RESEARCH PAPER

ORGANIC QUALITATIVE ANALYSIS EMPLOYING A MINIMALISTIC TECHNIQUE TO IDENTIFY THE TYPE AND FUNCTIONAL GROUP OF ORGANIC COMPOUNDS

By

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https://doi.org/10.26634/jchem.4.1.20939

Date Received: 29/06/2024   Date Revised: 14/07/2024   Date Accepted: 22/07/2024

ABSTRACT

This study uses a minimalistic approach to determine the type and functional group of organic compounds. Employing microscale techniques and simple, cost-effective methodologies, it aims to make organic compound identification accessible and sustainable without compromising accuracy. The focus is on commonly used qualitative tests adapted for minimal reagent use and basic laboratory equipment. This approach benefits educational settings such as schools, colleges, and research centres.

Keywords: Organic Qualitative Analysis, Organic Compounds, Type and Functional Groups.

INTRODUCTION

Organic qualitative analysis is a fundamental approach in organic chemistry that involves the identification of organic compounds through various chemical tests and techniques (Anim-Eduful & Adu-Gyamfi, 2022). These methods allow chemists to determine the type, functional groups and structure of unknown organic substances. Traditional methods used in practical chemistry sessions in academic institutions, research laboratories, and chemical industries often require substantial reagent volumes and complex apparatus. Continuous research employing newer techniques using semi-micro and micro-scale organic qualitative analysis is being explored by many researchers (Kelkar & Dhavale, 2000; Pavia et al., 1999). Our current study examines minimalistic techniques that can determine functional groups using fewer sample and reagent volumes to enhance sustainability, cost-effectiveness, and simplicity. By adapting qualitative tests to a microscale format, this approach aims to provide accurate results while reducing waste and enhancing safety.

1. Materials and Methods

1.1 Materials

1.1.1Apparatus and glasswares

- Eppendorf tubes
- Small dropper (1ml)
- Hickmann head apparatus (2ml)
- RB with 10b joint
- Condenser (length 10cm- 10b joint) with short loop water tube
- Capillaries
- Partial pipette
- Tiny copper guage
- Pair of tongs
- 10 ml beakers
- Different types of organic compounds (Acid, Phenol, Base, and neutral(SRL)).
- Standard reagents for Organic qualitative analysis (SRL).

- Microscale laboratory apparatus (micropipettes, capillaries, plastic groove plates, Eppendorf tubes, spotting ceramic tiles).

2. Methodology for Analysis

The process of organic qualitative analysis can be divided into several stages, including preliminary tests, volatility tests for liquids, checking the solubility in suitable solvents, tests for saturation and unsaturation, aliphatic and aromatic nature of the given organic compound and finally, confirmatory tests specific for various functional groups based on their type and elements (Furniss, 2011; Mayo et al., 2023; Shriner et al., 2003).

In our current study, we selected one sample from each type of organic compound, such as Acid (Benzoic acid), Phenol (β Naphthol), Base (Aniline) and Neutral (Acetone).

The general scheme for analysis followed in our current study included checking for the solubility of the organic compounds using water.

To determine the type of water-soluble organic compounds, colour change using litmus paper was used and to determine the type of insoluble organic compounds,Table 1 was followed.

Test for saturation or unsaturation in organic compounds:

The organic compounds in two Eppendorf tubes were mixed with Bromine in Carbon tetrachloride and diluted Potassium permanganate. The reagent's colour change was observed in the test samples against the colours of the original controls to determine whether the organic compoundwas saturated or unsaturated.

Test for the aliphatic or aromatic nature of the organic compounds:

A pinch of organic compound was taken on a copper gauze and heated directly on a flame to check for the sooty flame that could indicate the aromatic nature of the organic compounds and, if not, could indicate the presence of aliphatic compounds.

Based on the type and elements of each organic compound, a functional group test was performed using specific reagents to confirm the general formula of the organic compounds.

3. Results And Discussion

3.1 Solubility Test

The solubility of the four selected organic compounds such as Acid (Benzoic acid), Phenol, (β Naphthol), Base (Aniline) and neutral (Acetone) was checked and it was found that acid and phenol samples were insoluble in water, base was immiscible in water and the neutral sample was miscible in water, as shown in Figure 1.

a) Acid

b) Phenol

c) Base

d) Neutral

3.2 Type Determination of Organic Compounds

Acid and phenol types of organic samples showed reprecipitation with conc. HCl after dissolving the samples in sodium bicarbonate and sodium hydroxide, respectively. The base showed reprecipitation with sodium hydroxide after dissolving in 1:1 HCl as shown in Figure 2.

3.3 Test for Saturation and Unsaturation

3.3.1 Bromine in CCl_4 Test

The organic compound was taken in the Eppendorf tube and mixed with bromine in carbon tetrachloride. The reagent's colour change was observed in the test samples against the colours of the original control. Acid,

Test	Observation	Inference
Substance + 10% $NaHCO_3$ followed by the addition of conc. HCl	Substance dissolves on addition of 10% $NaHCO_3$ and reprecipitate on addition of conc. HCl	Acid is present
Substance + 1 ml 2 N NaOH followed by addition of conc. HCl	Substance dissolves on addition of NaOH and reprecipitate on addition of conc. HCl.	Phenol is present
Substance + 1 ml 1:1 HCl followed by the addition of 2N NaOH	Substance dissolves on addition of Hcl and reprecipitate on addition of NaOH.	Base is present
* If all the above tests are negative then the substance is neutral		

Table 1. Type determination for water-insoluble (immiscible) substances

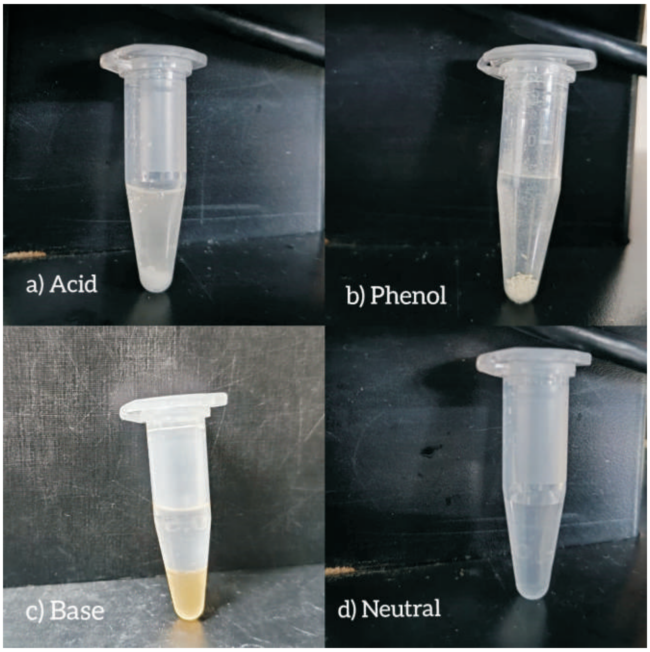

Figure 1. Solubility Test in Water

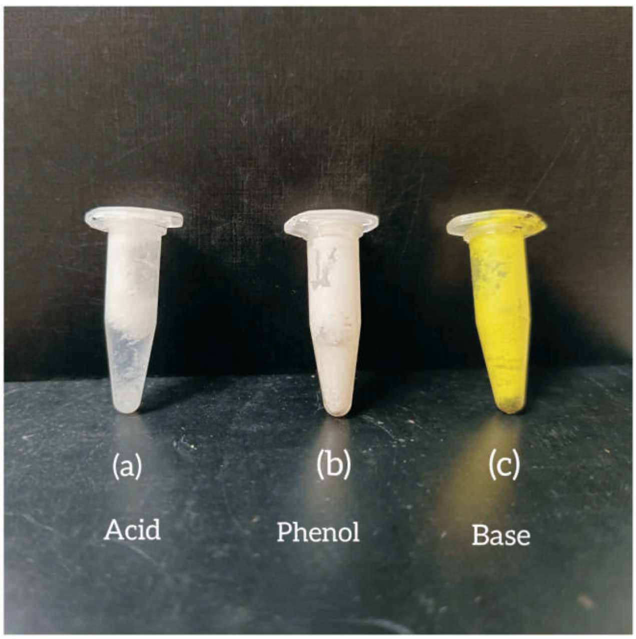

Figure 2. Type Determination

Phenol and Base did not show any decolourisation, indicating the presence of saturated compounds, as seen in Figure 3, whereas the neutral sample showed no decolourization at first but when few amount of dil HCl was added, it decolourized, indicating the presence of unsaturation, as seen in Figure 4.

3.3.2 Bayer's Test

The organic compound was taken in the Eppendorf tube and mixed with diluted solution of alkaline potassium permanganate. The reagent's colour change was observed in the test samples against the colours of the original control. Acid, Phenol and Base did not show any decolourization, indicating the presence of saturated compounds or not easily oxidizable compounds, as seen

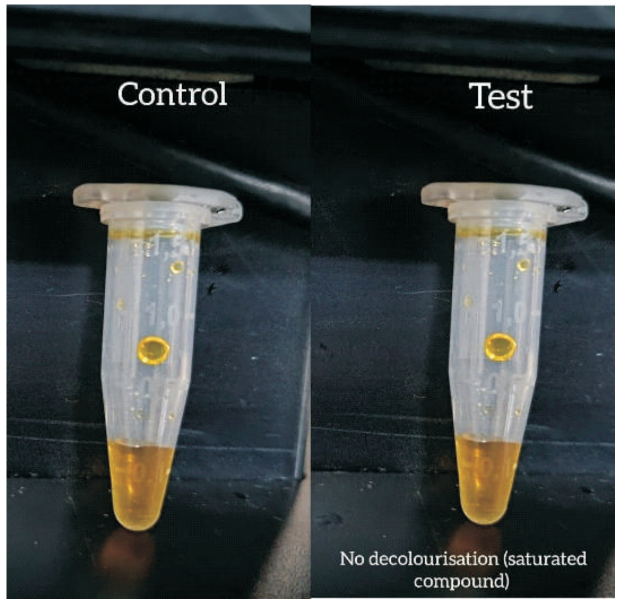

Figure 3. Bromine in CCl_4 Test for Saturation

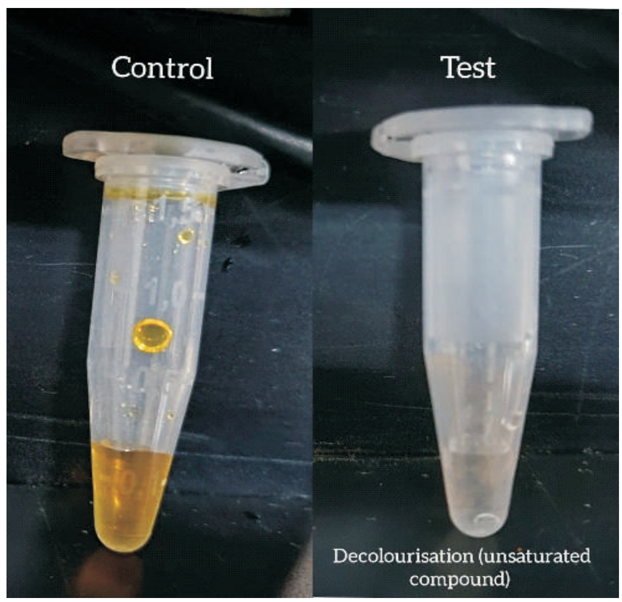

Figure 4. Bromine in CCl_4 Test for Unsaturation

in Figure 5, whereas the neutral sample showed decolourisation, indicating the presence of unsaturation or easily oxidizable compounds, as seen in Figure 6.

3.3.3 Functional Group Determination

To test the functional group of acid (Benzoic acid), 10% sodium bicarbonate was added to the sample taken in Eppendorf tube, shaken well to dissolve the sample, and reprecipitated with concentrated hydrochloric acid that confirmed the presence of acid as seen in Figure 7.

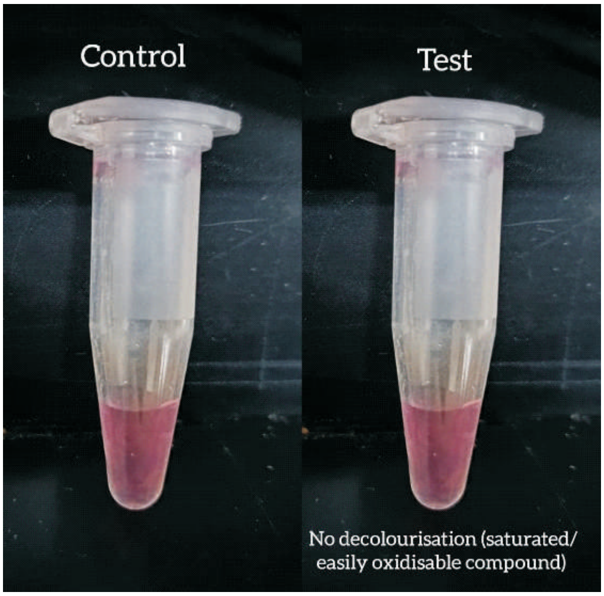

Figure 5. Bayer's Test Results for Saturation or Not Easily Oxidizable Compounds

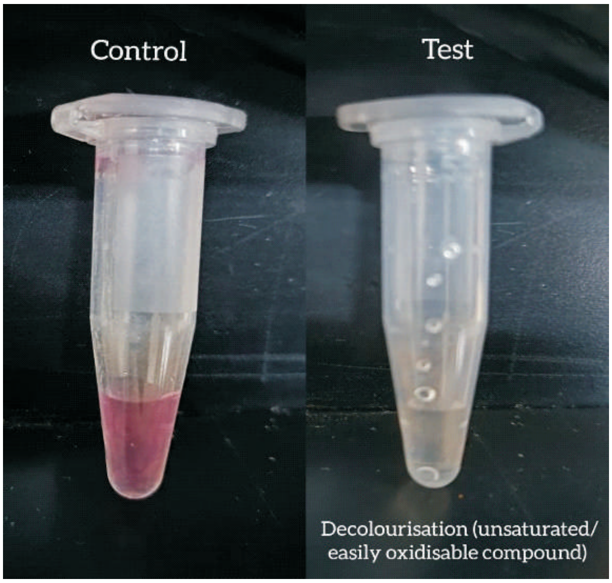

Figure 6. Bayer's Test Results for Unsaturation or Easily Oxidizable Compounds

To check for phenol (β Naphthol), 0.1 ml of methyl alcohol was added to the substance taken in the Eppendorf tube; the reaction mixture was shaken well, followed by the addition of 2 drops of neutral ferric chloride solution to check for colour change. A reddish-brown colour confirmed the presence of phenol as seen in Figure 7.

To check for the functional group of the base (Aniline), two drops of concentrated hydrochloric acid were added to the substance taken in the Eppendorf tube, boiled in a water bath, cooled in ice water and added two drops of sodium nitrite solution. This solution formed was then added to five drops of ice-coldsolution of β naphthol in sodium hydroxide to form orange dyestuff that confirmed the presence of base as seen in Figure 7.

To identify a neutral (acetone) solution, a nitroprusside test for ketones was performed. Two drops of sodium nitroprusside and two drops of sodium hydroxide were added to the substance taken in Eppendorf tube and shaken well to obtain a red-coloured solution that confirmed the presence of ketone as seen in Figure 7.

- Acid (Benzoic acid)
- Neutral (Acetone)
- Phenol (β-Naphthol)
- Base (Aniline)

Microscale qualitative tests demonstrated consistent and reliable identification of various functional groups. The reactions were observable even with the minimal reagent

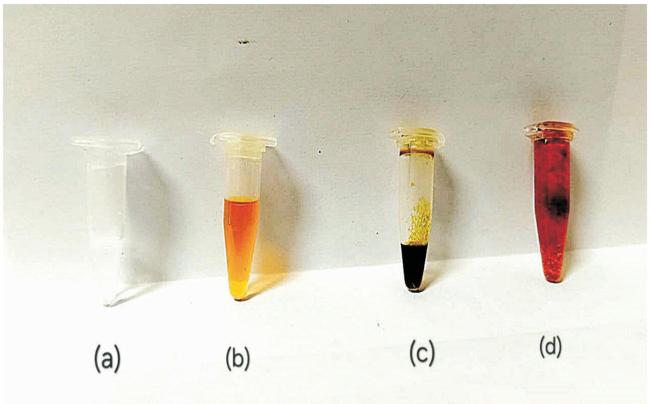

Figure 7. Functional Group Test for Acid, Neutral, Phenol and Base

volumes, confirming the presence of specific types and functional groups in the tested organic compounds.

Some of the researchers have utilized groove plates Sengupta et al. (2022) for organic compound analysis. In our current study, the minimalistic approach to determine the functional groups of organic compound was checked on Eppendorf tubes, as seen in Figure 6 and also performed on ceramic tiles, as seen in Figures 8, 9, 10& 11 and groove plates, as shown in Figure 12.All three methods offer several advantages, such as a significant decrease in reagent volumes. It reduces costs, simplifies procedures, which makes the tests accessible to educational settings; smaller reagent volumes minimize exposure to hazardous chemicals, enhancing safety; and the adapted tests maintain the precision and reliability of traditional methods.

Figure 8. Functional Group Test for Type Acid (benzoic Acid) on Ceramic Tile

Figure 9. Functional Group Test for Type Phenol (β Naphthol) on Ceramic Tile

Figure 10. Functional Group Test for Type Base (aniline) on Ceramic Tile

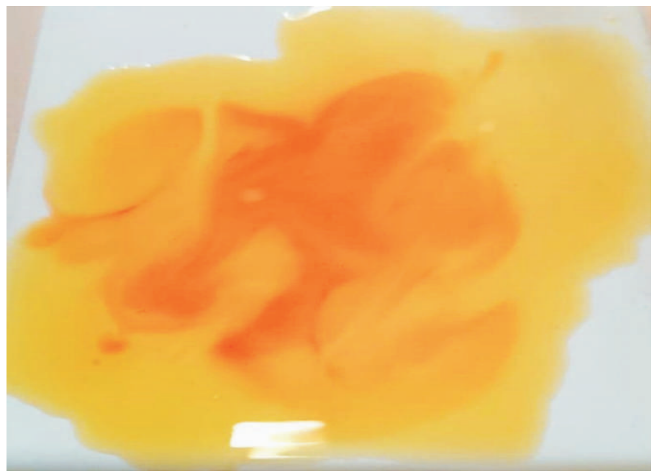

Figure 11. Functional Group Test for Type Neutral (acetone) on Ceramic Tile

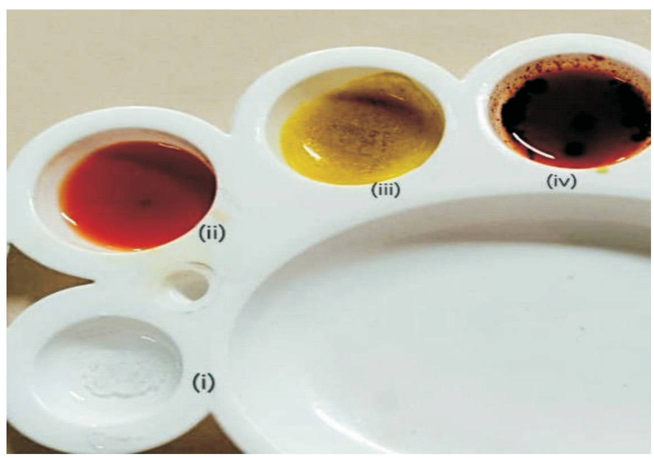

Figure 12. Functional Group Test for Different Types of Organic Compounds using Plastic Groove Plates

- Acid (Benzoic acid)
- Neutral (Acetone)
- Phenol (β-Naphthol)
- Base (Aniline)

The notable differences of the test were that in the ceramic tiles, the colour and precipitate obtained were spread out, and hence, the detection was not specific. Although the groove tiles also demonstrated color change, checking for precipitation and heating the reaction mixture was not possible during the analysis, as shown in Figure 12. Therefore, using Eppendorf tubes had the advantage of allowing for color change checks, shaking the tubes to observe any decolorization, and heating them in a water bath when necessary, as shown in Figure 7.

Our study emphasizes on analysing organic compounds for type and functional group determination using Eppendorf tubes due to its numerous advantages.

As shown in Figure 13, there is substantial 98% reduction in use of reagents for organic qualitative analysis using Eppendorf tubes as compared to the conventional methods of analysis.

Conclusion

Organic qualitative analysis is a crucial method in organic chemistry that involves identifying organic compounds through chemical tests and techniques. Traditional methods often require large reagent volumes and complex apparatuses. This study explores minimalistic techniques that can determine functional groups using fewer sample and reagent volumes to enhance sustainability, cost-effectiveness, and simplicity.

The study used different types of organic compounds (Acid, Phenol, Base, and neutral) and standard reagents for organic qualitative analysis (SRL) in a microscale laboratory apparatus. The analysis process can be divided into several stages, including preliminary tests, volatility tests for liquids, checking solubility in suitable solvents, tests for saturation and unsaturation, aliphatic and aromatic nature, and confirmatory tests specific for various functional groups based on their type and elements.

The study found that acid and phenol samples were insoluble in water, base was immiscible in water, and neutral was miscible in water. The type determination of

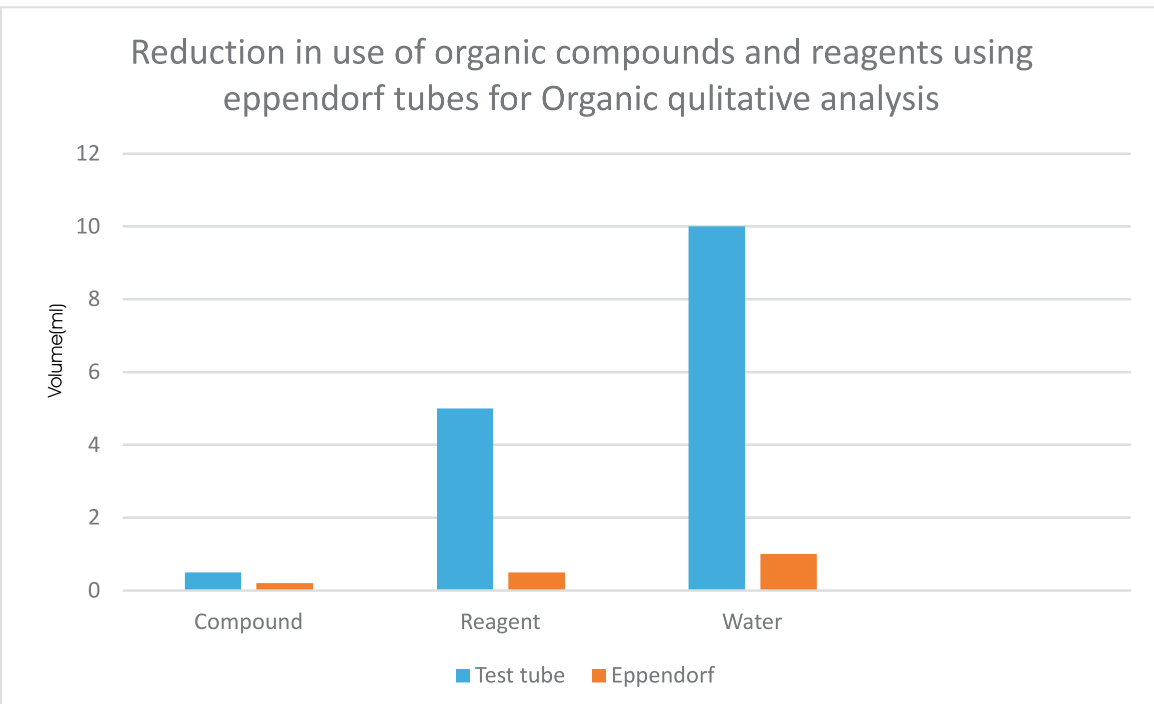

Figure 13. Comparison of Reagent Usage in Organic Qualitative Analysis in Conventional Test Tube Method Verses Eppendorf Method

organic compounds showed reprecipitation with conc. HCl after dissolving the samples in sodium bicarbonate and sodium hydroxide, respectively. The Bayer's test results indicated the presence of saturated compounds or not easily oxidizable compounds, while the neutral sample showed decolourization, indicating the presence of unsaturation or easily oxidizable compounds.

The study focuses on the functional group determination of organic compounds using microscale qualitative tests. The tests were conducted on various materials, including benzoic acid, phenol, and base. The results showed consistent and reliable identification of various functional groups, even with minimal reagent volumes. The study utilized Eppendorf tubes, ceramic tiles, and groove plates for the tests. These methods offer several advantages, such as a significant decrease in reagent volumes, reduced costs, simplified procedures, and accessibility to educational settings. They also minimize exposure to hazardous chemicals, enhancing safety. The study emphasizes the use of Eppendorf tubes for checking color change, shaking the tubes for decolorization, and heating the reaction mixture when necessary. The study emphasizes the importance of using Eppendorf tubes for organic compound analysis due to its numerous advantages. The study emphasizes the importance of using Eppendorf tubes for type and functional group determination in organic compounds analysis.Due to its numerous advantages, the study suggests using Eppendorf tubes to analyse organic compounds for type and functional group determination.

Acknowledgements

The authors acknowledge the Department of Chemistry, Fergusson College (Autonomous), Pune, for providing the materials and facilities necessary for conducting this study. We also acknowledge Shri Guru Teg Bahadur Khalsa College, New Delhi, for conducting a workshop on "Greener and safer chemistry Labs" which inspired us to take up the current minimalistic approach of qualitative analysis.

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