



FOUNDATIONS OF 15<sup>E</sup>  
**COLLEGE CHEMISTRY**

Morris Hein • Susan Arena • Cary Willard

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## Periodic Table of the Elements

Main groups																		Main groups						
1 <sup>a</sup> 1A <sup>b</sup>																		18 8A						
1	1 <b>H</b> Hydrogen 1.00794																	2 <b>He</b> Helium 4.002602						
2	3 <b>Li</b> Lithium 6.941	4 <b>Be</b> Beryllium 9.012182	Transition metals																5 <b>B</b> Boron 10.811	6 <b>C</b> Carbon 12.0107	7 <b>N</b> Nitrogen 14.00674	8 <b>O</b> Oxygen 15.9994	9 <b>F</b> Fluorine 18.998403	10 <b>Ne</b> Neon 20.1797
3	11 <b>Na</b> Sodium 22.989770	12 <b>Mg</b> Magnesium 24.3050	3 <b>B</b>	4 <b>B</b>	5 <b>B</b>	6 <b>B</b>	7 <b>B</b>	8 <b>B</b>		10 <b>B</b>	11 <b>B</b>	12 <b>B</b>	13 <b>Al</b> Aluminum 26.981538	14 <b>Si</b> Silicon 28.0855	15 <b>P</b> Phosphorus 30.973762	16 <b>S</b> Sulfur 32.066	17 <b>Cl</b> Chlorine 35.4527	18 <b>Ar</b> Argon 39.948						
4	19 <b>K</b> Potassium 39.0983	20 <b>Ca</b> Calcium 40.078	21 <b>Sc</b> Scandium 44.95591	22 <b>Ti</b> Titanium 47.867	23 <b>V</b> Vanadium 50.9415	24 <b>Cr</b> Chromium 51.9961	25 <b>Mn</b> Manganese 54.938049	26 <b>Fe</b> Iron 55.845	27 <b>Co</b> Cobalt 58.933200	28 <b>Ni</b> Nickel 58.6934	29 <b>Cu</b> Copper 63.546	30 <b>Zn</b> Zinc 65.39	31 <b>Ga</b> Gallium 69.723	32 <b>Ge</b> Germanium 72.61	33 <b>As</b> Arsenic 74.92160	34 <b>Se</b> Selenium 78.96	35 <b>Br</b> Bromine 79.904	36 <b>Kr</b> Krypton 83.80						
5	37 <b>Rb</b> Rubidium 85.4678	38 <b>Sr</b> Strontium 87.62	39 <b>Y</b> Yttrium 88.90585	40 <b>Zr</b> Zirconium 91.224	41 <b>Nb</b> Niobium 92.90638	42 <b>Mo</b> Molybdenum 95.94	43 <b>Tc</b> Technetium [98]	44 <b>Ru</b> Ruthenium 101.07	45 <b>Rh</b> Rhodium 102.90550	46 <b>Pd</b> Palladium 106.42	47 <b>Ag</b> Silver 107.8682	48 <b>Cd</b> Cadmium 112.411	49 <b>In</b> Indium 114.818	50 <b>Sn</b> Tin 118.710	51 <b>Sb</b> Antimony 121.760	52 <b>Te</b> Tellurium 127.60	53 <b>I</b> Iodine 126.90447	54 <b>Xe</b> Xenon 131.29						
6	55 <b>Cs</b> Cesium 132.90545	56 <b>Ba</b> Barium 137.327	57 <b>*La</b> Lanthanum 138.9055	72 <b>Hf</b> Hafnium 178.49	73 <b>Ta</b> Tantalum 180.9479	74 <b>W</b> Tungsten 183.84	75 <b>Re</b> Rhenium 186.207	76 <b>Os</b> Osmium 190.23	77 <b>Ir</b> Iridium 192.217	78 <b>Pt</b> Platinum 195.078	79 <b>Au</b> Gold 196.96655	80 <b>Hg</b> Mercury 200.59	81 <b>Tl</b> Thallium 204.3833	82 <b>Pb</b> Lead 207.2	83 <b>Bi</b> Bismuth 208.98038	84 <b>Po</b> Polonium [209]	85 <b>At</b> Astatine [210]	86 <b>Rn</b> Radon [222]						
7	87 <b>Fr</b> Francium [223]	88 <b>Ra</b> Radium 226.025	89 <b>†Ac</b> Actinium 227.028	104 <b>Rf</b> Rutherfordium [261]	105 <b>Db</b> Dubnium [262]	106 <b>Sg</b> Seaborgium [266]	107 <b>Bh</b> Bohrium [267]	108 <b>Hs</b> Hassium [269]	109 <b>Mt</b> Meitnerium [268]	110 <b>Ds</b> Darmstadtium [281]	111 <b>Rg</b> Roentgenium [272]	112 <b>Cn</b> Copernicium	113 <b>Uut</b>	114 <b>Ff</b> Flerovium	115 <b>Uup</b>	116 <b>Lv</b> Livermorium	117 <b>Uus</b>	118 <b>Uuo</b>						

*Lanthanide series	58 <b>Ce</b> Cerium 140.116	59 <b>Pr</b> Praseodymium 140.90765	60 <b>Nd</b> Neodymium 144.24	61 <b>Pm</b> Promethium [145]	62 <b>Sm</b> Samarium 150.36	63 <b>Eu</b> Europium 151.964	64 <b>Gd</b> Gadolinium 157.25	65 <b>Tb</b> Terbium 158.92534	66 <b>Dy</b> Dysprosium 162.50	67 <b>Ho</b> Holmium 164.93032	68 <b>Er</b> Erbium 167.26	69 <b>Tm</b> Thulium 168.93421	70 <b>Yb</b> Ytterbium 173.04	71 <b>Lu</b> Lutetium 174.967
†Actinide series	90 <b>Th</b> Thorium 232.0381	91 <b>Pa</b> Protactinium 231.03588	92 <b>U</b> Uranium 238.0289	93 <b>Np</b> Neptunium 237.048	94 <b>Pu</b> Plutonium [244]	95 <b>Am</b> Americium [243]	96 <b>Cm</b> Curium [247]	97 <b>Bk</b> Berkelium [247]	98 <b>Cf</b> Californium [251]	99 <b>Es</b> Einsteinium [252]	100 <b>Fm</b> Fermium [257]	101 <b>Md</b> Mendelevium [258]	102 <b>No</b> Nobelium [259]	103 <b>Lr</b> Lawrencium [262]

Atomic masses in brackets are the masses of the longest-lived or most important isotope of certain radioactive elements.

<sup>a</sup>The labels on top (1, 2, 3 ... 18) are the group numbers recommended by the International Union of Pure and Applied Chemistry.

<sup>b</sup>The labels on the bottom (1A, 2A, ... 8A) are the group numbers commonly used in the United States and the ones we use in this text.

<sup>c</sup>The names and symbols of elements 113 and above have not been assigned.

<sup>d</sup>Discovered in 2010, element 117 is under review by IUPAC.


Further information is available at the Web site of WebElements™.

## Atomic Masses of the Elements

Based on the 2005 IUPAC Table of Atomic Masses

Name	Symbol	Atomic Number	Atomic Mass	Name	Symbol	Atomic Number	Atomic Mass
Actinium*	<b>Ac</b>	89	227	Manganese	<b>Mn</b>	25	54.938049
Aluminum	<b>Al</b>	13	26.981538	Meitnerium*	<b>Mt</b>	109	268
Americium*	<b>Am</b>	95	243	Mendelevium*	<b>Md</b>	101	258
Antimony	<b>Sb</b>	51	121.760	Mercury	<b>Hg</b>	80	200.59
Argon	<b>Ar</b>	18	39.948	Molybdenum	<b>Mo</b>	42	95.94
Arsenic	<b>As</b>	33	74.92160	Neodymium	<b>Nd</b>	60	144.24
Astatine*	<b>At</b>	85	210	Neon	<b>Ne</b>	10	20.1797
Barium	<b>Ba</b>	56	137.327	Neptunium*	<b>Np</b>	93	237
Berkelium*	<b>Bk</b>	97	247	Nickel	<b>Ni</b>	28	58.6934
Beryllium	<b>Be</b>	4	9.012182	Niobium	<b>Nb</b>	41	92.90638
Bismuth	<b>Bi</b>	83	208.98038	Nitrogen	<b>N</b>	7	14.00674
Bohrium*	<b>Bh</b>	107	264	Nobelium*	<b>No</b>	102	259
Boron	<b>B</b>	5	10.811	Osmium	<b>Os</b>	76	190.23
Bromine	<b>Br</b>	35	79.904	Oxygen	<b>O</b>	8	15.9994
Cadmium	<b>Cd</b>	48	112.411	Palladium	<b>Pd</b>	46	106.42
Calcium	<b>Ca</b>	20	40.078	Phosphorus	<b>P</b>	15	30.973762
Californium*	<b>Cf</b>	98	251	Platinum	<b>Pt</b>	78	195.078
Carbon	<b>C</b>	6	12.0107	Plutonium*	<b>Pu</b>	94	244
Cerium	<b>Ce</b>	58	140.116	Polonium*	<b>Po</b>	84	209
Cesium	<b>Cs</b>	55	132.90545	Potassium	<b>K</b>	19	39.0983
Chlorine	<b>Cl</b>	17	35.4527	Praseodymium	<b>Pr</b>	59	140.90765
Chromium	<b>Cr</b>	24	51.9961	Promethium*	<b>Pm</b>	61	145
Cobalt	<b>Co</b>	27	58.933200	Protactinium	<b>Pa</b>	91	231.03588
Copernicium	<b>Cn</b>	112		Radium*	<b>Ra</b>	88	226
Copper	<b>Cu</b>	29	63.546	Radon*	<b>Rn</b>	86	222
Curium*	<b>Cm</b>	96	247	Rhenium	<b>Re</b>	75	186.207
Darmstadtium*	<b>Ds</b>	110	271	Rhodium	<b>Rh</b>	45	102.90550
Dubnium*	<b>Db</b>	105	262	Roentgenium*	<b>Rg</b>	111	272
Dysprosium	<b>Dy</b>	66	162.500	Rubidium	<b>Rb</b>	37	85.4678
Einsteinium*	<b>Es</b>	99	252	Ruthenium	<b>Ru</b>	44	101.07
Erbium	<b>Er</b>	68	167.26	Rutherfordium*	<b>Rf</b>	104	261
Europium	<b>Eu</b>	63	151.964	Samarium	<b>Sm</b>	62	150.36
Fermium*	<b>Fm</b>	100	257	Scandium	<b>Sc</b>	21	44.955910
Flerovium	<b>Fl</b>	114		Seaborgium*	<b>Sg</b>	106	266
Fluorine	<b>F</b>	9	18.9984032	Selenium	<b>Se</b>	34	78.96
Francium*	<b>Fr</b>	87	233	Silicon	<b>Si</b>	14	28.0855
Gadolinium	<b>Gd</b>	64	157.25	Silver	<b>Ag</b>	47	107.8682
Gallium	<b>Ga</b>	31	69.723	Sodium	<b>Na</b>	11	22.989770
Germanium	<b>Ge</b>	32	72.61	Strontium	<b>Sr</b>	38	87.62
Gold	<b>Au</b>	79	196.96655	Sulfur	<b>S</b>	16	32.066
Hafnium	<b>Hf</b>	72	178.49	Tantalum	<b>Ta</b>	73	180.9479
Hassium*	<b>Hs</b>	108	277	Technetium*	<b>Tc</b>	43	98
Helium	<b>He</b>	2	4.002602	Tellurium	<b>Te</b>	52	127.60
Holmium	<b>Ho</b>	67	164.93032	Terbium	<b>Tb</b>	65	158.92534
Hydrogen	<b>H</b>	1	1.00794	Thallium	<b>Tl</b>	81	204.3833
Indium	<b>In</b>	49	114.818	Thorium	<b>Th</b>	90	232.0381
Iodine	<b>I</b>	53	126.90447	Thulium	<b>Tm</b>	69	168.93421
Iridium	<b>Ir</b>	77	192.217	Tin	<b>Sn</b>	50	118.710
Iron	<b>Fe</b>	26	55.845	Titanium	<b>Ti</b>	22	47.867
Krypton	<b>Kr</b>	36	83.80	Tungsten	<b>W</b>	74	183.94
Lanthanum	<b>La</b>	57	138.9055	Uranium	<b>U</b>	92	238.0289
Lawrencium*	<b>Lr</b>	103	262	Vanadium	<b>V</b>	23	50.9415
Lead	<b>Pb</b>	82	207.2	Xenon	<b>Xe</b>	54	131.29
Lithium	<b>Li</b>	3	6.941	Ytterbium	<b>Yb</b>	70	173.04
Livermorium	<b>Lv</b>	116		Yttrium	<b>Y</b>	39	88.90585
Lutetium	<b>Lu</b>	71	174.967	Zinc	<b>Zn</b>	30	65.39
Magnesium	<b>Mg</b>	12	24.3050	Zirconium	<b>Zr</b>	40	91.224

\*This element has no stable isotopes. The atomic mass given is that of the isotope with the longest known half-life.



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CHEMISTRY**

**Morris Hein**

Mount San Antonio College

**Susan Arena**

University of Illinois, Urbana-Champaign

**Cary Willard**

Grossmont College

**WILEY**

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## → ABOUT THE AUTHOR

**MORRIS HEIN** earned his PhD at the University of Colorado, Boulder. He was Professor Emeritus of Chemistry at Mt. San Antonio College, where he regularly taught the preparatory chemistry course and organic chemistry. He was the original author of *Foundations of College Chemistry*, and his name has become synonymous with clarity, meticulous accuracy, and a step-by-step approach that students can follow. Morris passed away in late 2014 and was actively working on our texts till the very end. His sharp eyes and attention to detail will be sorely missed.

**SUSAN ARENA** earned a BS and MA in Chemistry at California State University-Fullerton. She has taught science and mathematics at all levels, including middle school, high school, community college, and university. At the University of Illinois she developed a program for increasing the retention of minorities and women in science and engineering. This program focused on using active learning and peer teaching to encourage students to excel in the sciences. She has coordinated and led workshops and programs for science teachers from elementary through college levels that encourage and support active learning and creative science teaching techniques. For several years she was director of an Institute for Chemical Education (ICE) field center in Southern California. In addition to *Foundations of College Chemistry*, 15th edition, she is co-author of *Introduction to General, Organic and Biochemistry*, 10th edition. Susan enjoys reading, knitting, traveling, classic cars, and gardening in her spare time when she is not playing with her grandchildren.

**CARY WILLARD** received her BS in chemistry from California State Polytechnic Institute, Pomona, and her PhD from the University of California, Davis. She has been teaching chemistry at Grossmont College in El Cajon, California for over 20 years. She teaches the chemistry courses for both science and nonscience majors. Her biggest successes are the students who come into chemistry afraid of the subject and leave having discovered that chemistry really is fun. Her interest in sharing the excitement of science to the community resulted in Grossmont College hosting a Science Festival, multiple Science Decathlons, model airplane flying, and robotics competitions. Cary is also a member of the BE WiSE (Better Education for Women in Science and Engineering) steering committee and works with the group to share the excitement of scientific research with a new generation of young women. In her spare time, Cary enjoys exploring the San Diego region both on foot and in her kayak.

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## GLOSSARY G1

## INDEX I1

## EULA

## → PREFACE

This new Fifteenth Edition of *Foundations of College Chemistry* presents chemistry as a modern, vital subject and is designed to make introductory chemistry accessible to all beginning students. The central focus is the same as it has been from the first edition: to make chemistry interesting and understandable to students and teach them the problem-solving skills they will need. In preparing this new edition, we considered the comments and suggestions of students and instructors to design a revision that builds on the strengths of previous editions including clear explanations and step-by-step problem solving. We have especially tried to relate chemistry to the real lives of our students as we develop the principles that form the foundation for the further study of chemistry, and to provide them with problem-solving skills and practice needed in their future studies. We have focused on using electronic materials to enhance the student experience. To that end we have authored and added new interactive features ourselves and enhanced our existing electronic materials to draw the students into direct involvement in an active learning experience.

*Foundations of College Chemistry*, 15th Edition, is intended for students who have never taken a chemistry course or those who have had a significant interruption in their studies but plan to continue with the general chemistry sequence. Since its inception, this book has helped define the preparatory chemistry course and has developed a much wider audience. In addition to preparatory chemistry, our text is used extensively in one-semester general-purpose courses (such as those for applied health fields) and in courses for nonscience majors.

### Development of Problem-Solving Skills

We all want our students to develop real skills in solving problems. We believe that a key to the success of this text is the fact that our problem-solving approach works for students. It is a step-by-step process that teaches the use of units and shows the change from one unit to the next. We have used this problem-solving approach in our examples throughout the text to encourage students to think their way through each problem. In this edition we continue to use examples to incorporate fundamental mathematical skills, scientific notation, and significant figures. We have added Problem-Solving Strategy boxes in the text to highlight the steps needed to solve chemistry problems. Painstaking care has been taken to show each step in the problem-solving process and to use these steps in solving example problems. We continue to use four significant figures for atomic and molar masses for consistency and for rounding off answers appropriately. We have been meticulous in providing answers, correctly rounded, for students who have difficulty with mathematics.

**FOSTERING STUDENT SKILLS** *Attitude* plays a critical role in problem solving. We encourage students to learn that a systematic approach to solving problems is better than simple memorization. Throughout the book we emphasize the use of our approach to problem solving to encourage students to think through each problem. Once we have laid the foundations of concepts, we highlight the steps so students can locate them easily. Important rules and equations are highlighted for emphasis and ready reference.

**STUDENT PRACTICE** Practice problems follow the examples in the text, with answers provided at the end of the chapter. The end of each chapter begins with a *Chapter Review* and *Review Questions* section, which help students review key terms and concepts, as well as material presented in tables and figures. This is followed by *Paired Exercises*, covering concepts and numerical exercises, where two similar exercises are presented side by side. The section titled *Additional Exercises* includes further practice problems presented in a more random order. The final section of exercises is titled *Challenge Exercises* and contains problems designed to stretch the student's understanding of concepts and to integrate

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concepts from other chapters. In our new edition we have changed a number of exercises per chapter. In addition we have expanded the electronic Enhanced Examples to a total of 178 throughout the chapters and developed two new electronic practice methods.

**PRACTICE 7.7**

Calculate the percent composition of  $\text{Ca}(\text{NO}_3)_2$ .

**PRACTICE 7.8**

Calculate the percent composition of  $\text{K}_2\text{CrO}_4$ .

Practice Problems

**PROBLEM-SOLVING STRATEGY****For Calculating Percent Composition from Formula**

1. Calculate the molar mass (Section 7.2).
2. Divide the total mass of each element in the formula by the molar mass and multiply by 100. This gives the percent composition:

$$\frac{\text{total mass of the element}}{\text{molar mass}} \times 100 = \text{percent of the element}$$

Problem-solving Strategy

**Organization**

We continue to emphasize the less theoretical aspects of chemistry early in the book, leaving the more abstract theory for later. This sequence seems especially appropriate in a course where students are encountering chemistry for the very first time. Atoms, molecules, and reactions are all an integral part of the chemical nature of matter. A sound understanding of these topics allows the student to develop a basic understanding of chemical properties and vocabulary.

Chapters 1 through 3 present the basic mathematics and the language of chemistry, including an explanation of the metric system and significant figures. We added a new section in Chapter 2 (2.7) on Percents to assist students in understanding how the concept is applied in chemistry. In Chapter 4 we present chemical properties—the ability of a substance to form new substances. Then, in Chapter 5, students encounter the history and language of basic atomic theory. In Chapter 8 we added a new section 8.3 “Why Reactions Occur” and revised the section discussing types of reactions extensively to better reflect the level and needs of our students.

We continue to present new material at a level appropriate for the beginning student by emphasizing nomenclature, composition of compounds, and reactions in Chapters 6 through 9 before moving into the details of modern atomic theory. Some applications of the Periodic Table are shown in early chapters and discussed in detail in Chapters 10 and 11. Students gain confidence in their own ability to identify and work with chemicals in the laboratory before tackling the molecular models of matter. As practicing chemists we have little difficulty connecting molecular models and chemical properties. Students, especially those with no prior chemistry background, may not share this ability to connect the molecular models and the macroscopic properties of matter. Those instructors who feel it is essential to teach atomic theory and bonding early in the course can cover Chapters 10 and 11 immediately following Chapter 5.

**New to This Edition**

In the Fifteenth Edition we have tried to build on the strengths of the previous editions. We have added a new author, **Cary Willard**, from Grossmont College in California. Cary revised the end-of-chapter materials and added exercises, including many applications in fields of interest for our students. She has focused on expanding and developing important and

meaningful media assets for the *WileyPLUS* course. Her focus has created deeper synergies between the content in print format and the electronic resources in our *WileyPLUS* course.

We continually strive to keep the material at the same level so that students can easily read and use the text and supplemental material to learn chemistry. With a focus on problem solving, student engagement, and clarity, some of the specific changes are highlighted below:

- Chemistry In Action boxes have been updated, and new boxes have been added to include different applications of the concepts in the text.
- Some of the older industrial chemistry applications have been removed and newer applications added as appropriate throughout the text.
- 229 Check Your Understanding Questions appear throughout the text to provide an opportunity for the students to determine their level of understanding of concepts. These are highlighted in the margins and refer the student to *WileyPlus* for completion.
- 178 Enhanced Examples are also located in *WileyPlus* and provide a more interactive experience and practice. Students receive immediate feedback on their answers and proceed stepwise through the example to its conclusion.
- 131 new Online Learning Modules movies provide a one-on-one learning experience that mimics the assistance an instructor provides in a help session. The modules are paired with in-text examples to provide an alternative way to learn problem solving.
- Each chapter is complemented by ORION, an adaptive learning module, available within *WileyPLUS*. These can be used individually for student review or can be assigned by instructors as a specific review assignment tailored to the chapters and sections on an exam.
- Chapters 19 and 20 (Introduction to Organic Chemistry and Introduction to Biochemistry) are now available online only. This provides an option for those desiring a shorter version of the text and for those wishing to cover this material in their course.
- The Putting It Together sections have been removed in order to provide a more flexible review source for students and instructors. This new resource is called Orion and is found on *WileyPlus*.
- New, modern design. The entire text has been redesigned to foster greater accessibility and increase student engagement. New icons and notes direct students to *WileyPlus* for more individual direct interaction with the material.
- Appendix II: Using a Scientific Calculator has been removed because most students begin using calculators in elementary school and there are so many kinds of calculators that specific instruction on their use is no longer possible.

#### CHECK YOUR UNDERSTANDING

##### 7.6 Molecules and Formula Units

→ **WileyPLUS**

**ENHANCED EXAMPLE 7.6** **WileyPLUS**

How many oxygen atoms are present in 1.00 mol of oxygen molecules?

**SOLUTION**

**Plan** • Oxygen is a diatomic molecule with the formula  $O_2$ . Therefore, a molecule of oxygen contains 2 oxygen atoms:  $\frac{2 \text{ atoms O}}{1 \text{ molecule } O_2}$ .

**Solution map:** moles  $O_2$  → molecules  $O_2$  → atoms O

The conversion factors needed are

$$\frac{6.022 \times 10^{23} \text{ molecules } O_2}{1 \text{ mole } O_2} \quad \text{and} \quad \frac{2 \text{ atoms O}}{1 \text{ molecule } O_2}$$

**Calculate** •  $(1.00 \text{ mol } O_2) \left( \frac{6.022 \times 10^{23} \text{ molecules } O_2}{1 \text{ mole } O_2} \right) \left( \frac{2 \text{ atoms O}}{1 \text{ molecule } O_2} \right)$   
 $= 1.20 \times 10^{24} \text{ atoms O}$

---

**PRACTICE 7.2**  
What is the mass of 2.50 mol of helium (He)?

**PRACTICE 7.3**  
How many atoms are present in 0.025 mol of iron?

#### ONLINE LEARNING MODULE

Finding Molecules in Moles of a Diatomic Substance

→ **WileyPLUS**



## Learning Aids

To help the beginning student gain the confidence necessary to master technical material, we have refined and enhanced a series of learning aids:

- **Learning Objectives** highlight the concept being taught in each section. These objectives are tied to **Example**, **Practice Problems**, **Review Exercises**, and **Exercises** to assist the student in mastering each concept module and objective.
- Important **terms** are set off in bold type where they are defined and are listed in gray at the beginning of each section. All **Key Terms** listed in the **Chapter Review** are also defined in the **Glossary**.
- Worked **examples** show students the how of problem solving using **Problem-Solving Strategies** and **Solution Maps** before they are asked to tackle problems on their own.
- **Practice problems** permit immediate reinforcement of a skill shown in the example problems. Answers are provided at the end of the chapter to encourage students to check their problem solving immediately.

- **Marginal notations** help students understand basic concepts and problem-solving techniques. These are printed in blue to clearly distinguish them from text and vocabulary terms.

**LEARNING AIDS: MATH SKILLS** For students who may need help with the mathematical aspects of chemistry, the following learning aids are available:

- A **Review of Mathematics**, covering the basic functions, is provided in Appendix I.
- **Math Survival Guide: Tips and Tricks for Science Students**, 2nd Edition, by Jeffrey R. Appling and Jean C. Richardson, a brief paperback summary of basic skills that can be packaged with the text, provides an excellent resource for students who need help with the mathematical aspects of chemistry.

## Supplements Package

**FOR THE STUDENT Study Guide** by Rachael Henriques Porter is a self-study guide for students. For each chapter, the **Study Guide** includes a self-evaluation section with student exercises, a summary of chapter concepts, one or more “challenge problems,” and answers and solutions to all **Study Guide** exercises.

**Math Survival Guide: Tips and Tricks for Science Students**, 2nd Edition, by Jeffrey Appling and Jean Richardson, is a paperback summary of basic skills, with practice exercises in every chapter.

**Foundations of Chemistry in the Laboratory**, 14th Edition, by Morris Hein, Judith N. Peisen, and Robert L. Miner includes 28 experiments for a laboratory program that may accompany the lecture course. Featuring updated information on waste disposal and emphasizing safe laboratory procedures, the lab manual also includes study aids and exercises.

**FOR THE INSTRUCTOR Test Bank**, by Harpreet Malhotra, includes chapter tests with additional test questions and answers to all test questions.

**Computerized Test Bank.** The test bank contains true-false, multiple-choice, and open-ended questions and is available in two formats.

**Digital Image Library:** Images from the text are available online in JPEG format. Instructors may use these to customize their presentations and to provide additional visual support for quizzes and exams.

**Power Point Lecture Slides:** Updated for this version by William Douglas Urban, these slides contain lecture outlines and key topics from each chapter of the text, along with supporting artwork and figures from the text.

## WileyPLUS

*WileyPLUS* is an innovative, research-based online environment for effective teaching and learning.

*WileyPLUS* builds students’ confidence because it takes the guesswork out of studying by providing students with a clear roadmap: **what to do, how to do it, if they did it right**. This interactive approach focuses on:

**CONFIDENCE:** Research shows that students experience a great deal of anxiety studying. That’s why we provide a structured learning environment that helps students focus on **what to do**, along with the support of immediate resources.

**MOTIVATION:** To increase and sustain motivation throughout the semester, *WileyPLUS* helps students learn **how to do it** at a pace that’s right for them. Our integrated resources—available 24/7—function like a personal tutor, directly addressing each student’s demonstrated needs with specific problem-solving techniques.



*WileyPLUS* is now equipped with an adaptive learning module called ORION.

## WileyPLUS with ORION is:



### BEGIN

A **personalized study guide** that helps students understand both strengths and areas where they need to invest more time, especially in preparation for quizzes and exams.



### PRACTICE

For each topic, students can either Study or Practice. **Study** directs the student to the specific topic they choose in *WileyPLUS*, where they can read from the e-textbook, or use the variety of relevant resources available there. Students can also **practice**, using questions and feedback powered by ORION's adaptive learning engine.



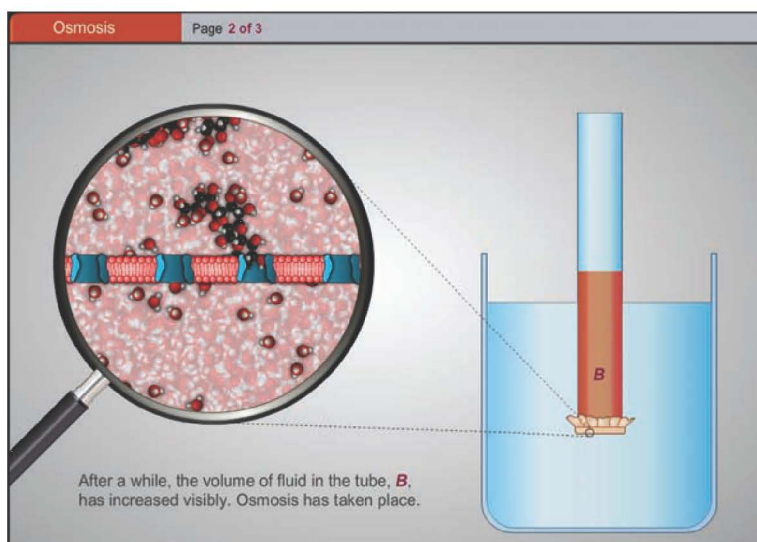
### MAINTAIN

ORION includes a number of reports and ongoing recommendations for students to help them maintain their proficiency over time for each topic.

Students can easily access ORION from within *WileyPLUS*. It does not require any additional registration, and there is no additional charge for students using this adaptive learning system.

## What Do Students Receive with WileyPLUS?

- The complete digital textbook, saving students up to 50% off the cost of a printed text.
- Math Skills module provides a comprehensive review of topics including: ratios, scientific notation, significant figures, and graphing.
- The Check Your Understanding Questions, Enhanced Examples, and Online Learning Modules outlined above are available by default to students for self-study, no instructor set-up is required.
- Visualizations of key concepts with audio narration.



## What Do Instructors Receive with WileyPLUS?

- All end-of-chapter questions are available for assignment and automatic grading.
- Every assignable question has been enhanced with additional content such as hints, solutions, and guided tutorials which can be made available to students at the instructor's discretion.

**GO Tutorial** Close

This GO Tutorial will provide you with a step-by-step guide on how to approach this problem. When you are finished, go back and try the problem again on your own. To view the original question while you work, you can just drag this screen to the side. **(This GO Tutorial consists of 3 steps).**

**Step 1 : Problem 12.10. Step 1 - Guide question 12-10a**

If 3.56L of an unknown gas measured at STP has a mass of 32.0g, what is the density of the gas in g/L?

Density of the gas =

*The number of significant digits is set to 3; the tolerance is +/-1 in the 3rd significant digit*

**Step 2 : Problem 12.10. Step 2 - Guide Question 12-10b**

What conversion factor is needed to convert density into molar mass?

molar volume  
 molar density  
 volume  
 mass

**Step 3 : Problem 12.10. Step 3 - Guide question 12-10c**

What is the molar volume of a gas at STP?

Molar volume =

*The number of significant digits is set to 3; the tolerance is +/-1 in the 3rd significant digit*

Now that you know how to solve the problem, go back and try again on your own. Close

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# 1

## An Introduction to Chemistry

**D**o you know how the beautiful, intricate fireworks displays are created? Have you ever wondered how a tiny seedling can grow into a cornstalk taller than you in just one season? Perhaps you have been mesmerized by the flames in your fireplace on a romantic evening as they change color and form. The spectacular colors of the aurora borealis shown above are the result of chemistry in our atmosphere. And think of your relief when you dropped a container and found that it was plastic, not glass. These phenomena are the result of chemistry that occurs all around us, all the time. Chemical changes bring us beautiful colors, warmth, light, and products to make our lives function more smoothly. Understanding, explaining, and using the diversity of materials we find around us is what chemistry is all about.



Jon Hilmason/Getty Images

### CHAPTER OUTLINE

**1.1 The Nature of Chemistry**

**1.2 A Scientific Approach to Problem Solving**

**1.3 The Particulate Nature of Matter**

**1.4 Classifying Matter**

-----

## 1.1 The Nature of Chemistry

**LEARNING OBJECTIVE** State the definition of chemistry and why the study of chemistry is important.

**KEY TERM**

Chemistry

Key terms are **highlighted in bold** to alert you to new terms defined in the text.

A knowledge of chemistry is useful to virtually everyone—we see chemistry occurring around us every day. An understanding of chemistry is useful to engineers, teachers, health care professionals, attorneys, homemakers, businesspeople, firefighters, and environmentalists, just to name a few. Even if you're not planning to work in any of these fields, chemistry is important and is used by people every day. Learning about the benefits and risks associated with chemicals will help you to be an informed citizen, able to make intelligent choices concerning the world around you. Studying chemistry teaches you to solve problems and communicate with others in an organized and logical manner. These skills will be helpful in college and throughout your career.

What is chemistry? One dictionary gives this definition: “**Chemistry** is the science of the composition, structure, properties, and reactions of matter, especially of atomic and molecular systems.” A somewhat simpler definition is “Chemistry is the science dealing with the composition of *matter* and the changes in composition that matter undergoes.” Neither of these definitions is entirely adequate. Chemistry and physics form a fundamental branch of knowledge. Chemistry is also closely related to biology, not only because living organisms are made of material substances but also because life itself is essentially a complicated system of interrelated chemical processes.

The scope of chemistry is extremely broad. It includes the whole universe and everything, animate and inanimate, in it. Chemistry is concerned with the composition and changes in the composition of matter and also with the energy and energy changes associated with matter. Through chemistry we seek to learn and to understand the general principles that govern the behavior of all matter.

The chemist, like other scientists, observes nature and attempts to understand its secrets: What makes a tulip red? Why is sugar sweet? What is occurring when iron rusts? Why is carbon monoxide poisonous? Problems such as these—some of which have been solved, some of which are still to be solved—are all part of what we call chemistry.

A chemist may interpret natural phenomena, devise experiments that reveal the composition and structure of complex substances, study methods for improving natural processes, or synthesize substances. Ultimately, the efforts of successful chemists advance the frontiers of knowledge and at the same time contribute to the well-being of humanity.

### Thinking Like a Chemist

Chemists take a special view of things in order to understand the nature of the chemical changes taking place. Chemists “look inside” everyday objects to see how the basic components are behaving. To understand this approach, let's consider a lake. When we view the lake from a distance, we get an overall picture of the water and shoreline. This overall view is called the *macroscopic* picture.

As we approach the lake we begin to see more details—rocks, sandy beach, plants submerged in the water, and aquatic life. We get more and more curious. What makes the rocks and sand? What kind of organisms live in the water? How do plants survive underwater?

What lies hidden in the water? We can use a microscope to learn the answers to some of these questions. Within the water and the plants, we can see single cells and inside them organelles working to keep the organisms alive. For answers to other questions, we need to go even further inside the lake. A drop of lake water can itself become a mysterious and fascinating *microscopic* picture full of molecules and motion. (FIGURE 1.1) A chemist



A health care professional needs to understand chemistry in order to administer the correct dose of medication.



**FIGURE 1.1** Inside a drop of lake water we find water molecules and some dissolved substances.

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