SECOND EDITION

RELEVANT PROBLEMS *for Chemical Principles*

Butler · Grosser

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PREFACE

The instructor who regards the plethora of introductory college texts as but another example of increasing entropy has our common sympathy. Moreover, apparently few texts are satisfactory to all instructors. Our experience with the shortcomings of most texts led us to establish two priorities in writing this supplementary problems book: We would provide detailed solutions to *every* problem, and we would include as many problems as possible to show the student that even a limited knowledge of the principles of chemistry would enable him to solve problems concerning real situations encountered not only in chemistry, but in other sciences, and even everyday life. Thus, we have included problems about space science, medicine, geology, dentistry, archaeology, biochemistry, urban pollution and hygiene, engineering, and solar and nuclear energy.

Another of our objectives was to allow students to proceed at their own pace through the book. We have purposely used a multiple-choice format, not to remind the student of the computer age on campus but to construct incorrect answers that correspond to common errors. The reasons for these incorrect answers are often discussed in the solution of the problem. So the student can either work through the solution to find he is correct or to find his error, or he can check only the discussion of the incorrect answer. For the well-prepared student, however, the number corresponding to the correct answer is prominently displayed within a circle in the margin under the solution number so he need not work through an entire solution.

We have taken advantage of the fact that this book is designed to form a part of the complete teaching system accompanying the text *Chemical Principles,* second edition, by Richard E. Dickerson, Harry B. Gray, and Gilbert P. Haight, Jr. Throughout both the text and this book, there are cross references that are intended to indicate to the student the areas in which he might find additional review. The student who continually chooses the wrong answer is referred to the appropriate section in *Programed Reviews of Chemical Principles,* by Jean D. Lassila *et al.* This book, which is another part of the teaching system, offers an introduction to systematic problem-solving that is of use when working the problems in our book.

Although the book closely parallels the text *Chemical Principles,* we have not hesitated to include additional material where we thought it warranted. For example, in Chapter 2, there is a section on molecular beams, and in Chapter 3, there are a number of problems on mass spectrometry.

Not only are students often uncertain of how much they must memorize, but generally they memorize too much. In a "memorization section" in the introduction to each chapter, the student is told exactly what he must memorize to solve the problems. We have tried to keep the memorization to a minimum by showing the student, within a problem, how to proceed quickly from the few memorized facts and equations to the ones necessary to solve the problem. Thus, there are a number of problems that build on each other, in which the results of one are used in the next, and so on. Therefore, we consider some of the problems to be "teaching problems."

The student is invited to evaluate his own progress by working examination questions, which are grouped in Appendix 1. We have not provided detailed solutions but have included answers to all of the examination questions.

We wish to thank our students and colleagues (especially Ferenc Kalos, Garry Stein, Donna Stern, Theodore Waech, Ivor Whorf, and Professor James J. Hogan) who so carefully worked all the problems and criticized our solutions. We would particularly like to thank Professor David N. Harpp, who wrote the problems for Chapter 12, "The Special Role of Carbon." Finally, we alone are, alas, responsible for any errors or inconsistencies throughout the book and would welcome any criticism and suggestions so we may improve it.

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NOTE TO THE STUDENT

A book of introductory chemistry problems usually seems like a formidable and tiresome epic with neither plot nor characters, and with insufficient narrative. Moreover, the exercises seem to be just that: a chemistry professor's equivalent to a muscle building course.

Our intention is to provide a change from this drudgery. Although we are primarily interested in helping you to master problems in chemistry, we think that it is also important to be learning something about how chemical principles relate to the real world. For this reason, we have tried to think of problems that involve areas such as space science, medicine, geology, archaeology, engineering, biochemistry, and a host of other fields from which you might derive some feeling of involvement.

Our method is to state a problem and to give five possible answers. Then we give a relatively detailed solution (not the *only* way to solve the problem, of course, and not even the shortest; we simply present an understandable way). We have chosen this multiple-choice format so we could deliberately construct incorrect answers that correspond to common errors. The reasons for these errors are often discussed in the solution. Nevertheless, if you are answering the questions correctly, you need not read through the entire solution. The number giving the correct answer is prominently displayed in the margin under the solution number. But if you are having trouble with these problems, we refer you periodically to *Programed Reviews of Chemical Principles*, by Jean D. Lassila *et al.*, for remedial work. This arrangement should allow you to proceed at your own pace. (In addition, we have cross-referenced to the text, *Chemical Principles*, second edition, by Richard E. Dickerson, Harry B. Gray, and Gilbert P. Haight, Jr. We follow the format of this text on a chapter-by-chapter basis.)

A word about memorization. We do not believe that it is important to commit a large quantity of information to memory. (Other scientists appear to agree, for they continually surround themselves with libraries and computers.) But some facts are so basic that it would be cumbersome to look them up time after time. We indicate at the beginning of each chapter what material you should, in our opinion, memorize. We believe that it is minimal.

Finally, we remain aware, even after watching TV commercials, that there are no panaceas. Nature will answer our questions, but only if we know how to ask them. And learning how to ask nature the proper questions is the business of scientists. In learning how to answer these questions, we hope that you learn to ask your own.

CONTENTS

CHAPTER 1 ATOMS, MOLECULES, AND MOLES

This chapter covers the concepts of atoms, gram-atoms, molecules, and moles, and introduces the quantitative aspects of chemical reactions. It is the interrelationship of these concepts with our everyday measures of quantity (weight and volume) that constitutes the basic vocabulary of the chemist.

You should be able to solve problems with a minimum of memorization. But that minimum is not zero. We will suggest what is necessary to memorize at the beginning of each chapter.

Memorize:

$N = 6.0 \times 10^{23}$ atoms g-atom^{-1}
or molecules mole^{-1}
1 liter = 10^3 cm^3
1 kg = 10^3 g

Solutions to problems in Chapter 1 begin on page 12.

PROBLEMS

PROBLEM 1–1

It is estimated that 9.3×10^6 kg (about 20 million lb, avdp) of carbon monoxide (CO) were produced by motor vehicles in Los Angeles in 1967. This is 3.3×10^8 moles of CO. How many gram-atoms of carbon (C) were consumed in producing this much CO? moles

(at. wt: C = 12, O = 16)

1 3.3×10^8
2 $12 \times 3.3 \times 10^8 = 4.0 \times 10^9$
3 $16 \times 3.3 \times 10^8 = 5.3 \times 10^9$
4 $28 \times 3.3 \times 10^8 = 9.3 \times 10^9$
5 Insufficient information; the chemical reaction to produce CO must be known.

PROBLEM 1–2

A car traveling at 10 miles per hour emits about 0.33 lb avdp of carbon monoxide (CO) gas per mile. How many moles of CO are emitted per mile under these conditions?

(at. wt: C = 12, O = 16; 1 lb avdp = 0.454 kg)

1 5.4×10^{-3} mole
2 1.2×10^{-2} mole
3 5.4 moles
4 9.4 moles
5 12.5 moles

PROBLEM 1–3

During the Apollo 11 moonwalk, a solar wind experiment was deployed. The solar wind collector was an aluminum strip of approximately 3000 cm^2 area (11.5 in. × 40 in.). If the solar wind strikes this foil (and sticks) with an intensity of 1×10^7 H atoms cm^{-2} sec^{-1}, what mass of H atoms was collected during the approximately 100-min experiment?

(at. wt: H = 1.0)

1 1×10^{-13} g
2 5×10^{-12} g
3 3×10^{-10} g
4 1 g
5 1.8×10^{14} g

PROBLEM 1–4

In World War I, 120,000 short tons (1.1×10^8 kg) of poison gas were fired on the Allied forces. (In 1918, half the shells fired by the Germans contained gas.) If the gas is assumed to be phosgene ($COCl_2$), how many *molecules* of the gas correspond to the amount fired on the Allied forces?

(at. wt: C = 12.0, O = 16.0, Cl = 35.5)

1 $1.1 \times 10^9/(6.0 \times 10^{23}) = 1.9 \times 10^{-15}$
2 $1.7 \times 10^9/(6.0 \times 10^{23}) = 2.9 \times 10^{-15}$
3 $6.0 \times 1.1 \times 10^{29} = 6.6 \times 10^{29}$
4 $6.0 \times 1.1 \times 10^{32} = 6.6 \times 10^{32}$
5 $6.0 \times 1.7 \times 10^{32} = 10 \times 10^{32}$

PROBLEM 1–5

The gram molecular weight of hydrogen peroxide (H_2O_2) is 34 g. What are the *units* of molecular weight?

(at. wt: H = 1, O = 16)

1 g
2 mole
3 g $mole^{-1}$
4 mole g^{-1}
5 No units.

PROBLEM 1–6

Which of the following statements concerning an isotope $^A_Z M$ of an element M is *incorrect?*

(a) *Z* is the mass number of the element.
(b) *A* is the mass number of the element.
(c) *Z* is the number of positive charges on the nucleus.
(d) *Z* is the atomic number.
(e) *A* is the sum of the number of protons and the number of neutrons in the nucleus.

1 (a) and (c)
2 (a)
3 (b) and (e)
4 (b) and (d)
5 (d) and (e)

PROBLEM 1–7 Which of the following are pairs of isotopes?

(a) $^{2}_{1}H^{+}$ and $^{3}_{1}H$
(b) $^{3}_{2}He$ and $^{4}_{2}He$
(c) $^{12}_{6}C$ and $^{14}_{7}N^{+}$
(d) $^{3}_{1}H$ and $^{4}_{2}He^{-}$

1 (b) only
2 (a) and (d)
3 (a) and (c)
4 (c) only
5 (a) and (b)

PROBLEM 1–8 Two thirds of the atoms in the water (H_2O) molecule are hydrogen. What percentage of the weight of a water molecule is the weight of the two hydrogen atoms?

(at. wt: H = 1.008, O = 16.00)

1 5.6%
2 11.2%
3 22.4%
4 33.3%
5 66.7%

PROBLEM 1–9 The atomic composition of the entire universe is approximately as given in Table 1–1.

Table 1–1

Atom	Atom percent (% of the total number of atoms)
H	93
He	7.0

Hydrogen atoms constitute what percentage of the universe by *weight?*

(at. wt: H = 1.0, He = 4.0)

1 20%
2 23%
3 77%
4 87%
5 93%