GLOBAL EDITION

Chemistry

EIGHTH EDITION

Robinson • McMurry • Fay

List of the Elements with Their Atomic Symbols and Atomic Weights

Name	Symbol	Atomic Number	Atomic Weight
Actinium	Ac	89	(227)*
Aluminum	Al	13	26.981538
Americium	Am	95	(243)
Antimony	Sb	51	121.760
Argon	Ar	18	39.948
Arsenic	As	33	74.92160
Astatine	At	85	(210)
Barium	Ba	56	137.327
Berkelium	Bk	97	(247)
Beryllium	Be	4	9.012182
Bismuth	Bi	83	208.98040
Bohrium	Bh	107	(272)
Boron	B	5	10.811
Bromine	Br	35	79.904
Cadmium	Cd	48	112.411
Calcium	Ca	20	40.078
Californium	Cf	98	(251)
Carbon	C	6	12.0107
Cerium	Ce	58	140.116
Cesium	Cs	55	132.90545
Chlorine	Cl	17	35.453
Chromium	Cr	24	51.9961
Cobalt	Co	27	58.933195
Copernicium	Cn	112	(285)
Copper	Cu	29	63.546
Curium	Cm	96	(247)
Darmstadtium	Ds	110	(281)
Dubnium	Db	105	(268)
Dysprosium	Dy	66	162.500
Einsteinium	Es	99	(252)
Erbium	Er	68	167.259
Europium	Eu	63	151.964
Fermium	Fm	100	(257)
Flerovium	Fl	114	(289)
Fluorine	F	9	18.998403
Francium	Fr	87	(223)
Gadolinium	Gd	64	157.25
Gallium	Ga	31	69.723
Germanium	Ge	32	72.64
Gold	Au	79	196.96657
Hafnium	Hf	72	178.49
Hassium	Hs	108	(270)
Helium	He	2	4.002602
Holmium	Ho	67	164.93032
Hydrogen	H	1	1.00794
Indium	In	49	114.818
Iodine	I	53	126.90447
Iridium	Ir	77	192.217
Iron	Fe	26	55.845
Krypton	Kr	36	83.798
Lanthanum	La	57	138.9055
Lawrencium	Lr	103	(262)
Lead	Pb	82	207.2
Lithium	Li	3	6.941
Livermorium	Lv	116	(293)
Lutetium	Lu	71	174.9668
Magnesium	Mg	12	24.3050
Manganese	Mn	25	54.938045
Meitnerium	Mt	109	(276)
Mendelevium	Md	101	(258)
Mercury	Hg	80	200.59
Molybdenum	Mo	42	95.96
Moscovium	Mc	115	(288)
Neodymium	Nd	60	144.242
Neon	Ne	10	20.1797
Neptunium	Np	93	(237)
Nickel	Ni	28	58.6934
Nihonium	Nh	113	(284)
Niobium	Nb	41	92.90638
Nitrogen	N	7	14.0067
Nobelium	No	102	(259)
Oganesson	Og	118	(294)
Osmium	Os	76	190.23
Oxygen	O	8	15.9994
Palladium	Pd	46	106.42
Phosphorus	P	15	30.973762
Platinum	Pt	78	195.094
Plutonium	Pu	94	(244)
Polonium	Po	84	(209)
Potassium	K	19	39.0983
Praseodymium	Pr	59	140.90765
Promethium	Pm	61	(145)
Protactinium	Pa	91	231.03588
Radium	Ra	88	(226)
Radon	Rn	86	(222)
Rhenium	Re	75	186.207
Rhodium	Rh	45	102.90550
Roentgenium	Rg	111	(280)
Rubidium	Rb	37	85.4678
Ruthenium	Ru	44	101.07
Rutherfordium	Rf	104	(265)
Samarium	Sm	62	150.36
Scandium	Sc	21	44.955912
Seaborgium	Sg	106	(271)
Selenium	Se	34	78.96
Silicon	Si	14	28.0855
Silver	Ag	47	107.8682
Sodium	Na	11	22.989769
Strontium	Sr	38	87.62
Sulfur	S	16	32.065
Tantalum	Ta	73	180.9479
Technetium	Tc	43	(98)
Tellurium	Te	52	127.60
Tennessine	Ts	117	(292)
Terbium	Tb	65	158.92535
Thallium	Tl	81	204.3833
Thorium	Th	90	232.0381
Thulium	Tm	69	168.93421
Tin	Sn	50	118.710
Titanium	Ti	22	47.867
Tungsten	W	74	183.84
Uranium	U	92	238.02891
Vanadium	V	23	50.9415
Xenon	Xe	54	131.293
Ytterbium	Yb	70	173.054
Yttrium	Y	39	88.90585
Zinc	Zn	30	65.38
Zirconium	Zr	40	91.224

*Values in parentheses are the mass numbers of the most common or longest lived isotopes of radioactive elements.

Periodic Table of the Elements

Main groups		Transition metals										Main groups					
1 1A																	18 8A
1 H 1.00794	2 2A											13 3A	14 4A	15 5A	16 6A	17 7A	2 He 4.002602
3 Li 6.941	4 Be 9.012182											5 B 10.811	6 C 12.0107	7 N 14.0067	8 O 15.9994	9 F 18.998403	10 Ne 20.1797
11 Na 22.989769	12 Mg 24.3050	3 3B	4 4B	5 5B	6 6B	7 7B	8	9 8B	10	11 1B	12 2B	13 Al 26.981538	14 Si 28.0855	15 P 30.973762	16 S 32.065	17 Cl 35.453	18 Ar 39.948
19 K 39.0983	20 Ca 40.078	21 Sc 44.955912	22 Ti 47.867	23 V 50.9415	24 Cr 51.9961	25 Mn 54.938045	26 Fe 55.845	27 Co 58.933195	28 Ni 58.6934	29 Cu 63.546	30 Zn 65.38	31 Ga 69.723	32 Ge 72.64	33 As 74.92160	34 Se 78.96	35 Br 79.904	36 Kr 83.798
37 Rb 85.4678	38 Sr 87.62	39 Y 88.90585	40 Zr 91.224	41 Nb 92.90638	42 Mo 95.96	43 Tc (98)	44 Ru 101.07	45 Rh 102.90550	46 Pd 106.42	47 Ag 107.8682	48 Cd 112.411	49 In 114.818	50 Sn 118.710	51 Sb 121.760	52 Te 127.60	53 I 126.90447	54 Xe 131.293
55 Cs 132.90545	56 Ba 137.327	71 Lu 174.9668	72 Hf 178.49	73 Ta 180.9479	74 W 183.84	75 Re 186.207	76 Os 190.23	77 Ir 192.217	78 Pt 195.094	79 Au 196.96657	80 Hg 200.59	81 Tl 204.3833	82 Pb 207.2	83 Bi 208.98040	84 Po (209)	85 At (210)	86 Rn (222)
87 Fr (223)	88 Ra (226)	103 Lr (262)	104 Rf (265)	105 Db (268)	106 Sg (271)	107 Bh (272)	108 Hs (270)	109 Mt (276)	110 Ds (281)	111 Rg (280)	112 Cn (285)	113 Nh (284)	114 FL (289)	115 Mc (288)	116 Lv (293)	117 Ts (292)	118 Og (294)

*Lanthanide series	57 *La 138.9055	58 Ce 140.116	59 Pr 140.90765	60 Nd 144.242	61 Pm (145)	62 Sm 150.36	63 Eu 151.964	64 Gd 157.25	65 Tb 158.92535	66 Dy 162.500	67 Ho 164.93032	68 Er 167.259	69 Tm 168.93421	70 Yb 173.054
†Actinide series	89 †Ac (227)	90 Th 232.0381	91 Pa 231.03588	92 U 238.02891	93 Np (237)	94 Pu (244)	95 Am (243)	96 Cm (247)	97 Bk (247)	98 Cf (251)	99 Es (252)	100 Fm (257)	101 Md (258)	102 No (259)

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CHEMISTRY

EIGHTH EDITION
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JILL K. ROBINSON
Indiana University

JOHN E. MCMURRY
Cornell University

ROBERT C. FAY
Cornell University

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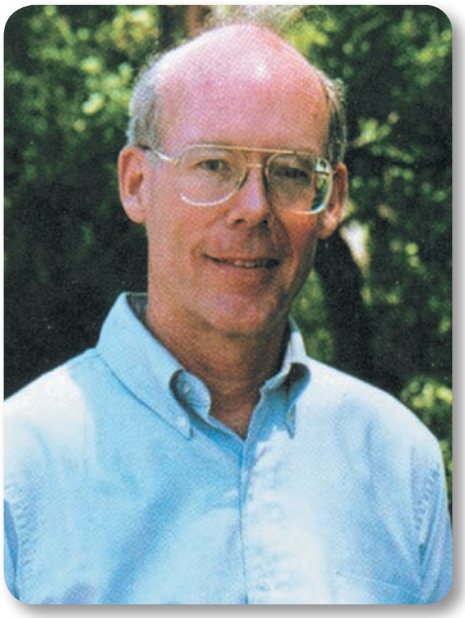
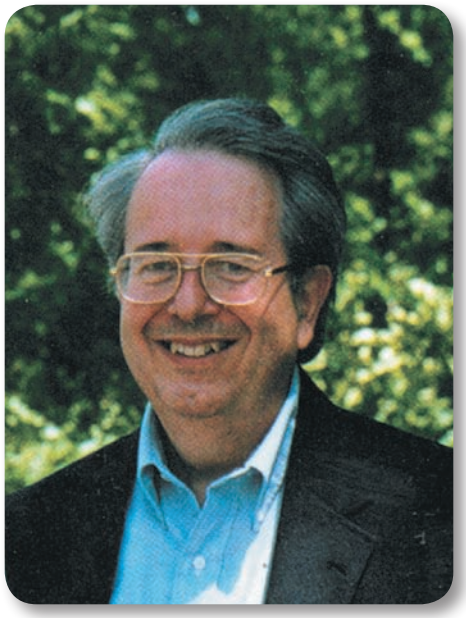
About the Authors

Jill K. Robinson received her Ph.D. in analytical and atmospheric chemistry from the University of Colorado at Boulder. She is a senior lecturer at Indiana University and teaches general, analytical, and environmental chemistry courses. Her clear and relatable teaching style has been honored with several awards including the President's Award for Distinguished Teaching at Indiana University and the J. Calvin Giddings Award for Excellence in Education from the American Chemical Society Division of Analytical Chemistry. She leads workshops to help faculty transition from lecture-based instruction to student-centered pedagogies.



John McMurry, educated at Harvard and Columbia, has taught more than 20,000 students in general and organic chemistry over a 40-year period. An emeritus professor of chemistry at Cornell University, Dr. McMurry previously spent 13 years on the faculty at the University of California at Santa Cruz. He has received numerous awards, including the Alfred P. Sloan Fellowship (1969–71), the National Institute of Health Career Development Award (1975–80), the Alexander von Humboldt Senior Scientist Award (1986–87), and the Max Planck Research Award (1991).



Robert C. Fay, professor emeritus at Cornell University, taught general and inorganic chemistry at Cornell for 45 years beginning in 1962. Known for his clear, well-organized lectures, Dr. Fay was the 1980 recipient of the Clark Distinguished Teaching Award. He has also taught as a visiting professor at Harvard University and the University of Bologna (Italy). A Phi Beta Kappa graduate of Oberlin College, Dr. Fay received his Ph.D. from the University of Illinois. He has been an NSF Science Faculty Fellow at the University of East Anglia and the University of Sussex (England) and a NATO/Heineman Senior Fellow at Oxford University.

Preface

FOR THE STUDENT

Francie came away from her first chemistry lecture in a glow. In one hour she found out that everything was made up of atoms which were in continual motion. She grasped the idea that nothing was ever lost or destroyed. Even if something was burned up or rotted away, it did not disappear from the face of the earth; it changed into something else—gases, liquids, and powders. Everything, decided Francie after that first lecture, was vibrant with life and there was no death in chemistry. She was puzzled as to why learned people didn't adopt chemistry as a religion.

—Betty Smith, *A Tree Grows in Brooklyn*

We know that not everyone has such a breathless response to their chemistry lectures, and few would mistake chemistry as a religion, yet chemistry *is* a subject with great logical beauty. We love chemistry because it explains the "why" behind many observations of the world around us and we use it every day to help us make informed choices about our health, lifestyle, and politics. Moreover, chemistry is the fundamental, enabling science that underlies many of the great advances of the last century that have so lengthened and enriched our lives. Chemistry provides a strong understanding of the physical world and will give you the foundation you need to go on and make important contributions to science and humanity.

HOW TO USE THIS BOOK

You no doubt have experience using textbooks and know they are not meant to read like a novel. We have written this book to provide you with a clear, cohesive introduction to chemistry in a way that will help you, as a new student of chemistry, understand and relate to the subject. While you *could* curl up with this book, you will greatly benefit from continually formulating questions and checking your understanding as you *work* through each section. The way this book is designed and written will help you keep your mind active, thus allowing you to digest important concepts as you learn some of the many principles of chemistry.

The 8th edition was revised to create an **interactive** study cycle based on research of effective learning methods. Many common study habits such as highlighting, rereading, and long study sessions create the illusion of fast progress, but these gains fade quickly. More deep and durable learning occurs from self-testing, difficulty in practice, and spaced practice of different skills. Let's see how specific steps in the study cycle use proven strategies to maximize your learning.

Step 1. Learning New Material

The 8th edition contains many new features that should be used to quiz yourself and receive feedback as you work through the material in each chapter.

- **Narrative:** As you read through the text, always challenge yourself to understand the "why" behind the concept. For example, you will learn that carbon forms four bonds, and the narrative will give the reason why. By gaining a conceptual understanding, you will *not need to memorize* a large collection of facts, making learning and retaining important principles much easier! ***Big Idea Questions*** were written to help you digest and apply the most important concepts.

- **Figures:** Figures are not optional! Most summarize and convey important points. ***Figure It Out* Questions** draw your attention to a key principle and provide guidance in interpreting graphs. Answer the question by examining the figure and perhaps rereading the related narrative. We've provided answers to Figure It Out Questions near the figure.
- **Worked Examples:** Numerous worked examples throughout the text show the approach for solving a certain type of problem. Each worked example uses a step-by-step procedure.
  - **Identify**—The first step in problem solving is to identify key information and classify it as a known or unknown quantity. This step also involves translating between words and chemical symbols. Listing knowns on one side and unknowns on the other organizes the information and makes the process of identifying the correct strategy more visual. The *Identify* step is used in numerical problems.
  - **Strategy**—The strategy describes how to solve the problem without actually solving it. Failing to articulate the needed strategy is a common pitfall; too often students start manipulating numbers and variables without first identifying key equations or making a plan. Articulating a strategy will develop conceptual understanding and is highly preferable to simply memorizing the steps involved in solving a certain type of problem.
  - **Solution**—Once the plan is outlined, the key information is used to answer the question.
  - **Check**—A problem is not completed until you have thought about whether the answer makes sense. Use both your practical knowledge of the world and knowledge of chemistry to evaluate your answer. For example, if heat is added to a sample of liquid water and you are asked to calculate the final temperature, you should critically consider your answer: Is the final temperature lower than the original? Shouldn't adding heat raise the temperature? Is the new temperature above 100 °C, the boiling point of water? The ***Check*** step is used in problems when the magnitude and sign of a number can be estimated or the physical meaning of the answer verified based on familiar observations.

  To test your mastery of the concept explored in Worked Examples, two problems will follow. **PRACTICE** problems are similar in style and complexity to the Worked Example and will test your basic understanding.

  Once you have correctly completed this problem, tackle the **APPLY** problem, in which the concept is used in a new situation to assess a deeper understanding of the topic. Answers to Apply Problems can be found at the end of the book.
- **Interactive Worked Examples:** Each chapter has two video tutorials for challenging problems that model the process of expert thinking. The videos are interactive and ask you to make predictions before moving forward to the complete solution.
- **Conceptual Problems:** Conceptual understanding is a primary focus of this book. Conceptual problems are intended to help you with the critical skill of visualizing the structure and interactions of atoms and molecules while probing your understanding of key principles rather than your ability to correctly use numbers in an equation. The time you spend mastering these problems will provide high long-term returns by solidifying main ideas.

Step 2. Problem-Solving Practice

We achieve more complex and long-lasting learning by practicing problems that require more effort and slow down the pace of learning.

- **End-of-Chapter Problem Sets:** Working problems is essential for success in chemistry! The number and variety of problems at the end of chapter will give you the

practice needed to gain mastery of specific concepts. Answers to every other problem are given in the "Answers" section at the back of the book so that you can assess your understanding. Your instructor may assign problems in an online format using the Mastering™ Chemistry platform, which comes with the added benefit of tutorials, feedback, and links to relevant content in the eText.

Step 3. Mastery

Once you have read the chapter and completed the end-of-chapter problems, you will need to review for the exam and assess which topics you have mastered and which still need to be solidified. Inquiry sections and practice tests are chapter capstones that strengthen mental representations by replaying learning and giving it meaning.

- **Inquiries:** Inquiry sections connect chemistry to the world around you by highlighting useful links in the future careers of many science students. Typical themes are materials, medicine, and the environment. The goal of these sections is to deepen your understanding and aid in retention by tying concepts to memorable applications. These sections can be considered as a capstone for each chapter because *Inquiry* problems review several main concepts and calculations. These sections will also help you prepare for professional exams because they were written in the same style as new versions of these exams: a passage of text describing an application followed by a set of questions probing your ability to apply basic scientific concepts to the situation.
- **End-of-Chapter Practice Test and Study Guide:** The end-of-chapter practice test and study guide are useful tools for exam preparation. Each practice test question is linked to a learning objective in the study guide. If you answer a question incorrectly or want more practice on that skill, refer to the study guide, which matches the learning objective to a concept summary, key skills for solving the problem, Worked Examples for assistance, and end-of-chapter problems so that you can practice your mastery of that skill.

For Instructors

NEW TO THIS EDITION

A primary change in the 8th edition is the development of an interactive learning environment. We designed interactive features for the text and classroom based on educational research and strategies proven to help students succeed. Questions have been developed to help instructors engage students during class using Learning Catalytics, a personal response system used with smart devices. A large body of educational literature has clearly demonstrated increased learning gains, higher attendance, and lower failure rates in classrooms that employ active learning. New features include:

1. **Big Idea Questions:** Efficient and skilled reading requires students to parse out main ideas and important details and relate new information to prior knowledge. Big Idea Questions probe understanding of important concepts from a text passage. These questions teach students how to actively read a science text by modeling the kinds of questions they should ask themselves and stimulate them to make connections between concepts and mathematical problems.
2. **Figure It Out Questions:** These questions test knowledge of key principles shown in a figure and the ability to read and interpret graphs. Answers to Figure It Out Questions are provided near the figure in the printed book.
3. **Interactive Worked Examples:** Each chapter has two video tutorials featuring lead author Jill Robinson as she models the process of expert problem solving. The videos require students to pause and digest information and then predict how to proceed at key points before moving forward to the complete solution.
4. **PRACTICE Problems:** These problems follow a Worked Example and test basic understanding. Answers to Practice Problems are provided at the end of the printed book.
5. **APPLY Problems:** These problems follow the Practice Problems and discourage a plug-and-chug approach to problem solving by providing an example of how the same principle can be used in different types of problems with different levels of complexity. Answers to Apply problems are provided at the end of the printed book.
6. **Practice Test Linked to Study Guide:** A useful way for students to review each chapter is by taking the Practice Test, which assesses mastery of chapter learning objectives. The Study Guide provides a targeted follow-up to the Practice Test through the linking of learning objectives to the main lessons in each chapter, associated worked examples, and end-of-chapter problems for more practice. When a student answers incorrectly in Mastering Chemistry, the Practice Test automatically links to worked examples and additional practice problems.
7. **Interactive Learning Catalytics Questions:** The Learning Catalytics questions developed for each chapter promote strong conceptual understanding and advanced problem-solving skills. Learning Catalytics includes prebuilt questions for every key topic in chemistry written by lead author Jill Robinson.

Inquiry Sections have been updated and integrated conceptually into each chapter.

Inquiry sections highlight the importance of chemistry, promote student interest, and deepen students' understanding of the content. The Inquiry sections include problems that revisit several chapter concepts and can be covered in class or recitation sections or assigned as homework in Mastering Chemistry. In the 8th edition, the delivery of

Inquiry problems in Mastering Chemistry has been improved and new topics have been developed. New Inquiries for the 8th edition are:

- Chapter 2: How can measurements of oxygen and hydrogen isotopes determine past climates?
- Chapter 3: How is the principle of atom economy used to minimize waste in a chemical synthesis?
- Chapter 8: Which is better for human health, natural or synthetic vitamins?
- Chapter 10: How do inhaled anesthetics work?
- Chapter 12: What are quantum dots, and what controls their color?
- Chapter 14: How do enzymes work?
- Chapter 15: How does high altitude affect oxygen transport in the blood?
- Chapter 20: How are radioisotopes used in medicine?

NEW! End-of-chapter problems continually build on concepts and skills from earlier in the chapter.

Educational research shows that interleaved and varied practice with different concepts and skills produces higher learning gains than drilling on a single topic. Section Problems at the end of the chapter now include questions that build on concepts taught earlier in the chapter. In previous editions, Section Problems focused only on learning objectives from that specific section in the text. New questions and questions from the Chapter Problems sections in previous editions that integrate multiple chapter concepts have been incorporated into Section Problems to revisit key ideas on a regular basis and apply them in different situations.

Here is a list of some of the key chemistry content changes made in each chapter:

Chapter 1 Chemical Tools: Experimentation and Measurement

- The scientific method is described in the context of a new case study in the field of nanoscience to help students see the utility of chemistry in solving important world problems.
- Nanotechnology Inquiry problems were updated to promote better understanding of the unique properties of matter on the nanoscale and the size of nanoparticles.
- Figure 1.8 was updated to show the most commonly used laboratory glassware.

Chapter 2 Atoms, Molecules, and Ions

- Several updates to terminology and the periodic table were made. The names of recently discovered elements 113, 115, 117, and 118 were officially assigned in 2016 and listed in Section 2.1 Chemistry and the Elements. A clarification about the definition and common use of the term *atomic mass unit* was added. The atomic mass unit (*amu*) is an obsolete unit, but it is commonly used interchangeably with the correct unit, unified atomic mass unit (*u*). Since 2011, the Union of Pure and Applied Chemistry gives the atomic weights for some elements as a range of values instead of a single value due to isotopic abundances that vary with the source of the sample.
- Section 2.10 Measuring Atomic Weight: Mass Spectrometry was added to describe how atomic weights are experimentally measured. The process of using a mass spectrum to calculate an atomic weight is described in a Worked Example, and follow-up problems and new end-of-chapter problems were written. The description of a mass spectrometer from Chapter 3 was moved into Chapter 2 because it is the instrument used to measure atomic weight.
- In Section 2.12 Ions and Ionic Bonds, additional details on writing formulas for ionic compounds were added for clarification.
- A new Inquiry on isotopes and the climate record provides a strong connection with the Chapter 2 topics of isotopes, atomic weight, and the mole concept.

Chapter 3 Mass Relationships in Chemical Reactions

- Chemical Arithmetic: Stoichiometry was a very long section and contained many concepts. It has been divided into two sections: Section 3.3 Molecular Weight and Molar Mass and Section 3.4 Stoichiometry: Relating Amounts of Reactants and Products.
- A new Inquiry on atom economy concisely summarizes the important concept of relating amounts of reactants and products and introduces green chemistry.
- The section on measuring molecular weight was revised because the mass spectrometer was previously described in Chapter 2 in the section on atomic weight.

Chapter 4 Reactions in Aqueous Solution

- Added a Remember note in the margin at the beginning of Section 4.3 Electrolytes in Aqueous Solution to remind students about the differences between molecules and ions.

- Section 4.7 Acids, Bases, and Neutralization Reactions: Added a Looking Ahead note regarding acids/bases coverage in Chapter 16. Also, added the dissociation reaction for sodium hydroxide and barium hydroxide when discussing strong and weak bases.
- More explanation added to Worked Example 4.12 to help students assign oxidation numbers.
- Section 4.11 Identifying Redox Reactions: New figure shows that silver-colored powdered iron is oxidized by oxygen to produce iron(III)oxide, which is red in color.

Chapter 5 Periodicity and Electronic Structure of Atoms

Chapter 5 contains abstract ideas such as particles behaving as waves and the notion of wave functions of electrons. Eight new figures and descriptive text were added to help students grasp these difficult concepts.

- In Section 5.1 Wave Properties of Radiant Energy and the Electromagnetic Spectrum, the double-slit experiment was described to show that both light and matter have wave properties. New Figure 5.4: Diffraction and interference are phenomena exhibited by waves. New Figure 5.5: Radiant energy exhibits wave properties in a double-slit experiment.
- Section 5.3 Atomic Line Spectra and Quantized Energy: The connection between quantized energy and atomic line spectra was strengthened by condensing content and placing both concepts into the same section. Also, radial distribution plots were added to help visualize the meaning of an orbital and explain electron shielding and the ordering of orbital energies.
- Section 5.4 Wavelike Properties of Matter: de Broglie's Hypothesis: New Figure 5.11: Wave properties of electrons illustrate the different behaviors of particles and waves in a double-slit experiment. Figure also shows that electrons have wave properties, which is a key idea for understanding orbitals.
- Added an electron microscope image that shows individual DNA molecules to illustrate the utility of the wave properties of an electron in Worked Example 5.5 and Apply problem 5.10.
- Section 5.7 The Shapes of Orbitals: New Figure 5.14: Representations of a 1*s* orbital. New Figure 5.15: Concert hall analogy for radial probability. A figure was added to help explain the concept of radial probability in a familiar way.
- New Figure 5.18: Radial probability plots for the 1*s*, 2*s*, and 3*s* orbitals in a hydrogen atom. Radial probability plots are a useful way to explain the differences in size, energy, and number of nodes for the different *s* orbitals.
- Section 5.9 Orbital Energy Levels in Multielectron Atoms: New Figure 5.23: Radial distribution plots for 3*s*, 3*p*, and 3*d* orbitals. The penetration of the different orbitals determines the ordering of orbital energies ($3s < 3p < 3d$).
- Section 5.10 Electron Configurations of Multielectron Atoms: New Figure 5.24: Energy levels of orbitals in multielectron atoms was placed in the margin for easy reference when writing electron configurations.

Chapter 6 Ionic Compounds: Periodic Trends and Bonding Theory

- Section 6.1 Electron Configurations of Ions: Added text and a figure to make it more clear why *n*s electrons are lost before $(n - 1)d$ electrons when forming transition metal ions. A relatively recent article in the *Journal of Chemical Education* describes how many textbooks contain incomplete or inaccurate discussions of this topic. The *d* orbital collapse for transition metals was described as concisely has possible. (Reference: The Full Story of the Electron Configurations of the Transition Elements, J. Chem Ed., Vol 87, No. 4, April 2010)
- Modified Figure 6.6 so negative electron affinities appear below zero on the graph.
- In the reactions in the Born-Haber cycle, the energy of the reaction is written in units of kJ, not kJ/mol. Figures 6.7 and 6.8 were updated to reflect the change.
- Updated Inquiry questions on ionic liquids.

Chapter 7 Covalent Bonding and Electron-Dot Structures

- Electronegativity was defined earlier in the section to more clearly explain the existence of polar covalent bonds. Electrostatic potential maps of Cl_2, HCl, and NaCl were combined into one figure for comparison and to relate the extent of electron transfer to differences in electronegativity between the elements in the bond.
- Added the topics of dipole moment and percent ionic character to illustrate the extent of electron transfer as a continuum instead of as a sharp cutoff between a polar covalent bond and an ionic bond. A new Worked Example and new Practice and Apply problems were added. End-of-chapter problems were added as well. The content on percent ionic character was moved from Chapter 8 to Chapter 7 because it is much more relevant in this section.
- New Looking Ahead note about intermolecular forces in Section 7.4 A Comparison of Ionic and Covalent Compounds.
- Revised Inquiry Questions.

Chapter 8 Covalent Compounds: Bonding Theories and Molecular Structure

- Developed a new style for representing orbitals in all figures to more clearly show orbital overlap to form chemical bonds in valence bond theory.
- Clarified answer key for orbital overlap diagrams. Terminal atoms that have multiple bonds use the hybrid orbital model.
- References added to help students/instructors learn more about the vague statement "main-group compounds with five and six charge clouds use a more complex bonding pattern that is not easily explained by valence bond theory." The reference appears as a footnote. Some books report that main-group atoms that expand their octets use sp^3d or sp^3d^2 hybrid orbitals, which is not considered an accurate representation based on density functional theory calculations.
- The quantitative aspects of dipole moments were moved to Chapter 7 to help students better understand the differences

between a nonpolar covalent bond, polar covalent bond, and ionic bond. A qualitative discussion of dipole moments of molecules is sufficient for Chapter 8 and is aligned with how instructors cover this topic.

- Changed the order of presentation of the different types of intermolecular forces. We now start with London dispersion forces because all molecules have these types of forces. We then get more restrictive and describe polar molecules with dipole-dipole forces, followed by hydrogen bonding, which is more restrictive and a special case of dipole-dipole forces. Finally, ion-dipole is described. The ordering of presentation of forces is from weakest to strongest.
- New Inquiry topic on the difference between natural and synthetic compounds such as vitamins.

Chapter 9 Thermochemistry: Chemical Energy

- A new chapter introduction was written to better connect chapter topics to examples familiar to students.
- Improved the strategy for solving constant-pressure calorimetry problems in Worked Example 9.6.
- Changed the way constant-volume calorimetry was presented to more accurately reflect the way this type of experiment was carried out in the laboratory. A new Worked Example (9.7) and follow-up problems were written. End-of-chapter problems were revised to fit with this pedagogy.
- Section 9.11 on fossil fuels was removed. This section did not teach any new chemistry content, and the Inquiry on biofuels serves to connect thermochemistry concepts to fuels.

Chapter 10 Gases: Their Properties and Behavior

- Changed formulas for Graham's Law in Section 10.7 Gas Diffusion and Effusion: Graham's Law to replace mass (m) with molar mass (M).
- Removed the section on pollution to shorten the chapter. Most instructors do want to cover some relevant topic about the atmosphere, and the climate change section was improved. Figures on greenhouse gases and climate change were updated to include data from years since the last revision.
- New Inquiry on inhaled anesthetics.

Chapter 11 Liquids and Phase Changes

- The focus of Chapter 11 is on liquids, their properties, and phase changes. The topics of solids and unit cells have been moved to Chapter 12 on solids and solid-state materials.
- A new section on liquid crystals and end-of-chapter problems have been added.

Chapter 12 Solids and Solid-State Materials

- The topics of unit cells of solids and solid-state materials are closely related and are now contained in one chapter. (Chapters 11 and 21 content from the 7th edition is combined to make one coherent unit on solids.)
- Revised Inquiry on quantum dots.

Chapter 13 Solutions and Their Properties

- Added a new figure to show the difference between a solution and colloid using light-scattering properties.
- Divided Section 12.2 from the 7th edition into two new sections to improve the description of the solution-making process.
- Section 13.2 Enthalpy Changes and the Solution Process focuses on describing the intermolecular forces involved in solution formation and the overall effect on the heat of solution.
- New Figure 13.1: A molecular view of the solution making process.
- Section 13.3 Predicting Solubility relates the thermodynamic value of ΔG to the simple rule for solubility "like dissolves like."
- Added a paragraph to Section 13.5 Some Factors That Affect Solubility to explain why increasing temperature increases the solubility of solids but decreases the solubility of gases. A new Big Idea Question highlights this concept.
- Added a figure and description in Section 13.7 Vapor-Pressure Lowering of Solutions: Raoult's Law to illustrate ion pairing and explain why the dissociation of ionic compounds is not complete.
- Section 12.9 from the 7th edition on the fractional distillation of mixtures was deleted. There is already a lot of difficult material in this chapter, and this topic is not covered in most general chemistry courses.

Chapter 14 Chemical Kinetics

- Revised Figure 14.2 and text description to more clearly show how the instantaneous rate is determined from experimental data.
- Worked Example 14.8 (to replace 13.8) was revised to focus on the main idea of calculating half-life and not have students get lost in the details by referring to previous graphs.
- New analogy for rate-limiting step in Section 14.11 Rate Laws for Overall Reactions.
- New Inquiry on enzyme kinetics.
- Data in numerous end-of-chapter problems involving graphing were revised.

Chapter 15 Chemical Equilibrium

- Figure 15.1 was revised to show a macroscale and molecular scale representation of the N_2O_4/NO_2 equilibrium. This figure provides a picture of the data in the concentration versus time graphs in Figures 15.2 and 15.3.
- The feedback for practice problems in the eText provides an opportunity to give remediation in the mathematical operations including the quadratic equation. All steps in solving the algebraic expressions are shown to help students who may need a review.
- Inquiry focus was changed from the general concept of the equilibrium reaction of oxygen and hemoglobin to the more specific focus of the effect of altitude on oxygen supply in muscles.

Chapter 16 Aqueous Equilibria: Acids and Bases

- The procedure for solving acid-base equilibrium problems was reduced from eight steps to five steps, which are simpler to understand. All subsequent worked examples in Chapters 16 and 17 were modified using the new procedure. Figure 16.7 and the description of solving acid–base problems were revised to eliminate wording that was unusual and confusing. Examples are "big" concentrations and "small" concentrations.
- A photo sequence showing the pH change when CO_2 dissolves to produce carbonic acid was added to Worked Example 16.11.
- The Inquiry section was updated to discuss current problems related to acid rain.

Chapter 17 Applications of Aqueous Equilibria

- Section 17.2 The Common-Ion Effect was revised in three ways. The concept of the common-ion effect was presented before mathematical calculations to give students an understanding of the main idea first. Calculating the pH of a weak acid and conjugate base mixture was modified to follow the new simplified approach to solving equilibrium problems given in Figure 16.7. Two example calculations that were repetitive were combined into one example in Worked Example 17.2.
- Section 17.3 Buffer Solutions was rearranged to present the concept of a buffer before showing the calculation of pH change of a buffer upon addition of a strong acid or base. Figure 17.3 describes a buffer by showing pH change after adding a strong base to two different solutions: a strong acid and a buffer. The color change of an acid–base indicator shows that the buffer resists changes in pH. A conceptual Big Idea Question was created on the definition of a buffer.
- The Inquiry section on ocean acidification was updated with recent CO_2 and pH measurements. The problems were revised to promote understanding of the problem and for clarity.

Chapter 18 Thermodynamics: Entropy, Free Energy, and Spontaneity

- The introductory paragraph was revised to include familiar examples to students and review the concepts of reaction direction and extent of reaction.
- Two new figures were created to clarify the question in Worked Example 18.2 on calculating entropy.
- A more realistic example of a process that represents the standard free-energy change was described in Section 18.8 Standard Free-Energy Changes for Reactions.

Chapter 19 Electrochemistry

- In Section 19.1 Balancing Redox Reactions by the Half-Reaction Method, a brief review of oxidation numbers was added that includes a Remember note, a new figure showing oxidation numbers in redox reaction, and a Big Idea Question for students to assess themselves on this important concept from Chapter 4.
- Figure 19.1 showing the steps needed for balancing redox reactions by the half-reaction method was revised to make the individual steps clearer.
- New Worked Example 19.1 (Balancing a Redox Reaction in Acidic Solution): From the previous edition more detail was included so students can more easily follow the steps and canceling process when adding half-reactions.
- Revised Worked Example 19.2 (Balancing a Redox Reaction in Basic Solution): Added more detail so students can more easily follow the steps and canceling process when adding half-reactions.
- It is a convention in electrochemistry to put the anode half-cell on the left and cathode half-cell on the right. Several figures were changed to reflect this common convention.
- Worked Example 19.6 was revised to more clearly show the thought process for determining strengths of reducing agents.
- New Worked Example 19.8 was added on the very important concept of calculating voltage of a galvanic cell (a battery).
- The Inquiry was updated with recent status of commercialization of fuel-cell vehicles.

Chapter 20 Nuclear Chemistry

- In Section 20.3 Nuclear Stability, superheavy elements 113, 115, 117, and 118 were added to the periodic table. The discovery of these elements was connected to nuclear theory and the island of stability.
- In Section 20.3 Nuclear Stability, real examples of nuclear equations were provided instead of general equations to more clearly show how radioactive decay processes affect the neutron to proton ratio.
- Section 20.5 Dating with Radioisotopes was given its own section. The age of artifacts such as the Dead Sea Scrolls were updated based on improved methods of radiocarbon dating. The method of reporting artifact age using the term "Before Present (BP)" with the reference year 1950 was removed because it adds an extra step and is potentially confusing. The age of the object is now reported in the more conventional method of the time frame when the artifact was living. End-of-chapter problems were revised to match this change.
- In Section 20.7 Nuclear Fission and Fusion, Figure 20.9, which provides information on the number of nuclear reactors and nuclear power output worldwide, was updated.
- In Section 20.8 Nuclear Transmutation, information about the nuclear transformation reactions used in the synthesis of new elements $Z = 113–118$ was added, and new problems were written on this topic.
- New Inquiry topic: How are radioisotopes used in medicine? The previous text section was updated and expanded with some recent advances in nuclear medicine such as boron neutron capture therapy.

Chapter 21 Transition Elements and Coordination Chemistry

- Section 20.4 Chemistry of Selected Transition Elements was removed because it did not cover any new chemistry concepts

and involved memorization of specific reactions that would not be retained easily. This content is this section is not needed to understand the main concepts of transition metal chemistry such as the color and magnetic properties of complexes.

- Modified Figure 21.9 to label the chelate ring discussed in the text description and added a Figure It Out Question in order to identify a chelate ring.
- Figure 21.24 showing colors of nickel complexes was moved next to text describing the accompanying crystal field diagrams. A description of the connection between the crystal field energy diagrams and the observed color of the complexes was added.
- The section Valence Bond Theory of Coordination Complexes is now placed at the end of the chapter to strengthen the connection between the color of coordination compounds and crystal field theory. The key terms *high-spin* and *low-spin complex* are now defined based on crystal field theory instead of valence bond theory.
- Also, crystal field theory was developed before valence bond theory. The text was modified to reiterate how crystal field theory is different from bonding theories based on quantum mechanics. (Also, many books do not cover valence bond theory of coordination complexes, so placing it last gives instructors the option to omit it.)

Chapter 22 The Main-Group Elements

- The chemistry of each main group was merged into its own section and the content trimmed to avoid excessive memorization.
- Continued emphasis on relating main-group chemistry to previous topics in the book such as periodic trends, bonding, structure, equilibrium, and acid-base chemistry. New end-of-chapter problems were written with emphasis on reviewing important chemical principles.

Chapter 23 Organic and Biological Chemistry

- Section 23.3 Naming Organic Compounds, was removed because the focus of the chapter is on bonding and structure, and naming is not needed to address these topics.
- In Section 23.1 Organic Molecules and Their Structures: Constitutional Isomers on organic molecules and their structures, the concept of constitutional isomers (instead of simply isomers) was stressed. This allows other important types of isomers such as enantiomers and cis-trans isomers to be distinguished and addressed in later sections.
- Unnumbered figure of 2-methylbutane was revised to more clearly show the zigzag structure of the carbon chain, which serves as the basis for organic line drawings.
- New Section 23.2 Stereoisomers: Chiral Molecules. Chirality is an extremely important concept with organic molecules, and the topic warrants its own section. Worked Examples and a set of end-of-chapter problems were developed.
- New Worked Example 23.4: Interpreting Line Drawings for Molecules with Functional Groups.
- New Inquiry on chiral molecules and their biological response to connect with new Section 23.2 Stereoisomers: Chiral Molecules on chiral molecules.

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Jill K. Robinson
John McMurry
Robert C. Fay

REVIEWERS FOR THE EIGHTH EDITION

Stanley Bajue, Medger Evers College
Joe Casalnuovo, Cal Poly, Pomona
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Erik Wasinger, California State University–Chico
Steve Watton, Virginia Commonwealth University
Marcy Whitney, University of Alabama
James Wu, Tarrant County Community College
Mingming Xu, West Virginia University
Crystal Lin Yau, Towson University
James Zubricky, University of Toledo

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Reviewers
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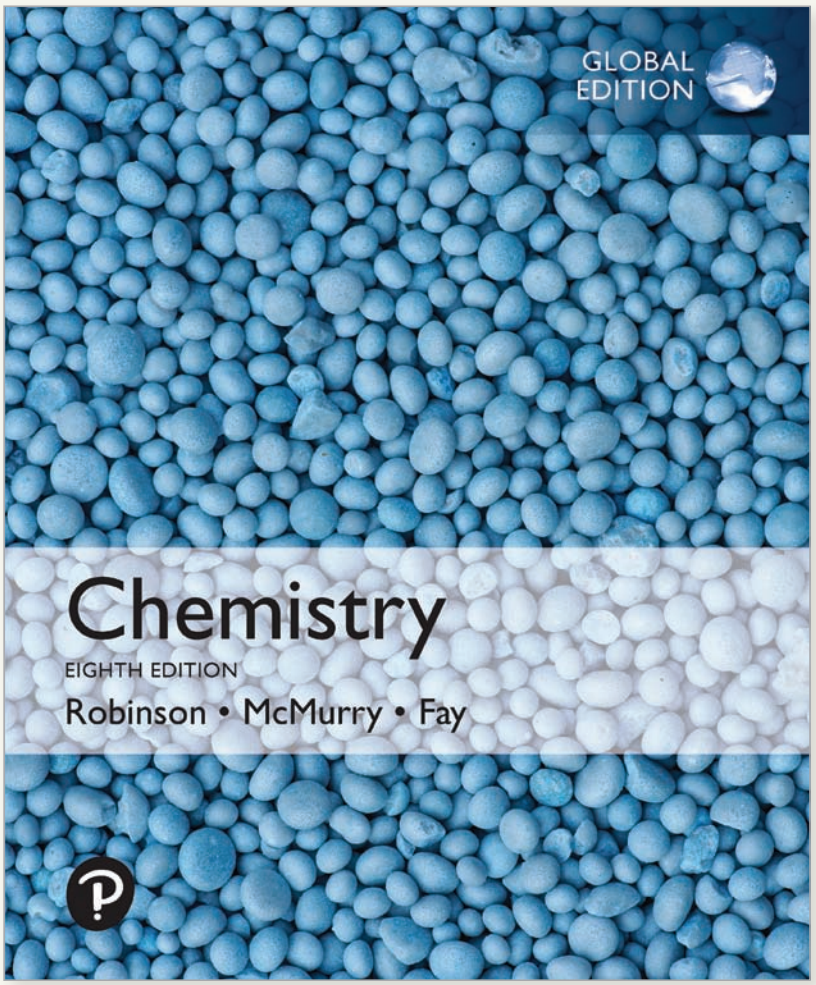

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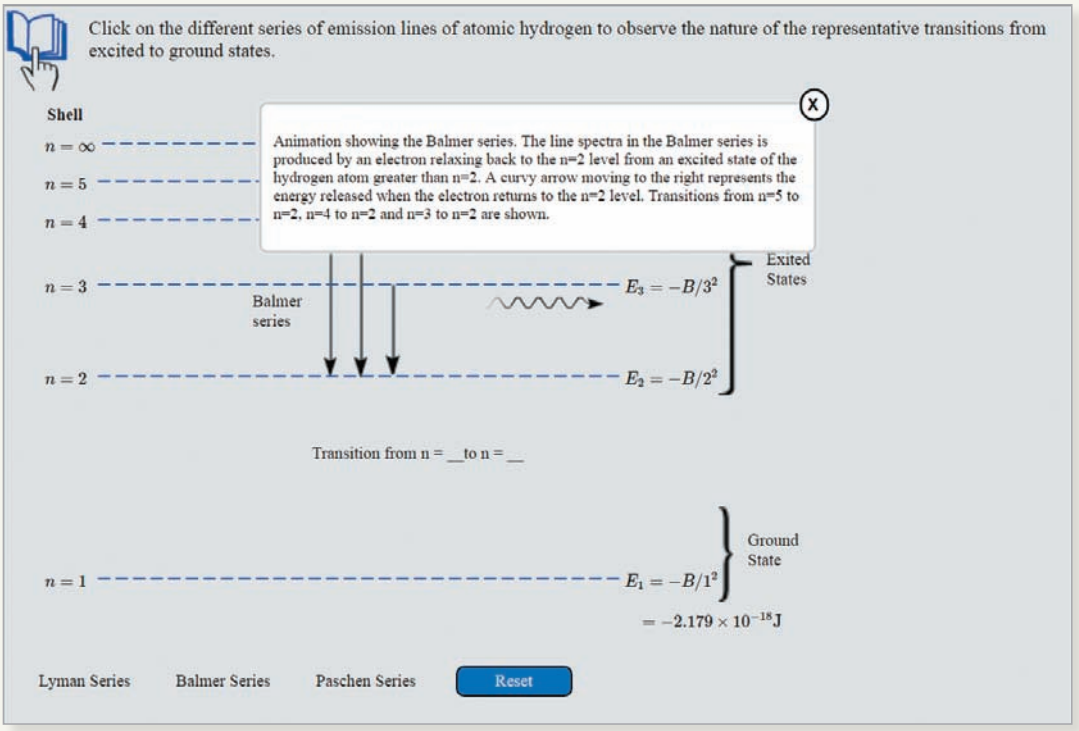

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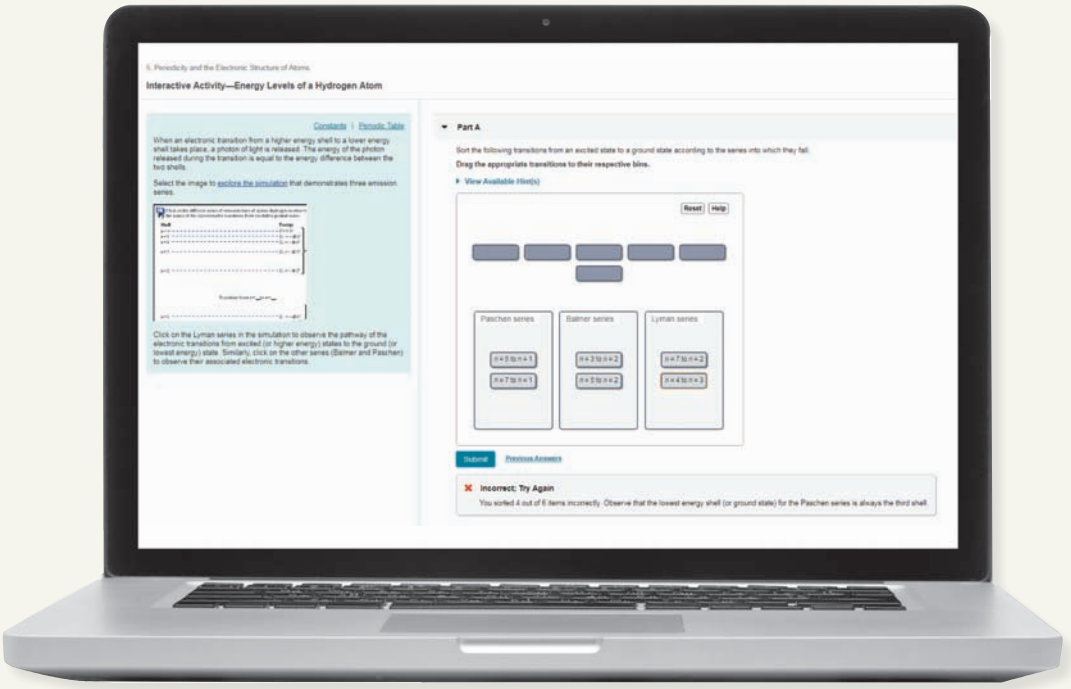

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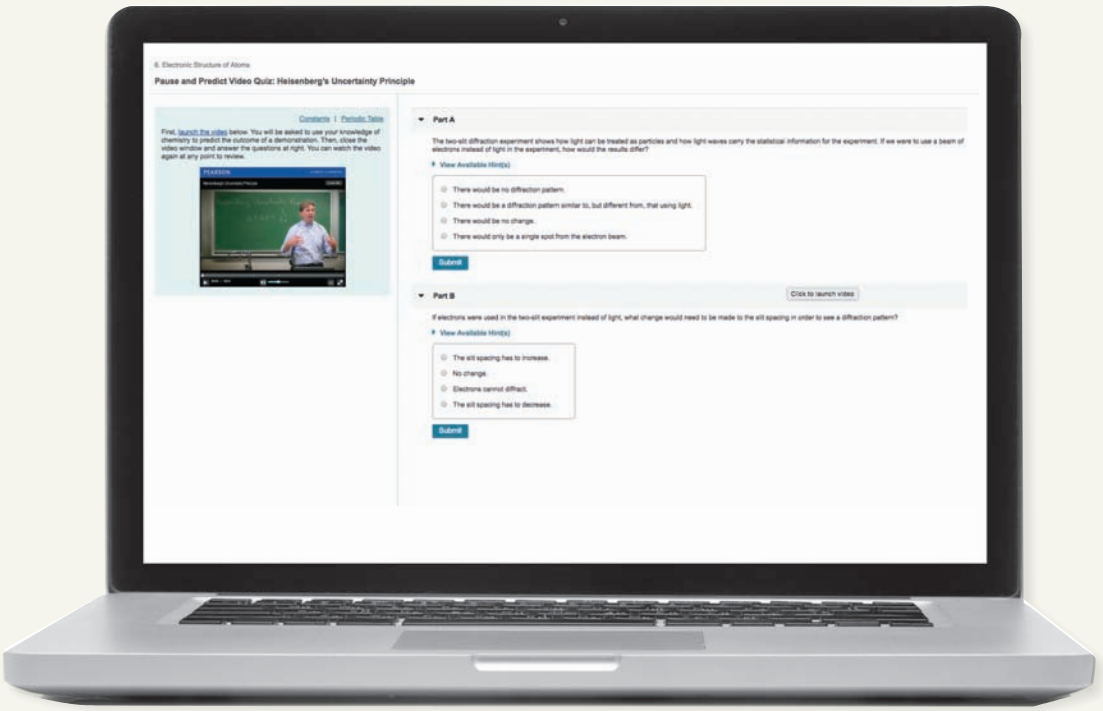

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