Utilization of Used-Up Consumer Product Collapsible Tube for Development of Chemistry Experiment

Sudesh Bhaskar Ghoderao

Associate Professor
Department of Chemistry,
RNC Arts, JDB Commerce and NSC Science College, Nashik Road, Nashik, India.

Abstract: It is quite essential that the students should be allowed to handle and manipulate materials and objects themselves to develop their creative, exploratory and inventive potentials. The cheaper and effective utilization of used-up materials as a starting chemical are fascinating subjects. The utilization of aluminium metal from collapsible tube, as used for toothpaste, for a common inorganic complex preparation of potassium trioxalato aluminate (III) trihydrate, is a training to save conventional costly chemicals. The present study will help the student to know the property of material in its many facets, to perform experiments and get a feel for doing science which includes used-up material.

IndexTerms **- Chemistry Education, Pedagogy, Low Cost Experiment, Collapsible Tube, Aluminium.**

I. INTRODUCTION

In selecting the laboratory experiments for Chemistry students, the costs of reagents, apparatus and equipment frequently become the determining factor. Those experiments are desirable which satisfy the following requirements:

a) efficient but inexpensive equipment,

b) less possibility of breakage and breakage or fault, if any, which can be taken care of by repairs with minimum cost and within less time,

c) rapid procedures (requiring less consumption of electricity, heat and water),

d) less spoilage or consumption of chemicals,

e) inexpensive alternative chemical sources for the chemicals used in regular practicals and

f) possibility of recovery or reclamation of reagents / chemicals used in the experiment.

A portion of the cost can be often offset by reverting the products obtained in these experiments into useful (starting) materials.

Following are some such representative references from literature which indicate effective execution of such ideas.

The pieces obtained from the metal seals for fitting rubber stoppers to the injection bottles have been used along with dilute acid like HCl or H_2SO_4 in the reduction of Fe (III) to Fe (II) prior to Fe (II) – Cr (VI) titrations as an alternative for $SnCl_2$-$HgCl_2$ or Zinc dust [1]. Similarly in the potentiometric determinations of F^- using La^{3+} solution as titrant in 60% methanol medium are used the objects like forks or knives instead of a stainless steel rod as ion selective electrode. Similarly beer can is also used as a substitute potentiometric sensor for aluminium rod – another ion – selective electrode [2]. There are reports for utilization of alternative chemicals for the conventional ones. Stephenko gives some such cheap sources, for inexpensive chemicals [3]. There is also the use of lime water instead of Baryta water [4]. An approach to recover the starting materials is useful with respect to not only the budget of chemistry practicals but also the problem of pollution due to throwing of the products as wastes [5].

Used- Up Collapsible Tube as Cheap Source of Aluminiuim

Aluminium, although third most abundant, element and the most abundant metal of all those in earth-crust, does not occur in the free state in nature [6]. It is extracted by electrolysis (Hall-Herault process) from its ores – mainly containing (oxide containing) ores. Due to the abundancy of ore and revolutionary developments in the extraction process, aluminium is now available in large amounts. Due to the useful properties of it as well as its alloys, it has variety of applications - from foils for candy-wrapper to sheets for roofing as well as from electric wires to utensils. Now-a-days there are variety of aluminium-containing articles in everyday use. Although aluminium has become a cheap as well as easily and commonly available material, one has to think of efforts and expenditures in getting the pure metal. The minimization in disposal of articles of aluminiun or in other words, the recovery of aluminium may be given a serious thought in this connection. To restrict the waste of aluminium, the collapsible plastic tubes (commonly of polyethylene), now a days, are used increasingly to replace aluminium tubes.

It is well-known that aluminium containers, especially she collapsible tubes, are largely used for packing toothpastes, shaving creams and other cosmetic and personal care products [7, 8]. The aluminium used for these tubes is of 99.7 % purity.

Enough care is taken in the production, filling-up and marketing of collapsible tubes so that no contamination of product (being filled in the tubes) should be possible by the container itself (tube material). e.g. coating of internal surface with a protective lacquer and heat treatment of lacquer. This also indicates the possibility of less effect of product on the material of the tube. The only care one has to take in using this material is to make it free from enamel or colors on outer surface and secondly from the lacquer on inner surface of the tube.

As compared to articles made up of aluminium foil e.g. strips of tablets, pouches for products as Jarda (Tobacco) or wrappers for cigarette) made in a similar way, the collapsible tube seems to be a better quantitative source of aluminium.

In the present study, it is tried to use the aluminium pieces obtained from a collapsible tube – the tube of toothpaste - as starting material for the preparation of a common inorganic complex. The success of this method is tested by examining the percentage purity of the complex.

Aluminium for aluminate complex

In the practicals of synthetic Inorganic Chemistry, the preparation of potassium trioxalato aluminate (III), trihydrate i.e. $K_3[Al(C_2O_4)_3].3H_2O$ has importance. This is an anionic metal chelate formed by $C_2O_4^-$ …a bidentate ligand. It has octahedral

geometry. It can be prepared and purified easily. The preparation and analysis of it give training of some basic techniques of preparation (precipitation, filtration and recrystallization) as well as determination (complexometry, redox titrations and gravimetry) to the under-graduate students. The determination of Al^{3+} and $C_2O_4^-$ can be done by EDTA titrations and permanganatometry respectively, while for the determination of water, the weight loss due to heating up to 110 ºC is useful [9,10]. The study can be can further be extended up to postgraduate level also with the techniques as IR and X-ray powder diffractometry - for detailed structural studies [10]. In short, this complex is a representative 'teaching aid' for teaching Analytical and Inorganic Chemistry.

The conventional methods of its preparation are either the reaction of hydrated alumina (i.e. aluminium oxide) (obtained generally from $Al_2(SO_4)_3.18H_2O$) with a solution containing appropriate amounts of potassium oxalate – oxalic acid [11,12]. The starting material containing aluminium is either the pure salt or the metal in the form of powder, wire, foil or shavings (turnings) [12, 13]. One may use commercial aluminium or aluminium-base alloy ("Dural" is most suitable which is an alloy with constituent – percentage as – 94.60 Al, 3.90 Cu, 0.45 Fe, 0.30 Si and 0.75 Mg) for getting aluminium metal. Instead of all these routine procedures we have used the aluminium pieces obtained from the front part of collapsible tube for preparing the aluminate complex. The body part is having the layer of paint (used in lithographic treatment) and requires the removal of this layer. So the front part is selected for getting aluminium.

The percentage purity of aluminium from the aluminium tube is tested as a prerequisite to the preparation. After preparing the aluminate complex, its purity is also checked to ensure the usefulness of starting material containing aluminium. The aluminium metal is dissolved in alkali and acidified later to prepare diluted known volume for determination. The aluminate complex is disintegrated using acids and the solution obtained is diluted to known volume prior to determination. The determination is done as per the indirect method by complexometry (back and blank titrations) using Eriochrome Black -T indicator at pH 7.

Certain metals like aluminium, form such stable metal-indicator complexes that the indicator can no longer be liberated by adding EDTA. Therefore, direct titration of such metal ions using Eriochrome Black-T as indicator is impracticable and metallic ions are said to "block" the indicator. However, with such type of metals the back titration can be carried out, for the rate of reaction of their EDTA complexes with the indicator is extremely slow and it is possible to titrate the excess of EDTA with standard zinc ion solution.

II. EXPERIMENTAL

(a) Aluminium from collapsible tube:

A used-up or empty collapsible tube of toothpaste is taken. Its plastic cap is removed and the neck with nozzle is separated from the body of tube by cutting with the help of scissors or hacksaw used for cutting metals. The separated portion is cut later into small pieces of size 1 cm2. They are cleaned with water several times to remove all the traces of toothpaste and then by organic solvent like alcohol or acetone. They are then dried in air and made ready for use.

(b) Preparation of $K_3[Al(C_2O_4)_3].3H_2O$:

Reagents

KOH (20 %): 20 g of potassium hydroxide (pellets) dissolved in water to get 100 mL solution just before use.

Ammonia (l:1): Equal volumes of ammonia (conc.) and water are mixed.

HCl-HNO_3 (1:1): Equal volumes of hydrochloric acid (conc.) and nitric acid (conc.) are mixed.

Oxalic acid, Ethyl alcohol, Acetic acid (glacial), Sulphuric acid (conc.)

Procedure:

An accurately weighed amount of 0.2 g of sample in form of aluminium metal pieces is taken in a 100 mL-beaker and to it 12 mL of water and 6 mL of freshly prepared potassium hydroxide (20 %) is added. After the vigorous reaction has subsided, the solution is heated to boiling on a hot plate or a water bath to effect complete oxidation of aluminium. To this solution 3.3 g oxalic acid dihydrate is added in small portions at a time with constant stirring. Initially addition of the acid causes formation of aluminium hydroxide as a gelatinous precipitate, but the addition of acid is continued. The solution may become clear on adding complete amount of acid. The solution is filtered through a Buchner funnel when it is still warm. This is for removing any insoluble material. The solution is then concentrated by heating to decrease its volume to two-third. It is then cooled to room temperature and 95% ethyl alcohol is added till slight turbidity develops (2 mL of alcohol required). The solution is then cooled in an ice-bath for 20 min. when crystalline material precipitates (due to its lesser solubility in mixed i.e. ethanol-water solvent system). The colorless crystals of the aluminate complex are filtered using suction pump. The product is washed with little amount (3 mL) of ethanol, dried in vacuum desiccator and weighed (Yield 2.8 g, 82 %).

Recrystallization of complex (before finding % purity):

A saturated solution is prepared by dissolving 1.0 g of the complex in minimum amount of water. The solution is filtered hot, concentrated and then cooled. The product is precipitated by adding 2 mL of ethanol and cooling in an ice bath. On filtration and drying in vacuum the product is used for finding purity.

(c) Disintegration of sample for purity:

Metal sample: An accurately weighed amount (0.05 g) is treated in a beaker with 10 mL of potassium hydroxide (10 % freshly prepared solution). As it is hot, it dissolves the metal in less time. After the vigorous reaction has ceased, the solution is heated, preferably on water bath, to dissolve the contents completely. The solution is slightly diluted and then acidified by drop wise addition of glacial acetic acid with stirring. (The solution is filtered if necessary to remove the insoluble material. The filter paper is given washings till free from acid and the washings are mixed with the filtrate). The solution is diluted to 100 mL exactly.

Metal complex: An accurately weighed amount (0.10 g) of complex is disintegrated using 5 mL of HCl – HNO_3 (1:1 mixture of concentrated acids) and warming the solution in a 100 mL conical flask. If the color developed does not fade, it is cooled and more quantity of acid mixture is used for complete disintegration. The solution is cooled and then is added 3 mL of concentrated sulphuric acid. The solution is heated again. After complete evolution of brown fumes the solution is cooled and diluted to 100 mL exactly.

(d) Complexometric determination of aluminium:

Reagents: EDTA (0.01 M approx.), Eriochrome Black T (1%), Ammonia-ammonium chloride buffer solution (pH - 10), EDTA (0.2 M), Zn^{2+} solution (0.01 M)

Standardization of EDTA

An aliquot of 10 mL of standard zinc ion solution (0.01 M) is taken in a conical flask with pipette and neutralized with dilute ammonia (1:1). To it is added 10 mL distilled water, 2 mL buffer (pH 10) and Eriochrome Black-T indicator. The solution is titrated versus EDTA (approx.0.01 M) till the end point as wine red to blue is obtained.

Back titration[18]: An aliquot of 10 mL of diluted aluminium solution is taken and neutralized using dilute ammonia (1:1) in the conical flask. To this solution is added known excess (25 mL exactly) of EDTA solution (previously standardized 0.01 M). The pH of solution is adjusted between 7 and 8 by the addition of ammonia (1:1). Then the solution is boiled for one to two minutes and cooled. Again, pH of solution is adjusted between 7 and 8 by the addition of ammonia (1:1). Then 5 mL of distilled water and few drops of Eriochrome Black-T indicator are added. The solution (unused or excess of EDTA in it) is titrated with standard zinc solution (0.01 M) from a burette till the end point as blue to wine red color is obtained.

Blank titration: The blank titration is carried out using 25 mL of EDTA with the use of above-mentioned reagents.

From the difference in the readings for blank and back titrations i.e. the volume of Zn^{2+} solution (0.01 M), the equivalent volume of EDTA can be calculated by the relation

$M_1V_1 = M_2V_2$.

Na_2H_2Y / 1 = Al / 1

where Na_2H_2Y is EDTA. The volume of EDTA is the one consumed by metal ion i.e. aluminium in the aliquot. So the amount of aluminiům in the aliquot can be determined by the following relation:

1 mL 1 M EDTA = 26.98 mg Al^{3+}

From this the total amount in diluted solution and therefore, the percentage of aluminium in the sample / complex can be determined.

Determination of purity

a) Sample of the used-up collapsible tube: toothpaste

Checking the purity of metal:

Amount of sample used - 0.03317 g

Volume of solution containing above mentioned sample = 100 mL

Complexometry using its 10 ml aliquot has readings as

Blank titration: 25.0 mL Zn^{2+} solution (0.01 M)

Back titration: 12.9 mL Zn^{2+} solution (0.01 M)

(Blank-Back) reading = 12.1 mL

Equivalent volume of EDTA (0.01 M) consumed by Al^{3+} = 12.1 mL

1 mL of 1 M EDTA = 26.98 mg of Al

Therefore, 12.1 mL of 0.01 M EDTA = 3.264 mg of Al (in 10 mL aliquot)

Therefore, Amount of Al^{3+} in 100 mL diluted solution = 32.64 mg (i.e. 0.03264 g)

Therefore, Amount of Al present in 0.03317 g of sample is 0.03264 g

Therefore, % of Al in the sample taken = 98.41

Therefore, % of purity of aluminium from collapsible tube = 98.41

b) Sample of aluminate complex prepared from aluminium pieces from collapsible tube:

Complex: $K_3[Al(C_2O_4)_3].3H_2O$ (MW : 462.27)

Calculated percentage of Al in complex = 5.84

Checking the purity of complex in terms of percentage of Al:

Amount of sample used: 0.09800 g

Volume of solution containing sample = 100 mL

For 10 mL aliquot of this solution the titration readings

Blank titration: 25.0 mL Zn^{2+} solution (0.01 M).

Back titration: 23.0 mL Zn^{2+} solution (0.01 M).

(Blank - Back) reading = 2.0 mL Zn^{2+}

Therefore, Equivalent volume of EDTA (0.01 M) consumed by Al^{3+} = 2.0 mL

1 mL of l M EDTA = 26.98 mg of Al

Therefore, 2.0 mL of 0.01 M EDTA = 0.5396 mg Al (in 10 mL aliquot)

Therefore, Amount of Al in 100 mL diluted solution = 5.396 mg i.e. 0.005396 g

Therefore, Amount of Al present in 0.09800 g of complex is 0.005396 g

Therefore, % of Al in the complex = 5.506 i.e. 5.51

Now, % purity of complex (in terms of its metal content) = Amount of metal observed x 100 / Amount of metal expected

Therefore, Purity of aluminate complex = 5.51 x 100 / 5.84

= 94.35

Table1: Percentage purity of collapsible tube and complex

Sample	Amount used for analysis g	Blank titration reading mL	Back titration reading mL	(Blank-Back) mL	Calculated purity %
Collapsible tube	0.03317	25.0	12.9	12.1	98.41
Complex $K_3[Al(C_2O_4)_3].3H_2O$	0.09800	25.0	23.0	2.0	94.35

III. Result and Discussion

The values of % purity (Table 1) indicate the following

1. The starting material is fairly pure (% purity 98.41 as compared to that mentioned in literature i.e. 99.7).

2. The aluminate complex indicates the percentage purity of 94.35, which is suggesting that the aluminium from collapsible tube may be the useful starting material for practicals. A neck of toothpaste weighs approximately 2.0 g, therefore, useful for ten students

for preparing the aluminate complex. One can find some way to clean the painted body portion of collapsible tube also and use the whole tube as a source of aluminium.

3. One may try for other following consumer products as cheap sources of aluminium.

i) Foil of pouches of products e.g. of food containers or soft-drink containers,

ii) Foil from strips of pharmaceutical capsules,

iii) Casing of body of starter of fluorescent tubes,

iv) Seals of LPG cylinders or injection vials,

v) Aluminium collapsible tubes for other consumer products.

4. The time required to get solution of aluminium is less. One can use, therefore, used-up consumer products containing aluminium for preparation of Al3+ complexes. It is a one step preparation rather than two stages if aluminium sulphate is used.

IV. CONCLUSION

The discussion presented above about the utilization of used-up material, collapsible tube, for Chemistry practicals is not only useful through budget point of view but also may be initiating one for introduction of such new ideas which may be better 'alternatives' to the conventional ones.

In general, for learning the science effectively, the importance of direct experiment using objects and materials by students can be useful. It is quite essential that the students should be allowed to handle and manipulate materials and objects themselves to develop their creative, exploratory and inventive potentials. The more inexpensive and readily available the material, the better is the achievement of this goal.

It is also being exceedingly felt that an elaborate and inexpensive experimental work is generally worthless for the student as it obtrusively intervenes between him and his urge for direct exploration of real things and materials. Thus for students, there is a positive virtue, if inexpensive and readily available familiar materials are used for doing science practicals. Many such materials are around us that cost almost nothing or many of them can even be obtained from junk, waste, throw-aways and discarded things.

The present work will help the student to know the property of material in its many facets. It will also help him or her to perform experiments and get a feel for doing science which includes used-up material.

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