PLANT EXTRACTS AS NATURAL INDICATORS IN ACID-BASE TITRATIONS

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Abstract

The analytical potential of the flower extracts is very promising as seen in itsapplication in acid-base titrimetry. Seven plant extracts from Violet cabbage, Beetroot, Red Hibiscus flower (shoe flower), Turmeric powder, Red rose flower, Henna Leaves and pink Mirabilis Jalapa flower (4 o'clock flower) were found to perform well in strong acid-strong base titrations. A sharp and clear colour change was observed from light pink to violet for Violet cabbage;dark brown to red for beetroot and pale yellow to pink for Red Hibiscus flower extract. The sharp contrast between their colours in acid and base made the pigment suitable foruse as acid-base indicators. Out of the seven extracts, three were in good agreement with the titre values obtained using phenolphthalein indicator. These flower extracts have a very simple, inexpensive, environmentally friendly extraction procedure and excellent performance with sharp colour changes at the end points of the titration, which could replace the standard indicators being used in conventional laboratories with natural flower indicators.

Keywords: natural indicators, titrations, synthetic indicators, plant extract, titrations, pH range

1. INTRODUCTION

In spite of the numerous instrumental techniques currently available for the chemical analyses of various samples, conventional methods of analyses are still relevant and find application in many situations. In titrimetry, the equivalence point is determined by the end point in the titration is usually indicated by some substances added into the analytic solution, which change colour immediately after the equivalence point has been attained. Several types of indicators are available for different types of titrimetric analyses.

Most indicators are synthesised from chemical reactions, but some indicators can be easily extracted from plant materials e.g. red cabbage, beetroot, blackcurrant and black bean using water or an organic solvent. Today synthetic indicators are the choice of acid-base titrations. Due to environmental pollution, availability and cost, natural compounds began to be investigated as acid-base indicators.

Some of the organic compounds i.e. flavonoids, flavonols, acylated flavonoids, anthocyanins, quinines, imines, polymethines, naphthaquinone, anthraquinonoids, indigoids, carotene etc. imparts colours to the flower. Flavonoids are coloured compounds that can be isolated from various parts of plants like flowers, fruits and are pH sensitive and give different colours in acidic and basic conditions. The equivalent points obtained from the fruit extract matched the equivalent points derived from standard indicators. Thus, it was hypothesized that the plant extract might be utilized as an indicator for acid-base titrations..

Earlier studies done on the synthetic indicators like phenolphthalein, methyl orange helped to identify their toxic and hazardous effects. Moreover, they also possess disadvantages like availability problems and high cost. In this study, we aimed to find a suitable alternative to synthetic indicators and to introduce the practice of using flower pigments as indicators in neutralization titrations.

Objectives of the study are:

- To extract coloured compounds from Violet cabbage, Beetroot, Red Hibiscus flower (shoe flower), Turmeric powder, Red rose flower, Henna Leaves and pink Mirabilis jalapa (4 o'clock flower)
- To investigate the change in colour of plant extracts with pH
- To investigate the use of plant extracts as acid-base indicators
- To compare the indicator property of these plant extracts with synthetic acid-base indicators.

2. Materials and Methods

Extraction of plant pigments

To extract the plant pigment from plant parts, two different procedures were used. The aqueous extracts of Violet Cabbage, Beetroot, Turmeric and Henna were prepared by the procedure given below.

A. Procedure:

The plant parts were washed thoroughly with distilled water. Plant materials were cut into small pieces. A measured amount of materials was placed in a beaker and added 30 cm^3 of distilled water. Using a hotplate the materials were boiled for 10 minutes. Stirred the materials occasionally while they were being heated. After cooling down, the plant extracts were obtained by filtration. The pigments of flowers Hibiscus rosa sinensis, Rose, and Four o'clock were extracted using the procedure given below using alcohol as the solvent.

B. Procedure:

The flower petals were washed thoroughly with distilled water. Flowers were cut into small pieces. A measured amount of materials were placed in a beaker and added 30 cm^3 of 90% alcohol and kept for 10 minutes with occasional stirring. The alcoholic extracts were obtained by filtration.

Test for variation in the colour of the pigment as a function of pH

Procedure:

0.1M solutions of varying pH from 1-13 were prepared . Measured and recorded the pH value of the solutions using pH meter. Labeled 6 clean test tubes with the pH values of the solution. Each tube was filled one-third full with the corresponding known pH solution. Added approximately 1 cm^3 of the plant extract to each test tube and mixed the solution. The colors of the plant extract under different pH conditions were recorded. The experiment was repeated with all plant extracts.

Table.1. Solutions and their pH

Sl. No	Solutions (0.1M)	pH
	Con. HCl	1.26
	Vinegar	2.4
	Water	7
	$NaHCO_3$	8.4
	NH_4OH	10.09
	NaOH	13

Acid- base indicator property - Titrations

Procedure:

0.1N solutions of HCl, NaOH, and $NaHCO_3$ were prepared. 20 ml NaOH was pipetted out into a clean conical flask. 5 drops of the plant extract was added and the colour noted. Titration was carried out using 0.1N HCl from the burette. The volume of HCl corresponding to the end point was noted. The experiment was repeated three times. The same experiment was conducted using phenolphthalein as the indicator.

3. RESULT AND DISCUSSION

Indicators are dyes or pigments that are isolated from a variety of sources, including plants, fungi, and algae. The use of natural dyes as acid–base indicators was first reported in 1664 by Sir Robert Boyle in his collection of essays *Experimental History of Colours*. Acid - base indicators are large organic molecules that behave as weak acids - they can donate hydrogen ions to water molecules to form their conjugate bases (Equation 1). The distinguishing characteristic of indicators is that the acid (HIn) and conjugate base (In^-) are different colours.

$$HIn\ (aq) + H_2O\ (l) \longleftrightarrow In^{-}(aq) + H_3O^{+}(aq) \quad \textit{(Equation 1)}$$

(Colour A) (Colour B)

The abbreviation HIn represents an uncharged indicator molecule, and In^{-} an indicator ion after it has lost a hydrogen ion. The colour changes of acid - base indicators illustrate an application of reversible reactions and equilibrium. Because indicators are weak acids, the reactions summarized in Equation 1 are reversible. Reversible reactions are easily forced to go in either direction, depending on reaction conditions. The actual colour of an indicator solution thus reflects the position of equilibrium for Equation 1 and depends on the concentration of $H3O^{+}$ ions (and hence the pH) of the solution.

There are three possible cases. (1) Most of the indicator molecules exist in the form HIn and the colour of the solution is essentially the colour of HIn. (2) Most of the indicator molecules exist in the form In^{-} and the colour of the solution is essentially the colour of In^{-}. (3) The solution contains roughly equal amounts of the two forms and the resulting colour is intermediate between that of HIn and In^{-}. The exact concentrations of H_3O^{+} at which cases 1 - 3 will predominate depend on the structure of the indicator and the equilibrium constant for Equation 1. Different indicators change colour in different pH ranges. Natural indicator solutions are obtained through a process called extraction by treating flowers and fruits with a suitable solvent, such as boiling water, ethyl alcohol, chloroform. The colour of an acid - base indicator depends on the concentration of H_3O^{+} ions, which is most conveniently expressed using the pH scale. The mathematical relationship between pH and $[H_3O^{+}]$ is given in Equation 2.

$$pH = -\log[H_3O^{+}] \quad \textit{(Equation 2)}$$

The H_3O^{+} concentration in water ranges from 1 M in 1 M hydrochloric acid to 10^{-14} M in 1 M sodium hydroxide. In pure water, which is neutral (neither acidic nor basic), the H_3O^{+} concentration is equal to 10^{-7} M. Thus, the negative logarithms (Equation 2) of typical H_3O^{+}concentrations are positive numbers from 0 - 14. The pH scale ranges from 0 - 14, with 7 being neutral. Acids have pH values less than 7, while bases have pH values greater than 7. Within the pH range of acid solutions, either a more concentrated or a strong acid solution will have a lower pH than a less concentrated or a weak acid solution, respectively.

pH of the plant extracts

After the preparation of extracts, pH of these pure extracts was measured using a pH meter. The pH values indicate that except henna leaf extracts all other extracts are almost neutral. Henna leaf extract shows lowest pH value and indicates that it is acidic in nature. Violet cabbage extract recorded maximum pH value and shows some alkaline nature.

Table.2. pH of plant extracts

Sl. No.	Extract	pH
1	Violet Cabbage	7.38
2	Beetroot	6.54
3	Turmeric powder	5.19
4	Red Rose flower	5.06
5	Mirabilis jalapa flower (red)	5.30
6	Henna leaves	3.96
7	Red Hibiscus flower	6.60

Investigation of indicator colour change with pH

In order to study the colour change of the plant pigment with pH, six solutions of different pH were taken and 0.1ml of the extract was added and the colour change was recorded.

Table.3. Indicator colour change with pH

No	Plant material	pH	1.3	2.4	7.0	8.4	10.1	13
1	Violet Cabbage		Crimson Red	Light pink	Violet	Prussian Blue	Pale Green	Golden Yellow
2	Beet root		Blood Red	Red	Red	Magenta	Dull green	Pale Green
3	Turmeric		Violet	Fluorescent yellow	Fluorescent yellow	Orange	Dark orange	Dark orange
4	Henna	Colour	Light Green	Dull Green	Orange	Bright Orange	Light Brown	Brown
5	Hibiscus flower		Dark pink	Light pink	Violet	Light violet	Pale yellow	Pale yellow
6	Rose flower		Orange	Pink	Colourless	Dull green	Yellow	Light Yellow
7	Four o'clock flower		Violet	Violet	Violet	Pale Green	Pale Green	Pale Green

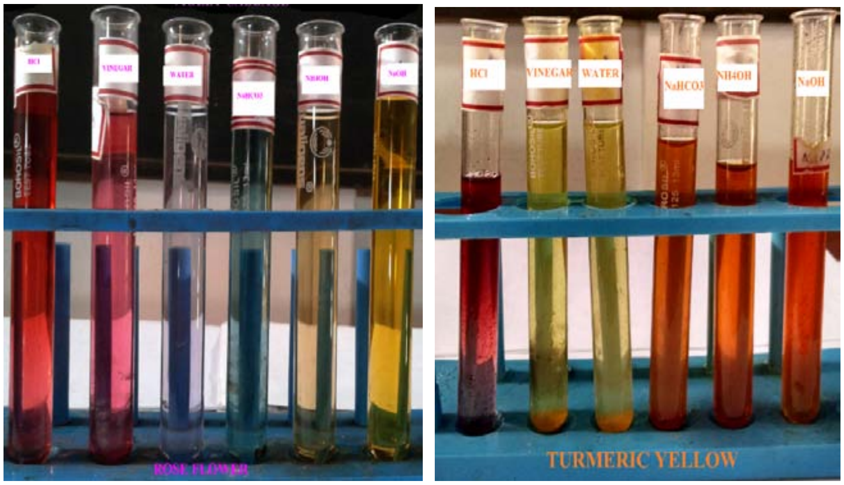

Fig.1. Rose Flower and Turmeric Yellow

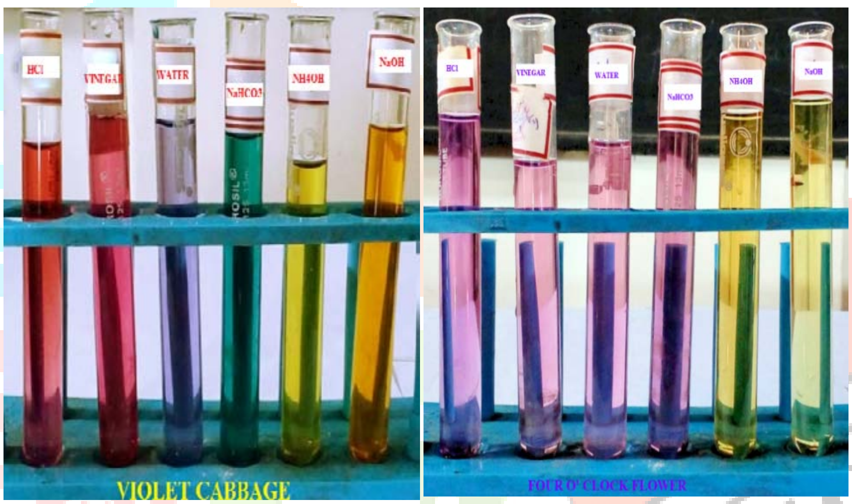

Fig.2. Violet cabbage and 4 O'clock flower

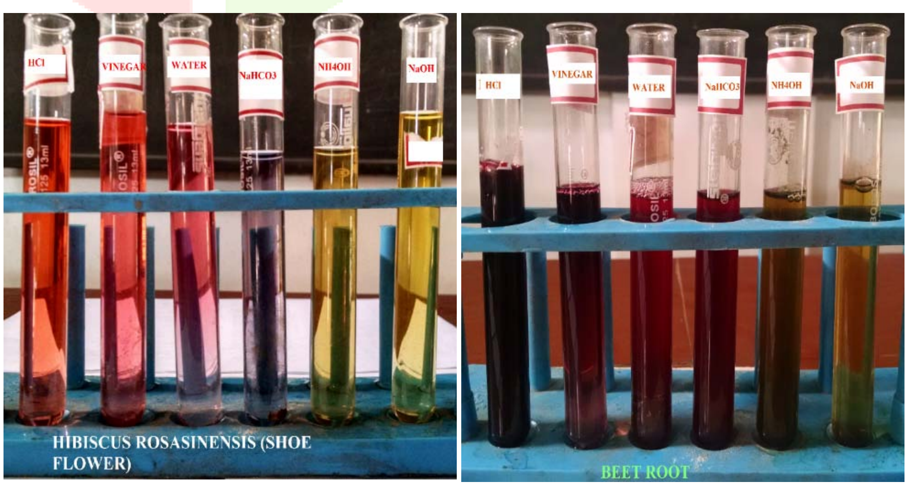

Fig.3. Shoe Flower and Beet Root

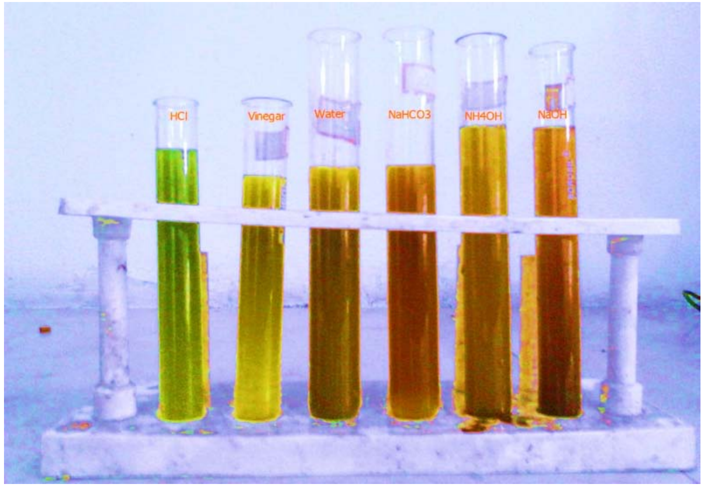

Fig.4. Henna leaf extract

TITRATIONS

In order to evaluate the potential for the use of the dyes as indicators in acid-base titrimetry, a number of demonstrated titrations were conducted. The end points of the demonstrated titrations using 2 to 3 drops of the dyes are reported in Table 4. The end points of the demonstrated acid-base titrations using commercially available indicators are also reported in the table.

The results of the experiments for strong acid strong base (HCl and NaOH) are tabulated below:

a) Titration of a strong acid (HCl) against strong base (NaOH)

Table. 4. Indicator end points

Volume of HCl using phenolphthalein indicator: 10.7ml

No.	Plant extract	Colour of the extract in base	Colour of the extract at the end point	Volume of HCl(ml)
1	Violet cabbage	Light pink	Violet	10.8
2	Beet Root	Dark Brown	Red	10.2
3	Hibiscus	Pale yellow	Pink	11
4	Henna	Brown	Light green	13.1
5	Four o'clock flower	Pale yellow	Dull pink	7.1
6	Turmeric	Golden Yellow	Pale yellow	9
7	Rose	Dark brown	Dull brown	18.3

The violet cabbage, Hibiscus and Beet root extract had similar titre value with phenolphthalein and therefore can as well replace the commercial indicators. The colour changed from light pink to violet in the case of aqueous extract of violet cabbage, pale yellow to pink in the case of alcoholic floral extract of Hibiscus Rosa sinensis and dark brown to red in the case of beet root. The equivalence point of the titrations using the plant extract almost reached close to the equivalence point using the standard indicator, phenolphthalein for all the titrations. The results obtained showed that the routinely used chemical indicator can be replaced successfully by violet cabbage, Hibiscus and Beet root extracts. Henna extract, turmeric yellow, Four o'clock flower, Rose extracts were not in agreement with the end points obtained with other. This observation suggests that these extracts cannot serve as a suitable indicator in acid/base titrations.

Indicators should be chosen in such a way that the pH at equivalence point lies within the pH range of indicator. For a titration between a strong alkali and a weak acid, the pH at equivalence point is below 7, so the pH range of the indicator should below 7 to give a sharp colour change at end-point.

4. CONCLUSION

In the present study, the results showed that the dye extracts have excellent analytical potential, as demonstrated by its application in acid-base titrimetry in which it performed best in strong acid-strong base titration with a sharp and clear colour change. The sharp contrast between their colours in acid and base made the pigment suitable for use as acid-base indicators. Out of the seven plant extracts prepared, violet cabbage, Hibiscus, Beet root extracts can serve as suitable indicators in acid-base titrimetry involving a strong acid and a strong base. These plant materials are readily available and the extraction procedure is simple, with excellent performance, precise and accurate results, making them an ideal replacement for presently available synthetic indicators. Thus, the use of natural indicator in acid base titration is more beneficial because of its economy, easy to prepare, simplicity, easy availability, pollution free, inert and accurate results.

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