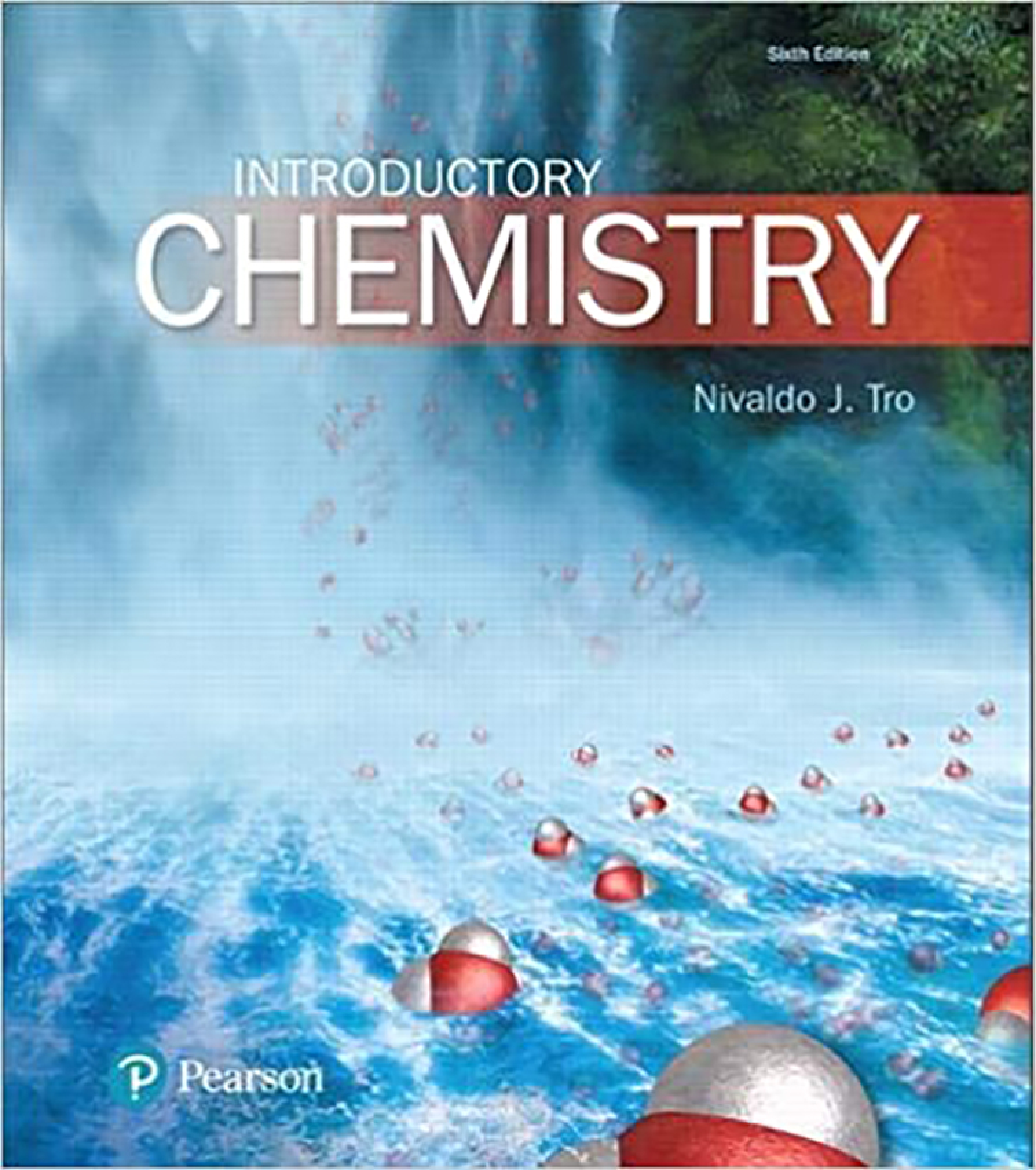

Sixth Edition
INTRODUCTORY
CHEMISTRY
Nivaldo J. Tro
Pearson

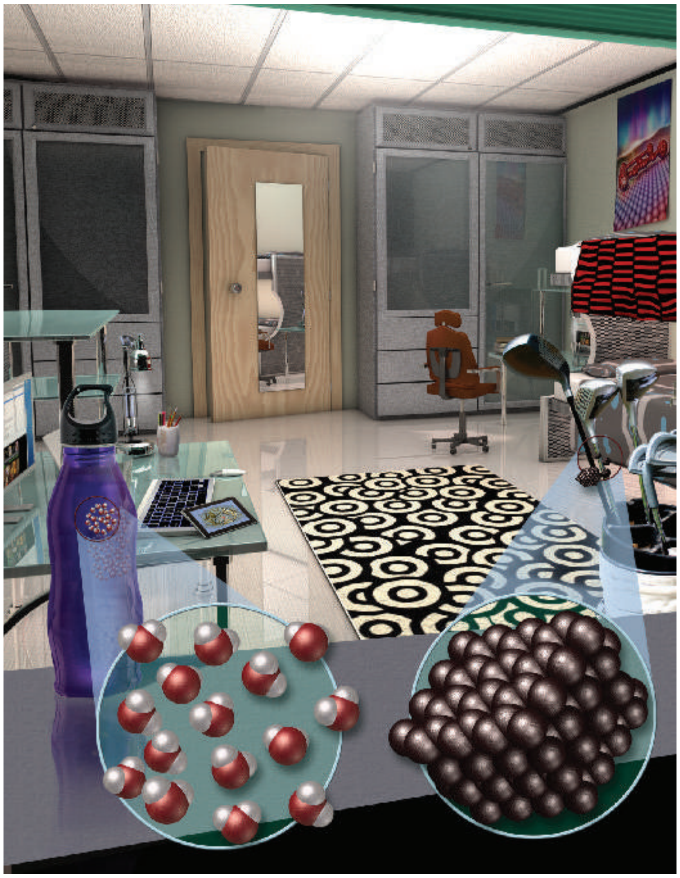
About the Author

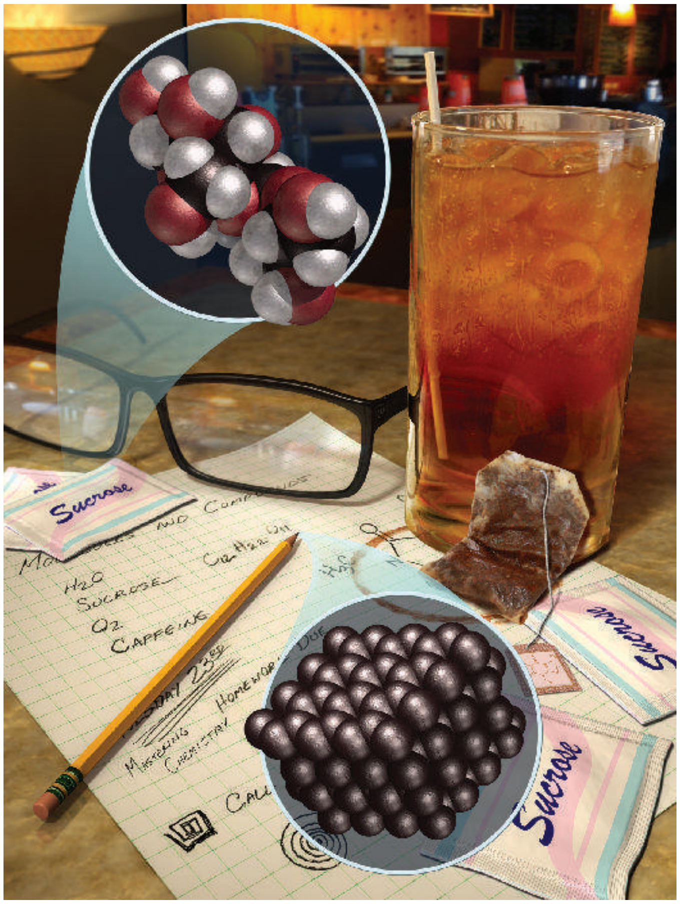
Nivaldo Tro is a professor of chemistry at Westmont College in Santa Barbara, California, where he has been a faculty member since 1990. He received his Ph.D. in chemistry from Stanford University for work on developing and using optical techniques to study the adsorption and desorption of molecules to and from surfaces in ultrahigh vacuum. He then went on to the University of California at Berkeley, where he did postdoctoral research on ultrafast reaction dynamics in solution. Since coming to Westmont, Professor Tro has been awarded grants from the American Chemical Society Petroleum Research Fund, from the Research Corporation, and from the National Science Foundation to study the dynamics of various processes occurring in thin adlayer films adsorbed on dielectric surfaces. He has been honored as Westmont's Outstanding Teacher of the Year three times and has also received the college's Outstanding Researcher of the Year award. Professor Tro lives in Santa Barbara with his wife, Ann, and their four children, Michael, Ali, Kyle, and Kaden. In his leisure time, Professor Tro enjoys mountain biking, surfing, and being outdoors with his family.

To Annie

Brief Contents

Contents




Sucrose
Sucrose

7 Chemical Reactions 206

8 Quantities in Chemical Reactions 248

9 Electrons in Atoms and the Periodic Table 284

10 Chemical Bonding 324

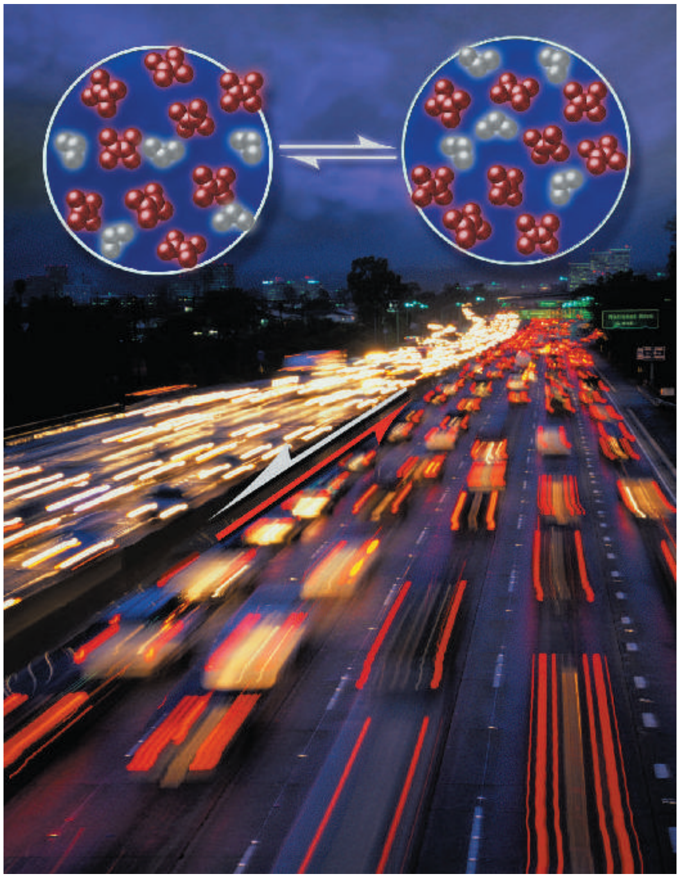
11 Gases 358

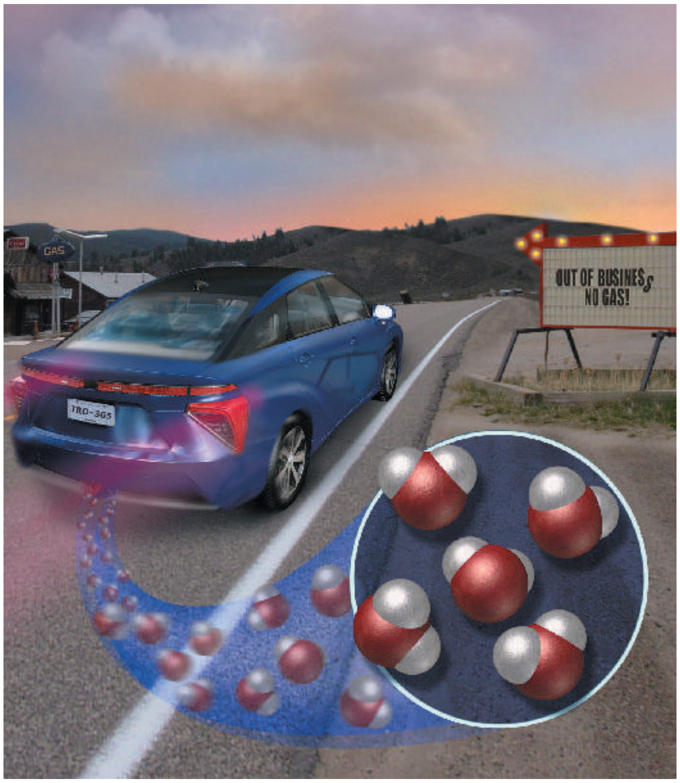
12 Liquids, Solids, and Intermolecular Forces 408

13 Solutions 444

14 Acids and Bases 484

15 Chemical Equilibrium 526





16 Oxidation and Reduction 572

17 Radioactivity and Nuclear Chemistry 608

18 Organic Chemistry 640

Three-Column Problem Solving Strategies

Interactive Media Contents

Key Concept Videos

The eText 2.0 icon indicates that this feature is embedded and interactive in the eText.

Interactive Worked Examples

To the Student

This book is for *you*, and every text feature is meant to help you learn and succeed in your chemistry course. I wrote this book with two main goals for you in mind: to see chemistry as you never have before and to develop the problem-solving skills you need to succeed in chemistry.

I want you to experience chemistry in a new way. I have written each chapter to show you that chemistry is not just something that happens in a laboratory; chemistry surrounds you at every moment. Several outstanding artists have helped me to develop photographs and art that will help you visualize the molecular world. From the opening example to the closing chapter, you will *see* chemistry. My hope is that when you finish this course, you will think differently about your world because you understand the molecular interactions that underlie everything around you.

My second goal is for you to develop problem-solving skills. No one succeeds in chemistry—or in life, really—without the ability to solve problems. I can't give you a one-size-fits-all formula for problem solving, but I can and do give you strategies that will help you develop the *chemical intuition* you need to understand chemical reasoning.

Look for several recurring features throughout this book designed to help you master problem solving. The most important ones are: (1) a four-step process (Sort, Strategize, Solve, and Check) designed to help you learn how to develop a problem-solving approach; (2) the solution map, a visual aid that helps you navigate your way through problems; (3) two-column Examples, in which the left column explains in clear and simple language the purpose of each step of the solution shown in the right column; and (4) three-column Examples, which describe a problem-solving procedure while demonstrating how it is applied to two different Examples. In addition, the For More Practice feature at the end of each worked Example directs you to the end-of-chapter Problems that provide more opportunity to practice the skill(s) covered in each Example. In addition, Interactive Worked Examples are digital versions of select worked Examples from the text that help you break down problems using the book's "Sort, Strategize, Solve, and Check" technique. Interactive Worked Examples can be found in the eText 2.0 and can be accessed directly at: https://media.pearsoncmg.com/ph/esm/esm_tro_intro_6/media/index.html.

Recent research has demonstrated that you will do better on your exams if you take a multiple-choice pre-exam before your actual exam. At the end of each chapter, you will find a Self-Assessment Quiz to help you check your understanding of the material in that chapter. You can string these together to make a pre-exam. For example, if your exam covers Chapters 5–7, complete the Self-Assessment Quizzes for those chapters as part of your preparation for the exam. The questions you miss on the quiz will reveal the areas you need to spend the most time studying. Studies show that if you do this, you will do better on the actual exam.

Lastly, I hope this book leaves you with the knowledge that chemistry is *not* reserved only for those with some superhuman intelligence level. With the right amount of effort and some clear guidance, anyone can master chemistry, including you.

Sincerely,

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To the Instructor

I thank all of you who have used any of the first five editions of *Introductory Chemistry*—you have made this book the best-selling book in its market, and for that I am extremely grateful. The preparation of the sixth edition has enabled me to continue to refine the book to meet its fundamental purpose: teaching chemical skills in the context of relevance.

Introductory Chemistry is designed for a one-semester, college-level, introductory or preparatory chemistry course. Students taking this course need to develop problem-solving skills—but they also must see *why* these skills are important to them and to their world. *Introductory Chemistry* extends chemistry from the laboratory to the student's world. It motivates students to learn chemistry by demonstrating the role it plays in their daily lives.

This is a visual book. Wherever possible, I use images to help communicate the subject. In developing chemical principles, for example, I worked with several artists to develop multipart images that show the connection between everyday processes visible to the eye and the molecular interactions responsible for those processes. This art has been further refined and improved in the sixth edition, making the visual impact sharper and more targeted to student learning. For example, I have continued to expand and refine a hierarchical system of labeling in many of the images: the white-boxed labels are the most important, the tan boxes are second in importance, and the unboxed labels are the third most important. In many cases, this system allows information to be placed closest to its point of relevance, instead of being lumped together in the caption. In addition, this allows me to treat related labels and annotations within an image in the same way, so that the relationships between them are immediately evident. My intent is to create an art program that teaches and presents complex information clearly and concisely. Many of the illustrations showing molecular depictions of a real-world object or process have three parts: macroscopic (what we can see with our eyes); molecular and atomic (space-filling models that depict what the molecules and atoms are doing); and symbolic (how chemists represent the molecular and atomic world). Students can begin to see the connections between the macroscopic world, the molecular world, and the representation of the molecular world with symbols and formulas.

The problem-solving pedagogy employs four steps as it has done in the previous five editions: Sort, Strategize, Solve, and Check. This four-step procedure guides students as they learn chemical problem solving. Students will also encounter extensive flowcharts throughout the book, allowing them to better visualize the organization of chemical ideas and concepts.

Throughout the worked Examples in this book, I use a *two-* or *three-column* layout in which students learn a general procedure for solving problems of a particular type as they see this procedure applied to one or two worked Examples. In this format, the *explanation* of how to solve a problem is placed directly beside the actual steps in the *solution* of the problem. Many of you have told me that you use a similar technique in lecture and office hours. Since students have specifically asked for connections between worked Examples and end-of-chapter Problems, I include a For More Practice feature at the end of each worked Example that lists the end-of-chapter review Examples and end-of-chapter Problems that provide additional opportunities to practice the skill(s) covered in the example. Also in this edition, we have 39 Interactive Worked Examples, which can be accessed in the eText 2.0.

A successful feature of previous editions is the Conceptual Checkpoints, a series of short questions that students can use to test their mastery of key concepts as they read through a chapter. For this edition, all Conceptual Checkpoints are embedded in eText 2.0. Emphasizing understanding rather than calculation, they are designed to encourage active learning even while reading. Your continued embrace of this feature prompted me to add more of these to the sixth edition.

In this edition, I have also added a new category of End-of-Chapter Questions called *Data Interpretation and Analysis*. These questions present real data in real-life situations and ask students to analyze and interpret that data. They are designed to give students much needed practice in reading graphs, understanding tables, and making data-driven decisions.

In my own teaching, I have been influenced by two studies published in the last few years. The first one is a mega analysis of the effect of active learning on student learning in STEM disciplines.[1] In this study, Freeman and his coworkers convincingly demonstrate that students learn better when they are active in the process. The second study focuses on the effect of multiple-choice pretests on student exam performance.[2] Here, Pyburn and his coworkers show that students who take a multiple-choice pretest do better on exams than those who do not. Even more interesting, the enhancement is greater for lower performing students. In my courses, I have implemented both active learning and multiple-choice pretesting with good results. In my books, I have developed tools to allow you to incorporate these techniques as well.

To help you with active learning, I have added 12 Key Concept Videos to the media package that accompanies this book. These three- to five-minute videos each introduce a key concept from the chapter. They are themselves interactive because every video has an embedded question posed to the student to test understanding. In addition, there are 19 new Interactive Worked Examples adding to a total of 39 new and revised Interactive Worked Example videos in the media package. This means that you now have a library of 31 new interactive videos and a total of 51 new and revised interactive videos to enhance your course.

In my courses, I use these videos in conjunction with the book to implement a *before, during, after* strategy for my students. My goal is simple: *Engage students in active learning before class, during class, and after class.* To that end, I assign a video *before* most class sessions. All Key Concept Videos and Interactive Worked Examples are embedded and interactive in eText 2.0, allowing students to review and test their understanding in real-time. The video introduces students to a concept or problem that I will cover in the lecture. *During* class, I expand on the concept or problem using *Learning Catalytics*™ to question my students. Instead of simply passively listening to a lecture, they are interacting 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 are actively learning and have to think and process and interact. Finally, *after* class, I give them another assignment, usually a short follow-up question or problem. At this point, they must apply what they have learned to solve a problem.

To help you with multiple-choice pretesting, each chapter contains a Self-Assessment Quiz. Like the Conceptual Checkpoints and the videos, these quizzes are embedded in eText 2.0. These quizzes are designed so that students can test themselves on the core concepts and skills of each chapter. I encourage my students to use these quizzes as they prepare for exams. For example, if my exam covers Chapters 5–8, I assign the quizzes for those chapters for credit (you can do this in MasteringChemistry™). Students then get a pretest on the core material that will be on the exam.

My goal with this new edition is to continue to help you make learning a more active (rather than passive) process for your students. I hope the tools that I have provided here continue to aid you in teaching your students better and more effectively. Please feel free to email me with any questions or comments you might have. I look forward to hearing from you as you use this book in your course.

Sincerely,

Nivaldo J. Tro
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[1] Freeman, Scott; Eddy, Sarah L.; McDonough, Miles; Smith, Michelle K.; Okoroafor, Nnadozie; Jordt, Hannah; and Wenderoth, Mary Pat; Active learning increases student performance in science, engineering, and mathematics, 2014, Proc. Natl. Acad. Sci.

[2] Daniel T. Pyburn, Samuel Pazicni, Victor A. Benassi, and Elizabeth M. Tappin *J. Chem. Educ.*, 2014, 91 (12), pp. 2045–2057.

Preface

What's New in This Edition?

The book has been extensively revised and contains more small changes than can be detailed here. The most significant changes to the book and its supplements are listed below.

- I have added a new category of end-of-chapter questions called *Data Interpretation and Analysis*. These questions present real data in real-life situations and ask students to analyze that data. They give students much needed practice in reading graphs, digesting tables, and making data-driven decisions. A new section (Section 1.4), including a new in-chapter worked Example (Example 1.4), introduces these skills.
- There are 12 new Key Concept Videos and 19 new Interactive Worked Examples to accompany the book. That means there are 31 new videos and 51 total new and revised interactive videos to accompany the material in the sixth edition. All Key Concept Videos and Interactive Worked Examples are embedded and interactive in eText 2.0, allowing students to review and test their understanding in real-time. These tools are designed to help professors engage their students in active learning. Recent research has conclusively demonstrated that students learn better when they are active in the learning process, as opposed to passively listening and simply taking in content. The Key Concept Videos are brief (three to five minutes), and each introduces and explains 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, they walk 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. The examples also have 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.
- All chapter-ending Self-Assesment Quizzes are embedded in eText 2.0.
- I have added 13 new Conceptual Checkpoint questions throughout the book. For this edition, all Conceptual Checkpoints are embedded in eText 2.0.
- I have updated the data throughout the book to reflect the most recent measurements and developments available. I changed the half-life of carbon-14 to 5715 years in Table 17.2 and throughout Chapter 17 to reflect the current accepted value, and I also added new information about *thermoluminescent dosimeters* (and deleted the information on film badge dosimeters) to Section 17.4. Other updates include changes to Figure 8.2, *Climate change*; Section 10.1, *Bonding Models and AIDS Drugs*; Table 11.5, *Changes in Pollutant Levels for Major U.S. Cities, 1980–2014*; the *Chemistry in the Environment* box in Section 12.8, *Water: A Remarkable Molecule*; and Section 17.8, *Nuclear Power: Using Fission to Generate Electricity*.

- Several chapter-opening sections and (or) the corresponding art, including Sections 1.1, 2.1, 12.1, and 16.1, have been replaced or significantly modified.
- I added a new section (Section 2.8) and new worked example (Example 2.12) as well as new end-of-chapter Problems to address conversions involving quantities with combined units such as mL/kg or km/hr.
- I have extensively modified the art program to move information from the captions and into the art itself. This allows relevant information to be placed right where it is most needed and makes the art a more accessible study and review tool. I have modified 70 figures in this way.
- I have modified end-of-chapter Problems that were showing low levels of student success when assigned in MasteringChemistry™.
- I have added temporary symbols for elements 113, 115, 117, and 118 (Uut, Uup, Uus, and Uuo, respectively) to all periodic tables.
- In all chapters, chapter text was edited for clarity and to limit use of passive voice and extraneous words and phrases.

Teaching Principles

The development of basic chemical principles—such as those of atomic structure, chemical bonding, chemical reactions, and the gas laws—is one of the main goals of this text. Students must acquire a firm grasp of these principles in order to succeed in the general chemistry sequence or the chemistry courses that support the allied health curriculum. To that end, the book integrates qualitative and quantitative material and proceeds from concrete concepts to more abstract ones.

Organization of the Text

The main divergence in topic ordering among instructors teaching introductory and preparatory chemistry courses is the placement of electronic structure and chemical bonding. Should these topics come early, at the point where models for the atom are being discussed? Or should they come later, after the student has been exposed to chemical compounds and chemical reactions? Early placement gives students a theoretical framework within which they can understand compounds and reactions. However, it also presents students with abstract models before they understand why they are necessary. I have chosen a later placement; nonetheless, I know that every course is unique and that each instructor chooses to cover topics in his or her own way. Consequently, I have written each chapter for maximum flexibility in topic ordering. In addition, the book is offered in two formats. The full version, *Introductory Chemistry*, contains 19 chapters, including organic chemistry and biochemistry. The shorter version, *Introductory Chemistry Essentials*, contains 17 chapters and omits these topics.

Print and Media Resources

Instructor and Student Supplements	
0134564057 / 9780134564050	Instructor Resource Manual with Complete Solutions
013455342X / 9780134553429	TestGen Test Bank (Download only)
0134553446 / 9780134553443	Instructor Resource Materials (Download only)
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0134555554 / 9780134555553	Modified MasteringChemistry™ with Pearson eText–Instant Access
0134555570 / 9780134555577	MasteringChemistry™ with Pearson eText–Instant Access

Acknowledgments

This book has been a group effort, and I am grateful for all of those who helped me. First and foremost, I would like to thank my editor Scott Dustan. I have known Scott for many years and in various roles, and am grateful to have him as my editor. I appreciate his straightforward style, constant support, and commitment to my work. I am also in a continual state of awe and gratitude to Erin Mulligan, my development editor and friend. Thanks, Erin, for all your outstanding help and advice. Thanks also to Jackie Jakob, media editor extraordinaire. Jackie is the force behind the media elements that accompany this book, and I am grateful for her vision, guidance, and friendship. Thanks also to Jennifer Hart, with whom I have now worked for over a decade. Thanks Jennifer for your constant attention, guidance, and wisdom on all of my projects at Pearson. I am also grateful for Jeanne Zalesky, Adam Jaworski, Paul Corey and the rest of Pearson leadership. You have supported my projects and my vision from the beginning, and I am privileged to work with you.

I would also like to thank Elizabeth Ellsworth, my marketing manager, whose creativity in describing and promoting the book is without equal. I am also grateful to Coleen Morrison, whose help with editing and manuscript preparation was invaluable. Thanks also to the MasteringChemistry™ team who continue to provide and promote the best online homework system on the planet. I also appreciate the expertise and professionalism of my copy editor, Betty Pessagno, as well as the skill and diligence of Francesca Monaco and her colleagues at codeMantra. I am a picky author, and they always accommodated my seemingly endless requests. Thank you, Francesca. Thanks as well to my content producer, Chandrika Madhavan and the rest of the Pearson editorial and production team—they are part of a

first-class operation. This text has benefited immeasurably from their talents and hard work. I owe a special debt of gratitude to Quade Paul, who continues to make my ideas come alive in his chapter-opener and cover art.

I am grateful for the assistance of my colleagues, Allan Nishimura, David Marten, Stephen Contakes, Kristi Lazar, Carrie Hill, Michael Everest, Amanda Silberstein, and Heidi Henes-Vanbergen, who have supported me in my department while I worked on this book. I owe a special debt of gratitude to Michael Tro. He has been helping me with manuscript preparation, proofreading, organizing art manuscripts, and tracking changes in end-of-chapter material for the past six years. Michael has been reliable, accurate, and invaluable. Thanks Mikee! I also owe a special thanks to my colleagues Michael Everest and Tom Greenbowe, who collaborated with me in creating some of the end of chapter questions.

I am grateful to those who have given so much to me personally while writing this book. First on that list is my wife, Ann. Her patience and love for me are beyond description. I also thank my children, Michael, Ali, Kyle, and Kaden, whose smiling faces and love of life always inspire me. I come from a large Cuban family, whose closeness and support most people would envy. Thanks to my parents, Nivaldo and Sara; my siblings, Sarita, Mary, and Jorge; my siblings-in-law, Jeff, Nachy, Karen, and John; my nephews and nieces, Germain, Danny, Lisette, Sara, and Kenny. These are the people with whom I celebrate life.

Lastly, I am indebted to the many reviewers, listed next, whose ideas are found throughout this book. They have corrected me, inspired me, and sharpened my thinking on how best to teach this subject we call chemistry. I deeply appreciate their commitment to this project.

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Help students develop 21st-century skills to succeed in chemistry courses, future careers, and beyond.

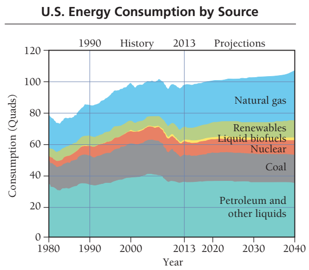
Nivaldo Tro's approach introduces students to 21st-century skills, encouraging them to think critically when they encounter complex information and real-world problems.

NEW! Data Interpretation and Analysis Questions at the end of each chapter allow students to work with real data to develop 21st-century problem-solving skills. These questions ask students to sort, analyze and interpret actual data from real-life situations. Students practice reading graphs, digesting tables, and making data-driven decisions.

Data Interpretation and Analysis

124. The graph at right shows U.S. energy consumption by source from 1980 to 2040 (based on projections). The consumption is measured in quadrillion BTUs or quads (1 quad = 1.055×10^{18} J).

(a) What were the three largest sources of U.S. energy in 2013 in descending order? What total percent of U.S. energy do these three sources provide?
(b) What percent of total U.S. energy is provided by renewables in 2013?
(c) Which two sources of U.S. energy decline as a percentage of total energy use between 1989 and 2040 (based on projections)?
(d) How much U.S. energy (in joules) was produced by nuclear power in 1990?



A new section (Section 1.4), which includes a new in-chapter worked example (Example 1.1), introduces data interpretation and analysis skills and emphasizes their importance in student success.

All Data Interpretation and Analysis Questions are assignable in MasteringChemistry™

1.4 Analyzing and Interpreting Data

▶ Identify patterns in data and interpret graphs.

We just learned how early scientists such as Lavoisier and Dalton saw patterns in a series of related measurements. Sets of measurements constitute scientific *data*, and learning to analyze and interpret data is an important scientific skill.

Identifying Patterns in Data

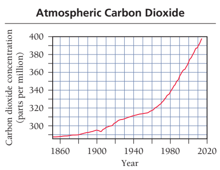
Suppose you are an early chemist trying to understand the composition of water. You know that water is composed of the elements hydrogen and oxygen. You do several experiments in which you decompose different samples of water into hydrogen and oxygen, and you get the following results:

Sample	Mass of Water Sample	Mass of Hydrogen Formed	Mass of Oxygen Formed
A	20.0 g	2.2 g	17.8 g
B	50.0 g	5.6 g	44.4 g
C	100.0 g	11.1 g	88.9 g

Do you notice any patterns in this data? The first and easiest pattern to see is that the sum of the masses of oxygen and hydrogen always sums to the mass of the water sample. For example, for the first water sample, 2.2 g hydrogen + 17.8 g oxygen = 20.0 g water. The same is true for the other samples. Another pattern, which is a bit more difficult to see, is that the ratio of the masses of oxygen and hydrogen is the same for each sample.

Sample	Mass of Hydrogen Formed	Mass of Oxygen Formed	$\frac{\text{Mass Oxygen}}{\text{Mass Hydrogen}}$
A	2.2 g	17.8 g	8.1
B	5.6 g	44.4 g	7.9
C	11.1 g	88.9 g	8.01

The ratio is 8—the small variations are due to experimental error, which is common in all measurements and observations.



▲ **FIGURE 1.5 Atmospheric carbon dioxide levels from 1860 to present.**

Seeing patterns in data is a creative process that requires you to not just merely tabulate laboratory measurements, but to see relationships that may not always be obvious. The best scientists see patterns that others have missed. As you learn to interpret data in this course, be creative and try looking at data in new ways.

Interpreting Graphs

Data is often visualized using graphs or images, and scientists must constantly analyze and interpret graphs. For example, the graph in ◀ **FIGURE 1.5** shows the concentration of carbon dioxide in Earth's atmosphere as a function of time. Carbon dioxide is a greenhouse gas that has been rising as result of the burning of fossil fuels (such as gasoline and coal). When you look at a graph such as this one, you should first examine the *x* and *y* axes and make sure you understand what each axis represents. You should also examine the numerical range of the axes. In Figure 1.5, the *y* axis does not begin at zero in order to better display the change that is occurring. How would this graph look different if the *y* axis began at zero instead of at 290? Notice also that, in this graph, the increase in carbon dioxide has not been constant over time. The rate of increase—represented by the slope of the line—has intensified since about 1960.

EXAMPLE 1.1 Interpreting Graphs

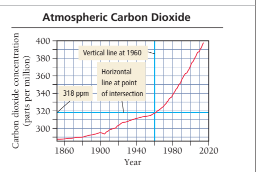
Examine the graph in Figure 1.5 and answer each question.

(a) What was the concentration of carbon dioxide in 1960?
(b) What was the concentration in 2000?
(c) How much did the concentration increase between 1960 and 2000?
(d) What is the average rate of increase over this time?
(e) If the average rate of increase remains constant, estimate the carbon dioxide concentration in 2030.

SOLUTION

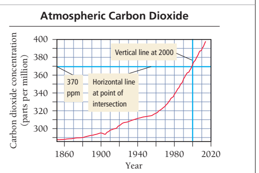
a) What was the concentration of carbon dioxide in 1960?

To determine the concentration of carbon dioxide in 1960, draw a vertical line at the year 1960. At the point where the vertical line intersects the carbon dioxide concentration curve, draw a horizontal line. The point where the horizontal line intercepts the *y* axis represents the concentration in 1960. So, the concentration in 1960 was 318 ppm.



b) What was the concentration in 2000?

Apply the same procedure as in part a, but now shift the vertical line to the year 2000. The concentration in the year 2000 was 370 ppm.



continued on page 10 ▶

Students build a framework for solving problems.

Nivaldo Tro's unique problem-solving technique, "Sort, Strategize, Solve, and Check," teaches students how to successfully approach, set up, and solve the problems they encounter in their introductory chemistry course. Solution maps visually walk students through problems and help them learn how to organize and use given information to successfully solve problems.

Two- and three-column example formats help students break down the steps of each problem and learn and practice problem-solving techniques they can apply in other assignments.

EXAMPLE **3.5** **Conversion of Energy Units**

A candy bar contains 225 Cal of nutritional energy. How many joules does it contain?	
SORT Begin by sorting the information in the problem. Here you are *given* energy in Calories and asked to *find* energy in joules.	**GIVEN:** 225 Cal **FIND:** J
STRATEGIZE Draw a solution map. Begin with Cal, convert to cal, and then convert to J.	**SOLUTION MAP** Cal → cal → J $\frac{1000\ \text{cal}}{1\ \text{Cal}}$ $\frac{4.184\ \text{J}}{1\ \text{cal}}$ **RELATIONSHIPS USED** 1000 calories = 1 Cal (Table 3.2) 4.184 J = 1 cal (Table 3.2)
SOLVE Follow the solution map to solve the problem. Begin with 225 Cal and multiply by the appropriate conversion factors to arrive at J. Round the answer to the correct number of significant figures (in this case, three because of the three significant figures in 225 Cal).	**SOLUTION** $225\ \text{Cal} \times \frac{1000\ \text{cal}}{1\ \text{Cal}} \times \frac{4.184\ \text{J}}{1\ \text{cal}} = 9.41 \times 10^5\ \text{J}$
CHECK Check your answer. Are the units correct? Does the answer make physical sense?	The units of the answer (J) are the desired units. The magnitude of the answer makes sense because the J is a smaller unit than the Cal; therefore, the quantity of energy in J should be greater than the quantity in Cal.

▶ **SKILLBUILDER 3.5** | **Conversion of Energy Units**
The complete combustion of a small wooden match produces approximately 512 cal of heat. How many kilojoules are produced?

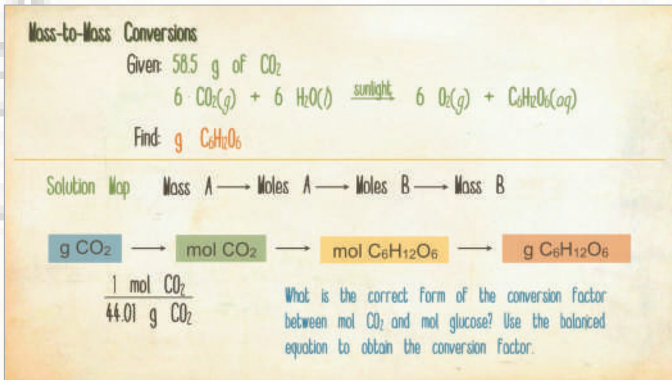
▶ **SKILLBUILDER PLUS** Convert 2.75×10^4 kJ to calories.

▶ **FOR MORE PRACTICE** Example 3.16; Problems 51, 52, 53, 54, 55, 56, 57, 58.

Problem-Solving Procedure	EXAMPLE **2.8** **UNIT CONVERSION** Convert 7.8 km to miles.	EXAMPLE **2.9** **UNIT CONVERSION** Convert 0.825 m to millimeters.
SORT Begin by sorting the information in the problem into *given* and *find*.	**GIVEN:** 7.8 km **FIND:** mi	**GIVEN:** 0.825 m **FIND:** mm
STRATEGIZE Draw a *solution map* for the problem. Begin with the *given* quantity and symbolize each step with an arrow. Below the arrow, write the conversion factor for that step. The solution map ends at the *find* quantity. (In these examples, the relationships used in the conversions are below the solution map.)	**SOLUTION MAP** km → mi $\frac{0.6214\ \text{mi}}{1\ \text{km}}$ **RELATIONSHIPS USED** 1 km = 0.6214 mi (This conversion factor is from Table 2.3.)	**SOLUTION MAP** m → mm $\frac{1\ \text{mm}}{10^{-3}\ \text{m}}$ **RELATIONSHIPS USED** $1\ \text{mm} = 10^{-3}\ \text{m}$ (This conversion factor is from Table 2.2.)
SOLVE Follow the *solution map* to solve the problem. Begin with the *given* quantity and its units. Multiply by the appropriate conversion factor, canceling units to arrive at the *find* quantity.	**SOLUTION** $7.8\ \text{km} \times \frac{0.6214\ \text{mi}}{1\ \text{km}} = 4.84692\ \text{mi}$ 4.84692 mi = 4.8 mi	**SOLUTION** $0.825\ \text{m} \times \frac{1\ \text{mm}}{10^{-3}\ \text{m}} = 825\ \text{mm}$ 825 mm = 825 mm
Round the answer to the correct number of significant figures. (If possible, obtain conversion factors to enough significant figures so that they do not limit the number of significant figures in the answer.)	Round the answer to two significant figures because the quantity given has two significant figures.	Leave the answer with three significant figures because the quantity given has three significant figures and the conversion factor is a definition and therefore does not limit the number of significant figures in the answer.
CHECK Check your answer. Are the units correct? Does the answer make sense?	The units, mi, are correct. The magnitude of the answer is reasonable. A mile is longer than a kilometer, so the value in miles should be smaller than the value in kilometers.	The units, mm, are correct, and the magnitude is reasonable. A millimeter is shorter than a meter, so the value in millimeters should be larger than the value in meters.
	▶ **SKILLBUILDER 2.8** | **Unit Conversion** Convert 56.0 cm to inches.	▶ **SKILLBUILDER 2.9** | **Unit Conversion** Convert 5678 m to kilometers.
	▶ **FOR MORE PRACTICE** Example 2.26; Problems 73, 74, 75, 76.	▶ **FOR MORE PRACTICE** Problems 69, 70, 71, 72.

PEARSON eText 2.0

NEW! and UPDATED! Interactive Worked Examples are digital versions of select worked examples from the text that make Nivaldo Tro's unique problem-solving strategies interactive. In these digital versions the author walks students through the problem-solving process, asking them to pause and answer questions along the way. Worked example videos are embedded in eText 2.0 and assignable in MasteringChemistry™.



Students learn to think critically about information in the classroom and in everyday life.

NEW! Key Concept Videos combine artwork from the textbook with 2D and 3D animations to create a dynamic on-screen viewing experience and help students understand and apply important concepts throughout the text. Key Concept Videos are embedded in eText 2.0 and are assignable in MasteringChemistry™.

These short (3–5 minutes) videos combine animation and live-action clips of author Nivaldo Tro explaining the key concept of each chapter. Embedded questions in each video increase engagement and test student understanding. Follow-up questions are assignable in MasteringChemistry™.

UPDATED! Chapter-in-Review Exercises and Self-Assessment Quizzes have been revised using MasteringChemistry™ metadata to identify questions that students struggled with in previous editions. In addition to a full complement of end-of-chapter questions, each chapter features a 10–15 multiple-choice question quiz that help students assess their understanding of chapter content, building critical thinking skills and reinforcing key concepts.

Chapter 3 in Review

MasteringChemistry™ provides end-of-chapter exercises, feedback-enriched tutorial problems, animations, and interactive activities to encourage problem solving practice and deeper understanding of key concepts and topics.

Self-Assessment Quiz

Q1. Which substance is a pure compound?
(a) Gold **(b)** Water
(c) Milk **(d)** Fruit cake

Q2. Which property of trinitrotoluene (TNT) is most likely a chemical property?
(a) Yellow color
(b) Melting point is 80.1 °C
(c) Explosive
(d) None of the above

Q3. Which change is a chemical change?
(a) The condensation of dew on a cold night
(b) A forest fire
(c) The smoothening of rocks by ocean waves
(d) None of the above

Q4. Which process is endothermic?
(a) The burning of natural gas in a stove
(b) The metabolism of glucose by your body
(c) The melting of ice in a soft drink
(d) None of the above

Q5. A 35-g sample of potassium completely reacts with chlorine to form 67 g of potassium chloride. How many grams of chlorine must have reacted?
(a) 67 g **(b)** 35 g **(c)** 32 g **(d)** 12 g

Q6. A runner burns 2.56×10^3 kJ during a five-mile run. How many nutritional Calories did the runner burn?
(a) 1.07×10^1 Cal **(b)** 612 Cal
(c) 6.12×10^5 Cal **(d)** 1.07×10^4 Cal

Q7. Convert the boiling point of water (100.00 °C) to K.
(a) −173.15 K
(b) 0 K
(c) 100.00 K
(d) 373.15 K

Q8. A European doctor reports that you have a fever of 39.2 °C. What is your fever in degrees Fahrenheit?
(a) 102.6 °F **(b)** 128.26 °F
(c) 71.2 °F **(d)** 4 °F

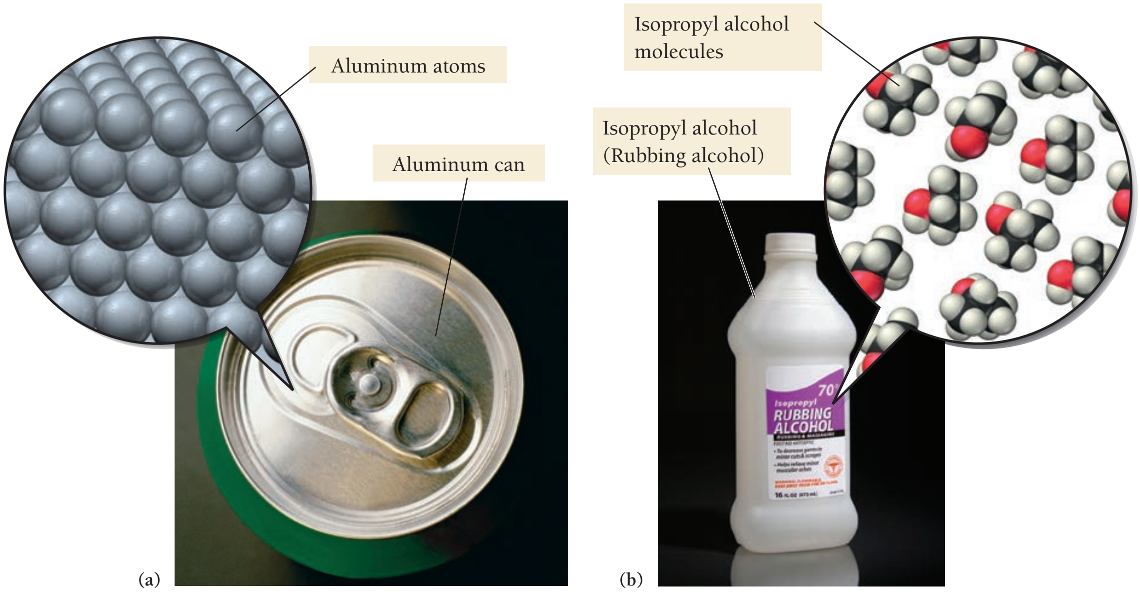
Q9. How much heat must be absorbed by 125 g of ethanol to change its temperature from 21.5 °C to 34.8 °C?
(a) 6.95 kJ
(b) 4.02×10^3 kJ
(c) 86.6 kJ
(d) 4.02 kJ

Q10. Substance A has a heat capacity that is much greater than that of substance B. If 10.0 g of substance A initially at 25.0 °C is brought into thermal contact with 10.0 g of B initially at 75.0 °C, what can you conclude about the final temperature of the two substances once the exchange of heat between the substances is complete?
(a) The final temperature will be between 25.0 °C and 50.0 °C.
(b) The final temperature will be between 50.0 °C and 75.0 °C.
(c) The final temperature will be 50.0 °C.
(d) You can conclude nothing about the final temperature without more information.

Answers: 1:b, 2:c, 3:b, 4:c, 5:c, 6:b, 7:d, 8:a, 9:d, 10:a

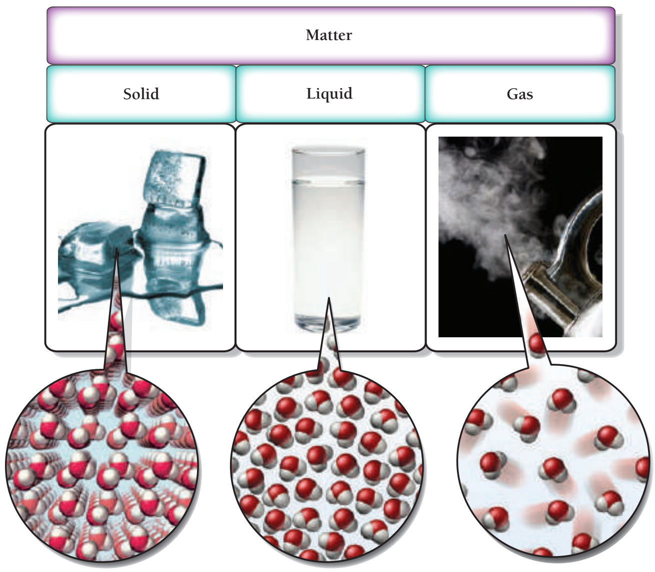
Multipart macroscopic and molecular images engage students in chemistry.

Multipart images allow students to see the relationship between the formulas they write down on paper (symbolic), the world they see around them (macroscopic), and the atoms and molecules that compose the world (molecular).



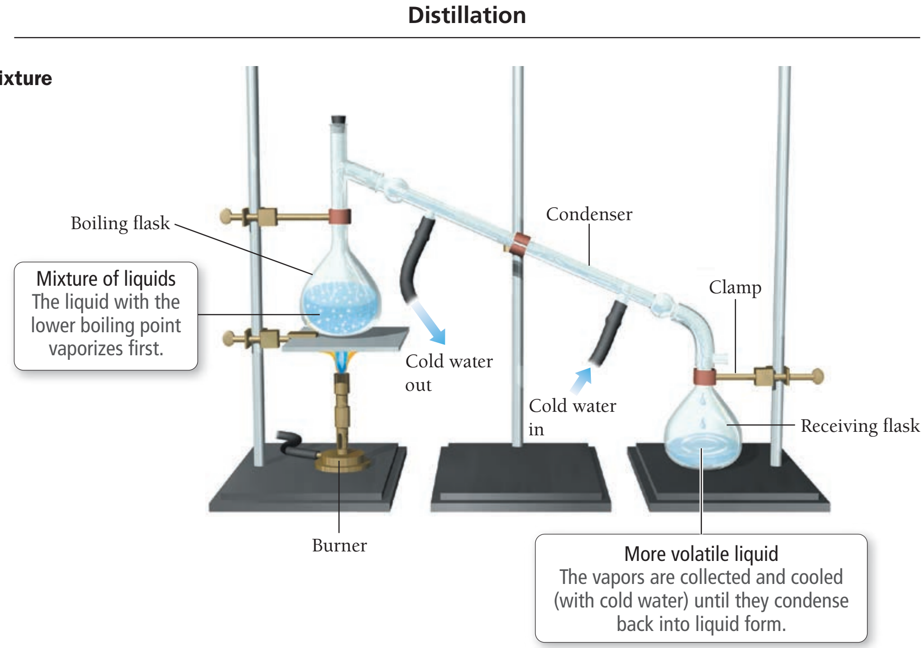
▲ **FIGURE 3.1 Atoms and molecules** All matter is ultimately composed of atoms. (**a**) In some substances, such as aluminum, the atoms exist as independent particles. (**b**) In other substances, such as rubbing alcohol, several atoms bond together in well-defined structures called molecules.

Abundant molecular-level views show students the connection between everyday processes that are visible to the eye and the behavior of atoms and molecules.

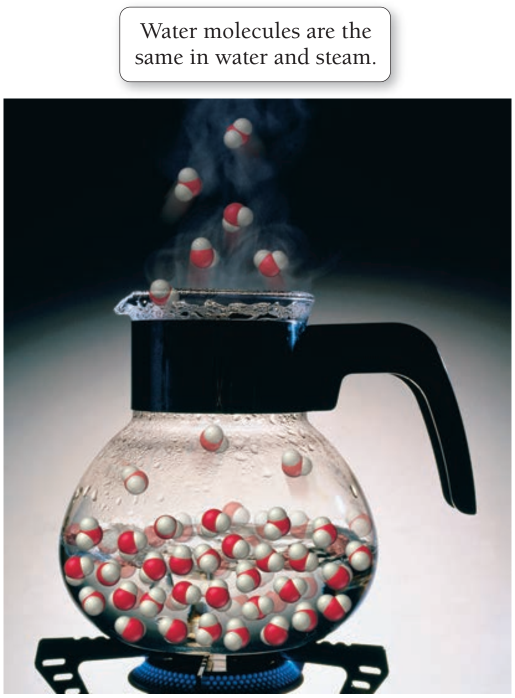


▶ **FIGURE 3.4 Three states of matter** Water exists as ice (solid), water (liquid), and steam (gas). In ice, the water molecules are closely spaced and, although they vibrate about a fixed point, they do not generally move relative to one another. In liquid water, the water molecules are also closely spaced but are free to move around and past each other. In steam, water molecules are separated by large distances and do not interact significantly with one another.

A revised art program helps students make connections and see that chemistry is all around them.



▶ **FIGURE 3.13 Separating a mixture of two liquids by distillation**



▲ **FIGURE 3.9 A physical property** The boiling point of water is a physical property, and boiling is a physical change. When water boils, it turns into a gas, but the water molecules are the same in both the liquid water and the gaseous steam.

NEW and UPDATED! Illustrations include extensive labels and annotations to direct student attention to key elements in the art and promote understanding of the processes depicted. Numerous figures in the sixth edition have updated labels and annotations to focus readers on key concepts. Relevant information is placed where it is most needed and makes the art a vital study and review tool.

Dynamic Study Modules and the Chemistry Primer help students come to class prepared.

66 Dynamic Study Modules adapt to students' individual levels of understanding and help them study effectively on their own. Dynamic Study Modules continuously assess student activity and performance in real time. These are available as graded assignments prior to class and are accessible on smartphones, tablets, and computers.

Topics include key math skills and general chemistry concepts such as phases of matter, redox reactions, acids and bases, solutions, and chemical equilibrium.

The Chemistry Primer's pre-built diagnostic assignments get students up-to-speed at the beginning of the course, addressing topics such as math in the context of chemistry, basic chemical literacy, balancing chemical equations, mole theory, and stoichiometry. The Chemistry Primer scales to students' needs – remediation is only suggested to students that perform poorly on initial assessment, and involves Tutorials, Wrong-Answer Specific Feedback, Video Instruction, and Step-Wise Scaffolding to build student understanding.