STUDENT'S GUIDE TO MASTERTON AND SLOWINSKI'S

CHEMICAL PRINCIPLES

BOYINGTON

MASTERTON

STUDENT'S GUIDE TO MASTERTON AND SLOWINSKI'S

CHEMICAL PRINCIPLES

THIRD EDITION

RAY BOYINGTON
Department of Chemistry, University of Connecticut

WILLIAM L. MASTERTON
Department of Chemistry, University of Connecticut

SAUNDERS GOLDEN SUNBURST SERIES

W. B. SAUNDERS COMPANY *PHILADELPHIA • LONDON • TORONTO*

W. B. Saunders Company: West Washington Square
Philadelphia, PA 19105

1 St. Anne's Road
Eastbourne, East Sussex BN21 3UN, England

1 Goldthorne Avenue
Toronto, Ontario M8Z 5T9, Canada

The cover photo shows an enormous storm on the surface of the sun, as observed from a satellite. The picture was taken at 304Å in the light given off by He^+ ions as they go from the n = 2 to the n = 1 state. We are grateful to NASA for the permission to use this photo.

Student's Guide to Masterton and Slowinski's CHEMICAL PRINCIPLES ISBN 0–7216–1902–9

Last digit is the print number: 9 8 7 6 5 4 3 2

PREFACE

This study guide has been written as an aid to the student of general chemistry – to supplement a textbook or lecture series, or to guide independent study. The chapter sequence and selection of topics parallel that of *Chemical Principles*, 4th edition, by W. L. Masterton and E. J. Slowinski.

Each chapter begins with a set of questions. These are meant to suggest some of the things you should be looking for in studying the topics of the chapter and the corresponding text and lecture material. You should add your own questions to this partial listing. Next follows a list of concepts and mathematical manipulations with which you should already be familiar in order to get the most out of your study. A chapter summary then presents an overview of some of the ideas treated in this unit of study.

In addition, each chapter of the guide contains a section entitled Basic Skills. Here are listed the concepts and problem-solving techniques that must be mastered before you can work problems in the text or on an examination. Each skill is illustrated by an example, either directly or by reference to an appropriate example and corresponding problems in the text. Illustrative problems in the text are set off by key words which indicate the skill applied.

Next is the Self-Test, which consists of true-false and multiple choice questions (each with one best answer) as well as problems which generally apply more than one of the basic skills. There are also one or two "bonus" problems, set off by asterisks (*), which we hope you will find intriguing. Excluding these special problems, the entire Self-Test should require between 60 and 90 minutes to work. Each test is similar to the examinations we have given at Storrs over the last six years. In fact, many of the questions and nearly all the problems are taken from these exams.

Finally, following answers to the Self-Test, is a list of recommended readings. These may be used to supply more basic, background study, interesting and important applications, and in-depth study as well.

The major objective in writing this guide has been to provide you with tests by which you can measure your understanding; to help you apply what you learn to new problems and suggest new avenues of study; and to help you acquire a feel for the chemist's view of the physical world. We welcome your suggestions for the many ways there must be for making this a more useful guide.

SUGGESTIONS FOR THE USE OF THIS GUIDE

First, let's agree that what you get out of this study of general chemistry depends in great part on what you are willing to put into it. What follow are a few suggestions as to how you can make the most of your effort.

There are certain basic skills that you will frequently need to rely on, possibly further develop. The most fundamental of these are reading with comprehension and solving mathematical problems once they have been set up. There is probably no better way to learn or improve a language skill than through repeated usage, and that is one reason for this guide. Also, the problems and the tests in this guide will help you to decide just what you do and do not understand. As for the math, there are likely to be very few calculations in this course which you cannot do. These may consist of working with exponential notation or logarithms; solving first order (linear) equations; or solving less frequently encountered second order (quadratic) equations. For these you may simply need some review. Suggestions for background readings follow; additional help is generally yours for the asking, from fellow students and from your instructor.

1. Attend lectures and take notes. Notes are important in answering questions such as these: What seem to be the important points? What is the lecturer's emphasis? What new examples and applications are given? What kind of experiments are done? *Think* about what is being said, do not merely take notes.

2. Prepare for the lecture! Read over the material you expect to be discussed. Try to get a general idea of what the material is about. (Some lecturers assume a basic preparation, some do not. Even if the lecture should tell you little new, you will have learned more by having done the work yourself.) The more you know about what the lecturer is saying, the more you will be able to learn; the fewer notes you will need to take, and the better they will be; the more questions you can raise; or, the more time you can devote to other studies.

3. Get as much as you can out of discussions with other students and with your instructor, out of discussion or problem-solving classes – by being prepared, and by understanding (first by discovering for yourself) the inherent limitations and potentials of your class. (You will generally find, for example, that an instructor is better able to answer specific questions than he is to guess what problems you are having.) Make your problems known, as

early and as clearly as possible. Take advantage of the skills and insights of your instructor and your fellow students! You usually do have a very real influence on how beneficial a discussion class may be. Remember that this guide is designed to help you evaluate your progress for yourself, to recognize those areas where you need help, and to assist you in finding it; but it is no substitute for the classroom.

4. Review regularly and frequently. This is where your notes should be most helpful, and hopefully this guide as well. Keep this use in mind when taking notes from lecture or text. Look for connections between topics.

5. Read more chemistry – whether out of curiosity or from a feeling of helplessness. The more you do, the more rewarding this study must be.

To sum up:

Before attending lecture: Skim through the textbook chapter, reading introductory paragraphs and section headings, looking at tables and graphs; read and *add your own notes* to the first three sections of the study guide chapter. Then go back and *work* through the textbook chapter. In this and all other parts of the course, you've got to *actively participate.* Try to *anticipate* answers; write in questions you need answered; jot down your own conclusions in your own words.

Before discussing problems: Work through as many problems as possible in this guide and in your text; work the self-test in the guide; note anything requiring further explanation; think about your answers – do they seem reasonable in terms of what you already know? Do they suggest other problems?

Before taking exams: Review the main concepts and their physical meaning by referring to your notes and to the chapter summaries; recall and try to anticipate the emphases. Work some more problems.

For further assistance or enjoyment: Ask questions of your fellow students and your instructor. Do some reading. Teach what you have learned.

ADDITIONAL STUDY AIDS AND SUGGESTED READINGS

Math Preparation and Problem-Solving Manuals

Butler, I. S., *Relevant Problems for Chemical Principles*, Menlo Park, Calif., W. A. Benjamin, 1970.

Gibson, G. W., *Mastering Chemistry: A Problem Solving Guide for Introductory Chemistry*, Philadelphia, W. B. Saunders, 1975.

Masterton, W. L., and Slowinski, E. J., *Elementary Mathematical Preparation for General Chemistry*, Philadelphia, W. B. Saunders, 1974.

O'Connor, R., *Solving Problems in Chemistry*, New York, Harper & Row, 1974.

Peters, E. I., *Problem Solving for Chemistry*, 2nd ed., Philadelphia, W. B. Saunders, 1976.

Pierce, C., *General Chemistry Workbook*, San Francisco, W. H. Freeman, 1971.

Risen, W. M., Jr., *Problems for General and Environmental Chemistry*, New York, Appleton-Century-Crofts, 1972.

Sienko, M. J., *Chemistry Problems*, Menlo Park, Calif., W. A. Benjamin, 1972.

Programmed Instruction and Instruction in Programming

Barrow, G. M., *Understanding Chemistry*, New York, W. A. Benjamin, 1969.

Soltzberg, L., *BASIC and Chemistry*, Boston, Houghton Mifflin, 1975.

Journals and Magazines

Chemical and Engineering News
Chemistry
Journal of Chemical Education
Scientific American

Audio-Visual Aids

Tapes, films, slides, programmed instruction materials and other resources that might be used for self-instruction are often available but not used. Find out where they are and how to use them, and whether they are worth your time. Often available at any library. Reprints of published papers are often available free from the author; sometimes, for a small fee, from the publisher.

Consider:

O'Connor, R., *Topics-Aids: A Guide to Instructional Resources for General Chemistry*, Washington, D. C., American Chemical Society, 1975.

General References and Popular Accounts

Encyclopedia of Chemical Technology, New York, Wiley, 1970.

Rochow, E., *Modern Descriptive Chemistry*, Philadelphia, W. B. Saunders, 1977.

What's Happening in Chemistry?, Washington, D. C., American Chemical Society, 1976 (an annual publication).

Woodburn, J. H., *Taking Things Apart & Putting Things Together*, Washington, D. C., American Chemical Society, 1976.

Handbooks and Compilations of Data

Handbook of Chemistry and Physics, Cleveland, Chemical Rubber.
Lange's Handbook of Chemistry, New York, McGraw-Hill Book Co.

Foreign-Language Texts

Consider the translations of the text and lab manual of Masterton and Slowinski:

Chimie: Théorique et Expérimentale, G. S. Gantcheff (translator), Montreal, Les Editions HRW Ltée, 1974.
Experimentelle Einführung in Grundlagen und Methoden der Chemie, D. Krug (translator), Stuttgart, Gustav Fischer Verlag, 1976.

The authors wish to thank Elaine Rossi for typing the manuscript.

CONTENTS

1

CHEMISTRY: AN EXPERIMENTAL SCIENCE

QUESTIONS TO GUIDE YOUR STUDY

1. What role does chemistry play in today's world? How might this role change in the near future? (Can you recall any chemical issues recently debated in the news media?)

2. What kinds of problems do chemists try to solve? Are there any specially useful or simplifying approaches to their solution? Is there a chemist's "point of view"?

3. What kinds of materials does the chemist generally work with in the laboratory? (Are they, for example, the materials of the "real" world, such as steel, plastic, beer, and tobacco smoke?)

4. How does the chemist obtain, prepare, and purify the materials he studies?

5. What are some of the instruments and techniques of the chemist?

6. What properties or changes in properties does the chemist measure and use to describe materials? How are these measurements communicated to other scientists and to the public?

7. What limitations and uncertainties are there in these measurements? How are these communicated?

8. What kind of test would you perform in your kitchen to show that a sample of baking soda is "pure"? (What is the chemical meaning of "pure"?)

9. What are some of the unsolved problems – the frontiers – in chemistry?

10. What questions would you, a reporter for a local newspaper, want to ask of a government-employed chemist?

11.

12.

YOU WILL NEED TO KNOW*

Concepts

Though no previous encounter with chemistry is assumed at this point at least a general understanding is assumed for the notions of matter, energy composition, experiment, measurement . . . .

Math

1. How to use exponential notation – Appendix 4.
2. How to recognize and solve first order (linear) equations, such as $y = ax + b$ – see the Basic Skills section as well as the Readings.

CHAPTER SUMMARY

You know, perhaps all too well, that we live in an age of science and technology, an age that is now two to three centuries old yet very much with us. For example, nearly ninety per cent of all scientists that there have ever been are alive now. At least through the first half of this century science seemed, by any measure, to be growing exponentially: about every ten to fifteen years the number of scientific journals approximately doubled and the number of compounds known to chemists likewise doubled. (Try estimating the number of papers in chemistry expected in the year 2000, knowing that there were about 50,000 in 1950.) How long can this rapid growth continue? Are there signs that it has already begun to taper off?

This course of study will introduce you to the underlying principles and methods of one of the more fruitful areas of scientific endeavor, an endeavor involving many thousands of persons in many nations.

But just what does a chemist do? Most of us would probably agree that a chemist is one who is qualified to determine the feasibility of chemical

*All chapters and appendices referred to are in *Chemical Principles*; otherwise, see the readings list for appropriate background material.

change. A major objective of the chemist is to be able to predict the conditions under which a chemical reaction may occur and to describe the course the reacting system may take. (Does this suggest the kind of social role the chemist might play? After more than ten years of research, and applying a well known chemical principle, F. Haber was able to describe the conditions under which atmospheric nitrogen could be converted to ammonia. A process made commercial in 1913, the Haber synthesis now accounts for most of the ammonia produced, whether for eventual use in fertilizers, explosives, or Everybody's Ammonia Cleanser.)

The history of modern chemistry really began with the introduction of quantitative experimentation, with measurement. The idea of composition, barely mentioned here, is taken up in more detail in the next two chapters. There are several levels of meaning to *composition*: one speaks of atomic composition, for example; or elemental composition; or composition by weight, and so forth. All of these usages refer to the way in which component parts or building blocks, whether simple in themselves or very complex, are put together to form matter as we know it.

A major objective for the student in an introductory course is to see how the principles of chemistry are experimentally established and then applied in predictions of reaction feasibility. Consequently, the chemical systems that we will look at will be simple in composition and simple in the number of things that happen.

BASIC SKILLS

In this introductory chapter you are expected to become familiar with some of the common types of measurements that chemists make and the experiments they carry out to separate and identify substances. You should, for example, be familiar with the measurement of mass and the units in which masses of substances are commonly expressed. Again, you should understand the principles that govern such separation techniques as distillation and chromatography. In another area, you should be able to explain how such properties as boiling point and absorption spectrum can be used to identify a substance and check its purity.

A few specific skills are required in this chapter. They include the following.

1. Apply the rules of significant figures to calculations based upon experimental measurements.

These rules are illustrated both in the body of the text and in Examples 1.2 and 1.3. Students ordinarily have little trouble learning these rules, but they often forget to apply them in carrying out chemical calculations. None of the problems at the end of Chapter 1 refer directly to significant figures, but in each case you are expected to report an answer to the correct numb of significant figures. This will be true throughout the text and this stu guide.

2. Use the conversion factor approach to convert lengths, volum masses, or other measured quantities from one unit to another.

This is a general approach which can be applied to a wide variety problems in chemistry. It will be used extensively in later chapters of t text. If you are not familiar with it, this chapter gives you an excelle opportunity to become skilled in its use.

The principle behind the conversion factor approach is illustrated Examples 1.4 and 1.5 in the text. Notice (Example 1.4) that it is readi applied to conversions involving more than one step. The example belc further illustrates this application.

A certain European car is reported to have a fuel economy of 13.0 km/liter. Convert this to miles/gallon.______

Clearly, two conversions are required: kilometers must be converted to miles and liters to gallons. The first conversion factor is available directly from Table 1.1:

1. 1 mile = 1.609 km

The other factor does not appear directly in the table. However, the conversion may be accomplished by first converting liters to quarts

2. 1 liter = 1.057 qt

and then to gallons:

3. 4 qt = 1 gal

With these conversion factors available, we can set up the problem:

$$13.0\ \frac{\text{km}}{\text{liter}} \times \underset{(1)}{\frac{1\ \text{mile}}{1.609\ \text{km}}} \times \underset{(2)}{\frac{1\ \text{liter}}{1.057\ \text{qt}}} \times \underset{(3)}{\frac{4\ \text{qt}}{1\ \text{gal}}} = 30.6\ \frac{\text{miles}}{\text{gal}}$$

Notice that each conversion factor is set up in such a way (1 mile/1.609 km) that the original unit (km) cancels out, leaving the desired unit (miles).

Many of the problems at the end of Chapter 1 require conversions of or type or another. In Problem 1.2, for example, you are asked to carry out conversion which is exactly the reverse of the one just worked. Problen 1.11, 1.14, 1.25, and 1.28 illustrate other straightforward conversions fro one unit to another. Problem 1.32 is an interesting example of how th conversion factor approach can be applied, at a somewhat more advance level, to a practical problem of considerable environmental importance.

3. Use an algebraic equation to solve for an unknown quantity, given or having calculated all the other quantities in the equation.

This is another basic skill which you will use frequently in general chemistry. In this chapter it is illustrated in simple form by

– *temperature conversion (°C, °F, K) carried out using Equations 1.2 and 1.3.* Note Example 1.1 and Problems 1.3, 1.12a, and 1.26a at the end of the chapter.

– *relating density, mass, and volume, using the defining equation:*

$$\text{density} = \frac{\text{mass}}{\text{volume}} \; ; \; D = \frac{m}{V}$$

This equation is used in Example 1.3 and in the following example.

What is the volume of a sample of aluminum (density = 2.70 g/cm³) weighing 12.0 grams?________

Here, we rearrange the defining equation to solve for volume. To do this, we first multiply both sides of the equation by V to obtain

$$D \times V = m$$

and then divide both sides by the density, D:

$$V = \frac{m}{D}$$

Substituting the quantities given in the statement of the problem:

$$V = \frac{12.0 \text{ g}}{2.70 \text{ g/cm}^3} = 4.44 \text{ cm}^3$$

Several of the problems at the end of Chapter 1 (1.9, 1.12, 1.22, 1.23, 1.26) require that you be familiar with the density relation.

4. Use a table of solubilities (Table 1.7) to design an experiment to separate two solids by fractional crystallization.

The general approach followed here is described in the text discussion and applied in Problems 1.17 and 1.31. In working these problems note that

– solubilities at a given temperature can be treated like conversion factors. Thus, to work 1.17a, we might consider that, at 80°C, 98 g tartaric acid ≙ 100 g water.

– the solubility of one solid is assumed to be independent of t presence of the other. Thus, at 100°C, it is assumed that 100 g of water w dissolve 98 g of tartaric acid, regardless of how much succinic acid is preser and 71 g of succinic acid, regardless of how much tartaric acid is preser Obviously, this is an approximation, but it is probably more nearly accura than any other simple assumption we might make at this point.

SELF-TEST

True or False

1. Changes in physical state, like melting and boiling, tend to resolve matter into pure component substances. (

2. Physical properties may be used to characterize, identify, a substance. (

3. In trying to identify a certain liquid compound "L," a student finds that its density, freezing and boiling points, absorption spectrum, and behavior in a chromatography column are indistinguishable from those of known compound "Z." The student can safely assume that L and Z are one and the same compound. (

4. Nearly all countries have already adopted or are now adopting a metric system as the single recognized system of measurement. (

5. The simplification in using the metric system is that, when converting units within the system, a decimal point is moved. (

6. Appropriate conversion factors would allow you to convert from a volume measurement in cubic feet to a density measurement in grams per cubic centimeter. (

7. Since silicon is the second most abundant element in the earth's crust, it must be one of the cheapest to buy from a chemical supplier. (

8. Sodium chloride and potassium dichromate, both solids which are soluble in water, can probably be separated by taking advantage of differences in solubility. (

9. A liter is almost the same as a quart. (

10. In dividing 4.053 by 2.46 your calculator displays the answer 1.647560976. You should report 1.647560976 as your answer. (