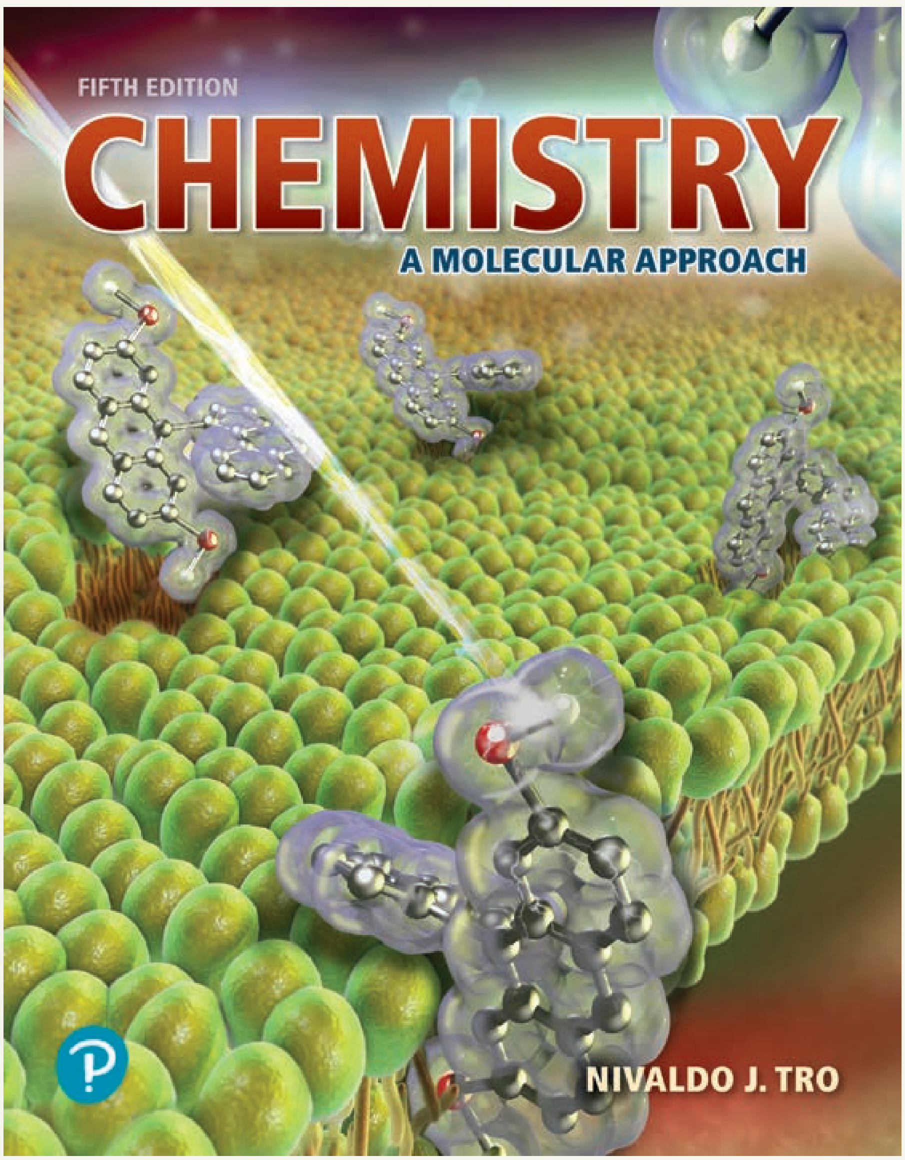
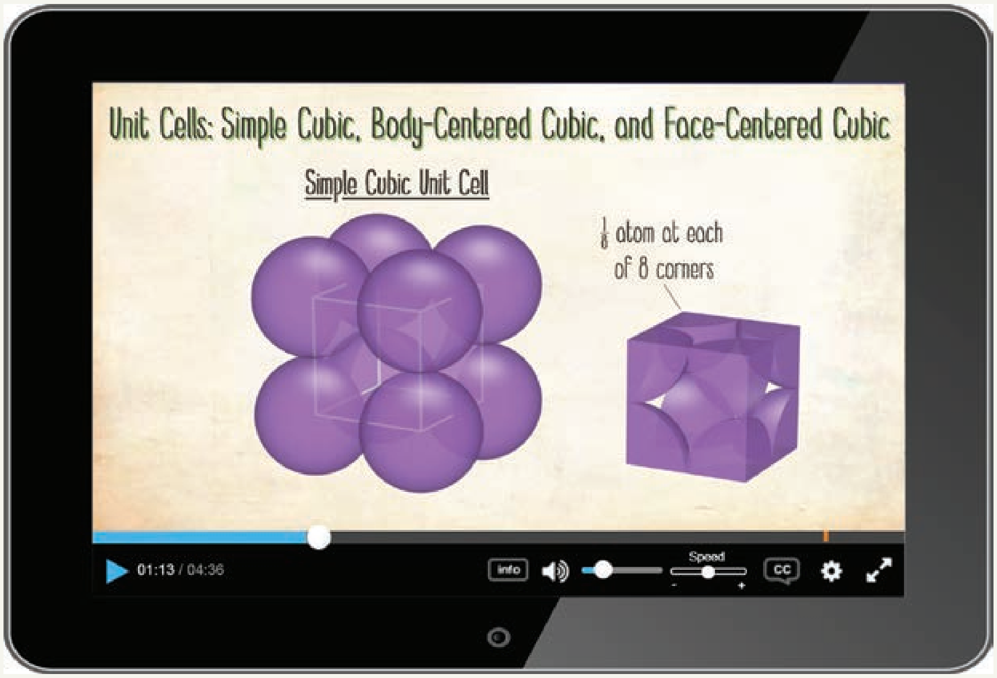
Actively Engage Students to Become Expert Problem Solvers and Critical Thinkers

Nivaldo Tro's *Chemistry: A Molecular Approach* presents chemistry visually through multi-level images—macroscopic, molecular, and symbolic representations—to help students see the connections between the world they see around them, the atoms and molecules that compose the world, and the formulas they write down on paper. The **5th Edition** pairs digital, pedagogical innovation with insights from learning design and educational research to create an active, integrated, and easy-to-use framework. The new edition introduces a fully integrated book and media package that streamlines course setup, actively engages students in becoming expert problem solvers, and makes it possible for professors to teach the general chemistry course easily and effectively.



Pearson

Learn core concepts...

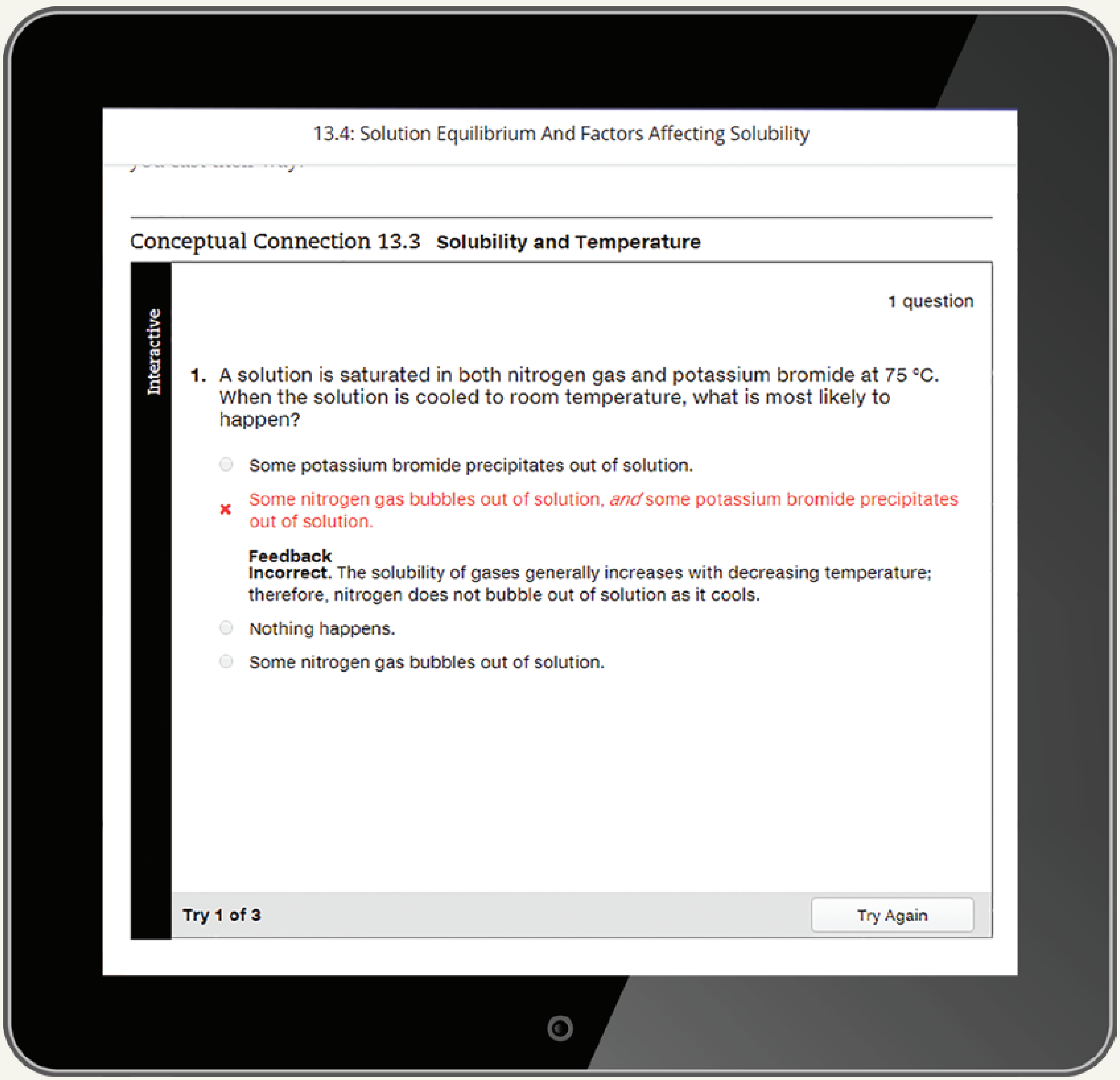


Key Concept Videos combine artwork from the textbook with 2D and 3D animations to create a dynamic on-screen viewing and learning experience. The 5th edition includes **16 new** videos, for a total of **74**.

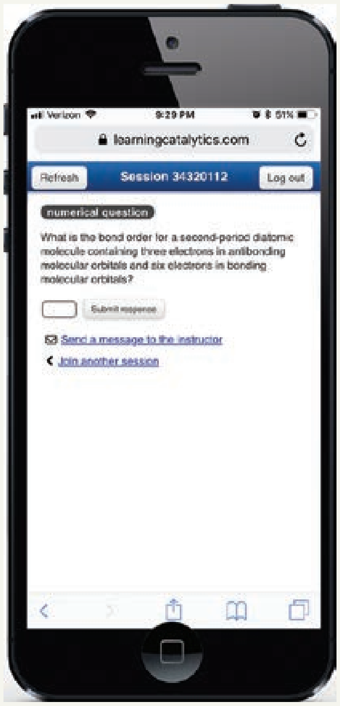
These short videos include **narration and brief live-action clips of author Nivaldo Tro** explaining every key concept in general chemistry. All Key Concept Videos are available on mobile devices, embedded in Pearson eText, and are assignable in Mastering Chemistry.

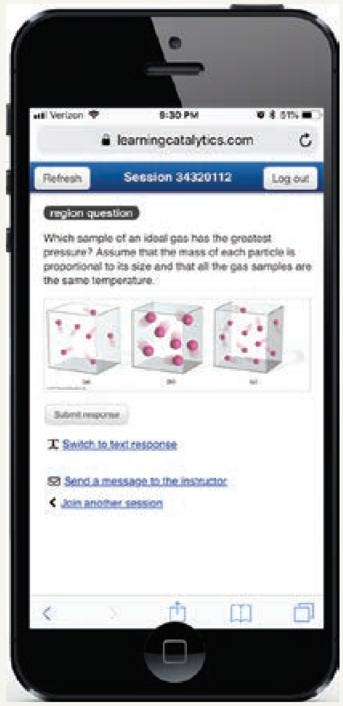
before students even come to class

Newly Interactive Conceptual Connections allow students to interact with all conceptual connections within the Pearson eText, so that they can study on their own and test their understanding in real time. **Complete with answer-specific feedback written by the author himself**, these interactives help students extinguish misconceptions and deepen their understanding of important topics, making reading an active experience.

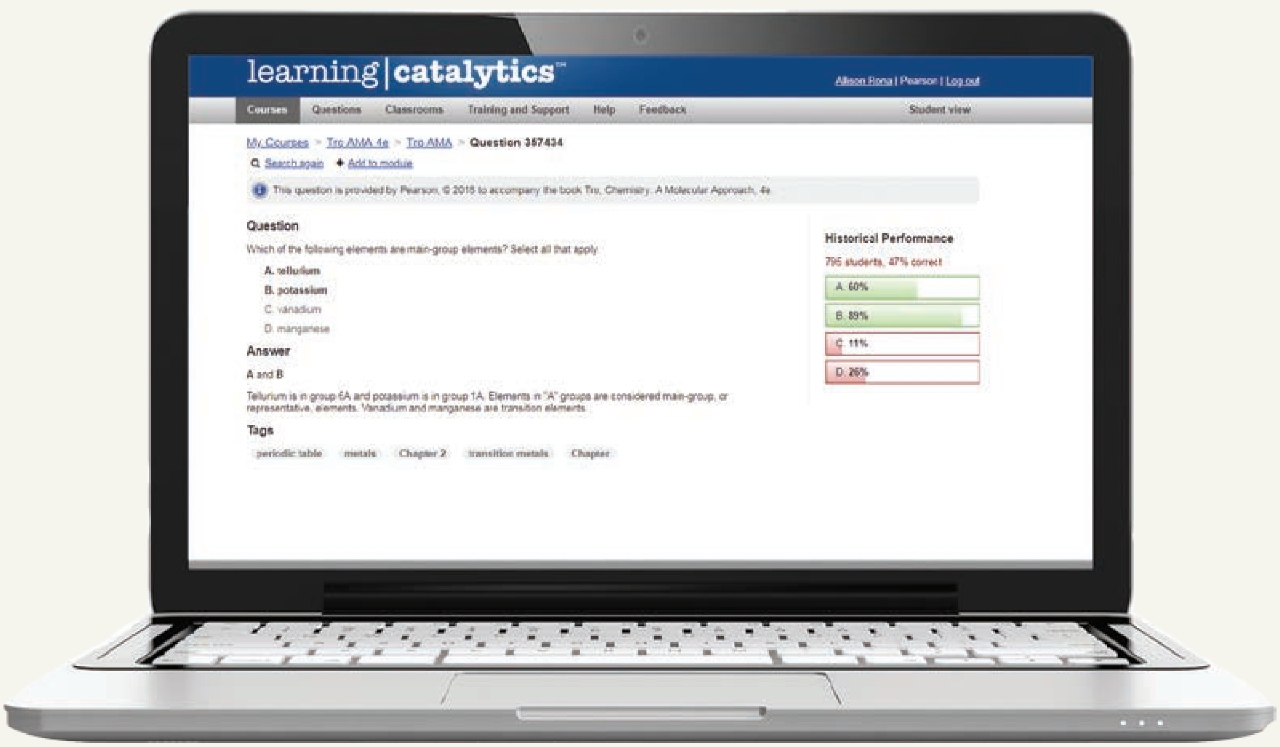


Actively engage students...





With Learning Catalytics, you'll hear from every student when it matters most. You pose a variety of questions that help students recall ideas, apply concepts, and develop critical-thinking skills. Your students respond using their own smartphones, tablets, or laptops.



You can monitor responses with real-time analytics and find out what your students do — and don't — understand. Then, you can adjust your teaching accordingly, and even facilitate peer-to-peer learning, helping students stay motivated and engaged. **Learning Catalytics includes prebuilt questions for every key topic in General Chemistry.**

with in-class activities

QUESTIONS FOR GROUP WORK

Active Classroom Learning

Discuss these questions with the group and record your consensus answer.

139. Explain why 1-propanol ($CH_3CH_2CH_2OH$) is miscible in both water (H_2O) and hexane (C_6H_6) when hexane and water are barely soluble in each other.

140. Have each group member make a flashcard with one of the following on the front: ΔH_{soln}, $\Delta H_{lattice}$, $\Delta H_{solvent}$, ΔH_{mix}, and $\Delta H_{hydration}$. On the back of the card, each group member should describe (in words) the ΔH process his or her card lists and how that ΔH relates to other ΔH values mathematically. Each member presents his or her ΔH to the group. After everyone has presented, members should trade cards and quiz each other.

141. Complete the following table by adding *increases, decreases*, or *no effect*:

	Increasing Temperature	Increasing Pressure
solubility of gas in water		
solubility of a solid in water		

142. When 13.62 g (about one tablespoon) of table sugar (sucrose, $C_{12}H_{22}O_{11}$) is dissolved in 241.5 mL of water (density 0.997 g/mL), the final volume is 250.0 mL (about one cup). Have each group member calculate one of the following for the solution and present his or her answer to the group:

a. mass percent
b. molarity
c. molality

143. Calculate the expected boiling and freezing point for the solution in the previous problem. If you had to bring this syrup to the boiling point for a recipe, would you expect it to take much more time than it takes to boil the same amount of pure water? Why or why not? Would the syrup freeze in a typical freezer (−18 °C)? Why or why not?

p. 628

Questions for Group Work allow students to collaborate and apply problem-solving skills on questions covering multiple concepts. The questions can be used in or out of the classroom, and the goal is to foster collaborative learning and encourage students to work together as a team to solve problems. All questions for group work are pre-loaded into Learning Catalytics for ease of assignment.

Numerous ideas for in-class activities can be found in the Ready-to-Go Teaching Modules in the Instructor Resources in Mastering Chemistry. There, instructors will find the most effective activities, problems, and questions from the text, Mastering, and Learning Catalytics, to use in class.

Kinesthetic Activity: Polarity

5 – 10 minutes
Average time for activity

In groups, students model molecules using rope (representing bond dipoles) to show which molecular shapes are polar or nonpolar. This activity can be done at the front of the classroom or in small groups. Example: For trigonal planar, have one student stand in the middle holding the ends of three ropes. Have three other students stand in a trigonal planar arrangement around the middle student and pull equally on the ropes. Since all the ropes (dipole moments) cancel out, the middle student does not get pulled in any direction; this illustrates that the trigonal planar shape is nonpolar. Other shapes that can be shown include: linear, bent, trigonal planar, square planar, T-shaped.

Master problem-solving...

PROBLEMS BY TOPIC

Solution Concentration and Solution Stoichiometry

21. Calculate the molarity of each solution.
MISSED THIS? *Read Section 5.2; Watch KCV 5.2, IWE 5.1*
a. 3.25 mol of LiCl in 2.78 L solution
b. 28.33 g $C_6H_{12}O_6$ in 1.28 L of solution
c. 32.4 mg NaCl in 122.4 mL of solution

22. Calculate the molarity of each solution.
a. 0.38 mol of $LiNO_3$ in 6.14 L of solution
b. 72.8 g C_2H_6O in 2.34 L of solution
c. 12.87 mg KI in 112.4 mL of solution

23. What is the molarity of NO_3^- in each solution?
MISSED THIS? *Read Sections 5.2, 5.4; Watch KCV 5.2, IWE 5.1*
a. 0.150 M KNO_3
b. 0.150 M $Ca(NO_3)_2$
c. 0.150 M $Al(NO_3)_3$

24. What is the molarity of Cl^- in each solution?
a. 0.200 M NaCl
b. 0.150 M $SrCl_2$
c. 0.100 M $AlCl_3$

25. How many moles of KCl are contained in each solution?
MISSED THIS? *Read Section 5.2; Watch KCV 5.2, IWE 5.2*
a. 0.556 L of a 2.3 M KCl solution
b. 1.8 L of a 0.85 M KCl solution
c. 114 mL of a 1.85 M KCl solution

26. What volume of 0.200 M ethanol solution contains each amount in moles of ethanol?
a. 0.45 mol ethanol
b. 1.22 mol ethanol
c. 1.2×10^{-2} mol ethanol

27. A laboratory procedure calls for making 400.0 mL of a 1.1 M $NaNO_3$ solution. What mass of $NaNO_3$ (in g) is needed?
MISSED THIS? *Read Section 5.2; Watch KCV 5.2, IWE 5.2*

28. A chemist wants to make 5.5 L of a 0.300 M $CaCl_2$ solution. What mass of $CaCl_2$ (in g) should the chemist use?

29. If 123 mL of a 1.1 M glucose solution is diluted to 500.0 mL, what is the molarity of the diluted solution?
MISSED THIS? *Read Section 5.2; Watch KCV 5.2, IWE 5.3*

30. If 3.5 L of a 4.8 M $SrCl_2$ solution is diluted to 45 L, what is the molarity of the diluted solution?

31. To what volume should you dilute 50.0 mL of a 12 M stock HNO_3 solution to obtain a 0.100 M HNO_3 solution?
MISSED THIS? *Read Section 5.2; Watch KCV 5.2, IWE 5.3*

32. To what volume should you dilute 25 mL of a 10.0 M H_2SO_4 solution to obtain a 0.150 M H_2SO_4 solution?

33. Consider the precipitation reaction:
MISSED THIS? *Read Section 5.3; Watch IWE 5.4*

$$2\,Na_3PO_4(aq) + 3\,CuCl_2(aq) \longrightarrow Cu_3(PO_4)_2(s) + 6\,NaCl(aq)$$

What volume of 0.175 M Na_3PO_4 solution is necessary to completely react with 95.4 mL of 0.102 M $CuCl_2$?

34. Consider the reaction:

$$Li_2S(aq) + Co(NO_3)_2(aq) \longrightarrow 2\,LiNO_3(aq) + CoS(s)$$

What volume of 0.150 M Li_2S solution is required to completely react with 125 mL of 0.150 M $Co(NO_3)_2$?

35. What is the minimum amount of 6.0 M H_2SO_4 necessary to produce 25.0 g of $H_2(g)$ according to the reaction between aluminum and sulfuric acid?
MISSED THIS? *Read Section 5.3; Watch IWE 5.4*

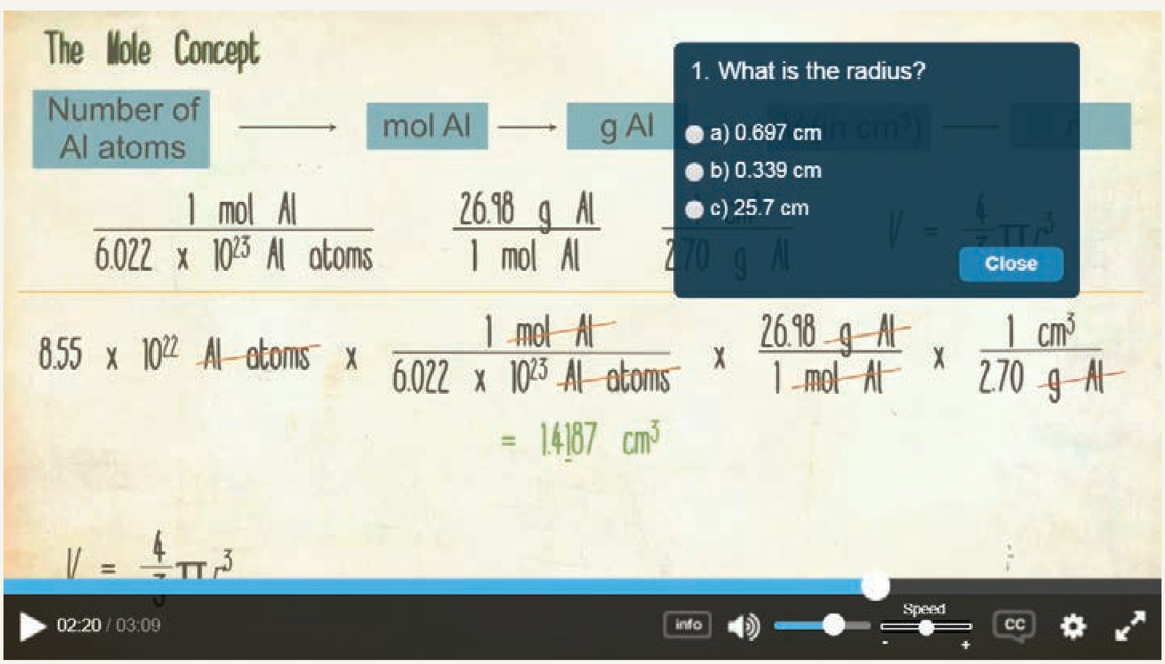
$$2\,Al(s) + 3\,H_2SO_4(aq) \longrightarrow Al_2(SO_4)_3(aq) + 3\,H_2(g)$$

36. What is the molarity of $ZnCl_2$ that forms when 25.0 g of zinc completely reacts with $CuCl_2$ according to the following reaction? Assume a final volume of 275 mL.

$$Zn(s) + CuCl_2(aq) \longrightarrow ZnCl_2(aq) + Cu(s)$$

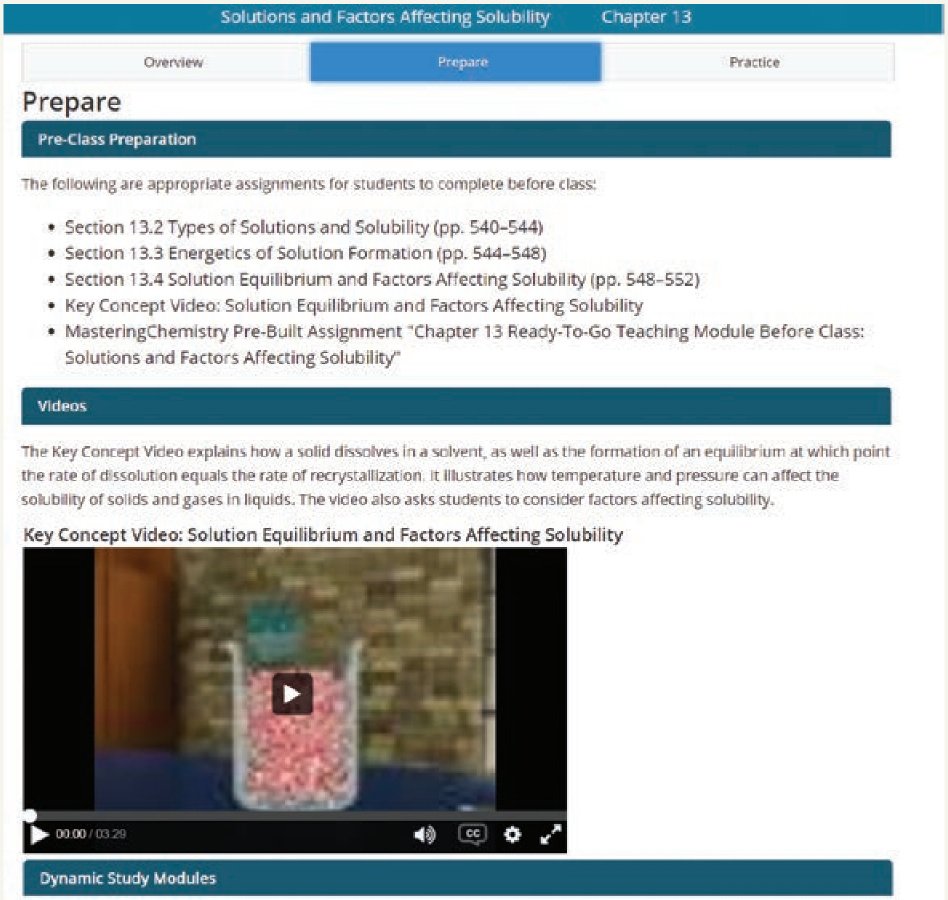
p. 204

NEW! MISSED THIS? appears in the end-of-chapter Self-Assessment Quizzes and each odd-numbered Problems by Topic exercise. *MISSED THIS?* provides sections to read and videos to watch to help students remediate where necessary.



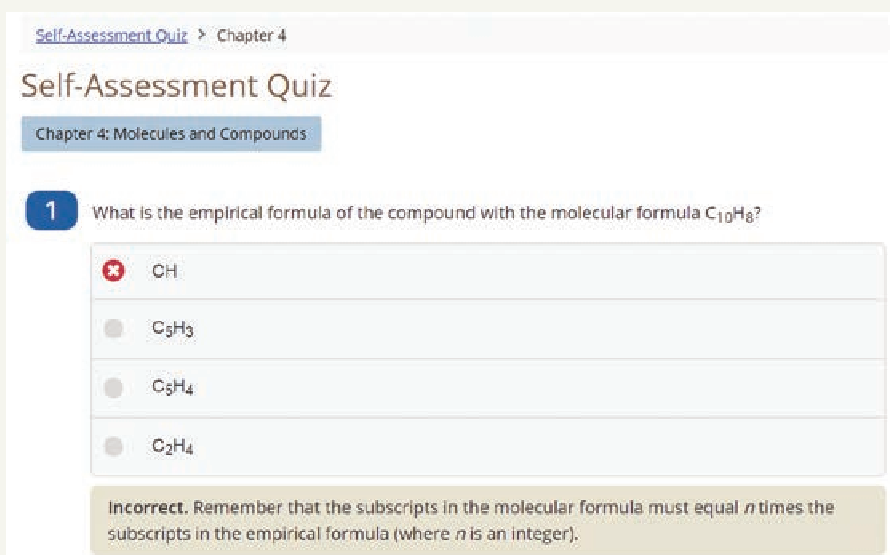
Interactive Worked Examples are digital versions of select worked examples from the text that instruct students how to break down problems using Tro's "Sort, Strategize, Solve, and Check" technique. The Interactive Worked Examples pause in the middle and require the student to interact by completing a step in the example. Each example has a follow-up question that is assignable in Mastering Chemistry. There are 24 new Interactive Worked Examples for a total of 125.

with tools students can use after class



NEW! Ready-to-Go Practice Modules in the Mastering Chemistry Study Area help students master the toughest topics (as identified by professors and fellow students completing homework and practicing for exams). Key Concept Videos, Interactive Worked Examples, and problem sets with answer-specific feedback are all in one easy to navigate place to keep students focused and give them the scaffolded support they need to succeed.

Newly Interactive Self-Assessment Quizzes, complete with answer-specific feedback, allow students to quiz themselves within the Pearson eText, so that they can study on their own and test their understanding in real time. The Self-Assessment Quizzes are also assignable in Mastering Chemistry. Professors can use questions from these quizzes to prepare a pretest on Mastering Chemistry. Research has shown that this kind of active exam preparation improves students' exam scores.



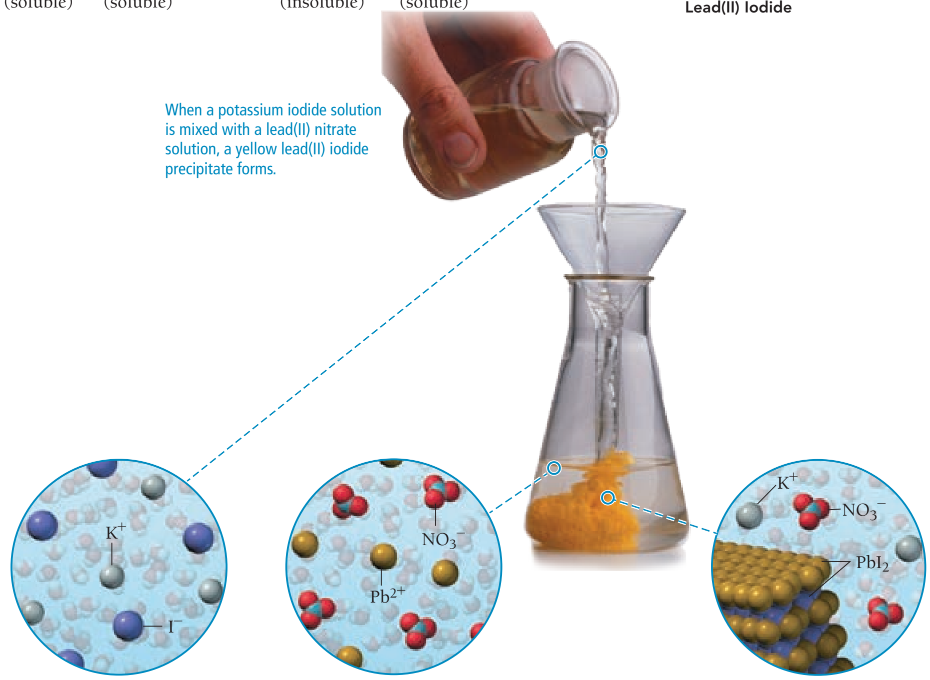
Teach with art based on learning design principles

Extensively updated art program better directs students' attention to key elements in the art and promotes understanding of the processes depicted. Dozens of figures in the 5th Edition were reviewed by learning design specialists to ensure they are clearly navigable for students and now include more helpful annotations and labels to help readers focus on key concepts.

Precipitation Reaction

$2\ KI(aq) + Pb(NO_3)_2(aq) \longrightarrow PbI_2(s) + 2\ KNO_3(aq)$
(soluble) (soluble) (insoluble) (soluble)

◀ **FIGURE 5.13** **Precipitation of Lead(II) Iodide**



$2\ KI(aq)$ (soluble) + $Pb(NO_3)_2(aq)$ (soluble) $\longrightarrow$ $PbI_2(s)$ (insoluble) + $2\ KNO_3(aq)$ (soluble)

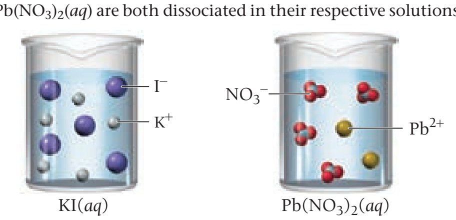
Precipitation reactions do not always occur when two aqueous solutions are mixed. For example, if we combine solutions of $KI(aq)$ and $NaCl(aq)$, nothing happens (Figure 5.14▶):

$$KI(aq) + NaCl(aq) \not\longrightarrow \text{NO REACTION}$$

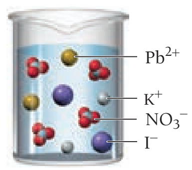
The key to predicting precipitation reactions is to understand that *only insoluble compounds form precipitates*. In a precipitation reaction, two solutions containing soluble compounds combine and an insoluble compound precipitates. Consider the precipitation reaction described previously:

$$\underset{\text{soluble}}{2\ KI(aq)} + \underset{\text{soluble}}{Pb(NO_3)_2(aq)} \longrightarrow \underset{\text{insoluble}}{PbI_2(s)} + \underset{\text{soluble}}{2\ KNO_3(aq)}$$

KI and $Pb(NO_3)_2$ are both soluble, but the precipitate, PbI_2, is insoluble. Before mixing, $KI(aq)$ and $Pb(NO_3)_2(aq)$ are both dissociated in their respective solutions:

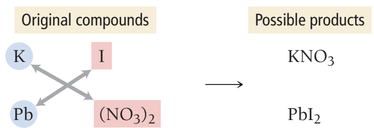


The instant that the solutions come into contact, all four ions are present:



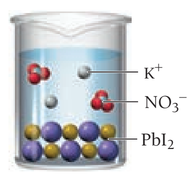
$KI(aq)$ and $Pb(NO_3)_2(aq)$

Now, new compounds—one or both of which might be insoluble—are possible. Specifically, the cation from either compound can pair with the anion from the other to form possibly insoluble products:



If the possible products are both soluble, no reaction occurs and no precipitate forms. If one or both of the possible products are insoluble, a precipitation reaction occurs. In this case, KNO_3 is soluble, but PbI_2 is insoluble. Consequently, PbI_2 precipitates.

To predict whether a precipitation reaction will occur when two solutions are mixed and to write an equation for the reaction, we use the procedure that follows. The steps are outlined in the left column, and two examples illustrating how to apply the procedure are shown in the center and right columns.

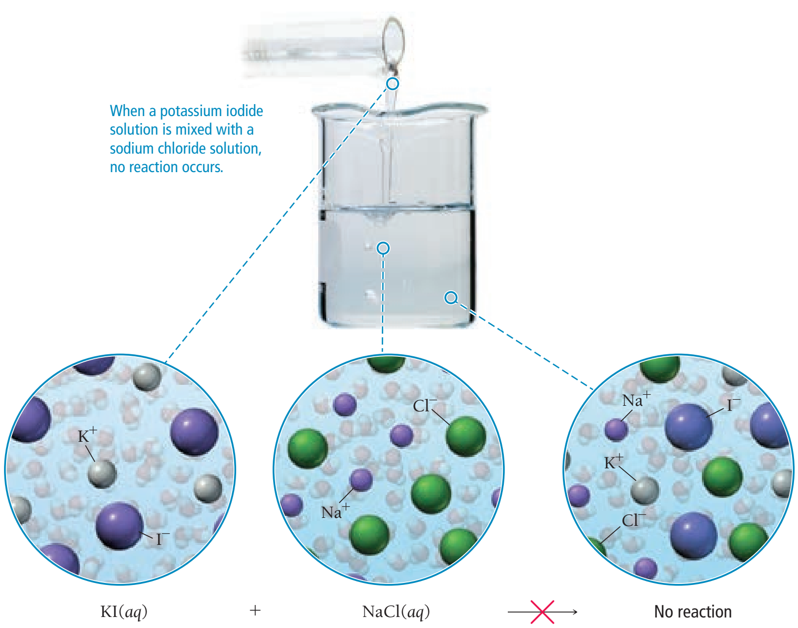


$PbI_2(s)$ and $KNO_3(aq)$

No Reaction

$KI(aq) + NaCl(aq) \not\longrightarrow$ No reaction

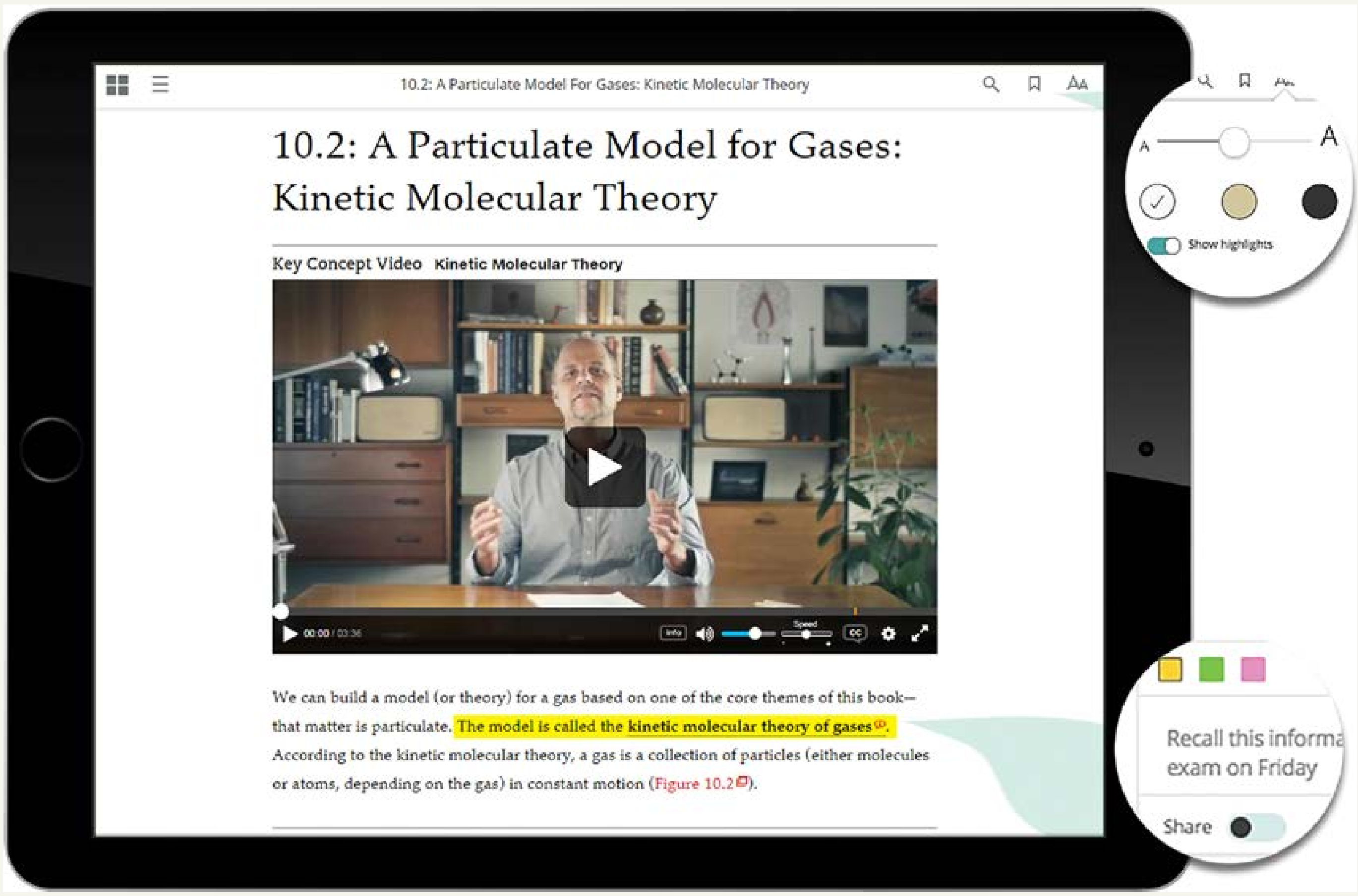
◀ **FIGURE 5.14** **No Precipitation**



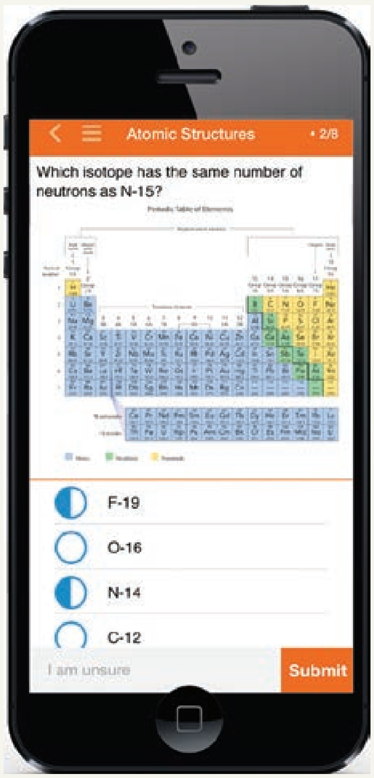
Tro's multipart images help students see the relationship between the formulas they write down on paper (symbolic), the world they see around them (macroscopic), and the atoms and molecules that compose the world (molecular).

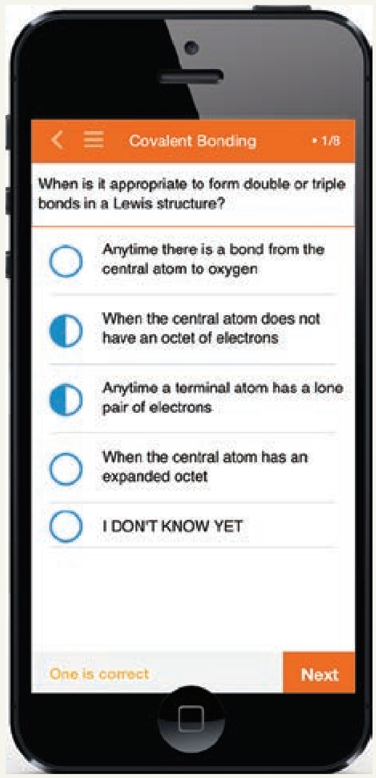
Deliver trusted content with Pearson eText

Pearson eText is a simple-to-use, mobile-optimized, personalized reading experience available within Mastering. It allows students to easily highlight, take notes, and review key vocabulary all in one place—even when offline. Seamlessly integrated videos, rich media, and interactive self-assessment questions engage students and give them access to the help they need, when they need it. Pearson eText is available within Mastering when packaged with a new book; students can also purchase Mastering with Pearson eText online.



Improve learning with Dynamic Study Modules

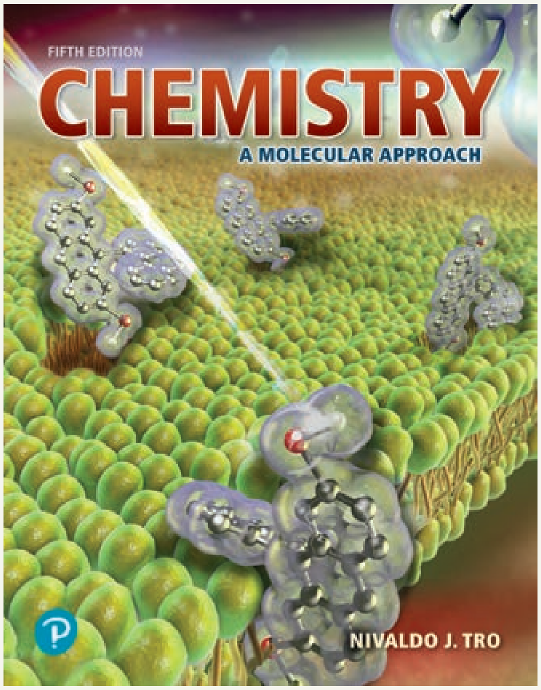




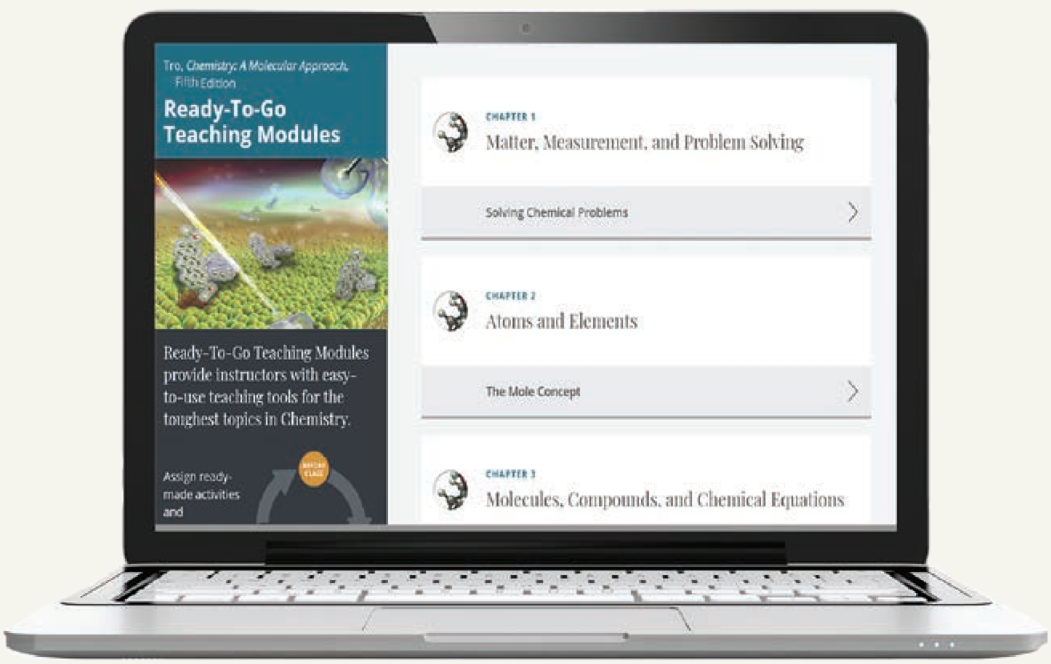
Dynamic Study Modules in Mastering Chemistry help students study effectively—and at their own pace—by keeping them motivated and engaged. The assignable modules rely on the latest research in cognitive science, using methods—such as adaptivity, gamification, and intermittent rewards—to stimulate learning and improve retention.

Each module poses a series of questions about a course topic. These question sets adapt to each student's performance and offer personalized, targeted feedback to help them master key concepts. With **Dynamic Study Modules,** students build the confidence they need to deepen their understanding, participate meaningfully, and perform better—in and out of class.

Instructor support you can rely on



Chemistry: A Molecular Approach includes a full suite of instructor support materials in the Instructor Resources area in Mastering Chemistry. Resources include new Ready-to-Go Teaching Modules; accessible PowerPoint lecture outlines; all images and worked examples from the text; all Key Concept Videos and Interactive Worked Examples; plus an instructor resource manual and test bank.



Ready-to-Go Study Tools provide organized material for every tough topic in General Chemistry. The modules – created for and by instructors – provide easy-to-use before and after class assignments, in-class activities with clicker questions, and questions in Learning Catalytics™. The modules are easily accessed via Mastering Chemistry.

Preface

To the Student

As you begin this course, I invite you to think about your reasons for enrolling in it. Why are you taking general chemistry? More generally, why are you pursuing a college education? If you are like most college students taking general chemistry, part of your answer is probably that this course is required for your major and that you are pursuing a college education so you can get a good job some day. Although these are good reasons, I would like to suggest a better one. I think the primary reason for your education is to prepare you to *live a good life*. You should understand chemistry—not for what it can *get* you—but for what it can *do* to you. Understanding chemistry, I believe, is an important source of happiness and fulfillment. Let me explain.

Understanding chemistry helps you to live life to its fullest for two basic reasons. The first is *intrinsic*: through an understanding of chemistry, you gain a powerful appreciation for just how rich and extraordinary the world really is. The second reason is *extrinsic*: understanding chemistry makes you a more informed citizen—it allows you to engage with many of the issues of our day. In other words, understanding chemistry makes *you* a deeper and richer person and makes your country and the world a better place to live. These reasons have been the foundation of education from the very beginnings of civilization.

How does chemistry help prepare you for a rich life and conscientious citizenship? Let me explain with two examples. My first one comes from the very first page of Chapter 1 of this book. There, I ask the following question: What is the most important idea in all of scientific knowledge? My answer to that question is this: **the behavior of matter is determined by the properties of molecules and atoms**. That simple statement is the reason I love chemistry. We humans have been able to study the substances that compose the world around us and explain their behavior by reference to particles so small that they can hardly be imagined. If you have never realized the remarkable dependence of the world we *can* see on the world we *cannot*, you have missed out on a fundamental truth about our universe. To have never encountered this truth is like never having read a play by Shakespeare or seen a sculpture by Michelangelo—or, for that matter, like never having discovered that the world is round. It robs you of an amazing and unforgettable experience of the world and the human ability to understand it.

My second example demonstrates how science literacy helps you to be a better citizen. Although I am largely sympathetic to the environmental movement, a lack of science literacy within some sectors of that movement and the resulting anti-environmental backlash create confusion that impedes real progress and opens the door to what could be misinformed policies. For example, I have heard conservative pundits say that volcanoes emit more carbon dioxide—the most significant greenhouse gas—than does petroleum combustion. I have also heard a liberal environmentalist say that we have to stop using hair spray because it is causing holes in the ozone layer that will lead to global warming. Well, the claim about volcanoes emitting more carbon dioxide than petroleum combustion can be refuted by the basic tools you will learn to use in Chapter 4 of this book. We can easily show that volcanoes emit only 1/50th as much carbon dioxide as petroleum combustion. As for hair spray depleting the ozone layer and thereby leading to global warming, the chlorofluorocarbons that deplete ozone have been banned from hair spray since 1978, and ozone depletion has nothing to do with global warming anyway. People with special interests or axes to grind can conveniently distort the truth before an ill-informed public, which is why we all need to be knowledgeable.

So this is why I think you should take this course. Not just to satisfy the requirement for your major and not just to get a good job some day, but to help you to lead a fuller life and to make the world a little better for everyone. I wish you the best as you embark on the journey to understanding the world around you at the molecular level. The rewards are well worth the effort.

To the Professor

First and foremost, thanks to all of you who adopted this book in its previous editions. You helped to make this book one of the most popular general chemistry textbooks in the world. I am grateful beyond words. Second, I have listened carefully to your feedback on the previous 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 have reviewed content or have contacted me directly, you will likely see your suggestions reflected in the changes I have made. Thank you.

Higher education in science is changing. Foremost among those changes is a shift toward *active learning*. A flood of recent studies has demonstrated that General Chemistry students learn better when they are active in the learning process. However, implementing active learning can be a difficult and time-consuming process. One of my main goals in this revision is to give you, the professor, a range of tools to easily implement active learning in your class. My goal is simple: *I want to make it easy for you to engage your students in active learning before class, during class, and after class.*

- **BEFORE CLASS** Although the term *active learning* has been applied mainly to in-class learning, the main idea—*that we learn better when we are actively engaged*—applies to all of learning. I have developed two main tools to help students prepare for class in an active way. The first tool is a complete library of 3– to 6–minute *Key Concept Videos* (*KCVs*) that, with this edition, span virtually all of the key concepts in a general chemistry course. The videos introduce a key concept and encourage active learning because they stop in the middle and pose a question that must be answered before the video continues playing. Each video also has an associated follow-up question that can be assigned using Mastering Chemistry. You can assign a video before each one of your classes to get your students thinking about the concepts for that day. A second tool for use before class is *active reading*. Each chapter in the book now contains 10–12 *Conceptual Connection* questions. These questions are live in the ebook, assignable in Mastering Chemistry, and contain wrong answer feedback. Instead of passively reading the assigned material with no accountability, you can now encourage your students to engage in *active reading*, in which they read a bit and then answer a question that probes their comprehension and gives them immediate feedback.
- **DURING CLASS** By delivering some content through key concept videos and active reading before class, you can make room in your lecture to pose questions to your students that make the class experience active as well. This book features two main tools for in-class use. The first tool is *Learning Catalytics*, which allows you to pose many different types of questions to your students during class. Instead of passively listening to your lecture, students interact with the concepts you present through questions you pose. Your students can answer the questions individually, or you can pair them with a partner or small group. A second tool for in-class use is the *Questions for Group Work*. These questions appear in the end-of-chapter material and are specifically designed to be answered in small groups.
- **AFTER CLASS** Active learning can continue after class with two additional tools. The first is another library of 3– to 6–minute videos called *Interactive Worked Examples (IWEs)*. Each IWE video walks a student through the solution to a chemistry problem. Like the KCVs, the IWE video stops in the middle and poses a question that must be answered before the video continues playing. Each video also has an associated follow-up problem that can be assigned using Mastering Chemistry. The second tool for after (or outside of) class active learning is *Active Exam Preparation*. Research studies suggest that students who take a pretest before an exam do better on the exam, especially if the pretest contains immediate feedback. Each chapter in this book contains a *Self-Assessment Quiz* that you can use to easily make a pretest for any of your exams. The *Self-Assessment Quizzes* are live in the ebook, assignable in Mastering Chemistry, and contain wrong answer feedback. Simply choose the questions that you want from each of the quizzes that span the chapters on your exam, and you can create an assignable pretest that students can use to actively prepare for your exams.

Although we have added many active learning tools to this edition and made other changes as well, the book's goal remains the same: *to present a rigorous and accessible treatment of general chemistry in the context of relevance.* Teaching general chemistry would be much easier if all of our students had exactly the same level of preparation and ability. But alas, that is not the case. My own courses are populated with students with a range of backgrounds and abilities in chemistry. The challenge of successful teaching, in my opinion, is figuring out how to instruct and challenge the best students while not losing those with lesser backgrounds and abilities. My strategy has always been to set the bar relatively high, while at the same time providing the motivation and support necessary to reach the high bar. That is exactly the philosophy of this book. We do not have to compromise rigor in order to make chemistry accessible to our students. In this book, I have worked hard to combine rigor with accessibility—to create a book that does not dilute the content and yet can be used and understood by any student willing to put in the necessary effort.

Chemistry: A Molecular Approach* is first and foremost a *student-oriented book. My main goal is to motivate students and get them to achieve at the highest possible level. As we all know, many students take general chemistry because it is a requirement; they do not see the connection between chemistry and their lives or their intended careers. *Chemistry: A Molecular Approach* strives to make those connections consistently and effectively. Unlike other books, which often teach chemistry as something that happens only in the laboratory or in industry, this book teaches chemistry in the context of relevance. It shows students *why* chemistry is important to them, to their future careers, and to their world.

Second, *Chemistry: A Molecular Approach* is a *pedagogically driven book.* In seeking to develop problem-solving skills, a consistent approach (Sort, Strategize, Solve, and Check) is applied, usually in a two- or three-column format. In the two-column format, the left column shows the student how to analyze the problem and devise a solution strategy. It also lists the steps of the solution, explaining the rationale for each one, while the right column shows the implementation of each step. In the three-column format, the left column outlines the general procedure for solving an important category of problems that is then applied to two side-by-side examples. This strategy allows students to see both the general pattern and the slightly different ways in which the procedure may be applied in differing contexts. The aim is to help students understand both the *concept of the problem* (through the formulation of an explicit conceptual plan for each problem) and the *solution to the problem.*

Third, *Chemistry: A Molecular Approach* is a *visual book.* Wherever possible, I use images to deepen the student's insight into chemistry. In developing chemical principles, multipart images help show the connection between everyday processes visible to the unaided eye and what atoms and molecules are actually doing. Many of these images have three parts: macroscopic, molecular, and symbolic. This combination helps students to see the relationships between the formulas they write down on paper (symbolic), the world they see around them (macroscopic), and the atoms and molecules that compose that world (molecular). In addition, most figures are designed to teach rather than just to illustrate. They are rich with annotations and labels intended to help the student grasp the most important processes and the principles that underlie them. In this edition, the art program has been thoroughly revised in two major ways. First, navigation of the more complex figures has been reoriented to track from left to right whenever possible. Second, figure captions have been migrated into the image itself as an "author voice" that explains the image and guides the reader through it. The resulting images are rich with information but also clear and quickly understood.

Fourth, *Chemistry: A Molecular Approach* is a "big-picture" book. At the beginning of each chapter, a short paragraph helps students to see the key relationships between the different topics they are learning. Through a focused and concise narrative, I strive to make the basic ideas of every chapter clear to the student. Interim summaries are provided at selected spots in the narrative, making it easier to grasp (and review) the main points of important discussions. And to make sure that students never lose sight of the forest for the trees, each chapter includes several *Conceptual Connections,* which ask them to think about concepts and solve problems without doing any math. I want students to learn the concepts, not just plug numbers into equations to churn out the right answer. This philosophy is also integral to the *Key Concept Videos*, which concisely reinforce student appreciation of the core concepts in each chapter.

Lastly, *Chemistry: A Molecular Approach* is a book that delivers the depth of coverage faculty want. We do not have to cut corners and water down the material in order to get our students interested. We have to meet them where they are, challenge them to the highest level of achievement, and support them with enough pedagogy to allow them to succeed.

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 contact me with any questions or comments about the book.

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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:

- **NEW INTERACTIVE VIDEOS** I have added 16 new *Key Concept Videos (KCVs)* and 24 new *Interactive Worked Examples (IWEs)* to the media package that accompanies the book. *The video library now contains nearly 200 interactive videos*. These tools are designed to help professors engage their students in active learning.
- **NEW IN-CHAPTER QUESTIONS WITH FEEDBACK** I have added approximately 67 new *Conceptual Connection* questions throughout the book and have changed the format to multiple choice (with wrong answer feedback in the ebook or through Mastering Chemistry). Each chapter now has 10–12 of these embedded assignable questions. These questions transform the reading process from passive to active and hold students accountable for reading assignments.
- **NEW *MISSED THIS?* FEATURE** I have added a new feature called *MISSED THIS?* to the *Self-Assessment Quizzes* and to the *Problems by Topic* section of the end-of-chapter problems. This feature lists the resources that students can use to learn how to answer the question or solve the problem. The resources include chapter sections to read, *Key Concept Videos (KCVs)* to watch, and *Interactive Worked Examples (IWEs)* to view. Students often try to solve an assigned question or problem before doing any reading or reviewing; they seek resources only *afte*r they have missed the question or problem. The *MISSED THIS?* feature guides them to reliable resources that provide just-in-time instruction.
- **NEW FOR PRACTICE FEEDBACK** I have enhanced 64 of the in-chapter *For Practice* problems (which immediately follow an in-chapter worked example) with feedback that can be accessed in the ebook or through Mastering Chemistry.
- **REVISED ART PROGRAM** The art program has been extensively revised. Navigation of the more complex figures has been reoriented to track from left to right, and many figure captions have been broken up and have been moved into the image itself as an "author voice" that explains the image and guides the reader through it.
- **REVISED DATA INTERPRETATION AND ANALYSIS QUESTIONS** The *Data Interpretation and Analysis* questions that accompany each chapter have been extensively revised to make them clearer and more accessible to students.
- **NEW SECTION ON DATA INTERPRETATION AND ANALYSIS** I have added a new section to Chapter 1 (Section 1.9) on the general topic of analyzing and interpreting data. This section introduces the skills required to address many of the revised data interpretation and analysis questions.
- **NEW HOW TO . . . FEATURE** All guidance for essential skills such as problem-solving techniques, drawing Lewis structures, and naming compounds is now presented in a consistent, step-by-step numbered list called *How To...*
- **REVISED CHAPTER 4** Chapter 4 in the previous edition covered both stoichiometry and chemical reactions in solution. In this edition, this content has been

expanded slightly and has been divided into two more focused chapters, so that Chapter 4 is now focused on stoichiometry and Chapter 5 on chemical reactions in solution. This new organization lessens the cognitive load for students and allows each chapter to be more direct and focused. All subsequent chapters have been renumbered accordingly.

- **NEW ACTIVITY SERIES CONTENT** I added a new subsection to Section 5.9 entitled *The Activity Series: Predicting Whether a Redox Reaction Is Spontaneous.* The new section includes new figures, tables, and a new worked example.
- **NEW READY-TO-GO LEARNING MODULES** These online modules offer students easy access to the best Tro content in Mastering Chemistry without needing to have it assigned.
- **NEW TWO-TIER OBJECTIVES** A system of two-tier objectives is being applied to the text and to the Mastering Chemistry assets. The two tiers are Learning Objectives, or LOs, and Enabling Objectives, or EOs. The LOs are broad, high-level objectives that summarize the overall learning goal, while the EOs are the building block skills that enable students to achieve the LO. The learning objectives are given in the Learning Outcomes table at the end of the chapter.
- **REVISED DATA** All the data throughout the book have been updated to reflect the most recent measurements available. These updates include Figure 4.2: *Carbon Dioxide in the Atmosphere*; Figure 4.3: *Global Temperatures*; the unnumbered figure in Section 7.10 of *U.S. Energy Consumption*; Figure 7.12: *Energy Consumption by Source*; Table 7.6: *Changes in National Average Pollutant Levels, 1990–2016*; Figure 15.19: *Ozone Depletion in the Antarctic Spring*; Figure 17.15: *Sources of U.S. Energy*; Figure 17.16: *Acid Rain*; and Figure 17.18: *U.S. Sulfur Dioxide Pollutant Levels*.
- **REVISED CHAPTER OPENERS** Many chapter-opening sections and (or) the corresponding art—including Chapters 1, 3, 4, 5, 6, 7, 10, 11, 18, 19, 20, and 22—have been replaced or modified.

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The book you hold in your hands bears my name on the cover, but I am really only one member of a large team that carefully crafted this book. Most importantly, I thank my editor, Terry Haugen. Terry is a great editor and friend. He gives me the right balance of freedom and direction and always supports me in my endeavors. Thanks, Terry, for all you have done for me and for general chemistry courses throughout the world. Thanks also to Matt Walker, my new developmental editor on this project. Matt is creative, organized, and extremely competent. He has made significant contributions to this revision and has helped me with the many tasks that must be simultaneously addressed and developed during a revision as significant as this one. Matt, I hope this is only the beginning of a long and fruitful collaboration. I also owe a special debt of gratitude to Barbara Yien and Laura Southworth. Barbara was involved in many parts of content development, and Laura played a critical role in the revision of the art program. Many thanks to the both of you!

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I am also grateful to those who have supported me personally while working on this book. First on that list is my wife, Ann. Her patience and love for me are beyond description, and without her, this book would never have been written. I am also indebted to 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, Nachy, Karen, and John; and my nephews and nieces, Germain, Danny, Lisette, Sara, and Kenny. These are the people with whom I celebrate life.

I am especially grateful to Michael Tro, who put in many hours proofreading my manuscript, working problems and quiz questions, and organizing appendices. Michael, you are amazing—it is my privilege to have you work with me on this project.

I would like to thank all of the general chemistry students who have been in my classes throughout my 29 years as a professor. You have taught me much about teaching that is now in this book.

Lastly, I am indebted to the many reviewers, listed on the following pages, whose ideas are embedded 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. I am particularly grateful to Corey Beck who has played an important role in developing the objectives for this edition. I am also grateful to the accuracy of reviewers who tirelessly checked page proofs for correctness.

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