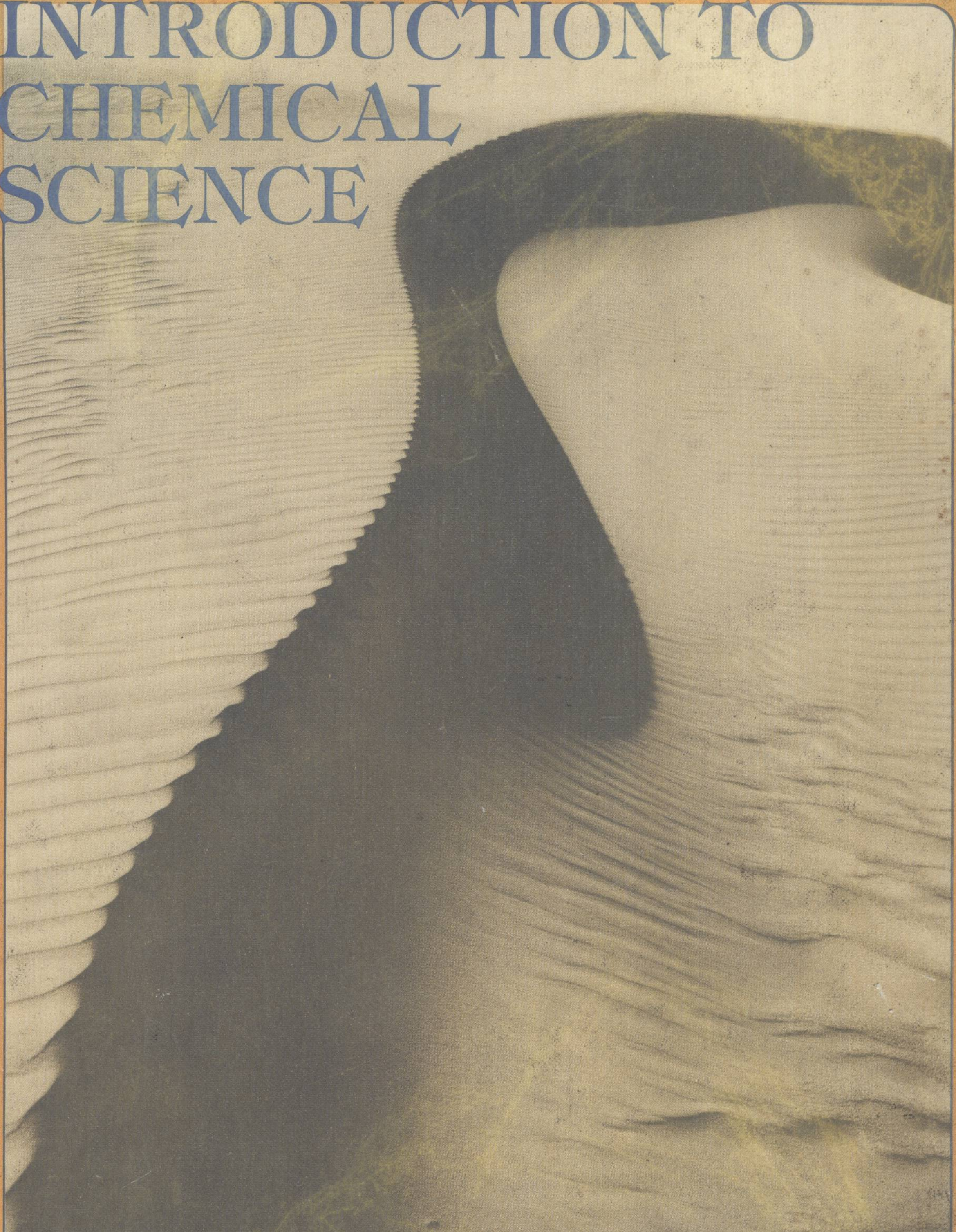
INTRODUCTION TO CHEMICAL SCIENCE



MARY MAIER

INTRODUCTION TO CHEMICAL SCIENCE

MARY MAIER
SAINT JOSEPH'S COLLEGE

WILLARD GRANT PRESS
BOSTON, MASSACHUSETTS

20 Newbury Street, Boston, Massachusetts 02116

Library of Congress Cataloging in Publication Data
Maier, Mary.
Introduction to chemical science.

Includes index.
1. Chemistry. I. Title.
QD31.2.M333 540 77-21432
ISBN 0-87150-722-6

Printed in the United States of America

Designers: Kay Riley, David Chelton, and the staff of Willard Grant Press
Art Studio: Phil Carver & Friends, with creative art by Dave Blanchette
Photo Researcher: Billie-Ann Harber
Compositor: European Printing Corporation, Ltd.
Printer and Binder: Halliday Lithograph Corp.

Table of Atomic Weights

(Based on Carbon-12)

Values in parentheses are mass numbers of isotopes of longest half-life or best known isotopes.

Name	Symbol	Atomic No.	Atomic Weight
Actinium	Ac	89	(227)
Aluminum	Al	13	26.982
Americium	Am	95	(243)
Antimony	Sb	51	121.75
Argon	Ar	18	39.948
Arsenic	As	33	74.922
Astatine	At	85	(210)
Barium	Ba	56	137.34
Berkelium	Bk	97	(247)
Beryllium	Be	4	9.012
Bismuth	Bi	83	208.981
Boron	B	5	10.811
Bromine	Br	35	79.904
Cadmium	Cd	48	112.40
Calcium	Ca	20	40.08
Californium	Cf	98	(251)
Carbon	C	6	12.011
Cerium	Ce	58	140.12
Cesium	Cs	55	132.905
Chlorine	Cl	17	35.453
Chromium	Cr	24	51.996
Cobalt	Co	27	58.933
Copper	Cu	29	63.546
Curium	Cm	96	(247)
Dysprosium	Dy	66	162.50
Einsteinium	Es	99	(254)
Erbium	Er	68	167.26
Europium	Eu	63	151.96
Fermium	Fm	100	(253)
Fluorine	F	9	18.998
Francium	Fr	87	(223)
Gadolinium	Gd	64	157.25
Gallium	Ga	31	69.72
Germanium	Ge	32	72.59
Gold	Au	79	196.967
Hafnium	Hf	72	178.49
Hahnium	Ha	105	—
Helium	He	2	4.003
Holmium	Ho	67	164.930
Hydrogen	H	1	1.008
Indium	In	49	114.82
Iodine	I	53	126.904
Iridium	Ir	77	192.2
Iron	Fe	26	55.847
Krypton	Kr	36	83.80
Kurchatovium	Ku	104	—
Lanthanum	La	57	138.91
Lawrencium	Lr	103	(257)
Lead	Pb	82	207.19
Lithium	Li	3	6.939
Lutetium	Lu	71	174.97
Magnesium	Mg	12	24.312
Manganese	Mn	25	54.938
Mendelevium	Md	101	(256)
Mercury	Hg	80	200.59
Molybdenum	Mo	42	95.94
Neodymium	Nd	60	144.24
Neon	Ne	10	20.183
Neptunium	Np	93	(237)
Nickel	Ni	28	58.71
Niobium	Nb	41	92.906
Nitrogen	N	7	14.007
Nobelium	No	102	(254)
Osmium	Os	76	190.2
Oxygen	O	8	15.999
Palladium	Pd	46	106.4
Phosphorus	P	15	30.974
Platinum	Pt	78	195.09
Plutonium	Pu	94	(242)
Polonium	Po	84	(210)
Potassium	K	19	39.098
Praseodymium	Pr	59	140.907
Promethium	Pm	61	(147)
Protactinium	Pa	91	(231)
Radium	Ra	88	(226)
Radon	Rn	86	(222)
Rhenium	Re	75	186.2
Rhodium	Rh	45	102.905
Rubidium	Rb	37	85.47
Ruthenium	Ru	44	101.07
Samarium	Sm	62	150.35
Scandium	Sc	21	44.956
Selenium	Se	34	78.96
Silicon	Si	14	28.086
Silver	Ag	47	107.868
Sodium	Na	11	22.990
Strontium	Sr	38	87.62
Sulfur	S	16	32.064
Tantalum	Ta	73	180.948
Technetium	Tc	43	(99)
Tellurium	Te	52	127.60
Terbium	Tb	65	158.924
Thallium	Tl	81	204.37
Thorium	Th	90	232.038
Thulium	Tm	69	168.934
Tin	Sn	50	118.69
Titanium	Ti	22	47.90
Tungsten	W	74	183.85
Uranium	U	92	238.03
Vanadium	V	23	50.942
Xenon	Xe	54	131.30
Ytterbium	Yb	70	173.04
Yttrium	Y	39	88.905
Zinc	Zn	30	65.38
Zirconium	Zr	40	91.22

Useful Conversion Factors

Length	1 inch = 2.54 cm 1 foot = 30.48 cm 1 mile = 1.61 km	1 cm = 0.3937 in. 1 meter = 39.37 in. 1 km = 0.62 mile
Mass	1 pound = 453.6 g	1 kg = 2.2046 lb
Volume	1 quart = 0.946 liter 1 cubic inch = 16.4 ml	1 liter = 1.06 qt 1 liter = 61.03 cu in.
Temperature	1 degree Fahrenheit = $\frac{5}{9}$ degree Celsius 1 degree Celsius = 1.8 degrees Fahrenheit 32°F = 0°C = 273°K	 212°F = 100°C = 373°K

PREFACE

Students come to college today with more diverse backgrounds than ever before. Their professional goals are just as varied. The era of the full-time, single-minded student with assembly-line high school preparation is past. This situation demands greater flexibility on the part of both teachers and educational tools. *Introduction to Chemical Science* was written to accommodate this variety of student needs. It was developed during the several years I taught beginning chemistry at Medgar Evers College of the City University of New York.

The text is written to be used in an introductory course for students with little or no background in chemistry. It is divided into two parts. Part I concentrates on fundamental math and science skills such as measurement, exponential notation, graphing, weight, mass, and volume. The gas laws are introduced here so the student can relate the more general concepts they are learning to chemistry. These chapters can be covered at any pace the instructor chooses and class make-up dictates. For some it may be only a quick review; others may be seeing these topics for the first time.

Part II presents the basic chemistry needed to go on to other courses, but, as I hope, in such a way that the student will want to learn it for its own sake. As I explain in "To the Student," chemistry does not have to be viewed just a series of brainteasing problems, but should enable students to understand and appreciate much more of what goes on around them. If a textbook can help to point out the links between chemistry and "the world," perhaps the chemistry itself will make more sense.

Every effort has been made to assist the student through the text:

—Learning objectives are provided before most sections within each chapter.

—Practice Exercises and Problems with answers (called "checkouts") follow many chapter sections. This method of presenting small chunks of information with immediate testing has been very successful with my students.

—There are two sets of problems at the end of each chapter. Those in the Review Questions mirror those in the Chapter Problems. Answers for Review Questions are provided in the back of the book.

—Example problems are worked out in detail, including some mathematical operations.

—Although each new word is defined the first time it appears in the text, there is also a glossary for easy reference.

—The Appendix contains a review of logarithms, with exercises.

—For students who require extra help in developing study habits, optional sections on reading scientific materials may be useful.

A study guide and laboratory program also accompany this text and are available from the publisher.

ACKNOWLEDGMENTS

A text comes into being as the result of many persons' contributions. Surely the opportunity to teach students of introductory chemistry contributed significantly to the development of this text. It was also necessary to receive the support and suggestions of other educators who served as reviewers for this text. I wish especially to recognize the contributions of Dr. Robert J. Merrer of Western Connecticut State College, whose teaching experience on this level gave special import to his helpful suggestions. Among the many other reviewers who contributed significantly to the finished product were Professors Pauline M. Doryland and David Brooks, both of the University of Nebraska, Lincoln; Marian K. Rowan of New Mexico State University; Robert J. Munn of the University of Maryland; Elsa Niedbala of Springfield Technical Community College; Peter B. Barcaski of Jersey City State College, Londa Borer of the California State University at Sacramento, Katherine McClean of Phoenix College, and Dexter Plumlee of Northern Virginia Community College.

My personal thanks are extended to the friendly and encouraging staff at Willard Grant Press. Ms. Maria Buonopane was an expert with the monumental typing tasks which had to be done as the text was revised. Mr. Bruce B. Thrasher, General Manager, and Ms. Jane O. Goedecke, Editor, deserve all the credit that can be given for the many hours which they have devoted to this production. To Mr. David Chelton, Production Editor, who exhibited such a personal interest in the book, which he skillfully assembled from a maze of rough drafts and galley proofs, I extend my sincere admiration and gratitude. He and his colleagues are also the kind of

people who can brighten the sometimes grim world of the textbook author with optimism and endurance.

It is perhaps unusual to discover someone who is at once an excellent student and teacher. Many contributions to this text came from a student at Columbia University, Mr. Nelson D. Rodriguez, who also assisted me as a tutor of introductory chemistry at Medgar Evers College. His special understanding of student problems and his ability to assist them in reaching solutions led to his suggesting many of the problems and chapter sequences. It was refreshing to discuss the teaching aspects of this material with someone who is a gifted student-teacher.

Mary Maier
Saint Joseph's College
Brooklyn, New York

TO THE STUDENT

Many people respond to chemistry the way I used to respond to modern art. I can recall standing before a painting entitled "Blue on Blue" and feeling left out, because, try as I might, I could not see what other people seemed to enjoy in the subject. Now that I have become accustomed to the language of the art and have been instructed in the interesting effects of line and color variations, I can say I really like modern art—well, most of it.

As a teacher of chemistry, I know that some people feel left out of the enjoyment of this subject. Chemistry can sound like a foreign language, but its mysteries can be unraveled too, if some interest and effort are applied to the task. Adventurous students discover that science is one of the avenues the mind travels in search of knowledge about the world in which we live.

Since you are interested in being introduced to chemical science, try to keep the same head on your shoulders when you are thinking about science as when you are thinking about the rest of life. Understand that the problems you are asked to solve are not artificial brainbusters, and that their relevance to other aspects of life will become clear as your scientific study progresses.

I do not know how much science you have studied. I do not even know if you like science. So, I am writing this text as if you have never read anything like it. I am presenting the skills and ideas that go with a scientific background as if you have never even heard of them. If you will go along with me through the ideas and problems I have prepared for you, I can assure you that together we will prepare a foundation for a college science degree program, if that is where you are headed. If you plan to be a nurse or medical technician, I have something for you. If what you want is to be able to understand this scientific age in which we live, I think that you and this book can handle it, along with a teacher who will explain and answer questions when you find yourself engrossed in this fascinating subject.

Whoever you are, I bet you know more science than you think you know. So, even if scientific study does no more than help you to discover that fact about yourself, it is worth the effort.

CONTENTS

PART I

1

TIME

2

LENGTH

3

WEIGHT

4

VOLUME

5

DENSITY

6

TEMPERATURE

PART II

ATOMIC THEORY

7

BONDING THEORY

8

MOLECULES AND FORMULA UNITS

9

10 THE MOLE

11 CHEMICAL REACTIONS

12 TYPES OF CHEMICAL REACTIONS

13 SOLUTION CHEMISTRY

14 ORGANIC CHEMISTRY

PART I

This photo of the Earth taken from outer space shows the seas and continents quite clearly – you can see South America in front and North America at the upper left. The photo also shows the clouds that surround the Earth. The properties that make the earth, the ocean, and the clouds different from each other can all be described by the basic processes of chemistry. (Courtesy of NASA)

What better place is there for your introduction to chemical science than the chemistry laboratory? The words "chemistry laboratory" bring to mind a picture of a room filled with strange furniture, unfamiliar odors, and a confusing array of bottles and glassware.

Anyone who ventures into the chemical laboratory for the first time to perform an experiment is faced with the challenges of understanding the reason for being there in the first place, and of knowing how to identify the required scientific equipment in the second place. In other words, order can emerge from the seeming chaos of a chemical laboratory provided you are able to recognize the tools of the trade and to use them.

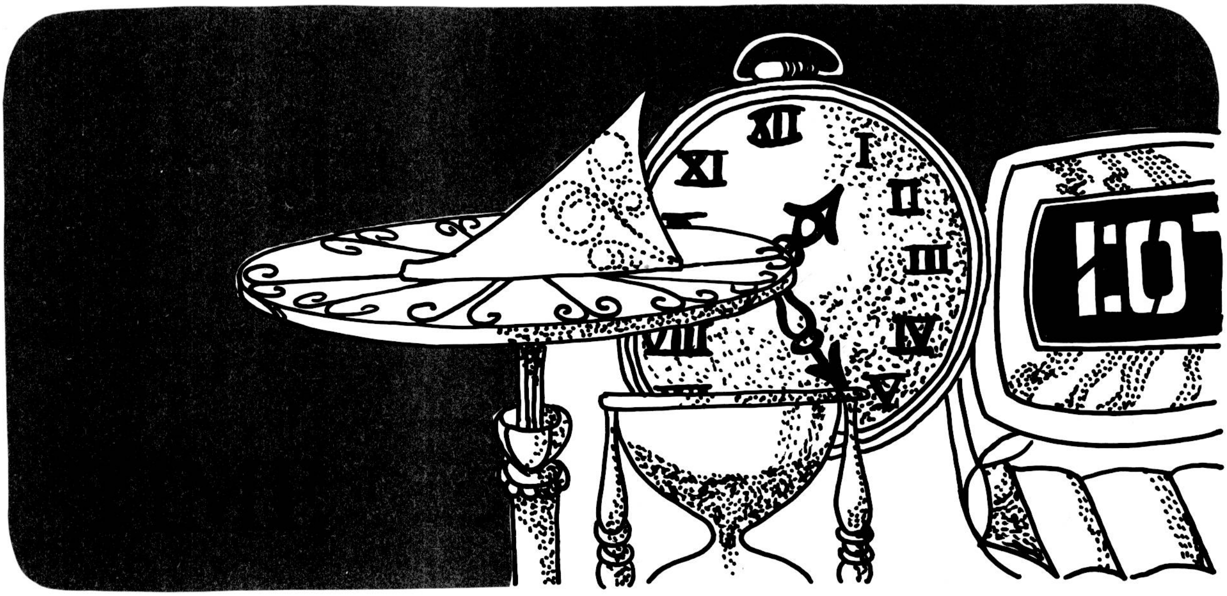
The first section of this text contains the tools of trade, so to speak. Your experience in chemical science, like every experiment, can be organized according to

Purpose
Materials needed
Procedure
Data and Calculations
Conclusion

The purpose or reason for your investigation of this chemical world will become clear to you as you study and question your way through Part I. During this part of your experience with chemical science you will also become familiar with the materials needed to measure and analyze what lies ahead.

After that, who knows where your scientific procedures will lead you . . . .

1

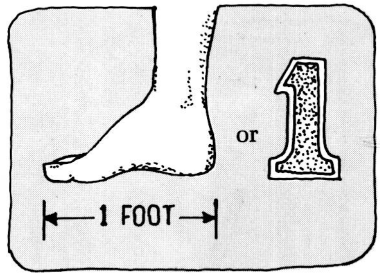


1.1
THE NEED FOR MEASUREMENT: Reading the Labels

Chemistry is an adventure into the mysteries of matter. The chemist is a person who investigates the various kinds of matter that make up the universe. Such an investigation necessarily involves classifying and measuring matter in a way that can be understood by all who wish to join the chemist in these explorations. The basic measurements required for the study of matter include time, length, mass, volume, and temperature.

A **system of measures** is developed when those who are interested agree to adopt a particular unit of time, length, temperature, and so on, as a standard. This standard unit is identified by a *number* and a *label*. For example, when people used their bodies to measure length, one foot was a standard unit of length. *One foot* creates a mental picture far different from the number *one*.

Systems for the measurement of matter have changed as the tools for measuring matter have changed. However, any system of measures is useful only to those who become accustomed to reading the labels.



1.2
UNITS OF TIME:
Marking Time

Give one reason for the invention of more precise instruments for measuring time.

How old are you? This is not the opening line for a commercial about vitamins, cucumber cream, or bee pollen tablets that will keep you forever young. How old are you? This is a simple question, which you might answer with a number and perhaps with a label to go with the number. When they say that "life begins at forty," the forty, of course, refers to years. Forty years is a measurement of the time that has passed since "they" were born. Whether you are twenty or forty, your age is measured by the number of times you have lived through the period of time called one year.

One year, therefore, is a defined amount of time which we have adopted as a **standard unit of time**. One year is a unit of time because everyone now agrees that this amount of time means the same to all kinds of people, babies and senior citizens alike.

The dictionary defines *time* as a period during which something exists, happens, etc. Since no one can see time, its passage can be observed only by relating time to something that can be seen. In the pages of history we find that our early ancestors noted the passage of time in relation to the sun, the moon, and the seasons. People who depended upon the earth and its seasons would certainly have noticed natural patterns that were repeated over and over again. In the tropics there were rainy seasons, in colder regions there were regularly occurring periods of snow, and in various places new crops and migrating birds appeared time after time with fairly regular amounts of time between appearances. Although primitive men did not call these time intervals by the names we use, that is, spring, summer, fall, and winter, they did observe that the cycle of seasons took just about the same amount of time to repeat itself.

Several ancient monuments indicate that people of early times were aware of what we now call the year. One of these monuments is Stonehenge, a circular arrangement of large stones