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Chemistry Connections

SECOND EDITION

The Chemical Basis of Everyday Phenomena

Kerry K. Karukstis and Gerald R. Van Hecke

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The Complementary Science Series is an introductory, interdisciplinary, and relatively inexpensive series of paperbacks for science enthusiasts. These titles cover topics that are particularly appropriate for self-study although they are often used as complementary texts to supplement standard discussions in textbooks. They are deliberately unburdened by excessive pedagogy, which is distracting to many readers, and avoid the often plodding treatment in introductory texts. The series was conceived to fill the gaps in the literature between conventional textbooks and monographs by providing real science at an accessible level, with minimal prerequisites so that students at all stages can have expert insight into important and foundational aspects of current scientific thinking.

Many of these titles have strong interdisciplinary appeal, such as a chemist writing about applications of biology to physics, or vice versa, and all have a place on the bookshelves of literate laypersons. Potential authors are invited to contact our editorial office at www.academicpressbooks.com.

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The important thing is not to stop questioning.
—Albert Einstein

To our parents

Preface(s)

SECOND EDITION

The very favorable response to *Chemistry Connections* encouraged us to prepare this expanded second edition. We have improved the collection of questions, particularly to enhance the number of applications in the area of organic chemistry. Furthermore, we have revised the organization of questions to assist instructors in selecting examples to coordinate with the principles and topics covered in their chemistry classes.

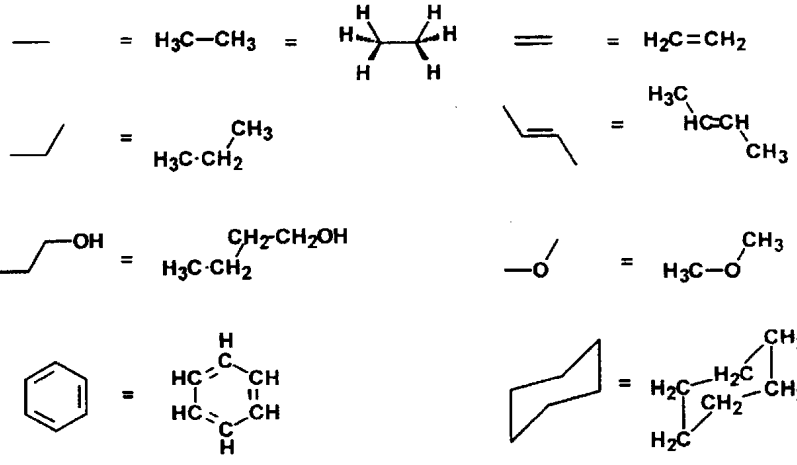
The new organization, photographs, and chapter headings will stream-line the connection with a range of general chemistry textbooks and courses. For the general reader, however, our intention is still to demonstrate the wide scope and significance of chemistry and the ever-present connection of the discipline to our daily lives.

Kerry K. Karukstis
Gerald R. Van Hecke

Conventions

The answers to many questions include chemical formulas shown in common drawing notation. For readers unfamiliar with such notation the examples below should help to interpret the figures. A line represents a chemical bond. The number of lines between two atoms represents the number of chemical bonds between the joined atoms. Unless stated otherwise, all lines join two carbon atoms. The junction of two lines implies the presence of a carbon atom, unless another atom is shown. Each carbon should have four lines drawn to it. Any missing line should be interpreted as a bond to a hydrogen atom. For example, a line that terminates should be viewed as a carbon bonded to three hydrogens and bonded to a fourth atom shown or implied. In this edition care has been taken to better illustrate the true three-dimensional structures that molecules represent. To this end, a solid wedge means the bond is coming out of the plane of the page, and a dashed

wedge implies the bond points below the printed page. See the drawings below for examples.



FIRST EDITION

Chemistry Connections: The Chemical Basis of Everyday Phenomena highlights the fundamental role of chemical principles in governing our everyday experiences and observations. This collection of contemporary real-world examples of chemistry in action is written in a question-and-answer format with presentations in both lay and technical terms of the chemical principles underlying numerous familiar phenomena and topical curiosities. Introductory college chemistry students and educators as well as laypersons with an inquisitiveness about the world around them will find the book an informative introduction to the context of chemistry in their lives.

Assessment of the Need for this Book

United States Education Secretary Richard W. Riley recently commented on the results of a national assessment of scientific literacy among U.S. high school graduates.[1] "We are confronted by a paradox of the first order. We Americans are fascinated by technology. Yet, at the same time, Americans remain profoundly ignorant."

Former National Science Foundation director Neal Lane concurs: "I have become especially conscious of the discrepancy between the public's interest in, even fascination with, science and its limited knowledge about scientific concepts and issues."[2] He further adds, "All scholarly fields—poetry or philosophy, architecture or agriculture—suffer from their separation from the public, although in the case of science, the separation may be more extreme. And yet science and the technology it spawns pervade the very structure of everyone's life...".

Perhaps no scientific field is less understood and appreciated by the public, and in particular by students, than chemistry. A general misunderstanding of the nature of chemistry and even the meaning of the word chemical pervades our society.

Students and the general public alike are further unaware of the broad scope of chemistry and the impact of the discipline on many fields. Conveying the importance and relevance of chemistry to our world is one of the greatest challenges facing chemists and chemical educators today.

The revitalization of chemistry education has received much recent attention and taken many forms. Modes of teaching, textbooks, laboratory instruction—all aspects of the chemistry curriculum have undergone scrutiny for reform. A recent National Science Foundation report, *Shaping the Future: New Expectations for Undergraduate Education in Science, Mathematics, Engineering, and Technology*[3] characterizes the nature of the most successful curricular and pedagogical improvements:

"A simple precis is that these improvements are attempting to nurture a sense of wonder among students about the natural world, to maintain students' active curiosity about this world while equipping them with tools to explore it and to learn." Indeed, a recent survey of college chemistry courses revealed findings that indicated an increased emphasis towards the presentation of chemical principles reflecting "the more 'relevant' chemistry of 'everyday living'."[4] These initiatives are based on the development of a curriculum that engages a broad base of students and that provides students with a familiar context for chemical concepts, stimulating their desire to explore further.

Approach Used in this Text

By what mechanism do chemistry textbooks and monographs demonstrate the *relevance* of chemistry? Most general chemistry texts include short features highlighting "real world" examples of the various chemical principles that are illustrated within each chapter. Some texts take a more revolutionary approach to promote the interest of students in chemistry by a text book structure that focuses on key household products (e.g., food, apparel) and technologies or industries (e.g., health, communications, transportation) as a means of introducing the chemical principles of a standard college curriculum. Other tradebooks are broad overviews of the global impact of chemistry on society, usually written in non-technical language.

In *Chemistry Connections* we have adopted a separate approach, collecting in one volume an assortment of provocative, topical questions that are raised by our everyday experiences and that are answered by the application of chemical principles.

The design of the book makes it compatible with any general chemistry text for students and educators or suitable as an independent book for any individual with a curiosity about the world around them. From the reader's viewpoint,

the pertinence of chemistry to each question ranges from straightforward examples to more intriguing applications. We chose the question-and-answer format to provide a motivating force to interest the reader to learn the necessary chemical principles to understand everyday phenomena. Explanations are provided in both lay and technical terms—an initial description to satisfy the curious reader, followed by a more in-depth account to underscore the chemical nature of the phenomenon. We expect that readers will also quickly appreciate that an interplay of several chemical principles is often needed to explain fully a real-world observation, a realization too often overlooked by the beginning student or casual readers. Each question is indexed according to key principles or terms to provide teachers with the flexibility to select pertinent examples for class discussion. To furnish readers with additional related information for further exploration, we chose to focus on references to Web sites. With today's increasing access to the Internet, these selections may be more readily available than many hardcopy references. We recognize the transient nature of the World Wide Web, however, and encourage the reader to use these sites as starting points for their own discovery of related electronic materials.

Kerry K. Karukstis
Gerald R. Van Hecke

References

[1] E. Woo, *Los Angeles Times,* May 3, 1997.

[2] *The Chronicle of Higher Education,* December 6, 1996, p. A84.

[3] Shaping the Future: New Expectations for Undergraduate Education in Science, Mathematics, Engineering, and Technology, Directorate for Education and Human Resources, 1996.

[4] H. L.Taft, *Journal of Chemical Education* 74, 595–599 (1997).

Contents

Chapter 1 ▶

Connections to Atomic Properties

1.1 Why Do Iodine and Barium Enhance CAT Scans?

The innovative and technological achievement of computerized axial tomography required a sophisticated understanding of physiology, mathematics, and radiology. A clear comprehension of chemical principles also contributes to the success of this diagnostic technique.

The Chemical Basics

The technique of computerized axial tomography (CAT) assists medical examiners in viewing the internal organs of the body. The technique has been widely used since its development in the 1970s by the British electrical engineer Sir Godfrey Hounsfield and the South African-born U.S. physicist Allen Cormack. These scientists won the Nobel Prize for Physiology or Medicine in 1979 for their contributions to the development of this diagnostic technique.[1]

In a CAT scan, cross-sectional images are generated using X-rays directed through the body using a rotating tube. X-rays not absorbed by the body reach a radiation detector where the signals are integrated to produce an image that assesses the density of tissues at various locations. X-rays are absorbed differentially — with denser objects such as bones absorbing extensively and soft tissues such as blood vessels absorbing relatively few X-rays. Thus bones appear as light areas on the image, soft tissues as dark regions.

What can one do to image specific soft tissues using X-rays? One must enhance the density of these regions to decrease the ability to transmit X-rays through the region. To aid in the creation of such images or CAT scans, *contrast media* are often ingested or injected into the body. Contrast medium fluids that are opaque (i.e., not transparent) to X-rays are known as *radiopaque media.* These

media highlight the areas of the body being scanned as a consequence of the inability of X-rays to penetrate these substances. Media containing barium or iodine meet these criteria. For imaging gastrointestinal tracts, barium-based media are orally ingested; for visualizing major blood vessels, iodinated contrast media are injected into the patient's veins using intravenous access.

The Chemical Details

Why are barium- and iodine-based materials selected for contrast media? The production of X-ray images depends on the differences between the X-ray absorbing power of various tissues. This difference in absorbing power is called *contrast* and is directly dependent on tissue density. To artificially enhance the ability of a soft tissue to absorb X-rays, the density of that tissue must be increased. The absorption by targeted soft tissue of aqueous solutions of barium sulfate and iodized organic compounds provides this added density through the heavy metal barium and the heavy nonmetal iodine.

KEY TERMS: X-ray contrast

References

[1] "Press release: The 1979 Nobel Prize in Physiology or Medicine." Nobelforsamlingen, Karolinska Institutet. The Nobel Assembly at the Karolinska Institute. 11 October 1979, http://www.nobel.se/medicine/laureates/1979/press.html

Related Web Sites

- "Computed Tomography." Radiological Society of North America, Inc. (RSNA) Center, Chicago, http://www.radiologyinfo.org/content/ct_of_the_body.htm

1.2 Why Does a Kitchen Gas Burner Glow Yellow When a Pot of Boiling Water Overflows?

A cook recognizes the tell-tale signs of an overflowing pot of boiling water—the characteristic hiss as the water hits the hot gas burner and evaporates and the familiar accompanying yellow glow. Chemistry on the atomic level is responsible for the brilliant yellow illumination.

The Chemical Basics

The yellow color imparted to a natural gas flame originates from the ignition of sodium atoms or ions. The common source of sodium is salt (sodium chlo-