THEODORE L. BROWN
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SOLUTIONS TO EXERCISES IN

Chemistry

The central science

2ND EDITION

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Prentice-Hall, Inc., Englewood Cliffs, New Jersey 07632

Printed in the United States of America

ISBN 0-13-128538-6

10 9 8 7 6 5 4 3 2 1

PRENTICE-HALL INTERNATIONAL, INC., London
PRENTICE-HALL OF AUSTRALIA PTY. LIMITED, Sydney
PRENTICE-HALL OF CANADA, LTD., Toronto
PRENTICE-HALL OF INDIA PRIVATE LIMITED, New Delhi
PRENTICE-HALL OF JAPAN, INC., Tokyo
PRENTICE-HALL OF SOUTHEAST ASIA PTE. LTD., Singapore
WHITEHALL BOOKS, LTD., Wellington, New Zealand

Introduction

Chemistry: The Central Science, 2nd edition, contains about 1600 end-of-chapter exercises. We have given much attention to these exercises because we believe that one of the best ways for students to master chemistry is by solving problems. Because of their limited time, students will normally be able to work only a portion of the available exercises. By grouping them according to subject matter, we have aided the student in selecting and recognizing particular types of problems. This grouping also aids the instructor in assigning an appropriate range of problems to be worked. For those who prefer general exercises, we have provided in each chapter a substantial number of these to supplement those grouped by type. Providing brief answers in the text to about 600 of these exercises has helped to make the text a useful self-contained vehicle for learning.

This manual, Solutions to Exercises in Chemistry: The Central Science, 2nd edition, was written to further facilitate the use of the end-of-chapter exercises. In providing complete, worked-out solutions to all of these exercises, this manual should give further assistance to both instructor and student. For the instructor, it will save time spent in working out solutions for assigned problem sets. For students, it gives a means of checking their understanding of the material. Most of the solutions have been worked in the same detail as the in-chapter sample exercises in order to guide the students in their studies.

We have tried to keep this book as error-free as possible. All exercises have been worked by at least two persons to ensure not only that the answer arrived at is correct but also that the steps in arriving at the answer are shown clearly and completely. However, it is probably too much to expect that we have caught all typographical errors in our proofreading. Should you find any errors, we would appreciate hearing from you. We hope, whether you are an instructor or a student, that you will find this manual helpful and instructive.

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Introduction: some basic concepts

1.1 Chemistry is an experimental science. The systems on which experiments are performed are relatively simple collections of matter. The experiments the chemist performs should be reproducible, and should reveal some new aspect of nature. Normally, there is no sense of an adversary relation toward nature. The laws formulated by the chemist are the logical outgrowth of experimental observations. These laws should be independent of the social or political origins of the chemist who formulates them.

By contrast, the lawyer and judge are intensely concerned with human values. The laws of society are based on judgments of what is good or bad for society. The laws rest mainly on intellectual judgments and are the logical outgrowth of a particular view of human society. They have less basis in "experiments" than do scientific laws. Evidence in the law is used to judge human conduct in relationship to laws, but not as a test of them as it is in science.

1.2 Science advances largely by showing that one or more hypotheses or theories is wrong because of a conflict with reliable experimental results. When conflicting hypotheses are advanced to account for a body of experimental data, it is usually possible to design an experiment that will prove one or the other hypothesis incorrect.

1.3 It should be called Coulomb's law, because it simply summarizes experimental observations regarding the forces between charged objects. A theory would advance an explanation for why the charged objects behave as they do.

1.4 Wöhler, by preparing a substance found in living systems from inorganic starting materials, showed that the compound, urea, did not need the agency of a living system for its formation. Thus, the basic assumption behind the vitalist theory was demolished.

1.5 (a) A hypothesis is an informed guess or tentative explanation about some aspect of nature, based on a relatively few experimental facts. A theory is a more comprehensive intellectual construct, or model, based on a large number of observations, which "explains" those observations and permits predictions regarding the results of new experiments. (b) A paradigm is a generally accepted set of beliefs about how things are based on wide experience on the part of an entire group of persons working in the same area. For example, among geologists it is generally accepted that the earth is about 4.5 billion years old. A law is a concise verbal statement or equation that summarizes a particular well-established set of observations. (c) Experiments are organized observations of how nature behaves under controlled conditions. A theory is an intellectual construct, an "explanation," that accounts for a number of related experiments in a single, unifying manner. (d) Quantitative experiments involve making accurate measurements; of quantities, temperature, times, and so forth. Qualitative observations are simply reports of what seemed to happen in an experiment (boiling, a yellow flame, a solid formed, etc).

1.6 (a) meters, m; (b) cubic meters, m^3; (c) kilograms, kg; (d) square meters, m^2; (e) second, sec or simply s

1.7 (a) kilo; (b) deci; (c) mega; (d) micro; (e) pico

1.8 (a) $(1.00 \text{ kg gold})\left(\frac{1000 \text{ g}}{1 \text{ kg}}\right)\left(\frac{0.0518 \text{ cm}^3 \text{ gold}}{1.00 \text{ g gold}}\right) = 51.8 \text{ cm}^3$

(b) $(1.00 \text{ dg gold})\left(\frac{0.1 \text{ g}}{1 \text{ dg}}\right)\left(\frac{0.0518 \text{ cm}^3 \text{ gold}}{1.00 \text{ g gold}}\right) = 5.18 \times 10^{-3} \text{ cm}^3$

(c) $5.18 \times 10^{-5} \text{ cm}^3$ (d) 0.518 cm^3 (e) $5.18 \times 10^{-9} \text{ cm}^3$

(f) $5.18 \times 10^{-6} \text{ cm}^3$

1.9 (a) 650 cm or 6.50×10^2 cm; (b) $33 \text{ kg}\left(\frac{1000 \text{ g}}{1 \text{ kg}}\right)\left(\frac{1000 \text{ mg}}{1 \text{ g}}\right) = 3.3 \times 10^7$ mg; (c) 1.2×10^4 msec; (d) 0.043 g; (e) 2.35×10^3 g; (f) 2.25×10^4 μm

1.10 (a) 5×10^5m; (b) 0.326 kg; (c) $476 \text{ nm}\left(\frac{1 \text{ m}}{10^9 \text{ nm}}\right)\left(\frac{100 \text{ cm}}{1 \text{ m}}\right) = 4.76 \times 10^{-5}$ cm; (d) 8.2×10^{-2} msec

1.11 (a) volume; (b) area; (c) mass; (d) length

1.12 3.08×10^{16}m. 3.08×10^{10}m per microparsec

$$\left(\frac{3.08 \times 10^{13} \text{km}}{1 \text{ parsec}}\right)\left(\frac{1000 \text{ m}}{1 \text{ km}}\right)\left(\frac{100 \text{ cm}}{1 \text{ m}}\right)\left(\frac{1 \text{ parsec}}{10^9 \text{ nparsec}}\right) = \frac{3.08 \times 10^9 \text{cm}}{1 \text{ nparsec}}$$

1.13 2.205 lb; 39.39 in.; 28.35 g; 0.4717 L;

$$55 \text{ cm}\left(\frac{1 \text{ m}}{100 \text{ cm}}\right)\left(\frac{1.094 \text{ yd}}{1 \text{ m}}\right)\left(\frac{3 \text{ ft}}{1 \text{ yd}}\right) = 1.80 \text{ ft}$$

1.14 $$\left(\frac{70{,}664 \text{ mi}^2}{649{,}000 \text{ people}}\right)\left(\frac{1760 \text{ yd}}{1 \text{ mi}}\right)^2\left(\frac{1 \text{ m}}{1.094 \text{ yd}}\right)^2 = \frac{281{,}802 \text{ m}^2}{\text{person}}$$

Round off to 3 significant figures, because the population is estimated to 3 significant figures. Thus, 282,000 m^2/person, or $2.82 \times 10^5 m^2$/person.

1.15 (a) four; (b) three; (c) three; (d) one; (e) two; (f) two, three or four - can't be sure without knowing the context; (g) six

1.16 (a) three; (b) three; (c) three; (d) from one to five - can't be sure; (e) three; (f) two

1.17 (a) 4.568×10^6; (b) 2.358×10^3; (c) 4.256×10^4; (d) 2.389×10^{-3}; (e) 9.876

1.18 (a) 1.245×10^3; (b) 6.50×10^4; (c) 5.975×10^4; (d) 4.56×10^{-3}

1.19 (a) 0.55; (b) 3.5×10^3; (c) 5.74×10^{-9}; (d) 2×10^{-6}; (e) 1.5; (f) 1.82×10^3

1.20 (a) 6.71×10^{-3}; (b) 9.0×10^{-3}; (c) 18.6; (d) 5.74

1.21 (a) 1.78 m; (b) 2.20×10^3kg; (c) 3282 ft; (d) 43.4 L

1.22 (a) $$1302 \text{ ft}\left(\frac{1 \text{ yd}}{3 \text{ ft}}\right)\left(\frac{1 \text{ m}}{1.094 \text{ yd}}\right)\left(\frac{1 \text{ fathom}}{1.8288 \text{ m}}\right) = 216.9 \text{ fathoms}$$

(b) $$10.000 \text{ furlong}\left(\frac{201.17 \text{ m}}{\text{furlong}}\right)\left(\frac{1.094 \text{ yd}}{1 \text{ m}}\right)\left(\frac{1 \text{ mi}}{1760 \text{ yd}}\right) = 1.250 \text{ mi}$$

1.23 (a) 1.2×10^2L; (b) 15.432 grains; (c) 1.62×10^3 pennywt.; (d) 1016 kg

1.24 (a) 86.62 dm^3; (b) 5.24 L; (c) 10^6 m^2; 0.386 mi^2

1.25 mass of toluene is 87.127 g - 57.832 g = 29.295 g.

$$(29.295\text{g toluene})\left(\frac{1 \text{ cm}^3 \text{ toluene}}{0.866\text{g toluene}}\right) = 33.8 \text{ cm}^3$$

The number of significant figures is limited by the accuracy with which we know the density of toluene.

1.26 (a) 10 miles is 1.760×10^4 yds; add 120 yds, obtain 1.772×10^4 yds.

$$1.772 \times 10^4 \text{ yds}\left(\frac{1 \text{ m}}{1.094 \text{ yd}}\right)\left(\frac{1 \text{ km}}{1000 \text{ m}}\right) = 16.20 \text{ km}$$

(b) $$2.74026 \times 10^8 \text{ yd}^3\left(\frac{1 \text{ m}}{1.094 \text{ yd}}\right)^3 = 2.09286 \times 10^8 \text{ m}^3 = 0.2093 \text{ km}^3$$

(c) $$11{,}647 \text{ ft}\left(\frac{1 \text{ yd}}{3 \text{ ft}}\right)\left(\frac{1 \text{ m}}{1.094 \text{ yd}}\right) = 3549 \text{ m}$$

(The four-place precision is limited by the precision of the conversion, 1.094 yd = 1m, Table 1.3. Using the value on the back inside cover, 1.0936, we obtain for (b), 0.20952 km^3; for (c), 3.5500 km.)

(d) 147 m high; 230 m on each side; 2.3×10^3 kg each

(e) 804 km race;

$$\frac{99.482 \text{ mi}}{1 \text{ hr}}\left(\frac{1760 \text{ yd}}{1 \text{ mi}}\right)\left(\frac{1 \text{ m}}{1.094 \text{ yd}}\right)\left(\frac{1 \text{ km}}{1000 \text{ m}}\right)\left(\frac{1 \text{ hr}}{3600 \text{ sec}}\right)$$

$$= 0.04446 \text{ km/sec} = 44.46 \text{ m/sec}$$

1.27 (a) $$1 \text{ mi}\left(\frac{5280 \text{ ft}}{1 \text{ mi}}\right)\left(\frac{12 \text{ in.}}{1 \text{ ft}}\right)\left(\frac{1 \text{ link}}{7.92 \text{ in.}}\right)\left(\frac{1 \text{ chain}}{100 \text{ links}}\right) = 80.0 \text{ chains}$$

(b) We can use the result from (a) to help answer part (b):

$$1 \text{ rod}\left(\frac{1 \text{ chain}}{4 \text{ rods}}\right)\left(\frac{1 \text{ mi}}{80 \text{ chains}}\right)\left(\frac{1760 \text{ yd}}{1 \text{ mi}}\right)\left(\frac{1 \text{ m}}{1.094 \text{ yd}}\right) = 5.027 \text{ m}$$

(c) We have that 80 chains = 1 mi. Thus $(80 \text{ chain})^2 = 1 \text{ mi}^2$ = 6400 $chain^2$. Using the answer from (b), we have

(d) $$1 \text{ yd}^3\left(\frac{1 \text{ m}}{1.094 \text{ yd}}\right)^3\left(\frac{1 \text{ rod}}{5.027 \text{ m}}\right)^3 = 5.13 \times 10^{-3} \text{ rod}^3$$

1.28 (a) $$\left(\frac{62 \text{ mi}}{1 \text{ hr}}\right)\left(\frac{1760 \text{ yd}}{1 \text{ mi}}\right)\left(\frac{1 \text{ m}}{1.094 \text{ yd}}\right)\left(\frac{1 \text{ km}}{1000 \text{ m}}\right) = 100 \text{ km/hr}$$

(b) 28 m/sec (c) $$\left(\frac{\$2.45}{1 \text{ lb}}\right)\left(\frac{2.205 \text{ lb}}{1 \text{ kg}}\right) = \$5.40/\text{kg}$$

$$\left(\frac{\$5.40}{\text{kg}}\right)\left(\frac{1 \text{ Mark}}{\$0.46}\right) = 11.7 \text{ Mark/kg}$$

(d) $12 \text{ fl oz} \left(\frac{1 \text{ qt}}{32 \text{ fl oz}}\right)\left(\frac{1 \text{ L}}{1.06 \text{ qt}}\right) = 0.35 \text{ L}$

<u>1.29</u> (a) $238{,}850 \text{ mi} \left(\frac{1760 \text{ yd}}{1 \text{ mi}}\right)\left(\frac{1 \text{ mi}}{1.094 \text{ yd}}\right)\left(\frac{1 \text{ km}}{1000 \text{ m}}\right) = 3.842 \times 10^5 \text{ km}$

The number of significant figures is limited to the number of significant figures in the conversion from m to yd. If we were to use a more precise number here, we could report the result to five significant figures, since there are that many in the originally given distance to the moon.

$27.32 \text{ days} \left(\frac{24 \text{ hr}}{1 \text{ day}}\right)\left(\frac{3600 \text{ sec}}{1 \text{ hr}}\right) = 2.360 \times 10^6 \text{ sec}$

$1081 \text{ mi} \left(\frac{1760 \text{ yd}}{1 \text{ mi}}\right)\left(\frac{1 \text{ m}}{1.094 \text{ yd}}\right)\left(\frac{1 \text{ km}}{1000 \text{ m}}\right) = 1739 \text{ km}$

$1.62 \times 10^{23} \text{ lb} \left(\frac{1 \text{ kg}}{2.205 \text{ lb}}\right) = 7.35 \times 10^{22} \text{ kg}$

<u>1.30</u> $4.84 \times 10^8 \text{ mi} \left(\frac{1760 \text{ yd}}{1 \text{ mi}}\right)\left(\frac{1 \text{ m}}{1.094 \text{ yd}}\right)\left(\frac{1 \text{ km}}{1000 \text{ m}}\right) = 7.79 \times 10^8 \text{ km}$

$11.86 \text{ yr} \left(\frac{365 \text{ day}}{1 \text{ yr}}\right)\left(\frac{24 \text{ hr}}{1 \text{ day}}\right)\left(\frac{3600 \text{ sec}}{1 \text{ hr}}\right) = 3.740 \times 10^8 \text{ sec}$

$\frac{1.330 \text{ g}}{1 \text{ cm}^3}\left(\frac{1 \text{ kg}}{1000 \text{ g}}\right)\left(\frac{100 \text{ cm}}{1 \text{ m}}\right)^3 = 1.330 \times 10^3 \frac{\text{kg}}{\text{m}^3}$

<u>1.31</u> $(4.5 \text{ cm})(12.54 \text{ cm})(1.25 \text{ cm}) = 71 \text{ cm}^3$ The result is limited to two significant figures because 4.5 cm contains just two.

$(71 \text{ cm}^3)\left(\frac{1 \text{ m}}{10^2 \text{ cm}}\right)^3 = 7.1 \times 10^{-5} \text{ m}^3$

<u>1.32</u> $\left(\frac{980.66 \text{ cm}}{\text{sec}^2}\right)\left(\frac{1 \text{ m}}{10^2 \text{ cm}}\right) = 9.8066 \text{ m/sec}^2$

<u>1.33</u> (a) volume $= \pi(6.5 \text{ cm})^2(28.6 \text{ cm}) = 3.8 \times 10^3 \text{ cm}^3$

(b) $\pi 8.0 \text{ ft} \left(\frac{1 \text{ yd}}{3 \text{ ft}}\right)\left(\frac{1 \text{ m}}{1.094 \text{ yd}}\right)(10.0 \text{ in.})^2\left(\frac{2.54 \text{ cm}}{1 \text{ in.}}\right)^2\left(\frac{1 \text{ m}}{100 \text{ cm}}\right)^2 = 0.49 \text{ m}^3$

(c) $0.49 \text{ m}^3 \left(\frac{100 \text{ cm}}{1 \text{ m}}\right)^3\left(\frac{1.00 \text{ g } H_2O}{1 \text{ cm}^3}\right)\left(\frac{1 \text{ kg}}{10^3 \text{ g}}\right) = 4.9 \times 10^2 \text{ kg}$

<u>1.34</u> $°C = (100.6 - 32)(5/9) = 38.1°C$

<u>1.35</u> (a) 19.4°C; (b) -22°C; (c) 628 K; (d) -123°C; (e) 322 K; (f) 227 K

<u>1.36</u> $1 \text{ dm}^3 \left(\frac{10 \text{ cm}}{1 \text{ dm}}\right)^3\left(\frac{13.6 \text{ g}}{1 \text{ cm}^3}\right) = 13{,}600 \text{ g} = 13.6 \text{ kg}$

<u>1.37</u> density $= \frac{\text{mass}}{\text{volume}} = \frac{4.268 \text{ kg}}{3.47 \text{ L}} = \frac{1.23 \text{ kg}}{\text{L}}\left(\frac{1 \text{ L}}{10^3 \text{ cm}^3}\right)\left(\frac{10^3 \text{ g}}{1 \text{ kg}}\right) = 1.23 \text{ g/cm}^3$

<u>1.38</u> $\frac{\$0.39}{600 \text{ mL}}\left(\frac{1 \text{ mL}}{1 \text{ cm}^3}\right)\left(\frac{1 \text{ cm}^3}{0.79 \text{ g}}\right)\left(\frac{10^3 \text{ g}}{\text{kg}}\right) = \frac{\$0.82}{\text{kg}}$

<u>1.39</u> density $= \frac{(251.65 - 204.58) \text{ g}}{58.3 \text{ cm}^3} = 0.807 \text{ g/cm}^3$

1.40 volume of room = (8.2)(13.5)(2.75) = $3.0 \times 10^2 m^3$

$$3.0 \times 10^2 m^3 \left(\frac{100\ cm}{m}\right)^3 \left(\frac{1.19\ g}{10^3\ cm^3}\right) = 3.6 \times 10^5\ g = 360\ kg$$

(Here we use the fact that 1 L = 1000 cm^3.)

1.41 Add enough water to the cylinder so that the marble will be completely immersed when it is added later. Weigh the cylinder as accurately as possible, and note the volume level as accurately as possible. Add the marble, and repeat both measurements. The difference in volume readings gives the volume of the marble; the difference in mass gives the mass of the marble. The density is simply the mass divided by the volume.

1.42 Weight-extensive; color-intensive; density-intensive; volume-extensive; temperature-intensive; melting point-intensive; ease of corrosion-intensive

1.43 (a) inappropriate - The circulation of a widely read publication would vary over a year's time, and could simply not be counted to the nearest single subscriber. Probably about 4 significant figures would be appropriate. (b) appropriate - It might be possible to do better than two significant figures, but an estimate to two significant figures should be easily possible. (c) Rainfall can be measured to within 0.01 in., but it is probably not possible to record an entire year's rainfall to the nearest 0.01 in. Further, the variation from year to year is sufficiently large that it does not make much sense to report the average to this number of significant figures. Probably two significant figures would be appropriate. (d) inappropriate - The population of a city is not constant during a year, and cannot probably even be counted at any one time to an accuracy of one person. Probably 51,000 would be an appropriate estimate.

1.44 -88°C; 185 K

1.45 (a) 5 ft 3 in. = 63 in. $\left(\frac{2.54\ cm}{1\ in.}\right)\left(\frac{1\ m}{100\ cm}\right) = 1.60\ m$

$100\ lb \left(\frac{1\ kg}{2.205\ lb}\right) = 49.9\ kg \qquad 122\ lb \left(\frac{1\ kg}{2.205\ lb}\right) = 55.3\ kg$

(b) 5 ft 9 in. = 69 in. $\left(\frac{2.54\ cm}{1\ in.}\right)\left(\frac{1\ m}{100\ cm}\right) = 1.75\ m$

$154\ lb \left(\frac{1\ kg}{2.205\ lb}\right) = 69.8\ kg \qquad 2.5\ oz \left(\frac{28.35\ g}{1\ oz}\right) = 71\ g$ protein

1.46 volume of room = (2.5)(15)(40) = $1.5 \times 10^3 m^3$

$$1.5 \times 10^3 m^3 \left(\frac{10\ mg\ CO}{1\ m^3}\right)\left(\frac{1\ g}{1000\ mg}\right) = 15\ g\ CO$$

1.47 100°C = 212 - 32 = 180°F Thus, 1°C = $\frac{180}{100}$ °F = 1.80°F

1.48 (a) $\left(\frac{4.5\ g}{cm^3}\right)\left(\frac{1\ kg}{1000\ g}\right)\left(\frac{100\ cm}{1\ m}\right)^3 = 4.5 \times 10^3 \frac{kg}{m^3}$

(b) $248\ cm^2 \left(\frac{1\ m}{100\ cm}\right)^2 = 2.48 \times 10^{-2} m^2$

(c) $\left(289\ \frac{g\ cm}{sec^2}\right)\left(\frac{1\ kg}{1000\ g}\right)\left(\frac{1\ m}{100\ cm}\right) = 2.89 \times 10^{-3}$ kg-m/sec^2

(d) $2230 \frac{dm^3}{hr} \left(\frac{1\ m}{10\ dm}\right)^3 \left(\frac{1\ hr}{3600\ sec}\right) = 6.19 \times 10^{-4} m^3/sec$

1.49 A most important characteristic of scientific activity is doing experiments under controlled and reproducible conditions. Experiments are designed so as to answer some question about an aspect of nature that interests the scientist. The evaluation of experimental results should be totally objective. That is, all who perform the experiment should be able to agree upon the results.

The interpretations placed on experimental observations are based on the model, or theory, one has about that aspect of nature. Such theories are evaluated on the extent to which they correctly account for experimental facts, and not on the basis of any other factors such as political or religious beliefs. Thus, a theory about a set of chemical observations is based on experimental data. By contrast, any theory one might have about the origins of the characters in Ulysses would necessarily be based on historical information, such as Joyce's letters and notes, and contemporary accounts. One's conclusions would very likely be influenced in part by one's own point of view regarding literary aesthetics, political theory, and religious beliefs. It is much less straightforward to subject such a theory to "experimental" test. All this, of course, does not mean that literary criticism has less validity than scientific research. It merely indicates that the two kinds of activity differ in important ways, in their methods and in their goals.

1.50 $8\ qt \left(\frac{1\ L}{1.06\ qt}\right)\left(\frac{1000\ cm^3}{1\ L}\right)\left(\frac{19.3\ g}{1\ cm^3}\right)\left(\frac{1\ kg}{1000\ g}\right) = 1.5 \times 10^2\ kg$

The thief would need to be exceptionally strong, since the bucket has a mass about twice that of an average man (see problem 1.45(b)).

1.51 $\frac{22.4\ mi}{gal}\left(\frac{1760\ yd}{1\ mi}\right)\left(\frac{1\ m}{1.094\ yd}\right)\left(\frac{1\ km}{1000\ m}\right)\left(\frac{1\ gal}{4\ qt}\right)\left(\frac{1.06\ qt}{1\ L}\right) = 9.55\ km/L$

1.52 $\frac{100\ m}{9.9\ sec}\left(\frac{1.094\ yd}{1\ m}\right)\left(\frac{1\ mi}{1760\ yd}\right)\left(\frac{3600\ sec}{hr}\right) = 22.6\ mi/hr$

1.53 (a) $2.00 \times 10^2\ g \left(\frac{1\ cm^3}{7.86\ g}\right) = 25.4\ cm^3$

volume of a sphere $= (4/3)\pi r^3 = 25.4\ cm^3$

$$r = \left(\frac{(25.4)(3)}{4\pi}\right)^{1/3} = 1.82\ cm$$

(b) 2.60 cm (c) 1.61 cm

2

Our chemical world: atoms, molecules, and ions

2.1 (a) mercury; (b) sulfur melts at 112°C; phenol (carbolic acid) melts at 41°C; naphthalene (used as moth crystals) melts at 80°C; (c) naphthalene or para-dichlorobenzene, used as moth crystals sublime slowly into the vapor state when allowed to stand. Solid CO_2, "dry ice," sublimes without melting.

2.2 Some distinguishing physical properties: solubility in water, melting point, density, hardness, crystal form. Some distinguishing chemical properties: sugar can be combusted in air, salt cannot; solutions of table salt produce precipitates when mixed with solutions of other ionic substances, whereas sugar does not. This and many other chemical distinctions will become more obvious as we proceed in the text.

2.3 (a) A battery fluid is a solution of sulfuric acid in water. (b) The gold bars should be pure substance. (c) Sand is a heterogeneous mixture of different minerals; this is so even within most individual grains of sand. (d) Seven-up is a solution, that is, a homogeneous mixture, of sugar and other substances, including carbon dioxide. (e) A Bufferin or Anacin tablet is a heterogeneous mixture of two or more substances.

2.4 (a) Burning of the magnesium ribbon is a chemical process; it involves oxidation of magnesium to magnesium oxide. (b) Extrusion of copper into copper wire is a physical process; it does not change the chemical nature of the substance. (c) Heating of a filament is mainly a physical process, though there may be a slow chemical change in the filament while it is hot that eventually causes the bulb to burn out. (d) Distillation is a physical process. (e) Crystallization is a physical process; chemical composition of the substance being crystallized does not change. (f) Tarnishing of silver is a chemical process; silver metal is converted to some other compound of silver, such as silver sulfide, Ag_2S.

2.5 (a) physical change; (b) Hard-boiling an egg is a chemical change; the protein in the egg has been chemically altered. (c) physical change; (d) Burning of coal produces new chemical substances; it is thus a chemical process. (e) Forming a solution of salt in water is a physical change; the salt is readily recovered by evaporating off the water. (f) The "dissolving" of an Alka-Seltzer tablet is in part a chemical reaction; we see gas given off, indicating that a new substance has been formed. (g) physical change.

2.6 (a) Fractional distillation; the methyl alcohol would distill over at lower temperature than butyl alcohol. (b) Place the two salts in water; sodium chloride dissolves, silver chloride does not; filter to remove silver chloride, then evaporate water off to recover sodium chloride. (c) Use column chromatography, as illustrated in Figure 2.6. (d) Use a large distillation apparatus with fractionating column, as shown in Figure 2.4.

2.7 Physical Properties: silver-white color; soft; good conductor of electricity; boils at 883°C; vapor is violet-colored. Chemical Properties: prepared by electrolysis of molten sodium chloride; tarnishes rapidly in air; burns on heating in air or in bromine vapor.

2.8 The molten material present on the surface of the hot planet can be considered a solution of many substances all together. Some of the components of this solution mixture could react with one another or with gases present in the atmosphere to form insoluble products that would separate as either solid precipitates or as liquids. Copper, for example, would not likely be soluble in a molten mineral mixture. Some of the mixture components that were soluble at higher temperatures would begin to crystallize out as the temperature dropped. These would then form blocks of essentially pure solids which would eventually be surrounded by other solid substances as the liquid cooled still further.

2.9 In the early days of the atomic theory, the evidence for an element was that the substance was incapable of being chemically broken down into still simpler substances. Thus the evidence was always negative in character. Only when means were devised for analyzing materials carefully could the elemental nature of a substance be fully established. Of course, there was also much reasoning by analogy. A substance with a bright, shiny metallic appearance was likely to be a metallic element.

2.10 The ink components are adsorbed onto the paper. The most strongly adsorbed components are those which move most slowly up the paper.

2.11 The product of reaction of hydrogen and bromine is a substance with a fixed ratio of one substance to the other, because the molecules of the product each contain the same relative numbers of hydrogen and bromine atoms. The composition of the product is fixed; the identity of the product depends on the fact that the composition of each molecule is the same. If there is an excess of one gas over the other when the two are reacted, molecules of the component present in excess remain unreacted. These observations illustrate the law of constant composition.

2.12 There is no difference in nutritional value. If the two preparations of ascorbic acid were different, it would be because traces of other substances were present. These other substances could be carried along in the purification processes, probably recrystallization. However, careful work should result in negligible levels of any other substances in the ascorbic acid isolated from either source.

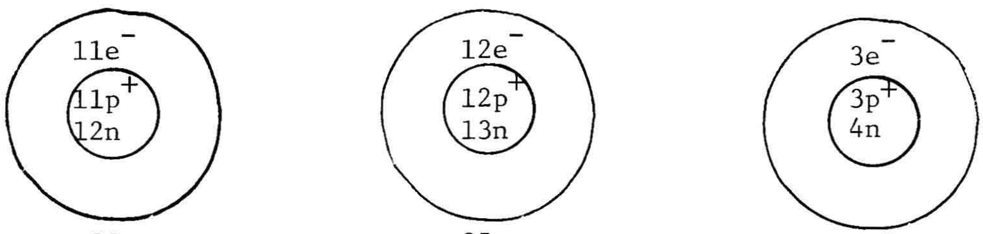
2.13 There are no simple ways to be sure that atoms retain their identity in molecules. Various sophisticated techniques are now available which make it possible to learn about the shapes and sizes of molecules, and about how charge and mass are distributed within them. It appears that "atoms" are present in molecules. For example, the water molecules, formula H_2O, appear to consist of a central mass connected to two smaller masses, with an overall boomerang-like shape. We presume that a central oxygen atom is connected to two hydrogen atoms.

When we electrolyze water, as in Figure 2.8, we obtain the two substances oxygen and hydrogen from which the water was formed in the first place. This suggests, but does not prove, that the oxygen and hydrogen atoms retain their identity in the water molecule.

2.14 Calculate the ratio mass oxygen/mass nitrogen. A, 1.14; B, 2.28; C, 1.705. Dividing through by the smallest of these, we obtain A, 1.00; B, 2.00; C, 1.50. To convert these to whole numbers, multiply by 2: A, 2.00; B, 4.00; C, 3.00. These data tell us that the ratios of oxygen to nitrogen in the three compounds are related to one another as small whole numbers. In other words, while we don't know yet, without doing more calculating, just what the ratio of oxygen to nitrogen atoms in compound A is, we know that in compound B there is twice as much oxygen relative to nitrogen; in Compound C there is 1.5 times as much.

2.15 Substance A must be a compound, because it is broken down into other substances on heating. The gas formed is also a compound, because it consists of carbon and oxygen. We do not know enough about B to know whether it is a compound or an element.

2.16



(a) ^{23}Na (b) ^{25}Mg (c) ^{7}Li

2.17 The tracks are long because the α particles encounter only empty space or the outer electrons of atoms in their path. By gradually losing energy via many contacts with the electrons of atoms, the α particles eventually slow down and are stopped. Occasionally, an α particle makes a direct hit on a small but highly charged nucleus of a nitrogen or oxygen atom. Such an encounter causes the α particle to be deflected from its course. However, these encounters are rare because the nuclei have such a small cross-section.

2.18 The droplets contain different charges because there may be 1,2,3 or more excess electrons on the droplet. The electronic charge is likely to be the lowest common factor in all the observed charges. Assuming this is so, we calculate the apparent electronic charge from each drop as follows:

A	$1.60 \times 10^{-19}/1$	=	1.60×10^{-19} coul
B	$3.15 \times 10^{-19}/2$	=	1.58×10^{-19} coul
C	$4.81 \times 10^{-19}/3$	=	1.60×10^{-19} coul
D	$6.31 \times 10^{-19}/4$	=	1.58×10^{-19} coul

The average value from these four observations is 1.59×10^{-19} coul. There appears to be an experimental uncertainty of about ±0.01 coul, so 3 significant figures are justified.

2.19 mass of 3 protons = $3 \times 1.67 \times 10^{-24}$ g = 5.01×10^{-24} g
mass of 4 neutrons = $4 \times 1.67 \times 10^{-24}$ g = 6.68×10^{-24} g
mass of 3 electrons = $3 \times 9.1 \times 10^{-28}$ g = 2.7×10^{-27} g

Total mass 11.69×10^{-24} g

proton fraction of mass = 5.01/11.69 = 0.429
neutron fraction of mass = 6.68/11.69 = 0.571
electron fraction of mass = $2.7 \times 10^{-27}/11.69 \times 10^{-24} = 2.3 \times 10^{-4}$

The electrons clearly constitute a very small fraction of the atomic mass, negligible in comparison with the masses of protons and neutrons.

2.20 $2.7\ \text{Å}\left(\frac{10^{-10}\ \text{m}}{1\ \text{Å}}\right)\left(\frac{10^{12}\ \text{pm}}{1\ \text{m}}\right) = 270\ \text{pm}$ $2.7\ \text{Å}\left(\frac{10^{-10}\ \text{m}}{1\ \text{Å}}\right)\left(\frac{10^{9}\ \text{nm}}{1\ \text{m}}\right) = 0.27\ \text{nm}$

$$\frac{1\ \text{Ir}}{0.27\ \text{nm}}\left(\frac{10^{9}\ \text{nm}}{1\ \text{m}}\right)\left(\frac{1\ \text{m}}{10^{3}\ \text{nm}}\right) = 3.7 \times 10^{6}\ \text{Ir atoms/mm}$$

2.21 Volume = $(4/3)\pi r^3 = 4/3\pi(0.75\ \text{km})^3 = 1.8\ \text{km}^3$

density = $2 \times 10^{30}\ \text{kg}/1.8\ \text{km}^3 = 1 \times 10^{30}\ \text{kg/km}^3 = 1 \times 10^{18}\ \text{g/cm}^3$
to be compared with 0.07 g/cm^3 for liquid H_2!

2.22 (a) Must contain the same number of protons, neutrons and electrons. (b) Must contain the same number of protons and electrons. (c) Must contain the same total number of protons plus neutrons.

2.23 (a) ^{13}C 6 protons, 7 neutrons, 6 electrons
(b) ^{55}Mn 25 protons, 30 neutrons, 25 electrons
(c) ^{97}Mo 42 protons, 55 neutrons, 42 electrons

2.24 (a) ^{6}Li 3 protons, 3 neutrons, 3 electrons
(b) ^{57}Fe 26 protons, 31 neutrons, 26 electrons
(c) ^{27}Al 13 protons, 14 neutrons, 13 electrons
(d) ^{19}F 9 protons, 10 neutrons, 9 electrons

2.25 (a) $^{39}_{19}K$; (b) $^{35}_{17}Cl$; (c) $^{29}_{14}Si$; (d) $^{32}_{16}S$, $^{34}_{16}S$

2.26 (a) Mn, a metal; (b) Se, a nonmetal; (c) Br, a nonmetal; (d) Zn, a metal; (e) Cr, a metal; (f) Ge, a metalloid; (g) S, a nonmetal

2.27 (a) Hydrogen, a nonmetal; (b) potassium, a metal; (c) nitrogen, a nonmetal; (d) antimony, a metalloid; (e) fluorine, a nonmetal; (f) barium, a metal; (g) cadmium, a metal; (h) cesium, a metal; (i) selenium, a nonmetal.

2.28 (a) Ca, calcium, and Sr, strontium, are both elements of group 2A, located in adjacent rows. One expects that they will be closely similar in chemical and physical properties. (b) Arsenic, As, antimony, Sb, and nitrogen, N, are all members of group 5A. However, nitrogen is quite removed from the heavier elements As and Sb. These two are thus the most closely similar pair.

2.29 The total number of molecules in the two flasks is the same. In the one, however, half the molecules are H_2, half are Cl_2. In the other, all