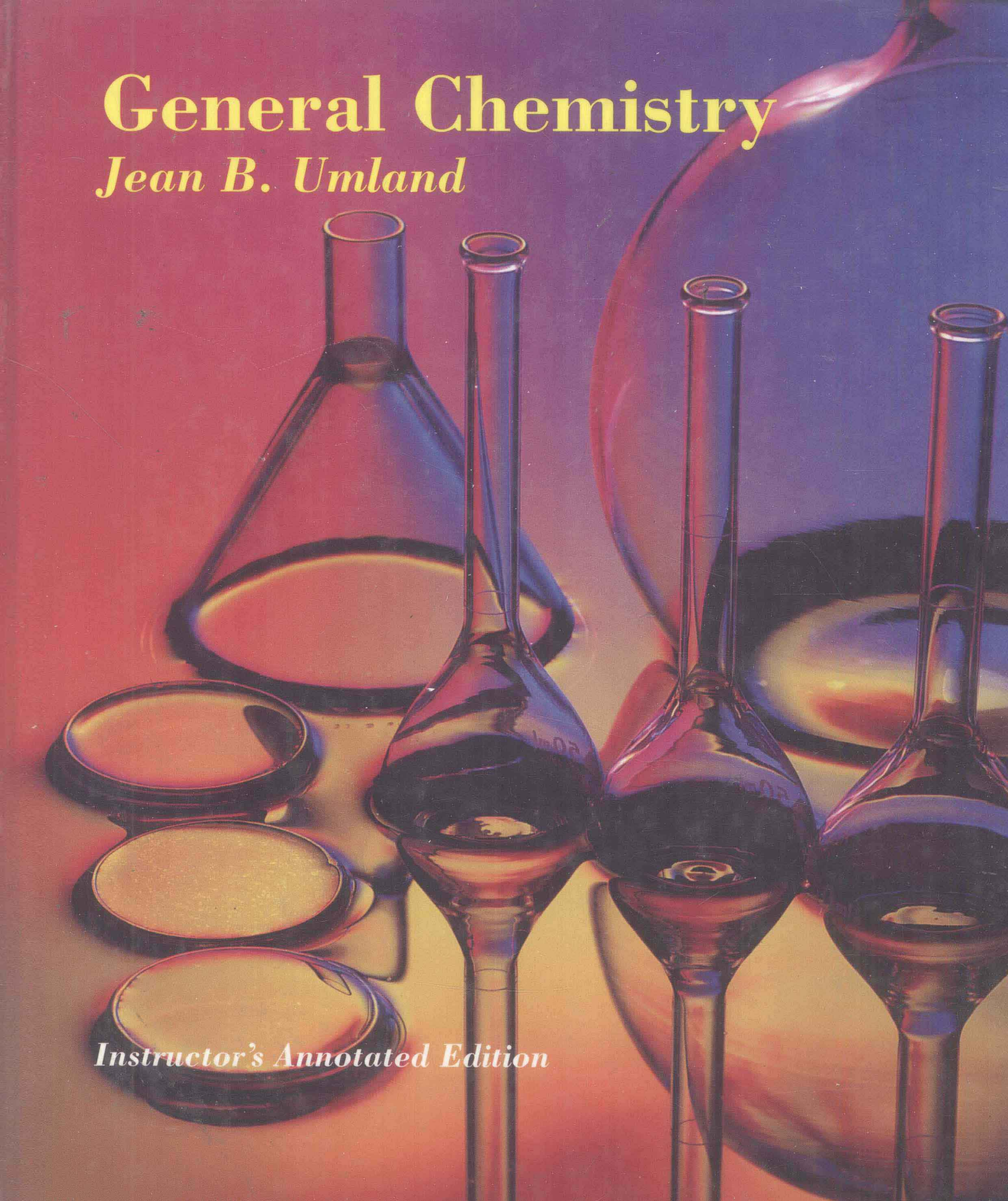
General Chemistry

Jean B. Umland



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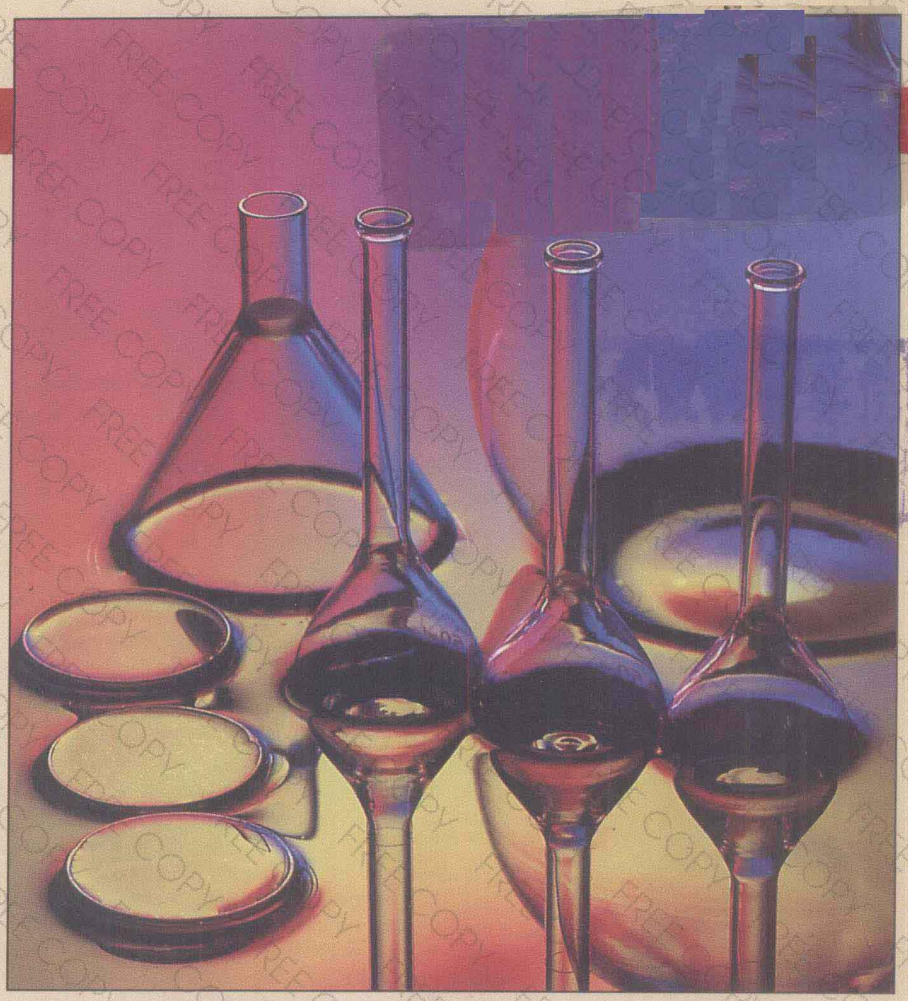

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To the Student

This book has been written to help you learn and enjoy chemistry. To do that, you must also learn to think like a chemist: to observe, to inquire, to draw reasonable conclusions, and to solve problems. These are the essential skills of chemistry. They will help you organize a large amount of information into an understanding of chemical processes. The ability to solve problems and to use relationships between concepts and information will be the measure of your mastery of the subject, not the acquisition of chemical "facts."

One of the major themes of this book is *building on what you know*. Although you may not come to general chemistry with a strong background in science or mathematics, you have had a chance to observe the chemical world just by living in it. By organizing and investigating your observations of the world, and of chemical behavior, you can understand underlying concepts.

In this book, the organization of the chapters reflects the emphasis on building on what you know and on connecting observations to understanding. Each chapter begins with an explanation of why the topic of the chapter is important to an understanding of chemistry and then reminds you of what you already know that relates to the chapter topic. The early sections of the chapter will usually include examples and discussions of chemical properties and behavior that will help you to understand the theories presented later in the chapter. In this way, theories are developed naturally, not just stated.

Throughout the chapters, you will find series of *related art and photographs* that illustrate the material being discussed in the text. Study these illustrations and their captions because they relate directly to the principles you are learning. You may see some of the reactions again in lab.

Marginal notes are used throughout the book to help you make connections. The *green flasks* signal learning hints and often will remind you of related material or a main idea. The *yellow flasks* mark safety hints, frequently concerning something you may encounter in the lab. *Red flasks* remind you to check your work. They are usually associated with the "*reasonableness checks*" that end many of the Sample Problems. Marginal notes without flasks are used to present related information without interrupting the flow of the discussion.

Another major theme of this book is the need for a *thoughtful, logical approach to problem solving*. Just as you build information and observations into an understanding of principles, you solve problems by using the principles in a reasoning process. Although some problems can be solved by memorizing a procedure, only by thinking through a problem will you increase your understanding so that you are able to solve problems that don't fit a simple pattern.

This book provides you with lots of assistance in developing your problem-solving skills. In each chapter, many *Sample Problems* demonstrate the use of each important concept or skill, using step-by-step explanations. Work through each Sample Problem, trying to follow the reasoning. Then try the *Practice Problems* that immediately follow the Sample Problems. Scientists read with paper, pencil, and calculator in hand. You should do each Practice Problem as you come to it, then check your answer in Appendix F. The more in-chapter problems you do, the better you will do on the "homework" problems at the end of the chapter.

The material at the end of the chapters is designed to help you check your understanding of concepts and skills:

- The *Summary* resembles a glossary in narrative form and gives the terms a meaning in context. Use it for a general review of the chapter content.
- The *Additional Practice Problems* are similar to the Practice Problems in the chapter. Try to work them without referring to the book. If you get stuck, look at the end of the problem for the section number (in parentheses) to which the problem is related; then restudy that section.
- The *Stop and Test Yourself* questions are multiple-choice questions covering the basic skills and concepts in the chapter. Check your answers in Appendix F before going on to the higher-level problems that follow.
- The *Putting Things Together* problems require you to combine skills from more than one section of the chapter and from different chapters.
- The *Applications* problems deal with real-world applications of chemistry. These problems challenge you to demonstrate your mastery of chemical concepts and problem-solving skills.

Answers to the blue-numbered problems appear in Appendix F. Other appendixes will help you review mathematics and chemical nomenclature and provide data that you will need to solve problems. Solutions to the problems with blue numbers may be available to you in the *Student Solutions Manual*.

If you need more help with problem solving, use the *Study Guide* that is available with the text. It has been written specifically for this text and gives you more Sample Problems to study and many Practice Problems to do. The Study Guide also includes a chapter with lots of ideas and help on how to study chemistry effectively.

Advice on Studying

At the end of each academic year, I ask my students to write down their advice to next year's class on how to succeed in chemistry. Here are some of their suggestions:

- Skim the assignments before coming to class. Write down any questions you have.
- If possible, always go to class. Ask questions if you don't understand something.
- After class, study the chapter carefully. Make sure you understand the worked-out examples, and do the in-chapter problems and check your answers to them as you go along. Use flash cards for memorization. Then work the assigned end-of-chapter problems.
- Set aside a regular time to study. Do assignments in little sections every day. Don't wait until the week before an exam to start studying. If you cram for the test, the material will be stored in your short-term memory, not long term, and you will forget it soon after the exam.
- Do not overstudy. Study just until you feel confident and comfortable with the material. Get a good night's sleep the night before a test so you are rested and ready to think during the exam. Don't drink a lot of coffee before a test.

To these suggestions, I would add one more: Pay careful attention to vocabulary. An important part of a first course in any subject is learning the meaning of the terms used in the field (which, unfortunately, do not always mean the same thing they do in everyday life or in other fields). In this book, new terms are in boldface type and are defined and explained as simply and accurately as possible. Most are

also included in the summary at the end of the chapter. If you do not remember the meaning of a term when you meet it again later, use the index at the back of the book to find the definition. The index also includes references to other places where the term is used.

If you are having difficulty, *use* the help that's available—your instructor's and teaching assistant's office hours, for example. Many colleges and universities also have computer programs, videodiscs, and other materials to assist you as well as services such as reading and math labs.

In writing this book, I have done my best to make chemistry both understandable and interesting. Please let me know where I have succeeded and where I have failed so that I can do better in the second edition. Good luck!

Jean B. Umland

To the Instructor

Audience

This book is intended for a full-year general chemistry course for pre-engineering students, pre-health professions students, and science majors, including chemistry majors. It assumes that students know how to solve simple algebraic equations, but no previous study of chemistry or physics is assumed.

Philosophy

In my experience, most students take chemistry for three purposes: (1) to learn how to think; (2) to learn something about science as a part of their general education; (3) to learn the chemistry needed for their other courses and future professions. This philosophy has influenced many aspects of this book.

Descriptive Chemistry. For students to learn to think, they must first know something to think about; therefore, in this text, descriptive chemistry and theory are integrated. Reactions, which I believe are the heart of chemistry, are introduced in the first chapter and are the subject of much of the third and fourth chapters. Throughout the book, marginal notes and footnotes, color photographs, Related Topic boxes, and the Applications problems supply a wealth of facts about chemicals and chemical reactions. Both common organic compounds and important inorganic compounds are used as examples. In the last four chapters, where descriptive chemistry is the main focus, I have tried to pull together the material from earlier chapters as much as possible. Students only master material by meeting it several times in different contexts. In these chapters, I have also tried to include more food for thought and fewer facts to be memorized than is usually the case in descriptive chemistry chapters.

Readability. To make the material as easy as possible to understand, definitions and explanations are written in familiar words: "make easier" rather than "facilitate," for instance. Also, more detail is often provided than in other texts. For example, most texts simply list rules about the number of significant figures; this text explains where the rules come from. I find that students who understand the rules are more willing and better able to follow them. I think that one of students' major problems in understanding chemistry is their lack of information that authors and instructors assume is common knowledge. Just as a stranger needs more detailed directions than someone who is familiar with a town, beginning students need more details to understand chemical concepts than people trained in the field.

Units. For the foreseeable future, students will need to be familiar with both SI and conventional units. For many purposes, SI units are more convenient to work with once you get used to them, and they are usually introduced first in the book. However, as long as mercury barometers are used to measure pressure in general chemistry labs, balances are read in grams, rulers in centimeters, and thermometers in degrees Celsius, I think that these units should also be used in general chemistry texts. Naturally, students are taught how to interconvert units. Because most students now use calculators, natural logarithms are used except for pH. The

popular form of the periodic table is introduced first (in Chapter 1) so that it can serve as a basis for organizing descriptive chemistry right from the start. The new form is presented later (in Chapter 8).

Organization and Coverage

In choosing which material to include, I first considered the needs of students who take general chemistry as a prerequisite for other science and engineering courses. Then I thought about students who take only one chemistry course. Although chemistry majors are also important, they can be taught in later courses whatever they need that has been omitted from general chemistry, providing they have a good foundation.

Chapter Organization. Each chapter starts with a preview of its contents and ends with a summary. At the beginning of each chapter is a "salespitch" to tell the student why he or she should be interested in learning what's in the chapter; this introduction is followed by a discussion of what the student already knows about the subject from everyday experience and, in later chapters, from previous study. Next some relevant experimental observations are introduced, and students are led to generalizations about the data. Theory to explain the generalizations is developed last. My intention was to involve students in the discovery process and let them experience the "Aha!" feeling; I think that this is the best way for them to learn how science works and why scientists enjoy their work. Students who have read the text have responded to this approach and have commented favorably.

Text Organization. Most general chemistry texts cover measurement and significant figures in the first chapter. This book begins with an introduction to *chemical reactions*, so that the first lectures—where students form their impression of the subject—can include more interesting demonstrations. Early chapters provide plenty of material for laboratory work involving chemical reactions as well as for quantitative experiments.

The concepts of both *enthalpy* and *entropy* are introduced early (Chapter 6). Entropy is as important, if not more important, than enthalpy in determining whether a change will take place and should, I feel, have equal time. However, because experimental measurement of enthalpy changes is much simpler than experimental measurement of entropy changes, enthalpy is treated quantitatively in Chapter 6, whereas a quantitative treatment of entropy is postponed until Chapter 17.

The idea of rate as a factor in whether a change will take place is also introduced in Chapter 6 and is used again and again. The quantitative treatment of *kinetics* follows thermodynamics because, just as shooting at a moving target is harder than shooting at a stationary one, kinetics is more difficult than thermodynamics. (If you prefer to do kinetics before thermodynamics, you can postpone the section on rate constants and equilibrium constants until after you have covered equilibrium constants.)

In some texts, *gases* are covered just before liquids and solids. But since the material on gases forms the basis for the atomic theory, it is presented here before atomic theory. As solids can't very well precede chemical bonding, gases and solids are separated. If you prefer gases just before liquids and solids, Chapter 5 can easily be postponed.

Hydrogen has a separate chapter, which includes water, because hydrogen is unique among elements and water is unique among compounds. *Organic chemistry* follows hydrogen because organic compounds are second in number and importance only to the compounds of hydrogen. I have tried to write an organic chapter that will give students an idea of what modern organic chemistry is about and how

the organic chemistry of carbon fits into the rest of chemistry. This approach seems preferable to trying to cram the reactions of all major classes of compounds into one chapter as is often done. One has only to glance at the abstracts of the papers from the Organic Division of any meeting to see the importance of chirality in contemporary organic chemistry. Therefore, stereoisomerism comes early in Chapter 22. *If models are used*, stereochemistry is very concrete, and my students do not find it difficult.

Throughout the writing of this text, many reviewers mentioned topics that they felt were important but optional. These *optional topics* are usually located at the ends of chapters so that they may be easily assigned for reading only or omitted entirely. See, for example, the section on the calculation of atomic and ionic radii and Avogadro's number in Chapter 12 or the section on colloids in Chapter 13. Later chapters do not assume knowledge of the material in these optional sections.

Problems and Problem Solving

In-Chapter Problems. Many worked-out *Sample Problems* are presented as examples throughout the chapters. Some teach students to use the pictures and graphs—two things experienced scientists usually do but students do not. In the Sample Problems, I have tried to teach students to use a thoughtful and logical approach to problem solving rather than simply memorizing procedures or using dimensional analysis as a substitute for thought. Dimensional analysis is stressed as a way to check answers, and the importance of checking work is emphasized by the "reasonableness checks" that conclude many Sample Problems.

An example has not been included for every kind of problem, however. Where I feel that the explanation in the text is adequate, I ask the student to answer questions without a Sample Problem. Students need to realize that they are supposed to be learning to solve problems, not just to follow examples. The concentration of Sample Problems decreases toward the end of the book; by the time they reach the final chapters, students should need worked-out examples only for completely new processes.

In the chapters, Sample Problems are usually followed by one or more *Practice Problems*. These give students a chance to work problems similar to the examples and to reinforce their understanding of skills and concepts. I have included more problems than usual within the chapter text because in-chapter problems encourage students to be active, not passive, readers. Students who work through the in-chapter problems will gain a much better understanding of concepts and skills than those who simply read through them. There are enough Practice Problems that some can be assigned as homework, along with end-of-chapter problems. Answers to all of the in-chapter Practice Problems appear in Appendix F, and solutions are available in the Student Solutions Manual.

End-of-Chapter Problems. The end-of-chapter problems begin with the *Additional Practice Problems*. These are drill-and-practice problems similar in difficulty and covering the same skills as the in-chapter problems. They are generally paired with the in-chapter Practice Problems. Although they begin at the end of the chapter, the Additional Practice Problems are numbered in continuous sequence with the in-chapter Practice Problems to emphasize the importance of the in-chapter problems. Approximately 85% of the Additional Practice Problems are followed by a parenthetical notation indicating the section of the chapter to which the problem refers. Not all of these problems are classified, however. Few problems I have met in the real world have come labeled "Boyle's law"; classifying problems is an important skill that students need to develop. The section or sections to which

each unclassified problem relates are given in the **Instructor's Resource Manual** to aid you in assigning a good selection of problems.

The next group of problems is called *Stop and Test Yourself.* It is a multiple-choice self-test covering the basic skills and concepts from the chapter so that students can quickly check their readiness to go on to higher-level problems. Also, skill in taking this type of test is important to many students (for admission to medical school, for example), and they need practice. Answers appear in Appendix F along with the number of the section to be restudied if the student answers the question incorrectly. The answers are explained in the Student Solutions Manual, which instructors may choose to make available to their students. The self-tests are in the book, not in the Study Guide, because the students who most need the self-tests are, in my experience, those least likely to use ancillaries.

The self-test is followed by *Putting Things Together* problems. Many students can do all of the individual operations, but have trouble putting them together. The Putting Things Together problems help students become better problem-solvers by requiring them to combine material from different sections of the current chapter or material from the current chapter with material from earlier chapters.

Last come *Applications* problems in which students must apply chemical skills and concepts to real-world problems. These problems appear last, after students have had lots of practice with "generic" problems.

The end-of-chapter problems range from simple to fairly challenging so that the level of the course can be tailored to suit different audiences. Each chapter also includes a few "*imported*" problems taken from texts in fields related to chemistry and from various standard examinations, such as the MCAT, to show students that we chemists are not the only people who think the topics discussed in general chemistry are important. These are printed exactly as they appear in the original sources to give students experience with different styles of questions, and include a few that are not as carefully worded as the problems original to this text. Many more problems are provided than any student will have time to do so that problem assignments can be varied from year to year. Solutions to many end-of-chapter problems (those with blue numbers) and all the in-chapter Practice Problems are given in the *Student Solutions Manual,* for the benefit of instructors who like their students to have solutions available. (For the same problems presented in the *Student Solutions Manual,* the answers only are provided in Appendix F.) Answers and solutions to the remaining end-of-chapter problems are given in the *Instructor's Solutions Manual.*

Special Features

Guest Essays. Guest Essays are included between the chapters to give students perspective on the importance of chemistry to life after college. Guest essayists of various backgrounds and ages (many not much older than most students) reflect on their experiences in general chemistry and describe the role of chemistry in their work. As students study chemistry throughout the year, these essays should remind them that an understanding of chemistry can lead to many opportunities and be of value in many career choices.

Accuracy. Research has shown that even competent scientists retain wrong information and inefficient ways of doing things if they learn them first. Therefore, in simplifying material for beginning students, it is very important that it should not be incorrect. In other words, those who go on in science should have correct facts and ideas to build on and not have to unlearn anything. In addition to the usual reviews by teachers of general chemistry, many chapters have also been reviewed by chemists who are specialists in the area concerned and by colleagues in related

fields such as astronomy, biology, geology, and physics. I have tried very hard to avoid "common textbook errors" and to use the best available data. The placement of La, Ac, Lu, and Lr in the periodic table is an example. Where the treatment is different from that in other texts, references to the literature are given in the *Instructor's Annotated Edition*.

Instructor's Annotated Edition. I have prepared a special edition of the text for the use of instructors. The *Instructor's Annotated Edition* contains marginal comments in blue to signal the location of related material, to explain why a particular approach is used, to cite references to the chemical literature, and so forth. Most of these marginal notes to instructors are derived from the "dialogues" that were carried on between the reviewers and myself in the margin of the manuscript through many drafts of the text.

A recurring comment on my student evaluations is that I have made the material in the text make sense. I hope that students who use this text will find that it helps them make sense of chemistry.

Supplements

An extensive package of supplements has been created to support both the instructor and the student. It includes the following:

- **Study Guide.** The Study Guide has been written by Kenneth J. Hughes of the University of Wisconsin—Oshkosh. Each chapter includes a review of the text material, followed by sample problems. Chapters conclude with diagnostic self-test questions and a variety of Practice Problems. Outline solutions are provided for all Practice Problems. An introductory chapter on reading and learning scientific material has been written with specific reference to the textbook; it provides practical strategies for learning chemistry, with particular emphasis on vocabulary.
- **Student Solutions Manual.** Prepared by Jean Umland and Byron Christmas of the University of Houston—Downtown, the Student Solutions Manual provides complete solutions to all of the in-chapter Practice Problems and to as many as half of the end-of-chapter problems (identified by blue numbers).
- **Instructor's Solutions Manual.** Written by Jean Umland and Byron Christmas, the Instructor's Solutions Manual contains solutions to all problems for which answers are not provided in the Student Solutions Manual.
- **Instructor's Resource Manual.** Written by Jean Umland, this supplement provides a variety of information, including suggestions for adapting the text to courses of different organizations, lengths, levels, and emphasis; references to section numbers for all unclassified problems; additional text sections (on normality, for example); suggested classroom demonstrations; and other resources.
- **Test Bank.** Prepared by Cleta Kay Hanebuth of the University of South Alabama, the test bank includes over 2200 questions in both multiple-choice and short-answer formats. The test bank is available in hard copy and on disk with a computerized test generator that allows instructors to modify, write, and display test questions. The testing program has outstanding graphics capability and a full range of chemical symbols. IBM and Macintosh versions available.
- **Transparencies.** Transparencies of about 160 of the most important illustrations from the text are available in full color.
- **Experiments in General Chemistry.** This laboratory manual by Steven Murov of Modesto Junior College provides 35 tested and clearly presented

experiments covering a wide range of topics. The presentation often uses an "inquiry" approach and emphasizes connections between text topics and lab experiences. Safe laboratory practices are emphasized, and the use of hazardous substances is limited to the minimum amount required for reliable results. Available with or without electronic lab worksheets customized for use with LabSystant software (see below).

- **Qualitative Inorganic Analysis.** This combined text and lab manual by William T. Scroggins of Chabot College introduces qualitative analysis techniques and their underlying equilibrium principles and provides a wide range of experiments.
- **Videotapes.** A variety of videotapes are available to adopters, including instructional tapes on *Graphing Scientific Information* and *Using a Scientific Calculator*, both of which have been created for this text by Michael Clay of the College of San Mateo.
- **Software.** *Introduction to General Chemistry*, by Falcon Software, provides a graphics-oriented student tutorial in 13 modules for IBM compatible computers. *LabSystant* by Trinity Software allows instructors to create electronic worksheets for quantitative labs. In addition a *Checker* program helps students find and correct errors in lab data and calculations, and prints out lab results. A disc available in the Murov lab manual provides electronic lab worksheets matching those printed in the lab manual.
- **Videodisc.** *General Chemistry* videodisc contains demonstrations and experiments that are difficult, expensive, or dangerous to perform in class. Most of the experiment footage is original, developed specifically for this text, with some footage also from *Exploring Chemistry: An Educator's Perspective* by Loretta Jones and Stanley G. Smith (University of Illinois at Champaign-Urbana). Much of the artwork from the textbook is also included, with animation when motion is inherent to the concept.

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I especially appreciate the participation of the guest essayists and their commitment to giving students a perspective on the diverse careers that can emerge from an educational background in chemistry. Melanie Shouse, editorial assistant, also deserves special thanks for her work in coordinating these essays.

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I also welcome your contributions to this book. If you should find any errors, I would be grateful if you would let me know so that I can correct them. Your comments and suggestions about any part of the text or its supplements will be appreciated.

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To my husband, Carl,
for his support and help during the years I have been writing,
and to students,
both those whom I have taught personally
and those who will use this book.

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This text begins with chemical reactions, not with measurement. Models are used from the beginning so that students get used to visualizing reactions and physical changes on a microscopic scale. The periodic table is introduced early and used often throughout the book.

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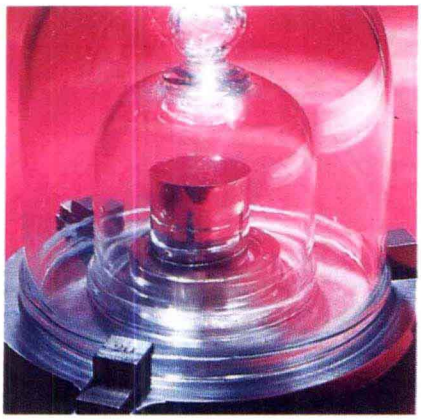

Analogies from everyday life are used to help students develop from concrete operational reasoners to formal operational reasoners; for an example, see page 61.

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