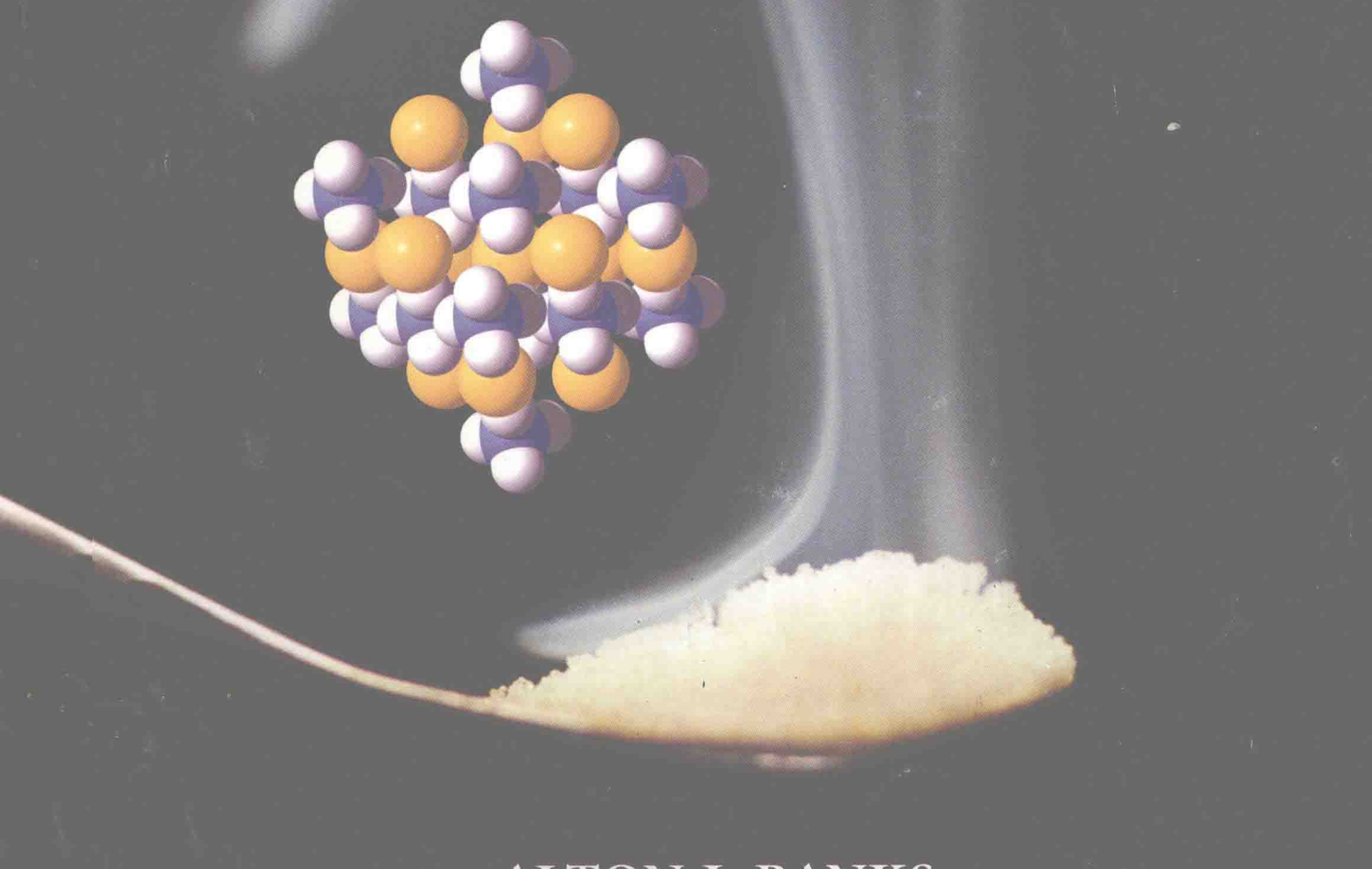
STUDENT SOLUTIONS MANUAL

to accompany

CHEMISTRY & Chemical Reactivity

Fourth Edition

KOTZ & TREICHEL



ALTON J. BANKS

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& Chemical Reactivity

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To the student:

The skills involved in solving chemistry problems are acquired only by discovering the conceptual paths which connect the available data to the desired piece(s) of information. These paths are discovered in different ways by different people. What is true is that those discoveries frequently require repetition. Working multiple problems is one very good approach to clarifying and solidifying the fundamental concepts. I would suggest that this **Solutions Manual** will provide maximum benefit if you consult it *after* you have attempted to solve a problem.

The selected Study Questions have been chosen by the authors of your text to allow you to discover the range and depth of your understanding of chemical concepts. The importance of mastering the "basics" cannot be overemphasized. You will find that the text, **Chemistry & Chemical Reactivity**, has a wealth of study questions to assist you in your study of the science we call Chemistry.

Many of the questions contained in your book—and this solutions manual—have multiple parts. In many cases, comments have been added to aid you in the process of gathering available data and applicable conversion factors and connecting them via those fundamental concepts which undergird this branch of science. In these multiple-step questions, you may find an answer which differs slightly from those given here. This may be a result of "rounding" intermediate answers. The procedure followed in this manual was to report intermediate answers to the appropriate number of significant figures, and to calculate the "final" answer without any intermediate rounding. In cases involving atoms and molecular masses, those quantities were expressed with one digit more than the number of digits needed for the data provided.

A word of appreciation is due to several people. Thanks go to the authors, especially Dr. John C. Kotz, for the many conversations held during the development of this manual. The many fine folks at Saunders have been very helpful. Beth Rosato, Sarah Fitz-Hugh and Peter McGahey were always helpful and efficient. Additionally I would like to thank my wife, Dr. Catherine Hamrick Banks for her invaluable assistance in typing and proofreading this manuscript. One of my blessings is to have such a person as a patient wife and a chemical colleague.

While we have worked diligently to remove all errors from this text, I am certain that some have escaped the many inspections. I accept responsibility for those errors.

I hope that you will find this **Solutions Manual** a useful addition in your exploration of chemistry.

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Chapter 1
Matter and Measurement

Review Questions

4. Liquids: mercury and water   Solid: copper

   Note that the liquid and mercury both conform to the shape of the test tube-one indication of the liquid phase.

   Most dense: mercury   Least dense: water

6. Determine if the property is physical or chemical property for the following:

   (a) color   a physical property
   (b) transformed into rust   a chemical property
   (c) explode   a chemical property
   (d) density   a physical property
   (e) melts   a physical property
   (f) green   a physical property

   Physical properties are those that can be observed or measured without changing the composition of the substance. Exploding or transforming into rust result in substances which are **different** from the original substances— and represent chemical properties.

8. The number of significant figures in each of the following numbers:

   (a) 9.87   3 significant figures
   (b) 1050   3 significant figures—the absence of a decimal point following the last zero indicates the uncertainty lies in the 5.
   (c) 0.00823   3 significant figures—the leading zeroes are NOT significant
   (d) 1.67×10^{-6} 3 significant figures— written in exponential notation, only digits in front of the "x 10"..... are significant

10. Qualitative observations: colorless, clear

    Quantitative observations: 2.65 g/cm^3 ; 2.5 g ; 4.6 cm

    Extensive observations: the mass, 2.5 g; the length, 4.6 cm.

    Intensive observations: the density, 2.65 g/cm^3; the color & transparency (colorless and clear)

Numerical and Other Questions

Density

12. What mass of ethylene glycol possesses a volume of 500. mL of the liquid?

$$\frac{500.\ \text{mL}}{1} \bullet \frac{1\ \text{cm}^3}{1\ \text{mL}} \bullet \frac{1.1135\ \text{g}}{\text{cm}^3} = 557\ \text{g}$$

14. Calculate the mass (in g) of 500. mL of water, given D = 0.997 g/cm^3 at 25 °C.

$$\text{Mass} = \text{D} \bullet \text{V} = \frac{0.997\ \text{g}}{1\ \text{cm}^3} \bullet 500.\ \text{mL} = 499\ \text{g}$$

Express this mass in kilograms: $499\ \text{g} \bullet \frac{1\ \text{kg}}{1000\ \text{g}} = 0.499\ \text{kg}$

16. The metal will displace a volume of water that is equal to the volume of the metal.
Hence the difference in volumes of water (20.7-6.7) corresponds to the volume of metal.
Since 1 mL = 1 cm^3, the density of the metal is then:

$$\frac{\text{Mass}}{\text{Volume}} = \frac{37.5\ \text{g}}{14.0\ \text{cm}^3} \text{ or } 2.68\ \frac{\text{g}}{\text{cm}^3}.$$

From the list of metals provided, the metal with a density closest to this is **Aluminum.**

18. Calculate the density of olive oil if 1 cup (237 mL) has a mass of 205 g:

Since $\text{Density} = \frac{\text{Mass}}{\text{Volume}}$ then $\frac{205\ \text{g olive oil}}{237\ \text{mL olive oil}} = 0.865$ g/mL or 0.865 g/cm^3

Temperature

20. Express 25 °C in kelvins:
K = (25 °C+ 273) or 298 kelvins

22. Make the following temperature conversions:

	°C	K
(a)	16	16 + 273.15 = 289
(b)	370 - 273	370
	$3.7 \times 10^2 - 2.73 \times 10^2 = 1.0 \times 10^2$	

	°C	K
(c)	- 40	- 40 + 273.15 = 230 (note no decimal point after -40)

24. The accepted value for a normal human temperature is 98.6 °F.

On the Celsius scale this corresponds to:

$$°C = \frac{5}{9}(98.6 - 32) = 37\ °C$$

Since the melting point of gallium is 29.8°C, the gallium should melt in your hand.

Elements and Atoms

26. Names for the following elements:

a. C - carbon c. Cl - chlorine e. Mg - magnesium

b. Na - sodium d. P - phosphorus f. Ca - calcium

28. Symbols for the following elements:

a. lithium - Li c. iron - Fe e. lead - Pb

b. titanium - Ti d. silicon - Si f. zinc - Zn

Units and Unit Conversions

30. Convert the distance 1500 m into kilometers; into centimeters:

$$\frac{1500\text{ m}}{1} \bullet \frac{1\text{ km}}{1000\text{ m}} = 1.5\text{ km} \quad \text{and} \quad \frac{1500\text{ m}}{1} \bullet \frac{100\text{ cm}}{1\text{ m}} = 1.5 \times 10^5\text{ cm}$$

Note that BOTH answers have only two significant figures, since 1500 (without a decimal point following the right-most zero has only two sf)

32. Express the area of a 2.5 cm x 2.1 cm stamp in cm^2; in m^2:

$$2.5\text{ cm} \bullet 2.1\text{ cm} = 5.3\text{ cm}^2$$

$$5.3\text{ cm}^2 \bullet \left(\frac{1\text{ m}}{100\text{ cm}}\right)^2 = 5.3 \times 10^{-4}\text{ m}^2$$

34. Express 250. mL in cm^3; in liters(L); in m^3 :

$$\frac{250.\ \text{mL}}{1\ \text{beaker}} \bullet \frac{1\ \text{cm}^3}{1\ \text{mL}} = \frac{250.\ \text{cm}^3}{1\ \text{beaker}}$$

$$\frac{250.\ \text{cm}^3}{1\ \text{beaker}} \bullet \frac{1\ \text{L}}{1000\ \text{cm}^3} = \frac{0.250\ \text{L}}{1\ \text{beaker}}$$

$$\frac{250.\ \text{cm}^3}{1\ \text{beaker}} \bullet \frac{1\ \text{m}^3}{1 \times 10^6\ \text{cm}^3} = \frac{2.50 \times 10^{-4}\ \text{m}^3}{1\ \text{beaker}}$$

36. Convert book's mass of 2.52 kg into grams:

$$\frac{2.52\ \text{kg}}{1\ \text{book}} \bullet \frac{1 \times 10^3\ \text{g}}{1\ \text{kg}} = \frac{2.52 \times 10^3\ \text{g}}{\text{book}}$$

38. Express the dimensions 8 1/2 x 11 inches in centimeters:

$$\frac{8.5\ \text{in}}{1} \bullet \frac{2.54\ \text{cm}}{1\ \text{in}} = 21.59\ \text{cm}$$ or 22 cm (to 2 significant figures)

$$\frac{11\ \text{in}}{1} \bullet \frac{2.54\ \text{cm}}{1\ \text{in}} = 27.94\ \text{cm}$$ or 28 cm (to 2 significant figures)

The area in square centimeters would be:

$21.59\ \text{cm} \bullet 27.94\ \text{cm} = 603.2\ \text{cm}^2$ or $6.0 \times 10^2\ \text{cm}^2$ (to 2 significant figures)

Note that multiplying 22 cm x 28 cm will provide an answer of 620 cm^2. One good habit to develop is to **round once** *after* all your calculations are done. This habit will eliminate the cumulative roundoff errors that can occur.

Accuracy, Precision, and Error

40. Using the data provided, the Averages and their deviations are as follows:

Data point	Method A	deviation	Method B	deviation
1	2.2	0.2	2.703	0.777
2	2.3	0.1	2.701	0.779
3	2.7	0.3	2.705	0.775
4	2.4	0.0	5.811	2.331
Averages:	2.4	0.2	3.480	1.166

(a) The average density for method A is 2.4 ± 0.2 grams while the average density for method B is 3.480 ± 1.166 grams—if one includes all the data points. Data point 4 in Method B has a large deviation, and should probably be excluded from the calculation. If one omits data point 4, Method B gives a density of 2.703 ± 0.001 g

(b) The error for each method :

Error = experimental value - accepted value

From Method A error = (2.4 - 2.702) = - 0.3

From Method B error = (2.703 - 2.702) = 0.001 (omitting data point 4)

error = (3.480 - 2.702) = 0.778 (including all data points)

(c) Precision and Accuracy of each method:

If one counts all data points, the deviations **for all data points** of Method A are less than those for **the data points of** Method B, Method A offers better *precision* . On the other hand, omitting data point 4, Method B offers both *better accuracy* (average closer to the accepted value) and *better precision* (since the value is known to a greater number of significant figures).

Significant Figures

42. Calculate the volume (in cubic centimeters) of a backpack whose dimensions are 22.86 cm x 38.0 cm x 76 cm .

Volume = l x w x h = 22.86 cm x 38.0 cm x 76 cm = 6.6×10^4 cm^3 (2 sf are allowed)

44. Express the product of three numbers to the proper number of significant figures:

$$(1.68)(7.847)\left(\frac{1.0000}{55.85}\right) = 0.236 \qquad \text{(3 sf are allowed)}$$

46. Solve for n and report the answer to the correct number of significant figures:

$$\underset{\substack{\uparrow\\ 4\text{ sf}}}{\frac{\overset{\substack{3\text{ sf}\\ \downarrow}}{43.7}}{760.0}} \bullet \underset{\substack{\uparrow\\ 3\text{ sf}}}{125} = n \bullet \underset{\substack{\uparrow\\ 5\text{ sf}}}{0.082057} \bullet \underset{\substack{\uparrow\\ 4\text{ sf}}}{298.2}$$

$$n = \frac{\frac{43.7}{760.0} \times 125}{0.082057 \times 298.2} = 0.294 \text{ to three significant figures.}$$

General Questions

48. Volume of a 1.50 carat diamond:

$$\frac{1.50 \text{ carat}}{1} \bullet \frac{0.200 \text{ g}}{1 \text{ carat}} \bullet \frac{1 \text{ cm}^3}{3.513 \text{ g}} = 0.0854 \text{ cm}^3$$

50. Separation of carbon atoms in (a) meters and (b) angstroms:

(a) $0.154 \text{ nm} \bullet \frac{1 \text{ m}}{10^9 \text{ nm}} = 1.54 \times 10^{-10} \text{ m}$

(b) $1.54 \times 10^{-10} \text{ m} \bullet \frac{1 \text{ Å}}{1 \times 10^{-10} \text{ m}} = 1.54 \text{ Å}$

52. Mass of a gold coin 2.2 cm in diameter and 3.0 mm thick:

To calculate the mass of the gram we'll need to determine the volume of the coin, and use the density of gold.

Volume = $\pi r^2 \bullet \text{thickness} = 3.14159 \bullet (\frac{2.2 \text{ cm}}{2})^2 \bullet (\frac{3.0 \text{ mm}}{1} \bullet \frac{1\text{cm}}{10\text{mm}}) = 1.1 \text{ cm}^3$

The mass of the coin is then: $V \bullet D = 1.1 \text{ cm}^3 \bullet \frac{19.3 \text{ g}}{\text{cm}^3} = 22 \text{ g}$ (to 2 sf)

Value of the coin:

$$\frac{\$410}{1 \text{ troy ounce}} \bullet \frac{1 \text{ troy ounce}}{31.10 \text{ g}} \bullet 22 \text{ g gold} = \$290$$

54. To calculate the density of the metal, first calculate the volume of the piece of metal:

$$2.35 \text{ cm} \bullet 1.34 \text{ cm} \bullet 1.05 \text{ cm} = 3.31 \text{ cm}^3$$

Then the density can be calculated by dividing the mass (29.454g) by the volume:

$$D = \frac{29.454 \text{ g}}{3.31 \text{ cm}^3} = 8.91 \frac{\text{g}}{\text{cm}^3}$$

Note that this answer is obtained by dividing the mass by the **unrounded** volume (3.30645 cm^3). Given this calculated density, the metal in question has to be **nickel**.

56. Which occupies a larger volume: 600 g of water or 600 g of lead ?

$$600 \text{ g } H_2O \bullet \frac{1 \text{ cm}^3}{0.995 \text{ g}} = 603 \text{ cm}^3 \quad (600 \text{ cm}^3 \text{ to 1 sf})$$

$$600 \text{ g Pb} \bullet \frac{1 \text{ cm}^3}{11.34 \text{ g}} = 52.9 \text{ cm}^3 \quad (50 \text{ cm}^3 \text{ to 1 sf})$$

58. Estimate the density of water at 20 °C :

Using the approximation that density varies linearly with temperature—over a short temperature range—the density at 20°C would be midway between the density at 15 °C and that at 25 °C.

$$D = \frac{0.99913 + 0.99707}{2} = 0.99810 \frac{\text{g}}{\text{cm}^3}$$

The suggested value is **not reasonable.**

60. Calculate the mass of platinum in 1.53 g of a compound that is 65.0% platinum:

$$\frac{1.53 \text{ g compound}}{1} \bullet \frac{65.0 \text{ g Pt}}{100.0 \text{ g compound}} = 0.995 \text{ g Pt}$$

62. Volume of 38.08% solution of sulfuric acid that contains 125 g of sulfuric acid.

Since the solution is ONLY 38.08% sulfuric, first calculate the MASS of the solution that contains 125 g of sulfuric acid:

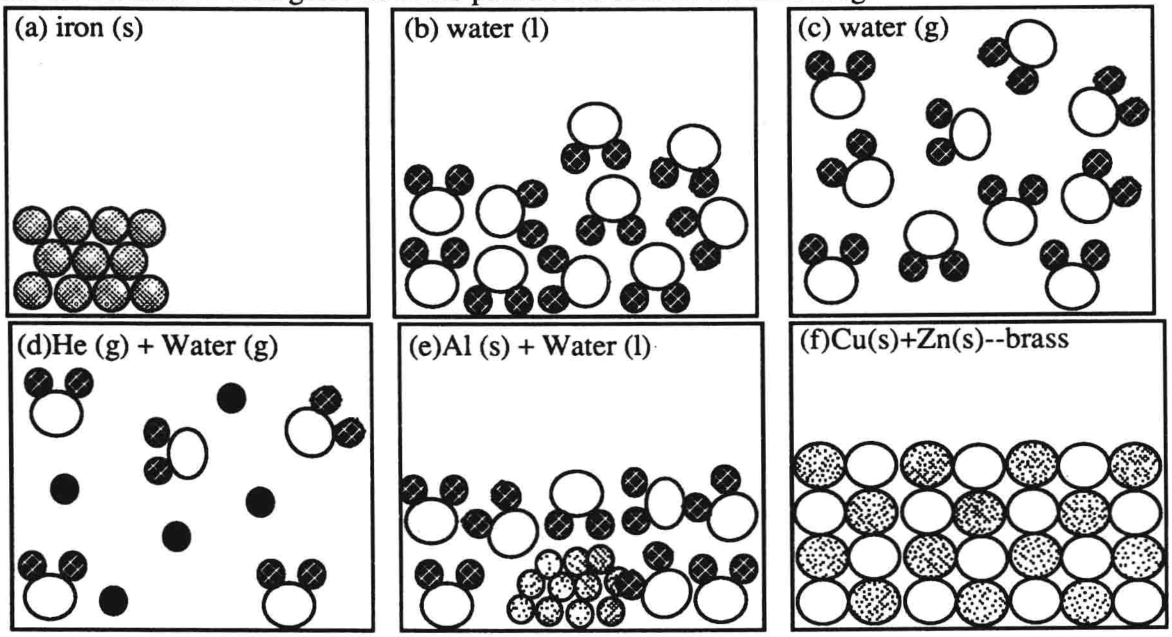
$$125 \text{ g } H_2SO_4 \bullet \frac{100 \text{ g solution}}{38.08 \text{ g } H_2SO_4} = 328.3 \text{ g solution or 328 g solution (3 sf)}$$

Now we can calculate the **volume** of solution that has this mass:

$$125 \text{ g } H_2SO_4 \bullet \frac{100 \text{ g solution}}{38.08 \text{ g } H_2SO_4} \bullet \frac{1 \text{ cm}^3 \text{ solution}}{1.285 \text{ g solution}} = 255 \text{ cm}^3 \text{ solution}$$

Conceptual Questions

64. Indicate the relative arrangements of the particles in each of the following:



66. Experimental method to determine the identity of a liquid:

There are several methods. One method would be to weigh an accurately known volume of the liquid. An empty dry weighed 10.0 mL graduated cylinder could be filled to the 10.0 mL mark with the liquid, and reweighed. The mass of liquid divided by the volume would provide the density of the liquid. That density could be compared with published values of the density of water *at that temperature*.

To determine if the water contains dissolved salts, test the electrical conductivity. Pure water is a very poor conductor. Water containing dissolved salts (and therefore the ions produced when that salt dissolves) would conduct an electric current.

68. Pouring three immiscible liquids into a test tube will result in three discrete layers in which the liquids arrange themselves from the most dense liquid (at bottom) to the least dense liquid (at top).

Least dense liquid: water

Medium density: carbon tetrachloride

Most dense liquid: mercury

70. To determine if a copper-colored metal is pure copper :

One can check some of the properties that identify copper. (1) Melting a sample of the wire and comparing the melting point of the sample to the melting point of pure copper. (2) Carefully determine the density of the wire, and compare that density with the literature value for the density of pure copper. (3) Test the electrical conductivity of the wire and compare that conductivity to copper's electrical conductivity.

Challenging Questions

72. Calculate the mass of 12 ounces of aluminum in grams and from that mass, the volume:

$$\text{Volume} = \frac{\text{Mass}}{\text{Density}} = \frac{12 \text{ oz} \bullet \frac{28.4 \text{ g}}{1 \text{ oz}}}{2.70 \text{ g/cm}^3} = 130 \text{ cm}^3 \quad \text{(to 2 sf)}$$

$$\text{Volume} = \text{Area} \bullet \text{Thickness}$$

Express the area in units of cm^2, then calculate the thickness by dividing the volume by the area:

$$\text{Area} = 75 \text{ ft}^2 \bullet \left(\frac{12 \text{ in}}{1 \text{ ft}}\right)^2 \bullet \left(\frac{2.54 \text{ cm}}{1 \text{ in}}\right)^2 = 7.0 \times 10^4 \text{ cm}^2$$

then $\text{Volume} = \text{Area} \bullet \text{Thickness}$

$$130 \text{ cm}^3 = 7.0 \times 10^4 \text{ cm}^2 \bullet \text{Thickness}$$

and $$\text{Thickness} = \frac{130\ \text{cm}^3}{7.0 \times 10^4\ \text{cm}^2} = 1.8 \times 10^{-3}\ \text{cm or } 1.8 \times 10^{-2}\ \text{mm}$$

74. Calculate the volume of the "cylinder" of copper wire with a density of 8.94 g/cm^3 and a mass of (57 kg) 125 lb:

$$125\ \text{lb} \cdot \frac{454\ \text{g}}{1\ \text{lb}} \cdot \frac{1\ \text{cm}^3}{8.94\ \text{g}} = 6350\ \text{cm}^3$$

The volume of a cylinder is equal to $\pi r^2 h$.

We can calculate the "length" of the wire (the height of the cylinder) since we are told that the diameter of the wire is 9.50 mm. Expressing the diameter in centimeters and converting the diameter into a radius (1/2 the diameter) we obtain:

$$\text{Volume} = \pi r^2 h$$

$$6350\ \text{cm}^3 = 3.1415 \cdot (0.475\ \text{cm})^2 \cdot h$$

then $$h = \frac{6350\ \text{cm}^3}{3.1415 \cdot (0.475\ \text{cm})^2} = 8.96 \times 10^3\ \text{cm}$$

Expressing this number in meters:

$$8.96 \times 10^3\ \text{cm} \cdot \frac{1\ \text{m}}{100\ \text{cm}} = 8.96 \times 10^1\text{m or } 9.0 \times 10^1\text{m (2 sf)}$$

76. To determine the thickness of the oil layer, we can think about the oil layer as having a certain volume,(V = l • w • h), and that our "task" is to determine the "thickness" -- or h in our formula. The volume of oil is 1 teaspoon (5 cm^3). The area covered (l • w) is 0.5 acres. So if we divide the volume by the area, we should have the **thickness**.

$$\underbrace{\frac{5\ \text{cm}^3}{1\ \text{teaspoon}} \cdot \frac{1\ \text{teaspoon}}{0.5\ \text{acre}}}_{\text{Volume / Area}} \cdot \underbrace{\frac{2.47\ \text{acres}}{1.0 \times 10^4\ \text{m}^2}}_{\text{Acre converted to square meters}} \cdot \underbrace{\left(\frac{1\ \text{m}}{100\ \text{cm}}\right)^2}_{\text{Conversion of sq.m to sq. cm.}} = 2 \times 10^{-7}\ \text{cm}$$

Assuming that a monolayer of oil is obtained, the thickness (2 x 10^{-7} cm) could correspond to the "length" of the oil molecules.

The Chemical Puzzler

78. When potassium reacts with water, one can write the equation to represent the reaction as:

$$2\ K\ (s)\ +2\ H_2O\ (l) \rightarrow 2\ K^+\ (aq) + 2\ OH^-\ (aq)\ + H_2\ (g)$$

(a) States of matter represented: solid: potassium -- a reactant
liquid: water-- a reactant
gas: hydrogen-- a product
solution: of KOH produced

(b) Types of changes observed: Chemical changes are exhibited—the chemical reactivity of potassium with water. One could also test the resulting solution to find it basic—since KOH is produced. The reaction produces much heat, which usually results in the hydrogen gas burning—a chemical change
Physical changes are also exhibited—the change in the color of elemental potassium metal and potassium ions. The heat would also vaporize liquid water to gaseous water.

(c) Qualitative observations: The color of the flame indicates that potassium is one of the reacting species. Litmus paper could be used to find that the solution is basic (turns red litmus paper blue). Carefully grasping the beaker at the conclusion of the reaction would demonstrate that heat is evolved as potassium reacts with water.

(d) Structure of potassium metal: Potassium atoms are stacked in a repeating array (in the picture, the atoms resemble squares stacked atop one another),with a potassium atom placed in the opening created between the two layers.

Chapter 2
Atoms and Elements

The Composition of Atoms

20. Mass number for

a. Na (at. no. 11) with 12 neutrons : 23

b. Ti (at. no. 22) with 26 neutrons : 48

c. Ge (at. no. 32) with 40 neutrons : 72

The mass number represents the SUM of the protons + neutrons in the nucleus of an atom. The atomic number represents the # of protons, so

(atomic no. + # neutrons) = mass number

22. Mass number (A) = no. of protons + no. of neutrons;

Atomic number (Z) = no. of protons

a. $^{39}_{19}K$ b. $^{39}_{18}Ar$ c. $^{60}_{27}Co$

24.

substance	protons	neutrons	electrons
a. magnesium-24	12	12	12
b. tin- 119	50	69	50
c. plutonium-244	94	150	94

Note that the number of protons and electrons are equal for any neutral atom. The number of protons is always equal to the atomic number. The mass number equals the sum of the numbers of protons and neutrons.

26.

Symbol	^{58}Ni	^{33}S	^{20}Ne	^{55}Mn
Number of protons	28	16	10	25
Number of neutrons	30	17	10	30
Number of electrons in the neutral atom	28	16	10	25
Name of element	nickel	sulfur	neon	manganese