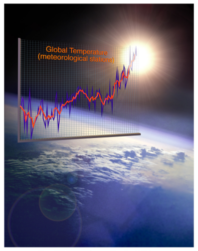
Chapter 2
Measurement and Problem Solving

Michael Stogsdill
Mott Community College
Chem 118
Introductory Chemistry



Map: Introductory Chemistry (Tro) https://chem.libretexts.org/@go/page/45050 (accessed Mar 25, 2022).

What Is a Measurement?

- Quantitative observation.
- Comparison to an agreed upon standard.
- Every measurement has a number and a unit.

A Measurement

- The unit tells you to what standard you are comparing your object.
- The number tells you:
  1. What multiple of the standard the object measures.
  2. The uncertainty in the measurement.

Scientists have measured the average global temperature rise over the past century to be 0.6 °C

- °C tells you that the temperature is being compared to the Celsius temperature scale.
- 0.6 tells you that:
  1. The average temperature rise is 0.6 times the standard unit of 1 degree Celsius.
  2. The confidence in the measurement is such that we are certain the measurement is between 0.5 and 0.7 °C.

Scientific Notation

A way of writing
large and small numbers.

Big and Small Numbers

- We commonly measure objects that are many times larger or smaller than our standard of comparison.
- Writing large numbers of zeros is tricky and confusing.
  - ✓Not to mention there's the 8-digit limit of your calculator!

The sun's diameter is 1,392,000,000 m.

An atom's average diameter is 0.000 000 000 3 m.

Scientific Notation

- Each decimal place in our number system represents a different power of 10.
- Scientific notation writes the numbers so they are easily comparable by looking at the power of 10.

The sun's diameter is 1.392 x 10^9 m.

An atom's average diameter is 3 x 10^{-10} m.

Exponents

- When the exponent on 10 is positive, it means the number is that many powers of 10 larger.
  - ✓Sun's diameter = 1.392 × 10^9 m = 1.392 × 1000000000 m = 1,392,000,000 m.
- When the exponent on 10 is negative, it means the number is that many powers of 10 smaller.
  - ✓Average atom's diameter = 3 × 10^{-10} m = 3 × 0.0000000001 m = 0.0000000003 m.

Scientific Notation

- To compare numbers written in scientific notation:
  - ✓First compare exponents on 10.
  - ✓If exponents are equal, then compare decimal numbers

1.23 x	10^{-8}

Exponent

Decimal part — Exponent part

1.23 x 10^5 > 4.56 x 10^2
4.56 x 10^{-2} > 7.89 x 10^{-5}
7.89 x 10^{10} > 1.23 x 10^{10}

Writing Numbers in Scientific Notation

1. Locate the decimal point.
2. Move the decimal point to obtain a number between 1 and 10.
3. Multiply the new number by 10^n .
   - ✓ Where *n* is the number of places you moved the decimal point.
4. If you moved the decimal point to the left, then *n* is +; if you moved it to the right, then *n* is − .
   - ✓ If the original number is 1 or larger, then *n* is + .
   - ✓ If the original number is less than 1, then *n* is − .

Writing a Number in Scientific Notation, Continued

12340

1. Locate the decimal point.

12340.

2. Move the decimal point to obtain a number between 1 and 10.

1.234

3. Multiply the new number by 10^n .
   - ✓ Where *n* is the number of places you moved the decimal point.

1.234 x 10^4

4. If you moved the decimal point to the left, then *n* is +; if you moved it to the right, then *n* is − .

1.234 x 10^4

Writing a Number in Scientific Notation, Continued

0.00012340

1. Locate the decimal point.

0.00012340

2. Move the decimal point to obtain a number between 1 and 10.

1.2340

3. Multiply the new number by 10^n .
   - ✓Where *n* is the number of places you moved the decimal point.

1.2340 x 10^4

4. If you moved the decimal point to the left, then *n* is +; if you moved it to the right, then *n* is − .

1.2340 x 10^{-4}

Writing a Number in Standard Form

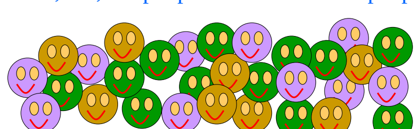
1.234 x 10^{-6}

- Since the exponent is -6, make the number smaller by moving the decimal point to the left 6 places.
  - ✓When you run out of digits to move around, add zeros.
  - ✓Add a zero in front of the decimal point for decimal numbers.

000 001.234
0.000 001 234

Example 2.1

- The U.S. population in 2007 was estimated to be 301,786,000 people. Express this number in scientific notation.
- 301,786,000 people = 3.01786 x 10^8 people



Practice—Write the Following in Scientific Notation, Continued

123.4 = 1.234 x 10^2	8.0012 = 8.0012 x 10^0
145000 = 1.45 x 10^5	0.00234 = 2.34 x 10^{-3}
25.25 = 2.525 x 10^1	0.0123 = 1.23 x 10^{-2}
1.45 = 1.45 x 10^0	0.000 008706 = 8.706 x 10^{-6}

Practice—Write the Following in Standard Form, Continued

2.1 x 10^3 = 2100	4.02 x 10^0 = 4.02
9.66 x 10^{-4} = 0.000966	3.3 x 10^1 = 33
6.04 x 10^{-2} = 0.0604	1.2 x 10^0 = 1.2

Inputting Scientific Notation into a Calculator

-1.23 x 10^{-3}

- Input the decimal part of the number.
  - ✓If negative press +/- key.
    - (–) on some.
- Press EXP.
  - ✓EE on some.
- Input exponent on 10.
  - ✓Press +/- key to change exponent to negative.

Input 1.23	1.23
Press +/-	-1.23
Press EXP	-1.23 00
Input 3	-1.23 03
Press +/-	-1.23 -03

Inputting Scientific Notation into a TI Graphics Calculator

-1.23 x 10^{-3}

- Use ( ) liberally!!
- Type in the decimal part of the number.
  - ✓If negative, **first** press the (-).
- Press the multiplication key.
- Type “10”.
- Press the exponent key, ^ .
- Type the exponent.
  - ✓If negative, **first** press the (-).

Press (-)	–
Input 1.23	–1.23
Press ×	-1.23*
Input 10	-1.23*10
Press ^	-1.23*10^
Press (-)	-1.23*10^-
Input 3	-1.23*10^-3

Significant Figures

Writing numbers to reflect precision.

Exact Numbers vs. Measurements

- Sometimes you can determine an exact value for a quality of an object.
  - ✓Often by counting.
    - Pennies in a pile.
  - ✓Sometimes by definition
    - 1 ounce is exactly 1/16th of 1 pound.
- Whenever you use an instrument to compare a quality of an object to a standard, there is uncertainty in the comparison.

Reporting Measurements

- Measurements are written to indicate the uncertainty in the measurement.
- The system of writing measurements we use is called **significant figures.**
- When writing measurements, all the digits written are known with certainty except the last one, which is an estimate.

45.872

Certain — Estimated

Estimating the Last Digit

- For instruments marked with a scale, you get the last digit by estimating between the marks.
  - ✓ If possible.
- Mentally divide the space into 10 equal spaces, then estimate how many spaces over the indicator is.

Copyright © 2009 Pearson Prentice Hall, Inc.

1.2 grams
the “1” is certain;
the “2” is an estimate.

Skillbuilder 2.3—Reporting the Right Number of Digits

- A thermometer used to measure the temperature of a backyard hot tub is shown to the right. What is the temperature reading to the correct number of digits?

Copyright © 2009 Pearson Prentice Hall, Inc.

103.4 °F

Significant Figures

- The non-placeholding digits in a reported measurement are called **significant figures**.
  - ✓Some zeros in a written number are only there to help you locate the decimal point.
- Significant figures tell us the range of values to expect for repeated measurements.
  - ✓The more significant figures there are in a measurement, the smaller the range of values. Therefore, the measurement is more precise.

12.3 cm has 3 significant figures and its range is 12.2 to 12.4 cm.

12.30 cm has 4 significant figures and its range is 12.29 to 12.31 cm.

Counting Significant Figures

- All non-zero digits are significant.
  - ✓1.5 has 2 significant figures.
- Interior zeros are significant.
  - ✓1.05 has 3 significant figures.
- Trailing zeros after a decimal point are significant.
  - ✓1.050 has 4 significant figures.

Counting Significant Figures, Continued

- Leading zeros are **NOT** significant.
  - ✓ 0.001050 has 4 significant figures.
    - 1.050 x 10^{-3}
- Zeros at the end of a number without a written decimal point are ambiguous and should be avoided by using scientific notation.
  - ✓ If 150 has 2 significant figures, then 1.5 x 10^{2}, but if 150 has 3 significant figures, then 1.50 x 10^{2}.

Significant Figures and Exact Numbers

- Exact numbers have an unlimited number of significant figures.
- A number whose value is known with complete certainty is **exact**.
  - ✓From counting individual objects.
  - ✓From definitions.
    - 1 cm is exactly equal to 0.01 m.
  - ✓From integer values in equations.
    - In the equation for the radius of a circle, the 2 is exact.

$$\text{radius of a circle} = \frac{\text{diameter of a circle}}{2}$$

Example 2.4—Determining the Number of Significant Figures in a Number, Continued

- How many significant figures are in each of the following numbers?

0.0035	2 significant figures—leading zeros are not significant.
1.080	4 significant figures—trailing and interior zeros are significant.
2371	4 significant figures—All digits are significant.
2.97×10^{5}	3 significant figures—Only decimal parts count.
1 dozen = 12	Unlimited significant figures—Definition
100,000	Ambiguous

Determine the Number of Significant Figures, the Expected Range of Precision, and Indicate the Last Significant Figure, Continued

- 1**2**000 2
  From 11000 to 13000.
- 12**0**. 3
  From 119 to 121.
- 12.0**0** 4
  From 11.99 to 12.01.
- 1.2**0** x 10^{3} 3
  From 1190 to 1210.
- 0.001**2** 2
  From 0.0011 to 0.0013.
- 0.0012**0** 3
  From 0.00119 to 0.00121.
- 120**1** 4
  From 1200 to 1202.
- 120**1**000 4
  From 1200000 to 1202000.

Multiplication and Division with Significant Figures

- When multiplying or dividing measurements with significant figures, the result has the same number of significant figures as the measurement with the fewest number of significant figures.

5.02 × 89,665 × 0.10 = 45.0118 = 45
3 sig. figs. 5 sig. figs. 2 sig. figs. 2 sig. figs.

5.892 ÷ 6.10 = 0.96590 = 0.966
4 sig. figs. 3 sig. figs. 3 sig. figs.

Rounding

- When rounding to the correct number of significant figures, if the number after the place of the last significant figure is:

1. 0 to 4, round down.
   - ✓ Drop all digits after the last significant figure and leave the last significant figure alone.
   - ✓ Add insignificant zeros to keep the value, if necessary.
2. 5 to 9, round up.
   - ✓ Drop all digits after the last significat figure and increase the last significant figure by one.
   - ✓ Add insignificant zeros to keep the value, if necessary.

Rounding, Continued

- Rounding to 2 significant figures.
- 2.34 rounds to 2.3.
  - ✓Because the 3 is where the last significant figure will be and the number after it is 4 or less.
- 2.37 rounds to 2.4.
  - ✓Because the 3 is where the last significant figure will be and the number after it is 5 or greater.
- 2.349865 rounds to 2.3.
  - ✓Because the 3 is where the last significant figure will be and the number after it is 4 or less.

Rounding, Continued

- 0.0234 rounds to 0.023 or 2.3×10^{-2}.
  - ✓ Because the 3 is where the last significant figure will be and the number after it is 4 or less.
- 0.0237 rounds to 0.024 or 2.4×10^{-2}.
  - ✓ Because the 3 is where the last significant figure will be and the number after it is 5 or greater.
- 0.02349865 rounds to 0.023 or 2.3×10^{-2}.
  - ✓ Because the 3 is where the last significant figure will be and the number after it is 4 or less.

Rounding, Continued

- 234 rounds to 230 or 2.3×10^{2}.
  - ✓ Because the 3 is where the last significant figure will be and the number after it is 4 or less.
- 237 rounds to 240 or 2.4×10^{2}.
  - ✓ Because the 3 is where the last significant figure will be and the number after it is 5 or greater.
- 234.9865 rounds to 230 or 2.3×10^{2}.
  - ✓ Because the 3 is where the last significant figure will be and the number after it is 4 or less.

Determine the Correct Number of Significant Figures for Each Calculation and Round and Report the Result, Continued

1. 1.01 × 0.12 × 53.51 ÷ 96 = 0.067556 = 0.068
   3 sf, 2 sf, 4 sf, 2 sf — Result should have 2 sf. 7 is in place of last sig. fig., number after is 5 or greater, so round up.
2. 56.55 × 0.920 ÷ 34.2585 = 1.51863 = 1.52
   4 sf, 3 sf, 6 sf — Result should have 3 sf. 1 is in place of last sig. fig., number after is 5 or greater, so round up.

Addition and Subtraction with Significant Figures

- When adding or subtracting measurements with significant figures, the result has the same number of decimal places as the measurement with the fewest number of decimal places.

5.74 + 0.823 + 2.651 = 9.214 = 9.21
2 dec. pl., 3 dec. pl., 3 dec. pl. → 2 dec. pl.

4.8 - 3.965 = 0.835 = 0.8
1 dec. pl, 3 dec. pl. → 1 dec. pl.

Determine the Correct Number of Significant Figures for Each Calculation and Round and Report the Result, Continued

1. 0.987 + 125.1 – 1.22 = 124.867 = 124.9
   3 dp, 1 dp, 2 dp — Result should have 1 dp. 8 is in place of last sig. fig., number after is 5 or greater, so round up.
2. 0.764 – 3.449 – 5.98 = -8.664 = -8.66
   3 dp, 3 dp, 2 dp — Result should have 2 dp. 6 is in place of last sig. fig., number after is 4 or less, so round down.

Both Multiplication/Division and Addition/Subtraction with Significant Figures

- When doing different kinds of operations with measurements with significant figures, evaluate the significant figures in the intermediate answer, then do the remaining steps.
- Follow the standard order of operations.
  - ✓ Please Excuse My Dear Aunt Sally. $( ) \rightarrow ^n \rightarrow \times \div \rightarrow + -$

3.489 × (5.67 – 2.3) =
(2 dp, 1 dp)

3.489 × 3.37 = 12
4 sf, 1 dp & 2 sf, 2 sf

Example 1.6—Perform the Following Calculations to the Correct Number of Significant Figures, Continued

a) $1.10 \times 0.5120 \times 4.0015 \div 3.4555 = 0.65219 = 0.652$

b) $4.562 \times 3.99870 \div (452.6755 - 452.33) = 52.79904 = 53$

c) $(14.84 \times 0.55) - 8.02 = 0.142 = 0.1$

Basic Units of Measure

Units

- Units tell the standard quantity to which we are comparing the measured property.
  - ✓ Without an associated unit, a measurement is without meaning.
- Scientists use a set of standard units for comparing all our measurements.
  - ✓ So we can easily compare our results.
- Each of the units is defined as precisely as possible.

The Standard Units

- Scientists generally report results in an agreed upon International System.
- The SI System
  - ✓ Aka *Système International*

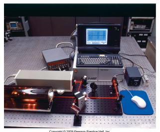
Quantity	Unit	Symbol
Length	meter	m
Mass	kilogram	kg
Time	second	s
Temperature	kelvin	K

Some Standard Units in the Metric System

Quantity Measured	Name of Unit	Abbreviation
Mass	gram	g
Length	meter	m
Volume	liter	L
Time	seconds	s
Temperature	Kelvin	K

Length

- Measure of the two-dimensional distance an object covers.
- SI unit = meter
  - ✓ About 3½ inches longer than a yard.
    - 1 meter = one ten-millionth the distance from the North Pole to the Equator = distance between marks on standard metal rod in a Paris vault = distance covered by a certain number of wavelengths of a special color of light
- Commonly use centimeters (cm).
  - ✓ 1 cm ~ width of your pinky nail
  - ✓ 1 m = 100 cm
  - ✓ 1 cm = 0.01 m = 10 mm
  - ✓ 1 inch = 2.54 cm (exactly)



Yardstick


Meterstick

Mass

- Measure of the amount of matter present in an object.
- SI unit = kilogram (kg)
  - ✓ About 2 lbs. 3 oz.
- Commonly measure mass in grams (g) or milligrams (mg).
  - ✓ 1 kg = 2.2046 pounds, 1 lbs. = 453.59 g
  - ✓ 1 kg = 1000 g = 10^3 g,
  - ✓ 1 g = 1000 mg = 10^3 mg
  - ✓ 1 g = 0.001 kg = 10^{-3} kg,
  - ✓ 1 mg = 0.001 g = 10^{-3} g

Time

- Measure of the duration of an event.
- SI units = second (s)
- 1 s is defined as the period of time it takes for a specific number of radiation events of a specific transition from cesium-133.

Temperature

- Measure of the average amount of kinetic energy.
  - ✓ higher temperature = larger average kinetic energy
- Heat flows from the matter that has high thermal energy into matter that has low thermal energy.
  - ✓ Until they reach the same temperature.
  - ✓ Heat is exchanged through molecular collisions between the two materials.


22 °C – Room temperature

Related Units in the SI System

- All units in the SI system are related to the standard unit by a power of 10.
- The power of 10 is indicated by a prefix.
- The prefixes are always the same, regardless of the standard unit.
- It is usually best to measure a property in a unit close to the size of the property.
  - ✓ It reduces the number of confusing zeros.

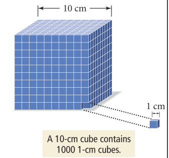
Common Prefixes in the SI System

Prefix	Symbol	Decimal Equivalent	Power of 10
mega-	M	1,000,000	Base x 10^6
kilo-	k	1,000	Base x 10^3
deci-	d	0.1	Base x 10^{-1}
centi-	c	0.01	Base x 10^{-2}
milli-	m	0.001	Base x 10^{-3}
micro-	µ or mc	0.000 001	Base x 10^{-6}
nano-	n	0.000 000 001	Base x 10^{-9}

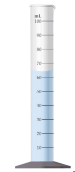
Prefixes Used to Modify Standard Unit

- kilo = 1000 times base unit = 10^3
  - ✓ 1 kg = 1000 g = 10^3 g
- deci = 0.1 times the base unit = 10^{-1}
  - ✓ 1 dL = 0.1 L = 10^{-1} L; 1 L = 10 dL
- centi = 0.01 times the base unit = 10^{-2}
  - ✓ 1 cm = 0.01 m = 10^{-2} m; 1 m = 100 cm
- milli = 0.001 times the base unit = 10^{-3}
  - ✓ 1 mg = 0.001 g = 10^{-3} g; 1 g = 1000 mg
- micro = 10^{-6} times the base unit
  - ✓ 1 µm = 10^{-6} m; 10^6 µm = 1 m
- nano = 10^{-9} times the base unit
  - ✓ 1 nL = 10^{-9}L; 10^9 nL = 1 L

Volume



- Derived unit.
  - ✓ Any length unit cubed.
- Measure of the amount of space occupied.
- SI unit = cubic meter (m^3)
- Commonly measure solid volume in cubic centimeters (cm^3).
  - ✓ 1 m^3 = 10^6 cm^3
  - ✓ 1 cm^3 = 10^{-6} m^3 = 0.000001 m^3
- Commonly measure liquid or gas volume in milliliters (mL).
  - ✓ 1 L is slightly larger than 1 quart.
  - ✓ 1 L = 1 dm^3 = 1000 mL = 10^3 mL
  - ✓ 1 mL = 0.001 L = 10^{-3} L
  - ✓ 1 mL = 1 cm^3



Common Units and Their Equivalents

Length

1 kilometer (km)	=	0.6214 mile (mi)
1 meter (m)	=	39.37 inches (in.)
1 meter (m)	=	1.094 yards (yd)
1 foot (ft)	=	30.48 centimeters (cm)
1 inch (in.)	=	2.54 centimeters (cm) exactly

Common Units and Their Equivalents, Continued

Mass

1 kilogram (km)	=	2.205 pounds (lb)
1 pound (lb)	=	453.59 grams (g)
1 ounce (oz)	=	28.35 (g)

Volume

1 liter (L)	=	1000 milliliters (mL)
1 liter (L)	=	1000 cubic centimeters (cm^3)
1 liter (L)	=	1.057 quarts (qt)
1 U.S. gallon (gal)	=	3.785 liters (L)

Which Is Larger?, Continued

- 1 yard or 1 meter?
- 1 mile of 1 km?
- 1 cm or 1 inch?
- 1 kg or 1 lb?
- 1 mg or 1 µg?
- 1 qt or 1 L?
- 1 L or 1 gal?
- 1 gal or 1000 cm^3?

Units

- Always write every number with its associated unit.
- Always include units in your calculations.
  - ✓ You can do the same kind of operations on units as you can with numbers.
    - cm × cm = cm^2
    - cm + cm = cm
    - cm ÷ cm = 1
  - ✓ Using units as a guide to problem solving is called ***dimensional analysis***.

Problem Solving and Dimensional Analysis

- Many problems in chemistry involve using relationships to convert one unit of measurement to another.
- Conversion factors are relationships between two units.
  - ✓ May be exact or measured.
  - ✓ Both parts of the conversion factor have the same number of significant figures.
- Conversion factors generated from equivalence statements.
  - ✓ e.g., 1 inch = 2.54 cm can give $\frac{2.54\,\text{cm}}{1\,\text{in}}$ or $\frac{1\,\text{in}}{2.54\,\text{cm}}$

Problem Solving and Dimensional Analysis, Continued

- Arrange conversion factors so the starting unit cancels.
  - ✓ Arrange conversion factor so the starting unit is on the bottom of the conversion factor.
- May string conversion factors.
  - ✓ So we do not need to know every relationship, as long as we can find something else the starting and desired units are related to :

$$\textit{start unit} \times \frac{\textit{desired unit}}{\textit{start unit}} = \textit{desired unit}$$

$$\textit{start unit} \times \frac{\textit{related unit}}{\textit{start unit}} \times \frac{\textit{desired unit}}{\textit{related unit}} = \textit{desired unit}$$

Solution Maps

- A solution map is a visual outline that shows the strategic route required to solve a problem.
- For unit conversion, the solution map focuses on units and how to convert one to another.
- For problems that require equations, the solution map focuses on solving the equation to find an unknown value.

Systematic Approach

1. Write down the given amount and unit.
2. Write down what you want to find and unit.
3. Write down needed conversion factors or equations.
   a. Write down equivalence statements for each relationship.
   b. Change equivalence statements to conversion factors with starting unit on the bottom.

Systematic Approach, Continued

4. Design a solution map for the problem.
   - ✓ Order conversions to cancel previous units or arrange equation so the find amount is isolated.
5. Apply the steps in the solution map.
   - ✓ Check that units cancel properly.
   - ✓ Multiply terms across the top and divide by each bottom term.
6. Determine the number of significant figures to report and round.
7. Check the answer to see if it is reasonable.
   - ✓ Correct size and unit.

Solution Maps and Conversion Factors

- Convert inches into centimeters.
  1. Find relationship equivalence: **1 in = 2.54 cm**
  2. Write solution map.

     in → cm

  3. Change equivalence into conversion factors with starting units on the bottom.

$$\frac{2.54\text{ cm}}{1\text{ in}}$$

Example 2.8—Convert 7.8 km to Miles

1. Write down the **Given** quantity and its unit.	**Given:**	7.8 km 2 significant figures
2. Write down the quantity you want to **Find** and unit.	**Find:**	? miles
3. Write down the appropriate **Conversion Factors**.	**Conversion Factor:**	1 km = 0.6214 mi
4. Write a **Solution Map**.	**Solution Map:**	km → mi $\frac{0.6214\text{ mi}}{1\text{ km}}$
5. Follow the solution map to **Solve** the problem.	**Solution:**	$7.8\text{ km} \times \frac{0.6214\text{ mi}}{1\text{ km}} = 4.84692\text{ mi}$
6. Significant figures and round.	**Round:**	4.84692 mi = 4.8 mi 2 significant figures
7. Check.	**Check:**	Units and magnitude are correct.

Practice—Convert 30.0 g to Ounces

(1 oz. = 28.32 g)

Convert 30.0 g to Ounces

• Write down the **Given** quantity and its unit.	**Given:**	30.0 g 3 sig figs
• Write down the quantity you want to **Find** and unit.	**Find:**	oz.
• Write down the appropriate **Conversion Factors.**	**Conversion Factor:**	1 oz = 28.35 g
• Write a **Solution Map.**	**Solution Map:**	g → oz $\frac{1\text{ oz}}{28.35\text{ g}}$
• Follow the solution map to **Solve** the problem.	**Solution:**	$30.0\text{ g} \times \frac{1\text{ oz}}{28.35\text{ g}} = 1.05820\text{ oz}$
• Significant figures and round.	**Round:**	1.05820 oz = 1.06 oz 3 sig figs
• Check.	**Check:**	Units and magnitude are correct.

Solution Maps and Conversion Factors

- Convert cups into liters.
  1. Find relationship equivalence: **1 L = 1.057 qt, 1 qt = 4 c**
  2. Write solution map.

c → qt → L

3. Change equivalence into conversion factors with starting units on the bottom.

$$\frac{1\text{ qt}}{4\text{ c}} \qquad \frac{1\text{L}}{1.057\text{ qt}}$$

Example 2.10—How Many Cups of Cream Is 0.75 L?

1.	Write down the **Given** quantity and its unit.	**Given:**	0.75 L 2 sig figs
2.	Write down the quantity you want to **Find** and unit.	**Find:**	? cu
3.	Write down the appropriate **Conversion Factors**.	**Conversion Factors:**	1 L = 1.057 qt 1 qt = 4 cu
4.	Write a **Solution Map**.	**Solution Map:**	L → qt → cu; $\frac{1.057\text{ qt}}{1\text{ L}}$ $\frac{4\text{ cu}}{1\text{ qt}}$
5.	Follow the solution map to **Solve** the problem.	**Solution:**	$0.75\text{ L}\times\frac{1.057\text{ qt}}{1\text{ L}}\times\frac{4\text{ cu}}{1\text{ qt}}=3.171\text{ cu}$
6.	Significant figures and round.	**Round:**	3.171 cu = 3.2 cu 2 sig figs
7.	Check.	**Check:**	Units and magnitude are correct.

Practice—Convert 30.0 mL to Quarts

(1 mL = 0.001 L; 1 L = 1.057 qts)

Convert 30.0 mL to Quarts

1.	Write down the **Given** quantity and its unit.	**Given:**	30.0 mL 3 sig figs
2.	Write down the quantity you want to **Find** and unit.	**Find:**	? qt
3.	Write down the appropriate **Conversion Factors.**	**Conversion Factors:**	1 L = 1.057 qt 1 mL = 0.001 L
4.	Write a **Solution Map.**	**Solution Map:**	mL → L → qt; $\frac{0.001\text{ L}}{1\text{ mL}}$ $\frac{1.057\text{ qt}}{1\text{ L}}$
5.	Follow the solution map to **Solve** the problem.	**Solution:**	$30.0\text{ mL}\times\frac{0.001\text{ L}}{1\text{ mL}}\times\frac{1.057\text{ qt}}{1\text{ L}}=0.0317\text{ qt}$
6.	Significant figures and round.	**Round:**	30.0 mL = 0.0317 qt 3 sig figs
7.	Check.	**Check:**	Units and magnitude are correct.

Solution Maps and Conversion Factors

- Convert cubic inches into cubic centimeters.
  1. Find relationship equivalence: **1 in = 2.54 cm**
  2. Write solution map.

in^3 → cm^3

3. Change equivalence into conversion factors with starting units on the bottom.

$$\left(\frac{2.54\text{ cm}}{1\text{ in}}\right)^3=\frac{2.54^3\text{ cm}^3}{1^3\text{ in}^3}=\frac{16.4\text{ cm}^3}{1\text{ in}^3}$$

Example 2.12—Convert 2,659 cm^2 into Square Meters

1.	Write down the **Given** quantity and its unit.	**Given:**	2,659 cm^2 4 significant figures
2.	Write down the quantity you want to **Find** and unit.	**Find:**	? m^2
3.	Write down the appropriate **Conversion Factors**.	**Conversion Factor:**	1 cm = 0.01 m
4.	Write a **Solution Map**.	**Solution Map:**	cm^2 → m^2; $\left(\frac{0.01\text{ m}}{1\text{ cm}}\right)^2$
5.	Follow the solution map to **Solve** the problem.	**Solution:**	$2{,}659\text{ cm}^2\times\frac{1\times10^{-4}\text{ m}^2}{1\text{ cm}^2}=0.2659\text{ m}^2$
6.	Significant figures and round.	**Round:**	0.2659 m^2 4 significant figures
7.	Check.	**Check:**	Units and magnitude are correct.

Practice—Convert 30.0 cm^3 to m^3

(1 cm = 1 x 10^{-2} m)

Convert 30.0 cm^3 to m^3

1.	Write down the **Given** quantity and its unit.	**Given:**	30.0 cm^3 3 sig figs
2.	Write down the quantity you want to **Find** and unit.	**Find:**	? m^3
3.	Write down the appropriate **Conversion Factors.**	**Conversion Factor:**	$(1\text{ cm} = 0.01\text{ m})^3$
4.	Write a **Solution Map.**	**Solution Map:**	cm^3 → m^3; $\left(\frac{0.01\text{ m}}{1\text{ cm}}\right)^3$
5.	Follow the solution map to **Solve** the problem.	**Solution:**	$3.00\times10^1\text{ cm}^3\times\frac{1\times10^{-6}\text{ m}^3}{1\text{ cm}^3}=3\times10^{-5}\text{ m}^3$
6.	Significant figures and round.	**Round:**	30.0 cm^3 = 3.00 x 10^{-5} m^3 3 sig figs
7.	Check.	**Check:**	Units and magnitude are correct.

Density

Mass and Volume

- Two main characteristics of matter.
- Cannot be used to identify what *type* of matter something is.
  - ✓If you are given a large glass containing 100 g of a clear, colorless liquid and a small glass containing 25 g of a clear, colorless liquid, are both liquids the same stuff?
- Even though mass and volume are individual properties, for a given type of matter they are related to each other!

Density

- Ratio of mass:volume.
- Its value depends on the kind of material, not the amount.
- Solids = g/cm^3
  - ✓1 cm^3 = 1 mL
- Liquids = g/mL
- Gases = g/L
- Volume of a solid can be determined by water displacement—Archimedes Principle.
- Density : solids > liquids > gases
  - ✓Except ice is less dense than liquid water!

$$Density=\frac{Mass}{Volume}$$

Density, Continued

- For equal volumes, the more dense object has a larger mass.
- For equal masses, the more dense object has a smaller volume.
- Heating objects causes objects to expand.
  - ✓This does not effect their mass!
  - ✓How would heating an object effect its density?
- In a heterogeneous mixture, the more dense object sinks.
  - ✓Why do hot air balloons rise?

Using Density in Calculations

Solution Maps:

$$\text{Density}=\frac{\text{Mass}}{\text{Volume}}$$

m, V → D

$$\text{Volume}=\frac{\text{Mass}}{\text{Density}}$$

m, D → V

$$\text{Mass} = \text{Density}\times\text{Volume}$$

V, D → m

Platinum has become a popular metal for fine jewelry. A man gives a woman an engagement ring and tells her that it is made of platinum. Noting that the ring felt a little light, the woman decides to perform a test to determine the ring's density before giving him an answer about marriage. She places the ring on a balance and finds it has a mass of 5.84 grams. She then finds that the ring displaces 0.556 cm^3 of water. Is the ring made of platinum? (Density Pt = 21.4 g/cm^3)

She places the ring on a balance and finds it has a mass of 5.84 grams. She then finds that the ring displaces 0.556 cm^3 of water. Is the ring made of platinum? (Density Pt = 21.4 g/cm^3)

Given: Mass = 5.84 grams

Volume = 0.556 cm^3

Find: Density in grams/cm^3

Equation: $\frac{m}{V}=d$

Solution Map:

m* and *V* → *d

m, V → *d*; $\frac{m}{V}=d$

She places the ring on a balance and finds it has a mass of 5.84 grams. She then finds that the ring displaces 0.556 cm^3 of water. Is the ring made of platinum? (Density Pt = 21.4 g/cm^3)

Apply the Solution Map:

m, V → *d*; $\frac{m}{V}=d$

$$\frac{m}{V}=d$$

$$\frac{5.84\text{ g}}{0.556\text{ cm}^3}=10.5\ \text{g}/\text{cm}^3$$

Since 10.5 g/cm^3 ≠ 21.4 g/cm^3, the ring cannot be platinum.

Practice—What Is the Density of Metal if a 100.0 g Sample Added to a Cylinder of Water Causes the Water Level to Rise from 25.0 mL to 37.8 mL?

Find Density of Metal if 100.0 g Displaces Water from 25.0 to 37.8 mL

1. Write down the **Given** quantity and its unit.	**Given:**	m = 100.0 g 3 sig figs displaces 25.0 to 37.8 mL
2. Write down the quantity you want to **Find** and unit.	**Find:**	d, g/cm^3
3. Write down the appropriate **Conv. Factor and Equation.**	**CF & Equation:**	1 mL = 1 cm^3 $d = \frac{m}{V}$
4. Write a **Solution Map**.	**Solution Map:**	$m, V \rightarrow d$ $d = \frac{m}{V}$
5. Follow the solution map to **Solve** the problem.	**Solution:** V = 37.8-25.0 = 12.8 mL	$12.8\,\text{mL} \times \frac{1\ \text{cm}^3}{1\ \text{mL}} = 12.8\ \text{cm}^3$ $d = \frac{100.0\ \text{g}}{12.8\ \text{cm}^3} = 7.8125\ \text{g/cm}^3$
6. Significant figures and round.	**Round:**	7.8125 g/cm^3 = 7.81 g/cm^3 3 significant figures
7. Check.	**Check:**	Units and magnitude are correct.

Density as a Conversion Factor

- Can use density as a conversion factor between mass and volume!
  - ✓Density of H_2O = 1 g/mL ∴ 1 g H_2O = 1 mL H_2O
  - ✓Density of Pb = 11.3 g/cm^3 ∴ 11.3 g Pb = 1 cm^3 Pb
- How much does 4.0 cm^3 of lead weigh?

$$4.0\ \text{cm}^3\ \text{Pb} \times \frac{11.3\ \text{g Pb}}{1\ \text{cm}^3\ \text{Pb}} = 45\ \text{g Pb}$$

Measurement and Problem Solving: Density as a Conversion Factor

- The gasoline in an automobile gas tank has a mass of 60.0 kg and a density of 0.752 g/cm^3. What is the volume?
- Given: 60.0 kg
- Find: Volume in cm^3
- Conversion factors:
  - ✓0.752 g/cm^3
  - ✓1000 grams = 1 kg

Solution Map:

kg $\xrightarrow{\frac{1000\ \text{g}}{1\ \text{kg}}}$ g $\xrightarrow{\frac{1\ \text{cm}^3}{0.752\ \text{g}}}$ cm^3

Measurement and Problem Solving: Density as a Conversion Factor, Continued

Solution Map:

kg $\xrightarrow{\frac{1000\ \text{g}}{1\ \text{kg}}}$ g $\xrightarrow{\frac{1\ \text{cm}^3}{0.752\ \text{g}}}$ cm^3

$$60.0\ \text{kg} \times \frac{1000\ \text{g}}{1\ \text{kg}} \times \frac{1\ \text{cm}^3}{0.752\ \text{g}} = 7.98 \times 10^4\ \text{cm}^3$$

Practice—What Volume Does 100.0 g of Marble Occupy? (d = 4.00 g/cm^3)

What Volume Does 100.0 g of Marble Occupy?

1. Write down the **Given** quantity and its unit.	**Given:**	m = 100.0 g 4 sig figs
2. Write down the quantity you want to **Find** and unit.	**Find:**	V, cm^3
3. Write down the appropriate **Conv. Factor and Equation.**	**CF & Equation:**	3 sig figs 4.00 g = 1 cm^3
4. Write a **Solution Map.**	**Solution Map:**	$m \xrightarrow{\frac{1\ \text{cm}^3}{4.00\ \text{g}}} V$
5. Follow the solution map to **Solve** the problem.	**Solution:**	$100.0\ \text{g} \times \frac{1\ \text{cm}^3}{4.00\ \text{g}} = 25\ \text{cm}^3$
6. Significant figures and round.	**Round:**	25 cm^3 = 25.0 cm^3 3 significant figures
7. Check.	**Check:**	Units and magnitude are correct.

Example 2.17—Density as a Conversion Factor

Example 2.17:

- A 55.9 kg person displaces 57.2 L of water when submerged in a water tank. What is the density of the person in g/cm^3?

Example:
A 55.9 kg person displaces 57.2 L of water when submerged in a water tank. What is the density of the person in g/cm^3?

- Write down the given quantity and its units.

Given: m = 55.9 kg
V = 57.2 L

Example:
A 55.9 kg person displaces 57.2 L of water when submerged in a water tank. What is the density of the person in g/cm^3?

Information
Given: m = 55.9 kg
V = 57.2 L

- Write down the quantity to find and/or its units.

Find: density, g/cm^3

Example:
A 55.9 kg person displaces 57.2 L of water when submerged in a water tank. What is the density of the person in g/cm^3?

Information:
Given: m = 55.9 kg
V = 57.2 L
Find: density, g/cm^3

- Design a solution map:

$m, V \rightarrow d$

$$d = \frac{m}{V}$$

Example:
A 55.9 kg person displaces 57.2 L of water when submerged in a water tank. What is the density of the person in g/cm^3?

Information:
Given: m = 55.9 kg
V = 57.2 L
Find: density, g/cm^3
Equation: $d = \frac{m}{V}$

- Collect needed conversion factors:
  - Mass: 1 kg = 1000 g
  - Volume: 1 mL = 0.001 L; 1 mL = 1 cm^3

Example:
A 55.9 kg person displaces 57.2 L of water when submerged in a water tank. What is the density of the person in g/cm^3?

Information:
Given: m = 55.9 kg
V = 57.2 L
Find: density, g/cm^3
Solution Map: $m,V \rightarrow D$
Equation: $d = \frac{m}{V}$
Conversion Factors: 1 kg = 1000 g
1 mL = 0.001 L
1 mL = 1 cm^3

- Write a solution map for converting the **Mass** units.

kg $\xrightarrow{\frac{1000\ \text{g}}{1\ \text{kg}}}$ g

- Write a solution map for converting the **Volume** units.

L $\xrightarrow{\frac{1\ \text{mL}}{0.001\ \text{L}}}$ mL $\xrightarrow{\frac{1\ \text{cm}^3}{1\ \text{mL}}}$ cm^3

Example:
A 55.9 kg person displaces 57.2 L of water when submerged in a water tank. What is the density of the person in g/cm^3?

Information:
Given: m = 55.9 kg
V = 57.2 L
Find: density, g/cm^3
Solution Map: $m,V \rightarrow d$
Equation: $d = \frac{m}{V}$

- Apply the solution maps.

$$55.9\ \text{kg} \times \frac{1000\ \text{g}}{1\ \text{kg}} = \text{g}$$

$= 5.59 \times 10^4$ g

Example:
A 55.9 kg person displaces 57.2 L of water when submerged in a water tank. What is the density of the person in g/cm^3?

Information:
Given: $m = 5.59 \times 10^4$ g
V = 57.2 L
Find: density, g/cm^3
Solution Map: $m,V \rightarrow d$
Equation: $d = \frac{m}{V}$

- Apply the solution maps.

$$57.2\ \text{L} \times \frac{1\ \text{mL}}{0.001\ \text{L}} \times \frac{1\ \text{cm}^3}{1\ \text{mL}} = \text{cm}^3$$

$= 5.72 \times 10^4$ cm^3

Example:
A 55.9 kg person displaces 57.2 L of water when submerged in a water tank. What is the density of the person in g/cm^3?

Information:
Given: $m = 5.59 \times 10^4$ g
$V = 5.72 \times 10^4$ cm^3
Find: density, g/cm^3
Solution Map: $m,V \rightarrow d$
Equation: $d = \frac{m}{V}$

- Apply the solution maps—equation.

$$d = \frac{m}{V} = \frac{5.59 \times 10^4 \text{ g}}{5.72 \times 10^4 \text{ cm}^3}$$

= 0.9772727 g/cm^3
= 0.977 g/cm^3

Example:
A 55.9 kg person displaces 57.2 L of water when submerged in a water tank. What is the density of the person in g/cm^3?

Information:
Given: $m = 5.59 \times 10^4$ g
$V = 5.72 \times 10^4$ cm^3
Find: density, g/cm^3
Solution Map: $m,V \rightarrow d$
Equation: $d = \frac{m}{V}$

- Check the solution:

d = 0.977 g/cm^3

The units of the answer, g/cm^3, are correct.
The magnitude of the answer makes sense.
Since the mass in kg and volume in L are very close in magnitude, the answer's magnitude should be close to 1.