Complete Solutions Guide

to accompany

Chemistry

Seventh Edition

Steven S. Zumdahl
Susan Arena Zumdahl

Thomas J. Hummel
Steven S. Zumdahl
Susan Arena Zumdahl

University of Illinois at Urbana-Champaign

HOUGHTON MIFFLIN COMPANY Boston New York

Publisher and Editor-in-Chief: Charles Hartford
Executive Editor: Richard Stratton
Development Editor: Rebecca Berardy Schwartz
Assistant Editor: Liz Hogan
Senior Project Editor: Cathy Brooks
Editorial Assistant: Susan Miscio
Senior Marketing Manager: Katherine Greig
Market Assistant: Naveen Hariprasad

Printed in the U.S.A.

ISBN-10: 0-618-52852-0
ISBN-13: 978-0-618-52852-3

1 2 3 4 5 6 7 8 9-POO-10 09 08 07 06

TABLE OF CONTENTS

TO THE STUDENT: HOW TO USE THIS GUIDE

Solutions to all of the end of chapter questions and exercises are in this manual. This "Solutions Guide" can be very valuable if you use it properly. The way NOT to use it is to look at an exercise in the book and then immediately check the solution, often saying to yourself, "That's easy, I can do it." Developing problem solving skills takes practice. Don't look up a solution to a problem until you have tried to work it on your own. If you are completely stuck, see if you can find a similar problem in the Sample Exercises in the chapter. Only look up the solution as a last resort. If you do this for a problem, look for a similar problem in the end of chapter exercises and try working it. The more problems you do, the easier chemistry becomes. It is also in your self interest to try to work as many problems as possible. Most exams that you will take in chemistry will involve a lot of problem solving. If you have worked several problems similar to the ones on an exam, you will do much better than if the exam is the first time you try to solve a particular type of problem. No matter how much you read and study the text, or how well you think you understand the material, you don't really understand it until you have taken the information in the text and applied the principles to problem solving. You will make mistakes, but the good students learn from their mistakes.

In this manual we have worked problems as in the textbook. We have shown intermediate answers to the correct number of significant figures and used the rounded answer in later calculations. Thus, some of your answers may differ slightly from ours. When we have not followed this convention, we have usually noted this in the solution. The most common exception is when working with the natural logarithm (ln) function, where we usually carried extra significant figures in order to reduce round-off error. In addition, we tried to use constants and conversion factors reported to at least one more significant figure as compared to numbers given in the problem. The practice of carrying one extra significant figure in constants helps minimize round-off error.

We are grateful to Claire O. Szoke for her outstanding effort in preparing the manuscript for this manual. We also thank Linda C. Bush for her careful and thorough accuracy review of the Solutions Guide.

TJH
SSZ
SAZ

CHAPTER ONE

CHEMICAL FOUNDATIONS

For Review

1. a. Law versus theory: A law is a concise statement or equation that summarizes observed behavior. A theory is a set of hypotheses that gives an overall explanation of some phenomenon. A law summarizes what happens; a theory (or model) attempts to explain why it happens.

   b. Theory versus experiment: A theory is an explanation of why things behave the way they do, while an experiment is the process of observing that behavior. Theories attempt to explain the results of experiments and are, in turn, tested by further experiments.

   c. Qualitative versus quantitative: A qualitative observation only describes a quality while a quantitative observation attaches a number to the observation. Examples: Qualitative observations: The water was hot to the touch. Mercury was found in the drinking water. Quantitative observations: The temperature of the water was 62°C. The concentration of mercury in the drinking water was 1.5 ppm.

   d. Hypothesis versus theory: Both are explanations of experimental observation. A theory is a set of hypotheses that has been tested over time and found to still be valid, with (perhaps) some modifications.

2. No, it is useful whenever a systematic approach of observation and hypothesis testing can be used.

3. a. No. b. Yes c. Yes

   Only statements b and c can be determined from experiment.

4. Volume readings are estimated to one decimal place past the markings on the glassware. The assumed uncertainty is ±1 in the estimated digit. For glassware a, the volume would be estimated to the tenths place since the markings are to the ones place. A sample reading would be 4.2 with an uncertainty of ±0.1. This reading has two significant figures. For glassware b, 10.52 ±0.01 would be a sample reading and the uncertainty; this reading has four significant figures. For glassware c, 18 ±1 would be a sample reading and the uncertainty, with the reading having two significant figures.

5. Accuracy: How close a measurement or series of measurements are to an accepted or true value.

   Precision: How close a series of measurements of the same thing are to each other. The results, average = 14.91 ± 0.03%, are precise (close to each other) but are not accurate (not close to the true value.

6. In both sets of rules, the lease precise number determines the number of significant figures in the final result. For multiplication/division, the number of significant figures in the result is the same as the number of significant figures in the least precise number used in the calculation. For addition/subtraction, the result has the same number of decimal places as the least precise number used in the calculation (not necessarily the number with the fewest significant figures).

7. Consider gold with a density of 19.32 g/cm^3. The two conversion factors are:

$$\frac{19.32\text{ g}}{1\text{ cm}^3} \text{ or } \frac{1\text{ cm}^3}{19.32\text{ g}}$$

Use the first form when converting from the volume of gold in cm^3 to the mass of gold and use the second form when converting from mass of gold to volume of gold. When using conversion factors, concentrate on the units crossing off.

8. To convert from Celsius to Kelvin, a constant number of 273 is added to the Celsius temperature. Because of this, $\Delta T(°C) = \Delta T(K)$. When converting from Fahrenheit to Celsius, one conversion that must occur is to multiply the Fahrenheit temperature by a factor less than one (5/9). Therefore, the Fahrenheit scale is more expansive than the Celsius scale, and 1 °F would correspond to a smaller temperature change than 1 °C or 1K.

9. Chemical changes involve the making and breaking of chemical bonds. Physical changes do not. The identity of a substance changes after a chemical change, but not after a physical change.

10. Many techniques of chemical analysis require relatively pure samples. Thus, a separation step often is necessary to remove materials that will interfere with the analytical measurement.

Questions

17 A law summarizes what happens, e.g., law of conservation of mass in a chemical reaction or the ideal gas law, PV = nRT. A theory (model) is an attempt to explain why something happens. Dalton's atomic theory explains why mass is conserved in a chemical reaction. The kinetic molecular theory explains why pressure and volume are inversely related at constant temperature and moles of gas present as well as explaining the other mathematical relationships summarized in PV = nRT.

18. The fundamental steps are:
   1. making observations
   2. formulating hypotheses
   3. performing experiments to test the hypotheses

The key to the scientific method is performing experiments to test hypotheses. If after the test of time, the hypotheses seem to account satisfactorily for some aspect of natural behavior, then the set of tested hypotheses turn into a theory (model). However, scientists continue to perform experiments to refine or replace existing theories.

19. A qualitative observation expresses what makes something what it is; it does not involve a number, e.g., the air we breathe is a mixture of gases, ice is less dense than water, rotten milk stinks.

The SI units are mass in kilograms, length in meters, and volume in the derived units of m^3. The assumed uncertainty in a number is ±1 in the last significant figure of the number. The precision of an instrument is related to the number of significant figures associated with an experimental reading on that instrument. Different instruments for measuring mass, length, or volume have varying degrees of precision. Some instruments only give a few significant figures for a measurement while others will give more significant figures.

20. Precision: reproducibility; Accuracy: the agreement of a measurement with the true value.

a. imprecise and inaccurate data: 12.32 cm, 9.63 cm, 11.98 cm, 13.34 cm

b. precise but inaccurate data: 8.76 cm, 8.79 cm, 8.72 cm, 8.75 cm

c. precise and accurate data: 10.60 cm, 10.65 cm, 10.63 cm, 10.64 cm

Data can be imprecise if the measuring device is imprecise as well as if the user of the measuring device has poor skills. Data can be inaccurate due to a systematic error in the measuring device or with the user. For example, a balance may read all masses as weighing 0.2500 g too high or the user of a graduated cylinder may read all measurements 0.05 mL too low.

A set of measurements which are imprecise implies that all the numbers are not close to each other. If the numbers aren't reproducible, then all of the numbers can't be very close to the true value. Some say that if the average of imprecise data gives the true value, then it is accurate data; a better description is that the data takers are extremely lucky.

21. Significant figures are the digits we associate with a number. They contain all of the certain digits and the first uncertain digit (the first estimated digit). What follows is one thousand indicated to varying numbers of significant figures: 1000 or 1×10^3 (1 S.F.); 1.0×10^3 (2 S.F.); 1.00×10^3 (3 S.F.); 1000. or 1.000×10^3 (4 S.F.).

To perform the calculation, the addition/subtraction significant figure rule is applied to 1.5 − 1.0. The result of this is the one significant figure answer of 0.5. Next, the multiplication/division rule is applied to 0.5/0.50. A one significant figure number divided by a two significant figure number yields an answer with one significant figure (answer = 1).

22. The volume per mass is the reciprocal of the density (1/density). The volume per mass conversion factor has units of cm^3/g and is useful when converting from the mass of an object to its volume in cm^3.

23. Straight line equation: y = mx + b where m is the slope of the line and b is the y-intercept. For the T_F vs. T_C plot:

$$T_F = (9/5)T_C + 32$$
$$y = \quad m \quad x + b$$

The slope of the plot is 1.8 (= 9/5) and the y-intercept is 32°F.

For the T_C vs. T_K plot:

$$T_C = T_K - 273$$
$$y = mx + b$$

The slope of the plot is one and the y-intercept is −273°C.

24. a. coffee; saltwater; the air we breathe ($N_2 + O_2$ + others); brass (Cu + Zn)

 b. book; human being; tree; desk

 c. sodium chloride (NaCl); water (H_2O); glucose ($C_6H_{12}O_6$); carbon dioxide (CO_2)

 d. nitrogen (N_2); oxygen (O_2); copper (Cu); zinc (Zn)

 e. boiling water; freezing water; melting a popsicle; dry ice subliming

 f. Elecrolysis of molten sodium chloride to produce sodium and chlorine gas; the explosive reaction between oxygen and hydrogen to produce water; photosynthesis which converts H_2O and CO_2 into $C_6H_{12}O_6$ and O_2; the combustion of gasoline in our car to produce CO_2 and H_2O

Exercises

Significant Figures and Unit Conversions

25. a. exact b. inexact

 c. exact d. inexact (π has an infinite number of decimal places.)

26. a. one significant figure (S.F.). The implied uncertainty is ±1000 pages. More significant figures should be added if a more precise number is known.

 b. two S.F. c. four S.F.

 d. two S.F. e. infinite number of S.F. (exact number) f. one S.F.

27. a. $\underline{6.07} \times 10^{-15}$; 3 S.F. b. $0.00\underline{3840}$; 4 S.F. c. $\underline{17.00}$; 4 S.F.

 d. $\underline{8} \times 10^{8}$; 1 S.F. e. $\underline{463.8052}$; 7 S.F. f. $\underline{3}00$; 1 S.F.

 g. $\underline{301}$; 3 S.F. h. $\underline{300.}$; 3 S.F.

28. a. $\underline{1}00$; 1 S.F. b. $\underline{1.0} \times 10^{2}$; 2 S.F. c. $\underline{1.00} \times 10^{3}$; 3 S.F.

 d. $\underline{100.}$; 3 S.F. e. $0.00\underline{48}$; 2 S.F. f. $0.00\underline{480}$; 3 S.F.

 g. $\underline{4.80} \times 10^{-3}$; 3 S.F. h. $\underline{4.800} \times 10^{-3}$; 4 S.F.

29. When rounding, the last significant figure stays the same if the number after this significant figure is less than 5 and increases by one if the number is greater than or equal to 5.

 a. 3.42×10^{-4} b. 1.034×10^{4} c. 1.7992×10^{1} d. 3.37×10^{5}