

PHARMACEUTICAL ANALYSIS - I

1. Significance of quantitative analysis in quality control, Different techniques of analysis, Preliminaries and definitions, Significant figures, Rules for retaining significant digits, Types of errors, Mean deviation, Standard deviation, Statistical treatment of small data sets, Selection of samples, Precision and accuracy. Fundamentals of volumetric analysis, methods of expressing concentration, primary and secondary standards.

2. Acid Base Titrations:

Acid base concepts, Role of solvent, Relative strengths of acids and bases, Ionization, Law of mass action, Common-ion effect, Ionic product of water, pH, Hydrolysis of salts, Henderson-Hasselbach equation, Buffer solutions, Neutralization curves, Acid-base indicators.

Theory of indicators, Choice of indicators, mixed indicators, Polybasic system, Polyamine and amino acid systems, Amino acid titration, applications in assay of HIO_4 , NaOH , CaCO_3 etc.

3. Oxidation Reduction Titrations :

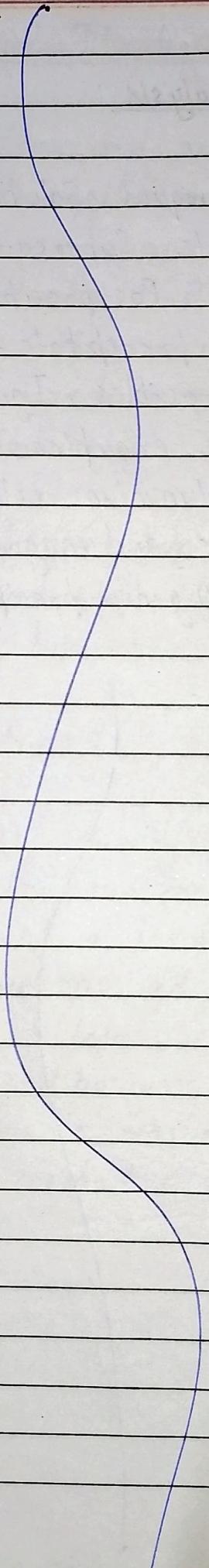
Concepts of oxidation and reduction, Redox reactions, Strengths and equivalent weights of oxidizing and reducing agents, Theory of redox titrations, Redox indicators, Cell representations, Measurement of electrode potential, Oxidation-reduction curves, Iodometry and Iodometric Titrations - involving ceric sulphate, potassium iodate, potassium bromate, potassium permanganate; titanous chloride and sodium 2, 6-dichlorophenol indophenol.

4. Precipitation Titrations :

Precipitation reactions, solubility products, Effect of acids, temperature and solvent upon the solubility of a precipitate. Argentometric titrations and titrations involving ammonium or potassium thiocyanate, mercuric nitrate, and barium sulphate, Indicators, Gray-Lussac method, Mohr's method, Volhard's method and Fajan's method.

5. Gravimetric Analysis :

Precipitation techniques, Solubility products ;
The colloidal state, Supersaturation
co-precipitation, Post precipitation, Digestional
washing of the precipitate, filtration, filter
papers and crucibles, Ignition, Thermogravimetric
curves, Specific examples like barium sulphate,
aluminium as aluminium oxide, calcium as
calcium oxalate and magnesium as magnesium
pyrophosphate, Organic precipitants.



Pharmaceutical analysis is analytical chemistry that deals with which process or series of process or series to identify and quantify the drug or formulation and purification of substances, separation of the components from mixture or solutions and determination of structure of chemical compound.

Techniques of Analysis

There are mainly two types of chemical analysis:

- (i) Qualitative analysis (identification)
- (ii) Quantitative analysis (estimation).

(i) Qualitative Analysis

Qualitative analysis gives an indication of the identity of the chemical species of the sample.

This method is perform to establish composition of natural or synthetic substances. It gives the information whether the substance or compound is present in the sample or not.

Qualitative analysis includes detection of evolved gas, formation of precipitate, limit test, colour change reaction, melting point and boiling point, taste etc.

1. Melting point.

The temperature at which a solid melts is known as the melting point.

It is a physical property of solid substances. This method is used to identify substances.

Melting point determination is a simple, fast and economic method used to obtain a first impression of the purity of a substance.

Pure crystalline substance gives a clear sharp melting point.

This method can identify purity of compound as small amount of impurities present in sample can change the melting or enlarge its melting range.

2. Boiling point

Boiling point is the temperature at which the vapour pressure of a liquid equal to the atmospheric pressure ~~or some other applied pressure~~.

Boiling point is physical property of liquids for indicating the purity of solvent or liquids.

The boiling point of a liquid varies depending upon the surrounding environmental pressure.

A liquid in a partial vacuum has a lower boiling point than when that liquid is at atmospheric pressure.

Refractive Index

Refractive index also called index of refraction is specific property of light. It gives information regarding behaviour of light.

The refractive index is measure of the bending of a ray of light when passing from one medium into another.

When light passes through any substance its velocity decreases and refractive index increases due to the effect of interaction between molecules of substance on light.

Refractometer is a device which is used to measure the refractive index of substance.

8/12/21

Optical Rotation

Optical rotation or optical activity is the rotation of the plane of polarisation of linearly polarised light as it travels through certain materials. Optical activity occurs only in chiral materials, those lacking microscopic mirror symmetry. Optical activity can be observed in fluids. This can include gases or solutions of chiral molecule such as Sugars, some proteins and also chiral liquid crystals.

The substance which rotates plane of polarisation of light towards right or in clockwise direction are called dextrorotatory.

The substance which rotates plane of polarisation of light towards left or in anti-clockwise direction are called levorotatory.

Polarimeter is used to measure the optical activity.

Quantitative Analysis.

These techniques are mainly used to quantify any compound or substance in the sample or to determine the amount of each compound present in the sample.

Types of Quantitative analysis:

1. Chemical Methods

- a). Volumetric or titrimetric methods.
- b). Gravimetric methods.
- c). Gasometric analysis.

2. Electrical methods.

3. Instrumental methods.

4. Biological and Microbiological methods.

1. Chemical Method.

a). Volumetric or titrometric methods:-

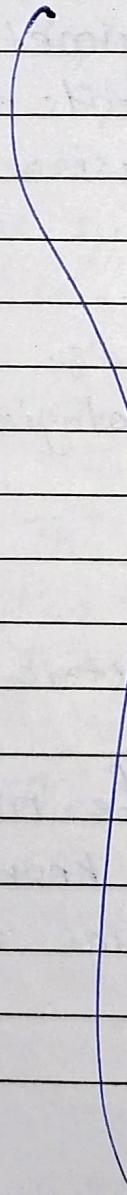
This method involves the measurement of volume of a solution of known concentration which is used to determine the concentration of the analyte.

Volumetric method is a simple method and requires less apparatus and they are susceptible of high accuracy.

Basic terms involved in Titrimetric or volumetric method.

1. Titrant :- A substance is to be titrated is called titrant.

2. Titrant :- A solution of known concentration is called titrant.



3. Indicator :-

Indicator is a substance that show colour change after completion of chemical reaction between titrate and titrant.

It depends upon pH of solution.

• End point or Equivalence point.

The equivalence point is the point in a titration at which the amount of titrant added is completely neutralises analyte in the solution.

• Standard solution.

A solution of known concentration is called standard solution.

Pharmaceutical Analysis - I

Qualitative

Quantitative

It refers to the chemical analysis of drug molecules or medicinal agents and their metabolites. It consists of quality and quantity of drug and fine chemicals which are used in pharmaceutical preparations.

* Pharmaceutical Analysis is generally involved in two steps.

(1) Separation of compound of interest.

(2) Quantification of compound.

Scope :-

The scope of pharmaceutical Analysis can be extended by incorporating during disease states which serves as diagnostic aid in medicine.

The main object and aim of quantitative analysis is to carry out the determination of the quantitative contents of the individual compound or element, ^{or} in a drug solution.

Importance of Quantitative analysis in quality control.

The various silent features with respect to the quantitative analysis in quality control are as experimented under:-

- (1) Chemical formula of an unknown substances:

Formula of an 'unknown' substances, either synthesized in a laboratory or isolated from natural occurring plant sources is invariably determined and established from the percentage contents of its constituents found by actual analysis.

- (2) In fact the chemical analysis represent the backbone of a Plethora of most impt. method of investigation and therefore, employed extensively and profusely in practical all branches of science that are intimately associated to chemistry.

e.g:- It finds it ~~add~~ abundant utility in pharmaceutical analysis of inorganic and organic chemical substances, microbiology, bio-chemistry, biotechnology, pharmaceutical technology, besides certain highly specific discipline → physiology,

Geology, Mineralogy, Medical and Agricultural Sciences.

③ The chemical analysis of possess an enormous potential in pharmaceutical industry in particular and others allied industries in general. On a rather more specific note a 'Pharmacist' should be fully aware at each and every steps of adopted production process the qualitative as well as quantitative chemical composition of the materials (substances) that have undergone expected and desired conversion (modification).

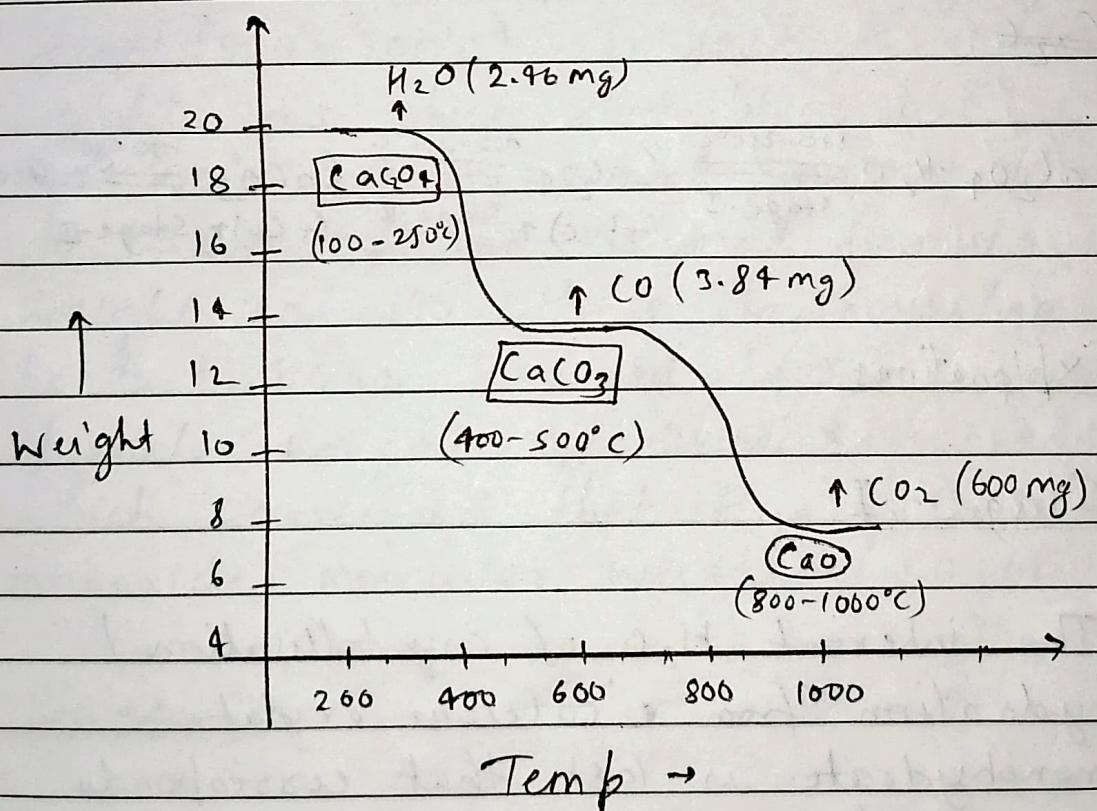
e.g.:> Thermogravimetric Analysis (TGA)
of calcium ~~ox~~ oxalate Monohydrate.

It has been duly observed that a large no. of chemical substances usually get decomposed upon heating. In fact this very idea and concept of heating a particular given sample to observe carefully that ensuing weight variations in the underlying principle of thermogravimetric analysis (TGA). Interestingly, the TGA of ~~ca~~ calcium oxalate monohydrate represents the dynamic TGA. Whereas in the solid

sample is specifically subjected to conditions of predetermined and controlled continuous increases in temperature which is mostly observed to be linear with time.

Method :-

The 'thermogram' for calcium oxalate monohydrate ($\text{CaC}_2\text{O}_4 \cdot \text{H}_2\text{O}$) is duly represented in fig. one may however distinctly observe the successive plateaus namely.



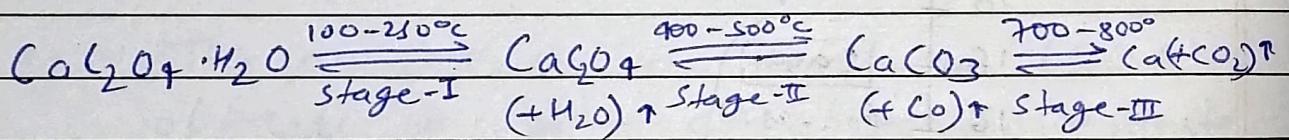
- Correspond to anhydrous oxalate (~~100-250°C~~).
- Correspond to calcium carbonate.
- Correspond to Calcium Oxide.

In other words, the three observed plateaus clearly designate the following vital aspect of the decomposition curve namely.

- (a) Clear indication of constant weight.
- (b) Stable phase encountered within a specific temperature interval.

The various distinct chemical reaction that are actually may be summarized as follows:-

Ca₂O₄



Explanations:-

Stage. - I

- (i) The inherent H₂O of crystallisation / hydroation from calcium oxylate monohydrate is lost that corresponds to 2.46 (12.3%) equivalent to 1 mole of H₂O b/w the temp. range 100°C - 250°C. In actual practice the (12.3%) weight has normally occur between 100°-250°

must correspond to 12.3% of the original formula weight for $\text{CaC}_2\text{O}_4 \cdot \text{H}_2\text{O}$ (146). Therefore the product which get lost eventually has a formula weight of $0.123 \times 146 = 17.958 (\approx 18)$ and it definitely correspond to H_2O (water) (Molecular weight of $\text{H}_2\text{O} = 18$)

Stage - 2

One mole carbon monoxide (CO) gets evolved from calcium oxalate (CaC_2O_4) corresponding to 3.84 mg (19.2%). between the temperature varying from $(400^\circ - 500^\circ\text{C})$. In fact the 19.2% weight loss which took place b/w $400 - 500^\circ\text{C}$ must actual correspond to 19.2% of the original formula weight of 146. Hence the resulting product being produced bears a formula weight of $0.192 \times 146 = 28.0$ which correspond that it is CO (carbon monoxide) molecular weight of $\text{CO} = (12 + 16 = 28)$

Stage - 3:

At the final stage, one mole of CO_2 (carbon dioxide get evolved from one mole of CaCO_3 which eventually correspond to 6.02 mg (3.0%) in the tempt range.

Varying b/w 700° - 800°C . Interestingly the weight loss corresponding to 3.01% which occurs in temp. range b/w 700° - 800° should be equivalent to 3.01% of the original formula weight of 146. Hence the generated product bears a formula weight of $0.301 \times 146 = 43.346 (\approx 44)$ and it corresponds to CO_2 (carbon dioxide) ($12 + 32 = 44$)

Imp

* ④ As to date this is widely accepted practice that no 'drug substances' is either taken into production for actual consumption without proper quality control screening that essentially characterises its overall quality, stability and suitability for various purpose. Importantly those ultimate result serve two major objective namely.

- ① To form the fundamental basis of all the processing calculation and,
- ② To determine exactly the 'naked cost' of various materials inputs that predominantly serve as core basis

of all financial estimates.

⑤ In a broader perspective, the utmost impt. of adequate and proper control of production is quite evident. Hence it is absolutely necessary each and every pharmaceutical industry should essentially have an well equipped analytical laboratory under the command of a qualified experienced and highly motivated pharmaceutical analysis personally. Now a days these laboratories are called 'Quality Assurance' and 'Quality control' laboratory for the chemical control physical parameters and microbiological screening of a raw material. Intermediates and finite product.

⑥ In actual practice, however pharmaceutical analysis major problem is most commonly simplified to a greater extent significantly by virtue of the fact that the qualitative composition of majority of the investigated product pure drug → substance chemically additives, pharmaceutical intermediate and finished dosage form is well known as

described in official compendia
 eg:- (I.P., B.P., U.S.P., E.P., International P.)
 Furthermore, the approximate contents
 of the individual elements are
 obviously known quite frequently.

Evidently in such particular instances
 the usual preliminary qualitative
 analysis become more or less
 unnecessary absolutely, thereby
 rendering the proper solution
 of the most appropriate technique
 of the qualitative analysis become
 much more easier and meaningful.

Types of Quantitative Analysis:-

① Titrometry :

Volumetric :- of quantitative method of
 analysis dealing with volume of
 solution and their measurement is
 termed as titrimetric analysis or
 titrometry. The substance is allow
 to react with an appropriate
 reagent added as a standard soln
 and the vol. of soln needed for
 complex rxn is determined.

The common types of rxn that are used in titrimetry are..

1) Neutralization rxn (acid, base)

Acid base titration is based on the neutralization rxn b/w the analyte and acidic or basic titrant. Those rxn used at pH indicator, pH meter, as a conductance meter to determine a end point.

2) Precipitate rxn.

A precipitation titration comprises a class of rxn that required a formulation of insoluble precipitate. Provided that the end point at which the precipitation is complete can be determined.

3) Oxidation Reduction rxn:-

a) Redox :-

A redox titration is based on an oxidation - reduction rxn b/w the analyte an oxidant or reductant.

A potentiometer or redox indicator is used to determine the end point. Frequently either the reactants or the titrant have a colour intense enough that an additional indicator is not needed.

(b) Complex forming rxn:-

A complexometric titration is based on the formation of a complex b/w the analyte and the titrant the chelating agent EDTA is very commonly used to titrate metal ions in the soln. This titration generally requires specialised indicators that forms weaker complexes with the analyte.

A common example is Eriochrome T for the titration of Ca and Mg ions.

* Non-aqueous titration

Non-aqueous titration is the titration of substance dissolve in a non-aqueous solvent. It is the most common titrimetry procedure used in pharmacopeial assay and serve a double purpose.

① It is suitable for the titration of very weak acid and bases.

② And it provides a solvent in which organic compound are soluble.

Gravimetry :

It involves the separation of the constituents to be estimated in the form of an insoluble precipitate.

The insoluble precipitate is vast to free it from all impurities, dried and weighted either as such as ignited to give a residue of some other compound which is the weight.

Now from its weighed and no one composition the amount of the constituents in the given sample is calculated.

Determination of chlorine content in common salt (NaCl) the various forms of gravimetry are :-

(ii) Electrogravimetry :-

It involves at electrolysis and the materials deposited on one of the electrodes is weighed.

(ii) Thermogravity :-

It estimates the change in ~~wood~~ weight as a function of temp.

(iii) Differential Thermalanalysis :-

Determine the difference in tempt. b/w a test substance and an inert reference material.

(iv) Differential Scanning colorimetry :-

Records the energy needed to establish at a zero tempt. difference b/w a test substance and a reference materials.

Volumetry.

It is concerned with measuring the vol. of gas evolved and absorbed in a chemical method.

★ (II) Physical Method of Analysis :-

It involves the determination of physical properties of liquid like specific gravity, viscosity or surface tension. The common types of

measurement that are used in physical method of analysis are.

1) Refractometry:

It involve the measurement of refractive index of liquids using a refractometer.

eg. → Refractive index of an oil against water.

2) Polarimetry:

It is used to measure optical rotation of an optically active compound using a polarimeter.

eg.. Optical rotation sucrose.

3) Viscometry:

It involves the measurement of viscosity of a liquid using viscometer.

eg. Viscosity of solvent.

III Electrical method of Analysis.

It ~~involves~~ involves the measurement of current voltage as resistance in relation to the concentration of a certain species in solution. The common types of measurements that are used in ~~the~~ electrical method of analysis includes :-

1. Voltammetry :-

It involves the measurement of current at a micro electrode at specified voltage.

2. Cationometry :-

It measures current and time needed to complete an ~~electrode~~ electrochemical rxn. or to generate sufficient materials to react completely with a specified reagent.

③ Potentiometry :-

It is used to measure the potential of an electrode in equilibrium with an ion to be determined.

① Spectroscopic method of Analysis.

Spectromethod measure the electromagnetic radiation i.e. absorbed scattered or emitted by the analyte the methods of measurement of radiation vary from one method to another. The imp. section spectro methods are :-

② Absorption spectroscopic :-

It depends on measuring the amount of a particular wavelength absorbed by the sample. Absorption method are usually classified according to wavelength involved as visible, ultraviolet or infra-red spectroscopy. The visible spectroscopy or spectroscoy photometry is some time called as calorimetry.

③ Turbidimetry and Nephelometric method :-

This process are used to measure the amount of light stopped or scattered by a suspension.

⑤ Emission Spectroscopy :-

It determines the amount of radiant energy of a particular wavelength emitted by the sample.

⑥ Flame photometry :-

It uses a solution of this sample injected into a flame.

⑦ Fluorimetry :-

It takes a suitable substance in solⁿ (commonly a metal fluorescent reagent complex) and excites it using visible or uv radiation.

⑧ Chromatographic methods :-

This methods are used to separate mixture of substances and to identify components of a mixture.

For eg.:- Paper chromatography, thin layer chromatography and gas-liquid chromatography.

II Special technique:

1. X-ray methods:

X-rays are produced when speed e^- collide with a solid target (which can be the material under investigation) it is possible to identify certain emission peaks that are characteristic of element contain in the target.

2. Radio-activity:-

This procedure measures intensity of the solution radiation from a naturally occurring radioactive material.

Measuring radioactivity induced by exposing the sample to a neutron source, (activation analysis) or isotope dilution and radioimmunoassay.

③ Kinetic methods:-

This methods are based on increasing the speed of a rxn by adding a small amount of a catalyst, within limits, and the rate of catalyst rxn will be governed by the amount of catalyst \oplus nt.

Volumetric method of Analysis :-

Volumetric analysis is depends on the measurement of the vol. of the solution of the interactive substances. In this analysis a measured vol. of solution of a substance is allowed to react completely with the solⁿ of a given strength of another substance. The end point of the rxn is indicated by some marked changes such as appear as disappearance of colour or formation of precipitate and the process is termed as titration. The stage during titration at which the rxn is just complete is known as equivalence or end point. Generally end point in a volumetric analysis is detected by the addition of a suitable substance called indicator that changes its colour when the rxn is just completed.

Fundamental of volumetric analysis:-

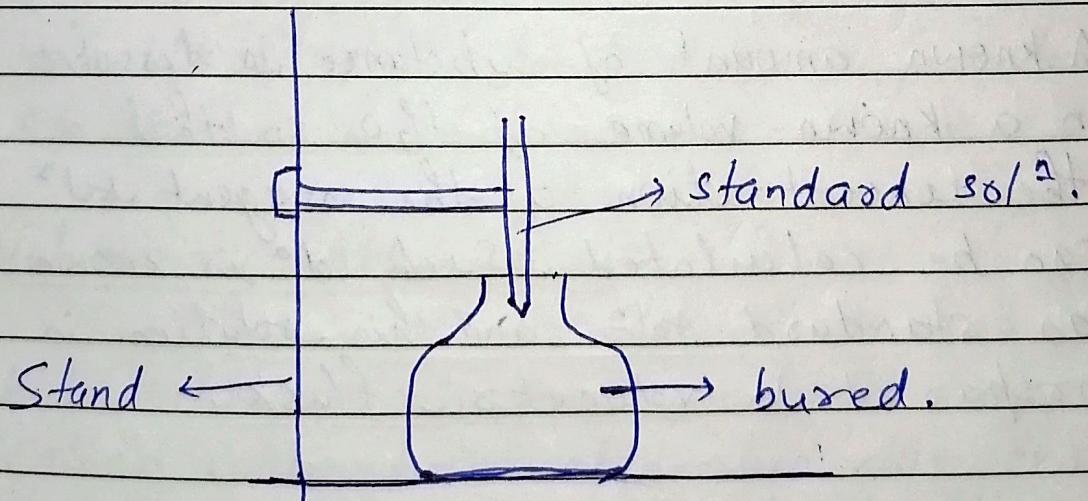
The fundamental requirements to carry out titrimetric or volumetric process are :-

① The rxn b/w titrate and titrand must be well defined i.e. definite amount of reactants must react to produce definite amount of products.

② The rxn must be rapid so that little time is needed to complete the titration. A catalyst may also be used to increase the rate of rxn.

③ Titrimetric cal. are based on 100% rxn b/w the reactants, thus mixing of equivalent amounts of the rxn must gives a complete rxn.

④ A standard solⁿ of reagent i.e. titrand should be taken in a buret and titrate is kept in a conical flask as shown in fig.



- (5) An indicator kept in a conical flask must be available to show the conclusion of the rxn.
- (6) The end point should be well defined
- (7) The vol. of titrand used for completion of a rxn is known as titre volume.
- (8) As the concentration of the reagent solⁿ is known the quantity of reagent left in the solⁿ can be calculated.

Step involved in Volumetric Analysis.

→ Volumetric determination of a solⁿ of a given substance (Analyte) with the reagents involves the following steps.

- (1) A known amount of substance is dissolved in a known volume of H₂O so that the concentration of the reagent solⁿ can be calculated. Such solⁿ is known as standard solⁿ. and this solution is prepared in volumetric flask.

② A known vol. of analyte solⁿ is taken in a conical flask with the help of a pipette. The analyte solⁿ is also called as sample solⁿ, test solⁿ or titrate solⁿ.

③ Few drops of an indicator are added to the titrand ~~sol~~ solⁿ taken in the conical flask. The use of the indicators is to show the colour change when the rxn b/w the analyte and the reagent solⁿ is just complete.

④ The objective of titrating an alkaline solⁿ with a standard solⁿ of an acid is to determine the amount of acid which is exactly equivalent chemically to the amount of the base nt. This point of neutralization is termed as equivalence point or theoretical end point due to formation of salt.

Volumetric Apparatus:-

Apparatus used for titrations are called volumetric apparatus due to involvement of measurement of volumes. Acid base titration form part of a group of laboratory procedures

Known as volumetric analysis.

Some of the characters are given as:-

① Pipette :-

Bulb pipette is designed to deliver an accurately known vol. of solution, after it has been filled exactly to the ~~tan~~ mark. They are available in volumes of 1, 2, 5, 10 and 20 ml. Also volumetric pipettes are calibrated in units of millimeter (mm). The pipette is held vertically to fix the mark at the same level as the eye.

~~Pip~~ Pipettes are of two types:-

② Transfer pipette :-

It has one mark and withdraw a small and constant vol. of solⁿ.

③ Measuring / Graduated pipette:

These are graduated used to deliver various small volume. During withdrawal the adhearing drops addition are removed by stoaking against an

inside walls of glass surface as touching to the surface of solⁿ.

② Beaker:-

It is a container having beak like structure. Borosil beaker is used as it withstands frequent heating and cooling. Beakers are different capacities.

e.g.: 50 ml, 100ml, 500ml and 1000ml are available in market.

The following process are carried out in such containers.

- (i) Preparation of solution
- (ii) Heating
- (iii) Precipitation.

③ Burette :-

A burette consists of a graduated tube fitted with stop cock and used to deliver variable vol. Burettes are normally available in max^m capacities of 25, 10, 25, 50 and 100 ml. Before using, the burette is thoroughly cleaned with a cleaning agent, rinsed well.

With a distilled H_2O the stop cock is lubricated and fixed in burette holder. The solⁿ is filled the help of a small funnel upto zero mark.

The liquid is discharged from a burette into a conical flask. The flask is gently rotated with the right hand for mixing of content well. Meniscus is a curve in the surface of a liquid and is produced in response to the surface of the container or another object.

It can be either concave or convex.

(4). Conical flask:

A conical flask is flat bottom pear shaped apparatus with short neck narrow neck of thin line marked around the neck indicates the volume that it holds at a certain definite temp. Solution to be titrated are usually pipette into a conical flask, also known as an Erlenmeyer flask.

(5) Volumetric flask :-

This flask are used to prepare standard solⁿ of solutes. In known mass of solute is placed in a flask,

dissolved in pure water and then made up a mark etched in the neck of flask. Volumetric flask are normally supplied in volumes of 100ml to 1000ml.

⑥ Measuring Cylinder:-

These are used to measure standard solⁿ of solutes with permanent graduations they are made up of borosilicate glass. The commonly used sizes of measuring cylinder are 10 ml, 50 ml, 100ml, 250 ml, 500 ml and 1000 ml. Before use the burette is thoroughly cleaned with a cleaning agent and rinsed well with distilled H₂O. While reading the measuring cylinder you should read the no. i.e. at the bottom of the minicus.

Some Important terms in volumetric analysis :-

① Titrand or Titrate :-

It is prepared by dissolving a known amount of substance into a known amount of H₂O as solvent. It is prepared in volumetric flask,

it has exactly exact purity non-hygroscopic in nature. It is also known primary standard solution, test solution or analyte solution.

Titrant:-

The secondary standard solⁿ is known as Titrant. It is used in process of standardization and whose content or concentration of active compound is found by comparison against primary standard. It is prepared in volumetric flask and taken in burette.

Indicator:-

Indicator is an organic dye which signal the completion of a rxn or titration by the visual change in the colour eg:- methyl orange, phenol red, starch and phenolphthalein etc.

Equivalence point :-

It is a point of a rxn or titration when the no. of titrand molecule reacting with titrate molecule will be equal.

Standardization :- It is the process where the concentration of one solution is determined by the known concentration of the other solution.

End point :

It is exact stage at which an indicator gives its visual colour change and the rxn is just completed.

Standard solution :

A solution whose concentration is accurately known is called standard solution.

Preparation :-

An exactly weight amount of the substance of definite and known volume in composition is dissolve in distilled water and made up to the

known vol. in graduated volumetric flask. From the known weight and volume, the concentration of the solution is calculated. These are of the following type of standard solⁿ.

① Primary Standard solⁿ:

A primary standard is a compound of efficient purity from which a standard solution can be prepared by direct weighing of a quantity of it and followed by dilution to give a definite vol. of solⁿ, the solⁿ then produced is primary standard solⁿ.

A primary standard solⁿ should satisfy the following requirements:-

- ⓐ It must be easy to purify, to dry (preferably at 110°- 180°C) and to preserve in pure water state.
- ⓑ The substance should not be altered in air during weighing.

- (c) The substance should be capable of being tested for impurities by qualities and other test of known sensitivity.
- (d) The substance should be readily soluble under each condition in which it is employed.
- (e) The αm with standard relationship b/w reactant and products in chemical αm .

Some ex. of primary standard solⁿ :-

- (i) Arsenic trioxide for standardization of iodine and calcium (IV) sulphate solution.
- (ii) Benzoic acid for standardization of TBAH (Tetra- butyl ammonium hydroxide) in methanol sol.
- (iii) Potassium bromate (KBrO_3) for standardization of sodium thiosulphate solⁿ.

Secondary standard solⁿ:

A secondary standard solⁿ is a substance which may be useful for standardization and whose content of the above active substance have been found by comparison against a primary std. solⁿ. They are prepared in a laboratory for specific analysis and are usually standardized against primary standard as follows that a secondary standard solⁿ is a solution in which the concⁿ of dissolve solute has not been determined from the weight of the compound dissolved but by oxⁿ (titration) of measured vol. of a primary standard solⁿ.

eg:-

- ① Alkali hydroxide \rightarrow potassium hydroxide (KOH), (NaOH).
- ② Mineral acids:- HCl, H₂SO₄ (sulphuric acid) and nitric acid (HNO₃).
- ③ Oxidizing agent:- Potassium permanganate (KMnO₄), and potassium dichromate (K₂Cr₂O₇).

The secondary standard component which is not obtain in pure state eg.: Caustic soda (NaOH) and Minerals acids (HCl , H_2SO_4) and (HNO_3) are prepared little more concentrated than required and to dilute it with distilled water until the desired normality is obtained. This sample must be standardized and for standardization they have to be titrated against the solution of pure substances of known concentration (primary standard).

Accuracy :-

The accuracy of determination may be defined as the closeness of a measured value of the true or most probable value for analytical methods there are 2 possible ways of determining the accuracy absolute method and comparative method.

① Absolute method. :

These test of accuracy of the method under consideration is carried out taking varying amounts of the constituents and proceeding

according to specified institution. The amount of the constituents must be varied by the determinate errors in the procedure may a function of the amount used. The difference between the mean of an adequate no. of results and the amount of constituents actually. \oplus nt is a measure of accuracy of the method in the substance. Here, primary std. are used.

Comparative method:-

In this method of accuracy the solid synthetic secondary standard sample of desired composition are prepared. The samples are assayed further as to determine the content of the constituents by one or more accurate method of analysis. This method indicates the absence of appreciable systematic error in the procedure of analysis.

Precision :-

Precision is defined as the agreement of a series of measurement of the same quantity when an analyst is able to reproduce two or more measurement with only slight difference in the result, this work may be reproduced as to be precision.

There are 2 forms of precision:-

① Run Precision Repeatability :-

If a analyst has marked the determination ^{on} ~~of~~ the same day in rapid succession, the set of result would be defined as repeatable.

② Run Precision reproducibility :-

If an analyst has made the determination on the separate days when laboratory condition may be vary, the set of results would be defined as reproducible.

(i) Mean or Average :-

Mean or average is obtained by dividing the sum of a set of

measurement by the no. of individual measurement in the set.

$$\boxed{\text{Mean} = \frac{M_n}{n}}$$

M = Individual measurement

n = total no. of measurement

(ii) Mean deviation of a single measurement :-

It is the mean of the deviations of all the individual measurements.
It can be calculated as.

- Determining the arithmetic mean of results.
- Calculating the deviation of each individual measurement from the mean.
- Calculating the deviation by the no. of measurements and.
- Coefficient of variable.

$$\boxed{(Cv) = \frac{s \times 100}{\bar{x}}}$$

s = Standard deviation, \bar{x} = mean.

Precipitation method :- Titration :-

- Q. Discuss principle of precipitation titration. Discuss Fajan method in detail ?

[14 marks]

Principle of ppt. titration :-

The main principle of precipitation titration is that the quantity of adding precipitating reagent or precipitant is equivalent to the substance been precipitated.

Significant figures :-

The number of digits necessary to express the result of a measurement consistent with measured precision or in other words a significant figure is digit having some practical meaning i.e., it is a figure or digits which denotes the amount of quantity in the place in which it stands or the digit of a number which are needed to express the precision of the measurements from which the numbers derived are known as significant figures.

The following guidelines indicate whether or not a digit is significant :

(1) All non-zero digits are significant digits

e.g. 1, 2, 3, 4, 5, 6, 7, 8, and 9

e.g. 345.76 has five significant digits.

(2) Zeros are significant if they :-

@ are the last digit of a measurement as long as they are to the right of the decimal point.

Example:- 3.70 has three significant digits.
 The zero is significant because it is the last digit.

- ② Come between two other significant digits.

Example:- 340.61 has five significant digits. The first zero is significant because it falls between 4 and the 6 which are both significant.

- ③ Zeroes are not significant if they act as placeholder.

e.g. 0.035 has two significant digits.
 The zeroes are placeholders and are not significant.

- ④ When the zeroes are on the left of the decimal point then they are not necessarily significant.

Ex → 2100 may have 2, 3 or 4 significant figures.

Ex → 350 may have 2 or 3 significant no.

This ambiguity can be avoided by writing the number in scientific notation.

- ⑤ In Scientific notation, all digits in the coefficient are significant. The exponent is not considered in terms of significant figure.

e.g. $\rightarrow 2.100 \times 10^3$ will have with certainty 4 significant figure.

$\rightarrow 3.50 \times 10^2$ will have with certainty 3 significant figure.

$\rightarrow 3.54 \times 10^5$ will have with certainty 4 significant figure.

- ⑥ Numbers that are known with complete certainty are said to be exact conversion factor, constraints, values that are part of a formula are said to be exact. These exact numbers are considered to have an unlimited number of significant figures and are never used as a limited factor in determining the number of significant figures in the result of an operation.

e.g.: - $1\text{ cm} = 10\text{ millimeter}$. Then number 10 will have ~~a~~ an infinity numbers of significant figure.

Rules for Retaining Significant figures

There are several rules to remember regarding significant figures when manipulating numbers.

- (1) When measurements are multiplied or divided, the answer can contain no more significant figures than the least accurate measurement.
- (2) When measurements are added or subtracted, the answer can contain no more decimal places than the least accurate measurement.

$$\begin{array}{r}
 150.0 \text{ g} \\
 + 0.507 \text{ g} \\
 \hline
 \underline{150.5}
 \end{array}
 \quad (\text{using significant figures})$$

- (3) In a quotient of experimental members, the final rebuilt has only as many significant figures as the factor with the smallest number of significant no.

eg. In the calculation =

$$= \frac{(0.0181057)(0197.15)(0.218)}{0.9970} = 1.568$$

$$= 1.57$$

least no. of significant figures is in number 0.218. Thus the answer should also be ~~experiment~~ expressed in three significant figures.

④ Two rules are given for rejecting superfluous digits :

i) When the last digit dropped is greater than 5, the last digit retained is increased by one. It is called rounding

8.492 → New value will be 8.50 as 2 is smaller than 5.

4.863 g → New value will be 4.9 as 8 is greater than 5.

ii) When the last digit discarded is less than 5, the last digit retained is decreased by one. It is called rounding off.

Errors :

It is observed that the numerical data obtained in quantitative analysis or determination differs to greater or lesser extent. Sometimes it is difficult to obtain the same measurement when performed under identical conditions. So, the reliability of the results depends upon the magnitude of the difference between the average value and the true value or more probable value. Under such conditions the determination is subjected to errors. Errors often denote the estimated uncertainty in a measurement or experiment.

Classification of errors:-

1. Systematic / determination or constant error.

- (a) Person error.
- (b) Operational error.
- (c) Instrument or reagent error.
- (d) Methodic error.

2. Random or Indeterminate error.

③ Errors in measurement

④ Gross error.

Systematic / determinate or constant errors:

The determinate errors are the errors that remain in a constant way and do a fixed degree in each of the determinations or affect the series of determination to the same degree. These errors can be avoided or their magnitude can be determined, thereby correct.

⑤ Personal error :-

These errors depend on the personal characteristics of an analyst himself. They may occur due to constitutional inability of the individual to certain observations accurately.
eg:-

① Inability in judging color change sharply in a visual titration.

(ii) The estimation of value between two scales deviation of the burette.

(iii) Inability to detect end point in the titration.

(iv) Error in calculation i.e. induplicate weighing and titration.

(v) Mechanical loss of material in various steps of analysis during bumping.

(b) Operational error:-

These errors are physical in nature and occur when sound analytical technique is not followed. They are easy to detect and eliminate.

e.g.

(i) Incomplete drying of analytical samples before weighing.

(ii) Under washing of the precipitate which gives consistent excessive results.

(iii) Over-washing of the precipitate resulting in systematic losses.

(iv) Incorrect draining of the solution from the precipitate.

(c) Instrument and reagent errors:-

These errors arise from the imperfections in the measuring device and quality of reagent used. eg :-

i) Inequality of the length of the balance arm.

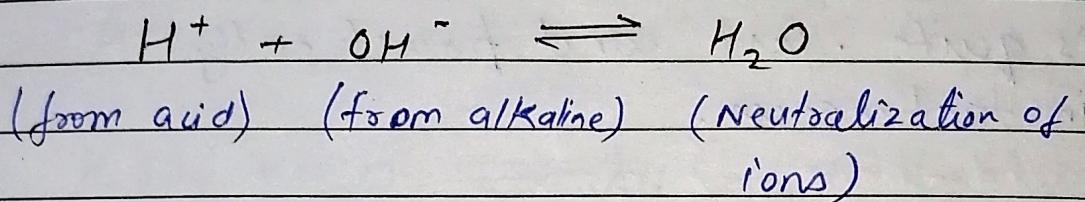
(ii) Incorrectly graduated burette.

(iii) Using impure reagent.

(iv) Incorrect technique involving in the transfer of solution.

ACID BASE TITRATION:-

Chemical reaction between an acid and a base (alkaline) take place the reaction is based on the principle of neutralization.



- Acidimetry :-

A substance acid solⁿ is used for quantitative determination of the base/ alkali.

- Alkalimetry :-

A standard solⁿ of base is used for quantitative determination of acid.

This acid base titration method is used for various volumetric determinations, which involves neutralization one another way.

e.g. - Determination of salt like

- Na_2CO_3
- $\text{Na}_2\text{B}_4\text{O}_7$ etc.

- These salt have strongly alkaline reaction that's why they are titrated with acid solution.

* Advantages of acid and base titration :-

- (a) The reaction between acid and base is quite fast and practically instantaneous.
- (b) The reaction in acid base titrations will be single without the side reaction.
- (c) The reaction will always reach to completion.
- (d) The reaction will always stoichiometric.

* Acid - base concepts (Theories)

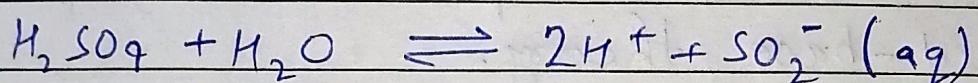
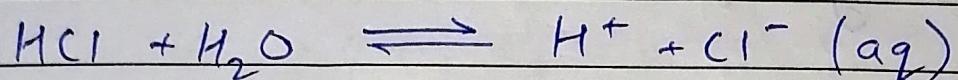
There are four theories proposed to understand the concept of acid-base titrimetric reaction:

(1) Arrhenius Theory [H^+ and OH^-]

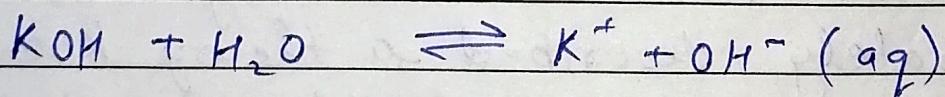
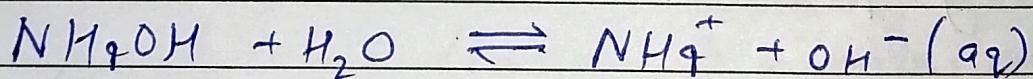
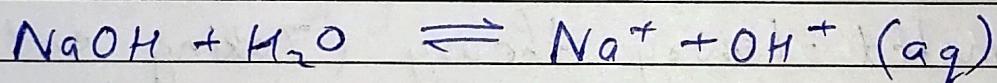
Arrhenius in 1884, first and foremost introduced a radical theory which slightly expatiates an adequate quantitative in an aqueous medium.

specifically.

According to arrhenius acid is any substance that ionizes (partially, completely) in water or aqueous medium to give hydrogen ions $[H^+]$



Base is any substance that ions (partially or completely) in water or aqueous medium to give hydroxyl ion $[OH^-]$.



Advantage :-

The concept explain the behaviour of an acid and base practically.

Limitation :-

- (a) In this concept acid and base is defined in aqueous medium only.
- (b) This concept fails to explain the stability of H^+ ions (s)
- (c) It does not explain the conjugate acid-base theory.
- (d) It does not able to define those acid and base O_2 and SO_2 (aq) which does not contain H^+ or OH^- ion
eg. $\rightarrow NH_3$ and Na_2CO_3 (base).

2. Brønsted - Lowry theory (Taking and giving proton).

In 1923 Brønsted and Lowry separately described a theory known as Brønsted Lowry concept.

According to this theory :-

Acids are those compounds or species which have tendency to donate the proton (H^+) in any type of solvent by any method.

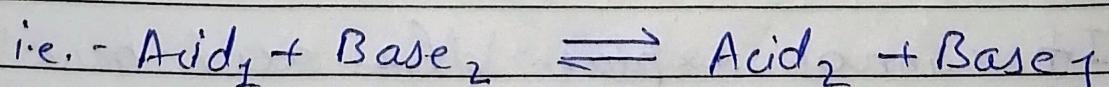
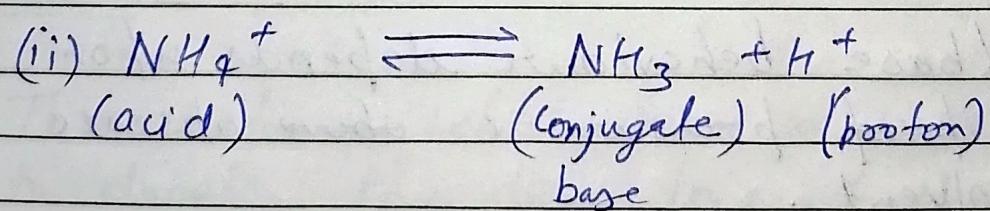
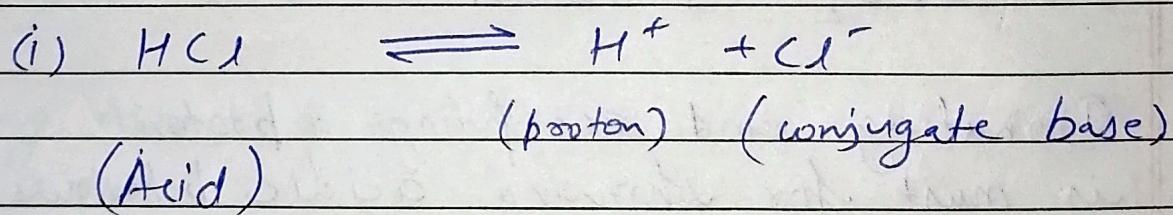
eg. H_2SO_4 , HCl , $HClO_4$, CH_3COOH etc.

Basers are those compounds or species which have tendency to accept the protons (H^+) in any type of solvent by any method.

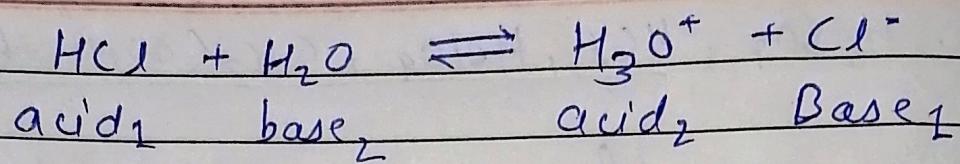
eg :- $NaOH$, KOH , $H_2SO_4^-$ etc

Conjugate pairs :-

A pair of substance which can be formed from one another by the gain or loss of proton are called as conjugate base and every base has its conjugate acid.



where, Base_1 = conjugate base of Acid 1
 Acid_2 = conjugate acid of Base 2.



Advantage :-

This concept explain the acid base in any type of solvent.

This concept is able to explain the stability of proton.

Limitation:-

1. Behaviours of SO_2 , SO_3 and CO_2 as acids and behaviour of CaO and BaO_2 as bases.
2. Donating and accepting a proton is must for showing acidic behaviours.
3. Acid / base behaviour depends upon the ~~heat~~ pressure or above absence of solvent.
4. It cannot explain the acid-base reaction taking place in non-protonic solvent, like BF_3 and AlCl_3 .

* Lewis theory [Taking and giving electrons]
 (lone pair of e^-)

- 1923, G.N. Lewis introduced the electronic theory of acid and base

- In this concept he was defined an acid and base according to the electron proton donor-acceptor concept.

Acids :-

Those species which have self tendency to accept the lone pair of electrons.

Lewis acids are electrophils.

eg. AlCl_3 , BCl_3 , SnCl_2 , CO_2 , SO_2 etc.

Bases:-

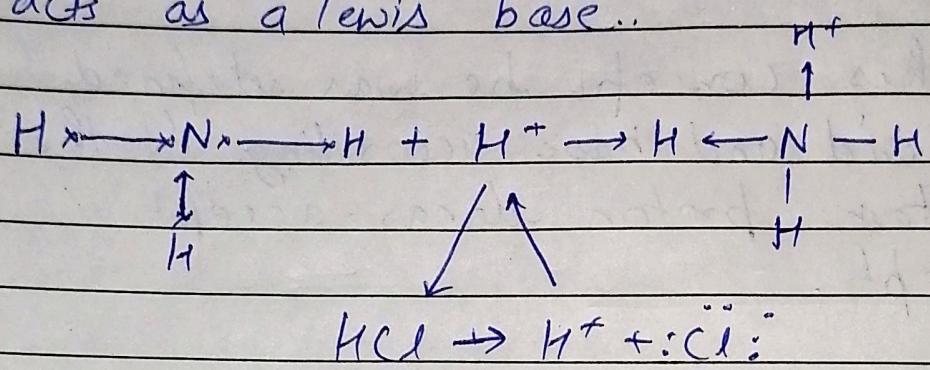
Those species which have tendency to donate the lone pair of electrons

Lewis bases nucleophils.

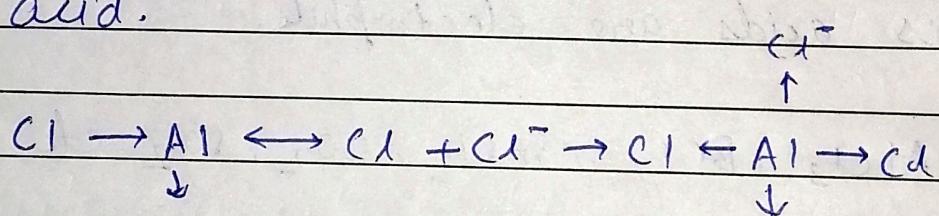
eg. $-\text{NH}_2$, $\text{C}_2\text{H}_5\text{NH}_2$, H_2O , SO_4^{2-} , F^- ,
 Cl^- etc.

Details of Lewis concept

If octet of bases is complete and molecule / ion is still having lone pair of e^- base can donate the electrons acts as a Lewis base..



If octet of any molecules / ions is incomplete so that will accept the lone pair of e^- and acts as Lewis acid.



Advantage :-

It defines acid and base without any types of solvent.

Limitations :-

The relative strength of acids and base cannot be explained by this

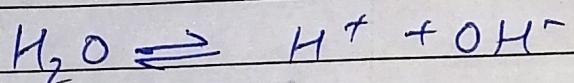
concept.

* Hard and Soft acid Base concept:-

<u>Hard Acid.</u>	<u>Soft Acid.</u>
① High +ve charge	① Low +ve charge
② Relative small size	② Relative large size..
③ Unfilled valence orbitals	③ Filled valence orbitals.
④ eg - H^+ , L^+ , Mg^+ , K^+ etc	④ Cu^{2+} , Ag^+ , Au^+ , Hg^+ , I^- .
<u>Hard Base.</u>	<u>Soft Base.</u>
① High electronegative	① Low electronegative
② easily reduces	② easily oxidized.
③ low polarizability.	③ high polarizability.
④ Stable valence shell	④ Unstable valence shell.
⑤ eg:- H_2O , OH^- , F^- , PO_4^{3-}	⑤ eg - Br^- , SO_4^{2-}

● Ionic product of water :-

Kohlrausch and Heydrich found in 1894 that the most highly purified water possesses a small and definite conductivity. So water must be highly ionized as per the equation :-



As per the law of mass action, the following equation is obtained at any given temp.

$$\frac{[\text{H}^+] \cdot [\text{OH}^-]}{[\text{H}_2\text{O}]} = \frac{[\text{H}^+] \cdot [\text{OH}^-]}{[\text{H}_2\text{O}]} \times \frac{[\text{H}^+] \cdot [\text{OH}^-]}{[\text{H}_2\text{O}]}$$

Water is only slightly ionized. so the ionic concentration is small and their activity coefficient is unity. The activity of the unionised molecule is also taken as unity.

So the expression is :-

$$\frac{[\text{H}^+] [\text{OH}^-]}{[\text{H}_2\text{O}]} = \text{a constant.}$$

In pure water or in dilute soln, the concentration of the undissociated water is considered constant.

$$\therefore [H^+] \times [OH^-] = k_w$$

k_w = Ionic product of water.

The ionic product of water varies with the temperature. At $25^\circ C$, its value is taken as 1×10^{-14} . The value is constant in dilute soln. If the product of $[H^+]$ and $[OH^-]$ in aqueous solution exceeds the value, the excess ions will immediately combine to form water. On the contrary, if the product of two ionic concentrations is less than 10^{-14} more water molecules will dissociate until the equilibrium value is obtained.

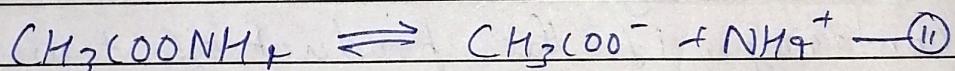
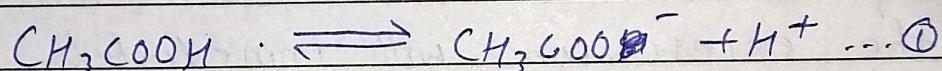
* Henderson - Hasselbalch Equation :-

The change in pH upon the addition of an acid or base and the pH of a buffer solution is calculated by buffer equation. The buffer equation is calculated by considering the effect of a salt on the ionization of a weak acid if the salt

and the acid have an ion in common.

Henderson - Hasselbatch equation :-

The pH of an acidic / basic buffer solution can be calculated from the dissociation constant K_a of all acids / bases, concentration of the acid / base and salt used. The dissociation expression of weak acid may be represented as :-



According to law of mass action :-

$$K_a = [H^+] [A^-] / [HA] \text{ or } [H^+] = \frac{K_a [CH_3COOH]}{[CH_3COO^-]}$$

Where, $[CH_3COOH]$ = representing the total concentration of an acid in solution and $[CH_3COO^-]$ = representing the total concentration of acetate ion as most of them are entirely contributed by salt (CH_3COONH_4).

$$H^+ = K_a \frac{(Acid)}{(Salt)}$$

Expressing of negative logarithm on both side.

$$-\log [H^+] = -\log K_a - \log \frac{(Acid)}{(Salt)}$$

$$\text{But, } -\log [H^+] = pH \text{ and}$$

$$-\log K_a = pK_a.$$

$$pH = pK_a - \log \frac{(Acid)}{(Salt)}$$

$$pH = pK_a + \log \frac{(Salt)}{(Acid)} \quad (\text{inverting the sign})$$

The relationship is called Henderson's Hasselbalch equation for acidic buffer. Similarly, the Henderson's Hasselbalch equation for a basic buffer can be derived as;

$$pH = pK_b + \log \frac{(salt)}{(base)}$$

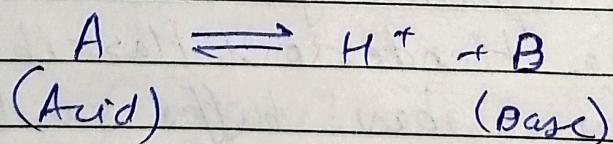
Significance :-

1. The pH of the buffer solution can be calculated from the initial concentration of the weak acid and the salt provided K_a is given.
2. It allows calculation of the ~~ratio~~ ratio in which the weak acid and its salt must be mixed in order to get a buffer solution of known pH.

★ Strength of acids and bases:-

An acid is a substance which ionizes to yield hydrogen ions or protons.

Base is a substance which combines with hydrogen ions so, an acid is a proton donor and a base is a proton acceptor.

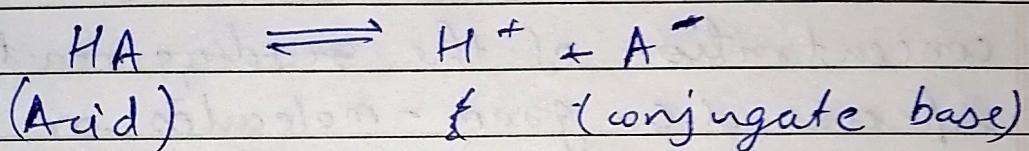


Strength of an acid is related to the concentration of hydrogen ions which it yield upon ionization and will depend upon the value of the degree of dissociation.

α at any given concentration.

The acid dissociation constant K_a provides a relationship between α and the concentration. It is a measure of the acid strength.

Similarly, the strength of a base is related to its dissociation constant.



$$K_a = \frac{[\text{H}^+][\text{A}^-]}{[\text{HA}]} \quad \text{and} \quad K_b = \frac{[\text{HA}][\text{OH}^-]}{[\text{A}^-]}$$

$$K_a K_b = \frac{[\text{H}^+][\text{A}^-]}{[\text{HA}]} \cdot \frac{[\text{HA}][\text{OH}^-]}{[\text{A}^-]}$$

$$\therefore K_a K_b = [\text{H}^+] [\text{OH}^-]$$

$$\therefore K_a K_b = K_w$$

Stronger acid the weaker its conjugated base.

* Law of mass action :-

This was first coined by Grulberg and Wage in 1867. The law is expressed as:-

The rate of a chemical reaction is proportional to the active masses of the reacting substance. In dil. solⁿ, the active mass is the concentration of the reacting species i.e. gram-molecules or gram-ions per litre. The constant of proportionality is the velocity constant. Here,

$A \rightarrow B$ is a reaction.

$$\text{Rate of reaction} = K [A]$$

$[A]$ = Concentrate of A

K = Velocity constant

A homogeneous reversible reaction is considered.



According to the law of mass action

$$V_f = k_1 [A] \cdot [B]$$

$$V_b = k_2 [C] \cdot [D]$$

V_f = velocity of forward sec^{-1}

V_b = velocity of backward sec^{-1} .

At equilibrium, $V_f = V_b$

$$k_2 [C] \cdot [D] = k_1 [A] \cdot [B]$$

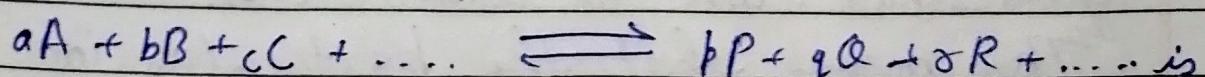
$$\frac{k_1}{k_2} = \frac{[C] \cdot [D]}{[A] \cdot [B]}$$

Since k_1 and k_2 are both constant
the fraction k_1/k_2 must also
be a constant.

$$\therefore k = \frac{[C] \cdot [D]}{[A] \cdot [B]}$$

k = Equilibrium constant of the reaction.

The equilibrium constant for the general reversible sec^{-1} is.



$$K = \frac{[P]^p \cdot [Q]^q \cdot [R]^r}{[A]^a \cdot [B]^b \cdot [C]^c}$$

Where, a, b, c and p, q, r are the no. of molecules of the reacting species.

Application of the law of mass action to solution of weak electrolytes :-

Strong electrolytes get completely dissociated even in less concentrated solution, so they do not constitute equilibrium system.

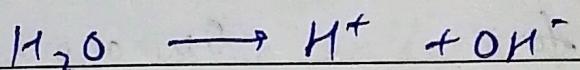
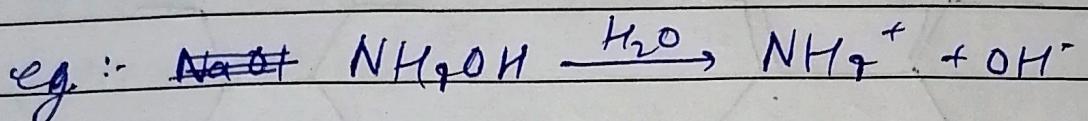
Weak electrolyte are only incompletely dissociated even in favourable ionization condition of dil. sol - so an equilibrium is considered in terms of the law of mass action which occurs b/w undissociated molecules and ions.

* Common ion effect:-

The concentration of a particular ion in an ionic reaction is increased by the addition of a compound which gives that ion on dissociation.

This means that the particular ion

is thus obtained from the compound present in solution and is also obtained from the added reagent. That is why the name 'common ion' is given;



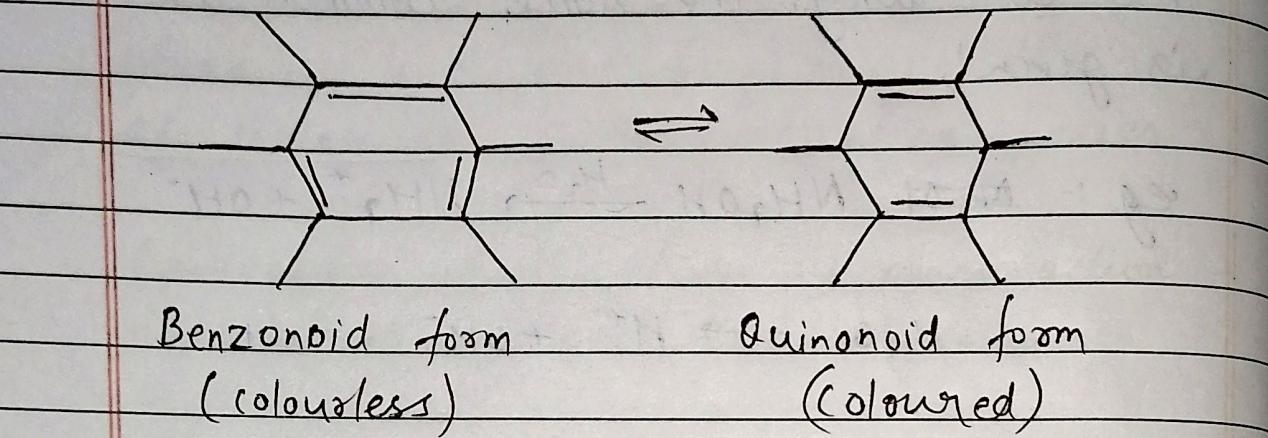
Here excess of OH^- ions is present. This system has excess of hydroxyl ion some of the hydroxyl ion combines with NH_3^+ ion to form ammonium hydroxide. OH^- ion is the common ion. This is the common ion effect.

* Theory of indicators:-

The theory suggests that the colour in organic compound is due to the ~~excess~~ presence of some ~~unst~~ unsaturated 'chromophores' like $\text{C}=\text{O}$, $\text{C}=\text{C}$, $\text{N}=\dots$ and $\text{N}=\text{N}$.

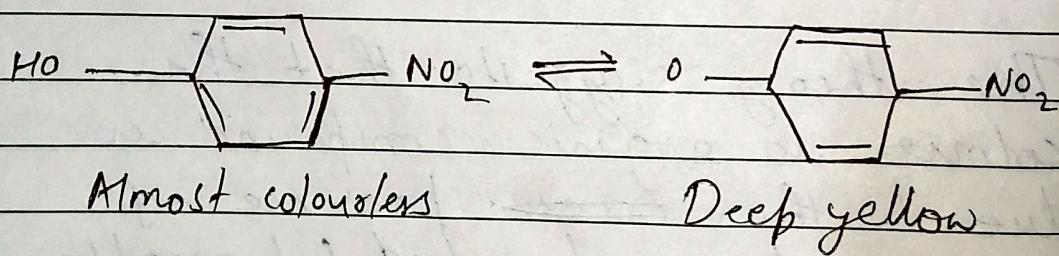
These chromophores are intensified by 'auxochromes' like NH_2 and OH group. The colour change of many indicators is due to the transformation of a benzoid structure into a

quinonoid and vice versa, along with the change in H^+ concentration of the solutions.



H.E Armstrong explained this case by taking the examples of nitrophenols

In alkaline solution p -nitrophenol is present as the yellow ion. But in acid solution, it is found as colourless nitro compound.



* Choice of Acid-Base indicators :-

Methyl orange is used in the assay of strong acids and in reactions where CO_2 is evolved. CO_2 does

not affect this indicator. Methyl red is used in the assay of weak bases.

Eg. - Ammonia ~~and~~ and amines.

Phenolphthalein is used in the assay of weak acids.

The choice of some well known indicators along with their pH range, colour changes are summarized below.

1. Congo red :-

It is sodium salt of an azo compound.

Its pH range is 3-5 causes blue colour to become red.

2. Dimethyl red:-

It is 4-dimethylamino azobenzene. its pH range is 2.8 - 4.0 it turns red to yellow. It gives latter end-point ~~is~~ strongly. alcoholic solution. It is used in the determination of carvone.

3. Methyl orange :-

It is the sodium salt of 4-dimethyl-amino azobenzene - 4-sulphonic acid.

Its pH range is 2.8 - 4.0 it turns red colour to yellow.

A 0.04% aqueous solution a/coholic solution is used.

4. Methyl red :-

It is 4-dimethyl amino azobenzene-2-carboxylic acid. Its pH range is 4.2 - 6.3. It turns red colour to yellow colour. The preparation of this indicator is described in pharmacopoeia. This methyl red indicator is used in place of methyl orange in the titration of NH_3 and other weak bases where it gives a better end-point.

5. Phenolphthalein :-

It turns colourless to red. It acts in the pH b/w 8.3 - 10.3. The colour limit of red varies with the concentration of the indicator. Generally, a 1% solution in alcohol is used in titration.

* Mixed indicators :-

In some cases it is required to have a sharp colour change in a narrow and soluted selected range of pH. This does not occur with an ordinary acid base indicator as the color change extends over two units of pH. This condition is achieved by a mixture of indicators.

Mixed indicators are selected so that their pK_{in} value are close together and the overlapping colours are complementary at an intermediate pH value. The examples are given below.

- (i) A mixture of equal parts of neutral red (0.1%) solution in ethanol and methylene blue (0.1% solution in ethanol) provides a sharp colour change from violet-blue to green. This occurs from acid to alkaline solⁿ at pH 7. This indicator is used to titrate acetic acid with NH_3 solution and vice-versa.

- (ii) A mixture of thymol Blue (3 part of a 0.1% aqueous solⁿ of the sodium salt) and cresol red (1 part of a 0.1% aqueous solⁿ of the sodium salt) changes its colour from yellow to violet

at pH 8.3. This indicator is used for the titration of carbonate to hydrogen carbonate stage.

Buffer action in a solution of a weak acid and its salt is due to the fact that H^+ ions are removed by the anions of a weak acid to form unionized molecules.

Guess Question and Answer

Q1. Discuss principle of precipitation titration. Discuss Fajan method in detail. - (17) marks.

→ Principle of precipitation titration:-

The main principle of precipitation titrations is that the quantity of added precipitating reagent or precipitant is equivalent to the substance being precipitated.

Fajan's Method:-

This method was given by K. Fajan in 1924. The method employs adsorption indicators for the detection of

end point in precipitation titration.

The principle of fajan's method of precipitation titration is based on the fact that at the end point, the indicator get adsorbed by the precipitate resulting in a substance of different colour. commonly used indicators in Fajan's method for the titration of halide and isocyanates silver nitrate are:

- (2) ^{mark} ① Fluorescein
 ② Dichlorofluorescein
 ③ Eosin (Tetraabromo fluorescein)
 ④ Erythrosine

Choice of adsorption Indicator

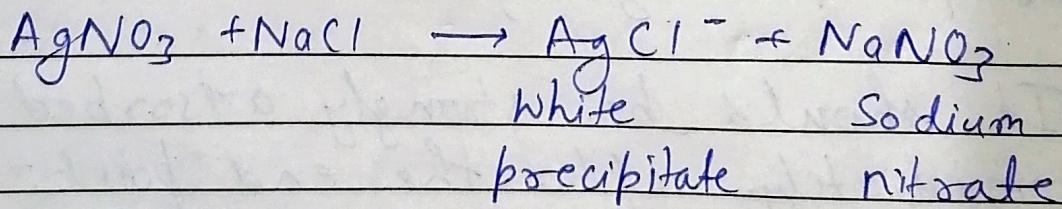
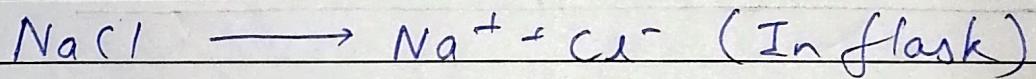
- ① The indicator ion (Fluoresceinate ion) must be an opposite charge to the ion of precipitating agent.
- ② It should be strongly adsorbed immediately after the end point.
- ③ The indicator should not be adsorbed before the precipitate formation.

Principle of adsorption Indicator:

The principle of adsorption Indicator is based upon the phenomenon of adsorption. The phenomenon of concentration of molecules of gas or liquid at a solid surface is termed as adsorption. The substance that concentrates at the surface is called adsorbate and solid surface on which concentration occurs is known as adsorbent.

e.g. Silver nitrate (AgNO_3) is titrated against sodium chloride (NaCl) solution.

In solution the ions present are.

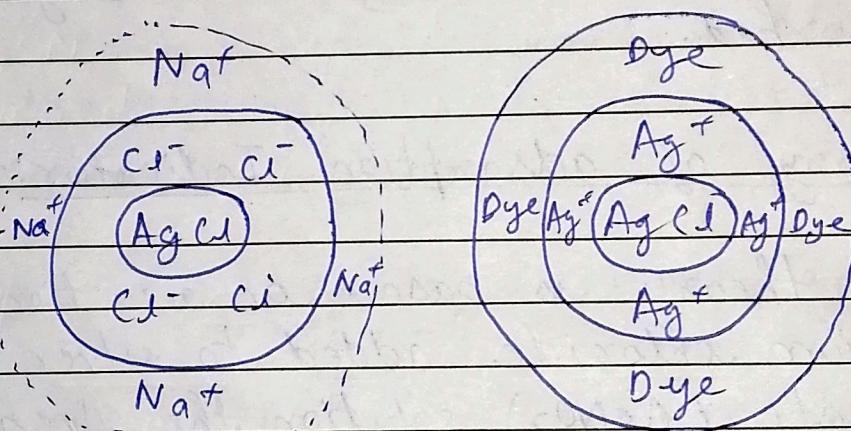


The precipitates of silver chloride (AgCl) adsorbs chloride ion (Cl^-) to form a primary adsorbed layer. It will hold secondary adsorbed positively charged ions as Na^+ from solution present in the flask. At the end point Ag^+ ions are added from the burette which are not primary adsorbed and oppositely charged NO_3^- ions will form the secondary adsorbed layer. Now on the surface of first traces of Ag^+ ions the modified fluoresceinate ions of indicator get adsorbed.

Theory of adsorption Indicator:-

The theory is based on reaction of sodium chloride added to silver nitrate (AgNO_3) solution the silver chloride precipitate will adsorb chloride ions which are initially in excess. Thus the chloride ions form the primary adsorbed layer. which is turn will hold the secondary adsorbed layer of oppositely charged Na^+ ions. Immediately after the equivalence point Ag^+ ions are in excess and hence silver chloride ions now adsorb Ag^+ ions as primary

adsorbed layer and NO_3^- as secondary adsorbed layer. Now if the sodium salt of fluorescein is also present in the solution then negatively charged fluorescein ions would be adsorbed instead of NO_3^- as secondary adsorbed layer and ~~here~~ this adsorption occurs along with a change to pink colour due to the formation of a pink coloured complex of Ag^+ and modified fluorescence ions.



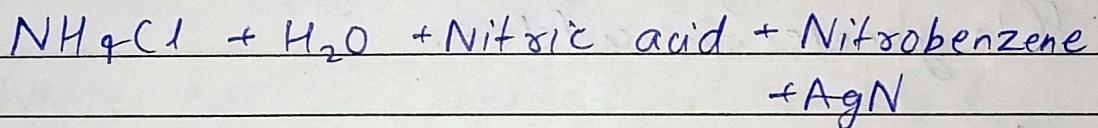
- (a) AgCl precipitated in presence of excess of Cl^- .
- (b) AgCl precipitated in presence of excess of Ag^+ .

Q.2. Discuss Vahlord's method of precipitation titration :-

→ (Indirect method or residual titration)

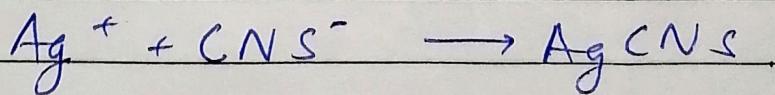
This method was given by Vahlord in 1874. In this method the excess of silver nitrate (AgNO_3) is added to the solution of halide acidified with nitric acid. The unreacted silver nitrate (AgNO_3) is treated against standard ammonium thiocyanate (NH_4SCN) solution using ferric salt as indicator.

e.g. : - Assay of Ammonium chloride.

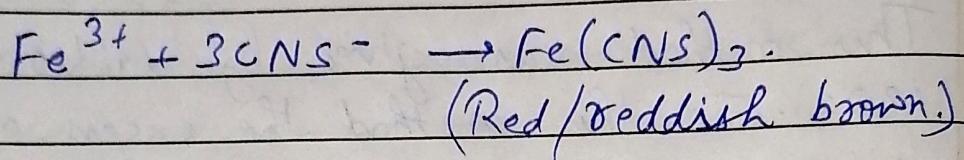


Shake vigorously for one minute and add ferric salt indicator → Titrate with 0.1N ammonium thiocyanate (NH_4SCN) till reddish brown color is obtained.

When standard solution as NH_4SCN is added to a solution of silver salt a precipitate of silver thiocyanate (AgCNS) continues to be formed till the Ag^+ ions are not completely precipitated.



The addition of further drop of thiocyanate react with the ferric ions to form a reddish brown ferric thiocyanate complex.



When the end point is approached the solution of silver thiocyanate (Ag(CN)) should be vigorously agitated because a large amount of the Ag^+ ions are absorbed on the surface of AgCNS precipitate which get removed only very slowly when thiocyanate is added.

Application :-

It is employed in the determinator of iodides, chlorides and thiocyanate ion.

Solubility product :-

[+ marks]

The process of gravimetric precipitation is completely based on the complex concepts of stability product let us consider a dissociation of slightly soluble salt AB .



Applying law of mass action.

$$K = \frac{[A^+][B^-]}{[AB]}$$

The concentration of the AB in the solution remains constant in presence of undissolved AB i.e.)

$$K_{sp} = \frac{[A^+][B^-]}{AB}$$

$$K_{sp} = [A^+][B^-]$$

Where K_{sp} is constant at constant temp and is called solubility product of salt $[AB]$ and is defined as maximum product of concentration of its constituent ion solution.

$[A^+]$ and $[B^-]$ = Ionic concentration in standard solution.

If ionic product or conc~~t~~ concentration is standard sol greater than K_{sp} . precipitation will occur.

If the Ionic product or concentration is equal to K_{SP} solution remains ~~constant~~ consistent.

If the ionic product or concentration is less than K_{SP} precipitation do not occur.

Types of Acid-Base Titration / Neutralization Titration curves :

A titration curve is the plot of the pH of the analyte solution versus the volume of the titrant added as the titration progresses.

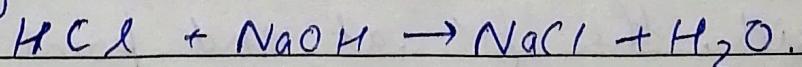
A. Aqueous Acid-Base Titration

These are normal titration between acids and base dissolved in water. Hence, they are called aqueous acid-base titration.

1. Strong acid and Strong base :-

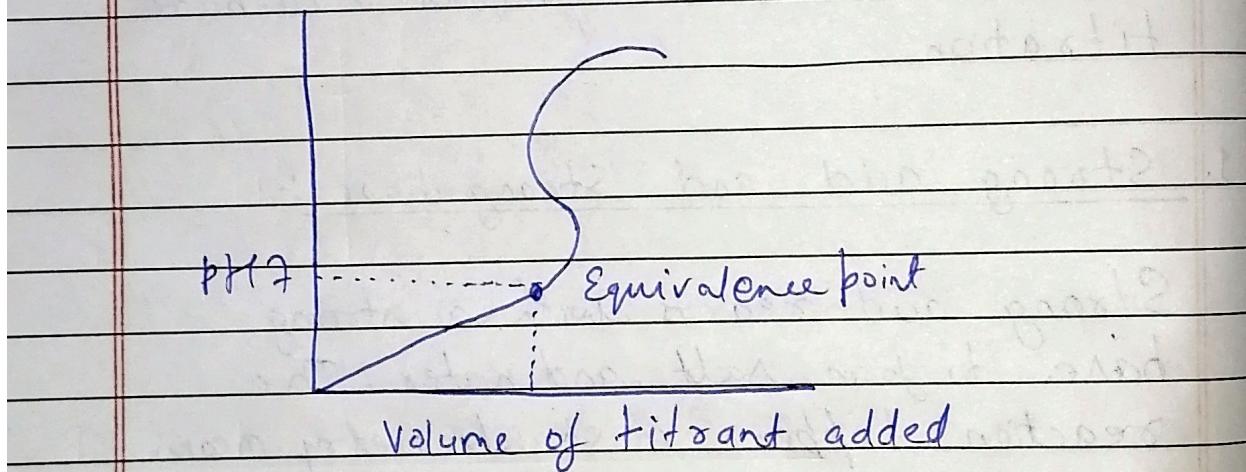
Strong acid reacts with a strong base to form salt and water. The reaction happens in stoichiometry means i.e. each molecule of acid reacts with corresponding molecule of base. At the end of reaction acid and base are completely reacted to form salt. Hence the end point or equivalence point is precise and sharp.

e.g. HCl as strong acid and NaOH strong base.



Initially, due to HCl, the pH of solution is less. As the NaOH added slowly, the dissociation of NaOH takes place and pH of solution increases.

At the equivalence point, HCl is completely reacted with NaOH to form water and salt. The pH of solution is 7. After the equivalence point the addition of NaOH increases the concentration of OH^- ions as HCl is completely react. The pH of solution increases.

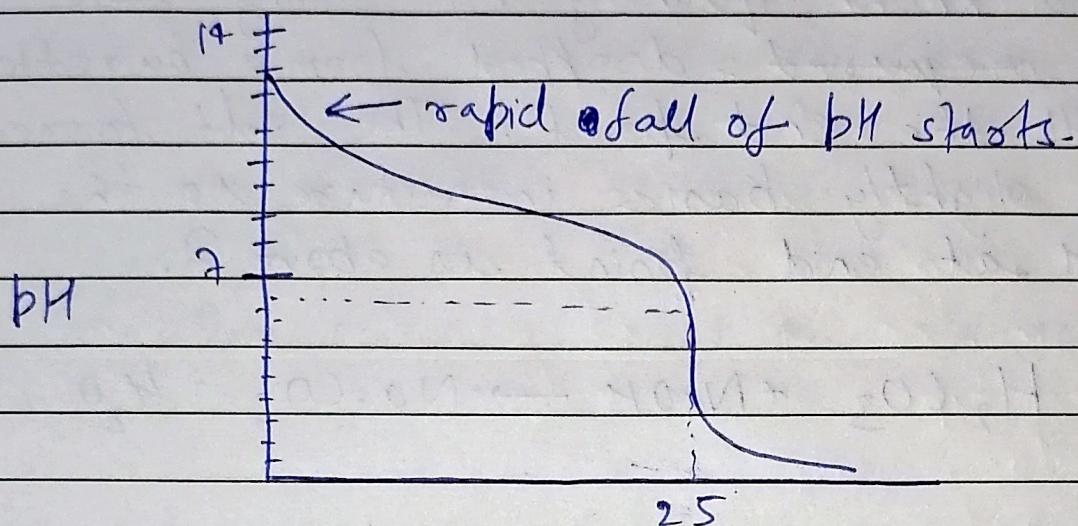
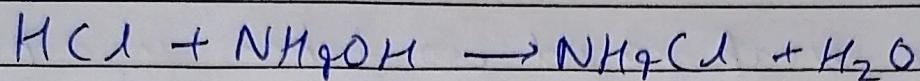


Titration curve for strong acid vs strong base.

(2) Strong acid vs Weak base :-

Here a strong acids reacts with weak base to form salt and water. But since, the reaction uses strong acid, the pH at end point will

be towards acidic i.e. below 7.

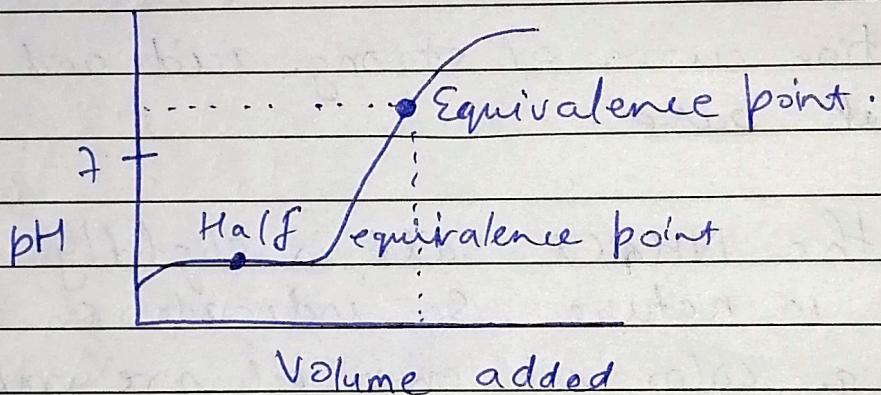
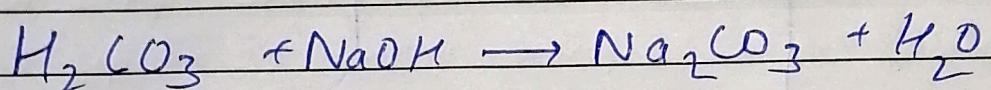


Titration curve of strong acid and weak base.

Here, the NH_4Cl salt is slightly acidic in nature. So indicators changing color at lower pH are employed. During reaction known concentration of strong acid is taken in burette and allowed to react drop by drop with the base in beaker. Initially the pH of solution is high due to ammonia. After end point, further addition of HCl decreases pH of solution as there is no ammonia present in solution to react.

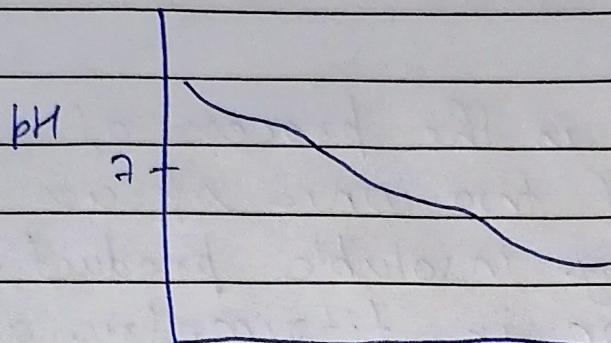
3. Weak acid vs Strong base.

The weak acid is taken in a beaker and known quantity of strong base is required, dropped from a burette till the end point. The salt formed is slightly basic in nature so the pH at end point is above 7.



4. Weak acid vs Weak base.

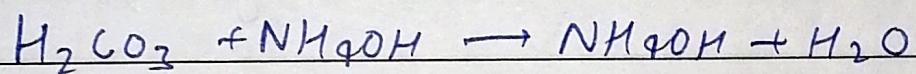
Here both acid and base are weak. So mostly they are avoided due to imprecise end point. At the end point, the pH will be theoretically but cannot be measured precisely as that is strong acid and strong base case.



Volume of titrant added.

Titration curve of weak acid and weak base.

An extra amount of titrant is needed to reach the end point due to imprecise reaction.



The end point is neutral as the salt is neutral but due to excess titrant added the pH can be in favour of it.

Precipitation

Precipitation is the process of combination of two ionic species to form a very insoluble product.

The reaction in titrimetric analysis occurs in a quantitative manner.

It must proceed completely to form the product of the reaction.

This type of reaction is neutralization & redox, completion and of precipitation reaction.

The reaction in titrimetric analysis must include the following requirements:

- i) The precipitate must be practically insoluble.
- ii) Precipitation reaction must occur in quantitative manner.
- iii) The reaction should be rapid.
- iv) The titration results must not be damage due to absorption or any kind of co-precipitation effect.

v) Determination of equivalence point during the titration must be detectable.

Principle of precipitation

Solubility depends on the solvent and temperature. It is the concentration of dissolved solute in moles per litre when the solution is in equilibrium with a solid solute.

In order to dissolve a solid the intermolecular forces of attraction must be overcome i.e. solute - solute attraction is ~~replaced~~ replaced by solute - solvent.

Here the solvent competes with crystal forces and overcome them. This means that the solvent environment must be similar to that provided by the crystal structure i.e. like dissolves like but during precipitation opposite things happen here in precipitation, intermolecular forces between the molecules of product are high so Solute - solute forces replace the Solute - solvent forces.