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Chemistry

Principles and Reactions

Eighth Edition

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To Jim, Joe, and Regina

They also serve who only stand and wait.
—John Milton
On His Blindness

Brief Contents

Contents

Preface

It is always difficult for an author to praise the virtues of one's own book. I could tell the instructors that the book is so inspiring that students will be turned on to chemistry with little or no effort on the instructor's part. I doubt you would believe that. I could also tell you that the text is so clearly written, so attuned to the students in the twenty-first century that your students will learn chemistry with little or no effort on their part. You certainly would not believe that. I can tell you that the two goals in writing this edition have been to make it as clear and as interesting as possible. I hope you believe that, because it is true.

Today's freshmen are quite different from those of a few years ago. Text messaging and Twitter™ have strongly influenced sentence length and structure. In current writing and conversation, short sentences or sentence fragments convey straight-to-the-point information. Multimedia presentations are a way of life. This edition, like the seventh, is written to be fully in tune with today's technology and speech.

Why Write a Short Book?

Rising tuition costs, depleted forests, and students' aching backs have kept me steadfast in my belief that it should be possible to cover a text completely (or at least *almost* completely) in a two-semester course. The students (and their parents) justifiably do not want to pay for 1000-page books with material that is never discussed in the courses taught with those texts.

The common perception is that a short book is a low-level book. I believe, however, that treating general concepts in a concise way can be done without sacrificing depth, rigor, or clarity. The criterion for including material continues to be its importance and relevance to the student, not its difficulty. To achieve this, the following guidelines are used.

1. Eliminate repetition and duplication wherever possible. Like its earlier editions, this text uses
   - Only one method for balancing redox reactions, the half-equation method introduced in Chapter 17.
   - Only one way of working gas-law problems, using the ideal gas law in all cases (Chapter 5).
   - Only one way of calculating ΔH (Chapter 8), using enthalpies of formation.
   - Only one equilibrium constant for gas-phase reactions (Chapter 12), the thermodynamic constant K, often referred to as K_p. This simplifies not only the treatment of gaseous equilibrium but also the discussion of reaction spontaneity (Chapter 16) and electrochemistry (Chapter 17).
2. Relegate to the Appendices or Beyond the Classroom essays topics ordinarily covered in longer texts. Items in this category include
   - MO (molecular orbital) theory (Appendix 4). Experience has shown (and continues to show) that although this approach is important to chemical bonding, most general chemistry students do not understand it but only memorize the principles discussed in the classroom.
   - Nomenclature of organic compounds. This material is of little value in a beginning course and is better left to a course in organic chemistry.
   - Qualitative analysis. This is summarized in a few pages in an essay in Chapter 15 in the Beyond the Classroom section. An extended discussion of the qualitative scheme and the chemistry behind it belongs in a laboratory manual, not a textbook.
   - Biochemistry. This material is traditionally covered in the last chapter of general chemistry texts. Although there are several biochemical topics included in the text (among them a discussion of heme in Chapter 19 and

carotenoids in Chapter 6), an entire chapter is not devoted to biochemistry. Interesting as this material is, it requires a background in organic chemistry that first-year students lack.

3. Avoid superfluous asides, applications to the real world, or stories about scientists in the exposition of principles. There are many applications incorporated in the context of problems and some of the exposition of general principles. In general, however, a bare-bones approach is used. Students can easily be distracted by interesting but peripheral tidbits while they are striving hard to understand the core concepts. Favorite real-world applications and personal stories about scientists are in separate sections, Beyond the Classroom and Chemistry: The Human Side. Students say that they read these two sections first and that these are the parts of the book that "we really enjoy the most." (Talk about faint praise!) They do admit to enjoying the marginal notes too.

What Changes Have Been Made?

The eighth edition has not been as radically changed as the seventh. I talked to students, instructors, and TAs and listened to suggestions and complaints.

While all the changes made to the seventh edition were enthusiastically received, there were areas where making small changes would make them better. For the eighth edition, the following changes were made:

- The Example format has been revised, so that the strategy, analysis, and solution follow each part of the example. The most common comment was: "Show me first how to do part (a) before asking me about part (b)."
- More flowcharts have been added. There was unanimous support and requests for more of them. We revised some of the existing ones and added a few more.
- The discussion of balancing redox equations has been moved from Chapter 4 to Chapter 17. Instructors comment that they have had to reintroduce redox equations in Chapter 17 and treat it like new material. Students and TAs both agree that Chapter 4 is a dense and heavy chapter. Thus, redox reactions are treated in Chapter 4 only as far as stoichiometric calculations are involved. Balanced equations are provided for these reactions.

Detailed List of Changes by Chapter

Global Changes
- Changes in about 25% of the topical end-of-chapter problems
- Almost all of the summary problems have either been revised or are completely new to this edition
- Revised artwork with enhanced labeling and several new photos
- Almost all of the chapter opening art is new

Chapter 1
- Redrawn flowchart for matter classification
- New Examples 1.3 and 1.6

Chapter 2
- Redrawn Figure 2.5 (Rutherford Experiment)
- New Examples 2.1 and 2.5
- New Beyond the Classroom essay on the origin of some elements' names
- Redrawn flowchart for naming molecular compounds

Chapter 3
- New Examples 3.1 (b), 3.5, 3.7, and 3.11

Chapter 4
- Redrawn Figure 4.1
- New Example 4.5
- Revised discussion of redox reactions excluding balancing of half and complete reactions
- New flowchart for determining oxidation number
- New figure summarizing differences between oxidation and reduction
- New Beyond the Classroom essay on antacids

Chapter 5
- New Figure 5.6
- New Examples 5.2 and 5.4 (a) and (b)
- Discussion of the relation of time and molar mass to the rate of effusion

continued

Chapter 6
- New Example 6.1
- New discussion on electron capacities for principal levels and subshells
- New table summarizing electron capacities in principal levels and subshells

Chapter 7
- New Figure 7.5

Chapter 8
- Replaced Figure 8.10 with a new table

Chapter 9
- Figure 9.3 redrawn

Chapter 10
- New Examples 10.9 and 10.10
- Figure 10.14 redrawn

Chapter 11
- New Figure 11.4
- Example 11.3 redone

Chapter 12
- Examples 12.1 and 12.6 rewritten

Chapter 13
- New Example 13.3
- Examples 13.2 and 13.9 rewritten
- Revised Figure 13.14

Chapter 14
- Example 14.3 rewritten

Chapter 15
- Example 15.3 rewritten
- Example 15.1 reclassified as nongraded
- Examples 15.8 and 15.9 reclassified as graded

Chapter 16
- Example 16.2 rewritten

Chapter 17
- New Section 17.1 on balancing redox half and complete reactions
- Review of oxidation, reduction, oxidizing agents, and reducing agents
- New schematic on balancing half-reactions
- New Examples 17.1 and 17.2

Chapter 18
- New Table 18.1—summary of different modes of radioactive decay
- New paragraph about SPECT (single proton emission computer tomography) scans

Chapters 19–23
No changes

Alternate Editions

***Chemistry: Principles and Reactions*, Eighth Edition Hybrid Version with Access (24 months) to OWLv2 with MindTap Reader**

ISBN: 978-1-305-08215-1

This briefer, paperbound version of *Chemistry: Principles and Reactions*, Eighth Edition does not contain the end-of-chapter problems, which can be assigned in OWLv2, the online homework and learning system for this book. Access to OWLv2 and the MindTap Reader eBook is included with the Hybrid version. The MindTap Reader is the full version of the text, with all end-of-chapter questions and problem sets.

Supporting Materials

Please visit **http://www.cengage.com/chemistry/masterton/CPAR8e** for information about student and instructor resources for this text, including custom versions and laboratory manuals.

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Many people worked on the editorial and production team for this text. They took pages of manuscript, rough ideas, crude sketches, and long wish lists and put them together to create this edition. They prodded, cajoled, and set impossible deadlines. They are:

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Maureen Rosener, Product Manager
Lisa Lockwood, Product Manager
Peter McGahey, Managing Developer
Elizabeth Woods, Associate Content Developer
Karolina Kiwak, Product Assistant
Lisa Weber, Media Developer
Brendan Killion, Media Developer
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Cecile N. Hurley
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To the Student

You've probably already heard a lot about your general chemistry course. Many think it is more difficult than other courses. There may be some justification for that opinion. Besides having its very own specialized vocabulary, chemistry is a quantitative science—which means that you need mathematics as a tool to help you understand the concepts. As a result, you will probably receive a lot of advice from your instructor, teaching assistant, and fellow students about how to study chemistry. We would, however, like to acquaint you with some of the learning tools in this text. They are described in the pages that follow.

Learning Tools in *Chemistry: Principles and Reactions,* Eighth Edition

Examples

In a typical chapter, you will find ten or more examples each designed to illustrate a particular principle. These examples are either general (green bars), graded (purple bars), or conceptual (blue bars). These have answers, screened in color. They are presented in a two-column format. Most of them contain three parts:

- **Analysis**, which lists
  1. The information given.
  2. The information implied—information not directly stated in the problem but data that you can find elsewhere.
  3. What is asked for.
- **Strategy**

  This part gives you a plan to follow in solving the problem. It may lead you through a schematic pathway or remind you of conversion factors you have to consider or suggest equations that are useful.
- **Solution**

  This portion shows in a stepwise manner how the strategy given is implemented.
- Many of the examples end with a section called **End Points.** These are either checks on the reasonableness of your answer or relevant information obtained from the problem.

You should find it helpful to get into the habit of working all problems this way.

EXAMPLE

Calculate the wavelength in nanometers of the line in the Balmer series that results from the transition $\mathbf{n} = 4$ to $\mathbf{n} = 2$.

ANALYSIS	
Information given:	$\mathbf{n} = 2$; $\mathbf{n} = 4$
Information implied:	speed of light (2.998×10^{8} m/s) Rydberg constant (2.180×10^{-18} J) Planck constant (6.626×10^{-34} J · s)
Asked for:	wavelength in nm

continued

STRATEGY

1. Substitute into Equation 6.4 to find the frequency due to the transition.

$$\nu = \frac{R_H}{h}\left(\frac{1}{\mathbf{n}_{lo}{}^2} - \frac{1}{\mathbf{n}_{hi}{}^2}\right)$$

Use the lower value for **n** as $\mathbf{n}_{lo}$ and the higher value for $\mathbf{n}_{hi}$.

2. Use Equation 6.1 to find the wavelength in meters and then convert to nanometers.

SOLUTION

1. Frequency

$$\nu = \frac{2.180 \times 10^{-18}\ \text{J}}{6.626 \times 10^{-34}\ \text{J} \cdot \text{s}}\left(\frac{1}{(2)^2} - \frac{1}{(4)^2}\right) = 6.169 \times 10^{14}\ \text{s}^{-1}$$

2. Wavelength

$$\lambda = \frac{2.998 \times 10^{8}\ \text{m/s}}{6.169 \times 10^{14}\ \text{s}^{-1}} \times \frac{1\ \text{nm}}{1 \times 10^{-9}\ \text{m}} = 486.0\ \text{nm}$$

END POINT

Compare this value with that listed in Table 6.2 for the second line of the Balmer series.

Graded Examples

Throughout the text, you will encounter special *graded* examples. Note that they are the problems with the purple bars. A typical graded example looks like the following:

EXAMPLE GRADED

For the reaction

$$\text{A} + 2\text{B} \rightarrow: \text{C}$$

determine

(a) the number of moles of A required to react with 5.0 mol of B.

(b) the number of grams of A required to react with 5.0 g of B.

(c) the volume of a 0.50 *M* solution of A required to react with 5.0 g of B.

(d) the volume of a 0.50 *M* solution of A required to react with 25 mL of a solution that has a density of 1.2 g/mL and contains 32% by mass of B.

There are two advantages to working a graded example:

1. By working parts (a) through (d) in succession, you can see how many different ways there are to ask a question about mass relations in a reaction. That should cushion the shock should you see only part (d) in an exam.
2. The parts of the graded example do not just progress from an easy mass relations question to a more difficult one. The value of the graded example is that the last question *assumes the ability to answer the earlier ones*. You may be able to answer parts (a) and (b) with a limited understanding of the material, but to answer part (d) you need to have mastered the material.

Use the graded example as you review for exams. Try to skip the earlier parts [in this case (a), (b) and (c)] and go directly to the last part (d). If you can solve (d), you do not need to try (a), (b), and (c); you know how to do them. If you can't, then try (c) to see where you may have a problem. If you can't do (c), then try (b). As a last resort, start at (a) and work your way back through (d).

Marginal Notes

Sprinkled throughout the text are a number of short notes in the margin. Many of these are of the "now, hear this" variety, others are mnemonics, and still others make points that we forgot to put in the text. (These were contributed by your fellow students.) Some—probably fewer than we think—are supposed to be humorous.

Chemistry: The Human Side

Throughout the text, short biographies of some of the pioneers of chemistry appear in sections with this heading. They emphasize not only the accomplishments of these individuals but also their personalities.

Chemistry: Beyond the Classroom

Each chapter contains a Beyond the Classroom feature. It is a self-contained essay that illustrates a current example either of chemistry in use in the world or an area of chemical research. It does not intrude into the explanation of the concepts, so it won't distract you. But we promise that those essays—if you read them—will make you more scientifically literate.

Chapter Highlights

At the end of each chapter, you will find a brief review of its concepts. A review is always helpful not only to refresh yourself about past material but also to organize your time and notes when preparing for an examination. The chapter highlights include

- The ***Key Terms*** in the chapter. If a particular term is unfamiliar, refer to the index at the back of the book. You will find the term in the glossary that is incorporated in the index and also the pages in the text where it appears (if you need more explanation).
- The ***Key Concepts*** and ***Key Equations*** introduced in the chapter. These are indexed to the corresponding examples and end-of-chapter problems. End-of-chapter problems available on OWLv2 are also cross-referenced. If you have trouble working a particular problem here, it may help to go back and reread the example that covers the same concept.

Summary Problem

Each chapter is summarized by a multistep problem that covers all or nearly all of the key concepts in the chapter. You can test your understanding of the chapter by working this problem. A major advantage of the summary problems is that they tie together many different ideas, showing how they correlate with one another. An experienced general chemistry professor always tells his class, "If you can answer the summary problem without help, you are ready for a test on its chapter."

Questions and Answers

At the end of each chapter is a set of questions and problems that your instructor may assign for homework. They are also helpful in testing the depth of your knowledge about the chapter. These sets include

- Conceptual problems that test your understanding of principles. A calculator is not (or should not be) necessary to answer these questions.
- Questions that test your knowledge of the specialized vocabulary that chemists use (e.g., write the names of formulas, write the chemical equation for a reaction that is described).
- Quantitative problems that require a calculator and some algebraic manipulations.

Classified problems start the set and are grouped by type under a particular heading that indicates the section and/or topic from the chapter that they address. The classified problems occur in matched pairs, so the second member illustrates the same principle as the first. This allows you more than one opportunity to test yourself. The second problem (whose number is even) is answered in Appendix 5. If your instructor assigns the odd problems without answers for homework, wait until the problem solution is discussed and solve the even problem to satisfy yourself that you understand how to solve the problem of that type.

Each chapter also contains a smaller number of **Unclassified** problems, which may involve more than one concept, including, perhaps, topics from a preceding chapter.

The section of **Challenge** problems presents problems that may require extra skill and/or insight and effort. They are all answered in Appendix 5.

Even-numbered questions and Challenge Problems answered in Appendix 5 have fully worked solutions available in the *Student Solutions Manual*. Please visit **http://www.cengage.com/chemistry/masterton/CPAR8e** for information about the *Student Solutions Manual*.

Appendices

The appendices at the end of the book provide not only the answers to the even-numbered problems but also additional materials you may find useful. Among them are

- Appendix 1, which includes a review of SI base units as well as tables of thermodynamic data and equilibrium constants.
- Appendix 3, which contains a mathematical review touching on just about all the mathematics you need for general chemistry. Exponential notation and logarithms (natural and base 10) are emphasized.

Other Resources to Help You Pass Your General Chemistry Course

Besides the textbook, several other resources are available to help you study and master general chemistry concepts. Please visit **http://www.cengage.com/chemistry/masterton/CPAR8e** for information about student resources for this text, including custom versions and laboratory manuals.