CHAPTER 7

Acids, Bases and Salts

SYNOPSIS

- **Arrhenius theory of Acids and Bases**

(i) An acid is a substance which contains hydrogen and produces H^+ ions in aqueous solution.

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

(ii) A base is a substance which produces OH^- ions in aqueous solution.

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

(iii) All acids which ionize completely and hence produce more concentration of H^+ ions in their aqueous solutions are called **strong acids**. All acids which ionize partially and hence produce less concentration of H^+ ions are called **weak acids**.

Examples: (a) $\underset{\text{strong acid}}{HNO_3} \rightarrow H^+ + NO_3^-$

(b) $\underset{\text{weak acid}}{CH_3COOH} \rightleftharpoons H^+ + CH_3COO^-$

(iv) All bases which ionize completely and hence produce more concentration of OH^- ions in their aqueous solutions are called **strong bases**. All bases which ionize partially and produce less concentration of OH^- ions are called **weak bases.**

Examples: (a) $\underset{\text{strong base}}{KOH} \rightarrow K^+ + OH^-$

(b) $\underset{\text{weak base}}{NH_4OH} \rightleftharpoons NH_4^+ + OH^-$

(v) **Neutralization** is defined as the reaction between an acid and a base to give salt and water.

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

The (neutralization) ions which remain unchanged during the reaction are called **spectator ions**.

Bronsted-Lowry theory of acids and bases:

(i) An acid is a substance which can donate one or more protons.

Example: HCl acts as a proton donor and hence is called an acid.

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

(ii) A base is a substance which can accept one or more protons.

Example: NH_3 acts as a base as it is a proton acceptor.

$NH_3 + H^+ \rightarrow NH_4^+$

(iii) An acid on losing a proton produces a species which is called **conjugate base** of the acid.

Example: $\underset{\text{Acid}}{HCl} \rightarrow \underset{\text{Conjugate base}}{H^+ + Cl^-}$

(iv) A base on accepting a proton produces a species which is called **conjugate acid** of the base.

Example: $\underset{\text{Base}}{NH_3 + H^+} \rightarrow \underset{\text{Conjugate acid}}{NH_4^+}$

(v) **Neutralization** is defined as the transfer of a proton from an acid to base to form a conjugate acid base pair. Since this theory mainly focuses on proton transfer, this is also known as **protonic concept of acids and bases.**

Example: $\underset{\text{Acid}}{HCl} + \underset{\text{Base}}{NH_3} \rightarrow \underset{\text{Conjugate acid}}{NH_4^+} + \underset{\text{Conjugate base}}{Cl^-}$

Lewis theory of acids and bases

(i) An acid is a substance which can act as an electron pair acceptor.

Examples: BF_3, $AlCl_3$ etc.

(ii) A base is a substance which can act as an electron pair donor.

Examples: NH_3, H_2O etc.

(iii) Acid base neutralization can be defined as the transfer of an electron pair from a base to an acid, which involves the formation of a coordinate covalent bond.

Examples:

(b) $H^+ + NH_3 \rightarrow [H \leftarrow NH_3]^+$ or NH_4^+

$H^+ + H_2O \rightarrow [H \leftarrow H_2O]^+$ or H_3O^+

❍ **Classification of acids and bases**

Acids and bases can be further classified on the basis of certain properties

❍ **On the basis of strength:** Strength of an acidic or basic solution depends upon degree of dissociation. Degree of dissociation can be calculated as

Degree of dissociation =

$$\frac{\text{Amount dissociated (mole}/\ell)}{\text{Initial concentration (mole}/\ell)}$$

Thus based on the strength, acids and bases can be further classified into strong acids and weak acids, strong base and weak base respectively.

(a) Strong acids: The acids which undergo nearly 100% or complete ionization in aqueous solutions are called **strong acids**. These produce a high concentration of H^+ ionsper unit volume of the solution.

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

(b) Weak acids: The acids which undergo partial ionization in aqueous solutions are called **weak acids.** These produce low concentration of H^+ ions per unit volume of the solution.

Example: $CH_3COOH \rightleftharpoons CH_3COO^- + H^+$

(c) Strong bases: Bases which undergo nearly 100% or complete ionization in aqueous solutions are called **strong bases.** These produce a high concentration of OH^- ionsper unit volume of the solution.

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

(d) Weak bases: Bases which undergo partial ionization in aqueous solutions are called **weak bases.** These produce low concentration of OH^- ions per unit volume of the solution.

Example: $NH_4OH_{(aq)} \rightleftharpoons NH_{4(aq)}^+ + OH^-_{(aq)}$

❍ **On the basis of basicity and acidity:** Number of H^+ or H_3O^+ ions produced by ionization of one molecule of an acid in aqueous solution is called **basicity**. Basicity is also called Hydroxicity.

(a) Monobasic acids: The acids which dissociate in aqueous solutions to produce one hydrogen ion or hydronium ion per molecule of the acid are called **monobasic acids**.

Examples: HCl, HBr, HNO_3, HI, CH_3COOH

(b) Dibasic acids: The acids which dissociate in aqueous solution to produce two hydrogen ions or hydronium ions per molecule of the acid are called **dibasic acids**.

Examples: H_2SO_4, $H_2C_2O_4$, H_2SO_3, H_2CO_3

(c) Tribasic acids: The acids which dissociate in aqueous solution to produce three hydronium ions per molecule of acid are called **tribasic acids.**

Example: H_3PO_4

Number of OH^- ions produced by the ionization of one molecule of base in aqueous solution is called **acidity**. Acidity is also called protocity.

(a) Monoacidic bases: The bases which dissociate in aqueous solution to produce one hydroxyl ion per molecule of the base are called **monoacidic bases**.

Examples: NaOH, KOH, NH_4OH

(b) Diacidic bases: The bases which dissociate in aqueous solutions to produce two hydroxyl ions per molecule of the base are called **diacidic bases**.

Examples: $Ca(OH)_2$, $Cu(OH)_2$, $Mg(OH)_2$

(c) Triacidic bases: The bases which dissociate in aqueous solutions to produce three hydroxyl ions per molecule of base are called **triacidic bases.**

Examples: $Al(OH)_3$, $Fe(OH)_3$

❍ **On the basis of concentration**

(a) Concentrated acid or base: An aqueous solution that has a high percentage of acid or base and a low percentage of water is said to be a concentrated acid or concentrated base respectively.

(b) Dilute acid or base: An aqueous solution that has a low percentage of acid or base and a high percentage of water is said to be a dilute acid or dilute base respectively.

- **General preparation methods of acids**
  (i) By synthesis/direct combination (for hydracids and binary acids)
  (ii) By the reaction of non-metallic (acidic) oxides with water
  (iii) By the oxidation of non-metals with oxyacids
  (iv) By the displacement of salts of more volatile acid with less volatile acid

- **General preparation methods of bases**
  (i) By the action of water on metals
  (ii) By the action of metallic oxides on water
  (iii) By the action of oxygen on metals
  (iv) By the decomposition of metal carbonates
  (v) Using soluble metal salts and NaOH/KOH
  (vi) Strong heating of metal nitrates
  (vii) By the action of oxygen on metal sulphides

- **Chemical properties of acids**
  (i) Metal oxide + Dilute acid $\rightarrow$ Salt + Water
  Metal hydroxide + Dilute acid $\rightarrow$ Salt + Water
  (ii) Carbonate or Bicarbonate + Acid $\rightarrow$ Salt + H_2O + $CO_2\uparrow$
  (iii) Metal sulphite or Bisulphite + Acid $\rightarrow$ Salt + H_2O + $SO_2\uparrow$
  (iv) Metal sulphide or Bisulphide + Acid $\rightarrow$ Salt + $H_2S\uparrow$
  (v) Active metal + Dilute Acid $\rightarrow$ Salt + $H_{2\uparrow}\uparrow$
  (vi) Metal chloride + Acid $\rightarrow$ Salt + Hydrochloric acid
  (vii) Metal nitrate + Acid $\rightarrow$ Salt + Nitric acid

- **Chemical properties of bases**
  (i) Alkali + Non-metallic oxide $\rightarrow$ Metal salt + H_2O
  (ii) Ammonium salt + Alkali $\rightarrow$ Metal salt + H_2O + $NH_3\uparrow$
  (iii) Soluble metallic salt + Base $\rightarrow$ Soluble salt + Insoluble hydroxide

- **Uses of Acids and Bases**

Some important acids	**Uses**
Sulphuric acid	Manufacture of fertilizers, dyes, drugs, explosives, paints, chemicals, artificial fabrics etc
Hydrochloric acid	Printing, tanning and tinning industries

Some important acids	**Uses**
Nitric acid	Manufacture of dyes, explosives, drugs, fertilizers and chemicals
Acetic acid	Preservation of food and as a flavouring agent
Citric acid	Curdling milk, flavouring soft drinks and as medicine (source of vitamin C)
Carbonic acid	Used in soft drinks
Oxalic acid	Used as ink stain remover
Boric acid	Preservation of grains, to wash eyes
Benzoic acid	As food preservative
Tartaric acid	onstituent of baking powder

Some important alkalies	**Uses**
NaOH	Manufacture of soap
KOH	Manufacture of soft soap and in alkaline batteries
NH_4OH	Used to remove grease stains from woollen clothes
$Ca(OH)_2$	Manufacture of mortar, softening temporary hard water, neutralizing acidity of soils and as a general germicide
$Mg(OH)_2$	Used as antacid for neutralizing gastric acidity
$Al(OH)_3$	Used as foaming agent in fire extinguishers

- **Neutralization:** It is the chemical reaction of acid and base to form salt and water while liberating heat. The relative amount of acids and bases undergoing neutralization depends on the actual concentration of H^+ or OH^- ions produced in the solution. If the acids and bases differ in their strengths, that is the degree of dissociation, then the concentration of H^+ and OH^- ions furnished by them also differs.

- **Equivalent mass of an acid** is defined as the number of parts by mass of the acid which contains 1.008 parts by mass of the replaceable hydrogens. Thus, the equivalent mass of an acid can also be defined as the amount of acid which can furnish one mole of H^+ ions on ionization.

Calculation of equivalent masses

Equivalent mass of acid

$$= \frac{\text{Molecular mass}}{\text{Number of replaceable hydrogen ions in the given reaction}}$$

- **Equivalent mass of a base** is defined as the mass of the base which can furnish one mole of OH^- ions on ionization. In other words, one equivalent of an acid is always neutralized by one equivalent of a base.

  Equivalent mass of base =

$$\frac{\text{Molecular mass}}{\text{Number of replaceable hydroxyl ions in the given reaction}}$$

- **Heat of neutralization:** A neutralization reaction is always associated with the liberation of heat. The amount of heat liberated when one equivalent of an acid reacts with one equivalent of a base is called **heat of neutralization**. For any strong acid-strong base reaction, the heat of neutralization has the same value that is 13.7 kcal/mole since the acid and base involved are completely ionized.

  ***Example*:** $HCl + NaOH \rightarrow NaCl + H_2O + 13.7$ kcal/mole

  When a weak acid or a weak base is involved in the reaction, some amount of heat is utilized to ionize the acid or base to furnish ions. This is called **heat of ionization**. Therefore, the net heat released is less than the heat of neutralization for strong acid-strong base reaction.

  ***Example*:** $CH_3COOH + NaOH \rightarrow CH_3COONa + H_2O + 13.4$ kcal/mole

  Heat of ionization = 13.7 – net heat liberated
  = 13.7 – 13.4 = 0.3 kcal/mole.

- **Uses of neutralization**

  (i) Slaked lime ($Ca(OH)_2$) is added to reduce the acidity of soil.
  (ii) Antacid tablets with $Mg(OH)_2$ or cold milk are used to treat acidity by neutralizing HCl in stomach.
  (iii) Sting of ants/bees containing HCOOH (formic acid) can be neutralized by rubbing soap (NaOH).
  (iv) Sting of wasps that contains an alkali can be treated by neutralizing it with CH_3COOH.
  (v) Lithium hydroxide is used to neutralize CO_2 exhaled by astronauts in spaceships or submariners in submarines.

- **Normality:** The number of equivalents of a solute present in one litre of solution is called **normality**. It is denoted by 'N'

$$\text{Normality} = \frac{\text{Number of equivalents}}{\text{Volume of solution in litres}} = \text{Number of equivalents} \times \frac{1000}{\text{V in ml}}$$

$$= \frac{\text{Mass}}{\text{Equivalent mass}} \times \frac{1}{\text{V in } \ell}$$

$$= \frac{\text{Mass}}{\text{Equvalent mass}} \times \frac{1000}{\text{V in ml}}$$

- Normality of a diluted solution can be calculated by using the concept that the total number of equivalents before and after dilution remain equal. This is called **law of dilution.** V_1 and N_1 are the volume and the normality respectively of the concentrated solution. V_2 and N_2 are the volume and the normality respectively of the diluted solution. According to the law of dilution, $V_1 N_1 = V_2 N_2$.
- **Ionic product of water:** Water ionizes partially to give H^+ and OH^- ions. An equilibrium exists between the ionized and unionized molecules.

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

  Applying the law of mass action to the above equilibrium, the equilibrium constant for the above reaction is, $K = \frac{[H^+][OH^-]}{[H_2O]}$

  $K[H_2O] = K_w = [H^+]\ [OH^-]$ where K_w is called ionic product of water.

  At normal temperature (25°C), the concentration of H^+ and OH^- ions remains equal that is 10^{-7} M

  $\therefore \quad [H^+] = [OH^-] = 10^{-7}$ mole/ℓ

  $K_w = [H^+]\ [OH^-] = 10^{-7} \times 10^{-7} = 10^{-14}$ mole^2/ℓ^2

  On adding a base, $[OH^-]$ increases and $[H^+]$ decreases but the product (K_w) remains constant at constant temperature.

- At 25°C,

  Neutral solution $\rightarrow [H^+] = [OH^-] = 10^{-7}$ mole ion/ℓ.

  Acidic solution $\rightarrow [H^+] > [OH^-] < 10^{-7}$ mole ion/ℓ.

  Basic solution $\rightarrow [H^+] < [OH^-] > 10^{-7}$ mole ion/ℓ.

- Addition of acid or base does not change the value of K_w. On the addition of acid, when $[H^+]$ increases a corresponding decrease in $[OH^-]$ keeps the K_w value constant.

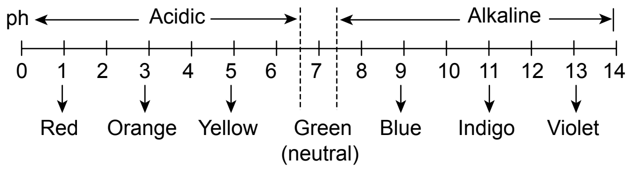
- pH is defined as the negative logarithm to base 10 of H^+ ion concentration or logarithmic reciprocal of H^+ ion concentration.

$$pH = -\log_{10}[H^+] \text{ or } \log_{10}\frac{1}{[H^+]} \text{ Similarly, } pOH = -\log_{10}[OH^-] \text{ or } \log_{10}\frac{1}{[OH^-]}$$

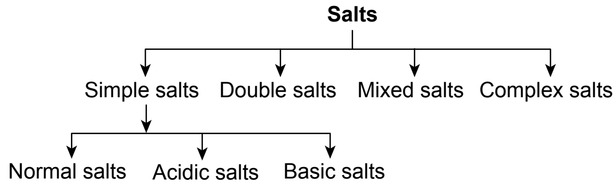
- **Indicators:** Indicators are organic dyes that have one colour in acidic solutions and another colour in basic solutions. There are two types of indicators
  (i) Common indicators
  (ii) Universal indicators

Indicator	Colour in acidic solution	Colour in basic solution
Litmus	Red	Blue
Methyl orange	Red	Yellow
Phenolphthalein	Colourless	Pink

- **Universal Indicator:** It is a mixture of organic dyes which gives different colours with solutions of different pH values. Hence this is more sensitive than other common indicators.
- **Determination of pH using universal indicators**



- **Classification of salts**



- **Simple salts:** The salts which contain only one type of positive ion and one type of negative ion are called **simple salts**. These are further classified into three types based on their chemical nature.

- **Comparative study of normal, acidic and basic salts**

	Normal Salts	Acidic salts	Basic salts
Definition	The salts which do not contain replaceable hydrogen or hydroxyl ions	The salts which contain one or more replaceable hydrogen ions	The salts which contain one or more replaceable hydroxyl ions
Formation	By complete neutralization of acids and bases **Example** $2NH_4OH + H_2SO_4 \downarrow (NH_4)_2SO_4 + H_2O$	By incomplete neutralization of acids and bases **Example** $NaOH + H_2SO_4 \downarrow NaHSO_4 + H_2O$	By incomplete neutralization of acids and bases **Example** $Cu(OH)_2 + HNO_3 \downarrow Cu(OH)NO_3 + H_2O$
Composition	All ionisable hydrogens are replaced by a metal or NH_4^+ ion	Partial replacement of ionizable hydrogen by a metal or NH_4^+ ion	Partial replacement of ionisable hydroxyl groups by non-metal ions or negative radicals
Properties	Neutral in nature. Do not react with acids or bases	Acidic in nature. React with bases	Basic in nature. React with acids
Examples	NaCl, $(NH_4)_2SO_4$, $Al_2(SO_4)_3$	$NaHSO_4$, NH_4HSO_4	$Cu(OH)NO_3$, $Cu(OH)Cl$

- **Double salts:** The salts which contain more than one simple salt are called double salts.
  Example: Potash alum – $K_2SO_4 . Al_2(SO_4)_3 . 24H_2O$
- **Mixed salts:** The salts which contain more than one basic or acidic radicals are called **mixed salts**.
  Example:
  Sodium potassium carbonate ($NaKCO_3$) (Na^+, K^+ and CO_3^{-2} radicals)
- **Complex salts:** The salts which contain one complex ion and one or more simple ions are called **complex**

salts. A complex salt dissociates into a complex ion and one or more simple ions.

Example: Sodium argento cyanide $Na[Ag(CN)_2]$

- **Water of crystallization:** The fixed number of water molecules which combine with a crystal and are necessary for the maintenance of crystalline properties, but capable of being lost either at normal temperature or at a higher temperature is called water of crystallization.

  Examples: Green vitriol ($FeSO_4.7H_2O$), blue vitriol ($CuSO_4.5H_2O$), washing soda ($Na_2CO_3.10H_2O$) etc.

- **Hydrated salts and anhydrous salts:** The salts which contain water of crystallization are called **hydrated salts**

- **Efflorescence and deliquescence:** There are some hydrated crystals which lose some of the water of crystallization or all the water of crystallization on exposure to air at normal temperature. This phenomenon is known as **efflorescence** and the hydrated crystals which lose water molecules are called efflorescent substances.

  Example: Glauber salt, $Na_2SO_4.10H_2O$

- Some crystalline salts absorb moisture on exposure to air and ultimately dissolve in it to form an aqueous solution. This phenomenon is called **deliquescence** and these crystalline salts are called deliquescent substances. These salts may or may not contain water of crystallization.

  Examples: Hydrated magnesium chloride ($MgCl_2.6H_2O$), hydrated calcium chloride ($CaCl_2.6H_2O$) etc.

- There are certain substances which absorb moisture from air without changing their physical state. These substances are called **hygroscopic substances.** They may exist in solid or liquid state under normal temperature and pressure.

  Examples: Calcium oxide (solid), concentrated sulphuric acid (liquid) etc.

- Hygroscopic substances which are used to remove water from the surroundings are called **desiccating agents.**

  Examples: Calcium oxide and anhydrous calcium chloride

- **Salt hydrolysis:** The phenomenon in which a simple salt on dissolution in water forms a parent acid and a parent alkali resulting in acidic, basic or neutral solution is called **salt hydrolysis**. It is the most important property of salts.

  Depending on the nature of the salts, it is classified into four types.

  (i) Hydrolysis of salts of strong acids and weak bases: This type of hydrolysis makes the solution acidic with pH < 7. (at 25°C)
  Examples: $CuSO_4$, $(NH_4)_2SO_4$, NH_4NO_3, $FeCl_3$ etc.

  (ii) Hydrolysis of salts of weak acids and strong bases: This makes type of hydrolysis the solution basic and has a pH > 7 (at 25°C).
  Examples: CH_3COONa, Na_2CO_3, CH_3COOK,

  (iii) Hydrolysis of salts of strong acids and strong bases: This type of hydrolysis makes the solution neutral with pH = 7 (at 25°C).
  Examples: NaCl, K_2SO_4, KNO_3

  (iv) Hydrolysis of salts of weak acids and weak bases: The exact value of pH of the solution depends upon the relative values of degree of dissociation of the acid and the base produced.
  Examples: $(NH_4)_2CO_3$, CH_3COONH_4

- **Qualitative analysis of simple salts:** A simple salt contains an acidic radical (anion) and a basic radical (cation). The qualitative analysis of a simple salt involves identification of the constituent acidic and basic radicals of the salt.

- **Identification of some important anions**

Anion	Test	Reactions involved	Observation and Inference
Carbonate (CO_3^{2-})	Action of dilute HCl	$CaCO_3 + 2HCl \downarrow CaCl_2 + H_2O + CO_2$	Colourless gas with brisk effervescence which puts off burning splinter and turns lime water milky. CO_2 gas is evolved.
Chloride (Cl^-)	Action of conc. H_2SO_4	$BaCl_2 + H_2SO_4 \downarrow BaSO_4 + 2HCl$; $HCl + NH_4OH \downarrow NH_4Cl + H_2O$	A colourless and pungent smelling gas is evolved (HCl). The gas when exposed to a glass rod dipped in NH_4OH forms white dense fumes.

(Continued)

Anion	Test	Reactions involved	Observation and Inference
Nitrate (NO_3^-)	Action of conc. H_2SO_4 in the presence of copper turnings	$4NaNO_3 + 2H_2SO_4 + Cu \downarrow 2Na_2SO_4 + 2NO_2 + Cu(NO_3)_2 + 2H_2O$	A reddish brown pungent gas is evolved (NO_2) and the solution turns blue. ($Cu(NO_3)_2$)

- **Confirmatory tests for anions**

Anion	Test	Reaction Involved	Observation
Carbonate (CO_3^{2-})	Reaction with $BaCl_2$ solution	$CaCO_3 + BaCl_2 \downarrow BaCO_3\downarrow + CaCl_2$	A white precipitate ($BaCO_3$) which is soluble in conc. HCl
Chloride (Cl^-)	Reaction with $AgNO_3$ solution	$2BaCl_2 + 2AgNO_3 \downarrow 2AgCl\downarrow + Ba(NO_3)_2$	White curdy precipitate (AgCl)
Nitrate (NO_3^-)	**Brown ring test:** Salt solution + freshly prepared ferrous sulphate solution+conc.H_2SO_4	$NaNO_3 + H_2SO_4 \rightarrow NaHSO_4 + HNO_3$ $6FeSO_4 + 3H_2SO_4 + 2HNO_3 \rightarrow 3Fe_2(SO_4)_3 + 4H_2O + 2NO$ $FeSO_4 + NO \rightarrow [Fe(NO)]SO_4$ (brown ring)	A reddish brown ring (nitroso ferrous sulphate) is formed at the junction of the two layers
Sulphate (SO_4^{-2})	Reaction with $BaCl_2$ solution	$ZnSO_4 + BaCl_2 \rightarrow ZnCl_2 + \underset{\text{White}}{BaSO_4\downarrow}$	A white precipitate ($BaSO_4$) which is insoluble in conc. HCl

- **Table showing different characteristic precipitations given by different metal ions**

Salt Solution and its colour	Cation of salt	Precipitate formed	
		NaOH	NH_4OH
$FeSO_4$ (Green)	Fe^{+2}	$Fe(OH)_2$ Dirty green Insoluble in excess NaOH	$Fe(OH)_2$ Dirty green Insoluble in excess NH_4OH
$FeCl_3$ (Brown)	Fe^{+3}	$Fe(OH)_3$ Reddish brown Insoluble in excess NaOH	$Fe(OH)_3$ Reddish brown Insoluble in excess NH_4OH
$CaCl_2$ (Colourless)	Ca^{+2}	$Ca(OH)_2$ Milky white Insoluble in excess NaOH	No reaction – –
$ZnSO_4$ (Colourless)	Zn^{+2}	$Zn(OH)_2$ White Soluble in excess NaOH (colourless solution)	$Zn(OH)_2$ White Soluble in excess NH_4OH (colourless solution)
$Pb(NO_3)_2$ (Colourless)	Pb^{+2}	$Pb(OH)_2$ Chalky white Soluble in excess NaOH	$Pb(OH)_2$ Chalky white Insoluble in excess NH_4OH

(Continued)

Salt Solution and its colour	Cation of salt	Precipitate formed	
		NaOH	NH_4OH
$CuSO_4$ (Blue)	Cu^{+2}	$Cu(OH)_2$ Pale blue Insoluble in excess NaOH	$Cu(OH)_2$ Pale blue Soluble in excess NH_4OH (deep blue solution)
$Mg(NO_3)_2$ (Colourless)	Mg^{+2}	$Mg(OH)_2$ Milky white Insoluble in excess NaOH	No reaction

Solved Examples

1. Acetic acid is a weak acid whereas HCl is a strong acid. Give reasons.

Solution: If the same concentration of acetic acid and hydrochloric acid are taken, acetic acid furnishes less number of H^+ ions in its aqueous solution than that of HCl. Hence, acetic acid is a weak acid whereas HCl is a strong acid in aqueous solution.

2. How is the degree of ionization related to strength of an acid? Explain.

Solution: Acids undergo ionization in aqueous solution. The degree of ionization of an acid in an aqueous solution is called the strength of that acid. Degree of ionization is denoted by the letter alpha (α).

$$\propto = \frac{\text{Number of ionised acid molecules}}{\text{Total number of acid molecules}} \times 100$$

On the basis of the degree of ionization, the acids are classified as

(a) strong acids (high degree of dissociation)

(b) weak acids (low degree of dissociation).

3. How does the concentration of hydronium ions change during dilution of an acid?

Solution: Dilution of an acid decreases the concentration of hydronium ions per unit volume.

4. Give reasons for the following.

(a) Metal oxides generally react with acids. But zinc oxide reacts even with sodium hydroxide.

(b) Heat of neutralization value for the reaction of HCl and NH_4OH is less than 13.7 kcal/mole

(c) All indicators are not suitable for all titrations.

Solution: **(a)** Zinc oxide is amphoteric in nature. Hence, it can react both with acids as well as bases.

(b) NH_4OH is a weak base and hence some heat is utilized to ionize the weak base.

(c) Indicator which underegoes colour change in the pH range of the titration is only suitable for a particular titration.

5. What is the pH value of 0.05 M H_2SO_4 solution?

Solution: $[H^+] = 0.05 \times 2 = 0.10$

$pH = -\log(0.05 \times 2) = 1$

6. Explain the action of phenolphthalein indicator in the titration of acetic acid versus sodium hydroxide.

Solution: Acetic acid is a weak acid having a pH value of more than 6. Sodium hydroxide is a strong base and addition of OH^- ions neutralizes the H^+ ions formed by the dissociation of acetic acid. Since H^+ ion concentration is very low, the addition of further OH^- ions increases the pH value abruptly. Therefore, the titration range of this reaction lies between 6.5 to 10.0. The pH range of phenolphthalein is 8.2 to 10.0 and hence it undergoes colour change in this range. Hence it acts as a suitable indicator for this titration.

7. Is a solution with pH 6 acidic, basic or neutral? Justify.

Solution: A solution with pH 6 will be acidic when the ionic product of water is 1×10^{-14} mole²/litre². In such a case, a solution with pH less than 7 is acidic in nature. On increasing the temperature, the ionic product of water increases due to increase in the ionization of water. When the ionic product of water increases to 1×10^{-12} mole²/litre², a solution with pH 6 will be neutral and below 6 will be acidic in nature.

8. Define salt hydrolysis. Explain the nature of aqueous solution of $CuSO_4$ on the basis of the above phenomenon.

Solution: The phenomenon in which a simple salt on dissolution in water forms a parent acid and a parent alkali resulting in acidic, basic or neutral solution is called salt hydrolysis. It is the most important property of salts.

$CuSO_4$ on hydrolysis produces a strong acid which ionizes and a weak base which does not ionize. This increases the concentration of H^+ ions making the solution acidic with pH < 7 (at 25 °C)

$$Cu^{+2} + SO_4^{-2} + 2H_2O \rightarrow Cu(OH)_2 + 2H^+ + SO_4^{-2}$$

As cation of the salt reacts with water, it is called cationic hydrolysis.

9. How do you identify the following cations in their aqueous solutions by using caustic soda solution?

(a) Fe^{+2} **(b)** Zn^{+2} **(c)** Al^{+3}

Solution: **(a)** Fe^{+2} gives light green precipitate of ferrous hydroxide ($Fe(OH)_2$)

(b) Zn^{+2} gives white precipitate of zinc hydroxide ($Zn(OH)_2$)

(c) Al^{+3} gives white gelatinous precipitate of aluminium hydroxide ($Al(OH)_3$).

10. What is the use of an indicator in titration? Name the indicator used when sodium hydroxide is titrated against sulphuric acid.

Solution: The neutralization point can be determined by the use of indicator. The indicator used when sodium hydroxide is titrated against sulphuric acid is phenolphthalein.

PRACTICE EXERCISE 7 (A)

Directions for questions 1 to 35: Select the correct alternative from the given choices.

1. Acetic acid contains four hydrogen atoms. So its basicity is _________.

(1) 1 (2) 2
(3) 3 (4) 4

2. According to Lewis theory, neutralization is the

(1) transfer of proton from acid to base.
(2) transfer of proton from base to acid.
(3) transfer of electron pair from acid to base.
(4) transfer of electron pair from base to acid.

3. The basicity of acetic acid is the same as the basicity of ______.

(1) HNO_3 (2) H_2SO_4
(3) H_3PO_4 (4) H_2CO_3

4. Neutralization reaction among the following is

(1) $Na_2O+CO_2 \rightarrow Na_2CO_3$
(2) $HCl + NH_3 \rightarrow NH_4^+ + Cl^-$
(3) $NH_3 + H^+ \rightarrow NH_4^+$
(4) All the above

5. Which among the following statements is false?

(1) Every protonic acid has its conjugate acid.
(2) Pair of Bronsted acid and base that differ by a proton is conjugate acid base pair.
(3) A substance that accepts an electron pair to form coordinate covalent bond is an acid.
(4) Arrhenius theory is confined to aqueous solutions.

6. Identify the acidic salt among the following.

(1) Na_2SO_4 (2) $NaHSO_4$
(3) $Cu(OH)NO_3$ (4) $CaoCl_2$

7. $X + H_2O \rightarrow Y$.Y is used to remove grease stains from woollen clothes. Identify X and Y.

(1) NH_3, NH_4 Cl
(2) NH_3, NH_4OH
(3) NH_4OH, NH_3
(4) Cl_2, HCl

8. Sting of a honey bee causes pain and burning senzation because it contains

(1) formic acid. (2) oxalic acid.
(3) acetic acid. (4) tartaric acid.

9. According to which theory/theories ammonia is a base?

(1) Arrhenious, Bronsted
(2) Bronsted, Lewis
(3) Arrheniouns, Lewis
(4) Both (2) and (3)

10. Arrange $HClO_3$, $HBrO_3$ and HIO_3 in the order of acidic strength.

(1) $HClO_3 > HBrO_3 > HIO_3$
(2) $HBrO_3 > HIO_3 > HClO_3$
(3) $HIO_3 > HBrO_3 > HClO_3$
(4) $HClO_3 > HIO_3 > HBrO_3$

11. Identify the strongest acid among the following.

(1) HOCl (2) $HClO_2$
(3) $HClO_3$ (4) $HClO_4$

12. Which of the following solutions has the same concentration of H^+ ions as 0.1 N HCl?

(1) 0.05 M H_2SO_4 (2) 0.3 M H_3PO_4
(3) 0.2 M HNO_3 (4) All the above

13. The indicator which shows colour change in the entire pH range is

(1) phenolphthalein (2) methyl orange
(3) universal indicator (4) thymol blue

14. Heat of neutralization is less than 13.7 kcal/mole for which of the following reactions?

(1) $HCl+ NaOH \rightarrow NaCl + H_2O$
(2) $H_2SO_4 + 2NaOH \rightarrow Na_2SO_4+2H_2O$
(3) $HNO_3 + NaOH \rightarrow NaNO_3 + H_2O$
(4) $CH_3COOH + NaOH \rightarrow CH_3COONa + H_2O$

15. The basicity of phosphorous acid is the same as the basicity of ______.

(1) HNO_3 (2) H_2SO_4
(3) H_3PO_4 (4) HCl

16. V_1 ml of x molar hydrochloric acid is mixed with V_2 ml of y molar sodium hydroxide. Arrange the following steps in correct sequence for calculation of pH of the mixture. ($y > x$ and $V_1 > V_2$)

(a) Calculation of the number of equivalents of acid and base.
(b) Calculation of the total volume of mixture.

(c) Calculation of the normality of acid and base.
(d) Calculation of the net OH^- ion concentration.
(e) Taking the negative logarithm of H^+ ion concentration.
(f) Dividing K_w by OH^- ion concentration
(1) a c b f d e (2) c a b d f e
(3) c a b f d e (4) a b c d f e

17. From the pH values given below, write the decreasing order of hydronium or H^+ ion concentration. 13, 11, 9.
(1) 13, 11, 9 (2) 9, 11, 13
(3) 9,13, 11 (4) 11, 13, 9

18. Equivalent mass of 'X' is equal to the molecular mass. Identify X.
(1) CH_3COOH (2) H_2SO_4
(3) H_3PO_4 (4) H_2CO_3

19. Calculate the equivalent mass of HCl.
(1) 31 (2) 35.5
(3) 36.5 (4) 18.2

20. 14.3 g of $Na_2CO_3\,xH_2O$ is dissolved in water and the volume is made up to 200 ml. 20 ml of this solution required 40 ml of $\frac{N}{4}$ HNO_3 for complete neutralization. Calculate x.
(1) 3 (2) 4
(3) 9 (4) 10

21. How many moles of NaOH must be added to 200 ml of 0.1 M solution of HNO_3 to get a solution having pH value 2? (considering NaOH in solid state)
(1) 0.08 (2) 0.018
(3) 0.011 (4) 0.01

22. 8 g of mixture of $NaNO_3$ and Na_2CO_3 are dissolved and made into 500 ml of solution. 50 ml of this solution neutralizes completely 25 ml of N/5 HNO_3. Calculate the mass of Na_2CO_3 present in the mixture
(1) 2.65 g (2) 5.35 g
(3) 8 g (4) 4.15 g

23. What kind of salt is $NaHSO_3$?
(1) Acidic salt (2) Basic salt
(3) Normal salt (4) Double salt

24. Three cations A, B, C are allowed to react with ammonium hydroxide solution. A and B produce a dirty green precipitate and a reddish brown precipitate respectively, both of which do not dissolve on further addition of NH_4OH. C gives pale blue colour precipitate with less amount of ammonium hydroxide and on further addition of NH_4OH, precipitate becomes soluble and deep blue colour solution is formed.
(1) Fe^{+2}, Fe^{+3}, Cu^{+2} (2) Fe^{+3}, Fe^{+2}, Cu^{+2}
(3) Cu^{+2}, Fe^{+2}, Fe^{+3} (4) Cu^{+2}, Fe^{+3}, Fe^{+2}

25. Two salts A and B are dissolved in water separately. When phenolphthalein is added to the two solutions, one solution turned pink and the other solution was colourless. Identify A and B.
(1) CH_3 COONa, NH_4Cl
(2) Na_2SO_4, CH_3COONa
(3) NH_4Cl, Na_2SO_4
(4) $NaNO_3$, Na_2SO_4

26. What could be the nature of aqueous solution of sodium sulphate?
(1) Acidic
(2) Basic
(3) Neutral
(4) Nature depends on the concentration of the solution.

27. Calculate the resultant pH of a solution when 20 ml of 0.1 N NaOH is mixed with 20 ml of 0.05 M $Ca(OH)_2$ at 25°C.
(1) 1 (2) 2
(3) 13 (4) 14

28. 100 ml of Na_2CO_3 solution containing 5.3 g of Na_2CO_3 was exactly neutralized by 200 ml of H_2SO_4 solution. What is the pH of H_2SO_4? (log 5 = 0.6990)
(1) 0.5 (2) 1
(3) 0.6990 (4) 0.3010

29. The ionic product of water is found to be 1×10^{-12} $mole^2/\ell^2$ at 60°C. What would be the nature of solution with pH = 7?
(1) Basic
(2) Acidic
(3) Neutral
(4) Cannot be determined

30. Two coloured salt solutions of two metals A and B gave precipitates with NaOH and NH_4OH. The oxidation states of salts of metal A and B are same. On further addition of NH_4OH, the precipitate disappears, in the case of B. There is no such change in the case of 'A' either with NaOH or NH_4OH. Identify A and B. Give necessary equations.

(1) Fe^{+2}, Cu^{+2} (2) Cu^{+2}, Fe^{+2}
(3) Fe^{+}, Fe^{+3} (4) Fe^{+3}, Cu^{+2}

31. Calculate the weight of nitric acid present in 40 ml of solution which completely neutralizes 20 ml of 0.01 M barium hydroxide assuming complete ionization.
(1) 0.40 g
(2) 0.0004 g
(3) 0.0252 g
(4) 0.063 g

32. Find the pH of resultant solution when 100 ml of 0.005 M H_2SO_4 at 25°C is diluted to 1000 ml. What is the amount of NaOH required to be dissolved in 500 ml to exactly neutralize the above solution?
(1) 4 g (2) 4×10^{-2} g
(3) 40 g (4) 0.4 g

33. Which of the following cannot act as an acid as well as a base according to protonic concept?
(1) HSO_4^- (2) H_2O
(3) HS^- (4) ClO_4^-

34. Predict the type of salts formed by the reaction between H_2SO_4 and $Ca(OH)_2$
(1) Normal salt (2) Acidic salt
(3) Basic salt (4) Both (1) and (2)

35. Calculate the equivalent mass of H_2SO_4 from the given reactions.
(a) $H_2SO_4 + NaOH \rightarrow NaHSO_4 + H_2O$
(b) $H_2SO_4 + 2NaOH \rightarrow Na_2SO_4 + 2H_2O$
(1) 49 and 98 (2) 98 and 49
(3) Both 49 (4) Both 98

PRACTICE EXERCISE 7 (B)

Directions for questions 1 to 35: Select the correct alternative from the given choices.

1. Identify the species which can give both conjugate acid and conjugate base.
(1) NH_4^+ (2) $H_2PO_4^-$
(3) PO_4^{-3} (4) H_3O^+

2. Which of the following is not a base according to any of the theories?
(1) $Mg(OH)_2$ (2) NH_3
(3) $H_2PO_4^-$ (4) BF_3

3. Which of the following species cannot have conjugate base?
(1) HSO_4^- (2) HPO_4^{-2}
(3) PO_4^{-3} (4) $H_2PO_2^-$

4. Which among the following pairs of acid and base are weak respectively?
(1) HCOOH and NH_4OH
(2) HCl and NaOH
(3) CH_3COOH and KOH
(4) $HClO_4$ and CsOH

5. What are the basicities H_3PO_4 and H_3PO_3 respectively?
(1) 2, 3 (2) 1, 2
(3) 3, 3 (4) 3, 2

6. Which of the following has the highest value of pH at the same temperature for the same concentration?
(1) HCl (2) NaOH
(3) $Ca(OH)_2$ (4) CH_3COOH

7. The pH of 0.001 N sodium hydroxide solution at 25°C is
(1) 3 (2) 4
(3) 11 (4) 12

8. Which of the following pH values at 25°C corresponds to the strongest acid?
(1) 2 (2) 4
(3) 6 (4) 8

9. A solution turns methyl orange red. It can turn the universal indicator to _______
(1) violet (2) blue
(3) orange (4) green

10. A strongly acidic solution is taken and a base is slowly added to it drop by drop. Arrange the colours observed during the process of addition in proper sequence.
(a) Green (b) Indigo
(c) Orange (d) Red
(e) Blue (f) Violet
(g) Yellow

(1) c d a g b e f
(2) d c g a e b f
(3) d c a g e b f
(4) c d g a f b e

11. What is the pH of 0.001 M HCl?

(1) 1 (2) 2
(3) 3 (4) 4

12. If two strong acids A, B having pH of 1 and 2 of same volume respectively are mixed, then what is the pH range of the new solution?

(1) Less than 1
(2) Greater than 2
(3) Between 1 and 2
(4) Can't be calculated

13. A solution of which of the following pH turns universal indication violet?

(1) pH = 1 (2) pH = 9
(3) pH = 5 (4) pH = 13

14. 10 ml of 1 N HCl, 25 ml of 2 N H_2SO_4 and 40 ml of X N HNO_3 are mixed and made up to 2000 ml. 100 ml of this solution required 30 ml of NaOH taken from a solution containing 4 g of NaOH in 250 ml of solution. What is the value of X?

(1) 2.5 N (2) 3.5 N
(3) 4.5 N (4) 5.5 N

15. The ionic product of water calculated by a student was found to be 1×10^{-16} mole$^2/\ell^2$ at 5°C. What is the nature of solution with pH = 7 at same temperature?

(1) Basic
(2) Acidic
(3) Neutral
(4) Cannot be predicted.

16. The nature of resultant solution when 20 ml of 0.05 M NaOH is mixed with 10 ml of 0.1 N HCl solution at 25°C is

(1) acidic
(2) basic
(3) neutral
(4) Can't be predicted

17. No indicator can be used for the titration between formic acid and ammonium hydroxide because

(1) formic acid is weak acid and ammonium hydroxide is weak base
(2) formic acid is weak acid and ammonium hydroxide is strong base
(3) formic acid is strong acid ad ammonium hydroxide is weak base
(4) formic acid is strong acid and ammonium hydroxide strong base

18. A solution of which among the following salts is basic in nature?

(1) $MgSO_4$ (2) $NaNO_3$
(3) CH_3COONa (4) NaCl

19. (a) Potash alum responds to the test for two cations and one negative radical
(b) Bleaching powder responds the test for two cations and one negative radical.
(c) Disodium potassium phosphate responds the test for three cations and one negative radical.
(d) Sodium argento cynide responds the test for one cation and one negative radical.

Which of the following option regarding the above statements is correct?

(1) a and d (2) b and c
(3) only d (4) a, c and d

20. An aqueous solution of carnalite salt can give a precipitate with silver nitrate but the aqueous solution of $[Co(NH_3)_3Cl_3]$ cannot give a precipitate with silver nitrate. How do you account for this?

(1) Both salts are double salts
(2) Both salts are complex salts
(3) First one is a double salt and other one is a complex salt
(4) First one is a complex salt and other one is a double salt

21. Both ammonium oxalate and potassium sulphate give neutral solutions in water. But, it is said that ammonium oxalate undergoes hydrolysis and potassium sulphate does not undergo hydrolysis. Because ammonium oxalate is a slat of _____ acid ___ base

(1) weak, weak (2) weak, strong
(3) strong, strong (4) strong, weak

22. An aqueous solution of Mohr's salt can give a precipitate with NaOH or NH_4OH. But, the aqueous solution of potassium ferrocyanide cannot give a precipitate with both reagents. How do you account for this?

(1) Both salts are double salts
(2) Both salts are complex salts
(3) First one is a double salt and other one is a complex salt
(4) First one is a complex salt and other one is a double salt

23. Find the pH of 0.005 M $Ba(OH)_2$ solution at 25°C. Also calculate the pH value of the solution when 100 ml of the above solution is diluted to 1000 ml. (Assume complete ionization of barium hydroxide)

(1) 8, 9 (2) 2, 3
(3) 10, 12 (4) 12, 11

24. What are the spectator ions in the reaction of potassium hydroxide with sulphuric acid?

(1) H^{+1}, OH^{-1} (2) H^{+1}, SO_4^{-2}
(3) K^{+1}, OH^{-1} (4) K^{+1}, SO_4^{-2}

25. Calculate the pH of resultant solution at 25°C when 10 ml of 0.04 M H_2SO_4 is diluted 1000 times and 100 ml of the diluted acid is mixed with 100 ml of 0.001 M NaOH solution at 25°C.

(1) 8.2 (2) 9.5
(3) 10.7 (4) 12.8

26. Give pH range of acidic, neutral and basic solutions at 25°C.

(1) <7, 7, >7
(2) <8, 9, >10
(3) <6, 7, > 7
(4) <5, 6, > 7

27. 10 ml of 0.01 N NaOH is diluted to 1000 ml. What should be the amount of sodium hydroxide required to be added in order to maintain the concentration of the solution as that of the earlier solution.

(1) 0.396 g
(2) 0.450 g
(3) 0.275 g
(4) 0.470 g

28. The acids present in tamarind and vinegar ___ and respectively.

(1) oxalic acid, acetic acid
(2) oxalic acid, tartaric acid
(3) tartaric acid, oxalic acid
(4) tartaric acid, acetic acid

29. Calculate the normality of a solution of sulphuric acid containing 0.49 g of substance in 250 ml solution.

(1) 0.01 N (2) 0.02 N
(3) 0.04 N (4) 0.06 N

30. Calculate the pH value of 0.01 M H_2SO_4 solution. (log 2 = 0.3010)

(1) 0.45 (2) 0.55
(3) 0.64 (4) 0.699

31. Assume that product of water is 12 at 50°C. Some statements related to the given statement are listed below.

(a) Addition of an acid at the given temperature to water increases the ionic product of water because of increase in H^+ ions.
(b) Addition of base to water decreases the ratio of H^+ to OH^-.
(c) Addition of an acid on a base suppresses the dissociation of water molecules.
(d) Ionic product of water varies only with temperature.

Which of the following option is correct?

(1) a, b and c
(2) b, c and d
(3) c and d
(4) a and b

32. (a) Incomplete neutralization of sodium hydroxide with sulphric acid gives rise to a basic salt.
(b) Incomplete neutralization of aluminum hydroxide with sulphric acid can give rise to an acidic salt and two basic salts.
(c) Incomplete neutralization of calcium hydroxide with sulphric acid can give rise to an acidic and a basic salt.
(d) Incomplete neutralization of cupric hydroxide with nitric acid gives rise to a basic salt.

Regarding the above statements, which of the following options is correct?

(1) only b
(2) only d
(3) a and b
(4) c and d

33. Identify dirty green precipitate among the following.

(1) $Fe(OH)_2$
(2) $Pb(OH)_2$
(3) $Mg(OH)_2$
(4) $Zn(OH)_2$

34. 200 ml of 0.2 N sodium carbonate solution is diluted by adding 800 ml of water. Calculate the normality of diluted solution.

(1) 0.04 (2) 0.4
(3) 0.1 (4) 0.01

35. Calculate the pH value of HNO_3 solution containing 0.315 g acid in 200 ml of solution. (log 2.5 = 0.3979)

(1) 1.6021 (2) 2
(3) 0.3979 (4) 1

ANSWER KEYS

PRACTICE EXERCISE 7 (A)

1. 1	**2.** 4	**3.** 1	**4.** 4	**5.** 1	**6.** 2	**7.** 2	**8.** 1	**9.** 2	**10.** 1
11. 4	**12.** 1	**13.** 3	**14.** 4	**15.** 2	**16.** 2	**17.** 2	**18.** 1	**19.** 3	**20.** 4
21. 2	**22.** 1	**23.** 1	**24.** 1	**25.** 1	**26.** 3	**27.** 3	**28.** 4	**29.** 1	**30.** 1
31. 3	**32.** 2	**33.** 4	**34.** 2	**35.** 2					

PRACTICE EXERCISE 7 (B)

1. 2	**2.** 4	**3.** 3	**4.** 1	**5.** 4	**6.** 2	**7.** 3	**8.** 1	**9.** 3	**10.** 2
11. 3	**12.** 3	**13.** 4	**14.** 3	**15.** 2	**16.** 3	**17.** 1	**18.** 3	**19.** 1	**20.** 3
21. 2	**22.** 3	**23.** 4	**24.** 4	**25.** 3	**26.** 1	**27.** 1	**28.** 4	**29.** 3	**30.** 4
31. 2	**32.** 2	**33.** 1	**34.** 1	**35.** 1					