ACID BASES AND SALTS

INTRODUCTION:

Acid and bases were recognized as the two groups of substances in the 15^{th} century by Muslim chemists.

In modern, it was recognized that substances having sour taste were called acids. They also recognized another group of substances having bitter taste and used as cleaning agents were called bases. Neutralization was also recognized in early 16^{th} century.

ACID IN DAILY LIFE:

Orange and grape contain citric acid. All citreous fruits contain large amount of ascorbic acid or vitamin C.

BASES IN DALY LIFE:

Bases are also common in use of house hold Ammonia solution. It is used as cleaning agent. Lye is commercial used for cleaning sink-drains. Milk of magnesia is used as an anti-acid.

SALTS:

Salts are formed as the result of neutralization having positive and negative ions. Salts are not only neutral, they may behave like acids or bases.

PROPERTIES OF ACIDS AND BASES: PHYSICAL PROPERTIES OF ACIDS:

1. Acids have sour taste.
2. They change the color of methyl orange and blue litmus to red.
3. Acids are electrolytes that means aqueous solution of acids contains electricity.
4. In human stomach 0.4% of gastric juice contains hydrochloric acid for proper digestion.
5. Acids destroy fabrics, skin and human tissues etc.

CHEMICAL PROPERTIES OF ACIDS:

Acid react with bases, metals, non-metals and other things etc. some of the properties are given below.

1. **Neutralization:**

   Acids react with bases to form salt and water, this is called Neutralization.

   $$HCl + NaOH \rightarrow NaCl + H_2O$$

2. **Reaction with metals:**

   Dilute acid reacts with certain metals such as (Zn, Mg and Fe to produce H_2 gas)
   For example: when dilute Hydrochloric acid reacts with Zn metal to produce H_2 gas.

   $$Zn + 2HCl \rightarrow ZnCl_2 + H_2$$

3. **Reaction with carbonate and bicarbonates:**

Acid react with carbonate and bicarbonate salts to produce CO_2 gas.

$$Na_2CO_3 + 2HCl \rightarrow 2NaCl + H_2O + CO_2$$

4. **Reaction with oxides and hydroxides of metals:**
   Metal oxide and hydroxide react with acid to form salt and water like neutralization.

$$FeO + H_2SO_4 \rightarrow FeSO_4 + H_2O$$

PHYSICAL PROPERTIES OF BASES:

1. Bases have bitter taste.
2. Bases have slippery or soupy touch.
3. They turn red litmus paper blue.
4. They turn colorless phenolphthalein into red or pink.
5. They are good electrolytes that is why the aqueous solution of bases conduct electricity.

DIFFERENT CONCEPTS OF ACIDS AND BASES:

1. ARRHENIUS THEORY:

A Swedish chemist Savant-Arrhenius in 1887 gave the following definition of acids and bases.
"A substance which produce H^+ ions in aqueous its solution is called an acid."
Example:

$$HCl \rightarrow H^+ + Cl^-$$

"A substance which produces Hydroxide (OH^-) ions in its aqueous solution is called base." Example:

$$NaOH \rightarrow Na^+ + OH^-$$

2. LOWRY AND BRONSTED ACID-BASES THEORY:

This theory was proposed by the English chemist Thomas Lowry and Danish chemist Johannes Bronsted in 1923.
According to which that an acid is a substance having tendency to donate one or more protons and bases is substance, having a tendency to accept protons.

3. LEWIS CONCEPT OF ACIDS AND BASES:

In 1923 G.N.Lewis proposed a more general concept of acids and bases.
According to the Lewis theory:
"An acid is any species (molecule or ion) which can accept a pair of electrons and base is any species which can donate a pair of electrons."

DISSOCIATION OF ACIDS AND BASES:

STRENGTH OF ACID:

Strength of an acid depends on dissociation into ions, higher the power of dissociation greater and vice versa.

STRONG ACID:

The acid which completely ionizes, that means it produces large number of ions (H^+) in aqueous solution, is called strong acid.

Example: HCl, HNO_3, H_2SO_4 and H_3PO_4etc. are the most common examples of strong because they ionize completely in water.

WEAK ACID:

An acid which partially or incompletely ionizes that means it produces very small amount of ions (H^+) inaqueous solution is called weak acid.

Example: H_2CO_3 (carbonic acid) and etc.

STRONG BASE:

A base which completely dissociates into ions that means it produces large number of hydroxyl ions in aqueous solutions is called strong base.

Example: NaOH, KOH, Ca $(OH)_2$ are the best examples of strong bases.

WEAK BASE:

A base which partially or incompletely ionizes into ions, that means it produces very small amount of hydroxyl ions in aqueous solution, is called strong base.

Example: NH_4OH, Mg $(OH)_2$ and Be $(OH)_2$ are few weak bases.

SALT:

"An ionic compound produced as a result of neutralization between acids and bases having positive and negative ions is called salt."

Example: potassium Hydroxide neutralizes Nitric acid to form Potassium Nitrate as salt and water.

$$KOH + HNO_3 \rightarrow KNO_3 + H_2O$$

GROUPS OF SALTS:

On the basis of their chemical nature, salts can be divided into three groups.

1. **Normal salt:**

   A salt which is formed by the incomplete neutralization of an acid by a base is called normal salts, which does not have replaceable ion (H^+) or hydroxyl ion (OH^-).

   Example: NaCl, $NaNO_3$etc. are normal salts.

2. **Acidic salt:**

   A salt which s formed by the partial or incomplete neutralization of an acid by a base is called acidic salt which has replaceable (H^+) ion.

   Example: $NaHSO_4$, $KHCO_3$, $NaHCO_3$etc. are basic salts.

3. **Basic salt:**

   A salt which is formed by the incomplete neutralization of a base by an acid is called basic salt which has hydroxyl ion (OH^-). Example: Mg (OH) Cl, Zn (OH) Cl etc. are basic salts.

DOUBLE SALTS:

The crystalline compound which is obtained when two specific salts are crystallized together are known as double salts.

Characteristics of Double Salt:

i. They have definite chemical composition.
ii. They contain definite number of water molecules.

Examples:

Potash Alum
Chrome Alum
Carnalities
Mohr's salt

INDUSTRIAL PREPARATION OF SODIUM CARBONATE (Na_2CO_3)

Now a day's washing soda is commercially prepared by Solvay process or Ammonium soda process.

Raw materials:

The raw materials are:

i. Lime stone ($CaCO_3$) ii.
Sodium chloride (NaCl) iii.
Ammonium Chloride (NH_4Cl)
iv. Carbon dioxide (CO_2)

The industrial process involve the following steps:

Step 1:

First of all lime stone ($CaCO_3$) is strongly heated in a special furnace under high temperature.

$$CaCO_3 \rightarrow CaO_{(s)} + CO_{2\,(g)}$$

Step 2:

The quick lime combines with Ammonium Chloride (NH_4Cl) to form Ammonia (NH_3) gas in another chamber

$$2NH_3Cl + CaO \rightarrow 2NH_3 + CaCl_2 + H_2O$$

Step 4:

Ammonium bi carbonate combine with aqueous cold solution of Brine at 15^oC to produce Sodium bi carbonate (Baking soda) in the form of insoluble precipitates due to 15^oC which is separated out.

Step 5:

Soda ash can be prepared by heating sodium Bicarbonate.

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

Step 6:

Finally anhydrous Sodium Carbonate (Soda Ash) is crystallized into washing soda ($Na_2CO_3.10H_2O$).

The raw materials like Ammonium Chloride, Carbon dioxide gas and water are reproduced during this process, so the expenses to prepare soda are very much reduced. So this Solvay process is of commercial importance.

USES OF SODIUM CARBONATE:

i. Hard water is changed into soft water by adding solution carbonate (Na_2CO_3). Which forms insoluble Calcium carbonate ($CaCO_3$) and Magnesium Carbonate ($MgCO_3$).
ii. It is used as cleaning agent in soap and detergent.
iii. Ordinary glass is prepared which is used to make bottles.

USES OF BAKING SODA:

i. Sodium Hydrogen Carbonate is used as baking powder.
ii. It is used in the preparation of effervescent drinks and fruit salts. iii. It is used in medicines to remove acidity in stomach as anti-acid.
iv. It is used in fire extinguishers.

COPPER SULPHATE ($CuSO_45H_2O$):

Preparation:

Copper sulphate or cupric sulphate which is also known as Blue Vitriol or Blue Stone has two preparation methods which are given below:

Method-I:

It may be prepared by reacting copper scraps with dilute Sulphuric acid in the presence of air.

$$2Cu(s) + 2H_2SO_4 + O_2 (g) \rightarrow 2CuSO_4 + 2H_2O$$

Method-II:

It can also be prepared by the treatment of CuO or $CuCO_3$ with dilute sulphuric acid (H_2SO_4)

$$Cu + H_2SO_4 \rightarrow CuSO_4 + H_2O$$

USES OF COPPE SULPHATE:

i. In textile (mordant), tanning, electric batteries, hair dyes and in electroplating.
ii. As germicide, insecticide, preservative for wood, paper pulp.
iii. In calico printing, making synthetic rubber and copper salts e.g. scheels, green paint.
iv. In paint and varnish industry.
v. A mixture of copper sulphate and milk lime is used to kill fungus and molds.

MAGNESIUM SULPHATE ($MgSO_4.7H_2O$) (EPSOM SALT):

Preparation:

It is prepared by the action of H_2SO_4 and magnisite or dolomite, but nowadays it is prepared by heating Kieserite under pressure with water.

i. $MgCO_3$ + H_2SO_4 → $MgSO_4 + H_2O + CO_2$
Magnesite

Uses of Magnesium Sulphate:

i. It is used as mild purgative in medicines.
ii. In dyeing and tanning processes.
iii. In making fire proof fabrics.
iv. As a filler in paper industry

PREPARATION OF POTASH ALUM:

The double salt K_2SO_4. Al $(SO_4)_3$. $24H_2O$ can be prepared by adding equal molecular
Quantities of potassium sulphate and aluminum sulphate by dissolving in water. This solution is crystallized to form Potash Alum.

DISSOCIATION OF WATER:

Water acts as acid as well as a base. A substance like water can behave as both an acid and a base is said to be an amphoteric substance.

In water molecules by adding acid or base water itself ionizes. A proton from one water molecules is transferred to another water molecule leaving behind OH^- ion and forming H_3O^+ ion.

ION PRODUCT OF WATER:

As the result of neutralization salt and water molecules are formed and the concentration of (H^+) ions and Hydroxide ions (OH^-) remain almost same as the following equation shows:

$$H_2O \rightarrow H^+ + OH^-$$

$$K_c = [H^+] [OH^-] / [H_2O]$$

K_c is the equilibrium constant. It shows that a very small fraction of water molecules are ionized. That means water remains mostly unchanged. Therefore,

$$K_c [H_2O] = K_w = [H^+] [OH^-]$$

Equation constant (K_w) is called ion product constant which is the product of molar concentration of (H^+) ion and (OH^-) ion at 25°C is found to be 10^{-14} $mole^2/dm^6$.

$$[H^+] = 1x10^{-7} \text{ M and } [OH^-] = 1x10^{-7} \text{ M}$$
$$K_w = (1x10^{-7}) \text{ x } (1x10^{-7}) = 1x10^{-14}$$

Above equation shows that $[H^+] = [OH^-]$ that is why water is neutral when $[H^+]$ ion concentration increases aqueous solution becomes acidic. If (OH^-) ionic concentration increases aqueous solution becomes basic.

PH SCALE:

The Danish chemist S.P.L Sorenson proposed that only the number in the exponent be used to express the acidity called pH. On this scale a concentration

($1x10^{-7}$) moles of H_2O ions per liter of solution becomes a pH of 7. Similarly a concentration $1x10^{-10}$ M becomes a pH of 10 and so on.

Definition:

The measurement of the negative logarithm of the Hydrogen ion concentration or (H_2O) ion concentration (in moles per liter) is called pH scale.

Mathematically:

$$pH = -\log [H^+]$$
$$= -\log [10^{-7}]$$
$$= - (-7) \log 10$$
$$= 7 \log 10$$
$$= 7 \times 1$$
$$pH = 7$$

Similarly in water p (OH) is negative logarithm of hydroxide ion (OH^-) concentration which is

$$P (OH) = -\log [OH^-]$$

The sum of Ph and Poh of water or any solution is always equal to 14

i.e. Ph + Poh = 14

The Measurement of Ph:

There are following three methods to measure the Ph of a solution.

1. By acid base indicator.
2. By Ph meters.
3. By Ph paper.

Ph paper method is most common in school laboratories. Ph paper strips prepared by treated papers with several different indicators can be used to estimate Ph. These strips are pH papers.

pH can be estimated by dipping the pH paper in a given solution, then by matching the change of color with given key colors with corresponding known values.

The Importance of Ph:

The value of pH in different solutions give information though which necessary steps to control the problems are possible. Water treatment, soil conditioning, swimming pool managements, corrosion control, food processing, electroplating and field of biology etc. are common areas of pH values play important role.

PREPARATION OF SOLUTION OF KNOWN MOLARITY:

Molar solution can be prepared by dissolving one mole of solute into one liter of solution. Consider the example of NaOH 23 + 16 + 1 = 40g sodium hydroxide dissolved in some amount of water in measuring flask etc. after that by adding water up to 1 liter mark, solution of 1M NaOH will be prepared.

STANDARD SOLUTION:

Standard solution is that whose strength or molarity etc. is known. **Example:**

1M solution of KOH contain 56g KOH in one liter solution. If half mole 28g KOH is dissolve in one liter solution, this standard solution is called semi molar (0.5M) solution of KOH.

TITRATION:

The volumetric analysis through chemical process in which by using standard solution, the value of concentration of another solution is determined. This method is called Titration.

Acid-Base Titration:

Standard solution of acid is used to standardize base (unknown concentration) by acid base titration or reverse method is possible, to standardize acid.

Steps for carrying out Titration:

Wash all apparatus with water and then rinse the burette with base and pipette with acid including conical flask. Fill the burette with NaOH up to zero mark. The solution in the burette is called Titer.

Pipette out 10ml of HCl in a conical flask and add one or two drops of phenolphthalein indicator. The solution in titration flask is called Titrant.

Add slowly the NaOH solution from the burette into flask with constant shaking until the lightest pink color is obtained. Record the final reading (lower meniscus).

This is called end point. Repeat the process at least three times to get concordant reading (two same difference at least in three readings).

After completing the observation we use the following formula to determine the Molarity of acid or base.

$$M_1V_1/n_1 = M_2V_2/n_2$$

Let M_1 = Molarity of Acid.
V_1 = Volume of Acid.
N_1 = No. o moles of acid (obtained from balanced equation)
N_2 = No. of moles of base (obtained from base)
V_2 = Volume of base (Burette reading)
M_2 = Molarity of base

NEUTRALIZATION:

The process in which equivalent quantities of an acid and base are reacted to form, salt and water is called neutralization reaction.

A common example is the reaction between HCl and NaOH.

$$HCl + NaOH \rightarrow NaCl + H_2O$$

The hydrogen on which is responsible for acidic properties, reacts with the Hydroxide ion which is responsible for the basic properties, producing neutral water (H-OH). Because the only change that takes place is the reaction of the hydrogen ion and hydroxide ion, the neutralization may be expressed simply as:

$$H^+ + OH^- \rightarrow H_2O$$

The neutralization is an exothermic reaction.

MONO AND POLY ACIDS AND BASES:

MONO BASIC AND POLY BASIC ACIDS:

Basicity of Acids:

The number of replaceable or ionizable Hydrogen atoms present in a molecule of an acid is called Basicity of the acid.

An acid yields protons. Different acids have different number of protons (acidic-hydrogen) per molecule and yield different number of H_3O^+ ion in a solution.

The common acids like HCl, HNO_3 and CH_3COOH contain only one acidic Hydrogen atom per molecule, when dissolved in water 1 mole of each of these acids is capable of producing 1 mole of hydrated H^+ = H_3O^+ ions and in order to neutralize this solution 1 mole of (OH^-) ions is required. Consequently these acids are called mono-basic acids more commonly called mono-protic acids

$$H - Cl + H - OH \rightarrow \quad H_2O + Cl$$

MONO-ACID AND POLY-ACID BASES:

Acidity of Bases:

The number of ionizable or replaceable (OH^-) ions, present in a molecule of base is called acidity of the base.

Similarly, bases that produce 1 mole of (OH^-) ions per mole of base (such as NaOH and KOH) are called mono-acid bases. Bases that produce 2 moles of (OH^-) ions per one mole of base (such as $Ca(OH)_2$ AND $Ba(OH)_2$) are called diacid bases and bases that produce 3 moles of (OH^-) ions per 1 mole of base (such as $Al(OH)_3$) and $Cr(OH)_3$ are called tri-acid bases.

Bases that contain two, three or more hydroxide (OH^-) ions per molecule are called poly-acid bases.

DISSOCIATION OF ACIDS AND BASES:

ACID STRENGTH AND BASE STRENGTH:

Definition:

A strong acid is one, that is almost completely dissociated (strong electrolytes) i.e. an acid that produce large number of (H^+) ions in aqueous solution is said to be a strong acid. Typical examples of strong acids are hydrochloric acid (HCl), Nitric acid and sulphuric acid. Different acids differ in their ability to donate protons.

Weak Acid:

A weak acid is one, that is only partially dissociated (weak electrolytes). Only small fraction of the weak acids transfer a proton to water. Typical examples of weak acids are nitrous acid. Phosphoric acid etc.

Strong base:

The strong base is one. That is almost dissociated completely (strong electrolytes). That is, a base which yield large number of (OH^-) ions in aqueous solution, is said to be a strong base.

Most metal hydroxides, such as NaOH and KOH are strong electrolytes and strong bases.

Weak Base:

A weak base is one, that is only partially dissociated weak electrolytes; weak bases dissociate to a small extent in water to yield (OH^-) ions.

Typical examples of weak bases are NH_4OH, $Mg(OH)_2$ and etc. hence, the relative strength of weak bases may be measured by the extent to which the dissociate in water to yield Hydroxide ions (OH)

EXERCISE

1. FILL IN THE BLANKS.
   The formula of baking soda is **$NaHCO_3$**.
   The formula of Epsom salt is **$MgSO_4.7H_2O$.**
   $K_2SO_4AL_2.24H_2O$ is the formula of **Potash Alum.**
   Molarity is the most convenient way of expressing concentration.
   The molarity of solution is denoted by **M.**
   A solution whose strength is known is called **Standard Solution**.
   Molarity is defined as number of moles per **liter or dm^3 of solution**

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