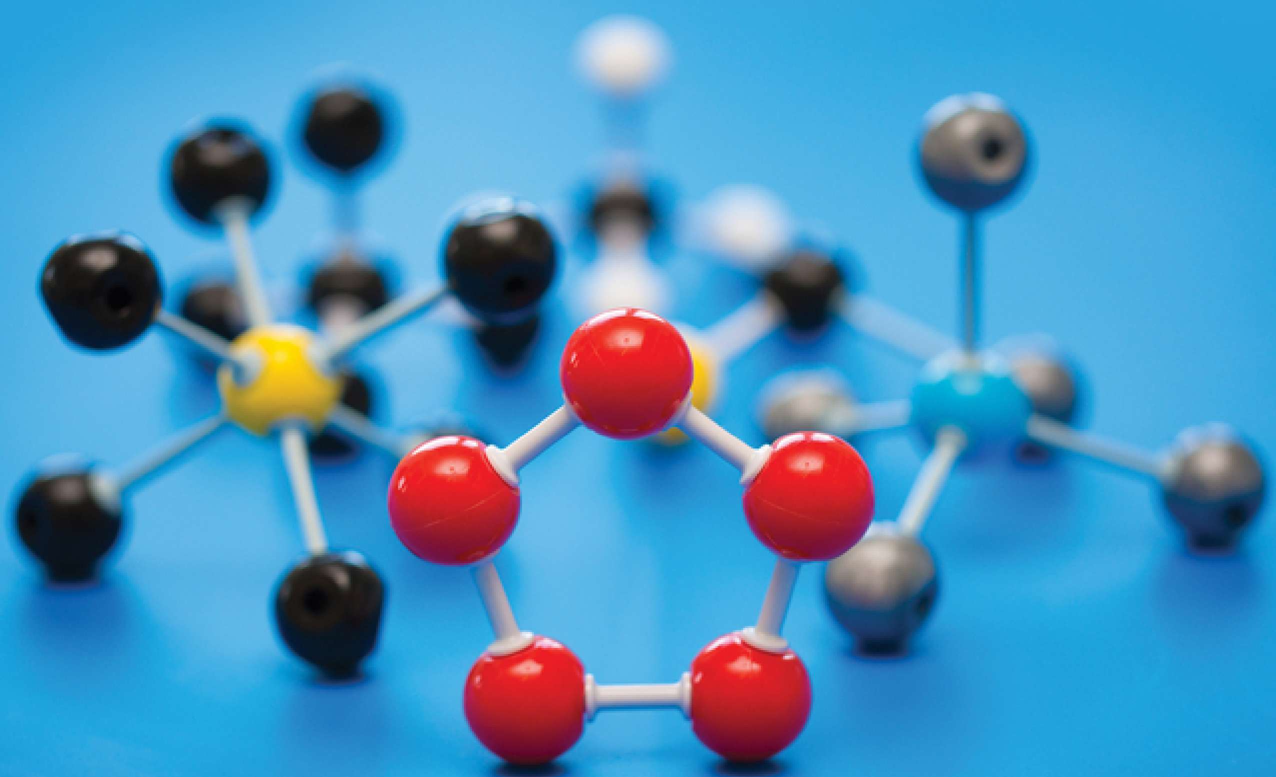
A SELF-TEACHING GUIDE

CHEMISTRY

THIRD EDITION



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Chemistry
A Self-Teaching Guide

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Chemistry

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Third Edition

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THIRD EDITION

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Preface

In our years of teaching the fundamental concepts of chemistry to students with widely divergent backgrounds, levels of preparation, career goals, and motivation, the most frequently asked question by those students has been, "Do you have something that I can study on my own?" followed immediately by, "I need some other review material" or "This is the first time I have encountered this stuff, so I need to start from scratch" or "It has been 3 years since my high school chemistry course. I need something to refresh my memory."

This book has been written to meet such needs. It can stand alone as a "first look" at chemistry or may be used as a supplement to any of the many excellent textbooks or methods of instruction currently in use. The material presumes no previous exposure to chemistry and requires only simple algebra.

There are no secrets. Each chapter includes an introductory statement, a list of objectives, and the main teaching section, which consists of frames of tutorial material with constant practice exercises. Each chapter closes with a self-test. You can use this self-test to assess whether you have mastered the chapter well enough to continue and to identify weaknesses that require additional study. Finally, some chapters include an end-of-chapter or transitional story connecting the material to a relevant topic in chemistry.

The topics presented are usually covered early in a general introductory course. The third edition also contains a new chapter on organic chemistry consistent with the material found in general chemistry textbooks. We have minimized "heavy" theoretical discussions, while emphasizing descriptive and practical concepts. There is enough theoretical explanation to provide a basis for understanding the material but not so much that you will get bogged down trying to work through the book.

Introduction

Chemistry: A Self Teaching Guide is unlike the ordinary textbook. It is designed to be completely self-instructional, requiring no chemistry background. The previous editions have been thoroughly tested as a successful means for self-instruction in chemistry for thousands of students. The book can also be used as a supplementary text for any general chemistry course. Each chapter is divided into objectives, an interactive tutorial study section, a self-test, and test answers.

- *Objectives*. By examining the chapter objectives, you can determine what information is contained in each chapter. If you already know the material, take the self-test at the end of the chapter. Review those questions you missed by checking the frame references given with the answer to each question.
- *Tutorial study frames*. The body of each chapter is divided into numbered frames. Each frame contains new information, a problem, or an example of a concept with one or more questions for you to answer. Answers for the questions in each frame are given immediately below the questions. Years of educational research have proven this method of immediate reinforcement with the correct answer to be the most effective and efficient means of learning for self-instruction. While having the answer just below each question assures immediate feedback to reinforce learning, it also requires discipline on your part to think about the answer before viewing. We suggest using a bookmark such as an index card as you go down each page, covering the answer below while you critically think about the answer or solve a problem. Each question and answer frame is crafted as a small step, like each step on a staircase, designed to lead to a fuller understanding of a concept in chemistry.
- *Self-test*. The self-test at the end of each chapter will help you to determine whether you have mastered the chapter material. After completing the chapter, take the test. Refer back to the chapter only if you need formulas or tables to answer specific questions. Compare your answers with those given immediately following the test. If your answers do not agree with the printed ones, review the appropriate frames cited after each answer.

The authors assume no prerequisites except simple high school algebra. However, each chapter builds upon the information provided in previous chapters, so we recommend that the chapters be covered in sequence.

Although we have tried to make this book as useful as possible to the student, any suggestions for improving future revisions would be appreciated. Please address your comments to:

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Acknowledgments

We wish to thank all those students who used the first two editions and took the time to write to us and to John Wiley & Sons, Inc. to express their gratitude for helping them understand chemistry and successfully complete a required chemistry course. They were high school, nursing school, community college, technical school, and university students of all ages. It is because of them we have written this third edition.

We also wish to thank those faculty who thought enough of the book that they adopted it for classroom use or recommended it as a self-paced, "second opinion" study guide.

We wish to thank our respective universities, all of our editors for all three editions—especially the late Judy V. Wilson, who had the vision for both the entire *Self-Teaching Guide* series as well as this book—and our publisher, John Wiley & Sons. We also thank the Wiley editorial and production staff for their very thorough editorial comments and enthusiastic encouragement during the preparation of this manuscript.

Chad Snyder would like to thank his wife and children for their love and support through this process. Authors Post and Houk likewise wish to thank their families for their encouragement, patience, and support in the development of this book in its current and previous editions.

APPRECIATING THE CONNECTIONS

The history of science and technology is often based upon a series of individual discoveries and historical events which at first seem unconnected, but in hindsight represent a chain of events that building upon one another result in a new discovery or idea. Scientists often describe this as, "We stood upon the shoulders of giants," acknowledging appreciation for their colleagues and forebears who set the groundwork for their discoveries.

This chain of events is also true of much of history. This book grew out of a need to develop self-instruction for a few concepts in chemistry. The initial authors had no plans for a book. They were directly supported and encouraged in developing their self-instructional materials and related research efforts by their university, where they would continue to spend the major part of their academic careers. Thus without the support of that university, this book would not exist.

By historical connection, that university would itself not exist without an idea presented in 1787, the land grant. As the first university in what was then known as the Northwest Territory, the land west of the Ohio River, Ohio University directly stems from the Northwest Ordinance of 1787, one of the primary documents of American history. The ordinance of Congress called for a public university as part of the settlement and eventual statehood of the Northwest Territory stipulating, "Religion, morality and knowledge being necessary to good government and the happiness of mankind, schools and the means of education shall forever be encouraged." That ordinance and that wording form the basis for a large historical landmark displayed at Ohio University's class gateway.

The authors' self-instructional material eventually came to the attention of Judy V. Wilson, who developed the *Self-Teaching Guide* series for publishers John Wiley & Sons. With the book now in its third edition, as you learn about the interesting and fundamental science of chemistry, you may find yourself becoming part of the chain of events. Let the authors and publisher know how this book contributed to your career through your study of chemistry. Wishing you success.

RP, CS, CCH

How to Use This Book

It is important to note that this book should be used as a tutorial. The content is designed to be interactive. Each separate block of information, called a "frame," ends in a question needing an answer or problem to solve. Each question and answer frame is crafted as a small step, like each step on a staircase, designed to lead to a fuller understanding of a concept in chemistry. Although the answer can be found directly below that block of information, that question or problem is for you to answer before going on to read more. Answering the question or solving the problem will require some critical thinking and application of the material just learned. The answer just below the frame will then provide immediate feedback.

That tutorial technique with immediate feedback has been proven to be a very effective means of learning backed by a great deal of research on instruction. Just cover the answer with an index card or bookmark, think about what you have just read, and provide your own answer. Then uncover the printed answer and compare your answer with that of the book. If your answer and the book answer agree, then go on to the next frame of information. If your answer does not agree, reread the frame and try to determine why.

The information presented has been carefully sequenced for step-by-step learning but requires the discipline for you to answer before checking and moving on to each following step or frame. Each frame is built upon preceding frames. Therefore, if the material is new to you, go through the frames in sequence. Skipping ahead will cause you to miss important information or practice.

Thousands of students have successfully learned the principles of chemistry through the proper use of this book. The authors wish you success as you join their ranks.

1 Atomic Structure, Periodic Table, Electronic Structure

There is a *smallest* unit of substance. This smallest unit may be only a single atom or a group of atoms chemically joined together.

This chapter deals with the structure of the atom, which is the very backbone of chemistry. In this chapter we introduce the three basic subatomic particles in an atom, their arrangement in the atom, and the similarities of this arrangement revealed by the position of the elements in the periodic table. A clear understanding of this chapter will give you a sound basis for learning chemistry.

OBJECTIVES

After completing this chapter, you will be able to

- define, describe, or illustrate: proton, neutron, electron, atom, nucleus, atomic number, shell, orbital, subshell, alkali metal, noble gas, halogen, alkaline earth, period, group, family, oxide, ductile, malleable, metal, nonmetal, metalloid, and Bohr model of an atom;
- determine the numbers of protons, neutrons, and electrons in a neutral atom when given its mass number and atomic number;
- compare and contrast the three fundamental particles in an atom according to mass and charge;
- determine the maximum number of electrons any given shell can hold;
- determine the maximum number of orbitals in any given shell;
- write the electron configuration for any element;
- determine what element is represented when given its electron configuration;
- use the periodic table to locate different families of elements and determine whether an element is a metal, nonmetal, or metalloid.

1 An **atom**, the smallest unit of an element, is composed primarily of three fundamental particles: **electrons**, **protons**, and **neutrons**. The combination of these particles in an atom is distinct for each element. An atom of the element radon is composed primarily of a specific combination of what three basic particles?______________

Answer: electrons, protons, neutrons (any order)

2 Let's forget about neutrons for the moment and consider just electrons and protons. Each atom of the same element has the same combination of protons and electrons. An atom of the element hydrogen in outer space has (the same, a different) ___________ combination of electrons and protons as that of an atom of hydrogen on earth.

Answer: the same

3 Each element has a unique combination of protons and electrons in its atoms. The combination of electrons and protons in an atom of one element is different from that in an atom of any other element. Since each element has a known unique number of protons and electrons in its atoms, would it be possible to identify an element if you know the number of protons and electrons in its atoms? ___________

Answer: yes (if you could compare the number of electrons and protons in your unknown atom with a list of the electrons and protons in atoms of each known element)

4 Protons are particles with a positive (plus) charge. Electrons are particles with a negative (minus) charge. Unless otherwise stated, an atom is assumed to be **neutral**, with the positive and negative charges being equal. In any neutral atom, the number of electrons (having a negative charge) is always equal to the number of protons (having a positive charge).

An oxygen atom contains eight protons. We assume the atom to be neutral. How many electrons must it have? __________

Answer: eight

5 An atom contains 10 electrons. How many protons does it contain? __________

Answer: 10

6 Each element has a unique number of electrons and protons in its atoms. Since the number of electrons in a neutral atom is equal to the number of protons, do you think we can identify an element if we know just the number of protons in its atoms? __________

Answer: yes (if we could compare the number of protons in an atom of the unknown element with a list or table of the number of protons in atoms of every known element)

7 The **periodic table** is a very useful table describing the atoms of every known element. A complete periodic table is included in Appendix (see page 399) of this book. Each box in the periodic table represents an element. The one- or two-letter symbol in each box is a shorthand notation used to represent a neutral atom of an element. The symbol "C" represents a neutral atom of the element carbon. The symbol "He" represents a neutral atom of the element helium.

The number of protons in an atom is listed above each symbol. (Ignore the number underneath the symbol, called the "atomic weight," for the time being as you will get this information from the periodic table. More on that to come.)

6	2
C	**He**
12.011	4.00260

An atom of carbon has six protons. How many protons does an atom of helium have? __________

Answer: two

Note: The table of atomic weights, located in the Appendix along with the periodic table, lists all the elements alphabetically and gives the symbol for each. (Ignore the atomic weights for now.) You'll be using the periodic table and the table of atomic weights throughout this book.

8 The number of protons in an atom of an element is called its **atomic number**. What is the atomic number of the element helium (He)? ____________

Answer: 2

9 The element iron (Fe) has an atomic number of 26. How many protons does an atom of iron contain? ________

Answer: 26

10 A neutral atom of iron contains how many electrons? __________

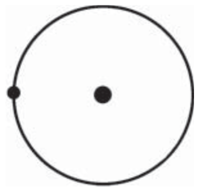
Answer: 26 (the same as the number of protons)

11 Using the periodic table, determine the number of electrons in a neutral atom of zinc (Zn). ________

Answer: 30 (the same as the number of protons)

BOHR ATOMIC MODEL

12 A Danish physicist, Niels Bohr, came up with a model that pictured the atom with a **nucleus** of protons in the center and electrons spinning in an orbit around it (similar to the movement of the planets around the sun). The following Bohr model contains one orbiting electron and a nucleus of one proton.



What is the atomic number of the element represented? __________

What element is represented? __________

Answer: 1 (The atomic number equals the number of protons.); hydrogen (H)

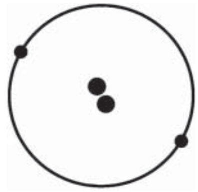
13 An electron always carries a negative charge. A proton carries a charge exactly opposite that of the electron. A proton must therefore have a (negative, positive, neutral) ____________ charge.

Answer: positive

14 An electron has very little mass when compared to a proton. It takes about 1836 electrons to equal the weight of just one proton. In a hydrogen atom consisting of just one proton and one electron, the greatest proportion by weight is accounted for by the (electron, proton) __________.

Answer: proton (The proton accounts for about 99.95% of the weight of a hydrogen atom and the electron 0.05%.)

15 The element helium (He), represented by the Bohr model below, has an atomic number of ________.



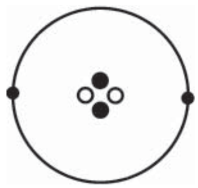
Answer: 2

16 The neutralatom of He contains how many protons? ________
How many electrons? ________

Answer: two; two

17 The weight of an atom of helium is not totally accounted for by the protons and electrons. A third subatomic particle, the **neutron**, is responsible for the additional weight. The neutral atoms of all elements except the most common form of the element hydrogen have one or more neutrons in the nucleus of their atoms. The diagram below shows the neutrons in the corrected Bohr model of helium.

Since a neutral atom contains equal numbers of negatively charged electrons and positively charged protons, what type of electrical charge do you think is possessed by a neutron? ______________ (negative, positive, no charge)



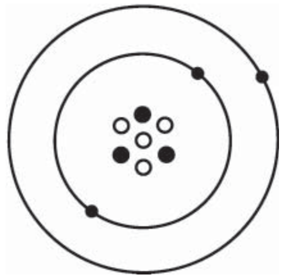
Answer: no charge (The name **neutron** means a neutral particle.)

18 A neutron is slightly heavier than a proton. Of the primary fundamental particles in an atom:

(a) which is the lightest in weight? __________
(b) which is the heaviest? __________
(c) which is between the other two in weight? __________

Answer: (a) the electron; (b) the neutron; (c) the proton

19 In the Bohr model of a lithium atom shown below, which subatomic particle(s) is (are) represented by the circular orbits shown by the larger circles? __________
Which particle(s) make(s) up the nucleus or center of the atom? __________



Answer: electrons; protons and neutrons

20 If the negative charge of an electron is represented by −1, the charge on the proton would be (−1, +1, neutral) ________ and the charge on the neutron would be (−1, +1, neutral) ________.

Answer: +1; neutral

21 Neutrons can be found in all atoms of all elements except the most common form of the simplest element. Identify that element. ________ (Hint: If you don't remember, reread frame 17.)

Answer: hydrogen

You have just learned the names, charges, and relative sizes of the fundamental particles that constitute an atom. You have also been shown one model representing the arrangement of these particles in an atom.

We have referred you to the periodic table and hinted that atoms with certain numbers of protons and electrons are located in a specific place in that table. You learned from your introduction to the periodic table that each atom is identified by a symbol.

We continue this chapter by looking more closely at the periodic table. You will be introduced to specific groups of elements and their physical and chemical properties as they relate to their location on the periodic table. We expand upon the use of symbols and the numbers of each particle in an atom as we prepare to study a second model of an atom.

PERIODIC TABLE

22 Look at the periodic table. An atom of each element is represented by a one- or two-letter symbol, such as "C" for carbon and "Al" for aluminum. These symbols serve as shorthand notation for the elements. The shorthand symbol in each case indicates a neutral atom. The symbol "Ca" represents a neutral atom of the element calcium. Remembering the definition of a neutral atom, you know that Ca contains 20 protons and how many electrons? __________

Answer: 20 (A neutral atom contains an equal number of protons and electrons.)

23 The periodic table of the elements is made up of several rows and some columns. The rows are called **periods** and the columns are called **groups**. The groups are labeled IA, IIA, IIIB, and so on. The elements Be, Mg, Ca, Sr, Ba, and Ra are included in which group? __________

Answer: Group IIA

24 The elements Li, Be, B, C, N, O, F, and Ne are all members of a (group, period) __________.

Answer: period

25 Groups are often called **families** because the elements that make up the groups or families have similar chemical properties. Argon (Ar) is part of Group VIIIA. It is a rather unreactive gas. Since families or groups of elements have similar properties, would you expect krypton (Kr) to be a highly reactive gas? _______

Answer: no (All of the elements in Group VIIIA are rather unreactive.)

26 Because all Group VIIIA elements are rather unreactive and are gaseous at room temperature, they have been named the **noble gas** family. An element in Group VIIIA may be generalized by its family name as a(n) (noble gas, alkaline earth, alkali metal) ________.

Answer: noble gas

27 Group IA on the left side of the chart is often called by the family name of **alkali metals** (with the exception of hydrogen). These elements can react vigorously with water to form strong alkaline solutions. If a friend told you that aluminum (Al) was an alkali metal, would he be right or wrong? __________

Answer: wrong (Aluminum is located in Group IIIA and the alkali metals are all located in Group IA.)

28 Group IIA elements are known as the **alkaline earth** metals because the oxides of these metals (chemical compounds of the metals and oxygen) form alkaline solutions in water. The element potassium (K) can be classified as a(n) (noble gas, alkaline earth, alkali metal) __________.

Answer: alkali metal (Group IA)

29 The element Ba (barium) can be classified as a(n) (alkali metal, alkaline earth, or noble gas) __________.

Answer: alkaline earth (Group IIA)

30 An unknown element is placed in water. A vigorous reaction takes place, and the result is an alkaline solution. Of which family is the element probably a member: alkaline earth, alkali metal, or noble gas?__________

Answer: alkali metal (Alkali metals react *directly* with water to form alkaline solutions. The *oxides* of alkaline earth elements react with water to form alkaline solutions.)

31 The elements in Group VIIA are known as the **halogens**, which means "salt formers." Elements from the halogen family combine with metals to form compounds known as salts. Common table salt (NaCl) is made up of sodium (Na) and chlorine (Cl). These two elements (Na and Cl) are members of what families or groups?

Na: __________
Cl: __________

Answer: Group IA, the alkali metals (either answer is acceptable); Group VIIA, the halogens (either answer is acceptable).

32 Strontium (Sr) is an element in the __________ family. Iodine (I) is an element in the __________ family.

Answer: alkaline earth; halogen

METALS, NONMETALS, AND METALLOIDS

33 The periodic table can also be divided into just three classes of elements: the metals, the nonmetals, and the metalloids. In the periodic table, you may have noticed a steplike line. Elements to the left of this line can be classified as **metals** (with the exception of hydrogen). A friend informed you that the element Cu (copper) is a metal. Is your friend correct? __________

Answer: Yes, copper can be classified as a metal.

34 Certain properties are characteristic of metals. Metals are usually **malleable** (can be beaten into fine sheets) and **ductile** (can be drawn into wires). Gold leaf is a very thin sheet of gold. In making gold leaf, we are using what common property of metals? __________

Answer: the property of malleability

35 Besides being malleable and ductile, metals are also good conductors of heat and electricity. Copper is useful in making electrical wiring. What two metallic properties would be useful in electrical wiring? __________

Answer: The metal is a conductor of electricity and it is ductile (can be drawn into fine wires).

36 Metals have a lustrous or shiny surface and are solid at ordinary room temperature (with the exception of mercury, which is liquid at room temperature). Metal cooking utensils take advantage of what two properties of metal? ________ (conducts electricity, conducts heat, ductile, solid)

Answer: Metal conducts heat and is solid.

37 **Nonmetals** are located on the right side of the steplike line in the periodic table. Which of the following families of elements are classified as nonmetals? ___________ (halogens, alkaline earths, noble gases)

Answer: halogens and noble gases

38 Nonmetals have properties almost opposite those of metals. Nonmetals are usually very brittle and do not conduct electricity or heat well. Most nonmetals are gases at ordinary temperatures, although some are liquids or solids. An unknown element exists as a gas at room temperature. How would you classify the unknown element, as a metal or as a nonmetal? __________