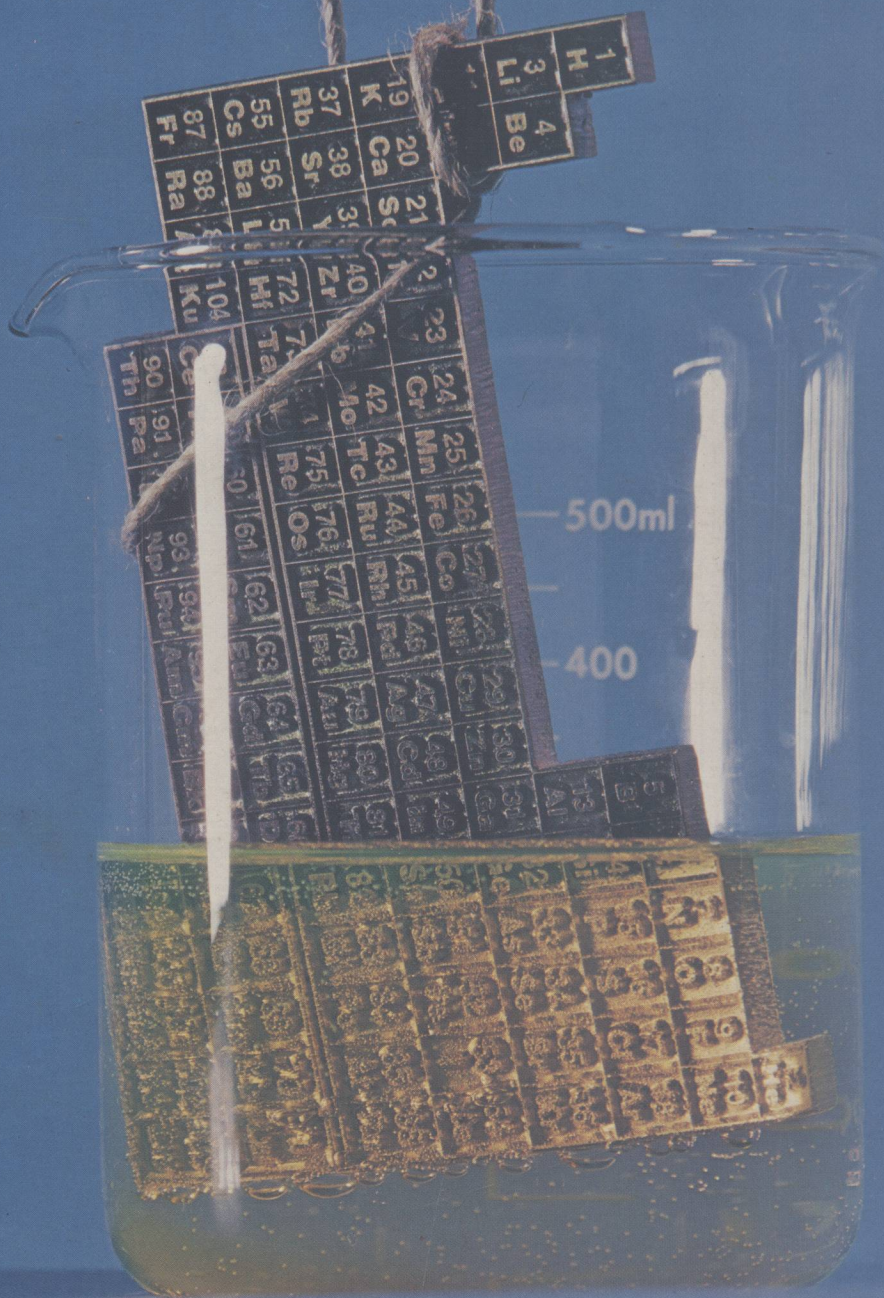


CHEMISTRY A First Course

Jacqueline I. Kroschwitz
Melvin Winokur



8051620

CHEMISTRY A First Course

Jacqueline I. Kroschwitz

Kean College of New Jersey

Melvin Winokur

Bloomfield College



E8051620

McGraw-Hill Book Company

New York St. Louis San Francisco Auckland

Bogotá Hamburg Johannesburg London Madrid

Mexico Montreal New Delhi Panama

Paris São Paulo Singapore

Sydney Tokyo

Toronto

Library of Congress Cataloging in Publication Data

Kroschwitz, Jacqueline I.
Chemistry, a first course.

Bibliography: p.
Includes index.

1. Chemistry. I. Winokur, Melvin, joint author.

II. Title.

QD31.2.K76 540 79-21461

ISBN 0-07-035531-2

CHEMISTRY
A First Course

Copyright © 1980 by McGraw-Hill, Inc. All rights reserved.
Printed in the United States of America. No part of this
publication may be reproduced, stored in a retrieval system,
or transmitted, in any form or by any means, electronic,
mechanical, photocopying, recording, or otherwise, without
the prior written permission of the publisher.

1 2 3 4 5 6 7 8 9 0 VHVH 8 9 8 7 6 5 4 3 2 1 0

This book was set in Century Expanded by York Graphic
Services, Inc.

The editors were Donald C. Jackson, Jay Ricci, and
James S. Amar;

the designer was Ben Kann;

the production supervisor was Dennis J. Conroy.

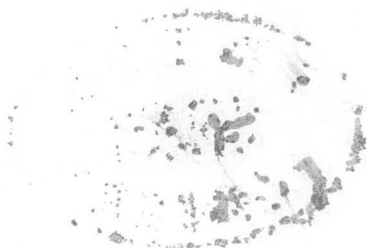
The drawings were done by J & R Services, Inc.

Von Hoffmann Press, Inc., was printer and binder.

CHEMISTRY
A First Course

McGraw-Hill Series in Chemistry
David L. Adams, Educational Consultant

Burgoyne A Short Course in Organic Chemistry
Companion Chemical Bonding
Compton Inside Chemistry
Durst and Gokel Experimental Organic Chemistry
Kroschwitz and Winokur Chemistry: A First Course
Pine, Hendrickson, Cram, and Hammond Organic Chemistry
Roach and Leddy Basic College Chemistry
Russell General Chemistry
Sienko and Plane Chemistry: Principles and Applications
Waser, Trueblood, and Knobler Chem One



to Rose, Irene, and Jack

Preface

"To teach is to learn." In writing this book we have attempted to apply the valuable lessons which our students have generously supplied as we have tried (with some success we think) to teach them the fundamental concepts of chemistry. Perhaps the most valuable lesson we have learned is that beginning chemistry students simply do not possess certain knowledge and reasoning skills which their science instructors generally take for granted. In this text, aimed primarily at the preparatory-level chemistry course, we take nothing for granted, neither prior scientific knowledge nor prior experience in deduction.

As we approached each topic our aim was to offer complete, logical explanations which include all necessary steps in the deductive reasoning process, rather than assuming that the student already has the ability to make deductive leaps. This approach gives students the opportunity to glimpse the complete development of scientific thought, which is usually not their natural way of thinking, and to develop their own reasoning skills as they explore increasingly complex phenomena.

We hope that students might enjoy their study of chemistry despite the fact that many are captives of a science course requirement. To this end we have used a conversational tone, a few anthropomorphic explanations, and occasionally introduced humor into some illustrations. Also, we encourage student visualization of microscopic phenomena both because such imagery is a valuable scientific skill and because it is fun.

As a convenience and learning aid, and in order to reinforce concepts and encourage necessary review, we frequently refer students to previous sections needed as a foundation for understanding the topic at hand. Cross-referencing is also used to inform students of "coming attractions" in subsequent chapters. Other convenient features and learning aids are

Sample Exercises are very carefully worked out in stepwise detail using the *Unit Conversion Method* wherever possible and appropriate. Sample Exercises are supplied copiously.

Problems frequently immediately follow Sample Exercises within the chapter so that the student can test his or her understanding of the concept explained. At the end of each chapter there are *numerous problems at varying levels* so that students can reach the limits of their own capacities.

Stepwise Procedural Rules or guidelines are provided for significant manipulations; for example, see "Guidelines for writing Lewis structures" in Section 10.10.

Tables are used extensively to organize and summarize information. *Illustrations* are an integral part of the explanations.

Summaries of the major points addressed conclude each chapter.

Chapter Accomplishments provide the student with the learning objectives of each chapter.

Math skills are given the status and full treatment of a chapter.

The usefulness of the *periodic table* is stressed and reiterated.

An entire chapter is devoted to the *mole concept*.

Selected answers to problems appear in Appendix 3.

Defined words are italicized in the index for ready location.

A preliminary edition of this text has been class tested and the responses of our students seem to suggest we have succeeded in writing a truly student-oriented book. Students describe the text as "self-teaching." In short, preparatory level students are able to read and understand this book and many report enjoying it in parts.

The order in which we have chosen to arrange topics is the one we have found to be most successful in teaching students with no prior experience. This scheme proceeds gradually from material which can be dealt with on a concrete reasoning level to material that demands abstract, formal thinking. Laboratory work is more easily correlated with this order of topics because nomenclature, formula and equation writing, and stoichiometry are introduced early. We have prepared an accompanying Laboratory Manual in which each experiment is related to a specific text section.

For those who prefer to introduce electronic structure and bonding at an earlier juncture than we have, there would be no problem, from the viewpoint of readability, if Chapter 9 (Electronic Structure of the Atom) were covered after Chapter 4, and Chapter 10 (Chemical Bonding) after Chapter 5. However, obviously we strongly recommend the order of topics presented. An Instructors Manual is available and provides additional comments on each chapter, suggested accompanying laboratory experiments, answers to all problems, and sample examinations for each chapter.

More material is included in this book than can be covered reasonably in one semester. The core curriculum as preparation for general chemistry would be Chapters 1-11. If time permits, the instructor then has the freedom to choose additional topics based on personal preference. Chapters 12, 13, 14, 17, and 18 stand independently of one another. Chapter 15 (Acids and Bases) relies on material in Chapter 13 (Solutions)

and Chapter 14 (Chemical Equilibrium). Chapter 16 presupposes coverage of Chapter 13.

We earnestly invite your comments and suggestions toward the improvement of this textbook as a learning device.

Acknowledgments We would like to acknowledge and thank the many individuals who helped and encouraged us as we developed this text. First of all, there are the CUNY community college students who were our original inspiration and the Chemistry 110 students (at Bloomfield College) who sustained the inspiration and who used the preliminary edition of this text thoughtfully and offered useful suggestions for improvement. To our colleagues at Kean College and Bloomfield College we offer our gratitude for their being resounding sounding boards. Thanks especially to Bryan Lees, who also shot our photographs, Alice Saylor, and George Luther. We are extremely grateful to our typists, Christina Hermann and Joyce Vogelaar, with their flying fingers and uncanny ability to decipher handwriting (especially that of one of us).

Dr. David Adams of North Shore Community College has read and reviewed the manuscript from its inception and through several revisions, giving detailed and valuable suggestions. Thanks also go to Dave for always believing in us. Jack Healy of Chabot College has been our most flattering reviewer and has prepared an excellent Study Guide as a supplement to this text. We also gratefully acknowledge the suggestions of our other chemist-reviewers, William G. Nickels, Schoolcraft College; Donald B. Fraser, Essex County College; and Vincent J. Sollimo, Burlington County College. Special thanks go to our nonchemist-reviewer and editor, Marie Hodge, who corrected us, taught us, and entertained us with her droll, marginal comments, or should it be droll comments in the margin?

We also thank the editors and other production staff at McGraw-Hill, especially Donald Jackson who initiated this project and with whom we shared some fine inspirational meals. Thanks also to James Amar who gave such careful attention to all details as the manuscript became a book.

Last, but not least, we acknowledge the indulgence of our family and friends from whom we have been reclusive of late.

*Jacqueline I. Kroschwitz
Melvin Winokur*

To the Student

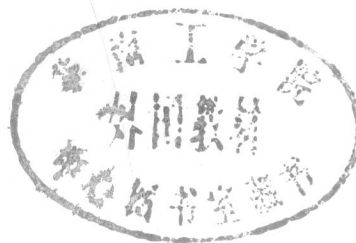
To successfully learn chemistry you cannot just read a chemistry book. You must *interact* with your book. Answer or at least ponder the questions that are asked rhetorically. Do the problems that are there to test your understanding. Ask questions.

You must be an *active* participant in your chemical education. Think, write, and question while you read. Go to it!

Jacqueline I. Kroschwitz

Melvin Winokur

Contents



Preface XV

To the Student XIX

Chapter 1

Classification of matter 1

- 1.1 Introduction 2
- 1.2 Classification of matter by physical state 2
- 1.3 Changes in state 3
- 1.4 Scientific method 5
- 1.5 Pure substances versus mixtures 5
- 1.6 Subdivisions of pure substances 7
- 1.7 Physical versus chemical change 9
- 1.8 Physical and chemical properties 11
- 1.9 Elements, compounds, and mixtures 12
- 1.10 Homogeneous versus heterogeneous matter 18
- 1.11 Chemical language 19
- 1.12 Energy 21
- Summary 22
- Chapter accomplishments 23
- Problems 24

Chapter 2

Math skills 27

- 2.1 Introduction 28
- 2.2 Signed numbers 28
- 2.3 Fractions 31
- 2.4 Scientific notation 34
- 2.5 Algebraic manipulations 42
- 2.6 Percentage calculations 44
- 2.7 Direct and inverse proportionality 46
- Summary 48
- Chapter accomplishments 49
- Problems 50

Chapter 3

Measurement 53

- 3.1 What is measurement? 54
- 3.2 The metric system 54
- 3.3 Unit conversion 60
- 3.4 Density 64
- 3.5 Temperature 68

3.6	Units of energy	71
3.7	What are significant figures?	73
3.8	Rounding off	76
3.9	Sig figs in calculations	76
	Summary	79
	Chapter accomplishments	80
	Problems	81

Chapter 4

	Elements and their invisible structure	85
4.1	Atomic theory	86
4.2	Picturing atoms and elements	87
4.3	Inside the atom	88
4.4	Atomic number	90
4.5	Isotopes	91
4.6	Mass number	92
4.7	Relative atomic mass	95
4.8	Average atomic weight	96
4.9	Periodic table	97
4.10	Elemental makeup	97
4.11	Charged atoms	100
	Summary	102
	Chapter accomplishments	103
	Problems	104

Chapter 5

	Compounds: Classification, formulas, and nomenclature	107
5.1	Law of definite composition	108
5.2	Molecular versus ionic compounds	111
5.3	Ionic charges	113
5.4	Polyatomic ions	115
5.5	Formulas for ionic compounds	116
5.6	Formulas for molecular compounds	120
5.7	Nomenclature	120
5.8	Molecular weight and formula weight	127
5.9	Percentage composition	129
	Summary	131
	Chapter accomplishments	131
	Problems	132

Chapter 6

	The mole concept	135
6.1	Individuals versus "packages"	136
6.2	Relative weights	136
6.3	How many particles are in a mole?	138
6.4	Chemical formulas revisited	140
6.5	Moles of compounds	141

6.6	Gram-mole-particle conversions	143
6.7	Moles within moles	145
6.8	Empirical formulas defined	147
6.9	Calculation of empirical formulas	148
6.10	Molecular formulas	151
	Summary	153
	Chapter accomplishments	154
	Problems	155

Chapter 7

Chemical reactions	158
7.1	What is a reaction? 160
7.2	Chemical equations 160
7.3	The meaning of balanced equations 161
7.4	Balancing equations 163
7.5	Use correct formulas 167
7.6	Helpful hints 168
7.7	Special symbols 169
7.8	Types of reactions 171
	Summary 179
	Chapter accomplishments 180
	Problems 181

Chapter 8

Stoichiometry	183
8.1	What is stoichiometry? 184
8.2	Molar interpretation of the balanced equation 184
8.3	"Equalities" and conversion factors from chemical equations 186
8.4	Mole-mole conversions 187
8.5	Gram-mole, mole-gram conversions 189
8.6	Gram-gram conversions 190
8.7	Conversions summarized 192
8.8	Limiting reactant 193
8.9	Theoretical yield 198
8.10	Actual yield 199
8.11	Percentage yield 199
8.12	Heat as a reactant or product 199
8.13	A page from a laboratory notebook 201
	Summary 202
	Chapter accomplishments 202
	Problems 204

Chapter 9

Electronic structure of the atom	207
9.1	Energy revisited 208
9.2	Concept of minimum energy 208
9.3	Minimum energy in the atom 209

CONTENTS

9.4	Electron configuration notation	218
9.5	Quantum numbers	220
9.6	Periodic table	226
9.7	Lewis electron dot structure	229
9.8	Periodic trends	229
	Summary	232
	Chapter accomplishments	233
	Problems	234

Chapter 10

Chemical bonding 237

10.1	Introduction	238
10.2	How can atoms achieve lower energy states?	238
10.3	Ionization energy revisited	239
10.4	Electron affinity	242
10.5	Electron transfer	243
10.6	The nature of the ionic bond	245
10.7	Why are there two types of compounds?	247
10.8	Diatomic molecules	247
10.9	The nature of the covalent bond	249
10.10	Lewis electron dot formulas	251
10.11	Coordinate covalent bonds	257
10.12	Electronegativity and polarity	259
10.13	Covalent, polar covalent, and ionic bonds	262
10.14	Molecular shape	262
	Summary	267
	Chapter accomplishments	268
	Problems	270

Chapter 11

Gases 273

11.1	Introduction	274
11.2	n, T, and V, measurements	276
11.3	Pressure	277
11.4	Dalton's law of partial pressures	281
11.5	Boyle's law	283
11.6	Charles' law	285
11.7	Combined gas laws	289
11.8	Standard temperature and pressure	294
11.9	Avogadro's hypothesis	295
11.10	Molar gas volume	297
11.11	Ideal gas law	299
11.12	Kinetic theory of gases	303
11.13	Gas stoichiometry	305
	Summary	308
	Chapter accomplishments	308
	Problems	310

Chapter 12

Liquids and solids	313
12.1 Introduction	314
12.2 Molecular polarity	314
12.3 Intermolecular forces	315
12.4 Condensation of gases	320
12.5 A model of liquids and solids	321
12.6 Physical properties of liquids	321
12.7 Crystalline versus amorphous solids	327
12.8 Classes of crystalline solids	328
12.9 Properties of solids	331
12.10 Heat changes and phase changes	333
Summary	335
Chapter accomplishments	335
Problems	337

Chapter 13

Solutions	341
13.1 Solutions defined	342
13.2 Solution terminology	343
13.3 Solution formation	347
13.4 Factors influencing solubility	351
13.5 Concentration expressions	353
13.6 Dilution	360
13.7 Electrolytes	362
13.8 Strong and weak electrolytes versus nonelectrolytes	364
13.9 Acids	364
13.10 Particles in solution	365
13.11 Ionic equations	365
13.12 Using the solubility rules	367
13.13 Predicting the occurrence of reactions	368
13.14 Solution stoichiometry	371
Summary	373
Chapter accomplishments	374
Problems	376

Chapter 14

Chemical equilibrium	379
14.1 Introduction: reversible reactions	380
14.2 Rates of reaction	382
14.3 Equilibrium constant	383
14.4 Rules for writing K_{eq}	385
14.5 Interpreting the value of K_{eq}	387
14.6 Le Châtelier's principle	389
14.7 "Going to completion"	392
Summary	394
Chapter accomplishments	394
Problems	395

Chapter 15

Acids and bases	399
15.1 Introduction	400
15.2 The Arrhenius definition	402
15.3 Brønsted-Lowry definition	402
15.4 Acid and base strength	404
15.5 Acid-base reactions	407
15.6 Ionization of water	409
15.7 pH	411
15.8 Measurement of pH	414
15.9 Neutralization	416
15.10 Titration	417
Summary	420
Chapter accomplishments	421
Problems	422

Chapter 16

Oxidation-reduction	425
16.1 Introduction	426
16.2 Electron-transfer reactions	426
16.3 Writing half-reactions	427
16.4 Oxidation numbers	429
16.5 Definitions revisited	432
16.6 Balancing redox reactions	433
16.7 Basic redox reactions	440
16.8 An alternate method	442
16.9 Activity series revisited	444
16.10 Use of redox	445
16.11 Redox in the body	450
Summary	451
Chapter accomplishments	451
Problems	453

Chapter 17

Nuclear chemistry	455
17.1 Introduction	456
17.2 The nucleus revisited	456
17.3 Radioactivity	457
17.4 Properties of α , β , and λ radiation	458
17.5 Ionizing radiation	459
17.6 Detection devices	460
17.7 Nuclear reaction	462
17.8 Radioactive decay series	465
17.9 Half-life, $t_{1/2}$	465
17.10 Uses of radioisotopes	469
17.11 Nuclear bombardment	471
17.12 Nuclear fission	473
17.13 Nuclear fusion	474

Summary	474
Chapter accomplishments	475
Problems	476

Chapter 18

Organic and biological molecules	479
18.1 Introduction	480
18.2 Bonding in carbon compounds	480
18.3 Geometry of carbon compounds	481
18.4 Functional group concept	482
18.5 Isomerism	484
18.6 Biological molecules	486
18.7 Hydrocarbons	487
18.8 Organic compounds containing oxygen	492
18.9 Organic compounds containing nitrogen	499
18.10 Biochemical reactions	502
Summary	504
Chapter accomplishments	505
Problems	506

Appendixes

1 Basic arithmetic review	513
2 Vapor pressure of water at various temperatures	518
3 Answers to selected problems	519

Index	547
--------------	-----