Masterton Hurley

CHEMISTRY

Principles & Reactions

SECOND EDITION

CHEMISTRY

Principles and Reactions

Second Edition

William L. Masterton
University of Connecticut

Cecile N. Hurley
University of Connecticut

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To Loris and Jim

For being both buffer and catalyst

Preface

Our goal in writing the second edition of *Chemistry: Principles and Reactions* was to produce a book of about 700 pages which could reasonably be covered in its entirety in the mainstream year course in general chemistry. We wanted to achieve this without deleting any fundamental topics; beyond that, we were determined to include enough explanatory material and applications to make chemistry intelligible and interesting to the student. Somewhat to our surprise, we achieved our goal of brevity; this book contains 21 chapters with an honest page count of 679. Enthusiastic reviewers tell us that we have indeed written a user-friendly text covering all the basics. Naturally we agree with them, but you, and particularly your students, will be the final judge of how well this book is written.

CHANGES IN THE SECOND EDITION

To reduce the length of the text, we sought to eliminate repetition and duplication wherever possible. For example, the book contains

— one and only one method of balancing redox equations, the half-equation approach introduced in Chapter 4.
— one and only one equilibrium constant for gas-phase reactions (Chapter 12), the thermodynamic constant *K*, commonly referred to as K_p. This simplifies and clarifies not only the treatment of gaseous equilibrium, but also the discussion of reaction spontaneity (Chapter 16) and electrochemistry (Chapter 17).
— one and only one bonding model for complex ions (Chapter 15). This is the crystal-field model, the basis for all modern treatments of the structure of coordination compounds.

Nearly all of the topics covered in the typical general chemistry text are found in this book, with a couple of notable exceptions.

— **molecular orbitals** A great many people have suggested deleting this material from general chemistry texts; we did it. It is our feeling that MO theory simply doesn't come across to first year students; they don't have the background to appreciate its importance.
— **biochemistry,** traditionally covered in the last chapter of every general chemistry text. Fascinating as this material is, it requires an understanding of organic chemistry that few students have. Our last chapter (Chapter 21) is devoted to organic chemistry, with emphasis on practical applications such as synthetic polymers.

Several topics discussed at some length in our first edition have been condensed in this revision. These include:

— **atmospheric chemistry,** eliminated as a separate chapter. Several relevant topics in this area now appear as end-of-chapter perspectives (the greenhouse effect in Chapter 5, the ozone story in Chapter 11, acid rain in Chapter 12).

— **qualitative analysis,** reduced from one chapter to one section (Section 19.4) which is flexible enough to be covered whenever students start cation analysis in the laboratory.

— **descriptive inorganic chemistry,** used throughout the book to illustrate chemical principles, is covered formally in two chapters (Chapter 19 on metals, Chapter 20 on nonmetals). This book is short enough so that both of these chapters can easily be covered. To help you do that, we've rewritten all the descriptive material to make it easier to teach, more interesting and less encyclopedic.

We believe that the selective pruning just described has produced a text of manageable length that retains all the basic topics of general chemistry. However, opinions will differ on that matter; what seems peripheral to us may be basic to you. Consequently, we have arranged with our publisher to make available to your students, selected topics from our 1000-page first edition. Essentially, this amounts to custom publishing; the basic core package (this text) can be supplemented with material from the publisher. Your local Saunders representative can furnish further details.

ORGANIZATION

As you can see from the Table of Contents on p. xxi, the organization of this text is more or less conventional. A few features are worthy of comment.

— Chapter 4 (Reactions in Aqueous Solutions) shows students how to write, balance and apply net ionic equations for precipitation, acid-base, and redox reactions. It seems reasonable to introduce this fundamental material early; among other things it establishes a background for a meaningful first-semester laboratory. If you prefer, this material can be postponed until Chapter 10, where the physical properties of solutions are covered.

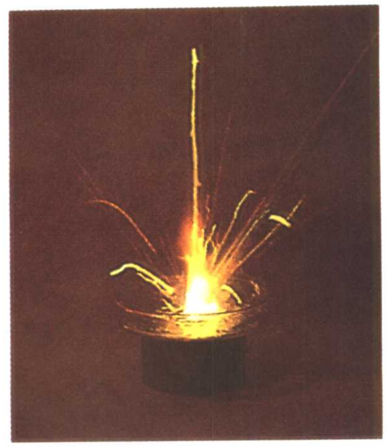
— the two factors that determine reaction feasibility, rate and equilibrium, are presented back-to-back in Chapters 11 and 12. This seems a logical starting point for the second half of the year course.

— a descriptive treatment of coordination chemistry (Chapter 15) is presented somewhat earlier than is customary. This is our subtle way of encouraging you to spend time on an area of inorganic chemistry that students find fascinating albeit challenging.

FEATURES

Returning to the theme of the opening paragraph, let us see how this book is designed to stimulate student interest in chemistry. First, and most important, brief discussions of current research have been integrated into the text; see, for example, the reference to "buckyball" on p. 238. Beyond that, there are:

— **end-of-chapter perspectives,** which apply chemical principles to the world around us. Several of these deal with the environment (Chaps. 5, 11, 12, 16, 18), others with nutrition (Chaps. 8, 19, 20). One that we strongly recommend discusses the production of maple syrup (Chap. 10; note particularly Figure 10.A).



— **chapter opening photographs and quotations,** chosen by CNH to show that chemistry is not as far removed from abstract art and literature as most people think.
— **historical boxes** that discuss the human qualities as well as the scientific accomplishments of some of the giants of chemistry, including G. N. Lewis (p. 169), J. Willard Gibbs (p. 442), and Marie Curie (p. 499).

The many learning aids incorporated into this text are discussed on p. xiii under the heading "To The Student." Three of these are new to this edition.

1. Each in-text Example includes a "Strategy" section outlining the reasoning behind the solution. This helps the student distinguish the "why" from the "how" of problem solving.
2. Each chapter ends with a "Highlights" section which includes key concepts, terms, and equations introduced in the chapter. The section closes with a Summary Problem designed to tie together all the major concepts.
3. Appendix 5 correlates and summarizes material on net ionic equations, spread over several chapters of the text. Typically, students have a great deal of trouble with this topic; we are sure this appendix will help.

ANCILLARY PACKAGE

A complete resource package has been prepared to enhance the student's learning and the professor's teaching of *Chemistry: Principles and Reactions,* 2/e.

Instructor's Manual by William L. Masterton. Included are lecture outlines and quizzes for discussion sections. Each chapter is accompanied by a list of references to appropriate demonstrations, emphasizing Volumes 1–4 of the Shakhashiri handbook and videotapes 1–3 (see below). Worked-out solutions are provided for all the end-of-chapter problems not answered in the text.

Study Guide/Workbook by Cecile N. Hurley. Worked examples and problem-solving techniques help the student understand the principles of general chemistry. Each chapter is outlined for the student with fill-in-the-blanks, and exercises and self-tests allow the students to gauge their mastery of the chapter.

Student Solutions Manual by John E. Bauman (University of Missouri). Detailed solutions to all the problems answered in the text, including the Challenge Problems.

Overhead Transparencies One hundred four-color figures from the text.

Test Bank and Computerized Test Bank Over 1000 multiple choice test bank questions reviewed by the text authors. Available in computerized versions for IBM and Macintosh computers.

Lecture Outline by Ronald O. Ragsdale (University of Utah). Organized to follow class lectures to free students from extensive note taking.

Chemical Principles in the Laboratory, 5/e, by Emil J. Slowinski, Wayne C. Wolsey and William L. Masterton. The industry's best-selling general chemistry laboratory manual includes 43 experiments, each with a pre-lab study assignment. An instructor's manual is also available.

Audiotape Lessons and Workbook, 2/e, by Bassam Shakhashiri, Rodney Schreiner and Phyllis Anderson Meyer (all of the University of Wisconsin–Madison). Enables students to learn chemistry at their own pace. Students listen to instructions on the tape and follow the examples in the workbook.

Shakhashiri Videotapes by Bassam Shakhashiri (University of Wisconsin–Madison). Fifty 3–5 minute classroom experiments.

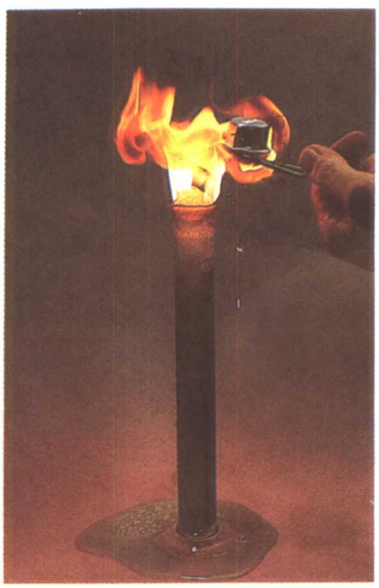
Videodisc and Barcode Manual contains all the Shakhashiri demonstrations and over 600 images drawn from various Saunders sources. Barcode manual allows easy access.

Periodic Table Videodisc: Reactions of the Elements by Alton J. Banks (Southwest Texas State University). Also published by JCE: Software. A visual compilation of information about chemical elements, their uses and their reactions with air, water, acids and bases. It is particularly useful as a way to demonstrate chemical reactions in a large lecture room.

Saunders Chemical Update Newsletters

ACKNOWLEDGMENTS

In this revision we have been guided by comments and suggestions from students and colleagues. We are indebted to the many reviewers who devoted so much time to this project, earning somewhat less than the minimum wage. These include:



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Many people at Saunders made major contributions to this book. **John Vondeling,** publisher, supported our efforts from the start, knowing full well that an innovative text such as this one is a risky investment. Perhaps the smartest move he made was to persuade **Mary Castellion,** a distinguished author in her own right, to help us develop the manuscript. Mary taught us a great deal about writing (really somewhat more than we wanted to know). **Elizabeth Rosato,** our developmental editor, used her knowledge of chemistry to do everything we asked of her, no matter how unreasonable. The greatest compliment we can pay Beth is to thank her for making the task of writing this book a (relatively) pleasant one.

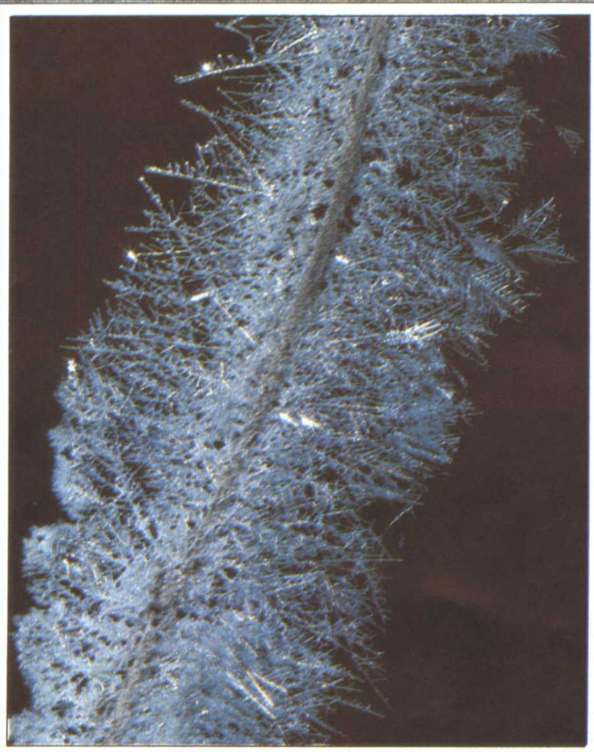
William L. Masterton
Cecile N. Hurley
Storrs, Connecticut
June 1992

To the Student

Over the next several months, you will probably receive a lot of advice from your instructor, teaching assistant, and fellow students about how to study chemistry. We hesitate to add our advice; experience as teachers and parents has taught us that students tend to do surprisingly well without it. We would, however, like to acquaint you with some of the learning tools in this text. They are described and illustrated in the pages that follow.

Chapter Opening Photograph and Quotation

Chosen by CNH to show that chemistry is not as far removed from abstract art and literature as most people think, these illustrate, in a somewhat abstract way, chemical reactions of one type or another. Each photograph is accompanied by a chemical equation and a page reference identifying where in the text the reaction is discussed.



YOAV LEVY/PHOTAKE NYC

$$Cu(s) + 2Ag^{+}(aq) \longrightarrow Cu^{2+}(aq) + 2Ag(s)$$

(See p. 491)

8
Thermochemistry

Some say the world will end
in fire,
Some say in ice.
From what I've tasted of
desire
I hold with those
who favour fire.

ROBERT FROST
Fire and Ice

Example 3.12 Ammonia used to make fertilizers for lawns and gardens is made by reacting nitrogen of the air with hydrogen. The balanced equation for the reaction is

$$3H_2(g) + N_2(g) \longrightarrow 2NH_3(g)$$

Determine

(a) the mass in grams of ammonia, NH_3, formed when 1.34 mol N_2 reacts.
(b) the mass in grams of N_2 required to form 1.00 kg NH_3.
(c) the mass in grams of H_2 required to react with 6.00 g N_2.

To go from moles of A to mass of A, use molar mass

Strategy In each case, you use the mole ratios given by the coefficients of the balanced equation to relate moles of one substance to moles of another. Beyond that, use molar mass to relate moles of one substance to mass in grams of that substance. Before starting, decide upon the path you will follow to go from the quantity given to that required, i.e.,

(a) $n_{N_2} \longrightarrow n_{NH_3} \longrightarrow$ mass of NH_3
(b) mass of $NH_3 \longrightarrow n_{NH_3} \longrightarrow n_{N_2} \longrightarrow$ mass of N_2
(c) mass of $N_2 \longrightarrow n_{N_2} \longrightarrow n_{H_2} \longrightarrow$ mass of H_2

To go from moles of A to moles of B, use the coefficients of the balanced equation

Conversions indicated by colored arrows involve mole ratios given by the coefficients of the balanced equation. The other conversions require only molar masses and are essentially identical to those carried out in Examples 3.4 and 3.5.

Solution

(a) $$\text{mass of } NH_3 = 1.34 \text{ mol } N_2 \times \frac{2 \text{ mol } NH_3}{1 \text{ mol } N_2} \times \frac{17.03 \text{ g } NH_3}{1 \text{ mol } NH_3} = 45.6 \text{ g } NH_3$$

(b) $$\text{mass of } N_2 = 1000 \text{ g } NH_3 \times \frac{1 \text{ mol } NH_3}{17.03 \text{ g } NH_3} \times \frac{1 \text{ mol } N_2}{2 \text{ mol } NH_3} \times \frac{28.02 \text{ g } N_2}{1 \text{ mol } N_2} = 823 \text{ g } N_2$$

(c) $$\text{mass of } H_2 = 6.00 \text{ g } N_2 \times \frac{1 \text{ mol } N_2}{28.02 \text{ g } N_2} \times \frac{3 \text{ mol } H_2}{1 \text{ mol } N_2} \times \frac{2.016 \text{ g } H_2}{1 \text{ mol } H_2} = 1.30 \text{ g } H_2$$

Examples

In a typical chapter, you will find 10 or more examples, each designed to illustrate a particular principle. These have answers, screened in yellow. More important, they contain a strategy statement which describes the reasoning behind the solution. You will find it helpful to get into the habit of working all problems this way. First, spend a few moments deciding how the problem should be solved. Then, and only then, set up the arithmetic to solve it.

Marginal Notes

Sprinkled throughout the text are a number of short notes that have been placed in the margin. Many of these are of the "now, hear this" variety; a few bring you up to date on current research in chemistry, in progress when the book was written. Some, probably fewer than we think, are humorous.

Chapter Highlights

At the end of each chapter, you will find a brief review of the material covered in that chapter. The "Chapter Highlights" include:

— the **key concepts** introduced in the chapter. These are indexed to the corresponding examples and end-of-chapter problems. If you have trouble working a particular problem, it may help to go back and re-read the example that covers the same concept.

— the **key equations** and **key terms** in the chapter. If a particular term is unfamiliar to you, refer to the index at the back of the book. You will find the term defined in a glossary incorporated into the index.

— a **summary problem,** covering all or nearly all of the key concepts in the chapter. You can test your understanding of the chapter by working this problem; you may wish to do this as part of your preparation for examinations. A major advantage of a summary problem is that it ties together many different ideas, showing how they correlate with one another.

CHAPTER HIGHLIGHTS

KEY CONCEPTS

1. *Convert between °F, °C, and K*
   (Example 1.1; Problems 5–8, 58)
2. *Determine the number of significant figures in a measured quantity*
   (Example 1.2; Problems 13, 14)
3. *Determine the number of significant figures in a calculated quantity*
   (Examples 1.3, 1.4; Problems 15–18)
4. *Use conversion factors to change the units of a measured quantity*
   (Examples 1.5, 1.6, 1.8; Problems 11, 12, 21–32, 43, 44, 59, 61)
5. *Relate density to mass and volume*
   (Example 1.7; Problems 35–42, 53–57, 60)

KEY EQUATIONS

$t_{°F} = 1.8t_{°C} + 32°$ $T_K = t_{°C} + 273.15$

KEY TERMS

boiling point	kilo-	—chemical
centi-	melting point	—extensive
compound	milli-	—intensive
conversion factor	mixture	—physical
density	nano-	significant figure
element	property	solution
joule		

SUMMARY PROBLEM

Potassium dichromate is a reddish-orange compound containing the three elements potassium, chromium, and oxygen. It has a density of 2.68 g/cm^3; its melting point is 398°C. At 20°C, its solubility is 12 g/100 g water; at 100°C, the solubility is 80 g/100 g water.

a. What are the symbols of the three elements present in potassium dichromate?
b. List the physical properties for potassium dichromate given above.
c. What is the volume of a sample of potassium dichromate weighing 32.349 g?
d. Express the density in pounds per cubic foot.
e. Express the melting point of potassium dichromate in °F and K.
f. How much water at 100°C is required to dissolve 88 g of potassium dichromate?
g. When the solution in (f) is cooled to 20°C, how much potassium dichromate remains in solution? How much crystallizes out?

Express all your answers to the correct number of significant figures; use the conversion factor approach throughout.

Answers

a. K, Cr, O
b. density, melting point, solubility
c. 12.1 cm^3 **d.** 167 lb/ft^3 **e.** 748°F; 671 K
f. 1.1×10^2 g **g.** 13 g, 75 g

Questions and Problems

At the end of each chapter is a set of questions/problems. Most of these are classified, that is, grouped by type under a particular heading. The classified problems are in matched pairs. The second member of each pair illustrates the same principle as the first; it is numbered in color and answered in Appendix 4. Your instructor may assign unanswered problems as homework. After these problems have been discussed, you should work the corresponding answered problems to make sure you know what's going on. Each chapter also contains a smaller number of unclassified and "challenge" problems. All of the challenge problems are answered in Appendix 4.

QUESTIONS & PROBLEMS

Symbols, Formulas, and Equations

1. Using information given in this chapter, write the chemical formula for

a. ammonia.
b. water.
c. methane.
d. hydrochloric acid.

2. Using the figures in this chapter, give the color and physical state at room temperature of

a. Cr_2O_3 **b.** CrO_3

3. Using the figures in the chapter, give the color, formula, and physical state of

a. anhydrous copper sulfate.
b. cobalt(II) chloride hexahydrate.

4. Using the figures in the chapter, give the color, formula, and physical state of

a. copper(II) sulfate pentahydrate.
b. cobalt(II) chloride tetrahydrate.

Atomic Theory and Laws

5. Who is the father of atomic theory? State in your own words the law of constant composition.

6. Who first stated the law of conservation of mass? State the law in its modern form.

7. Which of the three laws (if any) listed on p. 27 is illustrated by each of the following statements?

a. Lavoisier found that when mercury(II) oxide, HgO, decomposes, the total mass of mercury and oxygen formed equals the mass of mercury(II) oxide decomposed.

b. Analysis of the calcium carbonate, $CaCO_3$, found in the marble of Carrara, Italy, and in the stalactites of the Carlsbad Caverns of New Mexico gives the same value for the percent calcium.

c. The atom ratio of oxygen to hydrogen is twice as large in one compound as it is in another compound made up of the two elements.

d. Hydrogen occurs as a mixture of two isotopes, one of which is twice as heavy as the other.

8. Which of the three laws (if any) listed on p. 27 is illustrated by each of the following statements?

a. A cold pack has the same mass before and after the seal between the two compartments is broken.

b. It is highly improbable that the formula for carbon monoxide gas found in London, England, is $C_{1.1}O_{2.5}$.

c. The mass of phosphorus, P, combined with one gram of hydrogen, H, in the highly toxic gas phosphine, experiment, 3.56 g of magnesium ribbon is completely consumed in reacting with 7.00 g of oxygen to produce 5.93 g of magnesium oxide; some oxygen remains unreacted. In a second experiment, 2.50 g of magnesium ribbon reacts with 1.10 g of oxygen gas. This time, all the oxygen is consumed; some unreacted magnesium remains and 2.75 g of magnesium oxide is produced. Show that these results are consistent with the law of constant composition.

10. Mercury(II) oxide, a red powder, can be decomposed by heating to produce liquid mercury and oxygen gas. When a sample of this compound is decomposed, 3.87 g of oxygen and 48.43 g of mercury are produced. In a second experiment, 15.68 g of mercury is allowed to react with an excess of oxygen; 16.93 g of red mercury(II) oxide is produced. Show that these results are consistent with the law of constant composition.

Nuclear Symbols and Isotopes

11. Who discovered the electron? Describe the experiment that led to the deduction that electrons are negatively charged particles.

12. Who discovered the nucleus? Describe the experiment that led to this discovery.

13. Studies show that there is an inverse relationship between the selenium content of the blood and the incidence of breast cancer in women. $^{80}_{34}Se$ is the most abundant form of naturally occurring selenium. How many protons are there in an Se-80 atom? How many neutrons?

14. The eruption of Mount St. Helens in Washington state produced a considerable amount of a radioactive gas, radon-222. Write the nuclear symbol for this isotope of radon (Rn).

15. a. Do the symbols $^{57}_{26}Fe$ and $_{26}Fe$ have the same meaning?

b. Do the symbols $^{57}_{26}Fe$ and ^{57}Fe convey the same information?

16. Explain how the two isotopes of copper, Cu-63 and Cu-65, differ from each other. Write nuclear symbols for each isotope.

17. Lithium is an element that is used by physicians in the treatment of some mental disorders. Lithium-7 is one of its isotopes. How many

a. protons are in its nucleus?
b. neutrons are in its nucleus?
c. electrons are in a lithium atom?
d. neutrons, protons, and electrons are in the Li^+ ion formed from this isotope?

18. An isotope of iodine used in thyroid disorders is $^{131}_{53}I$. How many

Perspective

At the end of each chapter are essays that apply the chemical principles just learned to the world around us. Several of these essays deal with the environment (Chaps. 5, 11, 12, 16 and 18), others with nutrition (Chaps. 8, 19 and 20). One that we strongly recommend discusses the production of maple syrup (Chap. 10).

PERSPECTIVE • The Greenhouse Effect

This chapter has emphasized the common properties of different gases. Many properties, however, differ tremendously from one gas to another. One of these is the ability to absorb infrared radiation (heat). Among the major components of the atmosphere, only carbon dioxide and water vapor show this behavior. They absorb much of the infrared radiation given off by the warm earth. In this way, CO_2 and H_2O act as an insulating blanket to prevent heat from escaping into outer space; this is often referred to as the greenhouse effect.

Of the two gases, water vapor absorbs more infrared radiation than carbon dioxide because its concentration is higher. This property of water vapor accounts for the fact that the temperature drops less on nights when there is a heavy cloud cover. In desert regions, where there is very little water vapor, large variations between day and night temperatures are common.

Although the concentration of water vapor in the atmosphere varies greatly with location, it remains relatively constant over time. In contrast, the concentration of carbon dioxide has increased by more than 20% over the past century, due to human activities. Increased combustion of fossil fuels is mainly responsible. Every gram of fossil fuel burned releases about three grams of carbon dioxide into the atmosphere. Part of this CO_2 is used by plants in photosynthesis or is absorbed by the oceans, but at least half of it remains. Extensive land clearing, which reduces the amount of carbon dioxide consumed by photosynthesis, is also a factor in raising the CO_2 content of the atmosphere. This is one of the adverse effects of the destruction of tropical rain forests for agricultural purposes.

It has been estimated that, unless preventive action is taken, increasing CO_2 levels could raise the earth's temperature by 3°C over the next century. This could raise sea level by as much as 1 m, flooding many coastal areas, including much of the state of Florida. On a more optimistic note, an increase in CO_2 concentration would promote photosynthesis, perhaps increasing the world's food supply.

Recent studies show that average global temperatures have indeed increased over the past century, by about 0.5°C (1°F). Beyond that, the three years 1989, 1988, and 1987 were, in that order, the warmest on record. Nobody knows whether these data reflect increased concentrations of CO_2 and other greenhouse gases (Fig. 5.B) or statistical fluctuations. The general consensus among atmospheric scientists is that carbon dioxide emissions should be reduced to avoid a worst-case scenario. There are several ways to do this:

— raise fuel efficiency standards for automobiles
— impose a surtax on all carbon-containing fuels
— develop "clean" sources of energy, notably solar

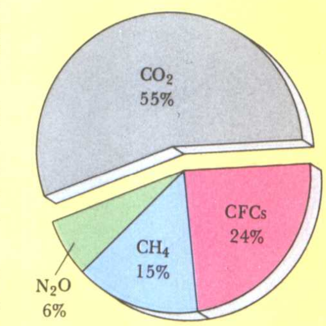
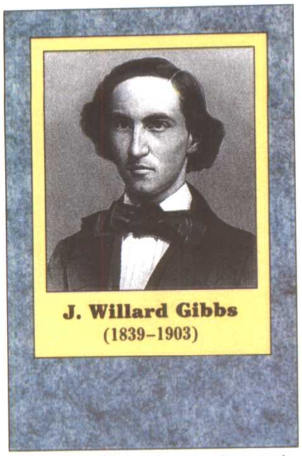


Figure 5.B
Contributions of different gases to global warming (1980–1990). Carbon dioxide is the major factor, but chlorofluorocarbons, such as CF_2Cl_2, make a contribution. These compounds are used in refrigerators, air conditioners, and, until recently, aerosol sprays.



J. Willard Gibbs (yearbook portrait as a graduating senior at Yale, Class of 1858.)

Two theoreticians working in the latter half of the nineteenth century changed the very nature of chemistry by deriving the mathematical laws that govern the behavior of matter undergoing physical or chemical change. One of these was James Clerk Maxwell, whose contributions to kinetic theory were discussed in Chapter 5. The other was J. Willard Gibbs, Professor of Mathematical Physics at Yale from 1871 until his death in 1903.

In 1876 Gibbs published the first portion of a remarkable paper in the *Transactions of the Connecticut Academy of Sciences* entitled "On the Equilibrium of Heterogeneous Substances." When the paper was completed in 1878 (it was 323 pages long), the foundation was laid for the science of chemical thermodynamics. Here, for the first time, the concept of free energy appeared. Included as well were the basic principles of chemical equilibrium (Chap. 12), phase equilibrium (Chap. 9), and the relations governing energy changes in electrical cells (Chap 16).

If Gibbs had never published another paper, this single contribution would have placed him among the greatest theoreticians in the history of science. Generations of experimental scientists have established their reputations by demonstrating in the laboratory the validity of the relationships that Gibbs derived at his desk. Many of these relationships were rediscovered by others; an example is the Gibbs-Helmholtz equation developed in 1882 by Helmholtz, a prestigious German physiologist and physicist who was completely unaware of Gibbs' work.

J. Willard Gibbs is often cited as an example of the "prophet without honor in his own country." His colleagues in New Haven and elsewhere in the United States seem not to have realized the significance of his work until late in his life. During his first 10 years as a professor at Yale he received no salary. In 1920, when he was first proposed for the Hall of Fame of Distinguished Americans at New York University, he received 9 votes out of a possible 100. Not until 1950 was he elected to that body. Even today the name of J. Willard Gibbs is generally unknown among educated Americans outside of those interested in the natural sciences.

Maxwell was perhaps the first to recognize Gibbs' genius

Admittedly, Gibbs himself was largely responsible for the fact that for many years his work did not attract the attention it deserved. He made little effort to publicize it; the *Transactions of the Connecticut Academy of Sciences* was hardly the leading scientific journal of its day. Gibbs was one of those rare individuals who seem to have no inner need for recognition by contemporaries. His satisfaction came from solving a problem in his mind; having done so, he was ready to proceed to other problems. His papers are not easy to read; he seldom cites examples to illustrate his abstract reasoning. Frequently, the implications of the laws that he derives are left for the readers to grasp on their own. One of his colleagues at Yale confessed many years later that none of the members of the Connecticut Academy of Sciences understood his paper on thermodynamics; as he put it, "We knew Gibbs and took his contributions on faith."

Historical Boxes

Several chapters contain boxed material on some of the giants of chemistry, including G. N. Lewis (p. 169), J. Willard Gibbs (p. 442) and Marie Curie (p. 499). The boxes focus on both the human qualities as well as the scientific accomplishments of the historical figure.

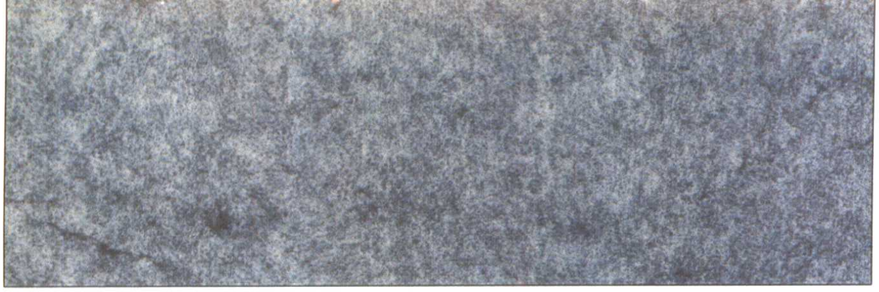
Appendices

In addition to Appendix 4, there are two other appendices designed to help you learn chemistry. These are

— Appendix 3, Review of Mathematics, which touches on just about all the mathematical techniques you will use in general chemistry. Exponential notation and logarithms (natural and base 10) are emphasized. There is also a short discussion of how to use your scientific calculator.

— Appendix 5, Net Ionic Equations. This topic is introduced in Chapter 4 and referred to in several later chapters (Chaps. 10, 13, 14, 17, 19, 20). The purpose of Appendix 5 is to tie all this material together. This should make you more proficient in writing, balancing, and interpreting chemical equations.

Contents Overview



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