

## Preface

### To the Student

In this book, I tell the story of chemistry, a field of science that has not only revolutionized how we live (think of drugs designed to cure diseases or fertilizers that help feed the world), but also helps us to understand virtually everything that happens all around us all the time. The core of the story is simple: Matter is composed of particles, and the structure of those particles determines the properties of matter. Although these two ideas may seem familiar to you as a twenty-first-century student, they were not so obvious as recently as 200 years ago. Yet, they are among the most powerful ideas in all of science. You need not look any further than the advances in biology over the last half-century to see how the particulate view of matter drives understanding. In the last 50 years, we have learned how all living things derive much of what they are from the particles (especially proteins and DNA) that compose them. I invite you to join the story as you read this book. Your part in its unfolding is yet to be determined, and I wish you the best as you start your journey.

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### To the Professor

First and foremost, thanks to all of you who adopted this book in its first edition. You made this book the market-leading atoms-first book. I am grateful beyond words. Second, know that I have listened carefully to your feedback about the first edition. The changes you see in this edition are the direct result of your input, as well as my own experience using the book in my general chemistry courses. If you are a reviewer or have contacted me directly, you will likely see your suggestions reflected in the changes I have made. Thank you.

In spite of the changes in this edition, the goal of the text remains the same: *to tell the story of chemistry in the most compelling way possible*. This book grew out of the *atoms-first* movement in General Chemistry. In a practical sense, the main thrust of this movement is a reordering of topics so that atomic theory and bonding models come much earlier than in the traditional approach. A primary rationale for this approach is for students to understand the theory and framework behind the chemical “facts” they are learning. For example, in the traditional approach students learn early that magnesium atoms tend to form ions with a charge of 2+. They don’t understand *why* until much later (when they get to quantum theory). In contrast, in an atoms-first approach, students learn quantum theory first and understand immediately why magnesium atoms form ions with a charge of 2+. In this way, students see chemistry as a coherent picture and not just a jumble of disjointed facts.

From my perspective, the atoms-first approach is better understood—not in terms of topic order—but in terms of emphasis. Professors who teach with an atoms-first approach generally emphasize: (1) the particulate nature of matter and (2) the connection between the *structure* of atoms and molecules and their *properties* (or their function). The result of this emphasis is that the topic order is rearranged to make these connections earlier, stronger, and more often than the traditional approach. Consequently, I chose to name this book *Chemistry: Structure and Properties*, and have not included the phrase *atoms-first* in the title. From my perspective, the topic order grows out of the particulate emphasis, not the other way around.

In addition, by making the relationship between structure and properties the emphasis of the book, I extend that emphasis beyond just the topic order in the first half of the book. For example, in the chapter on acids and bases, a more traditional approach puts the relationship between the structure of an acid and its acidity toward the end of the chapter, and many professors even skip this material. In this book, I cover this relationship early in the

of the chapter, and many professors even skip this material. In this book, I cover this relationship early in the chapter, and I emphasize its importance in the continuing story of structure and properties. Similarly, in the chapter on free energy and thermodynamics, a traditional approach does not emphasize the relationship between molecular structure and entropy. In this book, however, I emphasize this relationship and use it to tell the overall story of entropy and its ultimate importance in determining the direction of chemical reactions. In this edition, I have also changed the topic order in the gases chapter, so that the particulate view inherent in kinetic molecular theory comes at the beginning of the chapter, followed by the gas laws and the rest of the chapter content. In this way, students can understand the gas laws and all that follows in terms of the particulate model.

Throughout the course of writing this book and in conversations with many of my colleagues, I have also come to realize that the atoms-first approach has some unique challenges. For example, how do you teach quantum theory and bonding (with topics like bond energies) when you have not covered thermochemistry? Or how do you find laboratory activities for the first few weeks if you have not covered chemical quantities and stoichiometry? I have sought to develop solutions to these challenges in this book. For example, I include a section on energy and its units in **Chapter E**, “Essentials: Units, Measurement, and Problem Solving.” This section introduces changes in energy and the concepts of exothermicity and endothermicity. These topics are therefore in place when you need them to discuss the energies of orbitals and spectroscopy in **Chapter 2**, “Periodic Properties of the Elements,” and bond energies in **Chapter 5**, “Chemical Bonding I: Drawing Lewis Structures and Determining Molecular Shapes.” Similarly, I introduce the mole concept in **Chapter 1**; this placement allows not only for a more even distribution of quantitative homework problems, but also for laboratory exercises that require use of the mole concept.

In addition, because I strongly support the efforts of my colleagues at the Examinations Institute of the American Chemical Society, and because I have sat on several committees that write the ACS General Chemistry exam, I have ordered the chapters in this book so that they can be used with those exams in their present form. The end result is a table of contents that emphasizes structure and properties, while still maintaining the overall traditional division of first- and second-semester topics.

Some of the most exciting changes and additions to this edition are in the media associated with the book. To enhance student engagement in your chemistry course, I have added approximately 37 new Key Concept Videos and 50 new Interactive Worked Examples to the media package, which now contains over 150 interactive videos. There is a more detailed description of these videos in the following section entitled “New to This Edition.” In my courses, I employ readings from the book and these videos to implement a *before, during, after* strategy for my students. My goal is to *engage students in active learning before class, during class, and after class*. Recent research has conclusively demonstrated that students learn better when they are active as opposed to passively listening and simply taking in content.

To that end, in addition to a reading assignment from the text, I assign a key concept video *before* each class session. Reading sections from the text in conjunction with viewing the video introduces students to a key concept for that day and gets them thinking about it before they come to class. Since the videos and the book are so closely linked, students get a seamless presentation of the content. *During* class, I expand on the concept and use *Learning Catalytics*™ in MasteringChemistry™ to question my students. Instead of passively listening to a lecture, they interact with the concepts through questions that I pose. Sometimes I ask my students to answer individually, other times in pairs or even groups. This approach has changed my classroom. Students engage in the material in new ways. They have to think, process, and interact. *After* class, I give them another assignment, often an Interactive Worked Example with a follow-up question. They put their new skills to work in solving this assignment. Finally, I assign a weekly problem set in which they have to apply all that they have learned to solve a variety of end-of-chapter problems.

The results have been fantastic. Instead of just starting to learn the material the night before a problem set is due, my students are engaged in chemistry before, during, and after class. I have seen evidence of their improved learning through increases in their scores on the American Chemical Society Standard General Chemistry Exam, which I always administer as the final exam for my course.

For those of you who have used my other general chemistry book (*Chemistry: A Molecular Approach*), you will find that this book is a bit shorter and more focused and streamlined than that one. I have shortened some

chapters, divided others in half, and completely eliminated three chapters ("Biochemistry," "Chemistry of the Nonmetals," and "Metals and Metallurgy"). These topics are simply not being taught much in many general chemistry courses. *Chemistry: Structures and Properties* is a leaner and more efficient book that fits well with current trends that emphasize depth over breadth. Nonetheless, the main features that have made *Chemistry: A Molecular Approach* a success continue in this book. For example, strong problem-solving pedagogy, clear and concise writing, mathematical and chemical rigor, and dynamic art are all vital components of this book.

I hope that this book supports you in your vocation of teaching students chemistry. I am increasingly convinced of the importance of our task. Please feel free to email me with any questions or comments about the book.

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## New to This Edition

- Conceptual Connections and Self-Assessment Quizzes at the end of each chapter in the book are now embedded and interactive in eText 2.0. The interactive quizzes help students to study and test their understanding in real time. Quizzes are algorithmically coded into MasteringChemistry™ to allow students to practice the types of questions they will encounter on the ACS or other exams.
- I added a new chapter, **Chapter E**, "Essentials: Units, Measurement, and Problem Solving." This material, located in **Appendices I** and **II** and **Chapter 2** in the first edition, was moved to the front of the book to provide a foundation for students who need some review in these areas.
- I revised **Chapter 1**, "Atoms," to include a more personal introduction that documents my own introduction into the world of atoms. I also moved the mole concept for atoms, covered in **Chapter 2** in the first edition, into **Chapter 1** in the second edition.
- I moved phase diagrams into **Chapter 11**, "Liquids, Solids, Intermolecular Forces, and Phase Diagrams," to immediately follow the coverage of liquids, solids, and intermolecular forces.
- The chemistry of modern materials is now covered in **Chapter 12**, "Crystalline Solids and Materials," which includes new topics as well as the materials content found in other parts of the book in the first edition.
- With the help of my colleagues, Thomas Greenbowe (University of Oregon), Kristin Ziebert (Oregon State University), and Michael Everest (Westmont College), I added two new categories of end-of-chapter questions designed to help students build "twenty-first-century skills." The first new category of questions, Data Interpretation and Analysis, presents real data in real-life situations and asks students to analyze that data. These in-depth exercises give students much needed practice in reading graphs, digesting tables, and making data-driven decisions. The second new category of questions, Questions for Group Work, encourages students to work with their peers in small groups. The questions can be assigned in or out of the classroom to foster collaborative learning and to allow students to work together in teams to solve problems.
- I added 37 new Key Concept Videos and 50 new Interactive Worked Examples to the media package that accompanies the book. This book now has a video library of over 150 interactive videos designed to help professors engage their students in active learning. These videos are also embedded in the eText 2.0 version of the book.
  - The Key Concept Videos are brief (3 to 5 minutes), and each one introduces a key concept from a chapter. The student does not just passively listen to the video; the video stops in the middle and poses a question to the student. The student must answer the question before the video continues. Each video also includes a follow-up question that is assignable in MasteringChemistry™.
  - The Interactive Worked Examples are similar in concept, but instead of explaining a key concept, each video walks the student through one of the in-chapter worked examples from the book. Like the Key Concept Videos, Interactive Worked Examples stop in the middle and force the student to interact by completing a step in the example. Each example also has a follow-up question that is assignable in MasteringChemistry™. The power of interactivity to make connections in problem solving is immense. I did not quite realize this power until we started making the Interactive Worked Examples, and I saw how I could use the animations to make connections that are just not possible on the static page.
- In order to share best practices for using all of the rich print and media resources that are specific to this title with your students most effectively, professors across the country teaching with my materials curated NEW Ready-To-Go Teaching Modules for this edition. These modules provide instructors with a roadmap for teaching the toughest topics in chemistry.

- There are 13 new Conceptual Connection questions in the book. These questions make reading an active experience by asking students short questions designed to help them determine if they have understood what they are reading. All the Conceptual Connections in the book are embedded and interactive in eText 2.0 with answer-specific feedback.
- All the data in the book has been updated to reflect the most recent measurements available. Examples include [Figure 7.2](#), "Carbon Dioxide in the Atmosphere," [Figure 7.3](#), "Global Temperatures," and [Figure 14.19](#), "Ozone Depletion in the Antarctic Spring."
- I revised the art program throughout to move key points out of the caption and into the art itself. Changes have been made in figures in every chapter in the book. For example, see [Figure 5.6](#), "Hybridization," [Figure 8.2](#), "Concentrated and Dilute Solutions," and [Figure 8.3](#), "Preparing a 1.00 M NaCl Solution."
- I have revised several chapter-opening sections and (or) the corresponding art, including [Sections E.1](#), [1.1](#), [9.1](#), [11.1](#), [12.1](#), and [18.1](#).
- In [Section 7.5](#), "Stoichiometric Relationships: Limiting Reactant, Theoretical Yield, Percent Yield, and Reactant in Excess," you will find a new subsection ("Reactant in Excess") and a new in-chapter worked example ([Example 7.8](#), "Reactant in Excess") that address the amount of excess reagent left over after a reaction.
- In [Section 8.7](#), "Acid–Base Reactions," I added new content on acid–base reactions involving a weak acid and a new worked example ([Example 8.12](#), "Writing Equations for Acid–Base Reactions Involving a Weak Acid").
- In [Section 8.9](#), "Oxidation–Reduction Reactions," I added new content on the activity series for metals, including a new worked example ([Example 8.18](#), "Predicting Spontaneous Redox Reactions").
- I reorganized [Chapter 10](#), "Gases," so that kinetic molecular theory is covered earlier in order to emphasize the particulate nature of gases.
- There is a new worked example in [Section 12.3](#), "Crystalline Solids: Unit Cells and Basic Structures" ([Example 12.2](#), "Calculating the Packing Efficiency of a Unit Cell").
- I added a new section ([Section 18.4](#), "Entropy Changes Associated with State Changes") to [Chapter 18](#), "Free Energy and Thermodynamics," that includes a subsection on calculating the entropy changes associated with state changes. The section includes a new worked example ([Example 18.2](#), "Calculating  $\Delta S$  for a State Change") and new content on reversible and irreversible processes.
- Several sections and tables in [Chapter 20](#), "Radioactivity and Nuclear Chemistry," have been modified and updated including [Sections 20.3](#) and [20.5](#) and [Tables 20.1](#) and [20.4](#).
- The MasteringChemistry™ data indicating which problems give students the most trouble and where they need the most assistance for all end-of-chapter problems were reviewed and taken into account in revising the problems. Over 75% of the section problems have wrong answer-specific feedback.

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