Conversion Factors and Problem Solving

LABORATORY GOALS

- Round off a calculated answer to the correct number of significant figures or decimal places.
- Determine the area of a rectangle and the volume of a solid by direct measurement.
- Determine metric, U.S. system, and metric–U.S. system equalities and their conversion factors.
- Use conversion factors in calculations to convert units of length, volume, and mass.

LAB INFORMATION

Time:	3 h
Comments:	Tear out the report sheets and place them beside the procedures.
	Identify the smallest unit of measurement on each measuring tool you use.
	Include an estimated digit for each measurement.
	Round off the calculator answers to the correct number of significant figures.
Related Topics:	Conversion factors, significant figures or decimal places, density

CHEMICAL CONCEPTS

Every day, you make some measurements, such as weighing yourself or checking the temperature. Such measurements are probably in units of the U.S. system. In the laboratory, you will make measurements too, and perform calculations. Most of these measurements, or measured numbers, will use units from the metric system (see Figure 1).

▲ **FIGURE 1** There are many measurements in everyday life.

When you use measured numbers in calculations, the answers that you report must reflect the precision of the original measurements. Thus, it is often necessary to adjust the results you see on the calculator display. Every time you use your calculator, you will need to assess the mathematical operations, count significant figures, and your calculator can not do this for you!

A. Rounding Off

Usually there are more digits in a calculator display than there are significant digits in the measured numbers used in the calculation. Therefore, we adjust the calculator result by rounding off. If the first digit to be dropped is *less than 5,* it and all following digits are dropped. If the first digit to be dropped is *5 or greater,* all the following digits are dropped and the value of the last *retained* digit is increased by 1. When you round a large number, the correct magnitude is retained by replacing the dropped digits with *placeholder zeros* (see Sample Problem 1). When a whole number appears in the calculator display, significant zeros may need to be added.

SAMPLE PROBLEM 1

Round off each of the following to report an answer with three significant figures:

a. 75.6243 m

b. 0.528392 L

c. 3. 8765× 10^4 s

d. 4 kg

SOLUTION:

a. 75.6 m

b. 0.528 L

c. 3.88×10^4 s

d. 4.00 kg

B. Significant Figures in Calculations

When you measure the mass of a sample, the volume of a liquid, or the temperature of a solution, the measured numbers you obtain are often used in mathematical calculations. The answers you report depend on the number of significant figures in those measured numbers.

Multiplication/Division When multiplying or dividing, the final answer is written so that it has the same number of significant figures as the measurement with the *fewest significant figures* (*SFs*) (see Sample Problem 2).

SAMPLE PROBLEM 2

Solve: $\dfrac{0.025 \times 4.620}{3.44} =$

SOLUTION:

On your calculator, enter the number and the operation for multiplication or division as follows:

Two SFs		*Four SFs*		*Three SFs*			
0.025	×	4.620	÷	3.44	=	0.033575581	*calculator display*
					=	0.034	*answer rounded off to two SFS*

Addition/Subtraction When adding or subtracting, the final answer is written so that it has the same number of decimal places as the measurement having the *fewest decimal places* (see Sample Problem 3).

SAMPLE PROBLEM 3

Add: 2.11 +104.056 + 0.1205

SOLUTION:

2.11	*two decimal places*
104.056	*three decimal places*
+ 0.1205	*four decimal places*
106.2865	*calculator display*
106.29	*answer rounded off to two decimal places*

C. Equalities and Conversion Factors

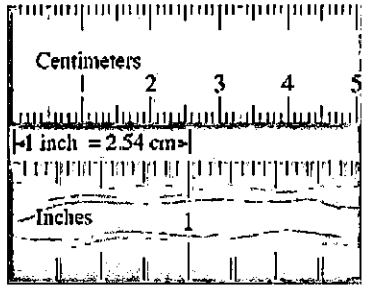
Metric Conversion Factors If a quantity is expressed in two different metric units, a *metric equality* can be stated. For example, the length of 1 m is the same as 1000 mm, which gives the equality 1 m = 1000 mm. The ratio of the two values is called a *conversion factor.*

Metric equality: $1\text{ m} = 1000\text{ mm}$

Conversion factors: $\frac{1\text{ m}}{1000\text{ mm}}$ and $\frac{1000\text{ mm}}{1\text{ m}}$

Two conversion factors are always possible for any equality. Metric conversion factors, which are from definitions, are exact and do not limit the number of significant figures in the answer.

Metric—U.S. System Conversion Factors A *metric—U.S. system* equality gives the relationship between a metric unit and a U.S. unit. For example, 454 g is the same mass as 1 lb. Usually one value is measured and the other value is exact. Then 454 g is a measured number with three SFs, while the 1 lb is exact. In the equality 1 in. = 2.54 cm, both numbers have been defined as exact (see Figure 2).



▲ **FIGURE 2** Comparing centimeters and inches

See Table 1 for some common equalities and conversion factors for length, mass, and volume from the metric system and the metric—U.S. systems of measurement.

TABLE 1 Common Equalities and Their Conversion Factors

	Metric—Metric		Metric—U.S.	
	Equality	**Conversion Factors**	**Equality**	**Conversion Factors**
Length	$1\text{ m} = 100\text{ cm}$	$\frac{1\text{ m}}{100\text{ cm}}$ and $\frac{100\text{ cm}}{1\text{ m}}$	$1\text{ in.} = 2.54\text{ cm}$	$\frac{2.54\text{ cm}}{1\text{ in.}}$ and $\frac{1\text{ in.}}{2.54\text{ cm}}$
Mass	$1\text{ kg} = 1000\text{ g}$	$\frac{1\text{ kg}}{1000\text{ g}}$ and $\frac{1000\text{ g}}{1\text{ kg}}$	$1\text{ lb} = 454\text{ g}$	$\frac{1\text{ lb}}{454\text{ g}}$ and $\frac{454\text{ g}}{1\text{ lb}}$
Volume	$1\text{ L} = 1000\text{ mL}$	$\frac{1\text{ L}}{1000\text{ mL}}$ and $\frac{1000\text{ mL}}{1\text{ L}}$	$1\text{ qt} = 946\text{ mL}$	$\frac{946\text{ mL}}{1\text{ qt}}$ and $\frac{1\text{ qt}}{946\text{ mL}}$

D. Problem Solving Using Conversion Factors

The process of problem solving in chemistry often requires the conversion of a given quantity with one unit to the needed quantity with a different unit (see Sample Problem 3).

SAMPLE PROBLEM 3

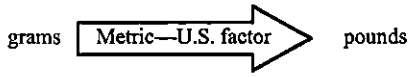
If a melon has a mass of 546 g, what is its weight in pounds?

SOLUTION:

Step 1 State the given and needed quantities.

Given: 546 g **Need:** weight in pounds

Step 2 Write a plan to convert the given unit to the needed unit.



Step 3 State the equalities and conversion factors.

Equality	**Conversion Factors**
1 lb = 454 g	$\frac{1\text{ lb}}{454\text{ g}}$ and $\frac{454\text{ g}}{1\text{ lb}}$

Step 4 Set up the problem to cancel units and calculate the answer.

Note that the conversion factor selected has grams in the denominator to cancel grams of the given unit in the numerator. Always begin the set up by writing the giving information, not the conversion factor. Use the conversion factor to convert into the desired unit.

Exact

$$546\ \text{g} \times \frac{1\text{ lb}}{454\ \text{g}} = 1.20\text{ lb}$$

Three SFs *Three SFs* *Three SFs*

EXPERIMENTAL PROCEDURES  *GOGGLES REQUIRED!*

A. Rounding Off

A student rounded off some numbers to three significant figures. In a few cases, significant zeros were added.

1. Determine whether the rounding was done correctly.
2. If it is incorrect, write the correctly rounded number.

B. Significant Figures in Calculations

B.1 Multiplication and Division

Solve the multiplication and division problems. Report your answers with the correct number of significant figures.

B.2 Addition and Subtraction

Solve the addition and subtraction problems. Report your answers with the correct number of decimal places.

B.3 Area

Materials: Meterstick or metric ruler

1. Use a metric ruler to measure the length (cm) and width (cm) of the rectangle drawn on the report sheet.
2. Calculate the area (cm^2) of the rectangle using your measurements and the formula $\text{Area} = L \times W$.
3. Obtain a second set of measurements from another student and record.
4. Calculate the area using the measurements from the other student.

B.4 Volume of a Solid

Materials: Meterstick or metric ruler, solid object

1. Record the shape of the solid object and the dimensions to measure (see list below).
2. Use a metric ruler to measure the dimensions of the solid in centimeters (cm).
3. Calculate the volume of the solid object, in cm^3, using the appropriate formula from the following:

Shape	Dimensions to Measure	Formulas for Volume
Cube	Length (L)	$V = L^3$
Rectangular solid	Length (L), width (W), height (H)	$V = L \times W \times H$
Cylinder	Diameter (D), height (H)	$V = \frac{\pi D^2 H}{4} = \frac{3.14 D^2 H}{4}$

C. Equalities and Conversion Factors

C.1 Metric—Metric Conversion Factors for Volume

Materials: 1-L graduated cylinder

1. Observe the markings on a 1-L graduated cylinder. Write an equality that states the number of milliliters in 1 L.
2. Write two conversion factors for the equality.

C.2 Metric—U.S. System Conversion Factors for Volume

Materials: 1-L graduated cylinder, 1-qt measure (or 1-pt measure)

1. Using a 1-pt or 1-qt measure, measure 1 qt (or 2 pt) of water and transfer to a 1-L graduated cylinder. Record the number of milliliters in 1 qt.
2. Write the true equality that states the number of milliliters in a quart.
3. Write two conversion factors for the equality.

C.3 Metric—U.S. System Conversion Factors for Length

Materials: Metric ruler or meterstick

1. Measure the vertical length of this page in inches and in centimeters.
2. Divide the number of centimeters by the number of inches to give the relationship of cm/in. Round off to give the *experimental* factor for the number of centimeters in 1 in.
3. Write the equality that states the number of milliliters in a quart.
4. Write two conversion factors for the equality.

C.4 Metric—U.S. System Conversion Factors for Mass

Materials: Commercial product with mass (weight) of contents given on label that list the contents in both metric and U.S. units.

1. Write the name of the commercial product.
2. Read the label on the product. Record the mass of the contents, in grams, and the weight, in ounces or pounds. (Do not weigh contents.)
3. If the weight is given in ounces, convert it to pounds (1 lb = 16 oz).
4. Divide the mass, in grams, of the product by its weight in pounds. This is your *experimental factor* for grams in one pound (g/1 lb).
5. Write the equality that states the number of grams in 1 lb.
6. Write two conversion factors for the equality.

D. Problem Solving Using Conversion Factors

Calculating Your Metric Height

Materials: Yardstick

1. Record your height in inches. Or use a yardstick to measure.
2. Using the appropriate conversion factor, calculate your height in centimeters. Show your setup for each calculation.

$$\text{Height (in.)} \times \frac{2.54 \text{ cm}}{1 \text{ in.}} = \text{your height (cm)}$$

3. Using the appropriate conversion factor, calculate your height in meters. Show your setup for each calculation.

$$\text{Height (cm)} \times \frac{1 \text{ m}}{100 \text{ cm}} = \text{your height (m)}$$

Date _____ Name _____

Section _____ Team _____

Instructor _____

Pre-Lab Study Questions

1. What are the rules for rounding off numbers?

2. How do you determine the number of significant figures for an answer obtained by multiplication or division?

3. How do you determine the number of decimal places for an answer obtained by addition or subtraction?

4. What is an equality and how is it used to write a conversion factor?

5. Write the equality and conversions factors for the relationship between miles and hours for a car traveling at 55 mi/h.

Date _____ Name _____

Section _____ Team _____

Instructor _____

REPORT SHEET

Conversion Factors and Problem Solving

A. Rounding Off

Initial Number	Student's Rounded Value	1. Correct? (yes/no)	2. Corrected (if needed)
143.63212	144		
532 800	533		
0.008 583 45	0.009		
8	8.00		

B. Significant Figures in Calculations

B.1 Multiplication and Division

Perform the following multiplication and division calculations. Give a final answer with the correct number of significant figures:

$0.1184 \times 8.00 \times 0.0345$ _____

$\dfrac{(42.4)(15.6)}{1.265}$ _____

$\dfrac{(35.56)(1.45)}{(4.8)(0.56)}$ _____

B.2 Addition and Subtraction

Perform the following addition and subtraction calculations. Give a final answer with the correct number of decimal places.

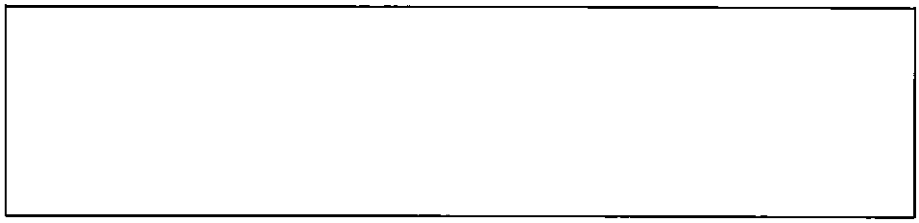
13.45 mL+0.4552 mL _____

145.5 m+86.58 m+1045 m _____

245.625 g – 80.2 g _____

4.62 cm – 0.885 cm _____

B.3 Area



	1. Your measurements	3. Another student's measurements
Length	_____	_____
Width	_____	_____
Area (2., 4.)	_____	_____

Why could two students obtain different values for the calculated area of the same rectangle?

B.4 Volume of a Solid

1. Shape of the solid _____

   Dimensions to measure _____

2. Height _____ Length _____

   Width _____ Diameter (if cylinder) _____

3. Formula for volume of solid _____

   Volume of the solid _____

   (*Show calculations of volume, including the units.*)

C. Equalities and Conversion Factors

C.1 Metric—Metric Conversion Factors for Volume

1. Equality 1 L = _____ mL
2. Conversion factors

C.2 Metric—U.S. System Conversion Factors for Volume

1. Number of milliliters in 1 qt _____ mL (*Experimental factor*)
2. True equality 1 qt = _____ mL
3. Conversion factors

How does your *experimental factor* compare to the conversion factor 946 mL/1 qt.?

C.3 Metric—U.S. System Conversion Factors for Length

1. Vertical page length (*measured*) _____ in.
   Vertical page length (*measured*) _____ cm
2. _____ cm/in. = _____ cm/1 in. (*Experimental factor*)
3. True equality _____ in. = _____ cm
4. Conversion factors

How does your *experimental factor* compare to the conversion factor 2.54 cm/1 in.?

C.4 Metric—U.S. System Conversion Factors for Mass

1. Name of commercial product _____
2. Mass, in grams, stated on label _____ g
   Weight, in pounds or ounces, stated on label _____
3. Weight in lb _____ lb
   (*Convert oz to lb if needed.*)
4. _____ g/lb = _____ g/1 lb
   (*Experimental factor*)
5. True equality 1 lb = _____ g
6. Conversion factors

How does your *experimental factor* compare to the standard conversion factor of 454 g/lb?

D. Problem Solving Using Conversion Factors

Your metric height

1. Height (inches) _____ in.

2. Height in centimeters _____ cm (*Show your calculations*)

3. Height in meters _____ m (*Show your calculations*)

Questions and Problems

Q1 A pencil is 16.2 cm long. What is its length in inches?

Q2 A person has a mass of 63.4 kg. What is that weight in pounds?

Q3 A bottle of olive oil contains 1.4 qt of olive oil. What is that volume in milliliters?

Q4 How many liters of plasma are present in 8.5 pt?