CHEMICAL PRINCIPLES

AND THEIR BIOLOGICAL IMPLICATIONS

Raymond F. O'Connor

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PREFACE

One of the most profound commentaries on the twentieth century might very well be this phrase from a song by Bob Dylan—". . . and the times they are a changin'." Nowhere is change more apparent than in science and education. Traditional boundaries between branches of science have all but disappeared. A scientist may be a biomedical engineer, a mathematical biologist, or an astrochemist, to name a few.

The philosophy and content of lower-division science courses is also changing. For example, one currently fashionable approach to the teaching of biology is to examine the way in which pollutants in soil, air, and water interact with living organisms, and to show how ecological relationships are upset by mismanagement of natural resources. An argument in favor of such an approach is that students tend to develop a positive attitude toward a subject when it is relevant to their own lives, and this attitude enhances their learning.

If this approach can be justified for one course, why not for others? Why not design a chemistry course for those who are not science majors but who need or want to know something of the role of chemistry in life processes? Why not, for example, design a chemistry course that nurses, physical education majors, and biologically oriented students would find relevant? These students are usually required to take chemistry, yet all too often they derive little profit, and less pleasure, from the experience. They are alienated by the emphasis on measurement and stoichiometry, or they become frustrated by an attempt to compress general, organic, and biological chemistry into one short course. There is a real need for a new approach—one that links basic chemical concepts with biological phenomena. This book is an attempt to meet that need.

Chemical Principles and Their Biological Implications was designed to be used in an introductory chemistry course. It assumes no previous knowledge of chemistry, and requires only the most basic arithmetic skills. Although the emphasis is on chemical theory and its applications, the quantitative aspects of chemistry are not ignored. Measurements, gas law calculations, and stoichiometry are included, but they are not unduly emphasized. The chief distinction of this book lies in its approach and in the examples that have been chosen to illustrate the relationships between chemistry and biology. Material from organic and biological chemistry is included wherever it is relevant, and not treated as a separate topic. This integration is unique in a text for beginning students.

Each chapter is preceded by a set of learning objectives designed to point out concepts and ideas that are particularly important so that the student will be especially attentive to them as he reads. The questions that follow each chapter can help a student to test his comprehension of these ideas. Answers to approximately one-third of these questions are found in the back of the textbook. A complete set of answers is contained in the teacher's manual.

A manual of relevant laboratory exercises is also available. Each exercise is designed to complement a particular segment of the text by requiring the student to relate his observations to chemical theory. Materials from plant and animal sources, including living cells and tissues, are used in the majority of exercises. Convenient report sheets simplify the instructor's evaluation of student performance.

Chemical Principles reflects the conviction that a textbook should be more than just an outline that must be filled in and interpreted by the instructor. It should contain a clear and logical sequence of ideas, and should be written in a style that is pleasing and easy to read. Hopefully, this textbook fulfills these requirements.

It is with pleasure that I acknowledge the editorial contributions of Nancy Marcus; the critical reviews of Professor Leonard Druding, Rutgers University, and H. L. Retcofsky, Shadyside Hospital School of Nursing, Pittsburgh, Pennsylvania; and the fine artwork of Dale Johnson. I would also like to express my appreciation to George Thomsen and Ron Lewton of Hamilton Publishing Company for their untiring efforts, and to Paul E. Harris, Jr., for his faith in this project.

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ABOUT THE AUTHOR

Raymond F. O'Connor is associate professor of chemistry and life science at Santa Barbara City College, Santa Barbara, California, where he has taught since 1965. He received his B.A. degree from Miami University at Oxford, Ohio, in 1951, and his M.S. degree from the University of Michigan at Ann Arbor, in 1954. Prior to his academic career, Professor O'Connor acquired a background of research and industrial experience through associations with Massachusetts Institute of Technology; Merck, Sharp & Dohme; and the University of California, Berkeley. He is the author of laboratory manuals in biology and in chemistry, and has contributed several articles to professional journals. His professional affiliations, past and present, include the Society of American Bacteriologists, A.A.A.S., Sigma Xi, the American Rocket Society, and the American Chemical Society.

Liquid crystals on a sheet of plastic. The color of the crystals is related to their temperature. (Courtesy LiquiCrystal, Inc., York, Pennsylvania)

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CHEMISTRY: THE THEME AND THE TECHNIQUES

Know

LEARNING OBJECTIVES

1. Explain the observed differences between solids, liquids, and gases, using a scientific model.
2. Distinguish between a measurement and a measurement system.
3. Describe the metric system of measurements.
4. Distinguish between mass and weight.
5. Describe the relationship that exists between the Fahrenheit, Celsius, and Kelvin temperature scales.
6. Explain the principle behind the operation of a barometer.
7. Convert a measurement expressed in either a British or metric unit to its equivalent in any other related unit.
8. Distinguish between density and specific gravity.
9. Starting with a solid substance at its freezing point, describe its pattern of heat absorption until it becomes a vapor.

KEY TERMS AND CONCEPTS

- calorie
- chemical property
- cryogenics
- density
- freezing point
- gram
- heat of fusion
- heat of vaporization
- liter
- matter
- meter
- physical property
- pressure
- scientific model
- specific gravity
- specific heat
- temperature
- torr

Impressions of chemistry are almost as varied as definitions of love. Chemistry is regarded by some as a branch of technology which produces such agreeable and useful items as mouthwash and color television sets; by others as a monastic vocation practiced by bearded and bespectacled bumblers who are almost out of touch with reality; and by still others as an enterprise only slightly less noble than the search for the Holy Grail. To many students in introductory courses, it seems an incomprehensible jumble of numbers and symbols. In reality it is a body of knowledge that has taken form gradually over a period of about 25 centuries, growing out of man's search for an explanation of the nature and meaning of his universe and of himself.

1.1 THE NATURE OF CHEMISTRY

Chemistry is a collection of observations and theories concerning the composition of material things and the changes that they undergo. It is a vigorous and rapidly changing discipline with indefinite boundaries, encompassing such diverse goals as finding a cure for cancer and unraveling the composition of moon rock.

Chemists often refer to themselves as "scientists" and to their procedures as "the scientific method." To the layman these words carry the implication that scientific investigations are carried out on a different level from that of ordinary thought processes. The thought processes of a chemist, however, are not significantly different from those of a gambler in deciding which horse to bet on: luck, intuition, and a knowledge of past events figure strongly in both. Louis Pasteur underscored the relationship between luck, knowledge, and success in scientific discovery when he said, "Chance favors the prepared mind." A willingness to look for new meaning in familiar objects and events has played an important role in such scientific advances as Fleming's discovery of penicillin, Watson and Crick's model of the DNA molecule, and Newton's elucidation of the laws of gravity.

Penicillin was discovered by Alexander Fleming, a British microbiologist. A culture of *Staphylococcus* had been contaminated by a blue-green mold called *Penicillium notatum*. Fleming observed that the bacteria did not grow in the vicinity of the *Penicillium* and correctly surmised that the inhibition was the result of a chemical produced by the mold. Although this inhibition had been noted by others before him, Fleming was the first to recognize its importance.

1.2 MATTER

The material objects studied by chemists may be collectively referred to as *matter*. Matter may be defined as anything which has mass and occupies space; this means that matter is both tangible and real. Matter (which has mass) has two behavioral features which can be measured: (1) matter is attracted toward other matter, and (2) matter once set in motion tends to continue in motion in the same direction unless acted upon by an outside force. Although both of these features of matter will be discussed later in detail, it is worth noting that the attraction between two bodies increases as the mass of either body increases. This attraction becomes readily apparent only when the mass of one (or both) of the bodies is relatively large, as for example, the attraction between a raindrop and the earth. The attraction between two raindrops is not so obvious because their masses are so small.

The technique called weighing is, in effect, measuring the force of attraction which the earth exerts on the mass of the object being weighed. The same object would weigh less on the surface of the moon because the moon's mass is smaller, and its attraction lower, than that of the earth (Figure 1.1). However, the mass of an object is always the same, regardless of its weight.

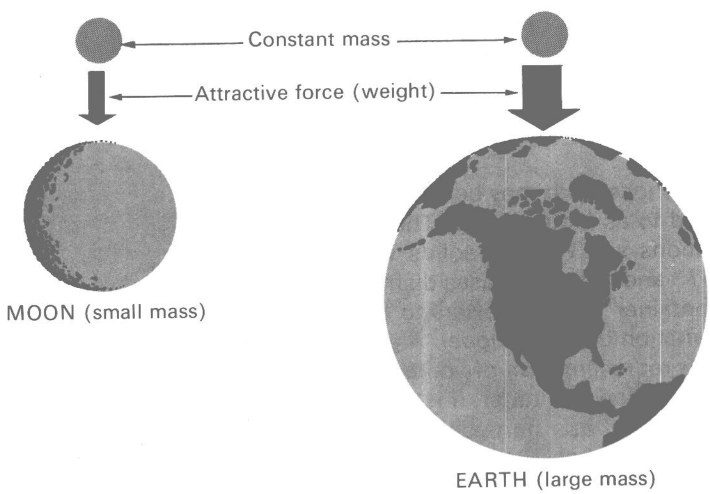

Figure 1.1
The effect of location on the mass and weight of an object. The mass remains the same regardless of its location. The weight varies in relation to other masses.

1.3 PHYSICAL STATES OF MATTER

Although the reality of earth rock in the liquid form becomes obvious enough during volcanic eruptions, earth rock is usually regarded as a rather substantial solid. However, the water which makes up a raindrop exists under ordinary conditions in three different forms or *physical states:* solid, liquid, and gas (vapor). An open bottle of carbonated beverage illustrates all three states of matter: the container is a solid,