313. Role of Demonstrations for Effective Communication Of Chemistry and Green Chemistry Concepts

Kartik Kumar Nandi
Department of Chemistry
Brahmananda Keshab Chandra College
111/2, B. T. Road, Kolkata 700 108
West Bengal; INDIA
kknandi@yahoo.com

Abstract. The demonstrations are widely accepted as complementary tools for science communication. With the progress of time and technology the use and mode of demonstrations have also been modified. Modern cognitive science research reveals the requirement of student's active role for better perception of conceptual learning. Strategically this can be achieved more effectively in an atmosphere in which ideas are openly generated, debated and tested through demonstration experiment. Both the laboratory experiences and demonstrations are found to activate student's interest for initiation & perception of learning. This paper will provide an overview of the role of chemical demonstration experiments for conceptual learning of chemistry as well as green chemistry.

Keywords: Chemical demonstration, Cognitive science, Conceptual learning, Green chemistry experiments

Introduction

Most of the chemistry teachers in particular and science teachers in general, feel the need of demonstration as an effective and complementary tool of communication for conceptual learning. Because of its wide acceptance nowadays science demonstrations techniques are used for the betterment of teaching learning processes. Starting from 1950 the mode of science demonstrations became more popular teaching strategy. With the progress of time and technology, especially in the era of information & communication technology, the use and mode of demonstrations have also been modified and proliferated1. According to the modern cognitive science research student's active role is vital and learner's mind must be engaged effectively for better perception & transformation of conceptual learning. In this relation lectures and instructions alone are not sufficient to promote conceptual learning2. N. W. Rakeswtraw3 rightly stated that the ultimate object is the ability to think abstractly and this can be attained only by learning to think correctly. No teacher can hope to instill enthusiasm of understanding into the learner by merely talking about the chemistry, without actually showing the processes and materials i.e. demonstration. At the same time to achieve more understanding, greater concreteness in teaching strategies and in instructional materials are also inevitable4. Beside demonstrations laboratory classes play a vital role in learning chemistry, even though demonstration experiments are very important for growing interest and also for proper perception and accumulation of conceptual learning. Both the laboratory experiences and demonstrations are found to be the powerful tools for activating student's interests and focusing their attention for initiation of learning and perception of conceptual learning of chemistry and green chemistry. Chemical demonstrations can also be used complementary tools, where practical class works are not possible. It can allow the students at least to see the experiments, which they otherwise would not be able to share. So the challenge of chemistry teachers is to attract and engage the active and visual learners by the use of well planned and effectively presented classroom demonstrations.

On the other hand green chemistry [i.e., design of chemical products and processes that reduce or eliminate the generation of hazardous substances] become an essential part of modern chemistry. But very little educational researches are found to promote the demonstrations for effective communications on green chemistry education. Although some reports on chemistry demonstrations workshops with educators are repoted5-6. The concept of learning with demonstration can also be applied for effective learning of green chemistry using green chemistry concepts, principles & experiments. Demonstration experiments based on green chemistry concepts and practices can provide pedagogical benefits to cope with the contents of greener curriculum [i.e., with the practical advantages of improved safety & reduced hazard]. Participatory demonstration of simple green chemistry experiments showed great impact on learner with the advantages of stimulating to find new/similar experiments to replace the existing hazardous one by them7. So the development of demonstration experiments based on green chemistry principles and practices for green chemistry communications are inevitable. This in-tern will definitely help to cope with greener curriculum of modern chemistry for sustainable development [reduction of adverse consequences of the substances/ chemicals/ techniques that we use or generate] of future world. This paper will provide an overview of the role of chemical demonstration experiments for conceptual learning of chemistry as well as green chemistry. Basis of selecting/choosing right kind of demonstration to prepare and conduct the same will also be attempted with critical analysis of some selective chemistry and green chemistry experiments.

Demonstration & Conceptual Learning

The primary job of a teacher is to generate and evolve the proper resolution of cognitive conflicts among the learners. Strategically this can be achieved more effectively in an atmosphere in which ideas are openly generated, debated and tested through demonstration experiment, either in lecture demonstration or in laboratory demonstration. Textbooks alone are not sufficient to develop a personalize understanding of concepts. Interesting demonstration can create links between previous knowledge and new concepts of learning among the students8. Chemical concepts may developed by analysis of experimental observation and careful reasoning. Series of observations and logical deductions will motivate learners to questioning to understand and reconstruct the concepts through discovery mode. Observing a new experiment/ demonstration/ incident definitely motivates and prompts student to ask questions with reasoned responses and finally to investigate & to draw conclusions that explain the foregoing observations. All these in-tern will enhance the cognitive skill of critical and analytical thinking followed by evaluation and synthesis, which is most essential to success in chemical sciences.

Different kinds of strategic demonstrations can be used with proper judgment and according to the need of the both of students and topics. (a) Classroom demonstration (syllabus oriented concept development) with the help of actual performing the demonstration experiment before the students. (b) Popular demonstration experiments with hands-on activity using easily available & inexpensive materials and active participation of students. (c) Magical demonstration to explore myths and mysteries of incidents. (d) Virtual demonstration with the aid of computer animations and video presentation9-10, etc. Choice of right kind of demonstration largely depends on targeted audience, teacher's skill and relevance with suitable concepts or topics.

Comprehensive Planning

The Demonstrations of all levels to communicate effectively should be of well planned to attract and engage the active and visual learners in modern classrooms. Success in effective communication largely depends on proper planning and choices of strategic type and/or proper blending of many types of demonstrations. Basic components of a good demonstration are;

(i) Complete, accurate instructions with purpose/ objectives,

(ii) List of equipments and materials with convenient sources for all,

(iii) Brief explanations of the concepts of chemistry & green chemistry involved,

(iv) Short description of stepwise demonstration procedure in simple languages, and

(v) Post demonstration works.

Steps for individual demonstration:

STEP-1:

Instruction sheet get ready with the following points;

Title of Demonstration,

Clearly stated academic purpose/objectives, Foundation/previous knowledge review to be required to link students' past experiences,

Explanation of the concepts of chemistry & green chemistry involved,

Materials and Equipments required,

Times required,

Short Introduction on Demonstration/ Experiment,

Presentation procedure,

Post demonstration testing and Conclusions.

STEP-2:

Procurement of Materials and Equipments; Mostly with the help of students and should be of inexpensive, easily available, popular/known and eco-friendly.

STEP-3:

Foundation of presentation;

Discussion of previous knowledge is required with short introduction that connect the demonstration to the previous knowledge attracting students attention for careful observations and questioning11.

STEP-4:

Performing the actual demonstration; The teacher will perform the demonstration with active participation of the students. Materials/incidents/happenings are to be properly observed by students. Involving students in hands-on activity will encourage students for timely questioning to understand the incidents through immediate feedback/ discussions with peers and or instructors, i.e., active learning.

STEP-5:

Concept development;

Series of observations and logical deduction will automatically lead the students for further questions with reasoned responses. Teacher will assist the learners to construct and reconstruct the concepts through discovery mode.

STEP-6:

Post demonstration Evaluation;

Allowing the students to test and reconstruct their new knowledgebase/ understanding with new examples/ evidences/incidents and helping them for appropriate understanding of corresponding concepts.

Sample Tested Demonstrations:

Demo–I: Flame Tests Using Common Household Materials12

Objectives:

The academic purpose of this demonstration is to identify elements from color emitting materials.

Foundation:

Salts, ions, elements, color flames, etc.

Concepts:

Elemental identification based on color flame.

Materials:

Common house hold materials.

For Boron; 2 tsp boric acid (H_3BO_3) and 1/2 cup of 91% isopropyl alcohol (C_3H_8O) are mixed.

For Sodium; Equal amounts of 70% isopropyl alcohol (C_3H_8O) and water are mixed and then saturated with baking soda ($NaHCO_3$).

For Potassium; Equal amounts of 70% isopropyl alcohol (C_3H_8O) and water are mixed and then saturated with cream of tartar ($KC_4H_5O_6$) followed by addition of 1 Tbsp of vinegar.

For Calcium; Equal amounts of 70% isopropyl alcohol (C_3H_8O) and water are mixed and get saturated with deicer ($CaCl_2$).

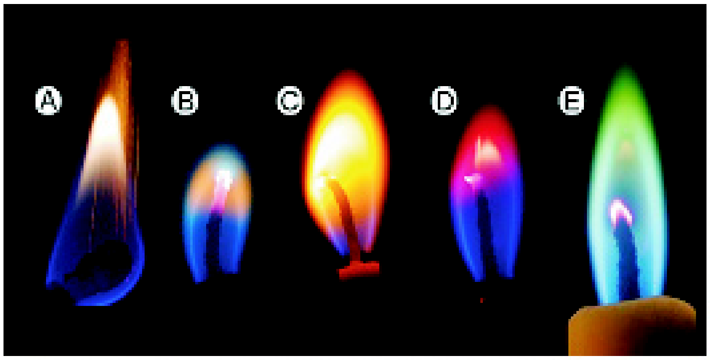
For Copper; 1 cup of ammonia and 1gm copper sulphate are mixed & shaken for 1 min, until solution turns blue. Then added one part blue solution to two parts 70% isopropyl alcohol (C_3H_8O). Etc.

Demonstration Experiments:

Household materials in mixtures of water and isopropyl alcohol are dissolved and the resulting solution is poured into a spray bottle. When the solution is sprayed as a very fine mist onto a flame generated by a wind-resistant grill lighter, a large flame is produced. The flame color depends upon the element present in the household item dissolved in the isopropyl alcohol – water mixture. Students are instructed to color in box of the element [in the periodic table] with the color of the flame observed.

Post demonstration Work:

In the post demonstration part students can easily find the possible element used in Colored Flamed Birthday Candles too.



(A) Isopropyl alcohol and water (B) cesium;
(C) Sodium; (D) lithium; and (E) copper.

Demo–II: Determination of the Formula of a Hydrate: A Greener Alternative13.

Objectives:

Academic purpose is to explain the principles of stoichiometry and gravimetric analysis.

Foundation:

Constant weight, water of crystallization, formula of salt hydrate, etc. are to be discussed.

Concepts:

Gravimetric Analysis;

Stoichiometry.

Materials:

Copper hydrate salts [Copper(II) Chloride dihydrate], Air-Oven, etc.

Demonstration Experiments: The determination of the formula of a hydrate is an experiment that introduces students to many fundamental chemical concepts including stoichiometry, the notion of a mole and nomenclature. Copper salts are being used because they are less toxic, less expensive, and recyclable and produce vivid color changes (blue to brown) during the experiment. Not only are students exposed to the concept of environmentally responsible chemistry, but are asked to determine the formula of a copper chloride hydrate salt by measuring the change in mass after water is evaporated from the sample. The lab is also made safer by dehydrating the copper salt using an air-oven instead of individual Bunsen burners. We utilize a copper hydrate salt that shows both a visual color change upon dehydration and ease of rehydration upon exposure to steam.

Post demonstration Work: Students are asked to calculate amount of water present per mole of experimental salt hydrate from the weight loss data, after getting constant weight. They will also report the gradual color changes. Finally teacher will assist them to find out the formula of a salt hydrate.

Demo–III: The Friedel-Crafts Reaction: Acetylation of Ferrocene7,14.

Objectives: Acetylation of ferrocene with a green alternative pathway.

Foundation: Green chemistry principles, Friedel-Crafts Reaction, Ferrocene, etc.

Concepts:

Electrophilic Substitution, ‘C-C’ bond synthesis and green method.

Green Principles:

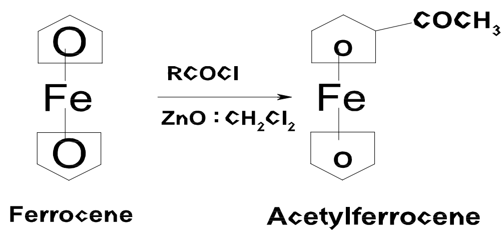
Less hazardous, Recyclable Catalyst and Energy minimization. Atom economy, etc.

Materials: Ferrocene, acidchloride, Zinc Oxide, Reaction set-up, etc.

Demonstration Experiments:

This experiment focuses on the Friedel-Crafts reaction - a powerful, widely used method of carbon-carbon bond synthesis that proceeds by the mechanism of electrophilic aromatic substitution.

Reaction:



Procedure

In this greener approach14 ferrocene was acylated with different acid-chlorides over eco-friendly ZnO catalyst at room temperature. The reaction completed in 15 minutes [monitored by TLC] and on normal work up acylferrocene was isolated characterized spectroscopically. The acylation of first ring deactivate the second thus only monoacylated product is obtained. The used ZnO was washed and reused (2-3 times) without loss of efficiency.

Green advantages:

(a) Eco-friendly easily available ZnO as recyclable catalyst.

(b) Room temperature reaction and simple method minimize the energy input.

(c) Small reaction time and less harmful method.

Non-green features

(a) Toxic acid-chlorides (RCOCl) are used as acylating agents.

(b) Chlorinated hydrocarbon, CH2Cl2 used as solvent.

The link to this laboratory procedure includes both pre- and post-lab questions.

Post demonstration Work:

Students have been self motivated to overcome the problems of removing non-green features and tried to find more green experiments. Instructor should guide with necessary information. They will also try for other suitable substrates.

Demo–IV: Solventless Friedel-Crafts Acylation with Carboxylic acids at Room Temperature14,15

Objectives: Acylation of aromatics with carboxylic acids as a green alternative acylating agent.

Foundation: Green chemistry principles, Friedel-Crafts Reaction, etc.

Concepts:

Electrophilic Substitution, Catalytic & Recyclable Pathway for C-C bond synthesis.

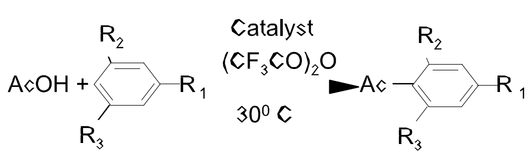
Green Principles:

Green Reagents, Atom economy and Energy Minimizations, Solvent less reactions, etc.

Materials: Bi(OTf)3 or Sc(OTf)3 with TFAA, Acetic acid, aromatic substrates, Reaction set-up, etc.

Demonstration Experiments:

Reaction



Catalysts: $Bi(OTf)_3$ or $Sc(OTf)_3$ with TFAA ; R1, R2, R3 = H / Me / OMe

etc. Procedure

In this method aromatic ketones are prepared in solventless condition at ambient temperature using recyclable catalysts [metal triflates] with trifluoroaceticanhydride [TFAA]. Both the aromatic and aliphatic carboxylic acids are used as successful green acylating agents. Required amount of catalyst were found 1% mole only. Here recycled catalyst specially, $Bi(OTf)_3$ was found to used without loss of activity11.

Green advantages

(a) Atom economy of the reaction is higher due to loss of by-product is only water. The water is a small molecule (18) of eco-friendly/ non-polluting nature.

(b) Reaction follows actual catalytic pathways [1% mole] instead of stoichiometric amount in conventional method. Catalysts can be recycled.

(c) Use of green acylating agents [RCOOH] and no solvent make the process green.

(d) Room temperature reaction and simple method minimize the energy requirement.

Post demonstration Work:

Instructor should explain how the green principles are applied to Organic synthesis, specially, towards applications finding more green methods.

Demo–IV: Bromination of trans-stilbene

Objectives: To Test the presence of double bond un-saturation through green methods.

Foundation: Green chemistry principles, conventional tests for un-saturation, etc.

Concepts: Double bond addition and in-situ reagents as green method.

Materials: trans-Stilbene - 1.8 g

HBr in water - 5.2 ml

30% Hydrogen peroxide - 7 ml

Ethanol - 10 ml

Demonstration Experiments: Reaction:

Stilbene + HBr + H_2O_2 → Ethanol + Dibromostilbene.

Green Procedure: Trans-stilbene (1.80 g) in ethanol (10 ml) was refluxed. The aqueous solution of HBr (33%) (5.2 ml) and hydrogen peroxide (H_2O_2, 30%) (7 ml) were added from a dropping funnel sequentially to this refluxing solution of stilbene. The colourless solution became deep orange in colour. Within 15 minutes, the orange colour disappeared. This indicates the bromination of stilbene. The solution was allowed to cool down. During this the precipitate due to stilbene dibromide separated out. The precipitate was filtered, recrystallized and dried. Conventional Procedure uses Non-green component of liquid bromine and Chlorinated solvents.

Green context

Corrosive liquid bromine is avoided

Atom efficient method and Water is the only byproduct in this method.

Conclusion

By using demonstrations with proper planning teachers can teach better and inspire the students more effectively.

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