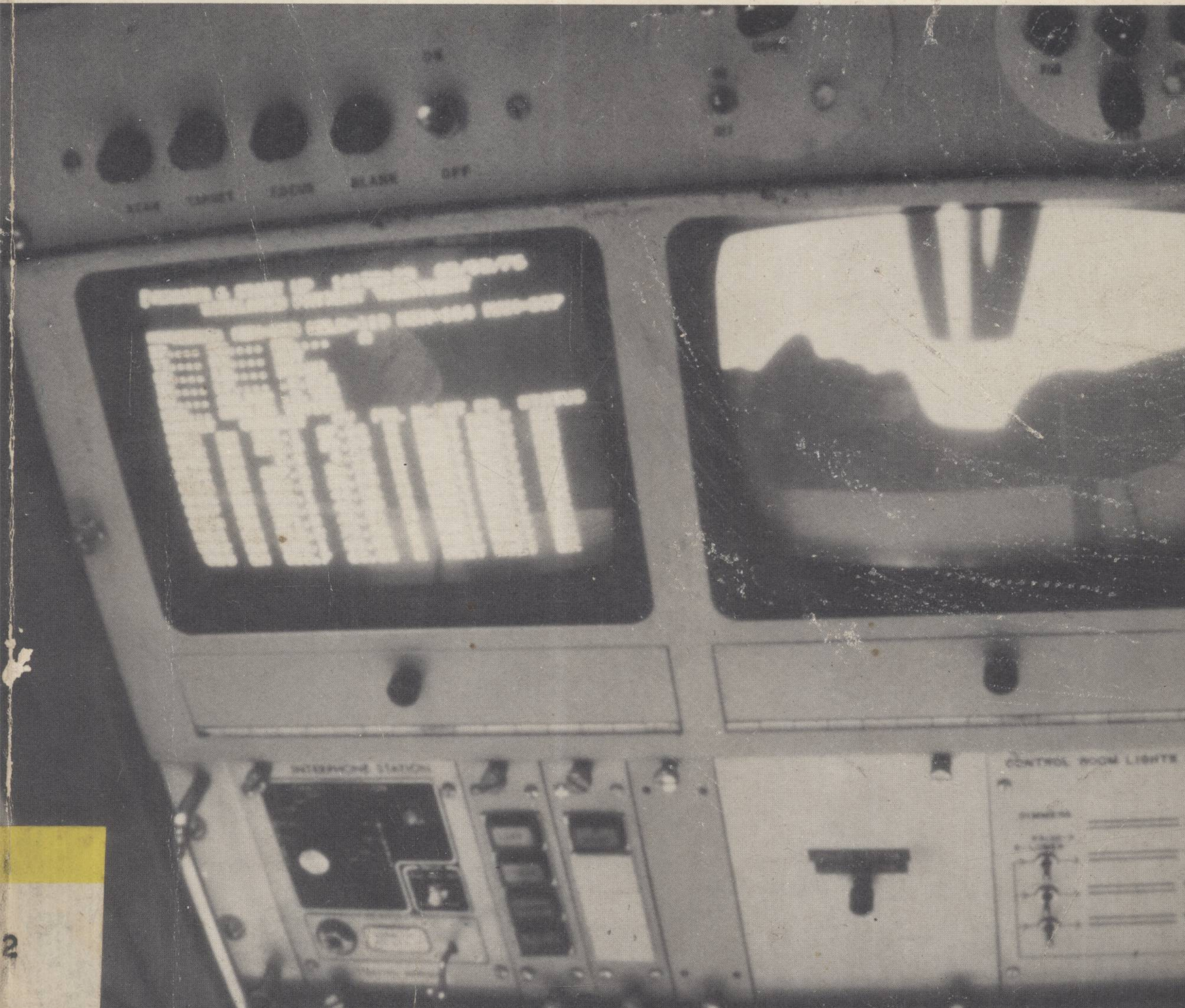
Student Self-Study Guide

Henrickson / Byrd

Chemistry for the Health Professions

Prepared by

John R. Wilson



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Chemistry for the Health Professions

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I am indebted to my teachers and colleagues who guided me through chemistry and to my students who made the experience such a pleasure.

I especially wish to thank Lisa, Jenny, and Brian, who gave me love and encouragement as I was writing this study guide and Sally Markee, my extraordinary secretary, who transformed my scribblings into a final manuscript.

1

Using your Study Guide

This Study Guide is designed to assist you as you learn the material in *Chemistry for the Health Professions* by Charles Henrickson and Larry Byrd. By asking you to answer a variety of questions about each chapter, the guide will direct you to sections of the chapter where you have weaknesses. There are four sections for each chapter:

I. *Self-Test on Terms.* This section reviews the new terms that are presented in the chapter and listed at the end of the chapter. If you miss the meaning of a term, review it in your text before proceeding to Section II.

II. *Reaching the Objectives.* Each chapter in your text has specifically stated objectives listed at the beginning. The more difficult of these objectives also appear in your Study Guide together with a series of questions related to them. If you answer several of these questions incorrectly, it indicates that you have not mastered the objective and should refer to the section of the chapter where material related to that objective is given. Reread the section thoroughly and try to understand why the answer you gave is incorrect.

III. *Chapter Quiz.* In this section you are asked to apply the knowledge you gained in Sections I and II. In Sections I and II you were asked questions that were directed toward one specific point. In this section, you are asked to combine your knowledge of several related points. Some of the questions are quite direct and easy; others are more involved and will require you to analyze and reason.

IV. *Solutions to Questions. Do not* turn to this section after each question. Wait until you have completed an entire section (or objective) before you check your answers. The answers to Section I are given without comment because if you do not know the terms you *must* return to the text to become more familiar with them if you expect to understand the material in the chapter. The answers in Section II will sometimes have comments or explanations to guide you in achieving the objectives in the chapter. The answers in Section III are more detailed to provide you with the reasoning process involved in reaching the answer.

I hope that this guide will serve as a friend and companion as you explore chemistry, but remember that it can be no more than that. A guide can direct a fisherman to the most fertile fishing areas and can suggest appropriate techniques, but he cannot get that hook into the mouth of the fish. That requires the skill, dedication, and tenacity of the fisherman. This guide is similar. It can direct and suggest, but its success depends on you and your effort.

2

Measurements in Chemistry and the Health Sciences

I. SELF-TEST ON TERMS

Fill in the blanks in the following synopsis of the chapter with the terms below.

Celsius	heat	meter
centi-	hecto-	micro-
conversion factor	Kelvin	milli-
deca-	kilo-	millimeter
deci-	kilogram	scientific notation
density	liter	specific gravity
Fahrenheit	mass	temperature
gram	mega-	weight

To be comfortable with measurements used in chemistry and related sciences, one must be familiar with the metric system of measurement. One of the properties that may concern us for an object is the quantity of matter that it contains; this is defined as its ________________(1). The ________________(2) is the basic unit of measurement for this property. Often it is desirable to measure the effect of gravity on the object; when gravity is considered, it is the object's ________________(3) that is measured. The basic metric units for measuring volume and length are the ________________(4) and ________________(5), respectively.

Frequently the basic metric unit of measurement is not suitable for measuring the property in question. For example, the meter is ideal for measuring a person's height, but it is much too small to measure conveniently the distance between two cities and it is too large to record the thickness of a pane of window glass. To provide units that are more suitable for larger and smaller measurements, a series of prefixes has been developed that is related to the basic unit by powers of ten. The prefixes ________________(6), ________________(7), ________________(8), and ________________(9) are used to signify tenth (.1), hundredth (.01), thousandth (.001), and millionth (.000001), respectively. Thus, if one needs a very small unit for measuring length in thousandths of meters, he could report the length in ________________(10). For measuring larger values, the prefixes ________________(11), ________________(12), ________________(13), and ________________(14) indicate that the basic unit has been multiplied by

10, 100, 1,000, and 1,000,000, respectively. The ________________(15), therefore, is a unit of mass that is equivalent to 1,000 grams.

To change from one unit of measurement to another (such as milliliters to decaliters or inches to centimeters) one needs to know the basic relationship that exists between the two measurements (1.00 inch = 2.54 centimeters). When one uses this relationship in mathematical calculations it is referred to as a ________________(16).

A thermometer is used to find the ________________(17) of an object, which is a measure of its hotness, thermal energy, or ________________(18). Three temperature scales are in common use: Water boils at 100° on the ________________(19) scale, at 212° on the ________________(20) scale, and at 373° on the ________________(21) scale.

At times the mass of a certain volume (mass divided by volume) is needed. This physical property is known as ________________(22). For liquids this information is sometimes given as ________________(23), which relates the density of the liquid to the density of a reference liquid such as water.

As the scientist does his measuring, he may need to record very large or small numbers. To avoid the inconvenience of writing a number such as 186,000, he can record the value as 1.86×10^5. This practice is known as recording the number in ________________(24).

II. REACHING THE OBJECTIVES

Objectives 1 and 2: Describing the metric units of length, volume, and mass, including modifying prefixes

First, indicate whether each of the terms in Group I applies to the measurement of length, volume, or mass. Next, consider the English system measurements listed in Group II, and indicate which measurement unit in Group I provides the most appropriate metric "translation." For example, if something were sold in quarts in this country, how might it be packaged in Europe? In liters?

<u>Group I</u>.
- A. kilogram
- B. milliliter
- C. gram
- D. meter
- E. centimeter
- F. liter
- G. microliter
- H. milligram
- I. kilometer
- J. millimeter

<u>Group II</u>.
- A. miles from Paris to London
- B. teaspoon of medicine
- C. yards of cloth
- D. pounds of steak
- E. gallons of milk
- F. ounces of gold
- G. diameter of wire in 0.05-inch units
- H. waist measurement in inches
- I. grains (about 0.002 oz) of aspirin

Objectives 4 through 8: Unit conversion and problem solving using the factor-label method

Work the following problems using the factor-label method, expressing your answers in scientific notation. The last four problems mix concepts to give you additional experience in problem solving.

A. The diameter of Mars is 4190 miles. How many centimeters is this?
B. An apple weighs 143 grams. What is its weight in pounds?
C. A recipe calls for 2 cups of milk. How many milliliters is this? (4 cups = 1 quart.)
D. A complex molecule has a length of 153 Å. How many millimeters is this?
E. Wine is measured in deciliters in Europe. How many 1-deciliter portions are in a quart of wine?
F. If a hungry student has a midnight snack of 2 Quarter Pounders, how many milligrams of hamburger has he eaten?
G. Liquid oxygen boils at -183.0°C. What is its boiling point in °F?
H. At Azizia, Libya, the world's record high temperature of 136.4°F was recorded in the shade. What is this temperature in °C and °K?
I. Space probes estimate the surface temperature of Venus at 803°K. What is this temperature in °F?
J. An antifreeze mixture protects a car's cooling system to -30°F. What is this temperature in °C and °K?
K. Balsa, with an average value of 0.12 g/cm^3, has the lowest density of any wood. A model made of balsa has a weight of 45.26 g. What is its volume in cubic centimeters?
L. The average density of Ganymede, the largest of Jupiter's moons, is 2.273 g/cm^3. Its volume is 6.775×10^{19} m^3. What is its mass in kilograms?
M. One gallon of milk weighs 8.585 pounds. What is the density of this milk in grams per cubic centimeter?
N. Lithium is one of the lease dense metals; osmium is one of the most dense. Their densities, respectively, are 0.534 and 22.48 g/cm^3. What is the volume of a block of lithium that has the same mass as a cube of osmium that has an edge of 2.00 cm?
O. A fish tank that is 1.20 m long and 28.3 cm wide is filled with water to a depth of 3.45 dm. A leak in the bottom allows water to drip out at a rate of 0.652 cm^3 per minute. In how many hours will the water be gone?
P. In 1972 Mark Spitz swam the 100.0 m butterfly in 54.27 sec. How fast in miles per hour did he swim?

III. CHAPTER QUIZ

A. The strength of nuclear weapons is rated in their equivalent explosive power in terms of tons of TNT. A hydrogen bomb rated as a 3.5-megaton weapon is equivalent to how many tons of TNT?
1. .0035
2. 35
3. 3,500
4. 3,500,000

B. At one time the term millimicrometer was used as a unit of measurement. How many millimicrometers were in 1 meter?
1. Fewer than 1
2. 10^3
3. 10^6
4. 10^9
5. 10^{12}

C. Which statement about the size of degrees used in measuring temperature is correct (> means "is greater than")?
1. °F > °C > °K
2. °C = °K > °F
3. °K > °C > °F
4. °C = °F > °K

D. Which length is shortest?
1. 0.0010 m
2. 1.00 in.
3. 1.00 cm
4. 100.0 mm

E. Which provides the fastest and most accurate means of measuring 25.50 ml of vinegar?
1. A graduated cylinder
2. A balance
3. A buret
4. A volumetric flask

F. An equation for distance is $d = vt$. If d is in meters and t is in seconds, then the units of v must be:
1. $\frac{\text{meters}}{\text{seconds}}$
2. $\frac{\text{seconds}}{\text{meters}}$
3. seconds
4. meters
5. meters x seconds

G. Most liquids (water is a notable exception) contract as they freeze. In these cases,
1. solids weigh more than liquids
2. solids are more dense than liquids
3. the solid state floats on the liquid state
4. liquids are more dense than solids

IV. SOLUTIONS TO QUESTIONS

I: Self-test on terms

1. mass
2. gram
3. weight
4. liter
5. meter
6. deci-

7. centi-
8. milli-
9. micro-
10. millimeter
11. deca-
12. hecto-
13. kilo-
14. mega-
15. kilogram
16. conversion factor
17. temperature
18. heat
19. Celsius
20. Fahrenheit
21. Kelvin
22. density
23. specific gravity
24. scientific notation

II. Reaching the objectives

Objectives 1 and 2:

<u>Group I</u>.
A. mass
B. volume
C. mass
D. length
E. length
F. volume
G. volume
H. mass
I. length
J. length

<u>Group II</u>.
A. kilometers
B. milliliters
C. meters
D. kilograms
E. liters
F. grams
G. millimeters
H. centimeters
I. milligrams

Objectives 4 through 8:

A. Sought: centimeters Given: miles
Plan: A basic English-metric conversion factor is needed: 1 in. = 2.54 cm. To use this conversion factor, other conversion factors in the English system are needed to change miles (given) to inches (required to use conversion factor).

1 mi = 5280 ft 1 ft = 12 in

No conversion factor in the metric system is needed since centimeters are the desired units. We may now arrange the units to convert miles to centimeters.

$$\cancel{mi} \times \frac{\cancel{ft}}{\cancel{mi}} \times \frac{\cancel{in}}{\cancel{ft}} \times \frac{cm}{\cancel{in}} = cm$$

Solution: $$4190\ mi \times \frac{5280\ ft}{1\ mi} \times \frac{12\ in}{1\ ft} \times \frac{2.54\ cm}{1\ in} = 674{,}000{,}000 = 6.74 \times 10^{8}\ cm$$

B. Sought: pounds Given: grams
Plan: The basic English-metric conversion factor of 1 lb = 454 g relates the given and the sought quantities. If the conversion factor is used with grams in the denominator, these units will cancel to give pounds.

$$\cancel{g} \times \frac{lb}{\cancel{g}} = lb$$

Solution: $$143\ \cancel{g} \times \frac{1\ lb}{454\ \cancel{g}} = 0.315\ lb = 3.15 \times 10^{-1}\ lb$$

C. Sought: milliliters Given: cups

Plan: The English-metric conversion factor of 1 qt = 946 ml is used with the English conversion factor: 1 qt = 4 cups. In the latter factor "cups" must appear in the denominator to cancel the given units. This puts quarts in the numerator, so in the other factor quarts must be in the denominator in order to cancel it out.

$$\text{cups} \times \frac{\text{qt}}{\text{cups}} \times \frac{\text{ml}}{\text{qt}} = \text{ml}$$

Solution: $2\ \text{c} \times \frac{1\ \text{qt}}{4\ \text{c}} \times \frac{946\ \text{ml}}{1\ \text{qt}} = 473\ \text{ml} = 4.73 \times 10^2\ \text{ml}$

D. Sought: millimeters Given: Ångstroms

Conversion factors: $1\ \text{Å} = 1 \times 10^{-10}\ \text{m}$

$1\ \text{mm} = 1 \times 10^{-3}\ \text{m}$

Solution: $153\ \text{Å} \times \frac{1 \times 10^{-10}\ \text{m}}{1\ \text{Å}} \times \frac{1\ \text{mm}}{1 \times 10^{-3}\ \text{m}} = 153 \times 10^{-7}\ \text{mm}$

$= 1.53 \times 10^{-5}\ \text{mm}$

Remember that when numbers in exponential form are divided, the exponents are subtracted: [-10 - (-3)] = [-10 + 3] = -7.

E. Sought: deciliters Given: quarts

Conversion factors: $1\ \text{deciliter} = 0.1\ \text{liter} = 1.0 \times 10^{-1}\ \text{liter}$

$1\ \text{qt} = 946\ \text{ml}$

Out English-metric conversion factor is in units that do not appear in our metric conversion factor; therefore, we need to have a factor to relate milliliters and liters: $1\ \text{ml} = 0.001\ \text{liter} = 1.0 \times 10^{-3}\ \text{liter}$.

Solution: $1\ \text{qt} \times \frac{946\ \text{ml}}{1\ \text{qt}} \times \frac{1.0 \times 10^{-3}\ \text{liter}}{1\ \text{ml}} \times \frac{1\ \text{dl}}{1.0 \times 10^{-1}\ \text{liter}}$

$= 946 \times 10^{-2}\ \text{dl} = 9.46\ \text{dl}$

F. Sought: milligrams Given: pounds

Conversion factors: $1\ \text{lb} = 454\ \text{g}$

$1\ \text{mg} = 1.0 \times 10^{-3}\ \text{g}$

Solution: $2 \times \frac{1}{4}\ \text{lb} \times \frac{454\ \text{g}}{1\ \text{lb}} \times \frac{1\ \text{mg}}{1.0 \times 10^{-3}\ \text{g}} = 227 \times 10^{3}\ \text{mg}$

$= 2.27 \times 10^{5}\ \text{mg}$

G. Sought: °F Given: °C

Plan: Use the equation: °F = (°C × 1.8) + 32

Solution: °F = (-183.0 × 1.8) + 32 = -329.4 + 32 = -297.4

H. Sought: °C and °F Given: °F

Plan: Use equations: $°\text{C} = \frac{°\text{F} - 32}{1.8}$ and °K = °C + 273

Solution: °C = (136.4 - 32)/1.8 = 58.0

°K = °C + 273 = 58 + 273 = 331

I. Sought: °F Given: °K

Plan: First find °C and then convert it to °F.

Solution:

$$°K = °C + 273$$
$$803°K = °C + 273$$
$$803 - 273 = °C$$
$$°C = 530$$

$$°F = (°C \times 1.8) + 32$$
$$= (530 \times 1.8) + 32 = 954 + 32$$
$$= 986$$

J. Sought: °C and °K Given: °F

Plan: First find °C and then convert it to °K.

Solution:

$$°C = \frac{°F - 32}{1.8} = \frac{-30° - 32°}{1.8} = \frac{-62}{1.8} = -34.4$$

$$°K = °C + 273 = -34.4 + 273 = -238$$

K. Sought: volume in cubic centimeters Given: density in grams per cubic centimeter and weight in grams

Plan: Density is defined as mass divided by volume, $D = M/V$. Commonly, weight is used in place of mass. This equation can be arranged to solve for volume: $DV = M$; therefore, $V = M/D$. To verify we can check the units:

$$\frac{g}{g/cm^3} = g \times \frac{cm^3}{g} = cm^3$$

Solution: $$\frac{42.56\ g}{0.12\ g/cm^3} = 350\ cm^3 = 3.5 \times 10^2\ cm^3$$

L. Sought: mass in kilograms Given: density in grams per cubic centimeter and volume in cubic meters

Plan: The relationship $D = M/V$ can be solved for the mass $M = DV$, but the units of mass and volume are not the same as those of density, so we will need conversion factors relating the different units:

$$1\ kg = 1.0 \times 10^3\ g \qquad 1\ m = 1.0 \times 10^2\ cm$$

Analyzing the units tells us how to relate the density equation to the conversion factors.

$$\frac{g}{cm^3} \times m^3 \times \left(\frac{cm}{m}\right)^3 \times \frac{kg}{g} = kg$$

Solution: $$2.273\ g/cm^3 \times 6.775 \times 10^{19}\ m^3 \times \left[\frac{1.0 \times 10^2\ cm}{1\ m}\right]^3 \times \frac{1\ kg}{1.0 \times 10^3\ g} = 1.540 \times 10^{23}\ kg$$

Comment: Remember that if a unit is raised to a power, then its conversion factor must be raised to the same power. Since centimeters are cubed, we also cube the conversion factor for centimeters to meters. Also remember that, when a number expressed exponentially is raised to a power, the exponents are multiplied; thus, $(10^3)^2 = 10^6$.

M. Sought: density in grams per cubic centimeters   Given: mass in pounds, volume in gallons

Plan: In addition to using $D = M/V$ we will need to use several conversion factors: 1 gal = 4 qt; 1 qt = 946 ml; 1 lb = 454 g; 1 ml = 1 cm^3. Analysis of units shows that we may think of our plan as converting the mass from pounds to grams and the volume from gallons to cubic centimeters.

$$D = \frac{M}{V} = \frac{\text{lb} \times \text{g/lb}}{\text{gal} \times \text{qt/gal} \times \text{ml/qt} \times \text{cm}^3/\text{ml}} = \frac{\text{g}}{\text{cm}^3}$$

Solution: $$\text{density} = \frac{8.585 \text{ lb} \times 454 \text{ g/lb}}{1 \text{ gal} \times 4 \text{ qt/1 gal} \times 946 \text{ ml/1 qt} \times 1 \text{ cm}^3/1 \text{ ml}}$$

$$= 1.03 \frac{\text{g}}{\text{cm}^3}$$

N. Sought: volume of lithium   Given: densities of lithium and osmium and dimensions of cube of osmium

Plan: This is a problem that involves several thought processes so we will take it by steps. Since we know the density of lithium, we can calculate the volume from $D = M/V$ *if* we know its mass. Since the problem requires that the mass of lithium equals the mass of osmium, we must find the mass of osmium. We can find the mass of osmium if we know its volume. Thus, our plan is:

A. Find the volume of the osmium cube;
V = length × width × height

B. Find the mass of osmium using $D = M/V$. This equals the required mass of lithium.

C. Find the volume of lithium from $V = M/D$.

Notice that we derived our plan by working backwards from what we seek to what we have.

Solution:

A. $V = 1 \times w \times h = 2.00 \text{ cm} \times 2.00 \text{ cm} \times 2.00 \text{ cm} = 8.00 \text{ cm}^3$ = volume of osmium

B. $D = M/V$; therefore, $M = D \times V = 22.48 \text{ g/cm}^3 \times 8.00 \text{ cm}^3 = 179.8 \text{ g}$

C. Now $V = \frac{M}{D} = \frac{179.8 \text{ g}}{0.534 \text{ g/cm}^3} = 337 \text{ cm}^3 = 3.37 \times 10^2 \text{ cm}^3$

O. Sought: time in hours   Given: dimensions of tank and leak rate

Plan: Once again we work backward to establish our plan. In order to know how long it will take, we must know how much water there is. We can calculate this volume from the dimensions of the tank. The units vary, so we will have to convert them to consistent units.

A. Find the volume of water in cubic centimeters by using given dimensions.
B. Find the time in minutes required from rate of leakage and convert it to hours.

$$V = l \times w \times h = (1.20\text{m} \times 100\text{ cm/1 m})(28.3\text{ cm})(3.45\text{ dm} \times 10\text{ cm/1 dm})$$
$$= 1.17 \times 10^5\text{ cm}^3$$

$$1.17 \times 10^5\text{ cm}^3 \times \frac{1\text{ min}}{0.652\text{ cm}^3} \times \frac{1\text{ hr}}{60\text{ min}} = 2.99 \times 10^3\text{ hr}$$

It would take over four months for the aquarium to drain.

P. Sought: speed in miles per hour   Given: distance and time

Plan: The units of speed tell us to divide distance by time after we convert to the appropriate units. We could do this as individual steps, but by factor labeling we can also do it in one calculation.

Solution:

$$\text{speed} = \frac{(100.0\text{ m})\left(\frac{1\text{ km}}{1000\text{ m}}\right)\left(\frac{1\text{ mi}}{1.609\text{ km}}\right)}{(54.27\text{ sec})\left(\frac{1\text{ min}}{60\text{ sec}}\right)\left(\frac{1\text{ hr}}{60\text{ min}}\right)} = 4.123\ \frac{\text{mi}}{\text{hr}}$$

III. Chapter quiz

A (4) Mega- means million as a prefix, so it is 3.5 million tons. The purist may object to mixing metric prefixes and English base units, but it is occurring to some extent in our language.

B (4) Milli- means one-thousandth or .001 or 1×10^{-3}, and micro- means one-millionth or .000001 or 1×10^{-6}. Thus this prefix means one thousandth of one millionth or $(1 \times 10^{-3})(1 \times 10^{-6})$ or 1×10^{-9}. (Add exponents when you multiply.) A millimicrometer is 1×10^{-9} meters, therefore, one meter contains 1×10^9 millimicrometers.

C (2) The *size* of Celsius and Kelvin degrees are identical; the reason that temperatures measured on these scales differ is that zero degrees is defined differently. The Fahrenheit degree has a smaller size.

D (1) To compare things, you must convert them to the same units. In this case you might convert them all to meters:
1.00 in. = 2.54 cm = 0.0254 m; 1.00 cm = 0.01 m; 100 mm = 0.100 m.

E (3) A balance measures mass; if the mass of the desired volume were known, it could be used as an accurate means of measurement, but it would not be very fast. The other three measure volumes, but graduated cylinders are not accurate to hundredths of a milliliter, and volumetric flasks can measure only the quantity of liquid they are marked to contain.

F (1) Let us analyze the dimensions:

$d = vt$
meters = (?) seconds

To have meters on the left side, we must have meters on the right side in the numerator. Seconds does not appear on the left side, so we must eliminate it on the right side. Because it is in the numerator, we must put it in the denominator in order to multiply it out. Therefore, the units of v must be in meters per second.

G (2) (1) is not correct; the weight of a liquid is not affected by freezing; if one started with 10 g of liquid, one would have 10 g of solid. The question concerns the mass per unit of volume (density). The formula for density is $D = M/V$. In the freezing process described, the volume decreases, which means that the value of the fraction (or the density) increases. Thus, the solid is more dense and would sink to the bottom of the liquid rather than float.