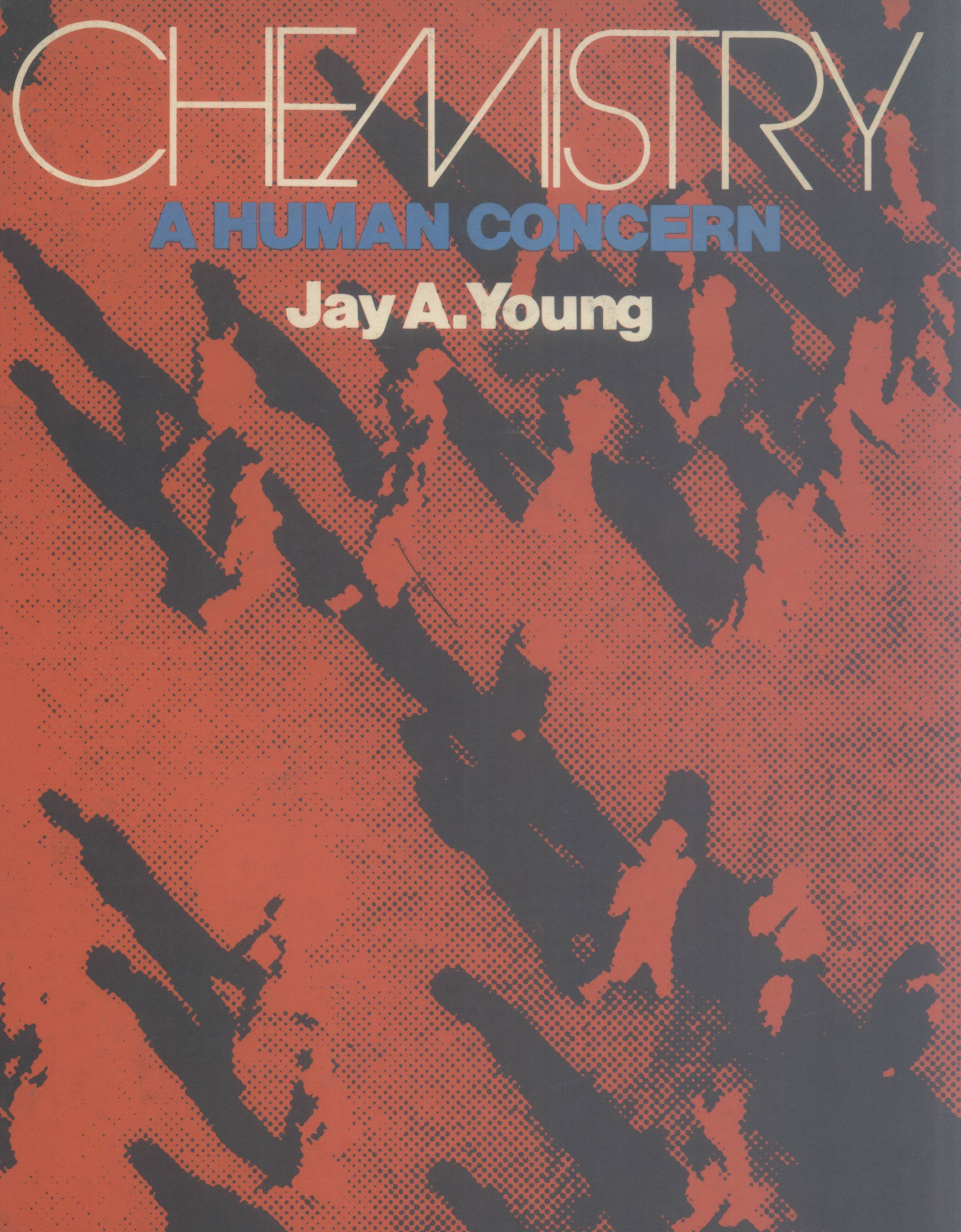
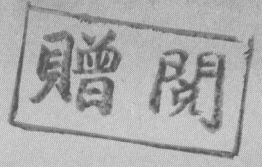
CHEMISTRY

A HUMAN CONCERN

Jay A. Young





Chemistry, A Human Concern

Jay A. Young

Professor of Chemistry, Emeritus,
King's College

Macmillan Publishing Co., Inc.
New York

Collier Macmillan Publishers
London

Printed in the United States of America

Macmillan Publishing Co., Inc.
866 Third Avenue, New York, New York 10022
Collier Macmillan Canada, Ltd.

Library of Congress Cataloging in Publication Data
Young, Jay A
Chemistry, a human concern
Includes bibliographies and index.
1. Chemistry. I. Title
QD31.2.Y68 540 76–30624
ISBN 0–02–431160–X

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

Chemistry, A Human Concern

He looks with favor upon their hearts
And shows them his glorious works
That they may describe
The wonders of his deeds
And praise his holy name.

Sirach: 17, 7–8

Preface

For students with major interests in areas distantly removed from chemistry, we have three choices for the content and presentation of a single, introductory course in chemistry. One, "What is good for the chemistry major is therefore good for everyone," is both arrogant in its assertion and all but impossible to execute. The second, "Give a general survey of chemistry, and try to cover all the bases," is in my opinion little better. Good students from other disciplines are insulted by a superficial approach, and students of lesser ability are also not stimulated to find much that is useful when such a presentation is used.

There are medians between these extremes. Of these, the one chosen for this book attempts to identify several topics which, in themselves, are of interest to most students (whatever their major curricular goals might be) and to relate these to chemistry. I have tried to write to the student, seeking to begin where the student is, and to lead from there into a bit of chemistry. Some of the chemistry is, indeed, not very sophisticated (there is no real molecular orbital theory in this book); some is reasonably challenging (the relation between structure and properties of polymers, for example). Many of the topics, though not the manner of exposition, are the same as those in "standard" introductory courses; several other topics are not.

Broadly, the book is divided into two parts, expositional chapters that discuss topics from introductory chemistry courses, and commentary chapters intended to extend the content of chemistry into areas that are already perceived to be meaningful (for nonchemical reasons) by the

students. Although the chapters are sequentially designed, most of them can be taken in any other order, and some omitted, without significant loss of continuity. This is discussed further in the "Mezzologue," which follows Chapter 7.

It is suggested that the course be taught in a manner so as to rely on short and long term papers, oral discussions, and prepared presentations as the means of evaluating students performance. For this purpose, each of the expositional chapters present discussion questions rather than the more familiar chemistry-oriented questions, at the end of each; the commentary chapters end with annotated bibliographies intended to encourage different students with differing interests to search in a variety of directions for further information that relates a portion of the chemistry studied to their own concerns. In my experience, the device is successful, and enjoyable for both professors and students.

Some may wish to consider this book for use as the text in a course which prepares students for more rigorous, or standard, introductory chemistry instruction. Of the two most direct ways to so prepare students, I have chosen to motivate rather than to engender awe. Even without mathematics, beginning chemistry is complicated enough; but without motivation it is impossible. The rigor, I feel, can come later; initially let us try to help students become sympathetic toward the reasons why rigor is ultimately necessary.

It is a distinct pleasure to acknowledge the chapter contributions by Dr. C. A. McAuliffe and by Dr. and Mrs. John W. Moore, and the helpful comments and suggestions of Professors Mary Berry, Harry Day, and Paul Melius. Two graduate student associates and friends, Francis McCullough and Patrick Morgan, were equally helpful. Mr. Wallace Shows stimulated me to write this book from my notes; his successor at Macmillan, Mr. James L. Smith, "inherited" this book when he assumed his present position as editor and has been most patient with a procrastinating author. Alphabetically last, but not otherwise so characterized, I acknowledge the assistance and personally expressed interest of Dr. Robert E. Varnerin, Manager of Education, Manufacturing Chemists Association. None of these friends is responsible for the errors which surely exist in this book.

Other friends are cordially encouraged to identify these to me for incorporation into a second edition, should this work prove to be that useful in its present form to my colleagues and to our students, to all of whom this book is herewith respectfully dedicated and now presented.

Washington, D.C. Jay A. Young

To the Instructor

This text is based upon the principle that every student taking the course is not expected to carry away the same knowledge and attitude as every other student in the course. In effect this amounts to an overt, explicit recognition of what has always been the case anyway, despite our attempts to induce some kind of conformity by administering the same exams and quizzes to each member of the class and our utilization of objective grading standards to the extent that this is possible.

However, the open suggestion that each student is different upon entry into the course and is expected to maintain his/her unique characteristics *because* of this course does imply the use of different teaching strategies. Some colleagues for good reason will reject the assertions made here. To these I recommend their adoption of some of the analogies and examples presented here and there in this text. For those who are still with me it may be useful to address three important matters:

> What might I do in the classroom, if I adopt this text?
> How does one arrive at a grade for students in the course?
> What about the laboratory, if time and other factors permit?

These possibilities suggest themselves for incorporation into the classroom: Generate, lead, and participate in student discussions based either on questions at the ends of some chapters or on cited references at the ends of other chapters. Add your own favorite chemical stories and instruction at appropriate places; to encourage this, some important and interesting

concepts have been deliberately omitted: asymmetric carbon and optical isomerism, entropy and the tendency toward randomness as a driving force, reaction rates and mechanisms, surface (colloid) chemistry, the chemistry of many common substances including soaps and detergents, waxes, fertilizers, cooking, cosmetics. Make liberal use of lecture demonstrations and lecture experiments. Much of the chemistry in this text is assertive and descriptive; add your own comments on the process of science, the logic and imagination between observed fact and accepted theory. Insert historical anecdotes and developments. Include your own illustrations of the liberal, humanizing aspects of chemistry. Select one or more of the references at the end of a chapter, building that discussion into a lecture or series of lectures.

Grading criteria are personal; the following comments are intended to suggest my own approach as a place for other instructors to start. I like to convey to the students that they are expected to show what they have obtained from the course. Early on, each student is asked to prepare a list of expectations and is aided to phrase these meaningfully. Both of us keep a copy. At the end of the course, students are asked to present or to refer to evidence that demonstrates their goals have or have not been achieved to some degree. Usually, new goals become evident during the course and students are asked to present or refer to evidence indicating accomplishment of these. The grade is based upon the degree of excellence in phrasing the goals initially, in identifying the degree of accomplishment in the stated and in the discovered goals, and on their contributions to classroom discussions. Alternatively, grades can be based upon the quality of short or long, frequent or infrequent, term papers coupled with performance on quizzes and examinations based upon the content of specified chapters and lectures. If this alternative is chosen, I recommend the use of performance objectives as the most efficient way to inform students for what they will be responsible in the quizzes and examinations.

If the latter alternative is chosen, the grading of term papers can become arduous. One solution is to require a short abstract and to form committees of students who then evaluate the term papers for the professor using as their primary criteria the degree of consonance and completeness between the term paper and the abstract. If this procedure is followed, there must be provision for appeal from the student-committee-assigned grade. Quizzes and examinations have another purpose, of course: to keep the class on its toes during the weeks of the semester or quarter. Sometimes, depending upon the class, and varying from year to year, such a technique is either necessary or insulting. When it is necessary, I prefer to use short answer (one to five or six words) questions and administer the quizzes almost daily. The

questions should be heavily dependent upon the content of the assigned chapter, and the quizzes should be announced in advance.

The conduct of the associated laboratory is usually a matter of local option. For large classes, the logistic problems will often preclude any laboratory instruction. In these cases extensive use of lecture experiments, perhaps by adding one more hour of scheduled lecture time to make room, seems advisable. In any event, suitable laboratory or lecture experiment work can be centered around three schemata:

The chemistry around us
Esthetics of chemistry
Practical and applied chemistry

As is obvious from many of the following examples, I consider laboratory work to be an opportunity to extend, rather than to review, what happened in the classroom, although there is certainly nothing wrong in emphasizing the latter instead of the former.

For the chemistry around us, an examination of the chemical and physical properties of polymers of various sorts, the analysis of vinegar, colorimetric analysis, electrolysis of water, the burning of steel wool in air and in oxygen, photographic chemistry, and qualitative analysis either in the traditional sense, or more briefly, presented instead as a search for clues in a hypothetical detective story, or as a study of the utility of solubility rules.

Esthetics of chemistry implies to some degree the fun of watching chemical phenomena. Examples include luminescent reactions, the iodine clock, reactions of some of the alkali metals with water or halogens, or other compounds and elements, various gas–gas reactions such as SO_2 and H_2S or SO_2 and HI, the thermal decomposition of $(NH_4)_2Cr_2O_7$, ligand exchanges which involve color change such as exchanging chloride ion for water on the copper ion, and a host of the other possibilities.

Practical and applied chemistry includes some applications of theory for its own sake, such as the Dumas determination of the molecular weight of a volatile liquid, and directly practical analogies, such as the reduction of copper oxide with illuminating gas or the reduction of lead oxide with charcoal, as analogous to the manufacture of pig iron. Other possibilities include the "nylon rope trick," generating nylon at the interface between immiscible liquid solutions of the two monomers, chromatographic separations, introductory studies of radioactivity, and so on.

Jay A. Young

Foreword to the Student

The very nature of our being human drives us, each and severally, to modify the conditions of our existence. Thus, one writes a poem, another invents a machine to pit cherries, someone else discovers oxygen, still another works to change the rules of football; none are satisfied with things as they are. Whether we are successful or not in these attempts, all of us are driven to pursue forever those changes that we hope will be effective.

This might have been a book about poetry or the art of making football rules. Both are important—perhaps equally, perhaps unequally, at least to some of us. As it happens, this is a book about chemistry, an attempt to relate how and why chemistry too can be used to modify the conditions of our existence.

It is necessary for someone to write good poetry. The same applies to pitting cherries, and to playing football and discovering oxygen. It is desirable that we nonpoets, cherry pie eaters, oxygen breathers, and football watchers recognize the drives that make others into poets, cherry pitter inventors, oxygen discoverers, and football players.

This book is about oxygen discoverers (in a metaphoric sense at least). It has been written to all poets, cherry pie eaters and cherry pitter inventors, to football players, rule makers and watchers, for information, and, I hope, for your enjoyment and response. As human beings, chemistry is a subject for our mutual concern, whether we are more, or less, interested in chemistry than we are in other important matters.

Jay A. Young

Contents

chapter 1

This Earth and Its Surroundings

Let's begin with where we are, on the Earth, one of nine planets of our solar system, traveling in a distorted circular, elliptical, orbit around the Sun. Actually, the Sun is a star, more or less average, not the biggest or smallest, not the brightest or the least bright, not as hot or as cold (if a star can be really cold) as some. This star, our Sun, is one of 100,000,000,000 stars (more or less) in our galaxy, which we call the Milky Way galaxy.

In the observable universe, there are approximately 100,000,000 galaxies, each with about 100,000,000,000 stars. Figure 1–1 is taken from a