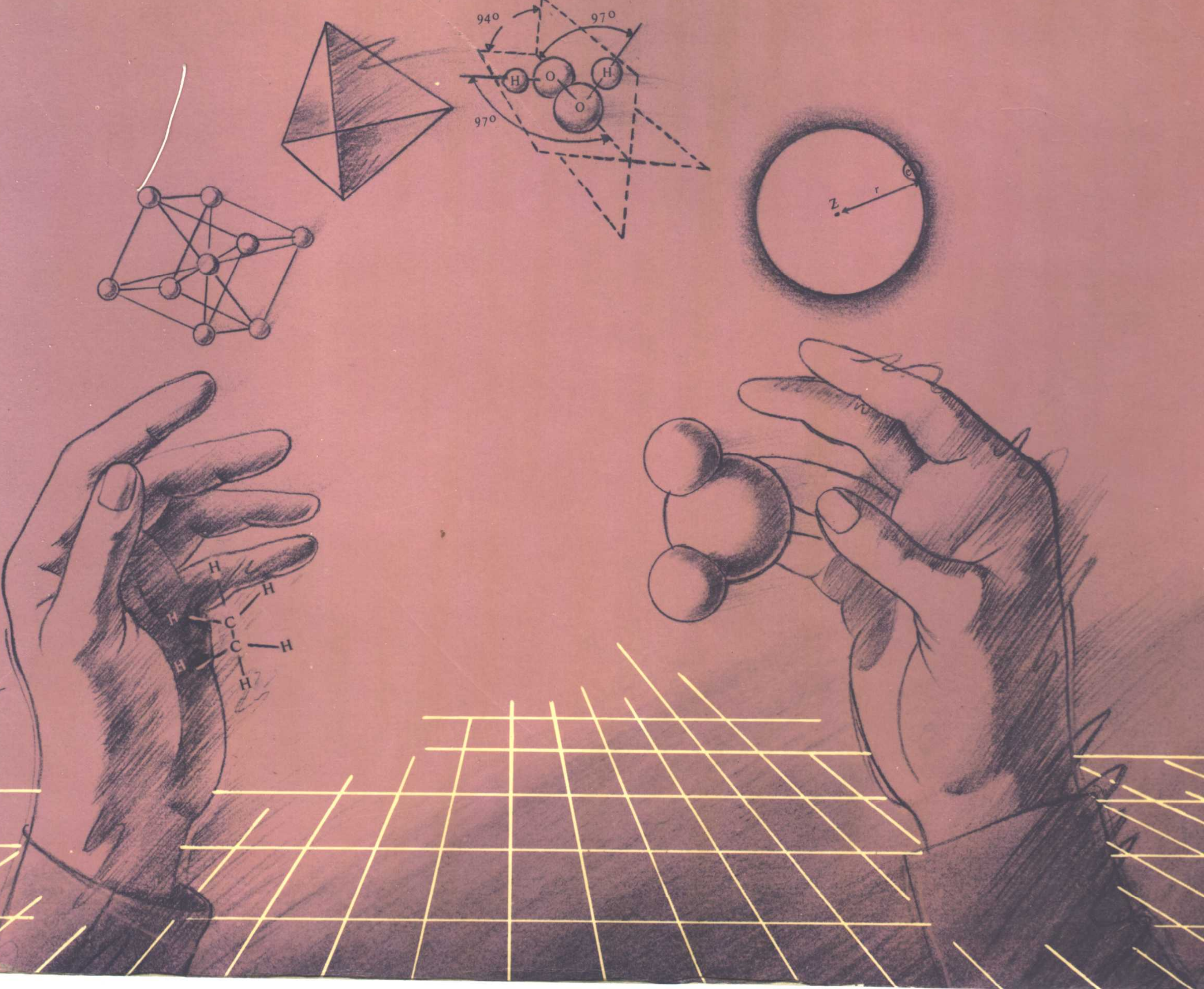
CHEMICAL SKILLS

EDWARD I. PETERS



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EDWARD I. PETERS
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PREFACE

Why a workbook? Because it works.

It is axiomatic that students learn by doing. They learn chemical formula and equation writing by writing formulas and equations. Problem solving is learned by solving problems. Students are told how important it is to work the problems and complete the formula and equation exercises at the end of the chapter. But unless homework is assigned, collected, and graded, most students do not heed this advice adequately. The textbook examples are looked at and a few problems are solved and exercises completed. Then, just before an exam, there is a huge effort to learn too much too late. The results are all too familiar.

A chemistry workbook is an almost totally neglected pedagogical device in chemical education. It is also a device with great promise, simply because the student is guided into "doing" chemistry while studying. The student who fills in all the blanks in Chatper 8 will write the formulas of 54 substances when given their names, and the names of 43 more from their formulas, before reaching the end-of-chapter exercise. Similarly, that student will write 13 equations and solve 13 stoichiometry problems while studying Chapters 9 and 13, and in Chapter 14 the student will solve 28 problems. This is all during the learning process, before working on any assigned problems. The percentage yield from <u>doing</u> is much higher than the percentage yield from "studying." It is less tedious, too, and takes less time for a given amount of learning.

"Interactive" is the popular buzzword at this time. Commonly applied to computer assisted instruction, it also describes the use of audio or slide programs. A workbook is interactive. After reading for a few minutes, the student is called upon to act, to participate—to learn. A workbook lacks the novelty of the newer devices, but enjoys two tremendous advantages over them: it is portable and no hardware is required. A workbook is "user-friendly." A student can begin learning chemistry from a workbook without first learning how to communicate with a machine. Learning can occur any time, any place. And if the student wants to check some point again, it is much more easily found in a workbook than on a diskette, on a tape, or among a set of slides.

The doing part of this workbook is in the example problems. Principles that underlie a problem, rules of nomenclature, or the procedures for writing equations are presented in textbook style. The illustrative examples are in a question-and-answer format in which the student solves the problem or writes the formula or equation before seeing the author's answer. The student is mentally productive during what is usually an absorptive period. This produces more learning in less time.

The first six chapters of <u>Chemical Skills</u> present a review of and an introduction to the mathematics of chemistry. Mathematically advanced students will progress through these chapters quickly, while those who need to be refreshed in basic arithmetic and algebra will find everything they need.

Even the advanced student will find new ideas in these chapters, where familiar topics are discussed as they are used in chemistry, not as presented in math classes. This is particularly true in the treatment of calculators in Chapter 1, graphing in Chapter 5, and logarithms in Chapter 6. Dimensional analysis, which is emphasized throughout the book, appears in Chapter 3. Among the first six chapters, those on calculators and graphing are completely new to the second edition, and the chapter on logarithms has been totally revised to take advantage of calculators now owned by all serious students.

Chapters 7 to 11 present the language of chemistry. After stressing some basic memorization requirements, the student is encouraged to learn the system of nomenclature that can be applied to many more compounds than are usually included in a general chemistry course, including substances never before encountered. Much of this system is based on the periodic table, which is stressed throughout the book. The student is even provided with a tear-out periodic table to be used as a shield and a source of atomic weights while solving example problems. Chapter 11 on oxidation-reduction equations is new in this edition.

The remaining chapters are devoted to the chemical problems that are apt to be encountered in the first semester of general chemistry. Chapters 16 on normality, 17 on colligative properties, and 19 on equilibrium are new in the second edition. Sections on percent, molality, and mole fraction have been added to the solutions chapter. The energy chapter has new sections on change of state and enthalpy summation problems.

Each chapter in Chemical Skills except the first begins with a list of prerequisites for the chapter, including a specific reference to where each topic is covered earlier in the book. This is followed by a list of "chemical skills" to be mastered in the study of the unit. These skills are written as learning objectives, which have been found particularly valuable in Keller Plan (PSI) and other self-learning courses. Then comes the main body of the text. This is followed by an abundant supply of practice problems and a chapter test. About two-thirds of the end-of-chapter problems are answered at the end of the book. Problem answers include complete calculation setups. Answers are given to questions on chapter tests, but not the problem setups. Complete solutions to unanswered and test problems appear in an instructor's manual.

Some users of this book may be interested in knowing that the camera-ready copy was produced on two NorthStar computers, one a Horizon model and the other an Advantage. WordStar was the word processing system used. The printer was a NEC Spinwriter, which has an alternate character set that makes 128 type characters available on a single print thimble. NEC's Scientific-Times Roman thimble sacrifices some basic punctuation in favor of scientific symbols. These were restored and other changes were made so almost the entire book could be printed from only one thimble. These changes were made by Dramco Sales, Inc., who will put just about anything on any print thimble, daisy wheel, or typewriter element. The entire process was a—what shall I say?—"revealing" experience in the area of manuscript and copy preparation. I would be glad to share my observations with others who may be interested in this new technology.

Edward I. Peters

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Edward I. Peters

HOW TO LEARN CHEMISTRY FROM THIS BOOK

The object of this book is to help you learn the basic skills you will need in your college level general chemistry course, and to provide an opportunity for you to apply those skills. To learn and to apply. The emphasis is on these two things. Obviously you cannot apply chemical skills without first learning them; and it is doubtful that you can learn them adequately without applying them. Application is a part of the learning process.

Each chapter in this book contains the following major sections:

Prerequisites. The chapter opens with a list of things you must know and will be expected to use in the chapter. All prerequisites are included within the book itself. In each case, you will be referred to a prior section for material you may wish to review before or during your work on the present chapter.

Chemical Skills. This is a list of skills you will learn and apply while working in the chapter. It is a list of activities, things you will be able to do as a result of your study. Read these as you begin work on the chapter. Then you will know where you are going and recognize each point when you arrive. As you complete each major portion of the chapter, read again the Chemical Skills for that portion to be sure you can really do the things described. If you cannot—if you have not mastered a particular skill—review the material again until it has been mastered. Finally, when you have completed the entire chapter, review the Chemical Skills as a group. If you can say with confidence, "I can do that," for each skill, you will have no difficulty with that topic in your chemistry course.

Text and Examples. Here's where the actual learning takes place. This section will be discussed in more detail shortly.

End-of-Chapter Questions and Problems. The questions and problems at the end of each chapter give you the opportunity to apply what you have learned. This is the clincher in the learning process. About two-thirds of the problems are answered in the back of the book. We recommend that you solve most of the answered problems, omitting only those that duplicate material you have already mastered.

Chapter Test. This is a list of questions such as are apt to appear on a test based on the chapter. We recommend that you treat these questions as a test and answer them under test conditions. Answers are in the back of the book.

We now turn to some of the details of how you can learn from the Text and Example section of each chapter. This is a workbook. It asks many questions and provides space for you to write answers to those questions. Learning is an active process, and your activity includes writing those answers. This is the immediate application of learning that does so much in making sure the learning "sticks" and gets you ready to learn more.

To learn from this book, you must equip yourself with three tools, a pencil, an opaque shield, and a calculator. Calculators are discussed in Chapter 1. The opaque shield is used while answering questions in examples. You will find these shields as perforated inserts elsewhere in the book. One side of each shield summarizes the instructions your are about to read, and the other side has a periodic table you will refer to constantly. When not in use, the shield can be used as a bookmark.

In general, each topic is introduced with some textbook-like material which you study in the usual way. This is followed by an example that is set apart like this:

When you reach such a point, you should glance down the page until you find five dashes on each side:

----- -----

This is where the shield is placed—just below the dashes so it covers the printing beneath that point. With the shield in place, return to the beginning of the example. Read the question or problem. Usually it is followed by some comment or suggestion about how to proceed. Follow that suggestion, writing the answer or solving the problem in the space provided, which will often be just above your shield. This is how you apply what you have just learned.

When you have solved the problem or answered the question, move the shield down the page to the next set of dashes or to the end of the example. The first thing you expose as you move the shield down is the correct answer to the question you have just answered. Compare your answer with the one in the book. If they are the same, as they will be most of the time, proceed as the book directs. If they are not the same, find out why. The comments that accompany the answer may be all the explanation you need. If not, restudy the text material preceding the problem, or any other earlier material you may not have understood that is responsible for your incorrect answer. When you have corrected whatever needs to be corrected, proceed to the remainder of the example. If you have reached the end of the example, it will close like this:

The importance of solving example problems in the manner described cannot be stated strongly enough. It is the core of the learning process in this workbook. Demand of yourself that you master each step in the book. Satisfying that demand is the difference between merely <u>doing</u> your chemistry homework and <u>learning</u> chemistry—and the only thing that counts is what you learn.

Edward I. Peters

CONTENTS

1

CALCULATORS

1.1 INTRODUCTION

Chemistry is a quantitative science. You, as a student, will use solutions prepared from chemicals measured in the storeroom, and you will measure out quantities of different chemicals in performing experiments. The worker in a chemical manufacturing plant measures out quantities based on the amount of product required. Part of studying chemistry is learning how to calculate the quantities that are needed and the quantities that will be produced. To do this, you must have a calculator.

If you are about to buy a calculator, you will find many from which to choose. You should be guided by your major course of study or by your intended career, and what you wish to invest at this time. Comments here are about the immediate needs of a beginning chemistry student. If you will use your calculator in other courses, you would be wise to seek advice from instructors in those fields too.

To solve the problems in this book, you and your calculator must be able to do the following:

(a) perform the basic functions of addition, subtraction, multiplication, and division;
(b) work in exponential notation;
(c) serve as a source of base 10 logarithms; and
(d) raise any base to any power.

Any calculator that can do these things will have other capabilities too. Most likely are reciprocals, squares and square roots, and natural logarithms, all of which are useful. Trigonometric functions are almost always present. Short cut keys for pi, percentage, enclosures, and different levels of storage and recall are often available. Calculators with all these capabilities can be purchased for less than twenty dollars at the time of this writing.

It is not the purpose of this book to recommend one calculator over another, and the use of one calculator as an example should not be taken as such a recommendation. It is necessary, however, to describe procedures that can be used on a real calculator. The Texas Instrument Model 30-II, hereafter identified as TI30-II, has been selected for this purpose. It has been chosen simply because it is popular among students. Calculation sequences on the TI30-II can be performed on most calculators with an Algebraic Operating System (AOS). Note that the order of operations (addition, multiplication, etc.) is the same on a Hewlett-Packard calculator, or any other that uses Reverse Polish Notation (RPN), but there is a difference in the order in which numbers and operations are keyed.

This chapter is limited to the calculator techniques required to solve the problems in this book. These techniques should take you all the way through lower-division chemistry courses. It is suggested that you perform each operation as you read it. If any operation cannot be performed as described, consult the instruction manual that came with your calculator.

1.2 ENTERING A NUMBER

To introduce a number into your calculator, you simply press the number keys in their proper order. This includes the decimal. If the number is negative, press the ± key (sometimes identified by CHS or some other symbol) after the last digit. The number will appear in the display window of the calculator as it is entered.

Some calculators permit you to fix the number of digits that will be displayed after the decimal point, or you may allow the decimal to "float." It is usually best in chemical calculations to work with a floating decimal. This will be done throughout this book.

Most calculators can display eight digits. A number with more than eight digits should be entered in exponential notation. This shows the number as the product of a coefficient, N, and an exponential, 10 raised to some integral (whole number) power, x, as $N \times 10^x$. In the standard form of exponential notation, N is equal to or more than 1, but less than 10. If you enter N outside of this range, the calculator adjusts the display to this form. Exponential notation is discussed in detail in Section 3.1 in this book.

The procedure for entering a number in exponential notation is:

1. Type the coefficient, N. If the number is negative, type ±.
2. Type EE (or whatever key is used for exponential notation).
3. Type the exponent. If the exponent is negative, type ±.

EXERCISE 1.1: Enter the following numbers into your calculator: 1.23×10^4; 5.67×10^{-8}; -9.87×10^6; -5.43×10^{-2}.

1.23×10^4

Enter	Press	Display
1.23	EE	1.23 00
4		1.23 04

5.67×10^{-8}

Enter	Press	Display
5.67	EE	5.67 00
8	±	5.67-08

-9.87×10^6

Enter	Press	Display
9.87	± EE	-9.87 00
6		-9.87 06

-5.43×10^{-2}

Enter	Press	Display
5.43	± EE	-5.43 00
2	±	-5.43-02

1.3 ONE-NUMBER FUNCTIONS

From the calculator standpoint, the easiest operations are those in which one number is keyed into the calculator, and then something is done with that number. These are called **one-number functions.** The common one-number functions are multiplying a number by itself (squaring the number); finding the square root of a number; finding the inverse, or reciprocal, of a number (dividing the number into 1); finding the logarithm of a number (finding the power to which 10 must be raised to produce the number); and finding the antilogarithm of a number (raising 10 to the power given).

A one-number function is calculated as follows:

1. Enter the number.
2. Press the desired function key.

EXERCISE 1.2: Calculate: 1/123; 123^2; $\sqrt{123}$; and log 123.

1/123

Enter	Press	Display
123	1/x	0.0081301

123^2

Enter	Press	Display
123	x^2	15129

$\sqrt{123}$

Enter	Press	Display
123	$\sqrt{x}$	11.090537

log 123

Enter	Press	Display
123	log	2.0899051

If $N = 10^x$, then

$$\log N = x \tag{1.1}$$

and

$$N = \text{antilogarithm } x = \log^{-1} x \tag{1.2}$$

(Logarithms and antilogarithms are discussed in detail in Chapter 6.) There are two ways to find antilogarithms on the TI30-II and other calculators, but only one of these is found on all calculators. That one is not a one-number function; it will be discussed in the next section. The one-number sequence requires two function keys. Finding an antilogarithm is the inverse of finding a logarithm. The INV key is therefore used before the log key:

EXERCISE 1.3: Find the antilogarithm of 1.23.

Enter	Press	Display
1.23	INV log	16.982437

1.4 EXPONENTIALS

An <u>exponential</u> is a number in which a base, N, is raised to a power, x, as in N^x. If your calculator has a key in which one variable is raised to another, that key can be used to find the value of any base raised to any power. The key usually has the symbol y^x. The general procedure is

1. Enter the base, N, the number that is to be raised to a power.
2. Press y^x.
3. Enter the exponent, the power to which the base is to be raised.
4. Press =.

EXERCISE 1.4: Calculate (a) 1.23^4; (b) $5.67^{0.25}$; (c) $(8.91 \times 10^{-2})^{3.4}$

1.23^4

Enter	Press	Display
1.23	y^x	1.23
4	=	2.2888664

$5.67^{0.25}$

Enter	Press	Display
5.67	y^x	5.67
.25	=	1.543106

$(8.91 \times 10^{-2})^{3.4}$

Enter	Press	Display
8.91	EE	8.91 00
2	± y^x	8.91-02
3.4	=	2.689-04

Equation 1.2 indicates that if $N = 10^x$, N is the antilogarithm of x. If x, the logarithm of N, is known, N can be found simply by raising 10 to the x power.

EXERCISE 1.5: Find the antilogarithm of (a) 3.42; (b) -4.322.

3.42

Enter	Press	Display
10	y^x	10
3.42	=	2630.268

-4.322

Enter	Press	Display
10	y^x	10
4.322	± =	0.0000476

1.5 ADDITION, SUBTRACTION, MULTIPLICATION, AND DIVISION

The general procedure for the one-step addition, subtraction, multiplication, or division of two numbers, A and B, is

1. Enter A.
2. Press required function key.
3. Enter B.
4. Press =.

EXERCISE 1.6: Calculate (a) 12 + 345; (b) 12 - 345; (c) 12 × 345; (d) 12 ÷ 345.

12 + 345

Enter	Press	Display
12	+	12
345	=	357

12 - 345

Enter	Press	Display
12	-	12
345	=	-333

12 × 345

Enter	Press	Display
12	×	12
345	=	4140

12 ÷ 345

Enter	Press	Display
12	÷	12
345	=	0.0347826

1.6 CHAIN CALCULATIONS

If a problem setup calls for two or more operations to be performed, one after the other, a chain calculation is required. The order in which the operations are performed may be critical. This order is identified and discussed in Section 2.3. Most AOS calculators are designed to perform calculations in the proper order when numbers and operations are entered exactly as they appear in the calculation setup. (This is not true with RPN calculators.) When a setup becomes highly complex, it is probably better to simplify some terms before performing the calculation. Rarely will you find such complexity at the general chemistry level.

In brief, the correct order of operations in a calculation is

1. Complete all one-number functions.
2. Complete all multiplications and divisions.
3. Complete all additions and subtractions.

Mathematically, the above order should be followed by all combinations of operations that are enclosed in parentheses before being applied to the whole setup. The procedure is followed by steps in this example:

$6 \times 5 - 2 + (19 - 7) \div 3 - 4^3$	
$6 \times 5 - 2 + 12 \div 3 - 4^3$	Clear parentheses
$6 \times 5 - 2 + 12 \div 3 - 64$	Complete one-number functions
$30 - 2 + 4 - 64$	Complete multiplications and divisions
-32	Complete additions and subtractions

With a calculator, the same operations may be performed from left to right, typing the parentheses and one-number functions where they appear.

EXERCISE 1.7: Evaluate $6 \times 5 - 2 + (19 - 7) \div 3 - 4^3$

Enter	Press	Display
6	×	6
5	−	30
2	+ (	28
19	−	19
7	) ÷	12
3	−	32
4	y^x	4
3	=	−32

Read the <u>enter</u> and <u>press</u> columns from left to right in the above exercise. Note that both numbers and operations are in exactly the same order as they appear in the problem, with the y^x step added.

Sometimes an expression has a numerator or a denominator that is the sum or difference of two numbers. Parentheses may not appear in the expression, but they must be used when the problem is keyed into the calculator. Using a fraction bar for division, Exercise 1.7 can be written

$$6 \times 5 - 2 + \frac{19 - 7}{3} - 4^3$$

If parentheses are omitted, the calculator interprets the problem as

$$6 \times 5 - 2 + 19 - 7 \div 3 - 4^3 = -19.333334$$