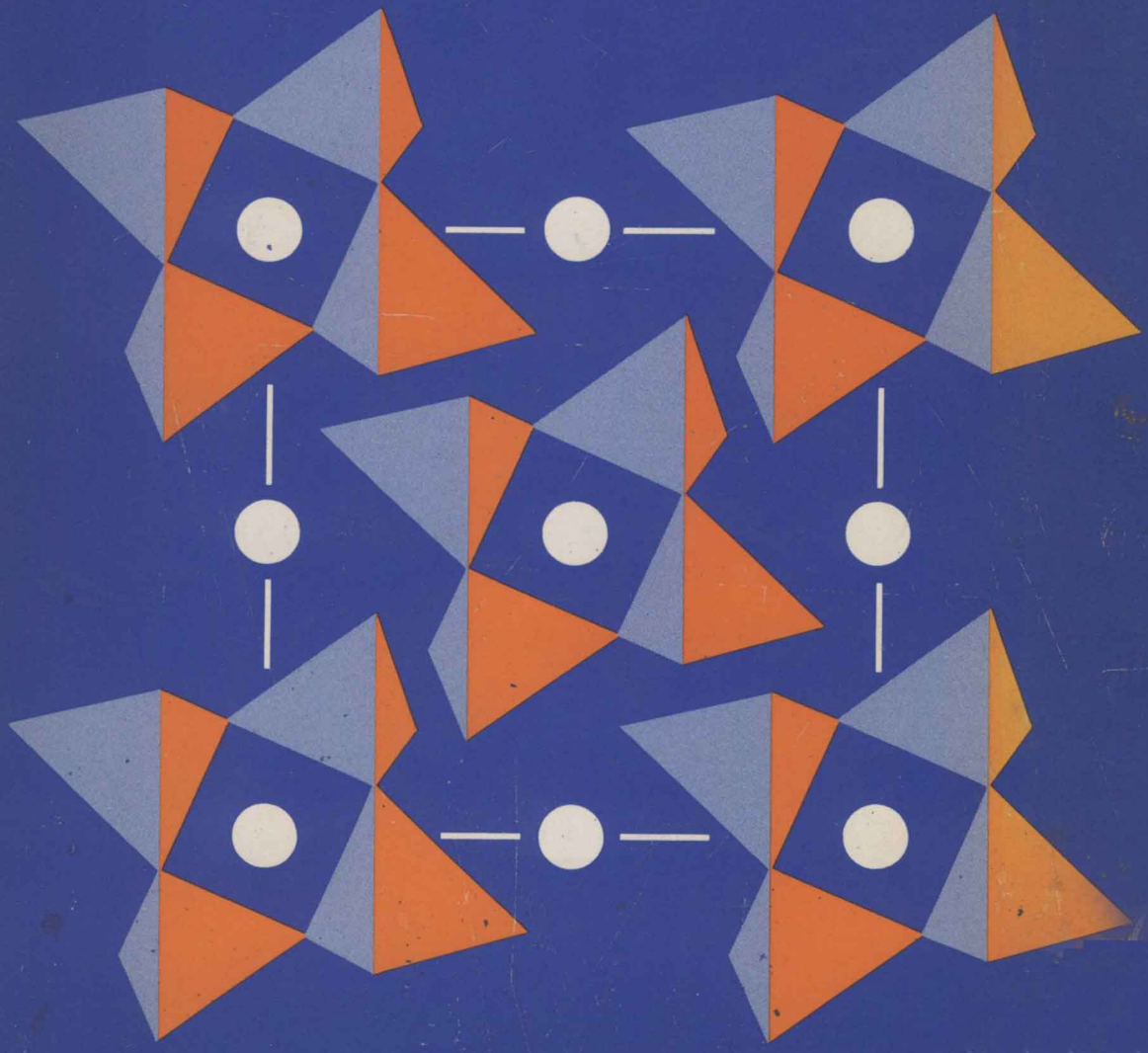
Problem Solving in General Chemistry

DeLorenzo



PROBLEM SOLVING IN GENERAL CHEMISTRY

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To Joy and Amy

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PREFACE

This book is intended for use in preparatory or general college chemistry courses. No previous math or chemical knowledge is assumed. All discussions begin at a low level and are developed in great detail. The main objective was to create a text that would hold student interest by integrating the solution of chemistry problems with real-life applications, analogies, ancedotes, and enhancements to comprehension. Material of sufficient interest and challenge for more advanced students is also included. The large number of applications to daily life and topics of general student interest make this text useful for both science and nonscience majors.

Each chapter is composed of five parts: an introduction, a dialogue, examples with detailed solutions, self-tests, and end-of-chapter problems. Answers are given for all problems so that students can check their work. Approximately 30% of the problems use SI units.

The first three chapters lay the basic foundation for the remainder of the text. Chapter 1 offers a stepwise development of mathematical skills associated with the handling of numerical calculations. Chapter 2 presents the dimensional analysis technique, and focuses on the importance of units in guiding students to a successful problem-solving technique. Chapter 3 is a slightly more advanced chapter on dimensional analysis that builds on the material of Chapters 1 and 2.

The remaining twelve chapters contain a multitude of example problems, each with very detailed solutions, that illustrate most of the major topics discussed in general chemistry courses. These topics include the mole, stoichiometry, gas laws, concentration units, equilibrium, chemical thermodynamics, electrochemistry, and nuclear chemistry.

Applications and analogies that students should find interesting include hot-blooded dinosaurs, the temperature of Hell, why hot water pipes freeze before cold water pipes do, the effects of aspirin on the stomach, how to open a beer can properly, Noah's ark, predicting the next California earthquake, black holes, the "big bang," and the neutron bomb.

Pedagogical Features: The text encourages the student to participate by picking up a pencil, solving problems, and writing brief responses. Questions and problems that encourage a written response are italicized, with rules above and below. The correct numerical answer, solution details, or written response is given in the paragraph(s) following the italicized material.

Other pedagogical features include:

- approximately 2500 problems and questions
- dimensional analysis used in all problems
- a gradual change in problem difficulty within a chapter
- detailed solutions to example problems
- end-of-chapter problems that parallel the example problems
- self-tests throughout each chapter to check comprehension
- answers for all self tests and end-of-chapter problems
- approximately 150 sketches and photographs
- chapter outlines at the beginning of each chapter
- chapter introductions to provide an overview and explain how the material ties in with previous and/or future chapters
- useful hints on preparing for and taking examinations

I am particularly indebted to my wife, Mary, who originally suggested this project. Without her continuing efforts, patience, suggestions, and encouragement this text would never have been written.

Of the various reviewers, I would particularly like to thank Dr. Larry Krannich, University of Alabama in Birmingham. His extra effort, beyond that expected, and his blend of skills as a chemist and educator helped greatly in the development of this manuscript.

I am very grateful to Dr. William J. Husa, Jr., Middle Georgia College, who gave so generously and freely of his time and energy while this manuscript was being developed.

I would like to thank Curtis Sears of Georgia State University and Dr. R. Allen Rhodes, Middle Georgia College, for their help. I am also grateful to Professor John Pasto, Department of Biology, Middle Georgia College, for his ideas and help with biologically related material.

It has been a pleasure to work with the personnel at D. C. Heath and Company. In particular, I would like to thank Harvey Pantzis, Stan Galek, Randi Bussin, and Cathy Cantin for their generous amounts of time, attention, and sound advice.

Ronald A. DeLorenzo

TO THE STUDENT

Each chapter in this book is made up of five elements: (1) an introduction, (2) discussions, (3) example problems, (4) self-tests, and (5) end-of-chapter problems.

You will find many questions that are italicized and separated from the text by horizontal lines. To use this book effectively, cover each page containing an italicized question with a piece of paper in such a way that you see only the written material above and within the horizontal lines. *Write* your calculations and answers to such questions on a piece of paper before reading the correct answers which follow all italicized questions. *Don't answer these questions mentally.* If you are asked for an explanation, *write* a brief paragraph before you read the correct answer given below the horizontal lines.

If your answer is correct, continue your reading. If your answer is incorrect, restudy the question, the correct answer, and the explanation given until you fully understand the material. Occasionally you may also need to reread the discussion material preceding the question. Never proceed to a new question or to new material until you understand and can answer correctly any questions that you miss.

You will find several self-tests scattered throughout each chapter. The self-tests usually contain only about four problems. Answers to the self-tests are shown immediately following the last self-test problem. Cover these answers with a piece of paper until you have finished taking the self-test. Do not go beyond a self-test until you are sure that you know how to do all of the self-test problems correctly.

After you have studied a small group of three to five example problems, you may benefit even further by going back to the first example problem in that group, covering the solution with a piece of paper, and trying to solve it and the other examples in that group on a separate piece of paper.

A series of problems and questions appears at the end of each chapter. These end-of-chapter problems parallel the examples in the chapter. This means, for example, that the fifth problem at the end of any chapter is very similar to the fifth example in that chapter. If you should have trouble with Problem 5 at the end of a chapter, go back and look over Example 5 in the same chapter. The answers are given at the end of the book for each end-of-chapter problem so that you can check your work.

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1.6 ROUNDING OFF

1.1 INTRODUCTION

The following is an excerpt from a speech given by historian Linda Kerber at the University of Iowa.

"The college at which I studied bore some resemblance to this one. It required art or music, English, history and the social sciences, and laboratory sciences. It did not, to my great relief, require mathematics in addition to what I had studied in high school. I took chemistry courses—until I reached the point that math skills were needed—and dropped chemistry. I took experimental psychology and did well in it—until I reached the level that math was needed—and I dropped psychology. I took economics—and did very well in it—until math was needed—and then I dropped economics.

"This process of elimination made my choice of a major somewhat easier. It is no accident that I ended in history—that is, a field which seemed to promise I would never again have to contemplate a number. It is an irony I muse upon each week as I join our beginning graduate students in a course on statistics and computers for historians, struggling to learn techniques without which I now risk becoming hopelessly out of date."

It is possible to study chemistry and gain some appreciation and understanding of it without mathematics. However, the depth of your comprehension of chemistry (and almost every other subject) is directly related to your math skills. The topics reviewed in the following sections are the essential math skills that you should master before studying college chemistry.

1.2 EXPONENTIAL NOTATION

If every number fell between 1 and 10, we would not have to bother with exponential notation (also called scientific notation). Unfortunately, numbers such as 93 000 000 000 000 000 and 0.000 000 000 000 000 458 exist. We find them awkward to write and more awkward to work with. And so, instead of writing 93 000 000 000 000 000 (that's 93 followed by 15 zeros), we write 9.3×10^{16}. This compact form of the number (9.3×10^{16}) is called exponential or scientific notation. The 16 is called an exponent and it means that the decimal point between the 9 and the 3 (in 9.3) would have to be moved 16 places to the right to produce the original number (93 000 000 000 000 000). Don't you agree that 9.3×10^{16} is easier to write? Later you will see that it is also easier to work with.

There are other reasons why exponential notation is used. One is related to the idea of significant digits (see Section 1.5).

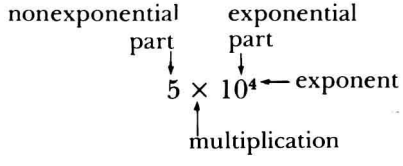
Here's a question that will give you a hint of things to come in the section on significant digits: What is the area of a rectangle whose sides, measured to the nearest inch, are found to be 2 inches and 20 inches?

If you wrote 40, you're wrong. (Did you actually pick up a pencil and write your answer as you should have?) Other incorrect answers typically given include 40 in., 40 inches^2, 40 in.^{2}, and 40. in.^{2}. The correct answer is 4×10^2 in.^{2}. We'll see why in the section on significant digits. But for now, it is important for you to realize that not every number can be written without using exponential notation. There is an important difference between 40 in.^{2} and 4×10^1 in.^{2}.

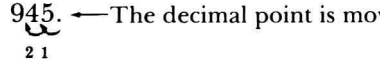
You will appreciate the third motive for learning exponential notation after you've read the section on skillful estimation techniques. The techniques, when mastered, will allow you to do most chemistry calculations in this book mentally. In fact, you'll be doing them faster than you could do them using a calculator. However, these techniques require a firm understanding of exponential notation.

Usually students who have trouble with exponential notation experience their trouble while performing calculations with exponential numbers (e.g., while adding or multiplying exponential numbers). We will go over several examples of such calculations. But first we will review how to write numbers in scientific notation and how to express numbers written in scientific notation as ordinary numbers.

A number expressed in exponential notation (such as 5×10^4) has three parts: (1) a nonexponential part, written first, which is usually a number between 1 and 10 (5 is the nonexponential part of 5×10^4), (2) an exponential part, which is 10 raised to a power (10^4 is the exponential part of 5×10^4), and (3) an exponent, which is the power of 10 (4 is the exponent in 5×10^4). The nonexponential part is always multiplied times the exponential part. In the number 5×10^4, the sign $\times$ represents multiplication.



To express large numbers (e.g., 945) in exponential notation (9.45×10^2), move the decimal point in the large number (945.) to the left to produce the nonexponential part (a number between 1 and 10). While moving the decimal point to the left, count the number of places (digits you pass by) that the decimal point is moved. The number of places the decimal point is moved to the left is equal to the exponent (power of 10) in the exponential part.



The number 945, expressed in exponential notation, is 9.45×10^2.