Incorporation of Consumer Products in the Teaching of Analytical Chemistry

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We have developed (or selected) a number of experiments involving the use of common consumer products and incorporated them into our quantitative and instrumental analysis laboratories. These experiments were designed to achieve the following objectives: (1) to illustrate best the basic principles and techniques associated with analytical chemistry, (2) to increase the student's awareness of the importance of chemistry in consumer products, and (3) to help the student learn and use "critical thinking" in solving real-world situations. Some of these experiments would also be suitable for use in first-year organic or nutritional chemistry courses.

Experiments

Bromide in Calmatives

The bromide in calmative tablets is determined by the same classical method that is used in the gravimetric determination of chloride (*1*). Excess silver nitrate is added, followed by the weighing of the resulting silver bromide precipitate. Since silver bromide is more susceptible to photodecomposition than silver chloride, exposure to light should be minimized.

Iron in Vitamins and Iron Tablets

The tablet is dissolved in fuming sulfuric acid followed by the reduction of the iron to the ferrous state by passage through a Jones reductor. The iron content is then determined by potentiometric titration with a standard solution of ceric solution.

Ethanol in Wine

After appropriate dilution, the ethanol in the wine is separated by distillation into a known excess of standard potassium dichromate solution. The ethanol reacts with the dichromate to produce acetic acid and $Cr.^{3+}$ The ethanol content is determined by back titration of the excess dichromate with standard ferrous solution. To increase interest in the experiment, the students are encouraged to bring their own wine samples, including homemade wine and beer, for analysis. With some modifications this method should also be applicable to the analysis of other consumer products containing alcohol, such as cough syrup and after-shave lotion.

Calcium in Powdered Milk

The calcium in milk is determined by titration with a standard solution of EDTA (sodium salt of ethylenediaminetetraacetic acid). This is a modification of the classical experiment for the determination of water hardness (*2*). To make the experiment more meaningful, the student is told that the recommended daily allowance (RDA) of calcium by the Food and Nutrition Board is 1 g and , using his experimental results, is asked to calculate what percent RDA of calcium will be provided in an 8-oz glass of milk. This method should also be applicable to other consumer products such as tofu and calcium supplement tablets, after suitable sample preparation.

Potentiometric Titration of Acidic and Basic Compounds in Household Cleaners (3)

The acidic or basic compounds present in the cleaners are determined by potentiometric titration using a pH meter equipped with glass and calomel electrodes. The acids or acidic compounds commonly found in household cleaners are hydrochloric acid, phosphoric acid, and sodium hydrogen sulfate. The bases or basic compounds commonly found are sodium hydroxide, sodium orthophosphate, ammonium hydroxide, sodium carbonate, sodium bicarbonate, and sodium hypochlorite. This method of analysis is not only applicable to cleaners containing single acidic or basic compounds but also applicable to cleaners containing two-component systems such as Liquid Plumr, which contains sodium hydroxide and sodium hypochlorite. From the titration curves, the dissociation constants of weak acids or bases can also be determined.

Coulometric Determination of Sodium Hypochlorite in Bleach (4)

Sodium hypochlorite is the active ingredient in most commercial liquid bleaches. The hypochlorite content is determined by reacting a measured quantity of the liquid bleach solution with a large excess of iodide. The resulting elemental iodine is treated with a known excess of a standard thiosulfate solution. The remaining unreacted thiosulfate is back-titrated with iodine generated coulometrically at a platinum electrode. This technique obviates the need for the preparation and standardization of an iodine solution.

Students in the class are given samples of different bleaches for analysis, and the final tabulated results are made available for examination by all of the students. From the concentration of hypochlorite determined in the different brands, the students are asked to make price comparisons by calculating the cost (cents/ounce) of the active ingredient in the different brands of bleach solution. They can thus determine which product is the better buy.

Spectrophotometric Determination of Phosphorus in Detergents

The phosphorus additives in detergent, such as tripolyphosphate and pyrophosphate, are first hydrolyzed in sulfuric acid solution to orthophosphate. The phosphate solution is then subjected to spectrophotometric analysis by measurement of the colored complex formed upon the addition of vanadomolybdate solution. As part of the experimental lecture, the concern over phosphate pollution of the environment as well as the role of phosphate additives in the cleaning process is discussed. (Phosphates form moderately stable complexes with metal ions such as calcium, magnesium, and iron, thereby affording water-softening ability. They also disperse dirt and provide a buffered alkaline water condition for more effective cleaning.)

Separation of Components in Analgesic Tablets

Separation of the active ingredients (aspirin, caffeine, and acetaminophen) in analgesic tablets, such as Excedrin, is performed by thin-layer (*5*) and also by high-performance liquid chromatography (*6*). In the case of thin-layer chromatography, the students are asked to identify the components by their R_f values as well as by their ultraviolet spectra, obtained after removal from the plate and dissolution in methanol. In the case of high-performance liquid chromatography, the students are asked not only to identify but also to calculate the amounts of each of the active ingredients in the tablet.

Discussion

The following discussion explains in some detail how the above experiments achieved the three objectives that were stated in the introduction.

(1) *To illustrate best the basic principles and techniques associated with gravimetric, volumetric, and instrumental methods of analysis and to provide the students with a firm foundation in analytical chemistry.* It is important that the

student be taught the basic principles and techniques of analytical chemistry. Principles provide the student with the basics and the means to attack an analytical problem, and techniques provide the tools and the manipulation necessary to solve the problem and to obtain good data. All of the experiments listed above involve not only the use of common consumer products but also the basic principles and techniques intended to be illustrated. For example, the gravimetric experiment (bromide in calmatives) is designed to replace the classical gravimetric chloride experiment. It still illustrates the same basic principles and techniques such as solubility product, precipitation, filtration, etc., meant to be demonstrated by the classical experiment. However, because the sample used is a common consumer product, it is more interesting and thus more beneficial to the students.

(2) *To stimulate students' interest and to bridge the gap between academic life and real life, increasing the awareness of students of the importance of chemistry in consumer products.* For years, concerns have been raised regarding the lack of balance between teaching of theory and application in chemical education and the lack of relevancy between chemistry and everyday life (*7, 8*). As discussed earlier, principles and techniques are the fundamental components and foundation in the teaching of analytical chemistry. However, with only principles and techniques, the student would find the material being taught to be pedestrian and uninspiring. It would be a disservice to the students to instruct them only in subject matter that bears no relationship to their everyday living. A real-life example can enhance principle, and principle can help explain real-life examples.

The use of common consumer products in our experiments serves to stimulate students' interest as well as bridge this gap between academic life and real life. Whenever appropriate, instruction should be directed toward achieving this objective. One way would be to discuss the chemistry involved in the working of the consumer products. For example, in the experiment on the titration of acidic and basic compounds in household cleaners, it could be explained to the students how sodium hydroxide and sodium hypochlorite together work well as a drain cleaner. Another way would be to require students not only to analyze the sample but also to make use of the information to answer other questions concerning the consumer product. For example, in the experiment involving coulometric determination of hypochlorite in bleach, the students are asked to make price comparison by calculating the cost of unit quantity of the sodium hypochlorite in different brands of bleach.

(3) *To help the students to learn "critical thinking" by exercising their individual thought process.* In real-world situations, chemical analysis is generally not as simple as merely following a certain procedure to determine a specific component or the composition of a sample. Frequently, existing methods need to be modified or a new method devised in order to solve the problem at hand. "Critical thinking" enables the student to tie in all aspects toward one objective, which is to attack the problem efficiently and conclusively using both principles and techniques. The use of common consumer products is one of the important components in the training of students to learn "critical thinking" by exercising their thought process. With common consumer products the student is faced with real-life situations that not only exercise his or her thinking but also arouse interest in his or her work. In addition, the following have been incorporated into our teaching of analytical chemistry:

(1) *Not all details in the analytical procedure are given.* For example, the student is provided with the concentration range of phosphate in household detergent and is then expected to compute the proper sample size to use in an analysis.

(2) *Students are required to answer problem-oriented questions.* In the real world, chemical analysis is usually performed not as an end in itself, but rather for the resolution or elucidation of a problem. For example, the determination of the percent calcium in milk is important because it permits one to calculate the amount of milk that must be consumed to obtain the RDA of calcium. The determination of the RDA makes the experiment more interesting and places it in proper perspective as the objective of the analysis.

(3) *Students are asked to modify an existing method to overcome an analytical problem.* For example, the student is asked to modify the procedure for the spectrophotometric determination of phosphate in detergent so that it can be applied to the analysis of phosphate in cola drink. Because the color of the cola drink will interfere with spectrophotometric measurements, the analytical problem can be overcome by first passing the sample through activated charcoal. Furthermore, the step involving hydrolysis with sulfuric acid can be eliminated since all phosphorus in cola is already in the phosphate form.

(4) *Use of real analytical case studies to illustrate how principles and techniques are applied to solve analytical problems.* These problems usually require more than routine analysis and the solution of the problem generally involves assessment of the situation, selection of the best analytical approach, initial experimentation, review and possible modification of the method used, and final determination. The use of real analytical case studies not only exercises the students' "critical thinking", but also serves to unify the field of analytical chemistry for the students.

Conclusion

The use of consumer products in the teaching of analytical chemistry has been incorporated into our Quantitative Analysis and Instrumental Methods of Analysis courses in the last several years. From the enthusiasm and positive responses of students, we feel that the objectives for incorporation of consumer products in these courses have been met. The great majority of the students find the laboratory to be meaningful, not only in terms of being interesting and stimulating but also in terms of instilling a greater awareness of the close relationship of chemistry and consumer products. The students' enthusiasm is also reflected in the questions and lively discussions that usually ensue after a consumer product related topic is introduced in lecture. Finally, it should be stated that the use of consumer products is intended as a complement and not as a complete replacement for the conventional unknowns used in an analytical laboratory. The conventional unknowns have the advantage that the true percentages are known with a greater degree of accuracy and thus permit a more reliable evaluation of the student's performance.

Literature Cited

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