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.
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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,

Nivaldo J. Tro
tro@westmont.edu
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. Whenever 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.

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. 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. 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 language comprehension 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 that 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
tro@westmont.edu

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.
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-Assessment 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.

MasteringChemistry™ Access/Supplements

MasteringChemistry™ is the most effective and powerful online tutorial, homework, and assessment system available, proven to improve results by helping students master concepts quickly. Interactive, self-paced coaching activities provide individualized coaching to help students stay on track. With a wide range of activities available, students learn actively and master challenging course concepts. See the MasteringChemistry™ visual walkthrough section for more in-depth details.

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**For the Teacher**

Most of the teacher supplements and resources for this text are available electronically to qualified adopters within Mastering and on the Instructor Resource Center (IRC). Upon adoption or to preview, please go to www.pearsonschool.com/access_request and select Instructor Resource Center. You will be required to complete a brief one-time registration subject to verification of educator status. Upon verification, access information and instructions will be sent to you via e-mail. Once logged into the IRC, enter 0-13-455737-9 in the “Search our Catalog” box to locate resources.

**Instructor Manual with Complete Solutions**

This manual features lecture outlines with presentation suggestions, teaching tips, suggested in-class demonstrations, and topics for classroom discussion. It also contains full solutions to all the end-of-chapter problems from the text. This is available for download from the Instructor’s Resource Center.

**TestGen**

This download-only test bank includes more than 2000 questions and is available on the Instructor’s Resource Center.

**MasteringChemistry™ Instructor’s Resources**

MasteringChemistry™ provides a wealth of instructor resources in addition to those listed above. These resources include PowerPoint tools, images, videos, animations, and more.

**For the Student**

*The following resources are for purchase.*

**Study Guide**

Each chapter of the Study Guide contains an overview, key learning outcomes, a chapter review, as well as practice problems for each major concept in the text. Each chapter is followed by two or three self-tests with answers so students can check their work.

**Student Solutions Manual**

The manual provides solutions to those problems that have a short answer in the text’s Answers section (problems numbered in blue in the text).
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 Silverstein, 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.

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.

### 1.4 Analyzing and Interpreting Data

Identify patterns in data and draw inferences.

We just learned how early scientists such as Lavoisier and Dalton saw patterns in a series of related measurements. Lists of measurements contain 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:

<table>
<thead>
<tr>
<th>Sample</th>
<th>Mass of Water</th>
<th>Mass of Hydrogen</th>
<th>Mass of Oxygen</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>20.0 g</td>
<td>2.2 g</td>
<td>17.8 g</td>
</tr>
<tr>
<td>B</td>
<td>10.0 g</td>
<td>1.1 g</td>
<td>8.9 g</td>
</tr>
</tbody>
</table>

Do you notice any patterns in the data? The first and second patterns to note is that the mass of the samples of oxygen and hydrogen always sums to the mass of the water. In fact, the oxygen and hydrogen are fixed in a 2:1 ratio. The sum of the masses of hydrogen and oxygen = 20.0 g water. The same is true for the other sample. 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.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>2.2 g</td>
<td>17.8 g</td>
<td>1</td>
</tr>
<tr>
<td>B</td>
<td>1.1 g</td>
<td>8.9 g</td>
<td>1</td>
</tr>
</tbody>
</table>

The ratio in the second samples are due to experimental error, which is common in all measurements and observations.

#### Data Interpretation and Analysis

**Conceptual Checkpoint:** What was the average rate of increase in carbon dioxide concentration from 2000 to 2013?

**Solution:**

Using the graph in Figure 1.1 and answer each question:

(a) What was the concentration of carbon dioxide in 1990?
(b) What was the concentration in 2000?
(c) What was the concentration in 2007?
(d) What was the average rate of increase over time?
(e) If the average rate of increase remains constant, what is the carbon dioxide concentration in 2015?

**Graph:** See the graph for the concentration of carbon dioxide from 1990 to 2013. The graph shows the concentration of carbon dioxide in Earth's atmosphere at different times. The graph has a trend line that indicates an increase in carbon dioxide concentration over time. The rate of increase is represented by the slope of the line—has increased since about 1960.

**Answers to Conceptual Checkpoints**

1. The average rate of increase for carbon dioxide concentration from 1990 to 2013 was 1.055 ppm/year.
2. The average rate of increase for carbon dioxide concentration from 1990 to 2000 was 1.07 ppm/year.
3. The average rate of increase for carbon dioxide concentration from 2000 to 2007 was 1.06 ppm/year.
4. The average rate of increase for carbon dioxide concentration from 2007 to 2013 was 1.04 ppm/year.

**Skillbuilder 3.11**

**U.S. Energy Consumption by Source**

![Graph showing U.S. energy consumption by source from 1860 to present.](image)

**Questions:**

(a) Which two sources of U.S. energy decline as a percent of total energy use between 1860 and 2013? (b) How much U.S. energy (in joules) was produced by nuclear power in 1990? (c) How much U.S. energy (in joules) was produced by hydroelectric power in 2013? (d) Which two sources of U.S. energy increase as a percent of total energy use between 1860 and 2013? (e) Which two sources of U.S. energy increase as a percent of total energy use between 2013 and 2040? (f) Which source of U.S. energy is predicted to be the largest source of energy by 2040? (g) Which two sources of U.S. energy were the largest sources of energy in 2013? (h) What is the predicted percent of total energy use for each source from 1980 to 2040? (i) What total percent of U.S. energy is provided by natural gas in 2013? (j) Which sources provide the most energy to U.S. industries? (k) How much U.S. energy (in joules) was produced by coal in 1990? (l) Which two sources provide the most energy to U.S. homes? (m) Which two sources provide the most energy to U.S. businesses? (n) Which two sources were the largest sources of energy in 1860? (o) Which sources did not change their percent of energy use between 1860 and 2013? (p) Which sources increased their percent of energy use between 1860 and 2013? (q) Which sources increased their percent of energy use between 2013 and 2040? (r) Which sources did not change their percent of energy use between 2013 and 2040? (s) Which sources increased their percent of energy use between 1860 and 2013? (t) Which sources increased their percent of energy use between 2013 and 2040? (u) Which sources increased their percent of energy use between 1860 and 2013? (v) Which sources increased their percent of energy use between 2013 and 2040? (w) Which sources increased their percent of energy use between 1860 and 2013? (x) Which sources increased their percent of energy use between 2013 and 2040? (y) Which sources increased their percent of energy use between 1860 and 2013? (z) Which sources increased their percent of energy use between 2013 and 2040?
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.

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™.

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

**Self-Assessment Quiz**

<table>
<thead>
<tr>
<th>Q1. Which substance is a pure compound?</th>
<th>(a) Gold</th>
<th>(b) Water</th>
<th>(c) Milk</th>
<th>(d) Fruit cake</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q2. Which property of trinitrotoluene (TNT) is most likely a chemical property?</td>
<td>(a) Yellow color</td>
<td>(b) Melting point is 80.1 °C</td>
<td>(c) Explosive</td>
<td>(d) None of the above</td>
</tr>
<tr>
<td>Q3. Which change is a chemical change?</td>
<td>(a) The condensation of dew on a cold night</td>
<td>(b) A forest fire</td>
<td>(c) The smoothening of rocks by ocean waves</td>
<td>(d) None of the above</td>
</tr>
<tr>
<td>Q4. Which process is endothermic?</td>
<td>(a) The burning of natural gas in a stove</td>
<td>(b) The metabolism of glucose by your body</td>
<td>(c) The melting of ice in a soft drink</td>
<td>(d) None of the above</td>
</tr>
<tr>
<td>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?</td>
<td>(a) 67 g.</td>
<td>(b) 35 g.</td>
<td>(c) 32 g.</td>
<td>(d) 12 g.</td>
</tr>
<tr>
<td>Q6. A runner burns 2.58 × 10^3 kJ during a five-mile run. How many nutritional Calories did the runner burn?</td>
<td>(a) 1.07 × 10^4 Cal</td>
<td>(b) 612 Cal</td>
<td>(c) 6.12 × 10^3 Cal</td>
<td>(d) 1.07 × 10^4 Cal</td>
</tr>
</tbody>
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<table>
<thead>
<tr>
<th>Q7. Convert the boiling point of water (100.00 °C) to K.</th>
<th>(a) 373.15 K</th>
<th>(b) 0 K</th>
<th>(c) 100.00 K</th>
<th>(d) 373.15 K</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q8. A European doctor reports that you have a fever of 39.2 °C. What is your fever in degrees Fahrenheit?</td>
<td>(a) 102.6 °F</td>
<td>(b) 128.26 °F</td>
<td>(c) 71.2 °F</td>
<td>(d) 4 °F</td>
</tr>
<tr>
<td>Q9. How much heat must be absorbed by 125 g of ethanol to change its temperature from 21.5 °C to 34.8 °C?</td>
<td>(a) 6.95 kJ</td>
<td>(b) 4.02 × 10^3 kJ</td>
<td>(c) 86.6 kJ</td>
<td>(d) 4.02 kJ</td>
</tr>
<tr>
<td>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?</td>
<td>(a) The final temperature will be between 25.0 °C and 50.0 °C.</td>
<td>(b) The final temperature will be between 50.0 °C and 75.0 °C.</td>
<td>(c) The final temperature will be 50.0 °C.</td>
<td>(d) You can conclude nothing about the final temperature without more information.</td>
</tr>
</tbody>
</table>
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).

**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 3.1 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.

**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.

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.

**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.

**Figure 3.14** Distillation
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.
MasteringChemistry™ ensures student engagement before, during, and after class.

With questions specific to Tro’s Introductory Chemistry, Learning Catalytics™ generates class discussion, guides lecture, and promotes peer-to-peer learning with real-time analytics. Instructors can:

- **NEW!** Upload a full PowerPoint® deck for easy creation of slide questions
- Help students develop critical thinking skills
- Monitor responses to find out where students are struggling
- Adjust teaching strategy with real-time data
- Automatically group students for discussion, teamwork, and peer-to-peer learning

**UPDATED!** MasteringChemistry™ offers a wide variety of problems, ranging from multi-step tutorials with extensive hints and feedback to multiple-choice End-of-Chapter Problems and Test Bank questions.

To provide additional scaffolding for students moving from Tutorial Problems to End-of-Chapter Problems we created **NEW! Enhanced End-of-Chapter Problems** that now contain specific wrong-answer feedback.
Students can study anywhere with fully interactive and mobile eText 2.0 features.

**NEWLY INTERACTIVE!** Self-Assessment Quizzes and Conceptual Checkpoints allow students to interact with all Conceptual Checkpoints and Self-Assessment Quizzes within eText 2.0! With one click these activities are brought to life, allowing students to study on their own and test their understanding in real-time. These interactives help students extinguish misconceptions and deepen their understanding of important concepts and topics.

An icon in the text alerts students to interactive eText 2.0 features. The eText is fully optimized for use on mobile devices, allowing students to study anywhere.

In addition to **Conceptual Checkpoints** and **Self-Assessment Quizzes**, all **Key Concept Videos** and **Interactive Worked Examples** are available in the eText.