Lab 2 Conversion Factors and Problem Solving

Objectives

- Report a calculation to the correct number of significant figures
- Measure dimensions to calculate area and volume
- Convert between metric and other units for length, volume, and mass

Background

Measurements are a constant part of life. For example, you may use a thermometer to measure the outside temperature or a kitchen scale to measure the mass of an ingredient. Measurements are also a large part of laboratory experiments, usually using the metric system.

Measurements involve two parts: the number and the unit. The unit reflects what property is being measured. For example, the unit of grams indicates a mass measurement. The number in the measurement primarily indicates the quantity of the measurement units. The number also reflects how precisely the measurement is known based on how many digits are included in the measurement.

Rounding

Because the number of digits in a measurement is important, any calculations using the measurement need to maintain the indication of precision. Calculations need to be rounded to the proper number of digits, and not all numbers from a calculator should be reported.

Once you know the correct number of digits to report, count the number of allowed digits starting from the left. Then, the next digit is the first digit to be dropped. If the first digit to be dropped is less than 5, do not change the last retained digit and drop all following digits. If the first digit to be dropped is equal to 5 or greater, increase the last retained digit by 1 and drop all following digits.

Example: *Round the number 17.62 to two digits.*

The first digit to drop is a 6 so the last retained digit, 7, gets increased to an 8 and the other digits are dropped.

The number 17.62 rounds to 18 when reporting two digits.

Note that some large numbers need placeholder zeros when digits are dropped in order to keep the same magnitude. For example, 6541 rounded to three digits is 6540, with the last zero holding the place of the dropped digit.

Significant Figures in Calculations

The digits in a measured number are called significant figures. Any calculation using measured numbers needs to base its number of significant figures on both the significant figures of the measured numbers and the mathematical operation involved.

Identifying Significant Figures

The first step in working with significant figures is being able to recognize how many are present in a given measurement. Table 1 provides the guidelines for determining significant figures and an example of each.

Table 1 Guidelines for Counting Significant Figures

Guideline	Example
All non-zero digits are significant	1.23 cm has 3 significant figures
Zeros between non-zero digits are significant	4.062 g has 4 significant figures
Zeros to the left of all non-zero digits are NOT significant	0.98 mL has 2 significant figures
Zeros to the right of all non-zero digits are significant ONLY with a decimal point	5.60 m has 3 significant figures but 560 cm has 2 significant figures

Multiplication and Division

If a calculation uses multiplication and/or division, the result should have the same number of significant figures as the involved measurement with the fewest significant figures.

Example: *Report the result of the calculation with the correct number of significant figures.*

$$\frac{5.60 \times 0.98}{1.23}$$

The involved number with the fewest significant figures is 0.98, which has two significant figures. From the calculator, the result is 4.461788618, but that needs to be rounded to two significant figures.

The result reported with the correct number of significant figures is 4.5.

Addition and Subtraction

If a calculation uses addition and/or subtraction, the result should have the same number of digits past the decimal point as the involved measurement with the fewest digits past the decimal point.

Example: *Report the result of the calculation with the correct number of significant figures.*

$$4.062 + 1.23 + 560$$

The involved number with the fewest digits past the decimal point is 560 with zero digits. From the calculator, the result is 565.292, but that needs to be rounded to have zero digits past the decimal point.

The result reported with the correct number of significant figures is 565.

Conversion Factors

Any measured property can be measured in multiple different units. For example, length can be measured in units of meters or yards. Units that measure the same property have a direct equality that allows them to be interconverted.

Metric Conversions

Metric units for the same property are all related by powers of ten and represented by the prefix of the unit. For example, both grams (g) and milligrams (mg) measure mass. The difference between the units is the prefix milli-, which indicates the power of 10 that relates them. Specifically, the equality for these units is 1 g = 1000 mg. The equality between two units defines the conversion factor, or ratio of the two values, necessary for a conversion.

Example: *Write the equality and two conversion factors between grams and milligrams.*

Equality: $1\text{ g} = 1000\text{ mg}$

Conversion factors: $\frac{1\text{ g}}{1000\text{ mg}}$ and $\frac{1000\text{ mg}}{1\text{ g}}$

The correct conversion factor depends on the starting unit of the measurement.

Note that the values involved in metric equalities are exact and do not limit the significant figures in any calculation using them.

Conversions between Metric and U.S. Units

As stated, any units that measure the same property have a relationship or equality between them. This is true even if the units come from different systems, such as between metric and U.S. units. For example, both centimeters (cm), a metric unit, and inches (in), a U.S. unit, measure length, so there is an equality that 2.54 cm = 1 in that allows conversion between them. The relationship between cm and in is exactly defined. However, most equalities between units from different systems include a measured, rounded value. For example, the equality between grams (g) and pounds (lb) is 454 g =1 lb. The 454 g value has been measured and reported to three significant figures as the grams in exactly 1 pound.

See Table 2 for some common relationships between units.

Table 2 Common Equalities and Conversion Factors

	Metric–Metric		Metric–U.S.	
Property	Equality	Conversion Factors	Equality	Conversion Factors
Length	$1\ \text{m} = 100\ \text{cm}$	$\frac{1\ \text{m}}{100\ \text{cm}}$ and $\frac{100\ \text{cm}}{1\ \text{m}}$	$1\ \text{in} = 2.54\ \text{cm}$	$\frac{1\ \text{in}}{2.54\ \text{cm}}$ and $\frac{2.54\ \text{cm}}{1\ \text{in}}$
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 $\frac{1000\ \text{mL}}{1\ \text{L}}$	$1\ \text{qt} = 946\ \text{mL}$	$\frac{1\ \text{qt}}{946\ \text{mL}}$ and $\frac{946\ \text{mL}}{1\ \text{qt}}$

Using Conversion Factors in Problem Solving

Many of the calculations in chemistry can be summarized as identifying equalities between starting measurements and the desired unit or related property. The equality can then become a conversion factor by which to multiply the starting measurement. Consider a worked-out example of this process applied to a unit conversion.

Example: *If a bed is 1.91 m long, what is the bed's length in cm?*

Step 1: Identify the given and desired values/units.

Given: 1.91 meters Desired: length in centimeters

Step 2: Plan out the connections needed.
Determine whether the given and desired values can be connected directly or need to use multiple steps.

Only one step needed in this example due to direct equality between m and cm

Step 3: State the equalities and conversion factors from your plan.

Equality: $1\ \text{m} = 100\ \text{cm}$ Conversion factors: $\frac{1\ \text{m}}{100\ \text{cm}}$ $\frac{100\ \text{cm}}{1\ \text{m}}$

Step 4: Set up calculation to cancel starting units and give desired units.
Start by writing the given value. Then, select the conversion factor that has the desired units on the top and starting units on the bottom. Finally, multiply the given, starting value by the selected conversion factor.

$$1.91\ \cancel{\text{m}} \times \frac{100\ \text{cm}}{1\ \cancel{\text{m}}} = 191\ \text{cm}$$

Step 5: Review the magnitude and precision of your answer.
Check that the relative size of your answer makes physical sense and that the answer is reported with the correct significant figures.

Magnitude: A centimeter is a smaller length than a meter, so there are more cm than m in the same length.

Precision: The starting measurement was reported with 3 significant figures in a multiplication/division calculation with an exact metric conversion factor, so the answer is reported with three significant figures

Materials

- Meter stick or metric ruler
- Solid object
- 1-L graduated cylinder
- 1-qt or 1-pt measure
- Commercial product with mass/weight given in metric and U.S. units
- Yardstick

Comments

- For each measurement tool, note the smallest unit of measurement.
- Include an estimated digit in each recorded measurement.

Safety goggles are required!

Check with TA or Instructor for any other supplies you may need.

Procedure

Rounding

1) A student rounded off multiple numbers to three significant figures.

2) Determine whether the rounding was done correctly.

3) If the rounding was incorrect, write the correctly rounded number.

Significant Figures in Calculations

1 – Multiplication and Division

Solve the multiplication and division problems, reporting the answer with the correct number of significant figures.

2 – Addition and Subtraction

Solve the addition and subtraction problems, reporting the answer with the correct number of significant figures.

3 – Area

1. Use a meter stick or metric ruler to measure the length and width in centimeters (cm) of the rectangle drawn on the report sheet.
2. Calculate the area (in cm^2) of the rectangle using your measurements and the equation area = length × width.
3. Consult another student to get their set of measurements for the rectangle.
4. Calculate the area of the rectangle using the other student's measurements.

4 – Volume of a Solid

4) Record the shape of the solid object and which dimensions need to be measured from Table 3.

5) Use the meter stick or metric ruler to measure the dimensions of the solid object in centimeters (cm).

6) Calculate the volume of the solid object using the equation from Table 3.

Table 3 Dimensions and Equations for Volume of Shapes

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

Using Conversion Factors in Problem Solving

Calculating Your Metric Height

1. Record your height in inches. Use the yardstick if needed.
2. Use the appropriate conversion factor to calculate your height in centimeters. Write out your work for each calculation, striking through units as they cancel.
3. Use the appropriate conversion factor to calculate your height in meters. Write out your work for each calculation, striking through units as they cancel.

Lab 2 Conversion Factors and Problem Solving Report Sheet

Date _____ Name _____

Section _____ Team _____

Instructor _____

Rounding

Initial Number	Student's Rounded Value	Correct Rounding? (yes/no)	Correct Rounded Value (if needed)
243.6193	244	_____	_____
654900	655	_____	_____
0.00731582	0.007	_____	_____
3	3.00	_____	_____

Significant Figures in Calculations

1 – Multiplication and Division

Solve the multiplication and division problems, reporting the answer with the correct number of significant figures.

$0.1184 \times 8.00 \times 0.0345$ _____

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

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

2 – Addition and Subtraction

Solve the addition and subtraction problems, reporting the answer with the correct number of significant figures.

$13.45\ \text{mL} + 0.4552\ \text{mL}$ _____

$145.5\ \text{m} + 86.58\ \text{m} + 1045\ \text{m}$ _____

$245.625\ \text{g} - 80.2\ \text{g}$ _____

$4.62\ \text{cm} - 0.885\ \text{cm}$ _____

3 – Area

	Your Measurements	Another Student's Measurements
Length	_____	_____
Width	_____	_____
Area	_____	_____

Why might two students have different calculated areas when measuring the same rectangle?

4 – Volume of a Solid

1. Shape of the solid _____

   Dimensions to measure _____

2. Height _____

   Length _____

   Width _____

   Diameter _____

3. Formula for volume of solid _____

   Volume of the solid _____

Show your calculations of the volume, including units.

Conversion Factors

1 – Volume Conversion Factors between Metric Units

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

2 – Volume Conversion Factors between Metric and U.S. Units

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

How does your experimental factor compare to the true equality of 946 mL/1 qt?

3 – Length Conversion Factors between Metric and U.S. Units

1. Measured vertical page length _____ in

   Measured vertical page length _____ cm
2. _____ cm/in = _____ cm/1 in
   (experimental factor)
3. True equality 1 in =_____ cm
4. Conversion factors

How does your experimental factor compare to the true equality of 2.54 cm/1 in?

4 – Mass Conversion Factors between Metric and U.S. Units

1. Name of commercial product _____

2. Mass, in g, from label _____ g

   Weight, in lb or oz, from label _____

3. Weight in lb
   (convert oz to lb if needed) _____ lb

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 true equality of 454 g/1 lb?

Using Conversion Factors in Problem Solving

Calculating Your Metric Height

1. Height (inches) _____ in

2. Height (centimeters) _____ cm
   Show your calculations

3. Height (meters) _____ m
   Show your calculations