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RESEARCH ARTICLE

Natural indicator for acid base titration from ethnobotanical resources of Tripura, India using green chemistry principles

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Abstract

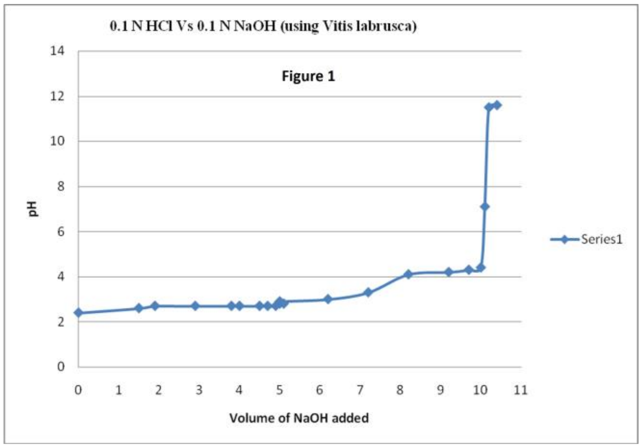
There are several plants, insects which give us certain organic compounds that possess extended conjugated systems of alternating single and multiple bonds, which allow for the absorption of visible light, hence give us coloured compounds that can be used as pigments, bio-colours, or natural indicators. Natural Indicators can be cost-effective, environment friendly, and have excellent performance with sharp colour change in end points of the acid base titrations, which can work as an alternative of synthetic indicator. In a titration at the end point conjugated systems changes and accordingly the absorption of visible light changes, hence the colour changes. For sustainable development, a list of suggestion based on Green Chemistry principles should be referred and one of them is natural Indicators. In the present research the plant-part extract of medicinally active plant species *Vitis labrusca, Artocarpus heterophyllus, Basella alba, Punica granatum, Beta vulgaris, Curcuma longa, Terminalia chebula* and *Areca catechu* have been experimentally found to be an alternative of phenopthalein and methyl orange for acid-base titration. These indicators are produced by the method of extraction using 100% distilled methanol. The extract was tested in solution with pH 1-12 and used as an indicator to identify the solutions and titration in acid-base topic. The study came to the conclusion that *Vitis labrusca, Artocarpus heterophyllus, Basella alba, Punica granatum, Beta vulgaris, Curcuma longa, Terminalia chebula* and *Areca catechu* could serve as an alternate source material for acid base indicators. The uses suggest an effort to have implemented the principles of green chemistry, including the prevention of the formation of hazardous wastes, the design of safe chemical products, the use of renewable materials, the design of materials that are easily degraded, and the use of safe solvents.

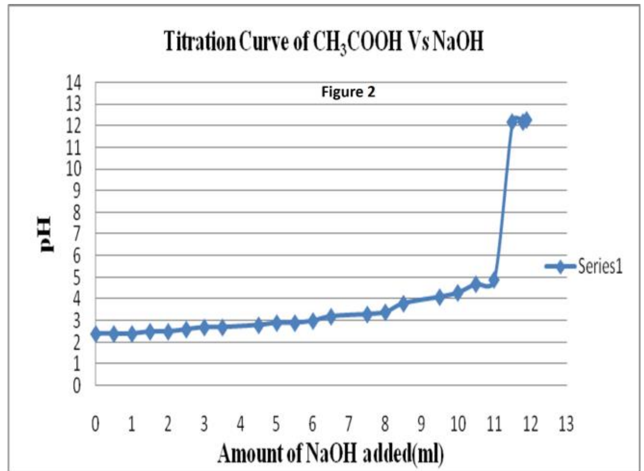
Keywords: Natural Indicator; Plant Source; Synthetic Indicator; Acid-Base Titration; End Point.

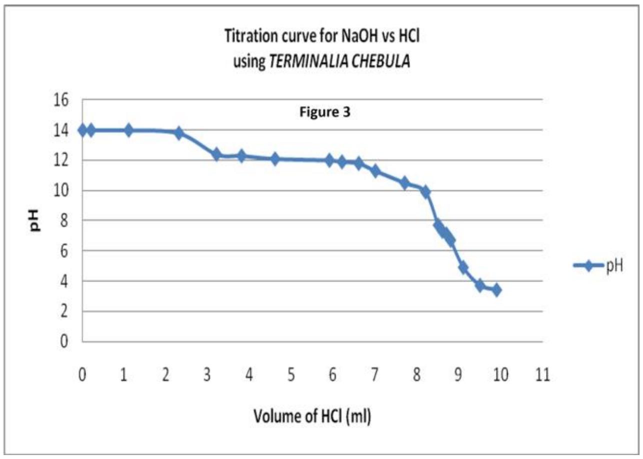
1. Introduction

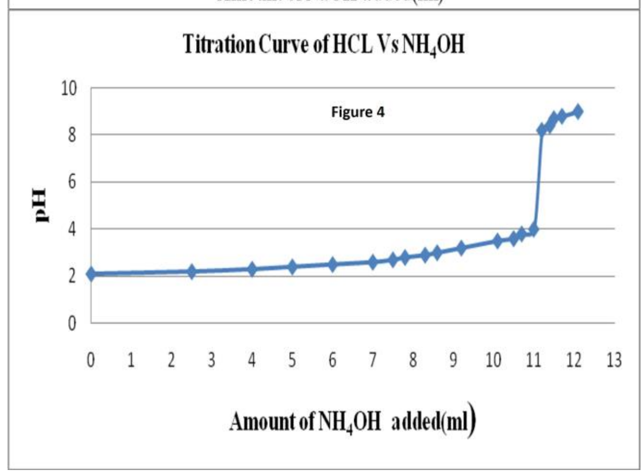
North East India is a treasure trove of ethno-plants that have been intimately intertwined with the lives and traditions of its indigenous communities for centuries. Its geographical isolation, nestled between the mighty Himalayas and the Bay of Bengal, has given rise to unique ecosystems and fostered the evolution of countless plant species with diverse medicinal, nutritional, ritualistic, and economic values. Medicinal properties of ethno-plants have been the subject of particular interest in recent times (Riaz et al., 2020). Beyond their medicinal applications, ethno-plants also hold significant economic value for the local communities. Many of these plants serve as a vital source of livelihood, either through trade or as an essential component of local handicrafts and traditional industries. The ethnobotanical species of North East India play a significant role in promoting sustainable development in the region (Das et al., 2024). Sustainable development aims to meet the needs of the present without compromising the ability of future generations to meet their own needs. The rich biodiversity and traditional knowledge associated with ethnobotanical species contribute to various aspects of sustainable development, including environmental conservation, economic growth, cultural preservation, and community empowerment (Kumar et al., 2021). The use of ethnobotanical species of North East India as indicators for acid-base titrations can have implications for sustainable development in the region. While synthetic indicators are more commonly used for the precision, incorporating ethnobotanicals as natural indicators can align with sustainable development principles. Ethnobotanicals are natural resources that are locally available and do not require extensive chemical synthesis or processing (Joeime et al., 2024). By using plant-based indicators, the reliance on synthetic chemicals can be reduced, leading to an eco-friendlier approach to acid- base titrations. There are particular synthetic indicators for acid-base titration, e.g. phenolphthalein, methyl orange, methyl red etc. The coloured plant ingredients have incredible potential for creating new indicator for acid base titration (Sashikala et al., 2023).

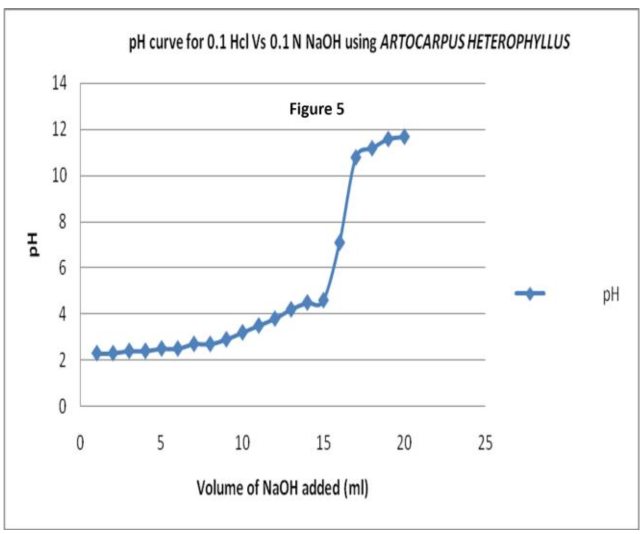
The plant selected for the current study are *Vitis labrusca, Artocarpus heterophyllus, Basella alba, Punica granatum, Beta vulgaris, Curcuma longa, Areca catechu and Terminalia chebula*, grown in Tripura, India. These plants and their parts were duly identified by the botanical experts and thereafter they were











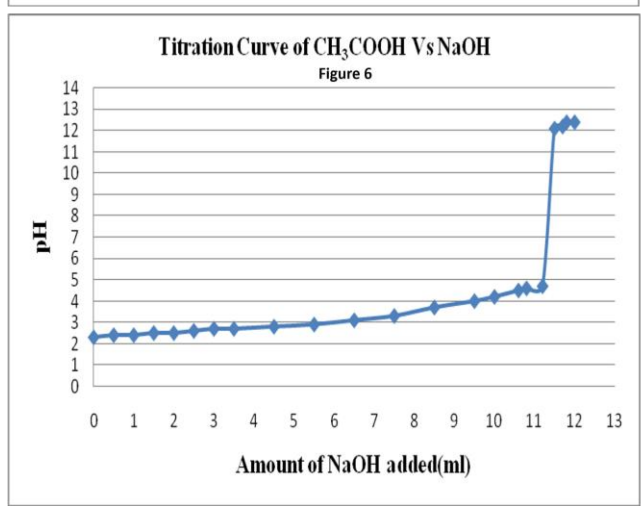
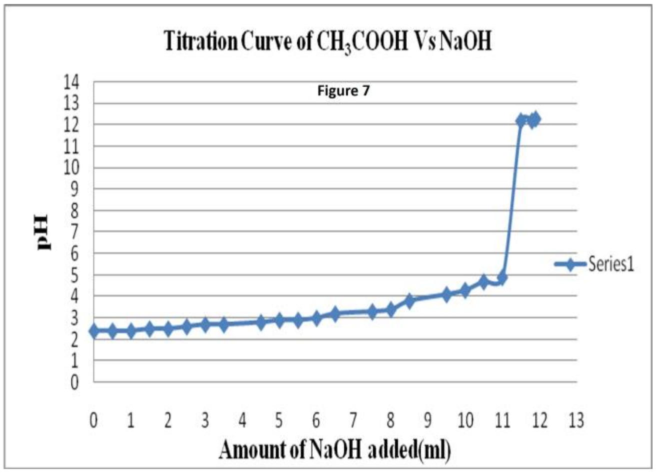
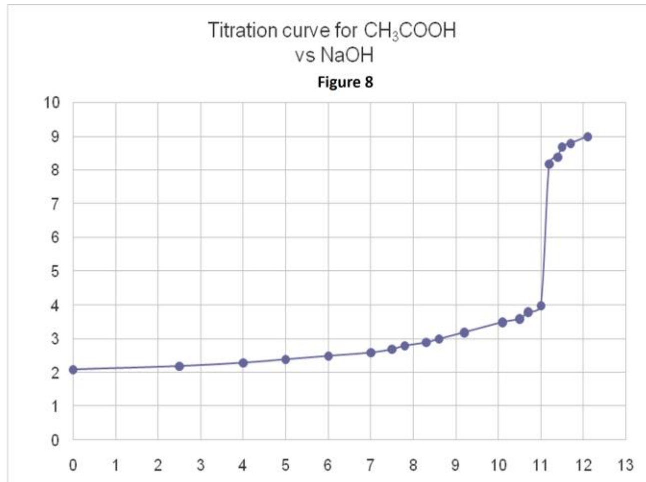


Figure 1. Titration curves for 0.1N HCL Vs 0.1N NaOH for the indicator *Vitis labrusca*.; **Figure 2.** Titration Curve of 0.1N HCl Vs 0.1N NaOH for the indicator Punica Granatum.; **Figure 3.** Titration Curve of 0.1N NaOH Vs 0.1N HCl for the indicator *Terminalia chebula;* **Figure 4.** Titration Curve of 0.1N HCL Vs 0.1N NH_4OH for the indicator *Vitis Labrusca;* **Figure 5.** Titration Curve of 0.1N HCl Vs 0.1N NH_4OH for the indicator Artocarpus heterophyllus; **Figure 6.** Titration Curve of 0.1N CH_3COOH Vs 0.1N NaOH for the indicator *Vitis Labrusca*.

subjected for thorough studies to check their suitability as the alternative of synthetic indicator in acid-base titration. *Vitis labrusca* is a species of grapevines belonging to the *Vitis* genus in the flowering plant family Vitaceae having red or black in coloured grape (Jancis Robinson, 2006). The leaves are used in the treatment of diarrhoea, hepatitis, stomach aches, fevers, headaches and thrush (Foster and Duke, 1990).





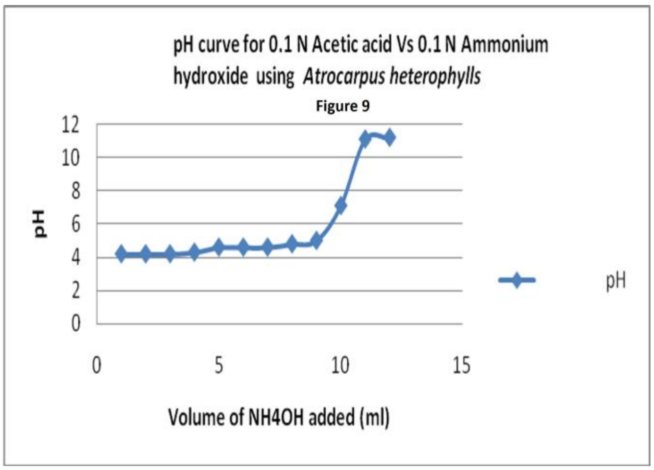


Figure 7. Titration Curve of 0.1N CH_3COOH Vs 0.1N NaOH for the indicator *Punica granatum;* **Figure 8.** Titration Curve of 0.1N CH_3COOH Vs 0.1N NaOH for the indicator *Beta vulgaris;* **Figure 9.** Titration Curve of 0.1N CH_3COOH Vs 0.1N NH_4OH for the indicator *Artocarpus heterophyllus.*

Artocarpus heterophyllus is a medium sized evergreen tree (8-25 m tall), branching near the base. Its fruit is covered with minute hairs, crown dome / pyramidal –shaped and exudes a white gummy latex when damaged or cut. Its origin is Bangladesh, India, Malaysia and used for Food, fodder, medicine, shade and ornament (Moerman, 1998). *Basella alba* (Basellaceae) is an edible perennial vine in and it is widely used as a leaf vegetable. It is a fast-growing, soft-stemmed vine, reaching 10 m (33 ft) in length. To treat boils and scores, its leaves paste is applied externally *Punica granatum* (Pomegranate) is a small tree (Shrub) and mainly found in Iran, the Himalayas in northern India, China, USA and throughout the Mediterranean region and also found in Northeast India, in Tripura (Hamid et al., 2012). Beetroot (*Beta vulgaris* subsp.) is an annual or biennial cultivated form with wound healing properties (Huarote et al., 2020). Beetroot can also be a good natural alternative to synthetic indicators and can be used for detecting pH of various solutions as pH indicator strips. As the fresh beetroot indicator developed microbial growth within few days, beetroot powder extracted from beetroot and can be stored for later use indicator (Mirmiran et al., 2020). *Curcuma longa* (Zingiberaceae) has rhizomes growing underground. The rhizomes is used since thousands of years as a remedy of a large variety of illnesses, such as inflammation, infectious diseases, and gastric, hepatic, and blood disorders in the traditional Indian and folk medicine (Kanad et al., 2020). Powdered lime and turmeric were utilized as the natural base and indicator, respectively (Kaana et al., 2022). Turmeric is also used as a natural indicator because turmeric changes its colour in the presence or absence of an acid or base. The active ingredient present in turmeric is curcumin as an acid-base indicator that is yellow in acidic and neutral solutions and orange or reddish-brown in basic solutions (Sam-ang et al., 2018). *Areca catechu* L., also named betel palm or betel nut, is used for treatment of diarrhea, dropsy, sunstroke, beri beri, throat inflammations, edema, lumbago, bronchial catarrh, and urinary disorders (Patil et al., 2018). *Areca catechu* seed extract as an efficacious indicator for various acid-base titrations (Cecile et al., 2011). *Terminalia chebula* has antimicrobial property and long-lasting antioxidant protection and reverses visible signs of pollution-induced skin damage (Narasimha et al., 2020).

2. Materials and methods

2.1. Reagents and materials used

Solvents were used of analytical grade. The pH meter of ELICO (Model: LI 613) and borosil made glass apparatus were used. Selected plant parts of *Vitis labrusca, Artocarpus heterophyllus, Basella alba, Punica granatum, Beta vulgaris, Curcuma longa* (rhizome), *Areca catechu* (nut) and *Terminalia chebula* were subjected for extraction by using Soxhlet apparatus by taking dried and crushed powder of plant ingredients of 200 gm in 200 ml of methanol and acetone separately. The pH of all extracts in room temperature including solvents was found out in pH meter and is presented in Table 1. The colour of concentrated extracts in naked eyes is also recorded in Table 1.

2.2. Study of colour change with change of pH

The colour change for all the extracts as described in Table 1 were individually studied with the change of pH. To change the pH, 0.1N HCl for acidic extract and 0.1N NaOH solution for basic extract were used. The colour change of individual extract as when taken place on addition of HCl or NaOH, that particular pH was recorded and the colour was also noted accordingly in Table 2.

2.3. Titration by using synthetic and natural indicator

0.1N solution of acids and bases were used to perform the different types of titrations using synthetic indicator solution and natural indicator extracts and so, end points were determined in every case by using pH meter. Synthetic standard acid-base indicators e.g. Phenolpthalein, Methyl orange was taken for further studies and were compared with the natural indicators. Acid-Base titrations were carried out by selecting the acid and base as: (a) Strong acid (0.1N HCl) Vs Strong base (0.1N NaOH), (b) Strong acid (0.1N HCl) Vs Weak base (0.1N NH_4OH), (c) Weak base (0.1N NH_4OH) Vs Strong acid (0.1N HCl), (d) Weak acid (0.1N CH_3COOH) Vs Weak base (0.1N NH_4OH) by taking titrant/Analyte (0.1 N) 10 ml in a conical flask and titrant was dropped from a burette till the end

Table 1. pH of the extracts and colour

SN	Extracts of plant parts	pH	Colour
1	Acetonic *Vitis labrusca*	5.6	Violet
2	Methanolic *Vitis labrusca*	6.1	Violet
3	Acetonic *Artocarpus heterophyllus*	7.2	Lemon green
4	Methanolic *Artocarpus heterophyllus*	6.9	Lemon green
5	Acetonic *Basella alba*	5.9	Palm red
6	Methanolic *Basella alba*	6.4	Palm red
7	Acetonic *Punica granatum*	5.9	Pink
8	Methanolic *Punica granatum*	6.3	Light pink
9	Acetonic *Beta vulgaris*	5.77	Deep pink
10	Methanolic *Beta vulgaris*	6.17	Pink
11	Acetonic *Curcuma longa*	7.39	Orange
12	Methanolic *Curcuma longa*	6.26	Orange
13	Acetonic *Areca catechu*	5.65	Light brown
14	Methanolic *Areca catechu*	6.35	Light brown
15	Acetonic *Terminalia chebula*	5.4	Wine red
16	Methanolic *Terminalia chebula*	4.8	Wine red

pH of solvent methanol = 7.4, pH of solvent Acetone = 7.0.

point and volume consumed was recorded in every cases. Experiments for each set were carried out thrice and average values are presented in Table 3 (for Standard Indicator) and Table 4 (for Natural Indicator).

3. Results and discussion

In our work we have taken the extracts of different parts of *Vitis labrusca, Artocarpus heterophyllus, Basella alba, Punica granatum, Beta vulgaris, Curcuma longa, Terminalia chebula* and *Areca catechu* to test their eligibility to be used as natural indicator for acid-base volumetric titration. Natural colours are showing different colours in acid and base solutions. The distinguished colour changes were also recorded with the minute changes of pH, as tabulated in the Table 3 and 4. The average volume of titrant consumed in end point was found almost same in both the cases of synthetic and natural indicators, and no significant differences were observed. In drawing of titration curve (pH in y axis and volume of titrant in x-axis) it was found that the presence of natural and synthetic indicators, both were not able to disturb the titration curve and both were capable to show same pattern of titration curve for all categorised pair of titrand – titrant; i.e. Strong acid (0.1N HCl) Vs Strong base (0.1N NaOH) titration (Figure 1, 2, 3), Strong acid (0.1N HCL) Vs Weak base (0.1N NH_4OH) titration (Figure 4, 5), Weak acid (0.1N CH_3COOH) Vs Strong base (0.1N NaOH) titration (Figure 6, 7, 8), Weak acid (0.1N CH_3COOH)Vs Weak base (0.1N NH_4OH) titration (Figure 9) (Jeffery et al., 1989).

4. Conclusion

From the present study, it can be concluded that the extracts of parts of all these plants were P^H sensitive and showed change of colour in acidic and as well as in alkaline medium; and able to detect end point in all type of acid-base titration. Therefore, in the present research work, the plant-part extract of medicinally active plants *Vitis labrusca, Artocarpus heterophyllus, Basella alba, Punica granatum, Beta vulgaris, Curcuma longa, Terminalia chebula and Areca catechu* have been experimentally found to be an alternative of phenopthalein and methyl orange for acid-base titration.

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Authors contribution
Swarnali Nath Choudhury: Conceptualization, Formal analysis, methodology, Recources Software, Writing – original draft, Writing – review and editing; Biplab De: Conceptualization, methodology, Resources, methodology, Supervision, Writing – original draft; Dwaipayan Banik: Software, Writing – original draft; Subrata Das: Software, Writing – original draft; Akash Datta, Barnana Chakraborty, Susmita Pal, Ajay Mili, Mary Naksang and Anu Ronya: Writing – original draft; All authors have read and agreed to the published version of the manuscript.

Declaration of conflict of interest
The authors declare no conflict of interest.

Table 2. Colour change of Concentrated extracted with pH change.

SN	Natural Product	Observation of colour change and recording of pH						
1.	Acetonic *Vitis labrusca*	pH	5.6	5.9	7.7	8.3	8.7	9.7
		Colour	Light Violet	Violet	Deep violet	Green	Deep Green	Violet
2	Methanolic *Vitis labrusca*	pH	6.1	6.4	8.0	8.3	8.7	9.7
		Colour	Light Violet	Violet	Deep Violet	Green	Deep Green	Violet
3.	Acetonic *Artocarpus heterophyllus*	pH	7.2	8.2	9.2	10.2	11.2	13.2
		Colour	Lemon Green	Lemon Green (Deep)	Lemon yellow (Light)	Lemon yellow	Lemon yellow (Deep)	Lemon yellow (More deep)
4	Methanolic *Artocarpas heterophyllus*	pH	6.9	8.2	9.2	10.2	11.2	13.2
		Colour	Lemon Green	Lemon Green (Deep)	Lemon yellow (Light)	Lemon yellow	Lemon yellow (Deep)	Lemon yellow (More deep)
5	Acetonic *Basella alba*	pH	5.9	5.4	4.8	3.7	3.2	2.9
		Colour	Palm red (Light)	Palm red	Palm red (Deep)	Palm red (More deep)	Blackish Palm red	Black
6	Methanolic *Basella alba*	pH	6.4	5.9	5.3	4.2	3.7	3.4
		Colour	Palm red (Light)	Palm red	Palm red (Deep)	Palm red (More deep)	Blackish Palm red	Black
7	Acetonic *Punica granatum*	pH	5.9	6.2	6.9	7.3	7.7	8.6
		Colour	Light Pink	Pink	Deep Pink	Pink (More Deep)	Brownish Pink	Brown Yellow
8	Methanolic *Punica granatum*	pH	6.3	6.6	7.1	7.7	8.1	9.0
		Colour	Light Pink	Pink	Deep Pink	Pink (More Deep)	Brownish Pink	Brown Yellow
9	Acetonic *Beta vulgaris*	pH	5.77	6.67	7.07	7.87	8.77	11.87
		Colour	Light pink	Pink	Deep pink	More Deep pink	Violet	Reddish Yellow
10	Methanolic *Beta vulgaris*	pH	6.17	7.07	7.47	8.27	9.17	12.27
		Colour	Light pink	Pink	Deep pink	More Deep pink	Violet	Reddish Yellow
11	Acetonic *Curcuma longa*	pH	12.04	10.7	7.39	1.3	0.68	0.44
		Colour	Light Orange	Orange	Deep Orange	Light Yellow	Yellow	Deep Yellow
12	Methanolic *Curcuma longa*	pH	12.11	6.26	2.38	1.52	0.84	0.66
		Colour	Light Orange	Yellowish	More Yellowish	Light Yellow	Yellow	Deep yellow
13	Acetonic *Areca catechu*	pH	12	11.73	5.65	1.86	1.09	0.97
		Colour	Light brown	Brown	Deep brown	Yellowish	About to colourless	Colourless
14	Methanolic *Areca catechu*	pH	12.79	10.63	6.35	2.19	1.77	0.76
		Colour	Light brown	Brown	Deep brown	Yellowish	About to colourless	Colourless
15	Acetonic *Terminalia chebula*	pH	5.4	5.6	6.0	7.0	8.0	8.8
		Colour	Wine red	Yellowish Green	yellow	Reddish Yellow	Wine red	Brown Red
16	Methanolic *Terminalia chebula*	pH	4.8	5.6	6.0	7.0	8.0	8.8
		Colour	Wine red	Yellowish Green	yellow	Reddish Yellow	Wine red	Brown Red

Table 3. Recording of titrant volume in end point by using standard indicator.

Titration Set	Titrand (10 ml taken)	Name of Standard Indicator	Colour Change in end point	Titrant dropped from burette	Titrant volume (concurrent reading) in ml at end point
1	0.1 N HCl	Phenolphthalein	Light pink	0.1 N NaOH	10.1
2	0.1 N NaOH	Methyl Orange	Yellowish light red	0.1 N HCl	9.9
3	0.1 N HCl	Phenolphthalein	Light pink	0.1N NH_4OH	13.1
4	0.1N NH_4OH	Methyl Orange	Yellowish light red	0.1 N HCl	14.8
5	0.1N CH_3COOH	Phenolphthalein	Light pink	0.1N NaOH	10.8
6	0.1N NaOH	Methyl Orange	Yellowish light red	0.1N CH_3COOH	10.2
7	0.1N CH_3COOH	Phenolphthalein	Light pink	0.1N NH_4OH	10.3
8	0.1N NH_4OH	Methyl Orange	Yellowish light red	0.1N CH_3COOH	10.4

Table 4. Recording of titrant volume in end point by using natural indicator.

Titration Set	Titrand 10 ml (0.1N) vs titrant (0.1N) dropped	Natural Indicator extract used	Colour Change recorded till end point	end point pH	Titrant volume consumed in ml
1. i.	HCl Vs NaOH	Acetonic *Vitis labrusca*	Colourless to Pink	7.1	10.1
1. ii.	HCl Vs NaOH	Methanolic *Vitis labrusca*	Colourless to Pink	7.1	10.1
1. iii.	NaOH Vs HCl	Acetonic *Vitis labrusca*	Pink to Colourless	7.1	9.9
1. iv.	NaOH Vs HCl	Methanolic *Vitis labrusca*	Pink to Colourless	7.1	9.9
1. v.	HCl Vs NH_4OH	Acetonic *Vitis labrusca*	Colourless to Pink	5.4	11
1. vi.	HCl Vs NH_4OH	Methanolic *Vitis labrusca*	Colourless to Pink	5.4	11
1. vii.	NH_4OH Vs HCl	Acetonic *Vitis labrusca*	Pink to Colourless	5.4	12.7
1. viii.	NH_4OH Vs HCl	Methanolic *Vitis labrusca*	Pink to Colourless	5.4	12.7
1. ix.	CH_3COOH Vs NaOH	Acetonic *Vitis labrusca*	Colourless to Pink	8.7	10.9
1. x.	CH_3COOH Vs NaOH	Methanolic *Vitis labrusca*	Colourless to Pink	8.7	10.9
1. xi.	CH_3COOH Vs NH_4OH	Acetonic *Vitis labrusca*	Colourless to Pink	7.1	10.5
1. xii.	CH_3COOH Vs NH_4OH	Methanolic *Vitis labrusca*	Colourless to Pink	7.1	10.5
2. i.	HCl Vs NaOH	Acetonic *Artocarpus heterophyllus*	Beige to Lemon Green	7.1	10.2
2. ii.	HCl Vs NaOH	Methanolic *Artocarpus heterophyllus*	Beige to Lemon Green	7.1	10.1
2. iii.	NaOH Vs HCl	Acetonic *Artocarpus heterophyllus*	Lemon Green to Beige	7.1	9.8
2. iv.	NaOH Vs HCl	Methanolic *Artocarpus heterophyllus*	Lemon Green to Beige	7.1	9.9
2. v.	HCl Vs NH_4OH	Acetonic *Artocarpus heterophyllus*	Beige to Lemon Green	5.4	11.1
2. vi.	HCl Vs NH_4OH	Methanolic *Artocarpus heterophyllus*	Beige to Lemon Green	5.4	11.2
2. vii.	NH_4OH Vs HCl	Acetonic *Artocarpus heterophyllus*	Lemon Green to Beige	5.4	12.7
2. viii.	NH_4OH Vs HCl	Methanolic *Artocarpus heterophyllus*	Lemon Green to Beige	5.4	12.8
2. ix.	CH_3COOH Vs NaOH	Acetonic *Artocarpus heterophyllus*	Beige to Lemon Green	8.7	10.9
2. x.	CH_3COOH Vs NaOH	Methanolic *Artocarpus heterophyllus*	Beige to Lemon Green	8.7	10.8
2. xi.	CH_3COOH Vs NH_4OH	Acetonic *Artocarpus heterophyllus*	Beige to Lemon Green	7.1	10.5
2. xii.	CH_3COOH Vs NH_4OH	Methanolic *Artocarpus heterophyllus*	Beige to Lemon Green	7.1	10.3
3. i.	HCl Vs NaOH	Acetonic *Basella alba*	Lemon Yellow to Beige	7.1	10.1
3. ii.	HCl Vs NaOH	Methanolic *Basella alba*	Lemon Yellow to Beige	7.1	10.2
3. iii.	NaOH Vs HCl	Acetonic *Basella alba*	Beige to Lemon Yellow	7.1	10.0
3. iv.	NaOH Vs HCl	Methanolic *Basella alba*	Beige to Lemon Yellow	7.1	9.9
3. v.	HCl Vs NH_4OH	Acetonic *Basella alba*	Lemon Yellow to Beige	5.4	11.0
3. vi.	HCl Vs NH_4OH	Methanolic *Basella alba*	Lemon Yellow to Beige	5.4	11.1
3. vii.	NH_4OH Vs HCl	Acetonic *Basella alba*	Beige to Lemon Yellow	5.4	12.7
3. viii.	NH_4OH Vs HCl	Methanolic *Basella alba*	Beige to Lemon Yellow	5.4	12.6
3. ix.	CH_3COOH Vs NaOH	Acetonic *Basella alba*	Lemon Yellow to Beige	8.7	10.8
3. x.	CH_3COOH Vs NaOH	Methanolic *Basella alba*	Lemon Yellow to Beige	8.7	10.9
3. xi.	CH_3COOH Vs NH_4OH	Acetonic *Basella alba*	Lemon Yellow to Beige	7.1	10.4
3. xii.	CH_3COOH Vs NH_4OH	Methanolic *Basella alba*	Lemon Yellow to Beige	7.1	10.5
4. i.	HCl Vs NaOH	Acetonic *Punica granatum*	Colourless to Pink	7.1	10.2
4. ii.	HCl Vs NaOH	Methanolic *Punica granatum*	Colourless to Pink	7.1	10.1
4. iii.	NaOH Vs HCl	Acetonic *Punica granatum*	Pink to Colourless	7.1	9.8
4. iv.	NaOH Vs HCl	Methanolic *Punica granatum*	Pink to Colourless	7.1	9.9
4. v.	HCl Vs NH_4OH	Acetonic *Punica granatum*	Colourless to Pink	5.4	11.1
4. vi.	HCl Vs NH_4OH	Methanolic *Punica granatum*	Colourless to Pink	5.4	11.0
4. vii.	NH_4OH Vs HCl	Acetonic *Punica granatum*	Pink to Colourless	5.4	12.7
4. viii.	NH_4OH Vs HCl	Methanolic *Punica granatum*	Pink to Colourless	5.4	12.6
4. ix.	CH_3COOH Vs NaOH	Acetonic *Punica granatum*	Colourless to Pink	8.7	10.9
4. x.	CH_3COOH Vs NaOH	Methanolic *Punica granatum*	Colourless to Pink	8.7	10.9
4. xi.	CH_3COOH Vs NH_4OH	Acetonic *Punica granatum*	Colourless to Pink	7.1	10.5
4. xii.	CH_3COOH Vs NH_4OH	Methanolic *Punica granatum*	Colourless to Pink	7.1	10.4
5. i.	HCl Vs NaOH	Acetonic *Beta vulgaris*	Deep Pink to reddish yellow	7.1	10.1

5. ii.	HCl Vs NaOH	Methanolic *Beta vulgaris*	Deep Pink to reddish yellow	7.1	10.3
5. iii.	NaOH Vs HCl	Acetonic *Beta vulgaris*	reddish yellow to Deep pink	7.1	9.7
5. iv.	NaOH Vs HCl	Methanolic *Beta vulgaris*	reddish yellow to Deep pink	7.1	9.8
5. v.	HCl Vs NH_4OH	Acetonic *Beta vulgaris*	Deep Pink to reddish yellow	5.4	11.2
5. vi.	HCl Vs NH_4OH	Methanolic *Beta vulgaris*	Deep Pink to reddish yellow	5.4	10.9
5. vii.	NH_4OH Vs HCl	Acetonic *Beta vulgaris*	reddish yellow to Deep pink	5.4	12.7
5. viii.	NH_4OH Vs HCl	Methanolic *Beta vulgaris*	reddish yellow to Deep pink	5.4	12.8
5. ix.	CH_3COOH Vs NaOH	Acetonic *Beta vulgaris*	Deep Pink to reddish yellow	8.7	10.9
5. x.	CH_3COOH Vs NaOH	Methanolic *Beta vulgaris*	Deep Pink to reddish yellow	8.7	10.8
5. xi.	CH_3COOH Vs NH_4OH	Acetonic *Beta vulgaris*	Deep Pink to reddish yellow	7.1	10.5
5. xii.	CH_3COOH Vs NH_4OH	Methanolic *Beta vulgaris*	Deep Pink to reddish yellow	7.1	10.3
6. i.	HCl Vs NaOH	Acetonic *Curcuma longa*	Yellow to Orange	7.1	10.1
6. ii.	HCl Vs NaOH	Methanolic *Curcuma longa*	Yellow to Orange	7.1	10.2
6. iii.	NaOH Vs HCl	Acetonic *Curcuma longa*	Orange to Yellow	7.1	9.9
6. iv.	NaOH Vs HCl	Methanolic *Curcuma longa*	Orange to Yellow	7.1	9.9
6. v.	HCl Vs NH_4OH	Acetonic *Curcuma longa*	Yellow to Orange	5.4	11.3
6. vi.	HCl Vs NH_4OH	Methanolic *Curcuma longa*	Yellow to Orange	5.4	11.1
6. vii.	NH_4OH Vs HCl	Acetonic *Curcuma longa*	Orange to Yellow	5.4	12.7
6. viii.	NH_4OH Vs HCl	Methanolic *Curcuma longa*	Orange to Yellow	5.4	12.9
6. ix.	CH_3COOH Vs NaOH	Acetonic *Curcuma longa*	Yellow to Orange	8.7	11.0
6. x.	CH_3COOH Vs NaOH	Methanolic *Curcuma longa*	Yellow to Orange	8.7	10.9
6. xi.	CH_3COOH Vs NH_4OH	Acetonic *Curcuma longa*	Yellow to Orange	7.1	10.4
6. xii.	CH_3COOH Vs NH_4OH	Methanolic *Curcuma longa*	Yellow to Orange	7.1	10.5
7. i.	HCl Vs NaOH	Acetonic *Areca catechu*	Colourless to Light Brown	7.1	10.2
7. ii.	HCl Vs NaOH	Methanolic *Areca catechu*	Colourless to Light Brown	7.1	10.3
7. iii.	NaOH Vs HCl	Acetonic *Areca catechu*	Light Brown to Colourless	7.1	9.9
7. iv.	NaOH Vs HCl	Methanolic *Areca catechu*	Light Brown to Colourless	7.1	9.8
7. v.	HCl Vs NH_4OH	Acetonic *Areca catechu*	Colourless to Light Brown	5.4	11.1
7. vi.	HCl Vs NH_4OH	Methanolic *Areca catechu*	Colourless to Light Brown	5.4	11.2
7. vii.	NH_4OH Vs HCl	Acetonic *Areca catechu*	Light Brown to Colourless	5.4	12.8
7. viii.	NH_4OH Vs HCl	Methanolic *Areca catechu*	Light Brown to Colourless	5.4	12.6
7. ix.	CH_3COOH Vs NaOH	Acetonic *Areca catechu*	Colourless to Light Brown	8.7	10.9
7. x.	CH_3COOH Vs NaOH	Methanolic *Areca catechu*	Colourless to Light Brown	8.7	11.0
7. xi.	CH_3COOH Vs NH_4OH	Acetonic *Areca catechu*	Colourless to Light Brown	7.1	10.5
7. xii.	CH_3COOH Vs NH_4OH	Methanolic *Areca catechu*	Colourless to Light Brown	7.1	10.4
8. i.	HCl Vs NaOH	Acetonic *Terminalia chebula*	Wine Red to Yellow	7.1	10.1
8. ii.	HCl Vs NaOH	Methanolic *Terminalia chebula*	Wine Red to Yellow	7.1	10.2
8. iii.	NaOH Vs HCl	Acetonic *Terminalia chebula*	Yellow to Wine Red	7.1	9.9
8. iv.	NaOH Vs HCl	Methanolic *Terminalia chebula*	Yellow to Wine Red	7.1	9.8
8. v.	HCl Vs NH_4OH	Acetonic *Terminalia chebula*	Wine Red to Yellow	5.4	11.1
8. vi.	HCl Vs NH_4OH	Methanolic *Terminalia chebula*	Wine Red to Yellow	5.4	11.0
8. vii.	NH_4OH Vs HCl	Acetonic *Terminalia chebula*	Yellow to Wine Red	5.4	12.6
8. viii.	NH_4OH Vs HCl	Methanolic *Terminalia chebula*	Yellow to Wine Red	5.4	12.7
8. ix.	CH_3COOH Vs NaOH	Acetonic *Terminalia chebula*	Wine Red to Yellow	8.7	10.8
8. x.	CH_3COOH Vs NaOH	Methanolic *Terminalia chebula*	Wine Red to Yellow	8.7	10.7
8. xi.	CH_3COOH Vs NH_4OH	Acetonic *Terminalia chebula*	Wine Red to Yellow	7.1	10.4
8. xii.	CH_3COOH Vs NH_4OH	Methanolic *Terminalia chebula*	Wine Red to Yellow	7.1	10.3

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