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Soil Chemical Analysis - Titrations and Indicators

S. Arun Kumar
Ph.D. Scholar, Department of Soil Science and Agricultural Chemistry, School of Agriculture, Lovely Professional University, Kapurthala, Punjab

SUMMARY

Titration, process of chemical analysis in which the quantity of some constituent of a sample is determined by adding to the measured sample an exactly known quantity of another substance with which the desired constituent reacts in a definite, known proportion. The process is usually carried out by gradually adding a standard solution (i.e., a solution of known concentration) of titrating reagent, or titrant, from a burette, essentially a long, graduated measuring tube with a stopcock and a delivery tube at its lower end. The addition is stopped when the equivalence point is reached. For many titration reactions it is possible to find a suitable visual colour indicator that will signal the end point at, or very close to, the equivalence point. Such titrations, classified according to the nature of the chemical reaction occurring between the sample and titrant, include: acid-base titrations, precipitation titrations, complex-formation titrations, and oxidation-reduction (redox) titrations. In acid-base titration (i.e., the titration of an acid with a base, or vice versa), the indicator is a substance that can exist in two forms, an acid form and a basic form, which differ in colour. For example, litmus is blue in alkaline solution and red in acid solution. Phenolphthalein is colourless in acid solution and red in alkaline solution. A wide choice of acid-base indicators is available, varying not only in the colours of the two forms but also in their sensitivity toward acid or base.

INTRODUCTION

Titration is a common laboratory method of using the quantitative chemical analysis. This method is used to determine the unidentified concentration of a known analyte. The volume measurement is known as volumetric analysis, and it is important in the titration. There are many types of titration when considering the goals and procedures. However, the most common types of titration in the quantitative chemical analysis are redox titration and acid-base titration. Indicators is a substance which is used to indicate the end point or completion of a reaction by its coloru change. An indicator is a chemical compound, usually an acid, whose conjugate base has a different colour to the acid. Each indicator has a specific pH range in which it will change colour and are used to indicate the endpoint of a titration.

Types of titrations

Aqueous titrations

- Acid-base Titrations.
- Redox Titrations.
- Precipitation Titrations.
- Complexometric Titrations.

Acid-base Titrations

The strength of an acid can be determined using a standard solution of base is called as acidimetry. In the same way, the strength of a base can be found with the help of a standard solution of an acid is known as alkalimetry. Both titrations involve in the neutralization of alkali.

$$HA+BOH \rightarrow BA+H_2O$$

Acid Alkali→Salt Water

OrH++A−+B++OH−→B++A−+H2O

Or H++OH−→H2O

The acid-base titration is based on the reaction that neutralization between a base or an acidic and analyte. In this type, a reagent is mixed with the sample solution until it reached the required pH level. This type of titration majorly depends on the track change in pH or a pH meter.

Acid-Base Titration: 5 Types

Aqueous acid-base titration.

These are normal titration between acids and base dissolved in water. Hence the name aqueous titration. They are prominently used in academic labs and for standardization.

Strong acid V/s strong base: Here are strong acid reacts with a strong alkali to form salt and water. The reaction of this type is swift and also complete. The reaction happens in stoichiometric means, i.e., each molecule of acid reacts with the corresponding molecule of the base. At the end of the reaction, no molecule of acid or base exists as every molecule in the reaction has completely reacted to form a salt. Hence the endpoint or equivalence point is precise and sharp. Example of these types of acids are HCl, H2So4, HNO3, HBr, HClO4 (perchloric acid), H3PO4, etc. The examples of strong bases are NaOH, MgOH2, Al2OH3, etc.

Strong Acid v/s Weak Base: Here a strong base reacts with weak acid to form salt and water. But since the reaction uses a strong acid, the pH at the endpoint will be towards acidic, i.e., below 7. **Reaction example:** HCl+NH4OH——————>NH4Cl + H2O.

Here the salt formed NH4Cl is slightly acidic. So indicators changing color at lower pH's are employed.

During the reaction, a known concentration of strong acid is taken in a burette and allowed to react drop by drop with the base in a beaker.

Weak Acid V/s Strong Base: Here the reaction happens between a weak acid and strong base. The weak acid is taken in a beaker and known quantity of strong base is dropped from a burrete till the endpoint.

Reaction example: H2CO3+ NaOH——————>Na2Co3+H2O

The salt formed is slightly basic, so the pH at the end point is above 7. The indicator used is one with a change in color at higher pHs.

Weak Acid V/s Weak Base: Here both acid and base are weak. So mostly they are avoided due to imprecise endpoints. At the endpoint, the pH will be seven theoretically. But cannot be measured precisely like that in strong acid and strong base case. An extra amount of titrant is needed to reach the endpoint due to the imprecise reaction.

Reaction example: H2CO3+NH4OH——————>NH4OH+H2O

The endpoint is neutral as the salt is neutral but due to excess titrant added the pH could be in favor of it.

Non-Aqueous titration

These are conventional methods of non-aqueous titration. Here instead of water as solvent glacial acetic acid is used to make the reactants. They are similar to above types of acid-base reactions. Since many drugs are water-insoluble and slightly acidic or basic, they are analyzed by non-aqueous titrations.They are extensively used for quality control and analysis of drugs.

Reaction example: psuedoephidrin+HCl

Redox Titrations

The redox titration is also known as an oxidation-reduction reaction. In this type of titration, the chemical reaction takes place with a transfer of electrons in the reacting ions of aqueous solutions. In this type the titrations are named after the reagent that is used in are as follows;

- Permanganate Titrations
- Dichromate Titrations
- Iodimetric and Iodometric Titrations

Permanganate Titrations: In this titration, the potassium permanganate is used as oxidizing agent. It is maintained with the use of dilute sulphuric acid. Here is the equation.

2KMnO4+3H2SO4→K2SO4+2MnSO4+3H2)+5[O]

Or MnO−4+8H+5e→Mn2++4H2O

Further, the solution remains colorless before the end point. The potassium permanganate is used to estimate oxalic acid, ferrous salts, hydrogen peroxide, oxalates and more. While the solution of potassium permanganate is always standardized before it is used.

Dichromate Titrations: These are titrations in which, potassium dichromate is used as an oxidising agent in acidic medium. The medium is maintained acidic by the use of dilute sulphuric acid. The potential equation is:

K2Cr2O7+4H2SO4→K2Cr2(SO4)+4H2O+3[O]

Or Cr2O−72+14H++ 6e→2Cr3++7H2O

The solution of potassium dichromate can be directly used for titrations. It is mainly used for the estimation of ferrous salts and iodides.

Iodimetric and Iodometric Titrations: The reduction of free iodine to iodide ions and oxidation of iodide ions to free occurs in these titrations.

l2+2e→2l− ……. (reduction)

2l−→l2+2e ……. (oxidation)

The solution is used as an indicator. Free iodine is used in the iodometric titration, while in the iodometric titration an oxidation agent is used to react to liberate free iodine.

Precipitation Titrations

The titration is based on the insoluble precipitate formation when the two reacting substance are brought into contact are called as precipitation titration. For instance. The solution of silver nitrate is used to a solution of ammonium thiocyanate or a sodium chloride, it reacts and forms a white precipitate of silver thiocyanate or silver chloride.

AgNO3+NaCl→AgCl+NaNo3

AgNO3+NH4CNS→AgCNS+NH4NO3

Complexometric Titrations

The complexometric titration is where an undissociated complex is formed at an equivalence point. It is greater than the precipitation titrations, and there will be no error due to co-precipitations.

Hg2++2SCN−→Hg(SCN)2

Ag++2CN−→[Ag(CN)2]−

The Ethylenediaminetetraacetic acid (EDTA) is an important reagent that forms complexes with metals.

Types of indicators

Redox indicators

Redox Indicators are an indicators that undergoes a definite color change at a specific electrode potential, and shows a reversible color change between oxidized and reduced forms. Loba chemie offers wide range of redox indicators which are use as a Indicator in redox titrations.

Neutralization indicators, or acid-base indicators.

They are auxiliary reagents added to the titrand solution in order to detect the equivalence point in acid-base titrations. They can also be used for an accurate quantitative measure of the pH.

Precipitation indicators

An indicator which precipitates from solution in a readily visible form at or near the equivalence-point.

Adsorption indicator

A type of indicator used in reactions that involve precipitation. The yellow dye fluorescein is a common example, used for the reaction $NaCl(aq)+AgNO_3(aq) \rightarrow AgCl(s)+NaNO_3(aq)$ As silver nitrate solution is added to the sodium chloride, silver chloride precipitates. As long as Cl^- ions are in excess, they adsorb on the precipitate

particles. At the end point, no Cl^- ions are left in solution and negative fluorescein ions are then adsorbed, giving a pink colour to the precipitate. The technique is sometimes known as Fajan's method.

$NaCl(aq)+AgNO_3(aq) \rightarrow AgCl(s)+NaNO_3(aq)$

Complexometric indicators

In analytical chemistry, complexometric indicators are used in complexometric titration to indicate the exact moment when all the metal ions in the solution are sequestered by a chelating agent (most usually EDTA). Such indicators are also called metallochromic indicators. The indicator may be present in another liquid phase in equilibrium with the titrated phase, the indicator is described as extraction indicator. Some complexometric indicators are sensitive to air and are destroyed. When such solution loses color during titration, a drop or two of fresh indicator may have to be added.

pH indicator

A pH indicator is a halochromic chemical compound added in small amounts to a solution so the pH (acidity or basicity) of the solution can be determined visually. Hence, a pH indicator is a chemical detector for hydronium ions (H_3O^+) or hydrogen ions (H^+) in the Arrhenius model. Normally, the indicator causes the color of the solution to change depending on the pH. Indicators can also show change in other physical properties; for example, olfactory indicators show change in their odor. The pH value of a neutral solution is 7.0 at 25°C (standard laboratory conditions). Solutions with a pH value below 7.0 are considered acidic and solutions with pH value above 7.0 are basic (alkaline). As most naturally occurring organic compounds are weak protolytes, carboxylic acids and amines, pH indicators find many applications in biology and analytical chemistry. Moreover, pH indicators form one of the three main types of indicator compounds used in chemical analysis. For the quantitative analysis of metal cations, the use of complexometric indicators is preferred, whereas the third compound class, the redox indicators, are used in titrations involving a redox reaction as the basis of the analysis.

Universal indicator

A universal indicator is a pH indicator made of a solution of several compounds that exhibits several smooth colour changes over a wide range pH values to indicate the acidity or alkalinity of solutions. Although there are several commercially available universal pH indicators, most are a variation of a formula patented by Yamada in 1933. Details of this patent can be found in Chemical Abstracts. Experiments with Yamada's universal indicator are also described in the Journal of Chemical Education. A universal indicator is typically composed of water, propan-1-ol, phenolphthalein sodium salt, sodium hydroxide, methyl red, bromothymol blue monosodium salt, and thymol blue monosodium salt. The colours that indicate the pH of a solution, after adding a universal indicator.

Double indicators

The method involves two indicator (Indicators are substances that change their colour when a reaction is complete) phenolphthalein and methyl orange. This is a titration of specific compounds.

Mixed indicator

Color-change indicator for acid-base titration end points in which a mixture of two indicator substances is used to give sharper end-point color changes.

Radioactive indicator

By use of suitable radioactive isotopes biochemical processes can be observed in plants, animals and humans, by measuring radioactive radiation of radioactive indicator. Artificial radioactive isotopes have the same chemical properties as natural ones, which enable us to mark those natural isotopes with addition of artificial ones and in this way follow the path of those elements during a chemical reaction. One of the most important radioactive indicators is the radioactive carbon ^{14}C.

CONCLUSION

A substance that changes color of the solution in response to a chemical change. Phenolphthalein indicator used in acid-base titration. A drop of indicator is added in the start of the titration, the endpoint has been appeared when color of the solution is changes. Redox indicators are also used which undergo change in color at specific electrode potential. Different indicators are used but depend on the strength of an acid and alkali. Universal indicators are not used for titration because they give different color at different pH. Methyl orange or phenolphthalein are mainly used they cause change in color at neutralization which is easier to see the end point of titration. The most important property of an indicator is pH range which is depend upon the strength of an indicator.

REFERENCES

Jackson, M.L.; P. Barak (2005). Soil Chemical Analysis: Advanced Course. UW-Madison Libraries Parallel Press. pp. 305–309. ISBN 1-893311-47-3

Patnaik, P. (2004). Dean's Analytical Chemistry Handbook (2 ed.). McGraw-Hill Prof Med/Tech. pp. 2.11–2.16. ISBN 0-07-141060-0

Whitney, W.D.; Smith, B.E. (1911). “Titrimetry”. The Century Dictionary and Cyclopedia. The Century Co. p. 6504.