Functional Group Analysis in Undergraduate Laboratory Safe, Cost-effective and Micro-scale Alternatives*

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Functional group analysis is an integral part of the university curriculum since it forms the basis of identification of unknown organic compounds. Traditional methods of analyzing functional groups employ an excess of reagents and generate enormous waste material, disposal of which is of prime concern. The present article focuses on alternative methods for the detection of some of the functional groups such as carboxylic acid, alcohol, phenol, carbonyl, ester, and carbohydrates with considerably less volume (few drops) of conventional reagents on a grooved tile. The procedures adopted are in accordance with the principles of green chemistry – consumption of less solvents and minimizing the waste. Hence, the mentioned experiments afford an efficient, safe and economical approach to functional group investigation. In addition, a comparison of this micro-scale green approach with conventional methods is presented. The success of the tests is valid for general organic compounds, and hence can be satisfactorily employed in undergraduate laboratories for analysis of functional groups.

1. Introduction

The presence of a functional group in an organic compound influences its physical and chemical properties. Hence the identification of functional group is essential to determine the complete structure of the organic compound. Apart from spectroscopic techniques, classical methods of detecting functional group in laboratories [1] are still in practice as they form a part of systematic analysis of unknown organic compounds. However, the

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conventional methods in use suffer from the serious drawback of employing large volumes of chemicals and generating a huge amount of non-degradable waste [2]. These standard but uneconomical and hazardous procedures demand a substitute for the reasons stated. The experiments presented here employing conventional reagents in micro amounts provides a new approach which can replace the conventional functional group analysis procedures still adopted in the undergraduate curriculum. The present approach is in accordance with the principles of green chemistry – safe, efficient and economic.

2. Use of Grooved Tiles

The functional group analysis approach we describe here is based on the use of grooved tiles to perform reactions. This strategy ensures the use of minimal solvents (1–2 drops) and minimizes the generation of waste.

The functional group analysis approach we describe here is based on the use of grooved tiles to perform reactions. This strategy ensures the use of minimal solvents (1–2 drops) and minimizes the generation of waste. Though spot tests [3] for functional groups on grooved tiles have already been reported in the literature, they involve expensive reagents which are not easily accessible to common laboratories. The tests explained here are positive for the organic compounds commonly referred to in the undergraduate laboratory curriculum.

3. Procedure

Tests for various functional groups [4, 5] were carried out using a grooved tile with the reagents and unknown organic compound taken in measures of drops. The blank reagent and compound to be tested were placed on the grooved tile. Drop(s) of the reagent was added to the unknown compound to observe the changes if any. All the tests were performed at room temperature without employing heat (energy efficient).

4. Results and Discussions

The procedural details to test each functional group along with the observations and discussions are tabulated in *Table* 1. *Figure*

Functional Group	Test	Procedure	Result & Discussion
Carboxylic Acid	Sodium bicarbonate	Two drops of saturated solution of sodium bicarbonate was added to the aqueous solution of carboxylic acid.	Brisk effervescence observed with oxalic acid, succinic, benzoic, phenylacetic acid and phthalic acid.
Alcohol	Ceric ammonium nitrate	Two drops of ceric ammonium nitrate was added to one or two drops of different alcohols taken in the spot plate.	Red coloration observed with ethanol, propanol, isoproyl alcohol, butanol.
Phenol	Ferric chloride	Two drops of ferric chloride solution was added to one or two drops of alcoholic solution of different phenols taken in the spot plate.	Violet coloration observed with – α-naphthol, resorcinol and green coloration observed with phenol, β-naphthol, quinol.
Carbonyl	2, 4-DNP	Two drops of 2, 4-DNP reagent was added to one or two drops of aldehydes and ketones taken in the spot plate.	Yellow/orange precipitate obtained with benzophenone, ethylmethyl ketone, benzaldehyde, acetophenone, cyclohexanone.
Ester	Feigl	Two drops each of ester and hydroxylamine hydrochloride were taken in a spot plate followed by the addition of one drop each of KOH, HCl and $FeCl_3$.	Violet/wine/magenta coloration observed in case of ethyl benzoate.

Table 1. Tests for functional groups (carboxylic acid, alcohol, phenol, carbonyl and ester).

1 gives the results obtained for the mentioned tests. A comparison of this approach with the conventional methods is described in *Table* 2.

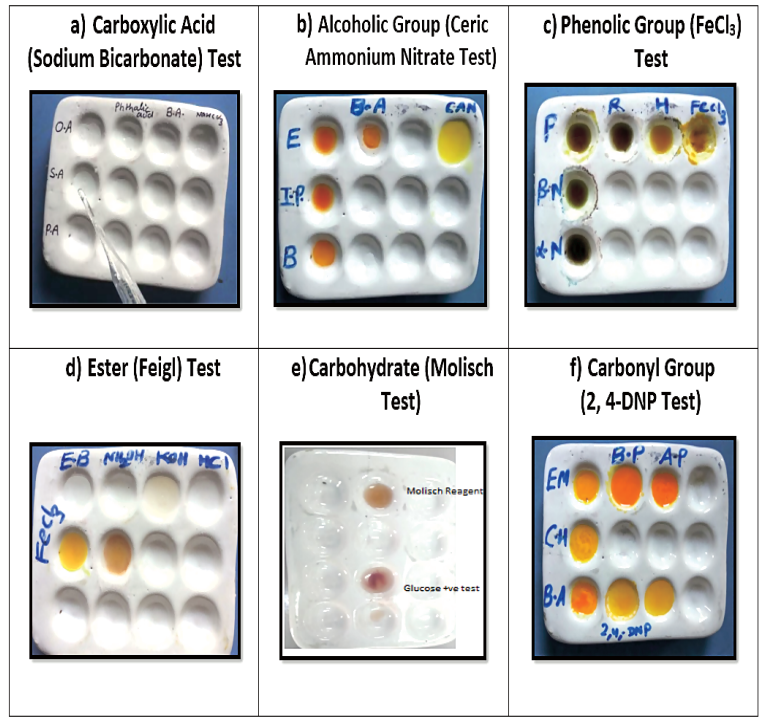

Figure 1. Tests for **(a)** Carboxylic acid P.A-phenyl acetic acid, S.A-succinic acid, O.A-oxalic acid, phthalic acid, B.A-benzoic acid; **(b)** Alcohol group [CAN-ceric ammonium nitrate reagent, B.A-benzyl alcohol, E-ethyl alcohol, I.P-isoproponal, B-butanol; **(c)** Phenolic group H-hydroquinone, R-resorcinol, P-phenol, β.N-β-Naphthol, α.N-α-Naphthol; **(d)** Ester E.B-ethylBenzoate; **(e)** Carbohydrate, **(f)** Carbonyl group B.A-benzaldehyde, C.H-cyclohexanone, E.M-ethyl methyl ketone, B.P-benzophenone, A.P-acetophenone.

5. Preparation of Reagents

The reagents already available in the laboratory for macro functional group analysis are used as such for this micro-scale approach.

6. Hazards

There is no use of hazardous organic solvents and LPG since the procedure avoids heating at any stage of the test.

7. Conclusions

This work has been carried out in the laboratory of our institute for undergraduate students of second year. All the tests are reproducible and thus can be carried out in any laboratory without

Conventional Method	Our Method (Grooved title)
In conventional method, the reagents and organic compound is taken in few ml volume.	Only few drops of the reagents and organic compounds are required to perform any test.
For the detection of few functional groups such as carbonyl and ester, heating after addition of reagent is required, i.e., requires energy.	No heating is required, simple addition of reagents give results, i.e., energy efficient.
In detection of phenols, neutral ferric chloride has to be prepared for detection, i.e., use of additional chemicals.	Test is possible even with aqueous/alcoholic solution of ferric chloride. i.e., saves the use of additional chemicals.
Each test has to be performed separately in different test tubes, i.e., extra apparatus is required.	Test for different functional groups for a given organic compound can be performed simultaneously on a single spot plate.
The amount of byproduct/waste products formed is considerable and hazardous.	The amount of byproduct/waste products formed is negligible, and hence the method is comparatively safer.

Table 2. Comparison of conventional method with alternative (grooved title) method.

employing special glass apparatus, instruments, etc. The work if incorporated in the curriculum, will inculcate environmental awareness among undergraduate chemistry students.

Suggested Reading

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