Introduction: made by S B Mirza (GCUF)

The word "titration" comes from the Latin "titalus," meaning inscription or title. The French word, titre, also comes from this origin, meaning rank is a common laboratory method of quantitative/chemical analysis that can be used to determine the concentration of a known reactant (analyte). The basis of the method is a chemical reaction of a standard solution (titrant) with a solution of an analyte.
The analyte (*A*) is a solution of the substance whose concentration is unknown and sought in the analysis. The titrant (*T*) is a solution in which the concentration of a solute is precisely known. Because volume measurements play a key role in titration, it is also known as volumetric analysis. Usually it is the *volume of the titrant* required to react with a given quantity of an analyte that is *precisely* determined during a titration.

Basics of titration

Equipments used :

- Buret,(is a cylindrical tube with a stopcock at one end).
- Pipette: Delivers an accurate volume of a solution. Often this is 25 cm^3.
- Volumetric flask:Used to make up an accurate volume of a solution, for example, 250 cm^3. This could be a **standard solution** (of exactly known concentration and known solute).
- Ph meter
- Indicators : provide some visual clue that the reaction is complete.

Standard method of TITRATION:

⇒ A known volume VA of the analyte is placed in a titration flask.

⇒ The burette is filled by a standard solution (titrant,) of known concentration c_T (M).

⇒ Before the titration is started, 1-3 drops of indicator (phenolphthalein) is placed in the titration flask with the analyte.The chosen indicator must be one color when the solution is acidic.

⇒ A base solution is then slowly added from the burette, drop by drop.

⇒ The titration continues, drop by drop, until the indicator suddenly achieves the intermediate color (weak pink) between that of the acid and the color of the base (fuchsia). At that point the titration ceases.

⇒ The point at which the system is neither acidic or basic is referred to as the

endpoint. The endpoint will correspond to a perfect stoichiometric relationship between the acid and the base.

⇒ Once the endpoint has been reached, the burette must be read. The bottom of the meniscus line determines the quantity of the base V_T that was required to reach the endpoint.

⇒ Once the titration is completed, the final calculations can be done.

Calculations:

Calculating the concentration c_A (M) of the analyte (acid):

i. From the balanced chemical equation

moles analyte = moles titrant

$$n_A = n_T \qquad (2)$$

ii. moles titrant: $n_T = V_T \cdot c_T$ (3)

iii. because $n_T = n_A$, the concentration of the analyte $c_A = n_A / V_A$ (4)

Titrating with a pH meter:

Titration with a pH meter follows the same procedure as a titration with an indicator, except that the endpoint is detected by a rapid change in pH, rather than the color change of an indicator.

Arrange the sample, stirrer, buret, and pH meter electrode so that you can read the pH and operate the buret with ease.

Titration Notes:

- Always rinse buret with water (from a beaker, not the faucet) first. Second, rinse with a small amount of the titrant and drain it through the tip.
- Fill the buret with the titrant using a funnel.
- Fill the buret tip by momentarily opening the stopcock.
- Now you are ready to read the initial volume (bottom of the meniscus). Remember that burets are graduated in a downward direction. The first estimated digit will probably be the hundredths place.
- Do not waste time trying to fill the buret to zero for each titration.
- Do not start above the 0 mL mark or titrate past the 50 mL mark.
- Always use white paper underneath your sample flask so that you will notice slight color changes.
- Learn to swirl the flask without removing it from underneath the buret.
- Use a drop, drop, drop pace until you see the color change becoming more than local (where the titrant meets the sample). Now proceed dropwise.
- Second and third trial titrations should always be fast assuming the sample will be about the same because you now know approximately how much titrant is needed. If the first titration required 25 mL than you can add 22 mL all at once and then proceed cautiously.

- Remember that the amount of water used to dilute the sample is not crucial because it does not affect "how many" of the sample molecules are present in the sample flask. Diluting with water allows you to see the color change easier.
- Always label multiple burets and sample flasks.
- Remember to add indicator.

Types of titration:

Titration Reaction types

1) Acid-Base Titrations
2) Redox titrations
3) Complexometric Titrations
4) Zeta- potential Tittrations
5) Miscellaneous titration
6) Iodimetry titration
7) Precipitation titration
8) KjeldahlTitration
9) Argentometric Titrations
    - 9.1) The Mohr titration:
    - 9.2) Volhard titration
    - 9.3) Fajans titration
10) Classification of titration by end-point techniques
    - 10.1) Conductometric titration
    - 10.2) Potentiometric titration
    - 10.3) Spectrophotometric titration
    - 10.4) Amperometric titration
    - 10.5) Thermometric or enthalpimetric titration
    - 10.6) Nonaqueous titration
    - 10.7) Automatic titration
    - 10.8) electrochemical titration
11) Back titrations
12) Virus titration

Titrimatery types:

1) volumetric titrimetry
2) gravimetric or weight titrimetry
3) coulometrictitrimetry
4) standardization

1) **Acid-Base Titrations:**

Titration is a process of neutralization whereby a titrant (a solution of known concentration) is delivered into an analyte (unknown solution) until the unknown solution is completely neutralized. This will allow information about the unknown solution to be determined. An indicator is (often) a weak acid that is placed into the unknown solution to determine the endpoint of the titration (the pH at which the indicator changes color). The equivalence point of the titration is the point when the moles of H^+ are equal to the moles of OH^- in a titration. The progress of an acid-base

titration is often monitored by plotting the pH of the solution being analyzed as a function of the amount of titrant added. The graph produced is called a titration curve.

Types of acid-base Titrations:

(i) Strong Acid / Strong Base: pH at equivalence point = 7

(ii) Weak Acid / Strong Base: pH at equivalence point >7

(iii) Strong Acid / Weak Base: pH at equivalence point <7

*Note: weak acid / weak base titrations are too complicated and are almost never carried out.

Example:

In titration, one solution (solution #1) is added to another solution (solution #2) until a chemical reaction between the components in the solutions has run to completion. Solution #1 is called the titrant, and we say that it is used to titrate solution #2. The completion of reaction is usually shown by a change of color caused by a substance called an indicator.

A typical titration proceeds in the following way. A specific volume of the solution to be titrated (solution #2) is poured into an Erlenmeyer flask (Figure 1). For example, 25.00 mL of a nitric acid solution of unknown concentration might be added to a 250 mL Erlenmeyer flask.

A solution of a substance that reacts with the solute in solution #2 is added to a buret. This solution in the buret, which has a known concentration, is the titrant. The buret is set up over the Erlenmeyer flask so the titrant can be added in a controlled manner to the solution to be titrated (Figure 1). For example, a 0.115 M NaOH solution might be added to a buret, which is set up over the Erlenmeyer flask containing the nitric acid solution.

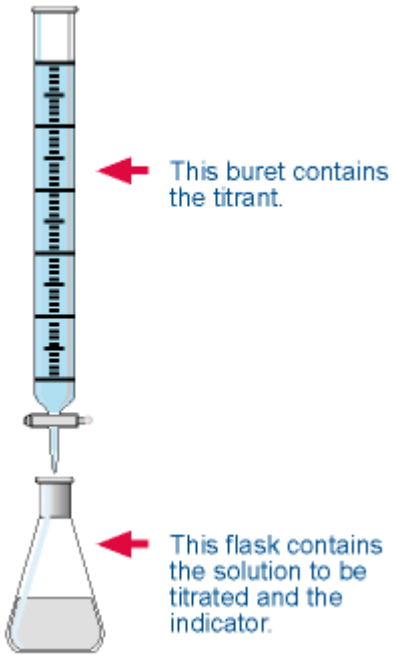


Figure 1 Setup for a Typical Titration

An indicator is added to the solution being titrated.In our example, phenolphthalein, which is a commonly used acid-base indicator, is added to the nitric acid solution in the Erlenmeyer flask. Phenolphthalein has two chemical forms. In acidic conditions, it is in the acid form, which is colorless. In basic conditions, an H+ ion is removed from each phenolphthalein molecule, converting it to its base form, which is red.

The titrant is slowly added to the solution being titrated until the indicator changes color, showing that the reaction is complete. This stage in the procedure is called the endpoint. In our example, the NaOH solution is slowly added from the buret until the mixture in the Erlenmeyer flask changes from colorless to red. The OH- ions in the NaOH solution react with the H3O+ ions in the HNO3 solution.

H3O+(aq) + OH-(aq) H2O(l)

As long as there are excess H3O+ ions in the solution, the solution stays acidic, the phenolphthalein stays mostly in the acid form, and the solution is colorless. When enough NaOH solution is added to react with all of the H3O+ ions, the reaction is complete. When a small amount of extra NaOH solution is added, perhaps one drop, there will be an excess of hydroxide ions, OH-, in solution. These react with the phenolphthalein molecules, changing them from the acid form to the base form. Because the base form is red, the solution turns red, telling us that the reaction is complete (or just slightly beyond complete).
The volume of titrant added from the buret is measured. For our example, lets assume that 18.3 mL of 0.115 M NaOH has been added. The following setup shows how the molarity of the nitric acid solution can be calculated from this data.

$$\frac{?\ \text{mol HNO}_3}{1\ \text{L HNO}_3\ \text{soln}} = \frac{18.3\ \text{mL NaOH soln}}{25.00\ \text{mL HNO}_3\ \text{soln}} \left(\frac{10^3\ \text{mL}}{1\ \text{L}}\right) \left(\frac{0.115\ \text{mol NaOH}}{10^3\ \text{mL NaOH soln}}\right) \left(\frac{1\ \text{mol HNO}_3}{1\ \text{mol NaOH}}\right)$$

$$= \quad \text{or } 0.0842\ \text{M HNO3}$$

The first step the dimensional analysis thought-process is to clearly identify the units that you want. Molarity describes the number of moles of solute per liter of solution, so we start by placing moles of HNO3 over 1 L HNO3 solution.
Because molarity is a ratio of two units, we begin our calculation with a ratio of two units. Knowing that we want volume of HNO3 solution on the bottom when we are done, we place 25.00 mL HNO3 solution on the bottom at the start. We place 18.3 mL NaOH solution on the top of our ratio, giving us the ratio of two units overall that we want.
We convert milliliters of HNO3 solution to liters of HNO3 solution using the relationship between milliliters and liters to convert milliliters. The last two conversion factors convert from amount of one substance in a chemical reaction (mL NaOH solution) to amount of another substance in the reaction (mol HNO3). Thus, this is an equation stoichiometry problem that requires at its core the conversion of moles of NaOH to moles of HNO3 using the molar ratio for the reaction between them.

NaOH(aq) + HNO3(aq) NaNO3(aq) + H2O(l)

In order to use the molar ratio to convert from moles of NaOH to moles of HNO3, we need to convert from volume of NaOH solution to moles of NaOH using the molarity as a conversion factor.

Indicator	Colour on Acidic Side	Range of Colour Change	Colour on Basic Side
Methyl Violet	Yellow	0.0 - 1.6	Violet
Bromophenol Blue	Yellow	3.0 - 4.6	Blue
Methyl Orange	Red	3.1 - 4.4	Yellow
Methyl Red	Red	4.4 - 6.2	Yellow
Litmus	Red	5.0 - 8.0	Blue
Bromothymol Blue	Yellow	6.0 - 7.6	Blue
Phenolphthalein	Colourless	8.3 - 10.0	Pink
Alizarin Yellow	Yellow	10.1 - 12.0	Red

Applications of acid-base titration:

- In the determination of iron in pharmaceutical preparations
- First of all, acid-base titration, to control acidity or alkilinity of solutions, to do neutralisation tests and analyze mixtures of acids
- Wide use is in titration processes

2) Red-ox titrartion:

Titration of a reducing agent by an oxidizing agent or titration of an oxidizing agent by a reducing agent. The concentrations of redox-active species can be determined by redox titrations. In a redox titration, a measured sample of the unknown is titrated against a standard solution of a substance that will oxidize or reduce the unknown.

Red-ox reaction:

A redox reaction (reduction and oxidation reaction) is a reaction in which there is a transfer of electrons. When an element is reduced, it gains electrons and its oxidation number is reduced. When an element is oxidized, it loses electrons and its oxidation number increases. Reduction and oxidation always happen at the same time

Key points about Red-ox titration:

- A REDOX titration is a volumetric method that relies on the oxidation of the analyte (substance to be analysed).
- The titrant (solution of known concentration) is often an oxidising agent.

Common oxidising agents are:

1. permanganate ion (MnO_4^-)
   $MnO_4^-{}_{(aq)} + 8H^+ + 5e \text{ -----> } Mn^{2+}{}_{(aq)} + 4H_2O \quad E^o = +1.51V$
   purple permanganate ion (MnO_4^-) is reduced to colourless manganese (II) ion (Mn^{2+})
2. dichromate ion ($Cr_2O_7^{2-}$)
   $Cr_2O_7^{2-}{}_{(aq)} + 14H^+ + 6e \text{ -----> } 2Cr^{3+}{}_{(aq)} + 7H_2O \quad E^o = +1.23V$
   orange dichromate ion ($Cr_2O_7^{2-}$) is reduced to green chromium (III) ions (Cr^{3+})

- At the equivalence point $E_{(forward)} = E_{(reverse)}$, or, $\triangle E_{(cell)} = 0$
- If the REDOX reaction does not produce a well-defined colour change at the equivalence point, an indicator should be used in the titration. Starch can be used as an indicator for REDOX titrations using iodine as the titrant (iodine is a weak oxidising agent) because starch forms a blue complex with iodine.
- The REDOX titration curve is a plot of Electrode Potential (volts) vs volume of titrant or analyte.

Application of Red-ox titrartion:

- In the determination of iron in pharmaceutical preparations
- Wide use is in titration processes
- We also perform redox titration for quantitative determination of metals such as Ca, Mg, Zn, Co, Ni, Fe(II) and (III), Mn(II), (IV) and (VII), Cr(III) and (VI), U (IV) and (VI), V(II), (IV) and (V) and PGMs;
- for determination of dissolved O2, H2O2 and anions such as NO2-, S2-, SO32-, Cl-and Br-
- to determine the oxidation state of elements.

3) Complexometric Titrations(i.e.,Complex formation ,chelometric):

The technique involves titrating metal ions with a complexing agent or chelating agent (Ligand) and is commonly referred to as complexometric titration. A technique of volumetric analysis in which the formation of a colored complex is used to indicate the end point of a titration. Also known as chelatometry. Also spelled complexiметric titration. These **titrations** are based on the **formation** of a **complex** between the analyte and the titrant.

This method represents the analytical application of a complexation reaction. In this method, a simple ion is transformed into a complex ion and the equivalence point is determined by using metal indicators or electrometrically. Various other names such as chilometric titrations, chilometry, chilatometric titrations and EDTA titrations have been used to describe this method. All these terms refer to same analytical method and they have resulted from the use of EDTA (Ethylene diamine tetra acetic acid) and other chilons. These chilons react with metal ions to form a special type of complex known as chelate. Metal ions in solution are always solvated, i.e. a definite number of solvent molecules (usually 2, 4 or 6) are firmly bound to the metal ion. However, these bound solvent molecules are replaced by other solvent molecules or ions during the formation of a metal complex or metal co-ordination compound.
The molecules or ions which displace the solvent molecules are called Ligands. Ligands or complexing agents or chelating agents can be any electron donating entity, which has the ability to bind to the metal ion and produce a complex ion.

Table-1: Indicators used in complexometric titrations

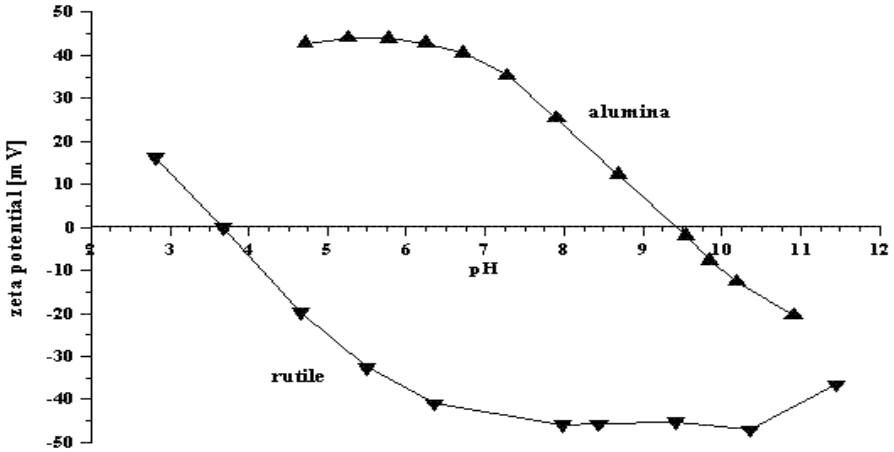
S.No.	Name of the Indicator	Colour change	pH range	Metals detected
1.	Mordant black II	Red to Blue	6-7	Ca, Ba, Mg, Zn, Cd, Mn, Pb, Hg
	Eriochrome blackT			
	Solochrome blackT			
2.	Murexide or Ammonium purpurate	Violet to Blue	12	Ca, Cu, Co
3.	Catechol-violet	Violet to Red	8-10	Mn, Mg, Fe, Co, Pb
4.	Methyl Blue	Blue to Yellow	4-5	Pb, Zn, Cd, Hg
	Thymol Blue	Blue to Grey	10-12	
5.	Alizarin	Red to Yellow	4.3	Pb, Zn, Co, Mg, Cu
6.	Sodium Alizarin sulphonate	Blue to Red	4	Al, Thorium
7.	Xylenol range	Lemon to Yellow	1-3	Bi, Thorium
			4-5	Pb, Zn
			5-6	Cd, Hg

Applications of Complexometric Titrations:

- Complexometric titrations have been employed with success for determination of various metals like Ca, Mg, Pb, Zn, Al, Fe, Mn, Cr etc. in different formulations that are official in I.P., and also for the determination of Hardness of water.
- Determination of total hardness of water by **Complexometric method**

4) Zeta potential titration :

is a **titration** of **heterogeneous** systems, such as **colloids**, **emulsions**, etc. Solids in such systems have very high **surface area**. This type of titration is used to study the **zeta potential** of these **surfaces** under different conditions.



Priperties of Zeta potential titration:

- The Iso-electric point is one such property. The iso-electric point is the pH value at which the zeta potential is approximately zero. At a pH near the iso-electric point (± 2 pH units), colloids are usually unstable; the particles tend to coagulate or flocculate. Such titrations use acids or bases as titration reagents. Tables of iso-electric points for different materials are available. The attached figure illustrates results of such titrations for concentrated dispersions of alumina (4% v/v) and rutile (7% v/v). It is seen that iso-electric point of alumina is around pH 9.3, whereas for rutile it is around pH 4. Alumina is unstable in the pH range from 7 to 11. Rutile is unstable in the pH range from 2 to 6.
- Another purpose of this titration is determination of the optimum dose of surfactant for achieving stabilization or flocculation of a heterogeneous system. Examples can be found in the book by Dukhin and Goetz.

Measurement:

In a zeta-potential titration, the Zeta potential is the indicator. Measurement of the zeta potential can be performed using microelectrophoresis, or electrophoretic light scattering, or electroacoustic phenomena. The last method makes possible to perform titrations in concentrated systems, with no dilution. The book by Dukhin and Goetz provides a detailed description of such titrations.

5) Miscellaneous titration:

A form of titration can also be used to determine the concentration of a virus or bacterium. The original sample is diluted (in some fixed ratio, such as 1:1, 1:2, 1:4, 1:8, etc.) until the last dilution does not give a positive test for the presence of the virus. This value, the titre, may be based on TCID50, EID50, ELD50, LD50 or pfu. This procedure is more commonly known as an assay.

6) Iodimetry titration:

Iodometry is a method of volumetric chemical analysis, a titration where the appearance or disappearance of elementary iodine indicates the end point.
Usual reagents are sodium thiosulfate as titrant, starch as an indicator (it forms blue complex with iodine molecules - though polyvinyl alcohol has started to be used recently as well), and an iodine compound (iodide or iodate, depending on the desired reaction with the sample).
The principal reaction is the reduction of iodine to iodide by thiosulfate:

$I_2 + 2\ S_2O_3^{2-} \rightarrow S_4O_6^{2-} + 2\ I^-$

Application of iodiometry titration:

- A common and illustrative use of iodometry is the measurement of concentration of chlorine in water. Chlorine in pH under 8 oxidizes iodide to iodine. An overabundance of potassium iodide is added to the known amount of sample in acidic environment (pH < 4, the reaction is not complete in more alkaline pH). Starch is added, forming a blue clathrate complex with the liberated iodine. The blue solution is then titrated with thiosulfate until the blue color vanishes.
- Determination of Vit-C (ascorbic acid) in fruit juices by **Iodimetric method**
- Analysis of commercial Hypochlorite solution lodometrically.
- Analysis of hydrogen peroxide Iodometrically.

7) Precipitation titration: Amperometric titration in which the potential of a suitable indicator electrode is measured during the titration. In a precipitation titration, one of the products is a precipitate.

Indicators used:

As this reaction is not of the acid/base type, the end point cannot be detected with indicators such as the methyl orange or phenolphthalein used in E13. Instead, a small amount of chromate ions, CrO_4^{2-}, is added as potassium chromate solution. Potassium chromate solution is yellow, whilst silver chromate is a red.

Applications of precipitation titration:

- To determine the equilibrium constant or the solubility product of a compound.
- We also perform precipitation titration, for example, argentometric determination of chlorides, cyanides and thiosulphites
- To determine electrode potential
- Precipitation Titrations are used for the analysis of halides and pseudo-halides for quantitative determination, as well as for some metal ions

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8) KjeldahlTitration:

Developed in 1883-still widely used to determine N content in substances (e.g. protein, milk, cereal, and flour)
In a long-necked flask (Kjeldahl) digestion of solid (decomposition and dissolution) inboiling H_2SO_4 is done.

- **Organic C, H, N→ NH_4^++ CO_2+ H_2O**
  - boiling H2SO4 w/ K2SO4
  - catalyzed by Hg, Cu, Se compounds

- Neutralization of NH_4^+**:** $NH_4^+ + OH^- \rightarrow NH_3(g) + H_2O$
- Distillation of NH_3into standard HCl**:** $NH^3 + H^+ \rightarrow NH^{4+}$
- Titration of unreacted HCl with NaOH**:** $H^+ + OH^- \rightarrow H_2$

9) Argentometric Titrations:

Titrimetric methods based on silver nitrate are sometimes called argentometric methods.

9.1) The Mohr titration:

In this method Sodium chromate can serve as an indicator for the argentometric determination of chloride, bromide , and cyanide ions by reacting with silver ion to from a brick-red silver chromate precipitate in the equivalence –point region.

9.2) The Fajan titration:

In this method a coloured indicator is absorbed onto the precipitate at end point .Absorption indicator is an organic compound that tends to be adsorbed onto the surface of the solid in a precipitation titration .the adsorption occurs near the equivalence point and results not only in a color change but also in a transfer of color from the solution to the solid.Fluorescein is a typical adsorption indicator that is useful for the titration of chloride ion with silver nitrate.

9.3) Volhard titration:

Determination of the halogen content of a solution by titration with a standard thiocyanate solution.

Application of vohard titration:

- Typically, it is used to determine the amount of chloride present in a sample. The sample solution is titrated against a solution of silver nitrate of known concentration. Chloride ions react with silver(I) ions to give the insoluble silver chloride:

Cl^- (aq) + Ag^+ (aq) → AgCl (s) ($K_{sp} = 1.70 \times 10^{-10}$)

- the Volhard titration involves the addition of excess silver nitrate to the analyte; the silver chloride is filtered, and the remaining silver nitrate is titrated against thiocyanate,[1] with iron(III) as an indicator which forms blood-red $[Fe(OH_2)_5(SCN)]^{2+}$ at the end point:

Ag^+ (aq) + SCN^- (aq) → AgSCN (s) ($K_{sp} = 1.16 \times 10^{-12}$)
$Fe(OH)(OH_2)_5^{2+}$ (aq) + SCN^- (aq)→ $[Fe(OH_2)_5(SCN)]^{2+} + OH^-$

10) Classification by end-point techniques:

The precision and accuracy with which the end point can be detected is a vital factor in all titrations. Because of its simplicity and versatility, chemical indication is quite common, especially in acid-base titrimetry.

10.1) Potentiometric titration

If a pH meter is used, its associated electrodes are first standardized by use of a buffer solution of known pH. By suitable choice of electrodes, potentiometric methods can also be applied to combination titrations and to oxidation-reduction titrations. The advent of modern ion-selective electrodes has greatly extended the scope of potentiometric titration and of other branches of titrimetry.

10.2) Conductometric titration

uses the change of conductivity of the solution. Conductometric titration is sometimes successful when chemical indication fails. The underlying principles of conductometric titration are that the solvent and any molecular species in solution exhibit only negligible conductance; that the conductance of a dilute solution rises as the concentration of ions is increased; and that at a given concentration the hydrogen ion and the hydroxyl ion are much better conductors than any of the other ions.

10.3) Spectrophotometric titration

We can use absorption of light to monitor the progress of the reaction.The spectrophotometer is an optical device that responds only to radiation within a selected very narrow band of wavelengths in the visual, ultraviolet, or infrared regions of the spectrum. The response can be made both quantitative and linearly related to the concentration of a species that absorbs radiation within this band. Titrations at wavelengths within the visual region are by far the most common.

10.4) Amperometric titration

By use of a dropping-mercury or other suitable microelectrode, it is possible to find a region of applied electromotive force (emf) in which the current is proportional to the concentration of one or both of the reactants in a titration.

Biamperometric titration is a closely related technique. An emf that is usually small is applied across two identical micro-electrodes that dip into the titrand solution. This arrangement, which involves no liquid-liquid junctions, is valuable in nonaqueous titrations, but also finds much use in aqueous titrimetry.

10.5) Thermometric or enthalpimetric titration

Many chemical reactions proceed with the evolution of heat. If one of these is used as the basis of a titration, the temperature first rises progressively and then remains unchanged as the titration is continued past the end point. If the reaction is endothermic, the temperature falls instead of rising. Thermometric titration is applicable to all classes of reactions.

10.6) Nonaqueous titration

This technique is used to perform titrations that give poor or no end points in water. Although applicable in principle to all classes of reactions, acid-base applications have greatly exceeded all others. Nonaqueous titrations in which the solvent is a molten salt or salt mixture are also possible.

10.7) Automatic titration

Automation is particularly valuable in routine titrations, which are usually performed repeatedly. One approach is to record the titration curve and to interpret it later. Another method is to stop titrant addition or generation automatically at, or very near to, the end point. Although a constant-delivery device is desirable, an ordinary buret with an electromagnetically controlled valve is often used. Microcomputer control permits such refinements as the continuous adjustment of the titrant flow rate during the titration. In some cases, it is possible to automate an entire analysis, from the measurement of the sample to the final washout of the titration vessel and the printout of the result of the analysis.

10.8) Electrochemical titration

In this weDetect a voltage change between electrodes.

12) Back titrations:

are like normal titrations, except that a known excess of a standard reagent is added to the solution being titrated. The solution is then titrated *back*, taking into account the addition of the excess. Back titrations are useful if the end point of the reverse titration is easier to identify than the end point of the normal titration.

13) Virus titration:

to determine the virus concentration. It may be based on TCID50 EID50,ELD50, LD50 or pfu.

Titrimetry types:

Titrimetry: measuring the quantity of a reagent of known conc required to react with a measured quantity of sample of an unknown con.

(i) Volumetric Titrimetry

involves measuring the volume of a solution of known concentration that is needed to react essentially completely with the analyte.

(ii) Gravimetric Titrimetry

differ only in that the mass of the reagent is measured instead of its volume.

(iii) **Coulometric Titrimetry**: The reagent is a constant direct electrical current of known magnitude that consumes the analyte the time required and thus the total charge to complete the electrochemical reaction is measured.

Types of Titration Curves:

Graph showing variation of concentration (or something proportional to concentration such as absorbance of light, voltage, or conductance) vs. volume of titrant addedThere are some titration curves used in complete description of titration
Titration Curves are plots of a concentration-related variables as a function of reagent volume.
Concentration change is large—use p function

$$pX = -\log_{10}[X]$$

(i) **Sigmoidal curve:**

p-function of analyte (or sometimes the reagent) is plotted as a function of reagent volume.

(ii) **Linear segment curve:**

measurement are made on both sides of but well away from the equivalence point. (advantageous for reaction that are complete only in the presence of a considerable excess of the reagent or analyte)

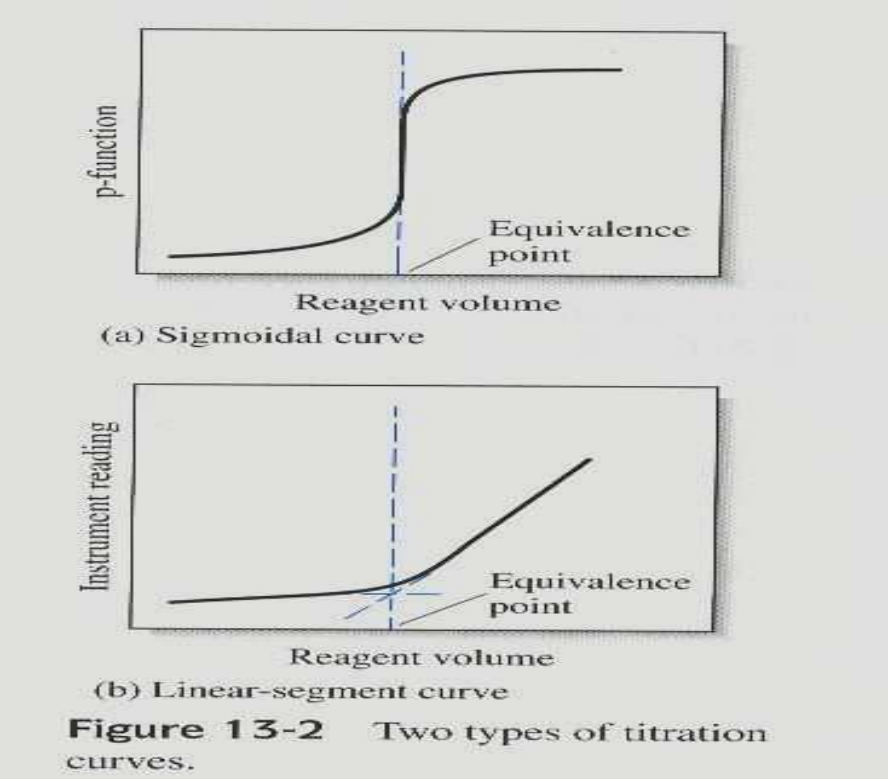

Figure 13-2 Two types of titration curves.

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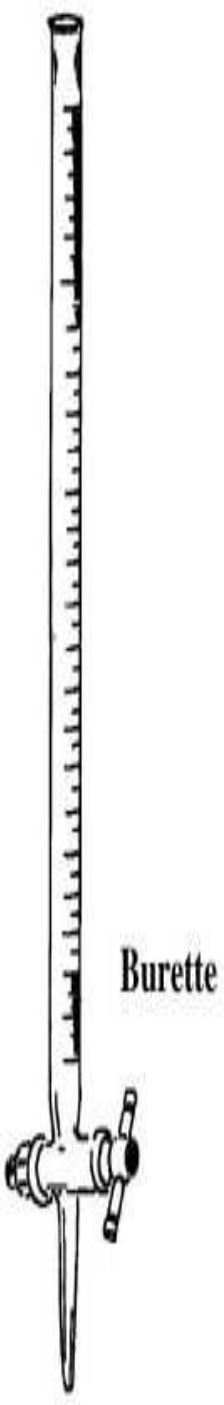

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