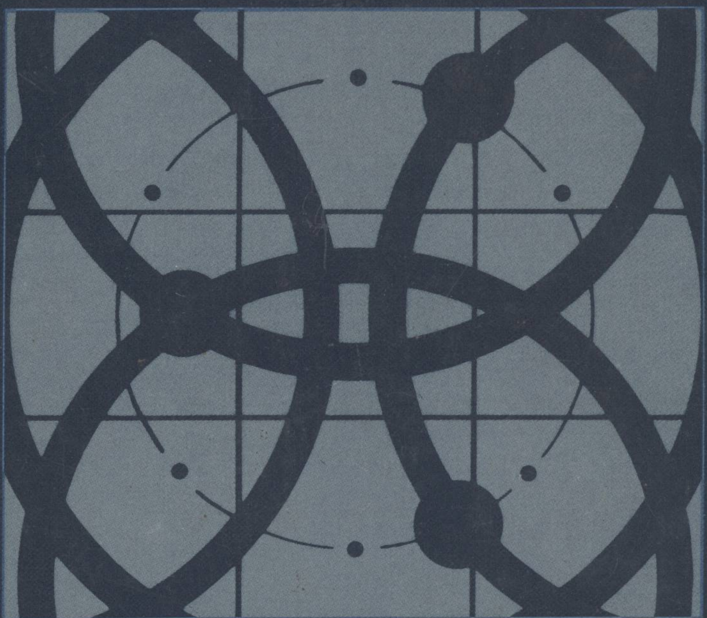
Understanding Chemistry



A Preparatory Course

J. Dudley Herron

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Understanding Chemistry: A Preparatory Course

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Purdue University

Random House New York

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Understanding Chemistry

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To
PETER PRESCOTT,
the person responsible for me writing this book,
DEBORAH CONNOR,
the person responsible for the book being what it is,
and my wife,
JOYCE,
the person who kept me sane during the process.

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Preface

When I began teaching a course for underprepared students in 1973, I had no idea that I would write a book for the course. Rather, I wanted to learn more about difficulties students have with chemistry. I did, and this book is an attempt to overcome them.

There are many reasons why students fail chemistry. Apart from lack of motivation, poor study habits, difficulty adjusting to life away from home, and diversions resulting from newly-found love—problems that plague college students in every subject—chemistry presents students with special problems.

Chemistry relies on reasoning that normally develops in early adolescence, but does not develop in some individuals until later in life. Without experiences to encourage the development of this reasoning, it may not develop at all. Some students haven't had those experiences.

We compare things quantitatively in two ways: we say that one stick is 3 cm longer than another and we say that a third stick is twice the length of the first. We may recognize an equality between two sticks that differ in length by 3 cm and two people who differ in length by 3 cm. Similarly, we may recognize an equality between two sticks, one of which is twice the length of the other, and two people, one of whom is twice as tall as the other. Understanding the first kind of equality develops early; however, the proportional relationship implied by the latter equality is not understood until early adolescence or later. Results from the National Assessment of Educational Progress suggest that it is understood by no more than half of the adults in this country. And yet proportional reasoning is involved in scores of important concepts in chemistry. Therefore, leading students to understand proportions is a necessary condition for their understanding of chemistry.

From Chapter 1, where students use proportional relationships to convert from one measurement to another, until Chapter 12, where students deal with direct and inverse proportions in a formal sense, a concerted effort has been made to make proportions sensible.

A second problem in chemistry is that so much of our reasoning is done using concepts that have no concrete reality. Until one can visualize atoms and molecules, it is doubtful that processes like melting, boiling, dissolving, or reacting can mean what they mean to a chemist. Nor can reaction kinetics, dynamic equilibrium, or thermodynamics be understood to explain chemical processes until one can think about unseen, microscopic particles.

Understanding begins with direct experience. Only gradually do we learn to invent abstract models to explain and organize our experience. Until early adolescence, all of our reasoning is in terms of direct experience. We have no difficulty with "if . . . then" statements such as, "If you drop the glass, then it will break," because such statements represent direct extrapolation from past experience. However, statements such as, "An ideal gas would have zero volume at zero temperature," are not easily understood because they depend on "if . . . then" relationships that are hypothesized and that contradict experience. Even after we learn to think in hypothetical terms, we have difficulty understanding relationships that are new and unfamiliar.

If students are to understand chemistry, they must begin with ideas that can be developed from direct experience, and move gradually to those ideas that rely on imagination. Consequently, an understanding of atoms is developed gradually, and the more abstract and elusive notions are not introduced until the end of this book. This has required an adjustment in the standard treatment of some topics, most notably a resurrection of the use of combining numbers when writing formulas is introduced. Many chemists may view such a move as regressive. If you are among them, I hope you will take time to read the arguments for this treatment presented in the instructor's manual. In case you are not convinced by those arguments, you are also told how to sequence chapters for a more traditional approach.

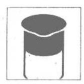
Students differ in aptitude for chemistry. We all know that, but we do not all view aptitude in the same way. Traditionally, aptitude has been viewed as a capacity for learning; those with high aptitude can learn a lot, those with low aptitude only a little. An alternative view of aptitude considers the time required for a person to learn a given amount of material; those with high aptitude learn in a short period of time, those with low aptitude take longer. In an average classroom students with the lowest aptitude require up to five times as much time and effort as students with the highest aptitude, in order for both groups to reach the same level of understanding.

Most texts written for preparatory courses appear to ignore the fact that students in those courses are likely to require more time studying an idea in order to understand it. Typically, texts written for a preparatory course present all of the ideas found in an ordinary introductory text but deal with them superficially. Students with low aptitude in chemistry are almost forced to memorize words, formulas, and equations without understanding what they mean. When students get to subsequent courses where they are asked to apply concepts and principles, they are doomed to failure.

This book takes a different approach. Fewer ideas are introduced, but those ideas are treated extensively so that the student can understand the concepts and principles at a level that allows application in later courses. Even so, students and instructors must recognize that some students will need far more study and practice than others. To succeed there must be a mutual faith that students can understand chemistry, and a realization that the time and energy required for understanding may be extensive.

In addition to the major pedagogical considerations just mentioned, you will find other characteristics of this book that will help students learn.

- Examples are presented in a programmed text format that encourages students to think through the example rather than reading it passively.
- Questions and problems are inserted throughout the text to encourage students to practice new skills immediately after they are introduced. Solutions are given at the end of each chapter so that students can check their results.
- Hundreds of additional questions are given at the end of the chapters for those who need additional practice. More challenging problems are identified as such.
- Objectives are given at the beginning of each chapter to help students identify important skills and ideas to be learned. The instructor can add to or delete from these lists according to the requirements of a particular course.
- Word lists are provided to help students identify key concepts.
- Each chapter ends with a summary that provides a review of important concepts and principles.
- Each chapter contains an article from a periodical, which can be used to show applications of ideas that students are learning, to provide a historical perspective, to introduce unresolved social issues related to science, or to simply inform students about periodical literature that can be used to continue their chemical education.
- The text is accompanied by a study guide and a laboratory manual, which were developed along with the text and are compatible with it.
- There is an instructor's manual that provides more than answers to homework. Sample tests with item analysis data, suggestions for demonstrations, suggestions for sequencing, and discussions of research on teaching are included. Many of the comments are keyed to specific sections in the text, and symbols such as 

and  found in the margin of the text indicate when specific suggestions are found in the manual.

I am grateful to have shared the wisdom of those who reviewed draft manuscripts of *Understanding Chemistry*. Richard Lungstrom of American River College, George Goth of the College of San Mateo, Norman Rose of Portland State University, Tamar Susskind of Oakland Community College, Lucy Pryde of Southwestern College, Jeff Davis of the University of South Florida, and Lynn James of the University of Northern Colorado all made thoughtful suggestions. Those suggestions were incorporated to the extent that it was possible to do so in a book of limited length and consistent philosophy.

Betsy Kean at the University of Wisconsin/Madison and Jane Copes of Hamline University deserve special thanks. Their task of writing a study guide and laboratory manual while the text was being reviewed and rewritten was a difficult

one. Not only did they produce outstanding ancillary materials, but they made significant contributions to the text as well.

To Keith, Alan, and Tom who took photographs and worked problems; to the secretaries who typed various drafts of the manuscript; to the editors and editorial assistants who struggled through differences in philosophy and style; I offer my sincere thanks and humble apologies.

A final word of appreciation must go to my wife, Joyce. She didn't type, collate, check problems, or otherwise participate in the writing of this book. What she did was endure long hours without a husband, tolerate absent stares when he was present, and keep our house a home while the book was being written. Hers was the most important task of all.

JDH
West Lafayette, IN
August 1980

A Word to Students

It is important that students and teachers have an understanding from the start. It saves headaches later on. With this in mind, I want to tell you what this book is designed to do and how you should use it.

This book is a *preparation* for general chemistry. Students get into a course like this for several reasons. Most are in the course because chemistry is required in their major and they haven't had high school chemistry. Some had chemistry long ago and fear they have forgotten (or just want to take things slower in the beginning). For all of these students, *the purpose of this course is to prepare you for success in an introductory college chemistry course.*

What is it that will make you successful? Do you need to memorize facts and solve problems or can you learn to beat the system? A little bit of each, I expect.

Students have trouble with chemistry for several reasons. One problem is mathematics. It is not so much a problem of basic math skills, although this may be a problem. It is usually difficulty with *mathematical reasoning* that is the obstacle. If you are to succeed in chemistry, you need some preparation in mathematical reasoning, and one of the major goals of this book is to provide it.

Another difficulty that students have with chemistry is with reading. Now I know that you think this doesn't apply to you, but you may be surprised. Reading a chemistry book isn't like reading a novel. It takes different skills and you need to develop them if you haven't done so already. This book will help you understand sentences like "$Pb + PbO_2 + 2\ H_2SO_4 \rightarrow 2\ PbSO_4 + 2\ H_2O$" and "$PV = nRT$" as well as the ones you have been reading.

Some students *can* do math and *can* read, but don't. They have poor study habits and fail because they are unwilling to believe that it is necessary to change those habits. They got by in high school and they expect to repeat the performance now. Perhaps they are right. Some students *do* get through chemistry with poor study habits. Most don't.

If your study habits need improvement, ask your instructor where you can get good advice. Then follow the advice when you get it. The following are suggestions that will help you study this book.

a) Schedule your study time. You have a class schedule and most of you feel obligated to meet your classes. You need to be just as disciplined about your study. Look at your class schedule and write in times that you will study chemistry.

Be realistic. Some people have exceptional ability in music, some appear to be natural athletes, and others have great aptitude in science. Each of us is able to do a great deal in all of these areas, but those of us with low aptitude in a subject need *three to five times* as much time to learn as those with a high aptitude in the subject. The *average* college student should spend two hours studying for every hour spent in class. *Schedule this much study time now.* After a few weeks, add more study hours to your schedule if they are needed.

b) One of the best times to study lecture material is immediately after class. If you can't study because of another class, make a habit of reviewing what was covered as you walk to your next class.

c) Read assigned text material *before* it is treated in lecture. As you read, write down questions in the margin of the book or underline confusing points. When you attend class, listen for clarification of ideas that you did not understand from the reading.

d) Work practice problems *immediately* after you are taught how to do them. If you wait a day to practice new skills, you will forget details and work problems incorrectly, or waste time going back to learn the details again. Immediate practice reinforces ideas and helps you to remember them.

e) Don't study a lot of chemistry at one sitting. For most students, one hour at a time is enough. Space your practice. One hour a day, five days a week, will be much more effective than five hours on the weekend.

f) Schedule for variety. If you *must* study several hours at a time, separate study on subjects like math and chemistry from work on English or social studies. Start with the things that you find *least* interesting and take an occasional break for physical activity.

g) Cram sessions before a major exam are not very effective. If you keep up with your work every day, a short review just before the exam is all you need. Take the night off and relax. Get a good night's sleep. You will be alert for the exam and you will make a higher score.

h) You can't relax before an exam if you know you haven't learned the material as you go along. As you read a textbook, make a habit of reading each heading and guessing what the section will be about. At the end of each section or two, restate the major ideas in your own words. (These major ideas, stated in your own words, are excellent for your last-minute review.) At the end of each chapter, review the objectives given in the beginning. Be sure you can do all of them.

Good study habits are necessary but not sufficient for success. Here are other suggestions that will help you.

Don't be bashful. Students don't like to ask dumb questions. Consequently they sit through lecture without understanding what is being said. They don't want others to know how little they know.

Keep in mind that all of us are born ignorant. People who are afraid to ask questions are likely to stay ignorant. Can you afford to protect your ego at the expense of never understanding?

Memorizing versus Thinking. Memorizing is an important part of any education. Certain information is used over and over and must be remembered. However, you should not place too much emphasis on memorization. Some students believe that all they need to do is memorize what they are told and be ready to recall that

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information when test time rolls around. This isn't true. You must be able to *use* information, to apply facts and skills to situations that are different from those given in class.

Students think they understand when they do not. Follow these suggestions to see if *you* understand.

a) State what you have read or heard in your own words. If you can't, you probably don't understand.

b) Think of an example, illustration, or application of the idea you have just learned.

c) Make up your own test questions about the material.

d) Explain the idea to someone who doesn't know it.

Overlearn basic skills. Practice. I can illustrate what I mean by telling you about a student in my class. The student did poorly on examinations because he made many math errors. When I pointed this out, he replied that he understood the math and that he had always done well in math class. I gave the student a diagnostic math test and he made several errors. When I pointed this out, he looked over the problems and said, "Oh, I see where I made the error here . . . I really know how to do that . . . I just made a silly mistake."

He really did understand the math. The problem was that he could only work the problems *when he had plenty of time and had nothing else to think about.* On a test he did not have all the time he wanted and had *many* other things to think about. As he tried to remember how to calculate molecular weight, what was meant by mole, the symbol of copper, and how to determine combining numbers, he had too many things on his mind to really think about the math that he was doing. As a result, he made mistakes.

Skills that are used repeatedly—basic math skills, units of metric measurement, the mole concept, atomic and molecular weights, and formula writing, for example—must be practiced to the point where you can almost do them in your sleep. If you do not, you will spend so much mental energy on these fundamental ideas that you will not be able to attend to *new* ideas that require the applications of these basic skills.

Be objective. Many students do poorly because they are unrealistic. Some students have an unrealisticly high opinion of their ability and background. When they get poor scores on a quiz or don't understand what they read, they attribute their lack of success to poorly written test questions or a poorly written text. This *may* be true, but if others in the class are understanding and doing well on the quiz, it probably means that you are missing something the professor considers important. Find out what it is, and make the effort to overcome the problem.

Other students have an unrealistically low opinion of their ability and background. When they get poor scores on a quiz or don't understand what they read, they decide that they are stupid and can't understand chemistry. Usually the problem is that the professor is using terms, symbols, and reasoning that is unfamiliar to the student. When this happens, you *can* learn, but it may require more time and more effort. The key to success is having faith in your ability, finding out what information you are missing, and not giving up the first time you have difficulty.

I honestly believe that every student who is reading this book *can* understand chemistry, even though the time required for some will be great. If *you* share that faith and have the time to devote to study, this book will provide the background you need to succeed in college chemistry.

Good luck!

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