Commentary

Reforming the General Chemistry Textbook

by Ronald J. Gillespie

Most of use who teach chemistry want students to *understand* what we teach them. But many students, perhaps most, do not try to understand. Even if they set out trying to understand they usually soon conclude that it is too difficult, at least in the time they have available, and they resort, like the others, to learning the material. By *learning* they mean *memorizing*—names of substances, formulas, definitions of oxidation and reduction, shapes of orbitals, recipes for assigning oxidation numbers and doing pH calculations, etc., etc. Most students do not particularly object to doing this because it is what they did in high school and is what it means to study. Many will object to being expected to understand, as they find it easier to memorize and most of them have little understanding of what it means to understand. Surprising as it may seem to us, they see chemistry as very abstract, very difficult, and unrelated to real life. But this is perhaps not so surprising if we remember that for these students, chemistry consists of a large amount of apparently unrelated, irrelevant, and useless material that they have memorized rather than understood! Their main objective is to pass the course and get on to something they consider more interesting and more useful. They take from the course very little of value in other courses or in later life and little, if any, understanding of what chemistry is really about—merely a conviction that they will never understand it. Over many years I have noticed that when I meet people socially and reveal that I am a professor of chemistry, they are amazed. How could an otherwise normal-appearing sort of guy possibly understand that stuff? They often admit, somewhat apologetically, that chemistry was their worst subject at high school or university or that it was the most difficult of all the subjects they took. Why do I rarely meet anyone who tells me chemistry was fascinating or exciting, or at least interesting? Why do most students find chemistry so abstract and difficult? Why do they not *understand* the chemistry that we try to teach them?

Chemistry: The Relation between the Microscopic and the Macroscopic

Many of us have felt for a long time that there must be something wrong with what we are teaching, but there has been very little agreement about what is needed to change the course so that students will not find chemistry so difficult, irrelevant, and abstract. One problem is that students have difficulty making the connection between the macroscopic world of observations and the microscopic world of atoms and molecules. Yet it is this aspect of chemistry that sets it apart from other sciences. If students do not make this connection, they fail to see the relevance and importance of chemistry to the real world. An understanding of this connection is probably the most important thing that a student can get out of an introductory course.

Why Has There Been So Little Change in the Course and the Textbook?

General Chemistry has been discussed at countless conferences and symposia, in task forces and committees, and in department meetings; but little change has occurred and General Chemistry remains much as it was 20 or even 40 years ago. Why? One reason may be that textbooks have not changed. No widespread change can occur until a new kind of text is published and widely adopted. There are many well written and lavishly illustrated texts, but almost all of them treat the same conventional material in more or less the same conventional way. No matter how excellent these texts appear to the instructors who choose them, they have not succeeded in interesting the vast majority of students or in providing them with an understanding of chemistry—or even with useful information that they remember and use later in life.

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Why have so few textbooks tried a new approach? Publishers are reluctant to invest in unconventional books on the chance that one might become a best seller and revolutionize General Chemistry. Even authors who are convinced of the need for change are reluctant to write a book that is too unconventional because of the difficulty of finding a publisher and getting it adopted. Why have none of the few nonmainstream books that have been published been widely adopted, leading to widespread reform of General Chemistry? Because most instructors do not see the need for change, or do not have time to adapt to a new text and write new course notes? Because no author has yet hit upon the right formula for stimulating the much-needed change?

Who Will Initiate and Support Reform?

It seems to me that discussion has gone on long enough. We will probably never get widespread agreement on how to reform General Chemistry until a truly new textbook is published, which influences enough teachers to change that the new way of teaching becomes the accepted way. Getting such books published and adopted will need some initiative from bodies such as the National Science Foundation, the American Chemical Society, or one or more of the large chemical manufacturers. Their support and financial assistance will be required not only to subsidize the writing and publication of such books, but also for retraining workshops for instructors. These organizations could make no more important contribution to the future of chemistry than to provide this support.

Some Suggestions for Future Textbook Authors

In the hope of stimulating discussion, I make a few suggestions for consideration by future textbook authors.

1. *Forget about the needs of chemistry majors.* Very few students in General Chemistry will become chemistry majors and only a small number will take even one more chemistry course. Although it is not the main reason for reforming the course, we hope to persuade more students to become chemistry majors. However, there is no need to include material in the text simply because it will be needed by majors. When the students' enthusiasm for chemistry has been ignited they will easily and eagerly absorb this material in the majors' courses.

2. *Continually emphasize the relationship between the macroscopic world of observations and the microscopic world of atoms and molecules.* This relationship is the unique aspect of chemistry, and understanding it makes chemistry alive and relevant. Demonstrations of the properties of substances and reference to the role of these substances in the real world, followed by explanation of the observations in terms of the atoms and molecules of which substances are composed, is essential. Putting observations first shows students that the theories and principles that are so large a part of General Chemistry are there not just to be learned, but to help in understanding these observations.

3. *Cut out unnecessary details and busy work; concentrate on what is needed to understand chemistry.* Why start a textbook with details about the names and formulas of substances? This is boring. Show students some real chemistry. Bring in what is essential for naming and writing formulas of substances only when they are being discussed. How many chemists ever bother to balance an equation, particularly the complicated redox equations so common in textbook exercises? A few students will enjoy the challenge, but are they learning chemistry? Although the principle is important, time spent balancing any but the simplest equation is time better employed on other topics. Is it really important that students know how to calculate the pH of a solution when they will never have to do such a calculation again? Even if at a future time they do need to know the pH of a solution, they will use a pH meter. This will give them a more accurate (in some cases much more accurate) value than the simplified calculation they learned (and have probably forgotten) how to do in General Chemistry. Do students really need to learn the shapes of orbitals? These shapes cannot be made understandable to students at this level. Is it not enough to understand that atoms are held together by the electrostatic attraction between electrons and nuclei? Details of bonding theories should be left for chemistry major courses.

4. *Show the broad scope of chemistry.* Students in General Chemistry have a broad range of interests. Why not show them that chemistry is indeed the central science, basic to understanding all materials, whether organic or inorganic, synthetic or naturally occurring; show them how chemistry is relevant to the geologist, biologist, engineer, astronomer, doctor, environmentalist—indeed, to everybody? Make General Chemistry truly general, rather than the elementary physical chemistry course it is at present.

5. *Make the textbook shorter,* so that the material can be covered at a pace that allows time for understanding. Many students are overwhelmed by the amount of material and detail in most texts.

Perhaps these suggestions will inspire some author to write, some publisher to publish, and some organization to support the revolutionary text that we need. Perhaps such a text will follow only some (or none) of my suggestions, but I hope the questions I have raised will provoke some potential authors to propose their own solutions. The approach of the year 2000 is inspiring many to think about change. Let us hope that chemists will be able to celebrate the new millennium with a new, more inspiring, approach to General Chemistry.

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Ron Gillespie invites comments by readers to his questions and suggestions. They may be sent directly to him or to the *Journal.* If there is sufficient interest they will be included in a future issue.