical name - Sodium carbonate decahydrate.
Chemical formuala - \(Na_2CO_3 \)
Preparation: By heating $NaHCO_3$
$2NaHCO_3(s) \rightarrow Na_2CO_3(s) + CO_2(g) + H_2O(g)$
$Na_2CO_3(s) + 10H_2O(l) \rightarrow Na_2CO_3.10H_2O(s)$

Uses
1. In glass, soap and paper industries
2. Softening of water
3. Domestic cleaner

Crystals of salts

Certain salts form crystals by combining with a definite proportion of water. The water that combines with the salt is called water of crystallisation.

Plaster of paris

$Gypsum,\ CaSO_4.2H_2O\ (s)\ on\ heating\ at\ 100^{\circ}C\ (373K)\ gives\ CaSO_4.\frac{1}{2}H_2O\ and\ \frac{3}{2}H_2O$

$CaSO_4.\frac{1}{2}H_2O$ is plaster of paris.

$CaSO_4.\frac{1}{2}H_2O$ means two formula units of $CaSO_4$ share one molecule of water.

Uses - cast for healing fractures.