Chapter 2 Acids Bases And Salts:

A salt is formed when hydrogen ions are replaced by a metal or an ammonium ion in an acid. A base is a material that reacts with an acid to produce just water and a salt. When an acid reacts with a base, it produces a salt.

Bases are commonly found in household cleansers that are used to remove oil from windows and floors, as well as soaps, toothpaste, egg whites, dishwashing liquids, and household ammonia.

Introduction to Acids, Bases and Salts

A substance that tastes sour in water, turns blue litmus red, and neutralises bases is known as an acid. If a substance's aqueous solution tastes bitter, turns red litmus blue, or neutralises acids, it's called a base. Salt is a neutral material that has no effect on litmus in aqueous solution.

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

To know more about Classification of Matter, visit here.

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.

Acids and Bases

An acid is any hydrogen-containing substance that is capable of donating a proton (hydrogen ion) to another substance. A base is a molecule or ion able to accept a hydrogen ion from an acid. Acidic substances are usually identified by their sour taste.

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 an H^+ (aq) ion donor.
A Bronsted base is an H^+ (aq) ion acceptor.

Example

In the reaction: HCl (aq) + NH_3 (aq) → 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.

Example: The flavours of curd, lemon juice, orange juice, and vinegar are all sour. Because they contain acids, these compounds have a sour flavour. Baking soda has a sour flavour. It's an example of a foundation.

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 a 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 a neutral solution – orange
In acidic solution – red
In basic solution – yellow

c) Phenolphthalein
In a neutral solution – colourless
In acidic solution – remains colourless
In basic solution – pink

Acid-Base Reactions

A neutralisation reaction occurs when an acid reacts with a base. A salt and water are the end products of this reaction. An acid–base neutralisation reaction is formulated as a double-replacement reaction in this standard approach.

Reactions of acids and bases

a) Reaction of acids and bases with metals

Acids, in general, react with metals to produce salt and hydrogen gas. Bases, in general, do not react with metals and do not produce hydrogen gas.

Acid + active metal → salt + hydrogen + heat

$2HCl + Mg \rightarrow MgCl_2 + H_2 (\uparrow)$

Hydrochloric acid + Magnesium → Magnesium chloride + Hydrogen

Base + metal → salt + hydrogen + heat

$2NaOH + Zn \rightarrow Na_2ZnO_2 + H_2 (\uparrow)$

Sodium hydroxide + Zinc → Sodium zincate + Hydrogen

A more reactive metal displaces the less reactive metal from its base.

$2Na + Mg(OH)_2 \rightarrow 2NaOH + Mg$

Sodium + Magnesium hydroxide → Sodium hydroxide + Magnesium

b) Reaction of acids with metal carbonates and bicarbonates

Acids produce carbon dioxide, as well as metal salts and water, when they react with metal carbonates or metal bicarbonates. Sodium chloride, carbon dioxide, and water are formed when sodium carbonate interacts with hydrochloric acid. Allowing carbon dioxide gas to travel through lime water turns it milky.

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) Reaction of Acid with Base

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 + Nonmetal oxide → salt + water + heat

$2NaOH + CO_2 \rightarrow Na_2CO_3 + H_2O$

3. Reaction of acids and base

A very common acid is hydrochloric acid. The reaction between strong acid says hydrochloric acid and strong base say sodium hydroxide forms salt and water. The complete chemical equation is shown below.

HCl (strong acid) + NaOH (strong base) → NaCl (salt) + H2O (water)

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:

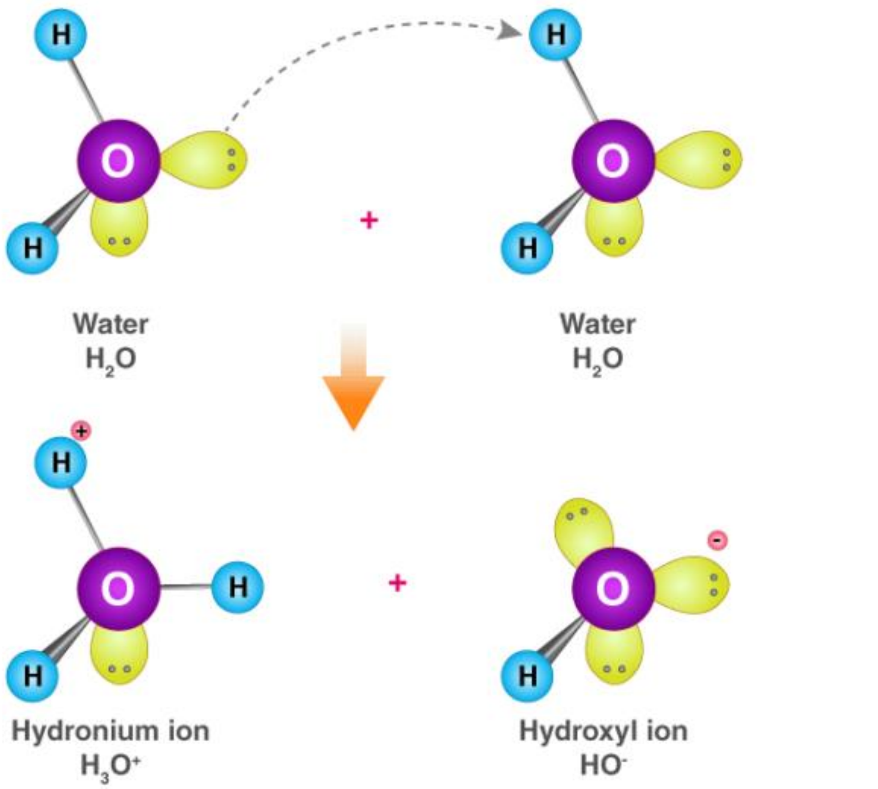
- Bases undergo neutralisation reaction with acids.
- They are comprised of metal oxides, metal hydroxides, metal carbonates and metal bicarbonates.
- Most of them are insoluble in water.

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.



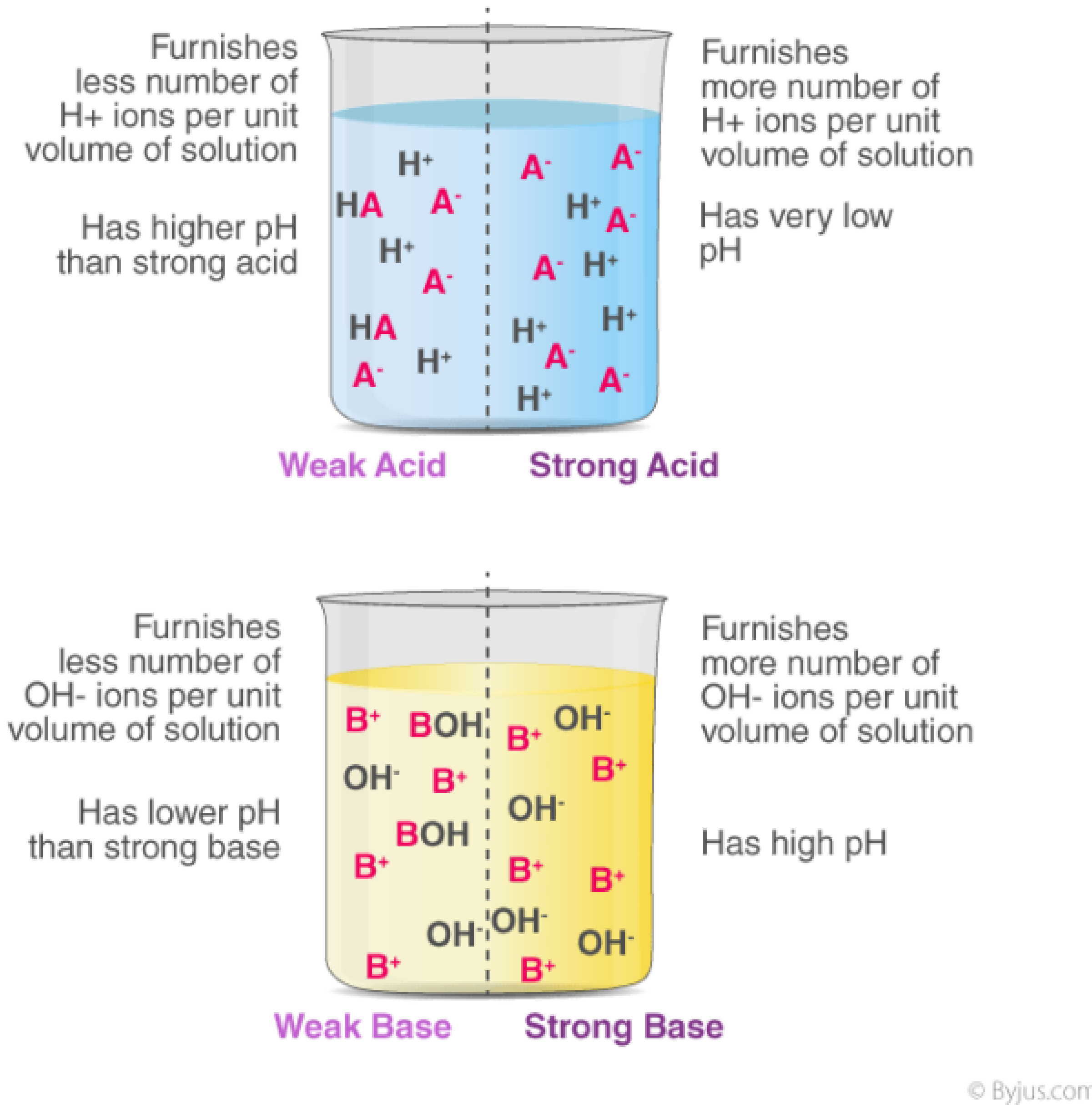
Formation of a hydronium ion

Dilution

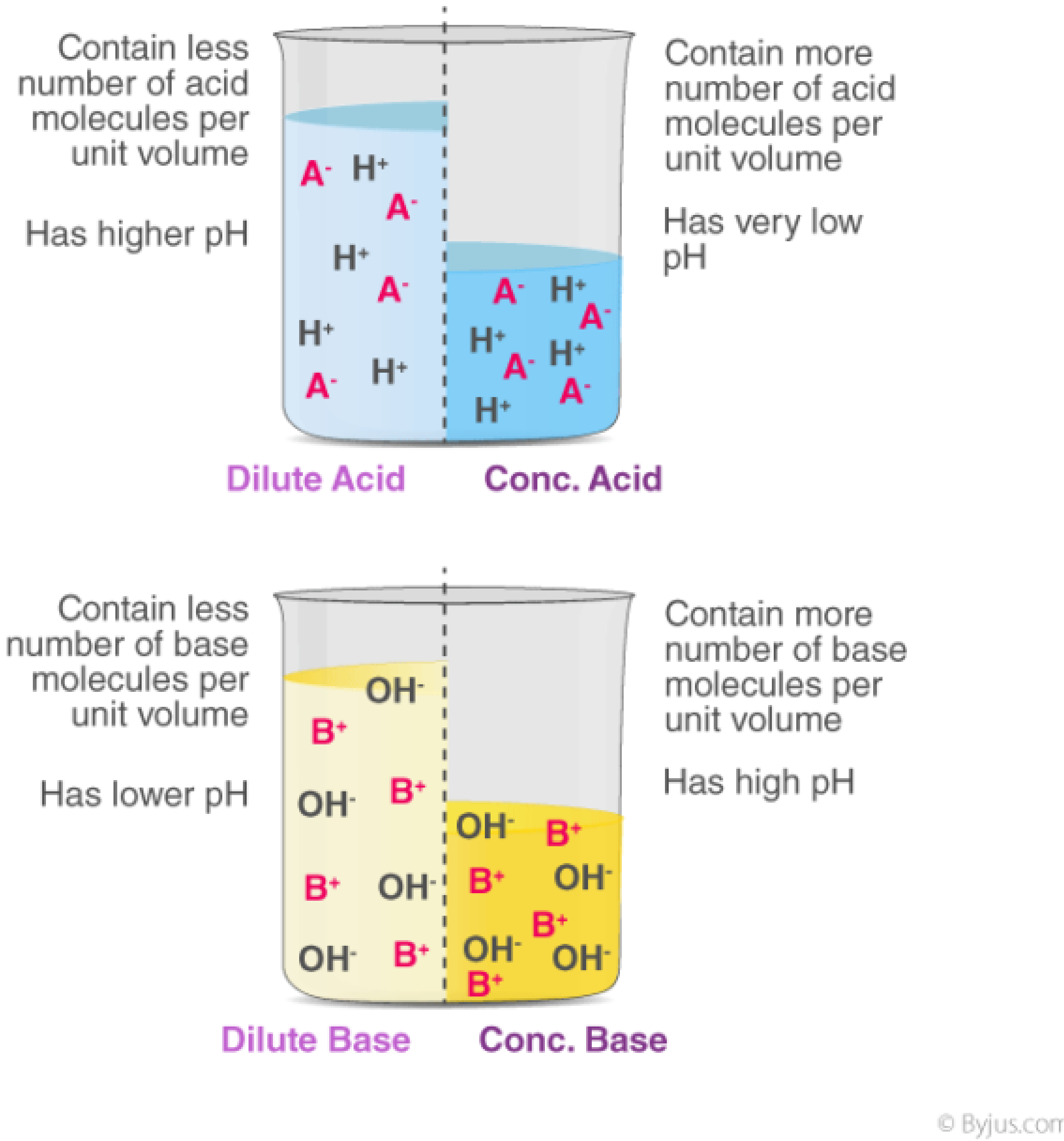
Dilution is the process of reducing the concentration of a solution by adding more solvent (usually water) to it.
It is a highly exothermic process.
To dilute acid, the acid must be added to water and not the other way round.

Strength of acids and bases

Strong acid or base: When all molecules of a 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 a 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.



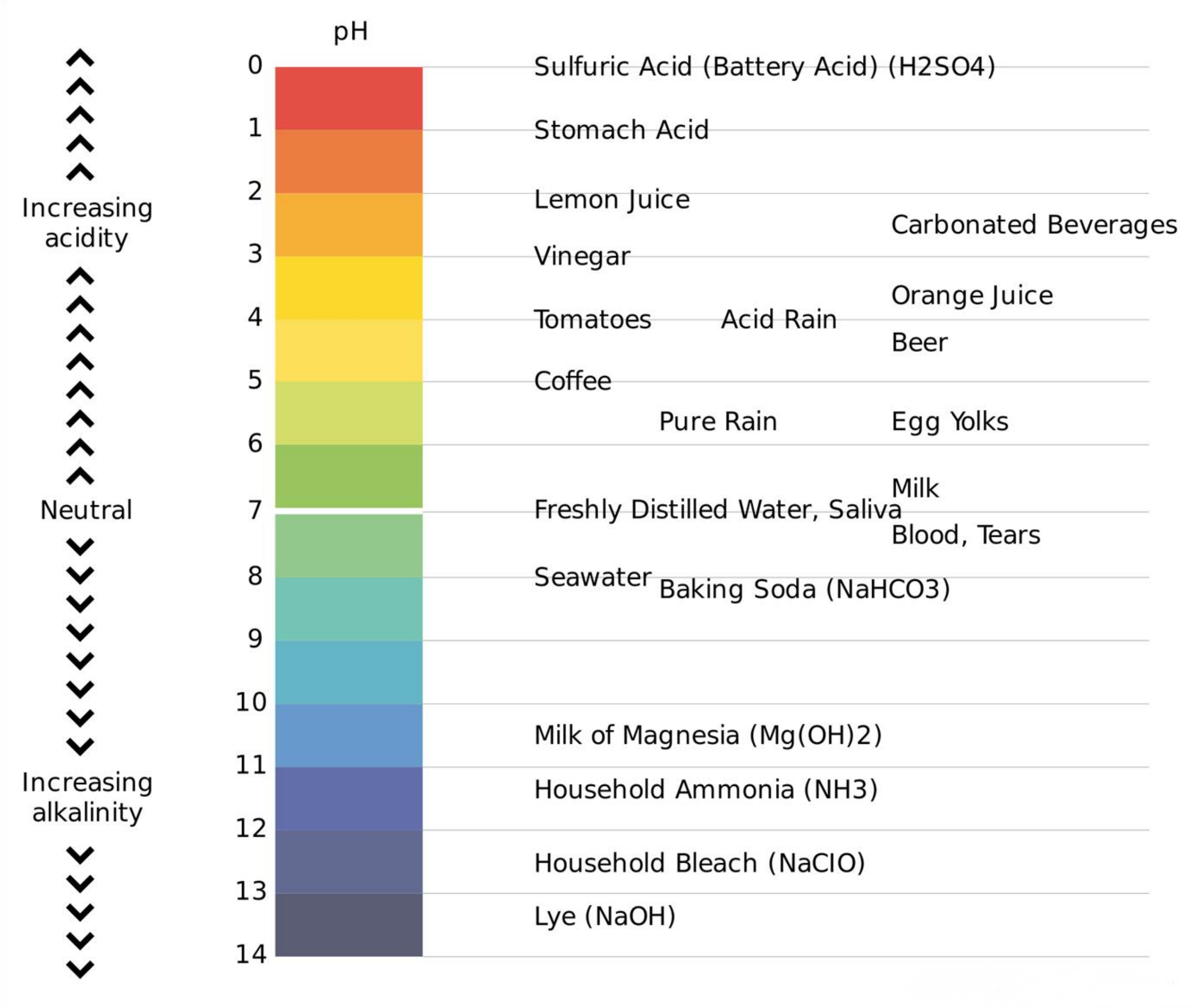
Universal indicator

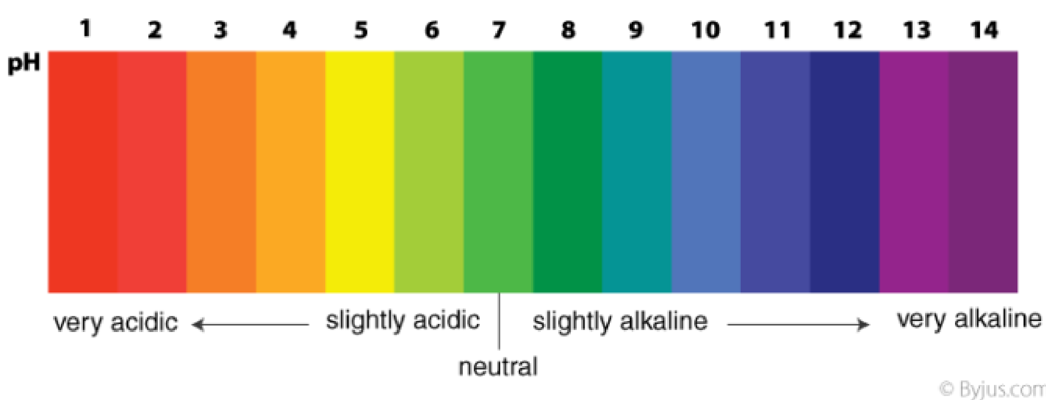
A universal indicator has a pH range from 0 to 14 that indicates the acidity or alkalinity of a solution.
A neutral solution has pH=7

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 to 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-defence by animals and plants

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

Manufacture of Acids and Bases

Manufacture of acids and bases

a) Nonmetal 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
$Zn(s) + H_2O(steam) \rightarrow ZnO(s) + H_2(g)$

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 the 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.

Chemicals from common salt

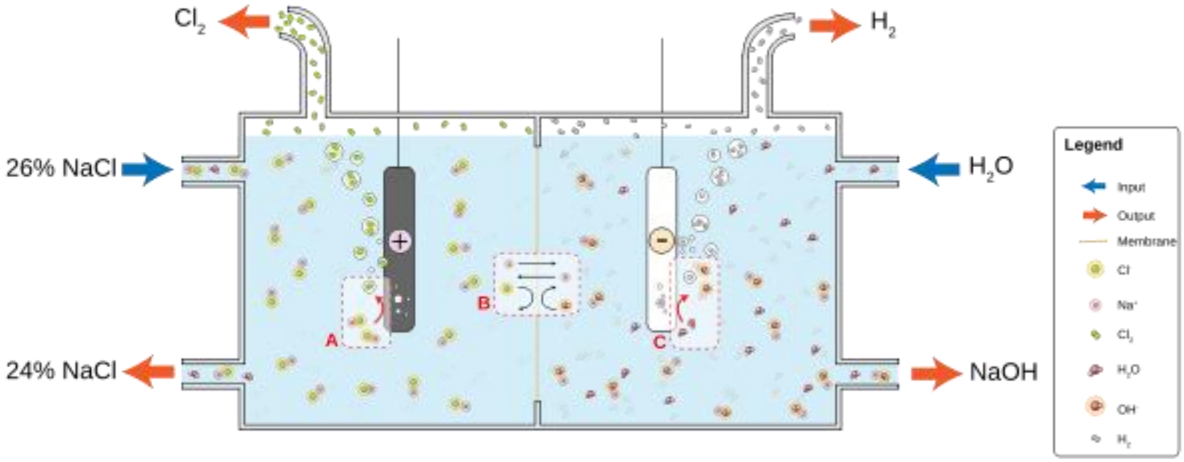
Sodium chloride is a common salt. NaCl is its molecular formula. The fundamental element in our meals is sodium chloride. It is used in our food as a flavour enhancer as well as a preservative. From common salt, we may make the following four compounds.

1. Sodium hydroxide or lye or caustic soda
2. Baking soda or sodium hydrogen carbonate or sodium bicarbonate
3. Washing soda or sodium carbonate decahydrate
4. Bleaching powder or calcium hypochlorite

Preparation of Sodium hydroxide

The strong base sodium hydroxide is a common and useful one. Preparing a solution of sodium hydroxide (NaOH) in water requires extra caution because the exothermic reaction releases a lot of heat. It's possible that the solution will spatter or boil. Here's how to manufacture a sodium hydroxide solution safely, as well as recipes for a variety of NaOH strengths.

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

Bleaching powder is soluble in water and is used as a bleaching agent in textile industries. It is also used as an oxidizing agent and a disinfectant in many industries. It should also be noted that bleaching powder is synthesized by the reacting chlorine gas on dry slaked lime i.e. Ca(OH)2.

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.

Uses of Bleaching Powder

- It is used for bleaching dirty clothes in the laundry, as a bleaching agent for cotton and linen in the textile industry.
- It is a strong oxidizing agent, hence used as an oxidizer in many industries.
- It is used as a disinfectant which is used for disinfecting water to make potable water.

Baking soda

Sodium bicarbonate, also known as baking soda or bicarbonate of soda, is a chemical compound with the formula $NaHCO_3$ and the IUPAC designation sodium hydrogencarbonate. A sodium cation (Na^+) and a bicarbonate anion (HCO_3) combine to form this salt. Sodium bicarbonate is a white, crystalline substance that is commonly found as a fine powder. It tastes slightly salty and alkaline, like washing soda (sodium carbonate).

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:

- Reduces the acidity in the stomach
- Acts as an antacid which is used to treat stomach upset and indigestion
- Used in the process of washing as a water softener

Washing 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. 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.

The process by which a solid forms, in which the atoms or molecules are strongly arranged into a structure known as a crystal, is known as crystallisation. Precipitation from a solution, freezing, and, more rarely, direct deposition from a gas are some of the ways crystals form.

Example:

Table salt (sodium chloride or halite crystals), sugar (sucrose), and snowflakes are examples of common materials that form crystals. Many gemstones, such as quartz and diamond, are crystals.

Plaster of paris

Plaster of Paris is a widely used chemical compound that is extensively used in sculpting materials and gauze bandages. Plaster of Paris is a white powdery chemical compound that is hydrated calcium sulphate that is usually obtained by calcining gypsum. While we have seen many applications of this material in our everyday lives, if we try to understand its chemistry, we will find that it is a white powdery chemical compound that is hydrated calcium sulphate that is usually obtained by calcining gypsum. To put it another way, Plaster of Paris is often manufactured of heated gypsum at a high temperature.

Gypsum plaster is another name for plaster of Paris. Plaster of Paris is expressed as $CaSO_4 . \frac{1}{2} H_2O$ in chemical formula.

Gypsum, $CaSO_4.2H_2O$ (s) on heating at 100°C (373K) gives $CaSO_4 . \frac{1}{2} H_2O$ and 3/2 H_2O
$CaSO_4 . \frac{1}{2} H_2O$ is plaster of paris.

$CaSO_4$. ½ H_2O means two formula units of $CaSO_4$ share one molecule of water.
Uses – cast for healing fractures.