Chapter 1 Suggested End-of-Chapter Problems

Review Question 4. For each of the following pieces of glassware, provide a sample measurement and discuss the number of significant figures and uncertainty.

Review Question 5. A student performed an analysis of a sample for its calcium content and got the following results:

14.92%
14.91%
14.88%
14.91%

The actual amount of calcium in the sample is \textbf{15.70\%}. What conclusions can you draw about the accuracy and precision of these results?

Review Question 8. On which temperature scale (°F, °C, or K) does 1 degree represent the smallest change in temperature?
4. You have two beakers, one filled to the 100-mL mark with sugar (the sugar has a mass of 180.0 g) and the other filled to the 100-mL mark with water (the water has a mass of 100.0 g). You pour all the sugar and all the water together in a bigger beaker and stir until the sugar is completely dissolved.

a. Which of the following is true about the mass of the solution? Explain.

i. It is much greater than 280.0 g.
ii. It is somewhat greater than 280.0 g.
iii. It is exactly 280.0 g.
iv. It is somewhat less than 280.0 g.
v. It is much less than 280.0 g.

b. Which of the following is true about the volume of the solution? Explain.

i. It is much greater than 200.0 mL.
ii. It is somewhat greater than 200.0 mL.
iii. It is exactly 200.0 mL.
iv. It is somewhat less than 200.0 mL.
v. It is much less than 200.0 mL.

5. You may have noticed that when water boils, you can see bubbles that rise to the surface of the water.

a. What is inside these bubbles?

i. air
ii. hydrogen and oxygen gas
iii. oxygen gas
iv. water vapor
v. carbon dioxide gas

b. Is the boiling of water a chemical or physical change? Explain.

8. Sketch a magnified view (showing atoms/molecules) of each of the following and explain:

a. a heterogeneous mixture of two different compounds
b. a homogeneous mixture of an element and a compound
26. Give four examples illustrating each of the following terms.
   a. homogeneous mixture
   b. heterogeneous mixture
   c. compound
   d. element
   e. physical change
   f. chemical change

28. Indicate the number of significant figures in each of the following:
   a. This book contains more than 1000 pages.
   b. A mile is about 5300 ft.
   c. A liter is equivalent to 1.059 qt.
   d. The population of the United States is approaching $3.1 \times 10^9$ million.
   e. A kilogram is 1000 g.
   f. The Boeing 747 cruises at around 600 mi/h.

30. How many significant figures are in each of the following?
   a. 100
   b. $1.0 \times 10^3$
   c. $1.00 \times 10^3$
   d. 100.
   e. 0.0048
   f. 0.00480
   g. $4.80 \times 10^{-3}$
   h. $4.800 \times 10^{-3}$

31. Round off each of the following numbers to the indicated number of significant digits, and write the answer in standard scientific notation.
   a. 0.00034159 to three digits
   b. $103.351 \times 10^2$ to four digits
   c. 17.9915 to five digits
   d. $3.365 \times 10^4$ to three digits

35. Evaluate each of the following, and write the answer to the appropriate number of significant figures.
   a. $212.2 + 26.7 + 402.09$
   b. $1.0028 + 0.221 + 0.10337$
   c. $52.331 + 26.01 - 0.9981$
   d. $2.01 \times 10^2 + 3.014 \times 10^3$
   e. $7.255 - 6.8350$
36. Perform the following mathematical operations, and express each result to the correct number of significant figures.

   a. \( \frac{0.102 \times 0.0821 \times 273}{1.01} \)
   b. \( 0.14 \times 6.022 \times 10^{23} \)
   c. \( 4.0 \times 10^4 \times 5.021 \times 10^{-3} \times 7.34903 \times 10^2 \)
   d. \( 2.00 \times 10^6 \)
   e. \( 3.00 \times 10^{-7} \)

37. Perform the following mathematical operations, and express the result to the correct number of significant figures.

   a. \( \frac{2.526 + 0.470 + 80.705}{3.1 + 0.623 + 0.4326} \)
   b. \( \frac{(6.404 \times 2.91)/(18.7 - 17.1)}{6.071 \times 10^{-5} - 8.2 \times 10^{-6} - 0.521 \times 10^{-4}} \)
   c. \( (3.8 \times 10^{-12} + 4.0 \times 10^{-13})/(4 \times 10^{12} + 6.3 \times 10^{13}) \)
   e. \( \frac{9.5 + 4.1 + 2.8 + 3.175}{4} \)

   (Assume that this operation is taking the average of four numbers. Thus 4 in the denominator is exact.)

   f. \( \frac{8.925 - 8.905}{8.925} \times 100 \)

   (This type of calculation is done many times in calculating a percentage error. Assume that this example is such a calculation; thus 100 can be considered to be an exact number.)

40.

   a. How many kilograms are in 1 teragram?
   b. How many nanometers are in 6.50 \times 10^3 terameters?
   c. How many kilograms are in 25 femtograms?
   d. How many liters are in 8.0 cubic decimeters?
   e. How many microliters are in 1 milliliter?
   f. How many picograms are in 1 microgram?

54. In recent years, there has been a large push for an increase in the use of renewable resources to produce the energy we need to power our vehicles. One of the newer fuels that has become more widely available is E85, a mixture of 85% ethanol and 15% gasoline. Despite being more environmentally friendly, one of the potential drawbacks of E85 fuel is that it produces less energy than conventional gasoline. Assume a car gets 28.0 miles/gallon using gasoline at \$3.50/gallon and 22.5 miles/gallon using E85 at \$2.85/gallon. How much will it cost to drive 500 miles using each fuel?

72. The density of pure silver is 10.5 g/cm^3 at 20°C. If 5.25 g of pure silver pellets is added to a graduated cylinder containing 11.2 mL of water, to what volume level will the water in the cylinder rise?
78. A copper wire (density = 8.96 g/cm³) has a diameter of 0.25 mm. If a sample of this copper wire has a mass of 22 g, how long is the wire?

79. Match each description below with the following microscopic pictures. More than one picture may fit each description. A picture may be used more than once or not used at all.

   a. a gaseous compound
   b. a mixture of two gaseous elements
   c. a solid element
   d. a mixture of a gaseous element and a gaseous compound

96. Which of the following are chemical changes? Which are physical changes?

   a. the cutting of food
   b. interaction of food with saliva and digestive enzymes
   c. proteins being broken down into amino acids
   d. complex sugars being broken down into simple sugars
   e. making maple syrup by heating maple sap to remove water through evaporation
   f. DNA unwinding

101. The density of an irregularly shaped object was determined as follows. The mass of the object was found to be 28.90 g ± 0.03 g. A graduated cylinder was partially filled with water. The reading of the level of the water was 6.4 cm³ ± 0.1 cm³. The object was dropped in the cylinder, and the level of the water rose to 9.8 cm³ ± 0.1 cm³. What is the density of the object with appropriate error limits? (See Appendix 1.5.)

106. The radius of a neon atom is 69 pm, and its mass is 3.35 × 10⁻²³ g. What is the density of the atom in grams per cubic centimeter (g/cm³)? Assume the nucleus is a sphere with volume = \( \frac{4}{3} \pi r^3 \).
107. Which of the following statements is(are) true?
   a. A spoonful of sugar is a mixture.
   b. Only elements are pure substances.
   c. Air is a mixture of gases.
   d. Gasoline is a pure substance.
   e. Compounds can be broken down only by chemical means.

109. A rule of thumb in designing experiments is to avoid using a result that is
the small difference between two large measured quantities. In terms of
uncertainties in measurement, why is this good advice?

111. Many times errors are expressed in terms of percentage. The percent error
is the absolute value of the difference of the true value and the experimental
value, divided by the true value, and multiplied by 100.

\[
Percent \ error = \frac{|true \ value - experimental \ value|}{true \ value} \times 100
\]

Calculate the percent error for the following measurements.

a. The density of an aluminum block determined in an experiment was
   \(2.64 \text{ g/cm}^3\). (True value \(2.70 \text{ g/cm}^3\).)

b. The experimental determination of iron in iron ore was 16.48\%. (True
   value 16.12\%.)

c. A balance measured the mass of a 1.000-g standard as 0.9981 g.
Solutions to suggested homework problems (Ch. 1)
p. 32, Review questions #4

(a) We can read, with certainty, only one digit
And we can estimate one more
In this case, we can report $2.5 \pm 0.1$

(b) We can read the gradations between 10 and 11, so we can, with certainty, read 10.7
And we can also guess where the meniscus is between the finest gradations (small lines)
In this case, we can report $10.73 \pm 0.1$
Somebody else may have less confidence in our eyeballing and report it as $10.73 \pm 0.2$

We can only read it to the "tens" with certainty. So we can say it's more than 20 and less than 30. We know only the first digit with certainty.
We can also guess the next digit.
In this case, we can report it as $21 \pm 1$ or $21 \pm 2$ depending on our confidence in our eyeballing.
Review question #5 (p.32)

The numbers are close to one another, with the spread in the last digit consistent with it being the only one with uncertainty. So they definitely suggest 14.9% to three significant figures (but all four digits in the numbers given are significant; we are just tidying up the number so we can compare it to 15.70).

The difference between 15.70 and 14.9 cannot be explained by the small spread of the given data. 15.70 clearly is outside of the average of the numbers plus or minus the uncertainty.

The given measurements are precise but inaccurate.

Review question #8 (p.32)

°C and K have equal magnitudes for temperature differences. However, there are 180°F between the freezing and boiling point of water, whereas the same difference corresponds to 100 degrees in °C scale. In other words, 1°F change corresponds to only \( \frac{5}{9} \) °C or \( \frac{5}{9} \) K change. Since \( \frac{5}{9} °C \) is less than 1°C, 1°F change corresponds to the smallest change in temperature.
Law of conservation of mass dictates that the mixture will have a mass equal to the sum of the masses of the individual components: exactly 280.0 g. (choice iii)

The solution volume will be less than 200 mL because some of the volume of the sugar was the "empty" space between sugar granules. The air in that space will be left out of the solution, and lead to a volume less than 200 mL (in other words, the true volume of the sugar was less than 100 mL)

*Fine print: Something similar can happen even when we mix substances with no air in them. Just as water fills the voids between sugar granules without increasing the total volume, smaller molecules can slip into the crevices of larger molecules when mixing with them, leading to a total volume that is less than the sum of the volumes of individual components.*

Water vapor (choice iv.)
When water boils, it's just liquid water turning into water vapor.

It's a physical change. Same substance, different physical state.
(a) brine (salty water), sugar dissolved in water, gasoline, air, vodka

(b) sand, pepper powder, pepper (it has a structure that is visible even to naked eye), mayonnaise (looks homogeneous but it’s just a suspension of oil droplets in an aqueous solution; the whole mixture is not homogeneous at the molecular scale), soil

(c) salt, sugar, ethanol, water, carbon dioxide

(d) hydrogen, oxygen, copper, gold, neon

(e) lake freezing over, water on the table drying, the car getting hot under the sun, snow melting, a balloon popping, crude oil being distilled into gasoline, diesel oil, and tar

(f) wood burning, iron rusting, a seed turning into a tree, a battery discharging, cooking anything
(a) 1
(b) 2
(c) 4
(d) 2
(e) ∞
(f) 1

30
(a) 1
(b) 2
(c) 3
(d) 3
(e) 2
(f) 3
(g) 3
(h) 4

31
(a) \( \sqrt[3]{0.00034159} \rightarrow 0.000342 = 3.42 \times 10^{-4} \)
   \( \uparrow \) rounded up\( \downarrow \)
   decimal point hops to the right by four spaces, which
   means the number is \(10^4\) times bigger now,
   which we compensate by multiplying by \(10^{-4}\)

(b) \( \frac{103.5}{10^2} \rightarrow 103.4 \times 10^2 \rightarrow 1.034 \times 10^4 \)
   \( \uparrow \) rounded up because it's followed by just 5 and no other nonzero digits
   in those cases, we round up or down to obtain an even last digit.

(c) \( \frac{505}{10^2} \rightarrow 7.992 \)

(d) \( 3.365 \times 10^5 \rightarrow 3.36 \times 10^5 \)
(35) (a) \[ 212.2 + 26.7 + 402.09 = 640.99 \Rightarrow 641.0 \]

[1 digit] [1 digit] [2 digits] [need to reduce to 1 digit]
after decimal point

(b) \[ \frac{0.102 \times 0.0821 \times 273}{1.01} = 2.26 \]

[2 sig figs] [3 sig figs] \[\text{only multiplication or division, and all numbers have 3 sig figs}\]

(c) \[ \frac{4.0 \times 10^4 \times 5.021 \times 10^{-3} \times 7.34993 \times 10^0}{2 \times 3 \times 6 \times 4} = \frac{147.6 \times 10^{3+2}}{2 \times 3+2} \]

\[= 1.5 \times 10^5 \]

(d) \[ \frac{2.00 \times 10^6}{3.00 \times 10^{-7}} = 0.667 \times 10^{13-1} = 6.67 \times 10^{12} \]

(37) (c) \[ 6.071 \times 10^{-5} - 8.2 \times 10^{-6} - 0.521 \times 10^{-4} \]

It's harder to deal with sig figs for addition/subtraction when we have scientific notation, because the number of digits after the decimal point is obscured by the exponential. Factor out the smallest exponential:

\[ 10^{-6} \times (6.071 \times 10^1 - 8.2 - 0.521 \times 10^2) \]

\[= 10^{-6} \times (6.071 - 8.2 - 52.1) \times (0.41) = 0.4 \times 10^{-6} = 4 \times 10^{-7} \]

\[\text{2 digits} \quad 1 \text{ digit} \quad 1 \text{ digit} \quad \text{keep 1 digit} \]

\[= 0.22 \]

(subtracting two numbers that are close in magnitude reduces the no. of sig figs, because formerly significant digits become leading zeros)
(a) \[ 1 \text{ teragram} \times \frac{10^2 \text{ gram}}{1 \text{ teragram}} \times \frac{1 \text{ kg}}{10^3 \text{ gram}} = 10^9 \text{ kg} \]

(b) \[ 6.50 \times 10^2 \text{ terameter} \times \frac{10^{12} \text{ nm}}{1 \text{ terameter}} \times \frac{1 \text{ nm}}{10^9 \text{ m}} = 6.50 \times 10^{21} \text{ nm} \]

(c) \[ 25 \text{ femtogram} \times \frac{10^{-15} \text{ g}}{1 \text{ femtogram}} \times \frac{1 \text{ kg}}{10^3 \text{ g}} = 25 \times 10^{-18} \text{ kg} = 2.5 \times 10^{-17} \text{ kg} \]

(d) \[ 8.0 \text{ dm}^3 \times \frac{1 \text{ L}}{1 \text{ dm}^3} = 8.0 \text{ L} \]

(e) \[ 1 \text{ mL} \times \frac{10^{-3} \text{ L}}{1 \text{ mL}} \times \frac{1 \mu \text{ L}}{10^{-6} \text{ L}} = 10^3 \mu \text{ L} \]

(f) \[ 1 \mu \text{ g} \times \frac{10^{-6} \text{ g}}{1 \mu \text{ g}} \times \frac{1 \text{ pg}}{10^{-12} \text{ g}} = 10^6 \text{ pg} \]

54. w/ gasoline: \[ 500 \text{ mi} \times \frac{1 \text{ gal}}{28.0 \text{ mi}} \times \frac{\$3.50}{1 \text{ gal}} = \$62.5 \]

w/EBS: \[ 500 \text{ mi} \times \frac{1 \text{ gal}}{22.5 \text{ mi}} \times \frac{\$2.85}{1 \text{ gal}} = \$63.3 \]

72. The volume will rise by an amount equal to the silver pellets' volume.

\[ d = \frac{m}{V} \Rightarrow V = \frac{m}{d} = \frac{5.25 \text{ g}}{10.5 \text{ g} \cdot (\text{cm}^3)^{-1}} = 0.500 \text{ cm}^3 \times \frac{1 \text{ mL}}{1 \text{ cm}^3} = 0.500 \text{ mL} \]

Final volume = 11.2 + 0.500 = 11.7 mL
Wire has a cylindrical shape

\[ D = 0.25 \text{ mm} \]

\[ \text{base of the cylinder} \]

Volume = (Area of base) \times (length of cylinder)

\[ d = \frac{m}{V} \implies V = \frac{m}{d} = \frac{22.8}{8.96 \text{ g/(cm}^3\text{)}} = 2.546 \text{ cm}^3 \]

keeping an extra sig. fig. for now

Area of base = \( \pi r^2 = \pi \left( \frac{D}{2} \right)^2 = (3.14) \left( \frac{1 \times 0.25 \text{ mm}}{1 \text{ mm}} \times \frac{1 \text{ cm}}{10^2 \text{ m}} \right)^2 \)

exact

Area of base = \( 4.91 \times 10^{-4} \text{ cm}^2 \)

length of cylinder = \( \frac{\text{Volume}}{\text{Area of base}} = \frac{2.46 \text{ cm}^3}{4.91 \times 10^{-4} \text{ cm}^2} = 5.0 \times 10^3 \text{ cm} \)

\( 79 \) (a) a gaseous compound \( \rightarrow \) iv

(b) a mixture of two gaseous elements \( \rightarrow \) vi

(c) a solid element \( \rightarrow \) v

(d) a mixture of a gaseous element and a gaseous compound \( \rightarrow \) ii and iii

\( 96 \) Chemical changes

* interaction of food w/saliva and digestive enzymes
* proteins being broken down into amino acids
* complex sugars being broken down into simple sugars

Physical changes

* the cutting of food
* making maple syrup by heating maple sap to remove water through evaporation
* DNA unwinding
Volume of object = volume increase in the graduated cylinder

\[ \frac{d}{V} = \frac{28.90 \pm 0.03}{(9.8 \pm 0.1) - (6.4 \pm 0.1)} \]

To find the implied uncertainty in \(d\), we must find the largest and smallest \(d\) values allowed by the uncertainties of the quantities in the formula.

\[ \Rightarrow d_{\text{max}} = \frac{28.93}{9.7 - 6.5} = 9.0 \text{ g/cm}^3 \]

\[ \Rightarrow d_{\text{min}} = \frac{28.87}{9.9 - 6.3} = 8.0 \text{ g/cm}^3 \]

The "normal" value of \(d\) is calculated as usual:

\[ \frac{d}{V} = \frac{28.90}{9.8 - 6.4} = 8.5 \text{ g/cm}^3 \]

\[ \Rightarrow d = 8.5 \pm 0.5 \text{ g/cm}^3 \]
\[ d = \frac{m}{V} = \frac{19.625 \text{ g}}{25.00 \text{ cm}^3} = 0.785 \text{ g/cm}^3 \]

\[ d_{\text{max}} = \frac{(19.625 + 0.002) \text{ g}}{(25.00 - 0.03) \text{ cm}^3} = 0.786 \]

\[ d_{\text{min}} = \frac{(19.625 - 0.002) \text{ g}}{(25.00 + 0.03) \text{ cm}^3} = 0.784 \]

\[ \Rightarrow \text{uncertainty is } \pm 0.001 \text{ g/cm}^3 \]

\[ d_{\text{ethanol}} = 0.789 \]

\[ d_{\text{isopropryl alcohol}} = 0.785 \]

The uncertainty in the measured \( d \) is only \( \pm 0.001 \)

\[ 0.785 + 0.001 < 0.789 \]

It is sufficiently precise.

\[ \text{Volume} = \frac{4}{3} \pi \left( 69 \text{ pm} \times \frac{10^{-12} \text{ m}}{1 \text{ pm}} \times \frac{1 \text{ cm}}{10^{-2} \text{ m}} \right)^3 = 1.38 \times 10^{-24} \text{ cm}^3 \]

\[ d = \frac{m}{V} = \frac{3.35 \times 10^{-23} \text{ g}}{1.38 \times 10^{-24} \text{ cm}^3} = 24 \text{ g/cm}^3 \]

Correction to the question: "Assume the nucleus is a sphere...

\[ \text{atom} \]

(e) true (depends on what is meant by "chemical means": a compound breaking down is necessarily a chemical reaction, but an electric heater providing the energy, for example, is a physical "means"; here we are referring to the chemical reaction and not who's driving it.)
Subtracting two numbers that are very close in value can remove many or most of the significant figures.
For example:

\[
\overline{8.9374} - \overline{8.9372} = 0.0002
\]

5 sig. figs     5 sig. figs     1 sig. fig!

\( (a) \quad \text{% error} = \frac{|2.70 - 2.64|}{2.70} \times 100 = 2 \% \)

\( (b) \quad \text{% error} = \frac{|16.12 - 16.48|}{16.12} \times 100 = 2.2 \% \)

It's a little strange to think of "% error in a percent", but it's just another measurement.

\( (c) \quad \text{% error} = \frac{|0.9981 - 1.000|}{1.000} \times 100 = 0.19 \% \)