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PHARMACEUTICAL ANALYSIS I

UNIT 2

TOPIC :

- **Acid base titration:** Theories of acid base indicators, classification of acid base titrations and theory involved in titrations of strong, weak, and very weak acids and bases, neutralization curves

Titration

- Titration is a quantitative analytical technique used in chemistry to determine the unknown concentration of a solution (analyte) by gradually adding a solution of known concentration (titrant) until the chemical reaction between them is complete.
- The point at which the reaction is exactly complete is called the equivalence point, and it is usually detected with the help of a chemical indicator that changes color or by using an instrument like a pH meter or conductometer.

Basic Terminology

- **Titrant**: A solution of known concentration added from a burette.
- **Analyte**: The solution of unknown concentration being analyzed.
- **End Point**: The point at which the indicator changes color.
- **Equivalence Point**: The actual point at which equivalent amounts of acid and base have reacted.
- **Indicator**: A chemical that changes color at (or near) the equivalence point.

Acid Base Titration

- In chemistry, acid – base titration is used for analysis the unknown organic compound concentration of an acid and base
- The principle of acid-base titration is based on the neutralisation reaction occurring between acid & base
- Phenolphthalein is the most commonly used indicator for acid-base titration
- Acid-Base reaction involve transfer of proton,

  Example :- Base accept proton from Acid

  $H^+ + OH^-$ H_2O
- It is most common Neutralisation reaction
- At bequivalent point, moles of H+ are equal to the moles of OH-

- During titration one rectant (mostly an acid) is added from the burette to the known volume of the other reactant (mostly base) in a conical flask to make the equivation point (end point) of the titration and indicator is used

Theories

There are 3 theories , explaining the comcept of acids and bases

- Arrhenius theory
- Bronsted Lowry theory
- Lewis theory

Theory	**Acid**	**Base**
Arrhenius	H+ Producer	OH- Producer
Bronsted lowry	H+ donar	H+ acceptor
Lewis	Electron pair acceptor	Electron pair donar

Arrhenius Theory

- The most commonly used concept of acids and bases was develop by Savante Arrhenius in 1884 termed as Arrhenius theory
- According to this theory an acid is a substance which dissociates in Aqu. Solution produce hydrogen ion on other hand a base is a substance which dissolve in aqueous solution to produce hydroxyl ion (OH-)

  For example

  - HCl is an Arrhenius acid HCL H+ + Cl-
  - NaOH is an Arrhenius base NaOH OH- + Na+
- Arrhenius theory was the first scientific theory that had given defination for acid and base as well as classified them It is the simplest theory and is useful in case of aqueous solution

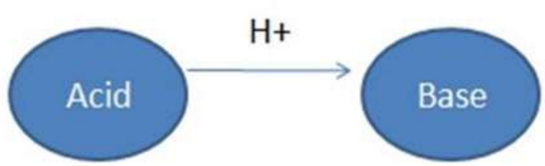
Limitations

- ❖ Acid and base have been defined only in terms of solution and not as a solid substance
- ❖ This theory also failed to explain the neutralistation of acid & base in the absence of solvent
- ❖ There are many basic substance (few organic substance) which do not have oh ions but are basie in nature this fact could not be explained by Arrhenius theory
- ❖ Acidic properties of many salts could not be explained by this theory

Bronsted Lowry theory

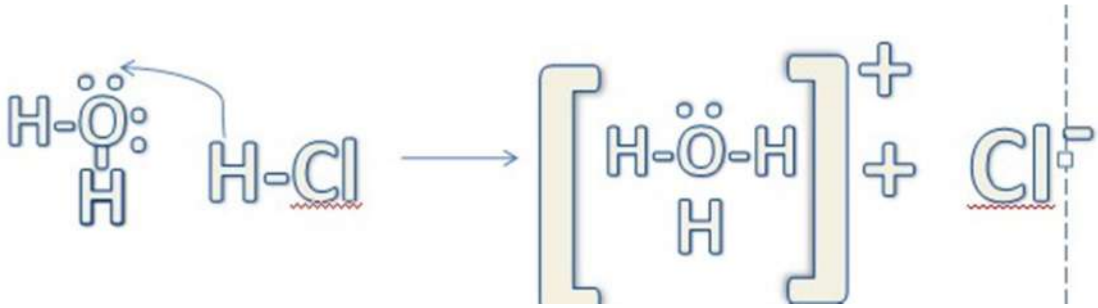
→ In 1923 J.N Bronsted and J.M Lowry was introduced a new concept of acid and base

→ According to the theory an acid is any mol or ion that can donate a proton (h+) and base is any mol or ion that can accept a proton H+



An acid is a proton donor While base is a proton acceptor

- ➢ A base qualifying Bronsted lowry concept is termed as Bronsted lowry base or Bronsted base
- ➢ Where an acid qualifying Bronsted lowry concept is termed as Bronsted lowry acid or Bronsted acid
- ➢ **For example :-** On dissolving dry HCl gas in water , each molecule of HCl produces hydronium ion (H_3O^+)by donating a proton to a water molecule



There fore it can be concluded that water which accept a proton is a bronsted base where HCl gas which donate a proton is a Bronsted.

Advantages

- Much wider scope Bronsted lowry concept of acid and base cover wider range of molecules and ions accepting proton (base) or donating proton (acid)
- Where arrhenius concept of acid & base involve only those substance which release H+ or OH- ions in aqueous solution
- Not limited to aqueous solution Arrhenius concept is limited only to aqueous solution Bronsted lowry theory not only covers aqueous sol but also gas phases
- Release of OH- not necessary to qualify as a base Bronsted base is a substance which accept a proton, where Arrhenius base is a substance which release OH- ions in aqueous solution

Limitations

- Bronsted lowry theory of acid & base is based on transfer on proton commonly most of the acids as protonic in nature but some are not
- There are many acid base chemical reaction in which proton transfer not occurs

Lewis Theory of Acids & Bases

- This method of Acid & Base was given by G.N Lewis in the early 1930
- He defined Acid is an electron pair acceptor
    - Base is an electron pair donar
- In this theory the Lewis acid & Lewis base share an electron pair given by base result in the formation of a covalent or coordinate bond between them
- This resultant compaired bounded with a covalent bond is known as a complex
    - A + B = A-B
    - LA LB Complex

According to this concept

- Lewis base are anion or molecule having a long pair of electron
- Lewis Acid are cation or molecule lacking of electron pair

Advantages

- It included the defination given by both Arrhenius and Bronsted Lowry.
- The lewis concept explain the acidic & basic nature on the basis of transfer or gain of electron accompanied by loss/donation of electron pair.

Limitations

- Lewis acid and base can not arranged in their order of strength as their strength depend on the reaction type
- Lewis acid and base reaction are explained are excepted to be very fast but to the involvement of electron but some of there reaction slow

Acid Base Indicators

→ An acid base indicator is the substance which is used to determine the end -point of acid base titration by changing the colour of reaction mixture.

Theory of Indicator

→ There are two theory of indicator. they are listed as following

.1Ostwald's Theory

.2Quinonoid Theory

.1**Ostwald's Theory :** According to Ostwald theory an acid base indicator is a weak acid or base in nature. These substances give different colour in different medium.

The formation of colour in different medium depends upon dissociative or non- dissociative state of indicator.

Example: a. Phenolphthalein

b. Methyl orange

a. Phenolphthalein (HPh)

HPh (colorless) ⇌ H++Ph−(pink)

when phenolphthalein is added to acidic medium

$Hph \rightleftharpoons H^+ + Ph^-$

$HCL \rightleftharpoons H^+ + cl^-$

→ common ion effect

When phenolphthalein is added to acid H^+ of acid (HCl) suppress H^+ of phenolphthalein due to Common ion effect. So it will remain in non dissociative form and then show no colour.

b. Methyl orange

MeOH ⇌ Me^+ + OH^-

(Yellow) (red)

When methyl orange is added to acidic medium

MeOH ⇌ Me^+ + OH^-

Hcl ⇌ Cl^- + H^+

OH^- of MeOH is used by H^+ of HCl so dissociative State it will show red colour

When base is added

MeOH ⇌ Me^+ + OH^-

NaOH ⇌ Na^+ + OH^-

due to common ion effect OH ions of MeOH is suppressed by OH^- of NaOH, to non dissociative State So yellow colour.

.2Quinonoid Theory

According to quinonoid theory indicator exist in two forms

a. benzenoid form (benzene nucleus)
b. quinonoid form (quinone nucleus)

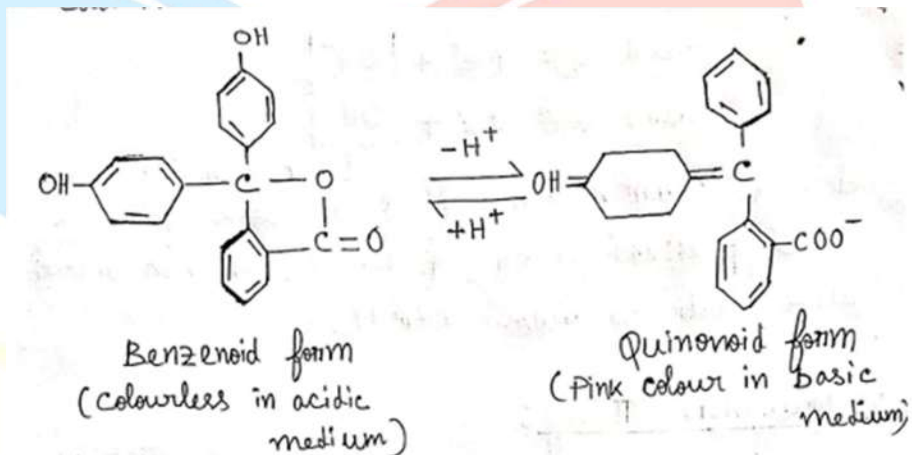
The different form of indicator give different colour in different medium

Example:

A- Phonolphthakin

B. Methyl orange

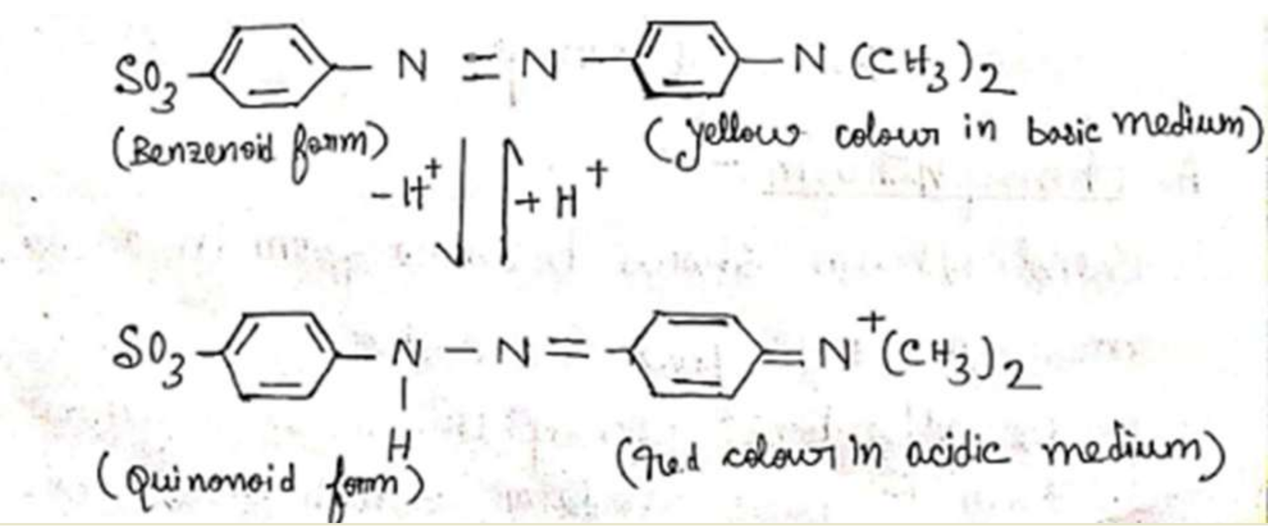
A. Phenolphthalein :- Phenolphthalein show's benzenoid form in acidic medium which no colour. on the other hand gives phenolphthalein shows quinonoid form in basic medium which gives pink colour



B. Methyl orange

Methyl orange shows benzenoid form in basic medium which gives yellow colour.

On the other hand methyl orange shows quinonoid form in acidic medium which gives red colour.



Classification of Acid-Base Titrations

→Acid-base titrations are classified based on the **strengths of the acid and base** involved in the reaction:

Type	Acid	Base
I	Strong Acid	Strong Base
II	Strong Acid	Weak Base
III	Weak Acid	Strong Base
IV	Weak Acid	Weak Base

Type I: Strong Acid vs. Strong Base

Example Reaction:

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

- Complete ionization of both acid and base.
- Sharp pH change near **pH 7** at the equivalence point.

Suitable Indicators

- Phenolphthalein
- Bromothymol Blue
- Methyl Orange

Used In:

- General laboratory acid-base titrations.

Type II: Strong Acid vs. Weak Base

Example Reaction:

$HCl + NH_4OH \rightarrow NH_4Cl + H_2O$

- Strong acid fully ionizes; weak base only partially ionizes.
- pH at equivalence point is < **7** (acidic).

Suitable Indicator

- Methyl Orange

Used In:

- Titration of strong acid with ammonia or organic bases.

Type III: Weak Acid vs. Strong Base

Example Reaction:

$$CH_3COOH + NaOH \rightarrow CH_3COONa + H_2O$$

- Weak acid partially ionizes; strong base fully ionizes.
- pH at equivalence point is > **7** (basic).

Suitable Indicator

- Phenolphthalein

Used In:

- Acetic acid titration with NaOH.

Type IV: Weak Acid vs. Weak Base

Example Reaction:

$CH_3COOH + NH_4OH \rightarrow CH_3COONH_4 + H_2O$

- Both weak acid and weak base only partially ionize.
- No sharp change in pH; no distinct equivalence point.

Suitable Indicator

- No suitable color indicator.
- Use instrumental methods (e.g., potentiometry, conductometry).

Used In:

- Special analytical procedures.

Neutralisation Curves

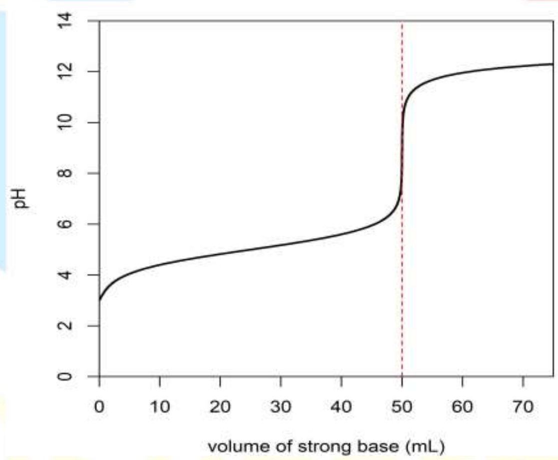
- A reaction in which an acid reacts with a base to produce a salt and a neutralised base is known as neutralisation reaction.
- **Example**

  Hydrochloric acid reacts with sodium hydroxide to formsodium chloride & water

  $HCl \ + NaOH \qquad H_2o \ + NaCl$
- Neutralisation Curve is obtained when ph is plotted against the percentage of acid neutralisation or the no of millilitres of alkali added
- Neutralisation curve can be plootted between the following variabled
  - Weak acid & Strong base
  - Strong acid & Strong base
  - Strong acid &Weak base
  - Weak acid & Weak base

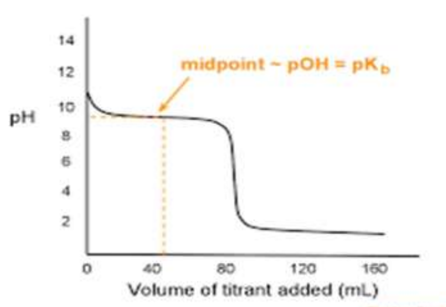
Strong acid & Strong base

- In this titration Strong acid & Strong base are reacted with each other by using a suitable indicator
- Acid & Base compounds are rapidly break down in its ions (Cation & Anion) and react with each other and form the salt & Water
- Initially slow rise in PH
- Sharp rise in PH due to present of excess alkali
- Attain the neutral point PH=7



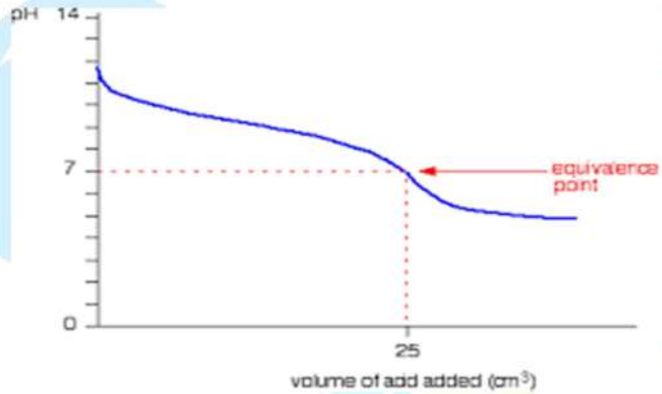
Weak Acid & Strong Base

- In this Titration Method weak acid is treated with the strong base by using the suitable indicator to detech the end point
- Doring the procedure weak acid are dissociated slowly in its compounts & strong base are dissociates rapidly in its componets
- Initially the PH normally & where reaction processes the curve will not raise much This point is said to be half neutralisation point
- Sharp rise in PH due to present of excess strong alkali



Weak Acid & Weak base

- In this titration method weak acid * weak base treated with each othe by using the suitable indicator
- The chief feature of the curve is that change of PH near equation point and during whole neutralisation is very gradual
- Hence the end point cannot be detected by ordinary indicator
- For detection of this titration mixed indicator are used .



Strong acid and Weak base

- In this Titration Method weak base is treated with the strong acid by using the suitable indicator to detech the end point
- During the procedure weak base are dissociated slowly in its compounts & strong acid are dissociates rapidly in its componets
- Initially the PH normally & where reaction processes the curve will not raise much This point is said to be half neutralisation point
- Sharp rise in PH due to present of excess strong alkali