A GENERAL CHEMISTRY COURSE FOR PROSPECTIVE ELEMENTARY SCHOOL TEACHERS

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The paper describes a general chemistry course designed for students who are planning to become elementary school teachers. The course has been structured so as to transmit the fun and excitement of experiencing chemistry and uncovering its basic principles by centering on laboratory and other discovery experiences. In addition, the course uses peer led workshops in which the students discuss these experiences. The course is thus a product of a particularly strong collaboration between public schools and college faculties. It is going to become a part of a new four-course sequence that will be required of all students intending to earn elementary education certification at Lehman College.

Introduction

This course is a one-semester, general chemistry course that has been redesigned specifically for students who intend to become elementary school teachers. It is a course, however, that should be appropriate for any non-science major. It has been transformed from a lecture course that surveys all of chemistry together with a laboratory that only, at best, validates the ideas discussed in the lecture; to a course that can transmit the fun and excitement of experiencing chemistry and uncovering its basic principles. In earlier work done by others, general chemistry courses for science majors have been developed that use either inquiry based methods [1] or collaborative learning approaches [2]. This paper describes a course that uses both. In this dynamic approach, the students are exposed to many chemical experiences, and learn how the concepts of chemistry explain what is observed. In addition, there are demonstrations as well as lectures for those aspects of the course that cannot be covered in the laboratory. After each experiment, the students participate in peer led workshops in which they get into discussions with one another about the experiments that have been done, and their meaning.

The idea for this course came out of discussions held between Marc Lazarus and Katina Lotakis, a middle school assistant principal in September of 1994. At that time, they were both working in the Transitional Grades Science Leadership Institute Project (TGSLIP), a program to improve the science backgrounds of fifth and sixth grade teachers funded by an Eisenhower Grant. Since undergraduates fear chemistry and many

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had failed, it was hoped that approaching the course with hands-on activities that were not just for verification of chemical laws or theories would lead to a better understanding of the content and concepts taught. When the New York Collaborative for Excellence in Teacher Education (NYCETP) began, Mrs. Lotakis together with Debra Hendry, a middle school science teacher, and Ellen Funk, an elementary school teacher, formed an advisory committee that reviewed the laboratory experiments, workshop questions, and lecture notes; and, they provided input as to where misconceptions would arise for the learner. The course is thus a product of a particularly strong collaboration between public schools and college faculties.

Details of the Course

There is no formal textbook for the course. In essence, the notes that summarize the student's experiences become the textbook for the course. The idea behind this approach is that a student can better understand ideas when they have experiences to relate to them. Thus, experiences here precede explanations.

The course is set up so that there is a 2-hour lecture on one day, followed by a three-hour laboratory on another day. A typical class will have about 20 students in it. On the first day of class, we break the class up into four workshop groups. There are two workshop leaders who are chemistry majors and who are typically in their second or third year of chemistry courses. Each of these workshop leaders runs two of the workshop groups. On the first day of class, the evaluation exam is given; of the 19 questions on this test, most students get 2 right. A couple of students will get 8 or 9 right, while a couple of students will get none right.

The first meeting in the laboratory takes place on the second day of class. The students form lab partnerships. These are usually made up of two or three students who work together. The students are told to carefully write down what they observe. They are also told that each student will have to write a laboratory report for each experiment performed during the semester. The report is to contain: an experimental section describing what they did, together with any materials that were used; a section on results which includes a discussion that carefully describes all the observations made, and any appropriate interpretations of these observations; and, a conclusion section summarizing any general ideas that can be extracted from the experiment. Before the report can be written, the students will have attended the next class session. In each lecture class following the laboratory, there are workshop discussions designed to get students to participate in answering the assigned workshop questions. A lecture is then given which emphasizes the main points that come out of the workshop, and includes some additional insights. When all of the workshop questions have been discussed and all of the lecture material has been covered, then and only then are the students given a set of notes summarizing the main ideas obtained from the laboratory, the workshops, and the lectures.

It is apparent that the course is based on an inquiry-based model that uses collaborative methods as well.

The following paragraphs provide a listing of the basic topics covered as well as the types of experiences used to cover the topics.

1. **Chemical Reactions:** In this first laboratory, the students observe a series of chemical reactions. They learn about making careful observations and the language used to describe the observations; and, that color changes, formation of a precipitate, bubbling of gases, and the giving off of heat are often indicative of a chemical reaction.
2. **Tests for Some Common Substances:** In this experiment, various gases are prepared and tests for each gas developed. The gases that are prepared are Hydrogen, Oxygen, and Carbon Dioxide. In addition, a test for water is developed.
3. **Mass, Weight, and Volume:** The questions what is mass, what is volume, and how are they different from one another are examined, as well as the law of conservation of mass for chemical reactions. By seeing a demonstration of weighing performed on both a spring scale, and a two-pan balance, students are able to observe the difference between mass and weight. By measuring volumes, students are able to see that it is the space occupied. Different groups of students run different precipitation reactions, and they observe for themselves that the law of conservation or mass is obeyed. They also run a reaction in which one of the products is a gas, and they should be able to explain why there appears to be a loss of mass.
4. **Combustion:** Change in mass of a candle before and after burning as well as the

change in mass of a metal before and after heating in air, is examined. This produces the question: why does the candle lose weight while the metal gains weight? The results are analyzed in terms of the law of conservation of mass. The composition of air, together with an explanation for combustion, is achieved by doing an experiment that shows only 20% of the air combines with a metal and that the remaining gas does not give positive tests for hydrogen, oxygen, or carbon dioxide. In addition, experiments are done that show that a burning candle requires air, and that it produces carbon dioxide and water. Other experiments also show that if the amount of air is limited, the metal gains less mass than when completely exposed to air.

5. **Mixtures, Pure Substances (Elements and Compounds):** By examining mixtures and pure substances, it is concluded that the components of a mixture retain their identities. It can be concluded from previous experiments that a metal that combines with oxygen in the air is unlikely to decompose, and belongs to a class of pure substances called elements, while certain other pure substances can be decomposed and are called compounds. Students conclude that although a compound is composed of two or more elements, it is not a mixture and has a unique identity different from the elements of which it is composed.

6. **Atoms:** From examining an ordinary substance and thinking about it, together with the existence of elements, compounds, and chemical reactions, the student is able to see how the existence of atoms can be inferred. It can also be shown how the law of conservation of mass is explained by the atomic concept. An experiment is done to demonstrate the law of definite proportions. By making magnesium oxide, this law can be demonstrated. The idea that atoms of fixed mass characterize an element can be inferred from this law.

7. **Periodic Table:** The students design their own Periodic Table of the Elements for just 10 elements. They see if they can make predictions by looking at the current table. They learn the symbols of the common elements.

8. **Chemistry and Electricity:** The students do experiments to show that an electric current can be obtained from a chemical reaction. A demonstration of the electrolysis of water done in experiment 6, as part of topic 5, shows that electricity can be used to produce a chemical reaction. This shows the link between chemistry and electricity. Experiments with static electricity establish the existence of two opposite electric charges, called positive and negative. A

demonstration is done of a cathode ray tube, and experiments with magnets establish that cathode rays are negatively charged. Part of a Power Point presentation on the origins of atomic structure contains animations of the effects of magnetic and electric fields on cathode rays. The presentation includes J.J. Thomson's interpretation of these experiments in terms of a negatively charged electron. We also discuss what constitutes an electric current.

9. **Origin of Atomic Structure:** The experiments that led to the Thomson model of the atom and Rutherford's discovery of the nucleus are shown on additional animations included in the Power Point presentation. Each student is able to see continuous spectra from a white light, as well as line spectra of individual elements using light dispersing gratings. The question arises: why do individual elements produce characteristic line spectra? The Power Point presentation concludes with an animation showing line spectra and how Bohr's model of the atom explains line spectra.

10. **Ions:** Conductivity of various solutions, and melts are examined using a light bulb circuit. Why do certain solutions conduct electric currents while others do not? The concept of the ion explains the observations. The students learn the names and charges of the various common ions, and how to name ionic compounds. Examining various solutions, the colors of a number of ions are identified. The students then experiment with and see for themselves: a) precipitation reactions and, b) single displacement redox reactions. The reactions are explained in terms of what happens to the ions in solution. They also learn how to represent these reactions as chemical equations.

11. **Acids, Bases, and pH:** Certain experiments are done using reactions between metals and acids that suggest that all acids contain the Hydrogen ion. An electrolysis of sulfuric acid solution producing hydrogen at the cathode will show that the hydrogen ion is positively charged. Tests are developed for detecting acids and bases using litmus paper. There is a discussion of the pH scale. They also do experiments from which they can conclude that metal oxides react with water to produce bases, while non-metal oxides react with water to produce acids. The applications to the acid rain phenomenon are discussed.

12. **Chemical Bonding:** By examining the known formulas of various compounds, it is possible to figure out the rules of valence for atoms of each element and how

they relate to the Bohr model of the atom. These rules of valence place limits on the kinds of compounds that can be made, as in organic chemistry.

The course is structured so as to expose various components of the scientific strategy. The opening part of the course (Topics 1 and 2 in the syllabus) is designed to develop an appreciation of careful observation, and the proper language for recording these observations. At the same time, tests are developed that will help the student understand combustion and other topics in the syllabus further along in the course. Combustion (Topic 4) is studied because it is a subject strongly tied to the origins of modern chemistry, and is an important common phenomenon that too few students seem to understand. It also can be interpreted in terms of the law of conservation of mass, which is discussed as part of Topic 3. This demonstrates how laws arise out of generalizations of observations. This again is seen in Topic 6 for the law of definite proportions. Topic 6 also shows, using atomic theory as an example, how theories arise to explain laws and observations. Topic 7 uses the development of the periodic table to show the importance of classification in science. The use of symbols for elements and compounds (Topics 5, 6, 7, 10) and the use of chemical equations (Topics 10 and 11) show the importance of representation in science. The evolution of the atomic model (Topics 8 and 9) demonstrates how scientific theories are changed as new experimental observations are made. Chemical Bonding (Topic 12) demonstrates how scientists search for the limits that nature imposes. Not every conceivable compound can be made.

Although the topics covered in this course are very basic and fundamental, discussions with science majors have led the author to conclude that many of these majors are not well grounded; they have difficulty understanding some topics, such as combustion. In addition, workshop leaders who are chemistry majors and who were taking the senior level inorganic chemistry course have commented on how helpful the Power Point presentation on atomic structure was in enabling them to better understand this topic as it was covered in their course.

In order to illustrate further the approach used in the course, the following description of a typical class is included.

Description of a Typical Class

In this experiment, the students prepare three gases. They are, however, not told what the three gases are. The students are required to make a line drawing of the gas-generating apparatus, together with their descriptions of the starting materials. They are also expected to describe what they see happening in the reaction vessel from which the gases are generated for each of the reactions.

As described in the experiment, they then perform separate tests on three separate samples of each gas. After the students have held a workshop discussion of the experiment, we hold a question and answer session in class in order to make sense out of what the students have observed.

The results of the tests performed on the gases are as follows:

Test	Gas1	Gas2	Gas3
Burning splint	Burned more brightly	Popped	Went out
Glowing splint	Reignited	Nothing happened	Went out
Barium hydroxide	Nothing happened	Nothing happened	White precipitate

It was noted that all three gases were colorless and odorless. However, they had different properties. It can be seen that a gas is defined by its properties. It is then assumed that the students were the first people to make these gases and we have some fun assigning names to the gases. This emphasizes that a name can be assigned to a gas with specific properties. Eventually, the student is told that gas 1 is oxygen, gas 2 is hydrogen, and gas 3 is carbon dioxide. These gases are then seen not just as names, since the student has had some experience with them.

In addition to the experiments on gases, the students test water and another clear, colorless liquid with cobalt chloride paper. The cobalt chloride paper turns from blue to pink in the presence of water, but remains blue in the presence of the other clear, colorless liquid. From this, they learn that not each clear, colorless liquid is water.

The tests for gases as well as the test for water are later used in the study of combustion.

Conclusion

This course will be a part of the four-course science sequence that will soon be required of all elementary education minors at Lehman College. It is hoped that this course will represent not only the subject of chemistry, but also a better way of teaching it.

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Bio

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References

[1] R.W. Ricci and M.A. Ditzler, "Discovery chemistry: A laboratory-centered approach to teaching general chemistry," *Journal of Chemical Education*, **68** (1991) 228.

[2] A.E. Woodward, M. Weiner, and D. Gosser, "Problem solving workshops in general chemistry (NSF)," *Journal of Chemical Education*, **70** (1993) 651.