

# Introduction to Chemical Principles

Seventh Edition

H. Stephen Stoker

Webster State University



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# **Preface**

Introduction to Chemical Principles is a text for students who have had little or no previous instruction in chemistry or who had such instruction long enough ago that a thorough review is needed. The text's purpose is to give students the background (and confidence) needed for a subsequent successful encounter with a main sequence, college-level, general chemistry course.

Many texts written for preparatory chemistry courses are simply "watered down" versions of general chemistry texts: they treat almost all topics found in the general chemistry course, but at a superficial level. *Introduction to Chemical Principles* does not fit this mold. My philosophy is that it is better to treat fewer topics extensively and have the student understand those topics in greater depth. I resisted the very real temptation to include lots of additional concepts in this new edition. Instead, my focus for the revision was on rewriting selected portions to improve the clarity of presentation.

### Important Features of This Textbook

- Development of each topic in this text starts out at "ground level." Because of the
  varied degrees of understanding of chemical principles possessed by students taking a
  preparatory chemistry course, each topic is developed step-by-step from "ground level"
  until the level of sophistication required for a further chemistry course is attained.
- 2. Problem solving receives major emphasis. My nearly thirty years of teaching experience suggest that student "troubles" in general chemistry courses are almost always centered on the inability to set up and solve problems. Whenever possible, I use dimensional analysis in problem solving. This method, which requires no mathematics beyond arithmetic and elementary algebra, is a powerful and widely applicable problemsolving tool. Most important, it is a method that an average student can master with an average amount of diligence. Mastering dimensional analysis also helps build the confidence that is so valuable for future chemistry courses.
- 3. Significant figure concepts are emphasized in all problem-solving situations. Routinely, electronic calculators display answers that contain more digits than are needed or acceptable. In all worked-out examples, students are reminded about these "unneeded digits" by the appearance of two answers to the example: the calculator answer (which does not take into account significant figures) and, in color, the correct answer (which is the calculator answer adjusted to the correct number of significant figures).
- 4. Detailed commentary accompanies the numerous worked-out example problems found within the textual material. The number of worked-out examples is greater than in most texts. The detailed commentary accompanying each of these examples, eases the transition from step-to-step in the solution. In addition, an unworked practice exercise is coupled to each worked-out example. I intended for students to work this exercise immediately after working through the example. A section at the end of each chapter gives the answers to these unworked practice exercises.
- 5. All end-of-chapter exercises occur in "matched pairs." In essence, each chapter has two independent, but similar, problem sets. Counting subparts to problems, there are over 5000 questions and problems available for students to use in their journey to proficient problem solving. Answers to all of the odd-numbered problems are found at the end of the text. Thus, two problem sets exist, one with answers and one without.
- 6. Each end-of-chapter problem set, except for Chapters 1 and 2, is divided into three sections: (1) Practice Problems, (2) Additional Problems, and (3) Cumulative Problems. The Practice Problems are categorized by topic and are arranged in the same sequence as the chapter's textual material. These problems, which are always single-concept, are "drill" problems that most students will find routine. The Additional Problem section

- contains problems that involve more than one concept from the chapter and are usually more difficult than the Practice Problems. The cumulative-skills section draws not only on materials from the current chapter but also on concepts discussed in previous chapters. The working of problems in this third group allows students to continue to use, rather than forget, problem-solving techniques presented earlier.
- 7. **Historical vignettes are used to address some of the "people aspects" of chemistry.** These vignettes, entitled "The Human Side of Chemistry," are brief biographies of scientists who helped develop the foundations of modern chemistry. In courses such as the one for which this text is written, it is so easy for students to completely lose any feeling for the people involved in the development of the subject matter they are considering. If it were not for the contributions of people, many of which were done under adverse conditions, chemistry would not be the central science that it is today.
- 8. "Chemical Extensions" are used to bridge the gap between mathematics and chemistry. These "extensions," which are appended to most of the worked-out examples in the text, focus on the chemical compound that is the subject of the calculation. They give information on the compound's occurrence, its properties and uses, its relationship to the environment, its relationship to living systems (biochemistry), and so on. It is easy for students to become so involved in the mathematics of problem solving that they completely forget about the "realness" of the compound or compounds that are the subject of their calculation.
- 9. **Marginal notes are used extensively.** The two main functions of the marginal notes are (1) to summarize key concepts and often give help for remembering concepts or distinguishing between similar concepts, and (2) to provide additional details, links between concepts, or historical information about the concepts under discussion.

#### New Features of the Seventh Edition

- 1. Added emphasis to significant figure considerations for input numbers in calculations is given. Students often experience a relatively high degree of frustration when they correctly solve a problem and yet obtain an answer that differs slightly from the one given in the answer section at the back of the book. They want to get the "exact" number shown in the answer section. Most often the discrepancy is due to differing degrees of uncertainty in the input numbers used for the calculation, for example in molecular mass values. To minimize such frustration, operational rules have been introduced for standardizing uncertainty in input numbers. The standard mode of operation is now to always (1) round all atomic masses to hundredths before using them in molecular mass calculations, and (2) specify frequently used numbers, such as Avogadro's number, molar volume, and the ideal gas constant to four significant figures. With these "ground rules" for input numbers student answers will match back-of-book answers to the last digit in the vast majority of situations.
- 2. Expanded end-of-chapter summaries have been added. End-of-chapter material for use when reviewing for examinations now includes (1) a listing of key concepts found in the chapter with a few sentences of commentary on each concept, and (2) a listing of terms defined in the chapter and the section in which each term is found. The defined terms are easily located within the specified section because they appear as self-standing sentences in which the defined term appears in boldface and the accompanying definition is always in italic.
- 3. The line-art program for the text has been extensively revised and expanded.

  Many of the diagrams present in the previous edition have been redrawn to further enhance their clarity and usefulness for students. In addition, a number of new diagrams have been added for concepts that previously lacked visual reinforcement.

#### For the Instructor

*Instructor's Solutions Manual* (ISBN 0130335118) by Nancy J. Gardner, California State University—Long Beach. Includes full solutions to all of the problems in the text.

*Test Item File* (ISBN 0130335126) by Bobby J. Stanton, University of Georgia. Contains approximately 800 multiple-choice and short-answer questions, all referenced to the text.

PH Custom Test (Windows: ISBN 0130335134; Mac: ISBN 0130335142) This powerful testing and grade management software creates exams from an electronic database version of the Test Item File. Instructors can generate alternate versions of the same test, add their own material, and edit existing tests effortlessly with this program.

Annotated Instructor's Manual to Prentice Hall Laboratory Manual for Introductory Chemistry 3e, (ISBN 0130968838) by Charles H. Corwin, American River College. Contains a complete listing of chemicals and reagent preparation directions for each experiment. It also provides suggested unknowns and answers to the postlaboratory assignments and a quiz item file with more than 500 class-tested multiple-choice questions.

#### For the Student

Student Solutions Manual (ISBN 0130335169) by Nancy J. Gardner, California State University—Long Beach. Includes full solutions to all odd-numbered problems in the text.

Math Review Toolkit (ISBN 0130342068) by Gary Long, Virginia Polytechnic Institute and State University. Designed to provide assistance to students with weaker math skills. This supplement includes a chapter-by-chapter math review keyed to problems in the text as well as a brief self-assessment test.

*Companion Website* (http://www.prenhall.com/stoker) by Debbie Miller, Albuquerque TVI Community College and Marie Villarba.

*Prentice Hall Laboratory Manual for Introductory Chemistry 3e* (ISBN 0130623334) by Charles H. Corwin, American River College. Contains twenty-five experiments and detailed safety information.

#### Acknowledgments

I'd like to gratefully acknowledge the valuable contributions of my reviewers: Stanley Grenda of University of Nevada, Ralph Benedetto, Jr. of Wayne Community College, Roberta Eddy of Indiana University of Pennsylvania, Laurie LeBlanc of Cuyamaca College, William Vanderbout of Sierra College, and Andreas Lippert of Weber State University.

Every effort has been made to rid this text of any typographical errors. I encourage my readers who notice anything suspicious, or who have other questions or comments, to e-mail me at the address below.

H. Stephen Stoker e-mail: hstoker1@weber.edu

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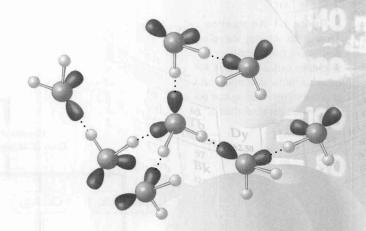
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# 1

# The Science of Chemistry



#### 1.1 Chemistry—A Scientific Discipline

Chemistry is part of a larger body of knowledge called *science*. **Science** is the study in which humans attempt to organize and explain, in a systematic and logical manner, knowledge about themselves and their surroundings.

Because of the enormous scope of science, the sheer amount of accumulated knowledge, and the limitations of human mental capacity to master such a large and diverse body of knowledge, science is divided into smaller subdivisions called *scientific disciplines*. A **scientific discipline** is a branch of science limited in size and scope to make it more manageable. Examples of scientific disciplines are *chemistry*, astronomy, botany, geology, physics, and zoology.

Figure 1.1 shows an organizational chart, with emphasis on chemistry, for the various scientific disciplines. These disciplines can be grouped into *physical sciences* (the study of matter and energy) and *biological sciences* (the study of living organisms). Chemistry is a physical science.

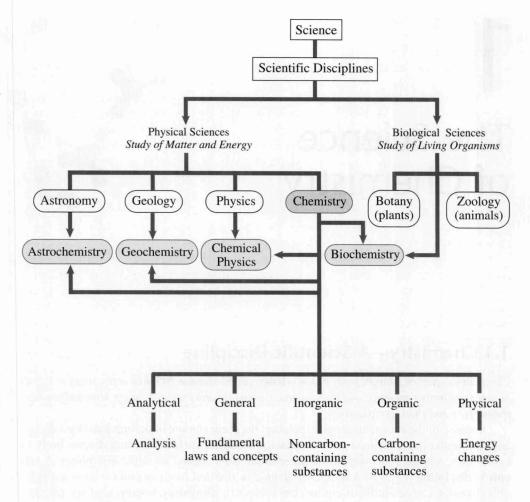
Rigid boundaries between scientific disciplines *do not exist*. All scientific disciplines borrow information and methods from each other. No scientific discipline is totally independent. Environmental problems that scientists have encountered in the last two decades particularly show the interdependence of the various scientific disciplines. For example, chemists attempting to solve the problems of chemical contamination of the environment find that they need some knowledge of geology, zoology, and botany. It is now common to talk not only of chemists, but also geochemists, biochemists, chemical physicists, and so on. The middle portion of Figure 1.1 shows the overlap of the other scientific disciplines with chemistry.

Discipline "overlap" requires that scientists, in addition to having in-depth knowledge of a selected discipline, also have limited knowledge of other disciplines. Discipline "overlap" also explains why a great many college students are required to study chemistry. One or more chemistry courses are required because of their applicability to the disciplines in which the student has more specific interest.

The body of knowledge found within the scientific discipline of chemistry is itself vast. No one can hope to master completely all aspects of chemical knowledge. However, the fundamental concepts of chemistry can be learned in a relatively short period of time.

- 1.1 Chemistry—A Scientific Discipline
- 1.2 Scientific Disciplines and Technology
- 1.3 The Scope of Chemistry and Chemical Technology
- 1.4 How Chemists Discover Things—The Scientific Method

▶ Figure 1.1 An organizational chart showing the relationship of the scientific discipline called chemistry to other scientific disciplines and also the substructuring that occurs within the discipline of chemistry.



The vastness of chemistry is sufficiently large that it, like most scientific disciplines, is partitioned into *subdisciplines*. The lower portion of Figure 1.1 shows the five fundamental branches of chemistry: analytical, general, inorganic, organic, and physical. Most of the subject matter of this textbook falls within the realm of *general chemistry*, the fundamental laws and concepts of chemistry.

technology, continually supplying it with new ideas to be worked on.

Science is the lifeline for

Whether or not a given piece of scientific knowledge is technologically used for beneficial or detrimental purposes depends on the motives of those men and women, whether in industry or government, who have the decisionmaking authority. In democratic societies, citizens (the voters) can influence many technological decisions. It is important for citizens to become informed about scientific and technological issues.

#### 1.2 Scientific Disciplines and Technology

Science is the pursuit of knowledge for its own sake. This pursuit results naturally from the curiosity and fascination of human beings for their surroundings. Science itself, however, does not cause a change in "our conditions" unless something is done with the body of knowledge that accumulates from scientific endeavors. Change is brought about by technology. **Technology** is the application of scientific knowledge to the production of new products to improve human survival, comfort, and quality of life. Technology manipulates nature for advantage. Technological advances began affecting our society about 200 years ago, and new advances still continue, at an accelerating pace, to have a major impact on human society. Section 1.3 considers numerous contributions of chemical technology to human well-being.

Both benefits and detriments can be obtained from the same "piece" of scientific knowledge depending on the technology used to put it to work. For example, knowledge concerning the structure of atoms—the fundamental building blocks for all substances (Chapter 5)—can be applied using one form of technology to build nuclear weapons and another form of technology to detect and cure disease in the human body (Chapter 17).

### 1.3 The Scope of Chemistry and Chemical Technology

Although chemistry is concerned with only a part of the scientific knowledge that has been accumulated, it is in itself an enormous and broad field. Chemistry touches all parts of our lives.

Many of the clothes we wear are made from synthetic fibers produced by chemical processes. Even natural fibers, such as cotton or wool, are the products of naturally occurring chemical reactions within living systems. Our transportation usually involves vehicles powered with energy obtained by burning chemical mixtures, such as gasoline, diesel, and jet fuel. The drugs used to cure many of our illnesses are the result of chemical research. The paper on which this textbook is printed was produced through a chemical process, and the ink used in printing the words and illustrations is a mixture of many chemicals. The movies we watch are possible because of synthetic materials called "film." The images on film are produced through the interaction of selected chemicals. Almost all of our recreational pursuits involve objects made of materials produced by chemical industries. Skis, boats, basketballs, bowling balls, musical instruments, and television sets all contain materials that do not occur naturally, but are products of human technological expertise.

Our bodies are a complex mixture of chemicals. The principles of chemistry are fundamental to an understanding of all processes of the living state. Chemical secretions (hormones) produced within our bodies help determine our outward physical characteristics such as height, weight, and appearance. Digestion of food involves a complex series of chemical reactions. Food itself is an extremely complicated array of chemical substances. Chemical reactions govern our thought processes and how knowledge is stored in and retrieved from our brains. In short, chemistry runs our lives.

A formal course in chemistry can be a fascinating experience because it helps us understand ourselves and our surroundings. We cannot truly understand or even know very much about the world we live in or about our own bodies without being conversant with the fundamental ideas of chemistry.

#### 1.4 How Chemists Discover Things— The Scientific Method

The word *chemistry* conjures up images of people in white lab coats peering at instruments and shaking test tubes or other similar apparati. Why is this generally valid image associated with chemists? The reason is simple. Chemists, as well as all other scientists, discover the general principles that govern the physical world (both its seen and unseen parts) through experimentation and observation. (See Fig. 1.2.)

A majority of the scientific and technological advances of the twentieth century are the result of systematic experimentation using a method of problem solving known as the scientific method. The scientific method is a set of procedures used to acquire knowledge and explain phenomena. The procedural steps in the scientific method are

- 1. Identify the problem, break it into small parts, and carefully plan procedures to obtain information about all aspects of this problem.
- 2. Collect data concerning the problem through observation and experimentation.
- 3. Analyze and organize the data in terms of general statements (generalizations) that summarize the experimental observations.
- 4. Suggest probable explanations for the generalizations.
- 5. Experiment further to prove or disprove the proposed explanations.

Occasionally a great discovery is made by accident, but the majority of scientific discoveries are the result of the application of these five steps over long periods of time. There