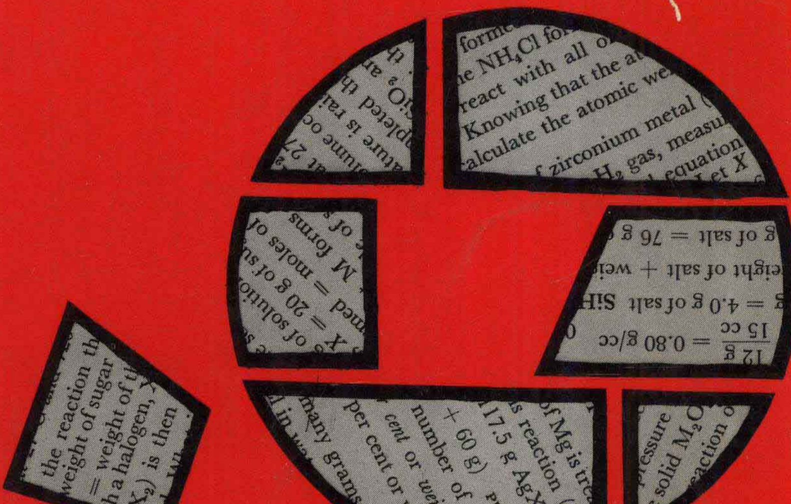
HOW TO SOLVE

GENERAL CHEMISTRY PROBLEMS

THIRD EDITION

SIMPLE EXPLANATIONS
STEP-BY-STEP SOLUTIONS

C. H. SORUM



1 $2.95 PRENTICE-HALL, INC.

How to Solve General Chemistry Problems

Current printing (last digit):

13 12 11 10 9 8 7 6 5

Library of Congress Catalog Number 63-7099

Printed in the United States of America
43416C

PRENTICE-HALL INTERNATIONAL, INC.
London Tokyo Sydney Paris
PRENTICE-HALL OF CANADA, LTD.
PRENTICE-HALL DE MEXICO, S.A.

PRENTICE-HALL CHEMISTRY SERIES

How to Solve General Chemistry Problems

Third Edition

C. H. Sorum
Professor of Chemistry
University of Wisconsin

Prentice-Hall, Inc.
Englewood Cliffs, N.J.

Preface

The following changes have been made in this revision:

1. The mole factor approach is emphasized in the solution of all problems. The concept of the mole is presented in Chapter 4 and is stressed throughout the rest of the book.
2. A number of more difficult and more challenging problems, identified by the letter **s** following the number of the problem, are placed at the end of each chapter. These problems are designed for use in more rigorous courses and for assignment to honors students. The problems in the beginning of each chapter clarify the basic concepts and, in general, are less difficult.
3. The discussions of chemical equilibrium and ionic equilibria have been revised and enlarged. The number of problems dealing with ionic equilibria has been substantially increased.
4. A new chapter, Oxidation Potentials, Chapter 22, has been added.

Complete solutions are given to enough problems in each chapter so that the book will, for the majority of students, be self-teaching. In certain of the problems hints rather than complete solutions are given.

Because each chapter contains problems of all ranges of difficulty, and because as few or as many of the chapters can be covered as the requirements of a course warrant, the book is flexible enough to serve the needs of practically any kind of student and any general chemistry group.

As in the previous edition, answers are given to approximately 50 per cent of the basic problems. Answers are given to all of the **s** problems. Unanswered problems are designated by an asterisk. A list of answers to the unanswered problems is available; requests for this list should be sent to the publisher or the author.

The author wishes to express his indebtedness to the members of his general chemistry teaching staff for their assistance in the preparation of this revision. He is particularly indebted to Duncan Poland and James Espenson.

C. H. SORUM

Contents

1 How to Solve a Problem

Every problem that you encounter, whether it is in chemistry or in some other area, is solved in essentially the same fashion. *First*, you size up the situation carefully, or read the problem carefully, and decide what you are supposed to do and what you have to do it with. *Second*, having determined *what* you are supposed to do and what you have to do it with, you figure out *how* to do it. *Finally*, you go ahead and *do it* according to plan. The first two steps represent the *analysis* of the problem. The third step represents the *arithmetical calculations*. Some problems are knottier than others, but they are all solved by these three fundamental steps.

To be more specific, when you go about solving any problem in this or any other book or in any test or examination:

1. Read the problem carefully. Note exactly what is given and what is sought. Note any and all special conditions. Be sure that you understand the meaning of all terms and units and that you are familiar with all chemical principles that are involved. Every problem in this book is designed to illustrate some principle, some relationship, some law, some definition, or some fact. If you understand the principle, relationship, law, definition, or fact you should have no difficulty solving the problem. The one big reason, the only reason in fact, why students have difficulty with chemistry problems is failure to understand, exactly and well, the chemical principles involved and the meaning and value of all terms and units that are used in the problem.

2. Plan, in detail, just how the problem is to be solved. Get into the habit of visualizing the entire solution before you execute a single step. Insist on knowing what you are going to do and why you are going to do it. Aim to learn to solve every problem in the most efficient manner; this generally means doing it the shortest way, with the fewest steps.

3. When you actually carry out the mathematical operation of solving the problem be sure to **specify definitely what each number represents and the units in which it is expressed.** Don't just write

$$\frac{192}{32} = 6$$

Write

$$\frac{192 \text{ g of sulfur}}{32 \text{ g of sulfur per mole of sulfur}} = 6 \text{ moles of sulfur}$$

or whatever the case may be. Always divide and multiply the *units* as well as the *numbers*. This is one way to give exactness to your thought process and is a very good way to help avoid errors. You should jot down the unit or units in which your answer is to be expressed as the first step in the actual solution. For instance, if you are solving for the number of grams of oxygen in 200 g of silver oxide, you should jot down the fact that the answer will be "= _____ g of oxygen." In reality, every problem is worked backward, since you first focus your attention on the units in which the answer is to be expressed and then plan the solution with these units in mind.

4. Having solved the problem, examine the answer to see if it is reasonable and sensible. The student who reported that 200 g of silver oxide contained 1380 g of oxygen should have known that such an answer was not sensible. When the slide rule is used, errors due to incorrect location of the decimal point are very likely to creep in unless you get into the habit of checking the answer to see if it is of the right order of magnitude.

5. If you do not understand how to solve a problem have it explained to you at the very earliest possible date. To be able to solve the later problems you must understand the earlier ones. After a problem has been explained to you, fix the explanation in your mind by working other similar problems at once, or at least within a few hours, while the explanation is still fresh in your mind.

2 Units of Measurement

It will be assumed in this book that every student is familiar, through laboratory experience, with the common units of measure in the metric system and that he has a fair idea of the volume represented by 1 liter, 100 ml, and 1 ml, the mass represented by 10 g, 100 g, or 1 kg, and the length represented by 760 mm, 10 cm, and 1 m, etc. Also, it will be assumed that he is familiar with the centigrade thermometer scale.

It should be recalled that the metric system employs decimal notations in which the prefix, *milli-*, means one thousandth, *centi-* means one hundredth, and *deci-* means one tenth, while *kilo-* means one thousand times.

Conversions of metric units (grams, liters, milliliters, cubic centimeters, centimeters, etc.) to other units (pounds, quarts, inches, feet, etc.) are not often required. The following table will serve where such conversions are called for.

Conversion Units

1 meter (m) = 10 decimeters (dm) = 100 centimeters (cm)
= 1000 millimeters (mm) = 39.37 inches (in.)
= 1.09 yards (yd)
1 kilogram (kg) = 1000 grams (g) = 1,000,000 milligrams (mg)
= 2.2046 pounds (lb)
1 gram (g) = 1000 milligrams (mg)
1 milligram (mg) = 0.001 gram (g)
1 pound (lb) = 453.6 grams (g)

1 liter (l) = 1000 milliliters (ml) = 1000.027 cubic centimeters (cc)
= 0.264 U.S. gallons (gal) = 1.06 U.S. quarts (qt)

1 milliliter (ml) = 1.000027 cubic centimeters (cc)

1 cubic centimeter is the volume of about 20 drops of water

A new U.S. 5-cent piece weighs 5 g

It should be noted that 1 liter is equal to 1000 milliliters (ml) and that 1 liter is also equal to 1000.027 cubic centimeters (cc). One milliliter is therefore equal to 1.000027 cc. For all practical purposes, however, 1 ml and 1 cc are equal to each other. One liter is, for all practical purposes, equal to 1000 cc and will be so considered in this book.

Interconversion of Centigrade and Fahrenheit Temperature Readings

The thermometers used in the laboratory are graduated in centigrade degrees; most household thermometers are graduated in Fahrenheit degrees. The fixed points on both the centigrade and Fahrenheit temperature scales are the boiling point and freezing point of water. On the centigrade scale the freezing point of water is 0° and the boiling point is 100°; the space between the fixed points is divided into 100 units and the space above 100° and below 0° is divided into the same size units. On the Fahrenheit scale the freezing point of water is 32° and the boiling point is 212°; the space between the fixed points is divided into 180 units and the space above 212° and below 32° is divided into the same size units. Since the space between the freezing point and boiling point of water is divided into 100° on the centigrade scale and 180° on the Fahrenheit scale, it follows that 100 centigrade degrees must represent the same temperature change as 180 Fahrenheit degrees. That means that 1 centigrade degree is equal to 1.8 Fahrenheit degrees; or expressing it in fractional form, 1 centigrade degree is equal to $\frac{9}{5}$ Fahrenheit degrees and 1 Fahrenheit degree is equal to $\frac{5}{9}$ of a centigrade degree.

With these facts in mind we see that, if we wish to find the Fahrenheit value of a certain number of centigrade degrees, C, we first multiply the centigrade reading by $\frac{9}{5}$; this gives us $\frac{9}{5}$ C. Since the reference temperature (the freezing point of water) on the F scale is 32° above zero we must add 32° to $\frac{9}{5}$ C in order to get the actual reading on the Fahrenheit scale.

$$\text{Fahrenheit temperature} = \frac{9}{5}\text{ centigrade temperature} + 32$$

or

(1) $$F = \frac{9}{5}C + 32$$

Equation (1) can be transposed to the form,

(2) $$C = \frac{5}{9}(F - 32)$$

Equation (2) tells us that, to find the value, in degrees centigrade, of a Fahrenheit temperature, we first subtract 32° from the Fahrenheit temperature (because the Fahrenheit freezing point reference is 32° above zero) and then take $\frac{5}{9}$ of that answer.

To illustrate the use of the above relationships:

(a) Convert 144°F to a centigrade reading.

In thinking our way through this problem we note that 144°F is (144 − 32) or 112° above the freezing point of water. Since 1 Fahrenheit degree is equal to $\frac{5}{9}$ of a centigrade degree 112 Fahrenheit degrees must be equal to 112 × $\frac{5}{9}$ or 62.2 centigrade degrees. That means that 144°F is 62.2 centigrade degrees above the freezing point of water. Since the freezing point of water is 0°C, 62.2 centigrade degrees above the freezing point of water will be 62.2°C.

(b) Convert 80°C to a Fahrenheit reading.

In thinking our way through this problem we note that 80°C is 80 centigrade degrees above the freezing point of water. Since 1 degree C equals $\frac{9}{5}$ degrees F, 80°C will be $\frac{9}{5}$ × 80 or 144 Fahrenheit degrees above the freezing point of water. But the freezing point of water on the Fahrenheit scale is 32°. Therefore, we must add 32 to our 144 to get the actual Fahrenheit temperature, 176°F.

Problems

2.1 What temperature, in degrees centigrade, is represented by each of the following Fahrenheit temperatures?

(a) 72.0°F

SOLUTION: See solutions of problems given above.

*(b) −20.0°F

2.2 What temperature in degrees Fahrenheit is represented by each of the following centigrade temperatures?

(a) 12.0°C

*(b) −50.0°C

2.3 At what temperature will the readings on the Fahrenheit and centigrade thermometers be the same?

2.4 Suppose you have designed a new thermometer called the X thermometer. On the X scale the boiling point of water is 130°X and the freezing point of water is 10°X. At what temperature will the readings on the Fahrenheit and X thermometers be the same?*

2.5 On a new Jekyll temperature scale water freezes at 17°J and boils at 97°J. On another new temperature scale, the Hyde scale, water freezes at 0°H and boils at 120°H. If methyl alcohol boils at 84°H what is its boiling point on the Jekyll scale?

$(x)^{3}$

Exponents

Chemical problems often involve numbers which are either very large or very small. Such numbers are most conveniently expressed in *exponential form.*

To illustrate:

The number, 100, is 10^2, which is 1×10^2; 1000 is 1×10^3 and 1,000,000 is 1×10^6.

The number, 2,000,000, is $2 \times 1{,}000{,}000$, which is 2×10^6.

The number, 324,000,000, is $3.24 \times 100{,}000{,}000$, which is 3.24×10^8; but it is also $32.4 \times 10{,}000{,}000$, which is 32.4×10^7, and $324 \times 1{,}000{,}000$, which is 324×10^6. In other words, 324,000,000 may be represented as either 3.24×10^8, 32.4×10^7, or 324×10^6. The first of these, in which there is only one digit to the left of the decimal point in the non-exponential factor, is the preferred form.

Note that, in the above example in which we are dealing with numbers *larger* than 1, a decimal point is placed to the *right* of the first digit in the number; the resulting expression is then multiplied by 10 raised to a positive power equal to the number of terms to the *right* of the decimal point.

To illustrate:

$$602{,}000{,}000{,}000{,}000{,}000{,}000{,}000 = 6.02 \times 10^{23}$$

and

$$31{,}730{,}000 = 3.173 \times 10^{7}$$

The number 0.0001 is one tenthousandth, which is 1/10,000, which is $1/10^4$.

Keeping in mind that (a) $1 = 10^0$, (b) the fraction, $1/10^4$, means 1 divided by 10^4, and (c) in division of exponential numbers the exponent of the denominator is subtracted from the exponent of numerator, then

$$\frac{1}{10^4} = \frac{10^0}{10^4} = 10^{0-4} = 10^{-4} = 1 \times 10^{-4}$$

Likewise,

$$0.00002 = 2 \times \frac{1}{100{,}000} = 2 \times \frac{1}{10^5} = 2 \times 10^{-5}$$

and

$$0.00000038 \text{ is } 3.8 \times \frac{1}{10{,}000{,}000} = 3.8 \times \frac{1}{10^7} = 3.8 \times 10^{-7}$$

Note that, in dealing with numbers *less* than 1, a decimal point is placed to the *right* of the first term to the right of the zeros and the resulting expression is then multiplied by 10 raised to a *negative* power equal to the number of terms to the *left* of this decimal point.

Thus

$$0.00000257 = 2.57 \times 10^{-6}$$

and

$$0.000016 = 1.6 \times 10^{-5}$$

Just as 3.24×10^8, 32.4×10^7, and 324×10^6 all represent the same number so 2.57×10^{-6}, 25.7×10^{-7} and 257×10^{-8} are all the same number and 48×10^{-6} is equivalent to 4.8×10^{-5}.

Note that, in changing 48×10^{-6} to its equal, 4.8×10^{-5}, and in changing 32.4×10^7 to 3.24×10^8, we *divide* the first factor (48 and 32.4) by 10 and *multiply* the second factor (10^{-6} and 10^7) by 10. Likewise, in changing 0.23×10^{-4} to 2.3×10^{-5} we *multiply* the first factor (0.23) by 10 and *divide* the second factor (10^{-4}) by 10. Since, in each example, we multiply one factor by 10 and divide the other by 10, the value of the number is not changed.

Thus

$$2.36 \times 10^{-5} = 23.6 \times 10^{-6} = 236 \times 10^{-7} = 0.236 \times 10^{-4}$$

and

$$4.92 \times 10^5 = 49.2 \times 10^4 = 492 \times 10^3 = 0.492 \times 10^6$$

The use of exponents makes it quite easy to determine the correct number of digits in the answer to an operation involving multiplication and division of many numbers. Thus, if the expression

$$\frac{417{,}000 \times 0.0036 \times 15{,}300{,}000}{0.000021 \times 293 \times 183{,}000}$$