Introduction

Everything you hear, see, smell, taste, and touch involves chemistry and chemicals (matter). And hearing, seeing, smelling, tasting, and touching all involve intricate series of chemical reactions and interactions in your body. With such an enormous range of topics, chemistry offers you fascinating opportunities to explore and to study. At the same time, the sheer breadth of these possibilities may make chemistry seem a daunting subject to study. Aware of both the fascination and the challenge of studying chemistry, the American Chemical Society chose a team of chemists to consider what concepts would help you open the doors to opportunities that require a knowledge of chemistry without being overwhelming. The team also took up the challenge to develop effective approaches to learning and teaching chemistry. The result of the team's efforts is this textbook, ***Chemistry,*** and its complementary materials, including project-based laboratory experiments, your molecular model kit, the ***Web Companion,*** and the ***Personal Tutor.***

Learning chemistry, even with a limited range of concepts and content, requires a good deal of effort from both you and your instructors. To facilitate your efforts, we have written ***Chemistry*** in a conversational tone designed to be accessible and engaging. But you cannot learn chemistry only by reading about it, just as you cannot learn how to write a short story or how to find fossils simply by reading about how others do it. Learning how others do something you want to do is important, but you must also practice doing it yourself. Chemists and other scientists learn about the world through experimenting. They then try, often in collaborative efforts, to develop models of the world at the molecular level that explain their results and allow them to predict the outcomes of other possible experiments. We have tried to incorporate this same approach in this textbook.

Throughout ***Chemistry,*** we present activities and thought-provoking questions that are intended to promote active small-group and whole-class participation. To encourage your participation and collaborative learning efforts, four features appear often in each chapter:

Intro.1 INVESTIGATE THIS

An *Investigate This* usually involves short experiments that introduce the chemical concepts explored in the subsequent paragraphs. The investigations are designed to be carried out in small groups or in the whole-class setting.

Intro.2 Consider This

A *Consider This* follows each *Investigate This* and usually asks you to discuss and develop hypotheses or explanations for what you have observed. At other places, a *Consider This* will ask you to think about and discuss the consequences of what has just been presented or to anticipate what is to come. The intent in all cases is to involve the class in a discussion.

Intro.3 Worked Example

Each *Worked Example* guides you through the reasoning involved in solving a problem. Thinking about *how* to solve a problem is often more important and more challenging than actually carrying out the solution procedure, so we place an emphasis on this thinking. Almost all *Worked Examples* include the following components, after the statement of the problem:

Necessary information:
What do you need to know, including the information from the problem statement, to solve the problem?

Strategy:
How do you put the information together to solve the problem? What concepts are involved and how are they to be used? With an appropriate strategy (there is often more than one) in hand, the problem is essentially solved.

Implementation:
Carry out the strategy using the needed information to solve the problem. Calculations, if necessary, are done at this stage.

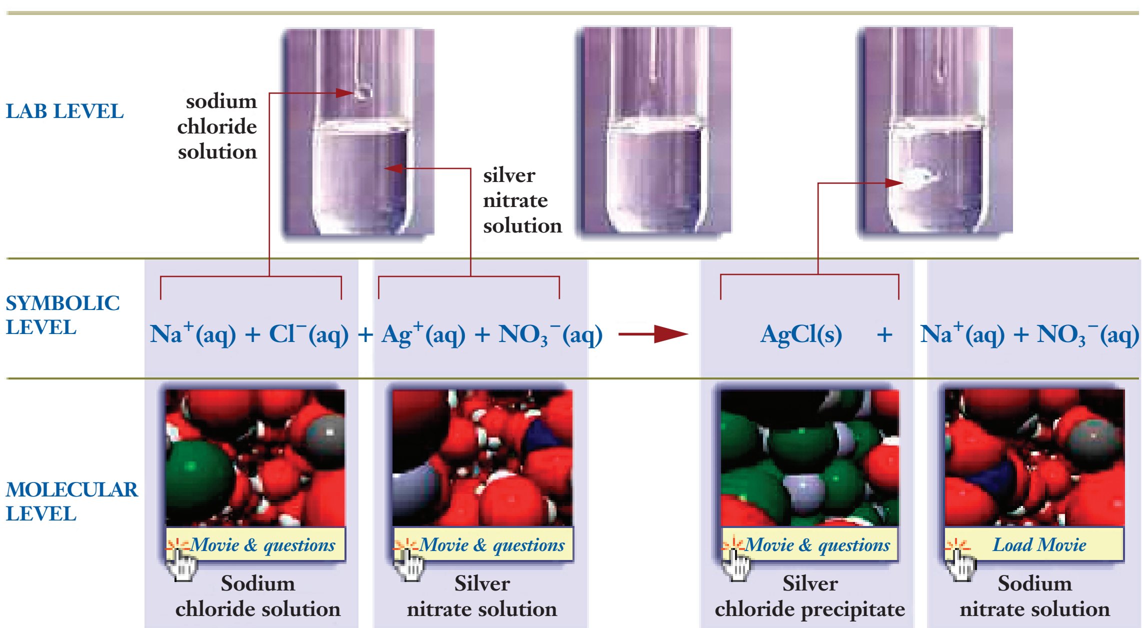
Does the answer make sense?
Once you get an answer to a problem, you should always check to be sure it makes sense. You should also check to be sure you have carried out any numerical calculations correctly; but making sense of the answer is a distinct task (and can sometimes flag possible numerical problems). Is the answer about the size you would expect (based on other experiences, for example)? Does it have the expected direction (sign or change from some baseline)? And so on . . . .

Intro.4 Check This

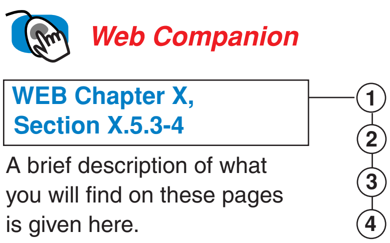
At least one *Check This* follows each *Worked Example* and presents a similar problem or problems so that you can practice the strategy presented in the *Worked Example*. *Check This* problems also appear in other places, where you are asked to practice some technique or answer questions based on what has just been presented in the text. ***Chemistry*** is designed to be used with paper, pencil, calculator, and model kit at hand, so you can try each *Check This* as you come to it.

In addition to these features within each chapter, there is an *Outcomes Review* section near the end of each chapter, a pause for *Reflection and Projection* at the end of every few sections, and *End-of-Chapter Problems* you can use to test your problem-solving skills. Use the *Outcomes Review* to remind yourself of the important ideas from the chapter and the *Reflection and Projection* pause to think back on the preceding sections and consider where they are heading. Use the *End-of-Chapter Problems* to check your understanding of all these ideas. Some of these problems will give you more practice with the kinds of problems you meet in the *Worked Example* and *Check This* activities throughout the chapter. Other *End-of-Chapter Problems* are included to stretch your thinking and engage you in problem-solving strategies that are combinations of strategies introduced in the chapter or that extend a bit beyond them. Most scientists work cooperatively, and we encourage you to try working on these problems collaboratively as well. Often a group can come up with more and better solutions than an individual working in isolation. The numerical answers to *Check This* and *End-of-Chapter Problems* are given in Appendix A, so you can check your solutions.

Throughout ***Chemistry***, you will find an emphasis on understanding and reasoning and on models of all kinds: physical, computer, and mathematical models and analogies. We use models, because it is difficult to observe individual atoms or molecules as they undergo the changes and interactions that lead to the events we can easily observe in nature or in the laboratory. As we try to understand the physical and chemical properties of atoms and molecules and how they cause observable effects, we will use three levels of description, which are exemplified by this page from the ***Web Companion:***



- ***Lab Level:*** These are the observations you make on macroscopic systems, such as that shown in these frames from a movie of a reaction between two solutions in a test tube or in your *Investigate This* activities.
- ***Symbolic Level:*** Intermediate between and connecting the Lab and Molecular Levels is the Symbolic Level of description. This is the descriptive level that you probably associate with chemistry. This level is essential because it combines a great deal of information in a succinct format. It is also the most abstract level of representation, since all the symbols need to be interpreted to make sense of the description. The usual approach in ***Chemistry*** will be first to try to understand systems at the Lab and Molecular Levels and only then proceed to the Symbolic Level.
- ***Molecular Level:*** These are our models of what is going on among the particles (atoms, ions, and molecules) that gives rise to the effects observed in the laboratory. These models are animated in the ***Web Companion*** and are usually shown as less complicated still figures in the text. You will also often use models you build yourself with your molecular model kit.



A brief description of what you will find on these pages is given here.

The ***Web Companion,*** from which the preceding figure is taken, is designed to afford you opportunities to use interactive animations, movies, and other resources that provide a visual (usually moving) means to examine many of the concepts included in the written text. When a ***Web Companion*** page (or pages) is available for some concept, a marginal icon and a description appear beside the text. The mouse, mousepad, and hand icon remind you that there is a computer-based complement to the accompanying written text. The rectangle contains the chapter and section reference in the ***Companion*** and the dangling circles are a reminder of how you can navigate within a section of the ***Companion.*** As indicated, each reference will be accompanied by a brief description of what to expect when you access the ***Companion.***

To access the ***Web Companion,*** visit www.whfreeman.com/acsgenchem and select "Web Companion." Find the appropriate location in the ***Companion*** by selecting the chapter and subsection referenced. The ***Companion*** may also be available on your institutional computers and, if so, your instructors will tell you how to access it. There are also *Consider This* and *Check This* problems, as well as *End-of-Chapter Problems*, based on the ***Web Companion.*** These are denoted by this icon, , a smaller version of the mouse, mousepad, and hand, and the problem will have a reference to the chapter and section you will need to access.

As you can see, we have tried to provide a rich and varied menu of ways for you to become engaged with chemistry and you and your class will probably not have time to delve deeply into all of them for every topic you study. Your instructors will be your guides to help make selections that they think best for what your course is intended to accomplish. To help them in this task, we have prepared an on-line ***Faculty Resource and Organizational Guide*** (the ***FROG***) that includes details and results for each *Investigate This* activity as well as alternatives to the ones in the text, further leading questions for discussions that result when you tackle the *Consider This* problems, possible solutions for all the *Check This* and *End-of-Chapter Problems*, and estimates of the time required for development and discussion of most topics in the text. Many of the ideas and suggestions in the ***FROG*** come from instructors who used draft versions of these materials.

We plan the ***FROG*** to be updated regularly. When your instructors use a strategy, an activity, or an example that is not in the text but helps you understand a concept better, we urge you to encourage them to submit their ideas for inclusion as the ***FROG*** is updated, so other students might benefit as well.

A very large percentage of students who take the general chemistry course in a college or university have already had at least one year of a high school chemistry course. We assume that you are in this category and have probably been exposed to a good deal of the nomenclature and methods that are part of the study of chemistry. We take advantage of this background to move quickly into an examination of the properties of water that depends on some familiarity with the properties of atoms and molecules. You probably have also done some of the algebraic and arithmetic calculations that are a part of essentially all beginning chemistry courses. We take advantage of this experience as well, by providing a review of only necessary concepts and then using them to try to answer questions based on our initial studies of water. The brief reviews we provide in the text may not, however, be enough to make you comfortable with the problems we pose, so we have provided a ***Personal Tutor.***

The primary purpose of the ***Personal Tutor*** is to give you more guidance and practice with problems and computations in the areas that seem to give students trouble. Using the ***Personal Tutor*** is much like visiting your instructor during office hours or going to a human tutor. Marginal boxes like this one will alert you to a section in the ***Personal Tutor*** that might be helpful for the topic under discussion. Before using the ***Tutor*** for the first time, visit www.whfreeman.com/acsgenchemhome, select "Personal Tutor," and take the diagnostic exam. When you have completed the exam, you will get feedback on what sections of the ***Personal Tutor*** would be helpful for you to study. You may need to take advantage of it frequently or you may need its assistance few times or not at all during the course. The questions in the ***Tutor*** can be a good review when preparing for tests, even if you are confident that you know how to solve the problems or do the computations. We urge you to take advantage of this resource in whatever ways it can be helpful.

Personal Tutor
A brief description directs you to the section you might find helpful for this part of the text.

We have outlined above how we designed this textbook and its complementary materials to provide you, your classmates, and your instructors the resources to learn and teach chemistry actively and interactively. Now let us return to the first task the American Chemical Society team considered, what concepts to include in ***Chemistry.*** Several concepts or "big ideas" recur in one form or another throughout the book. Here are brief statements of these concepts:

- Attractions between positive and negative centers hold matter together and are responsible for chemical reactions.
- The lower its energy, the more stable the system.
- During change, energy is conserved: $\Delta E_{net} = 0$.
- The properties of elements repeat periodically as the atomic number of their atoms increases.
- Electrons in atoms and molecules act like matter waves with quantized energies; the more spread out a matter wave, the lower (more favorable) its energy.

- Change occurs in the direction that increases the number of distinguishable arrangements of particles and/or energy quanta. Entropy, *S*, is a measure of this number, and in all spontaneous processes, net entropy increases, $\Delta S_{net} > 0$.
- Reactions are at equilibrium when $\Delta S_{net} = 0$ for the change from reactants to products.
- When a reaction at equilibrium is disturbed, the system reacts to minimize the disturbance. This is Le Chatelier's principle. Reactions at equilibrium are quantitatively described by a temperature dependent equilibrium constant ratio.
- Electric current can produce reduction–oxidation chemical reactions. Reduction–oxidation chemical reactions can produce an electric current.
- The rate of a chemical reaction depends on the concentrations of species and the temperature of the system. These are a result of the reaction pathway.

Some of the concepts in this list may look familiar and others probably do not. Our goal in structuring ***Chemistry*** to emphasize active and collaborative learning has been to provide the means for you to understand these concepts. The understanding you gain will allow you to apply the concepts not only to the problems we and your instructors provide but also to the problems and systems you meet in other courses, and most important, to interesting and intriguing systems you meet in the world outside the classroom. It has been an enjoyable challenge to write ***Chemistry*** and to develop the complementary materials. We hope it is an equally enjoyable challenge to use them to learn chemistry.