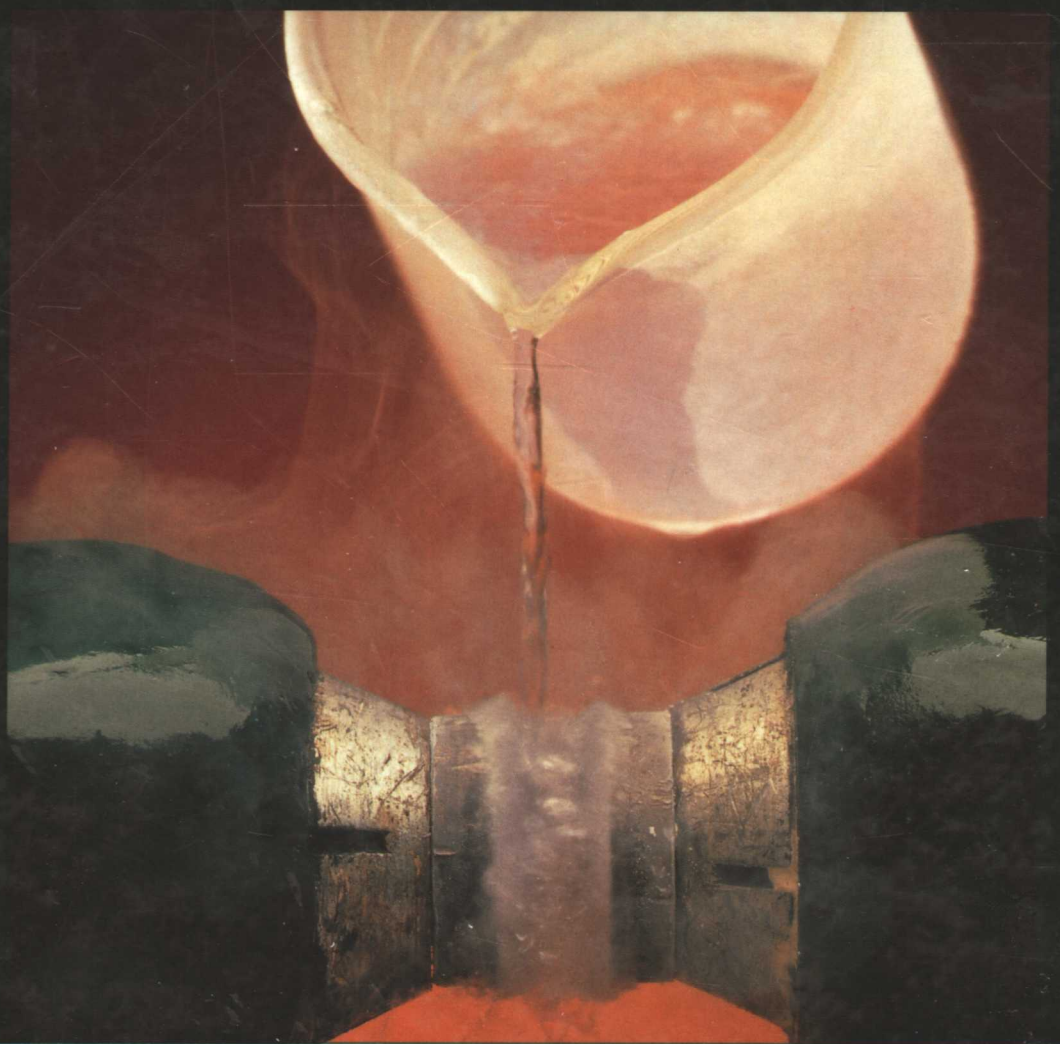
# GENERAL CHEMISTRY

## Principles & Modern Applications



SIXTH EDITION

PETRUCCI • HARWOOD

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## Principles and Modern Applications

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MACMILLAN PUBLISHING COMPANY New York

MAXWELL MACMILLAN CANADA Toronto

Editor: Paul F. Corey
Development Editor: Madalyn Stone
Production Supervisor: Elisabeth H. Belfer
Production Manager: Nicholas Sklitsis
Text Designer: Hudson River Studio
Cover Designer: Patricia Smythe
Cover Photograph: © Richard Megna/Fundamental Photographs
Photo Researchers: Yvonne Gerin and Ray Segal
Illustrations: Hudson River Studio

This book was set in Times Roman and Helvetica by York Graphic Services, Inc., printed and bound by R. R. Donnelley & Sons Company. The cover was printed by Lehigh Press.



Macmillan Publishing Company
866 Third Avenue, New York, New York 10022

Macmillan Publishing Company is part of the Maxwell Communication Group of Companies.

Maxwell Macmillan Canada, Inc.
1200 Eglinton Avenue East
Suite 200
Don Mills, Ontario M3C 3N1

Library of Congress Cataloging-in-Publication Data

Petrucci, Ralph H.
General chemistry : principles and modern applications / Ralph H. Petrucci, William S. Harwood. — 6th ed.
p. cm.
Includes index.
ISBN 0-02-394931-7
1. Chemistry. I. Harwood, William S. II. Title.
QD31.2.P48 1993
540—dc20 92-13854
CIP

Printing: 2 3 4 5 6 7 8 Year: 3 4 5 6 7 8 9 0 1 2

# GENERAL CHEMISTRY

## Principles and Modern Applications

# PREFACE

We are aware that most general chemistry students have career interests, not in chemistry, but in biology, medicine, engineering, and environmental and agricultural sciences, to name but a few. We also know that general chemistry will be the only college chemistry course for many students and their only opportunity to learn some practical applications of chemistry. We have designed this text for these "typical" students.

Students of this text probably have studied some chemistry previously, but those with no prior background will find that the early chapters develop fundamental concepts from the most elementary of ideas. Students who do plan to become professional chemists will also find opportunities in the text to pursue their special interests.

We think that the typical student needs help in identifying and applying principles and in visualizing their physical significance. The pedagogical features of this text are designed to provide this help, but at the same time we hope the text serves to sharpen student skills in problem solving and critical thinking. Throughout, we have attempted to strike the proper balances between principles and applications, qualitative and quantitative discussions, and rigor and simplification.

## Organizational Changes

A major organizational change in this edition is in the treatment of descriptive chemistry. In the fifth edition, one long chapter placed in the middle of the book presented an introduction to the descriptive chemistry of the first 20 elements. The remaining descriptive chapters came at the end of the book. In this edition a much shorter chapter dealing with the atmospheric gases and hydrogen is placed earlier in the text (Chapter 8), and again the remaining descriptive chapters come toward the end of the text.

The early descriptive chapter follows the opening series of chapters that deal with the fundamentals of chemistry and precedes the several chapters that concern atomic and molecular structure, liquids, solids, etc. This early descriptive chapter serves,

in part, to show how previously learned principles can be applied to descriptive topics and, in part, to establish the need for additional principles yet to come.

In addition to the new Chapter 8, other changes in the treatment of descriptive chemistry include moving the discussions of extractive metallurgy and the Group 2B metals from the chapter on main-group metals (Chapter 22) to the one on transition elements (Chapter 24). In Chapter 24 various metallurgical topics are taken up together early in the chapter. As in the fifth edition, many descriptive topics are interwoven into chapters throughout the text.

Other organizational changes involve the addition of a few topics and the deletion, reorganization, or relocation of others. For example, an introduction to the periodic table has been moved to an earlier position in Chapter 3. The concept of net ionic equations has been moved from Chapter 4 (Chemical Reactions) to Chapter 5 (Introduction to Reactions in Aqueous Solution). Heats of reaction and calorimetry have been moved to an earlier location in the thermochemistry chapter (Chapter 7). A section has been added at the end of Chapter 10 to apply the periodic table and atomic properties to a discussion of several periodic trends among elements and compounds. Bond energies and the energetics of ionic bonding have been moved to the end of the first chapter on chemical bonding (Chapter 11) to allow for a more rapid development of ideas concerning covalent Lewis structures. The discussion of molecular orbital theory in the second chapter on bonding (Chapter 12) has been shortened and simplified. The separate discussions of qualitative analysis in Chapters 5 and 19 of the fifth edition have been combined into a single section in Chapter 19. The discussions of equivalent weights in relation to acid–base reactions (Chapter 18) and oxidation–reduction reactions (Chapter 21) have been deleted in this edition.

## Special Features

The text contains a number of pedagogical features whose purposes are as follows.

*Important Expressions.* So that students may find them more readily, the most significant equations and expressions are highlighted with a yellow panel. Instructors are, of course, free to add to this list.

*Summary/Key Terms/Glossary.* Each chapter concludes with a comprehensive verbal Summary of important concepts and factual information, followed by a list of Key Terms. These terms appear in boldface type in the text and are also defined again in the Glossary (Appendix E). Students can use Key Terms lists and the Glossary to help them master the terminology of general chemistry.

*Are You Wondering . . .* In an attempt to clarify matters that often puzzle students, occasional questions are posed and answered under this heading.These questions are cast in the form in which students often ask them. Some are designed to help students avoid common pitfalls; others to provide analogies or alternate explanations of a concept.

*In-Text Illustrative Examples.* In each chapter most concepts—especially those that students will be expected to apply in homework assignments and examinations—are illustrated with worked-out examples. Often a line drawing or photograph accompanies an example to help students visualize what is "going on" in the problem.

*Practice Examples.* In previous editions, in-text illustrative examples made reference to similar examples among the end-of-chapter exercises. In this edition, illustrative examples are accompanied by practice examples that give students im-

mediate practice in applying the principle(s) illustrated in the example. More important, though, is that in some instances students are required to carry the calculation a step further than in the illustrative example or to use an additional concept previously learned. In these instances students are usually given hints. The idea is to help bridge the gap between the simpler one-step Review Questions and the more comprehensive Exercises and Advanced Exercises at the ends of the chapters. Answers to all Practice Examples are given in Appendix F. Complete solutions are given in the Student Study Guide.

*Summarizing Examples.* Each chapter concludes with a multipart example, usually of a practical nature. These examples link various important problem types introduced in the chapter with each other and often with problem types of earlier chapters. In the fifth edition these summarizing examples were solved, but in the present edition a solution is only outlined and intermediate results and a final answer given. Students are expected to work out the details of the solution. Complete solutions are given in the Student Study Guide.

*End-of-Chapter Exercises.* Each chapter has three categories of exercises. Review Questions require straightforward application of principles introduced in the chapter, each usually involving a single concept. Exercises are grouped by subject matter and are of a broader nature than the Review Questions. The Advanced Exercises are not grouped by type. As expected, some of these are more difficult than those in the other sections, but some are "advanced" only in the sense that they pursue certain ideas further than is done in the text or introduce new ideas. Answers to most Review Questions and to those Exercises and Advanced Exercises designated by green numbers or letters are given in Appendix F.

*Focus On.* It is our belief that relevant applications should be an integral part of the text, that asides should be limited to marginal notes and occasional Are You Wondering features, and that interesting but less vital issues should follow the main text of a chapter. With this view in mind, we have concluded the text of each chapter with a short essay on a practical topic appropriate to the subject matter of the chapter. These essays, which may be considered optional reading, focus on an idea introduced in the chapter. For example, the feature in Chapter 4 (Chemical Reactions) concerns industrial chemistry, the one in the first bonding chapter (Chapter 11) describes the recently discovered fullerenes, and the one in Chapter 17 (Acids and Bases) deals with acid rain.

## Supplements

The Student Study Guide is organized around a set of learning objectives for each chapter and features brief discussions of these objectives, drill problems, self quizzes, and sample tests.

The laboratory manual Experiments in General Chemistry contains 37 experiments that parallel the text, including a final group of six experiments on qualitative cation analysis. There is an accompanying instructor's manual.

The Solutions Manual contains worked-out solutions to all the Review Questions and Exercises.

The Instructor's Manual offers alternative organizational schemes for the general chemistry course, notes and comments on each chapter, and worked-out solutions of the Advanced Exercises.

A Test Bank, in printed form or computerized, and a set of 125 full-color transparencies, selected from the text, are available to adopters.

## Acknowledgments

The following colleagues helped by reviewing manuscript and/or being available for consultation on various matters that arose during the preparation of this textbook: from Cal State/San Bernardino—Arlo Harris, Dennis Pederson, Kenneth Mantei, James Crum, John Tate, and Lee Kalbus; from U Maryland/College Park—Alfred C. Boyd, Jr., Howard DeVoe, (late) Glen Gordon, James Huheey, Alice Mignerey, and William Walters. WSH would also like to thank Thomas Flores for his assistance with library research. Both authors want to acknowledge a special debt of gratitude to Robert K. Wismer (Millersville University) who, in addition to his own efforts in producing many of the supplements to this text, commented extensively on the manuscript, read proof, and acted as a sounding board for many of the new features.

We are grateful to many people at Macmillan Publishing Company for their help and encouragement, starting with our editor Paul Corey. Madalyn Stone, our development editor, read the entire manuscript in the spirit of an eager student and offered many helpful suggestions. Her unflagging enthusiasm was greatly appreciated. Special thanks to Elisabeth Belfer, our production supervisor, who has managed to convert manuscript, cut pages, scribbled notes, rough sketches, and telephone conversations into a very attractive final product. All this under very stringent deadlines.

We are also grateful for the patience and encouragement of our wives, Ruth Petrucci and Diana Harwood. Without their love and support, this book would not have been possible.

We appreciate the significant contributions of those who commented on the fifth edition or reviewed manuscript chapters of this edition.

Robert Allendorfer
State University of New York @ Buffalo

Conrad H. Bergo
East Stroudsburg University

Muriel B. Bishop
Clemson University

Bruce E. Cleare
Tallahassee Community College

H. Lawrence Clever
Emory University

Frank Dalton
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The United States Naval Academy

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Colgate University

Wayne L. Smith
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**W. S. H.**

# TO THE STUDENT

To some students chemistry is an almost magical art. Chemists seem to produce new compounds much as a magician pulls a rabbit out of a hat. In this course of study you will learn how these feats can be accomplished. As with magic, there are both mystery and excitement to chemistry. No one knows all the answers and many aspects of our science are not well understood. New materials, new methods, and, most important, new ideas are needed in all areas of chemistry.

In studying chemistry you will discover some of the ideas and concepts chemists use to understand and direct chemical changes. Some students find it possible to pursue a course in chemistry just by memorizing facts and mathematical equations, but we urge you not to settle for this approach. Demand of yourself, this text, and your instructors explanations of the why and how of chemistry. Seek the concepts behind the facts and equations.

Of course, skill in algebra and the assimilation of facts are important, but imagination is the key to mastering chemistry. At the heart of most chemistry problems is perceiving a connection between an observation in the macroscopic world—the "real" world—and an imagined change in the microscopic world—the world of atoms, ions, and molecules. Once you perceive this connection, finding the solution to a problem should become much simpler.

This book contains a number of special features designed to help you gain an understanding of the concepts and methods used by chemists. Read about these features in the Preface and take full advantage of them as you proceed through the text.

One study idea that you may find useful is to make a study sheet containing information on important concepts and methods. Include on the sheet information from your lecture notes as well as from the text. With the study sheet at hand, practice solving problems similar to those assigned as homework. You should attempt problems for which answers are not given as well as those that are answered in the text. This will allow you to simulate an exam situation where you do not have access to answers. Encourage a study partner also to solve some unanswered problems. If you both get the same answer, independently, then the answer is probably correct. If your answers differ, discuss the situation and determine which of you, if either, is correct. This type of discussion is an excellent stimulus to learning new material.

**WARNING:** Many of the compounds described or pictured in this text are hazardous, as are many of the chemical reactions. The reader should not attempt any experiment pictured or implied in the text. Experiments should be performed only in authorized laboratory settings and under adequate supervision.

# BRIEF CONTENTS

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