CHAPTER TWO: MEASUREMENTS AND PROBLEM SOLVING

Measurements: Our Starting Point

- Why should we begin our study of chemistry with the topic of measurement?
  - Much of the laboratory work in this course is based on measurements of some type or another
  - Both laboratory and lecture material require intelligent interpretation of measurements
  - Beginning students are rarely familiar with the strict measurement methods used in chemistry

Types of Measurements

- Suppose I ask the question:
  "How far is it from Rio Hondo College to UCLA?"
- Your answer must contain <u>two</u> pieces information
  - A numerical value
  - A unit
- Examples
  - About 25 miles
  - About 45 minutes

Types of Measurements

- Length
  - Distance from one location to another
  - Distance between the "center" of one atom and one it is attached to
- Mass
  - The quantity of matter in whatever it is we are measuring
  - The more matter an object contains, the greater its mass

Mass vs. Weight

- Weight measures the gravitational attraction between an object and the Earth (or moon, Jupiter, etc.)
- Weight is *not* the same as mass!
- Example: Consider a 1-ton (2,000 pound) rock on the surface of the Earth.
  - How will its weight change if we move it to the moon? To Jupiter?
  - How will its *mass* change?

Scientific Notation

- Many measurements in chemistry involve numbers that are extremely large or small.
  - Examples:
    - Number of atoms in a glass of water.
    - Distance between two atoms in a sugar molecule.
- Scientific notation is a convenient mathematical notation which simplifies working with numbers of this magnitude.

Scientific Notation: How it Works

- Take the value under consideration, and move the decimal point after the first non-zero digit.
  - Example: 582 ⟶ 5.82
- Next, consider *how many places* the decimal was moved, and *in what direction* it was moved.
  - The decimal moved 2 places to the left.
  - Our new value is 10^2, or 100 times, smaller than it was to begin with.
- Undo this by multiplying by 10 to the power of how many places the decimal moved.
  - This power is positive if the decimal moved to the left, negative if it moved to the right
  - Our value is 5.82×10^2

Examples

Express these numbers in scientific notation.

23,894.

0.004289

0.00232

Practice—Write the Following in Scientific Notation

Tro's "Introductory Chemistry", Chapter 2

123.4	8.0012
145000	0.00234
25.25	0.0123
1.45	0.000 008706

Practice—Write the Following in Scientific Notation, Continued

Tro's "Introductory Chemistry", Chapter 2

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

Practice—Write the Following in Standard Form

2.1×10^3

4.02×10^0

9.66×10^{-4}

3.3×10^1

6.04×10^{-2}

1.2×10^0

Practice—Write the Following in Standard Form, Continued

$2.1 \times 10^3 = 2100$

$4.02 \times 10^0 = 4.02$

$9.66 \times 10^{-4} = 0.000966$

$3.3 \times 10^1 = 33$

$1.2 \times 10^0 = 1.2$

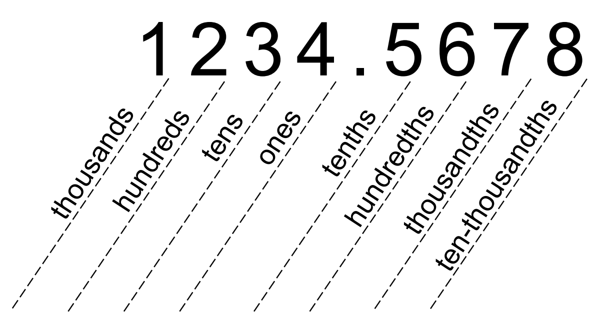
$6.04 \times 10^{-2} = 0.0604$

Certain and Uncertain Digits

- In every measurement we take, digits we are sure of are said to be <u>certain</u>.
- A digit which must be estimated is said to be <u>uncertain.</u>
- In taking a measurement, first determine which digits you know *without question.*
- Then estimate <u>exactly one</u> uncertain digit.

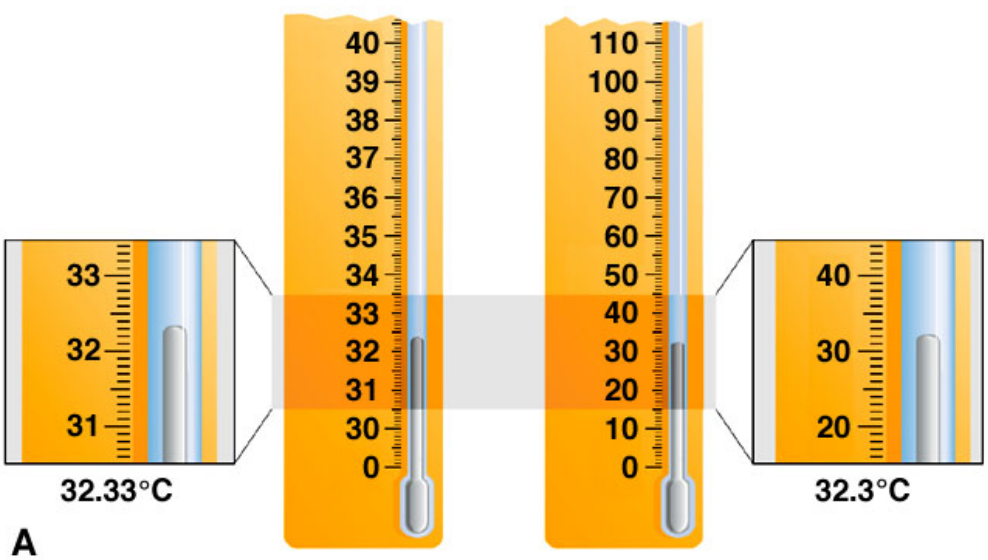
Place Value (an aside)

The digits in the number below are labeled according to their place value. You should be familiar with the names of all place values at this point.



When & Where To Estimate

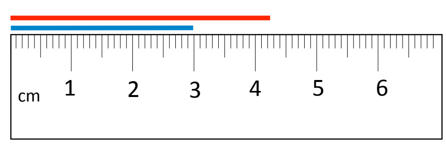
- Suppose you are taking a measurement with a ruler that has tenths (0.1) of a centimeter as its smallest markings.
  - You will estimate between the tenths mark, giving you an uncertain digit in the hundredths (0.01) place.
- Suppose you are using a thermometer which has whole degrees as its smallest markings.
  - You will estimate between each degree to the tenth of a degree.
  - Be careful not to drop the estimated digit!
    - If the thermometer is exactly at the 15 degree mark, report 15.0 degrees.



Which digits in each measurement are certain? Uncertain?

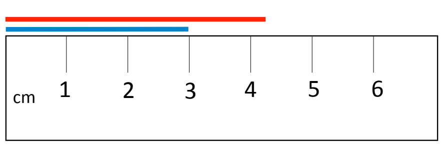
Which digits in each measurement are certain? Uncertain?

Practice with Measurements (Length)



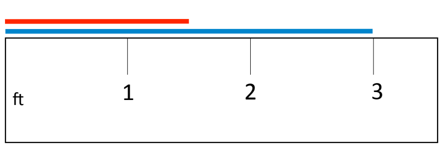
4.25 cm

3.00 cm



4.3 cm

3.0 cm

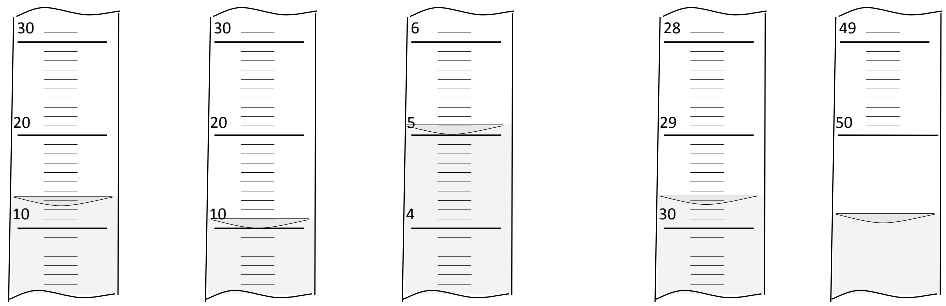


1.5 ft.

3.0 ft.

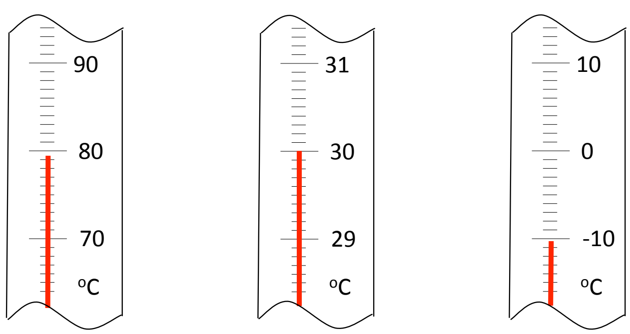
Practice with Measurements (Volume)

graduated cylinders (mL) — burets (mL)



12.5 mL — 10.0 mL — 5.00 mL — 29.75 mL — outside of measurement range

Practice with Measurements (Temperature)



79.5 °C — 30.00 °C — -10.2 °C

Certain and Uncertain Digits

- In summary, in a given measurement, digits which are unambiguous are considered as certain.
- In any measurement there is always exactly one uncertain digit which results from estimation. It is always the right-most digit.
- In general, when taking a measurement on a device which measures to a given decimal place, estimate one digit to the right of this decimal place.
  - This would not apply for most electronic devices (like digital balances), which already estimate for you.
- Question – Can you provide examples of where certainty of a measurement would be critical?

Significant Figures

- Clearly, when we take measurements, there is a limit as to how accurate our data can be.
- For example, compare your weight on a:
  - A bathroom scale
  - A truck scale
- Significant figures are those values in a measurement which we can rely on for accuracy.
- The term *significant digits* is sometimes also used, as are abbreviated terms like “sig figs” and “sig digs”

The Rules for Determining Which Digits are Significant

- Non-zero digits
  - All non-zero digits (1-9) are always significant.
  - Example: How many significant digits are there in each value below?
    48.9 7231.228
- Leading zeros are zeros to the *left* of the first non-zero digit.
  - Leading digits are not significant.
  - So, the zeros in 0.000825 and 0.0134 are not significant.
  - Why?

The Rules for Determining Which Digits are Significant

- Enclosed (*i.e.*, interior) zeros are zeros between other non-zero digits.
  - Enclosed zeros are always significant.
  - Examples of enclosed zeros:
    5,002 901.0802 101
- Trailing zeros are those zeros which come at the end (to the right) of a value.
  - Trailing zeros are significant if there is a decimal point in the value.
  - If there is no decimal, the zeros are ambiguous and generally not considered significant. Results should be represented in scientific notation. Let's consider 6,800

Practice With “Sig Digs”

How many significant digits do each of these values have?

462.0 1230 1230.

0.030900 0.0005

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

Tro's "Introductory Chemistry", Chapter 2

- 12000
- 0.0012
- 120.
- 0.00120
- 12.00
- 1201
- 1.20×10^3
- 1201000

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

- 12000 **2**
  From 11000 to 13000.
- 120. **3**
  From 119 to 121.
- 12.00 **4**
  From 11.99 to 12.01.
- 1.20×10^3 **3**
  From 1190 to 1210.
- 0.0012 **2**
  From 0.0011 to 0.0013.
- 0.00120 **3**
  From 0.00119 to 0.00121.
- 1201 **4**
  From 1200 to 1202.
- 1201000 **4**
  From 1200000 to 1202000.

Rounding

- In general, rules for rounding in chemistry do not differ from the rules you learned in earlier math courses
- Sometimes you may be asked to round to a particular place value
- Most times, you will need to round to a specific number of significant digits
- Question – In what situations could rounding be a bad thing?

Rounding

Examples:

Round 134.786 to

a. the hundredths place
b. four significant figures

Round 4,852.78 to

a. the tens place
b. two significant figures

Calculations: Multiplication & Division

- When performing multiplication and division, first count the number of significant digits in each part of the calculation.
- Then, determine which value has the least number of significant digits.
- Your answer will be rounded to that many significant figures.

Examples

$$2.5 \times 7.89 = 20.$$

$$\frac{100.}{25} = 4.0$$

Calculations:
Addition and Subtraction

- When adding or subtracting, consider the value with the *least* precision. Your answer must extend to that level of precision.
  - For example, suppose you are adding 60.82 and 7.831
    - 60.82 goes to the hundredths place
    - 7.831 extends to the thousandths place
    - Therefore, your answer will round to the hundredths place.
- VERY IMPORTANT: Note that in adding and subtracting, the number of significant figures in the values does <u>not</u> matter!

Example

$$\begin{array}{r} 5.846 \\ +\,4.23 \\ \hline 10.076 \end{array}$$

Round the answer to the hundredths place: 10.08

More Examples

23.649 – 17.2 =

8.75 + 9.414 + 105.32 =

(6.834 × 8.32) – 3.45 =

Calculations Involving Both Multiplication/Division and Addition/Subtraction

- Let's take the previous problem

(6.834 × 8.32) – 3.45 =

- Where do you begin first?
- Remember the mathematical order of operations, *i.e.*, '*Please Excuse My Dear Aunt Sally*'?
- In this case start with parenthesis and determine the sig figs.
- Then complete the remainder of the equation.
  - 6.834 x 8.32 = 56.85888 (how many sig figs?)
  - _______ - 3.45 = _______

Exact and Inexact Numbers

- Most measurements we have a certain amount of uncertainty associated with them
- A measurement with any degree of uncertainty is described as an <u>inexact number</u>
- Some numbers have no uncertainty associated with them
  - Number of eggs in a basket (countable)
  - Number of people in a room (countable)
  - Number of inches in a foot (a defined relationship)
  - Number of quarters (or pennies, nickels, or dimes) in a dollar (all are defined relationships)
- Such values are described as <u>exact numbers</u>
  - None of these values need to be estimated; they are either *countable* or *defined*

Exact Numbers and Significant Digits

- The rules regarding calculations of significant digits only apply to inexact numbers
- For example, *by definition* there are exactly 12 inches in 1 foot, never 12.001, 12.0001, etc.
  - The twelve and one in the last digit are exact numbers, so the significant figures concept does not apply to calculations involving them
- We ignore the exact numbers in determining the number of significant digits an answer can have when carrying out calculations

Calculations Involving Significant Digits

- In calculations involving the multiplication and division of numbers expressed in scientific notation, it is helpful to remember the algebraic expressions:

$$10^x \times 10^y = 10^{x+y}$$

$$\frac{10^a}{10^b} = 10^{a-b}$$

Examples

$$(6.27 \times 10^{3}) \times (9.347 \times 10^{-7}) =$$

$$\frac{2.189 \times 10^{13}}{(6.45 \times 10^{-3}) \times (9.2 \times 10^{14})} =$$

What about significant figures here?

Units of Measurement

- Units are used in measurements to tell us
  - What type of measurement we are making
    - Distance
    - Time
    - Energy
  - The general magnitude of the measurement
    - Use feet to measure a person's height
    - Use miles to measure distance between distant cities
    - Use light years to measure distance between distant galaxies.

The English System

- The English System of units includes many familiar units
  - Inches, Feet, and Miles
  - Liquid Ounces
  - Pounds and Tons
- Despite its popularity, the English System has a serious flaw

SI Units

- SI units (after "International System") are based on powers of 10
  - There are 10 millimeters in a centimeter
  - There are 10 centimeters in a decimeter
  - There are 10 decimeters in a meter.
- You only need to know what each prefix means to be able to easily convert from one unit to another.
- These prefixes are used in all types of measurements, including distance, volume, time, and energy among many others.

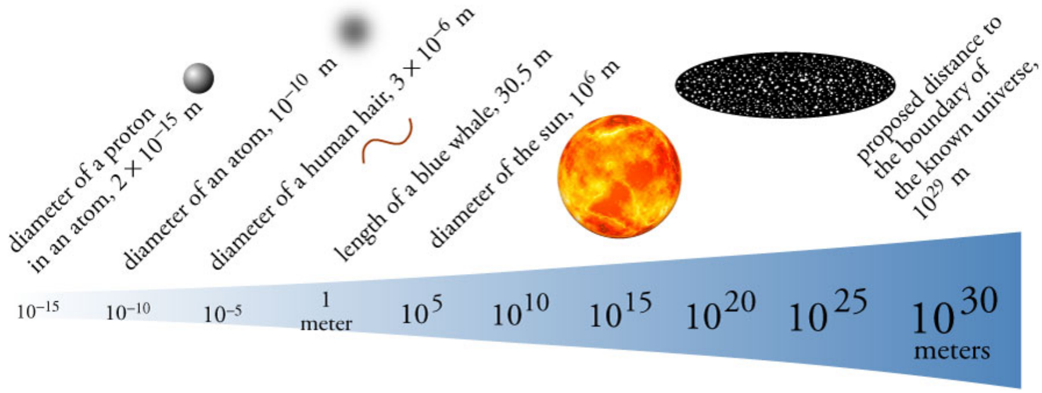
SI Units: Common Base Units

Type	Base Unit	Abbreviation
Length	Meter	m
Mass	Gram*	g
Volume	Liter	L
Energy	Joule	J
Time	Second	s
Temperature	Kelvin	K
Amount	Mole	mol

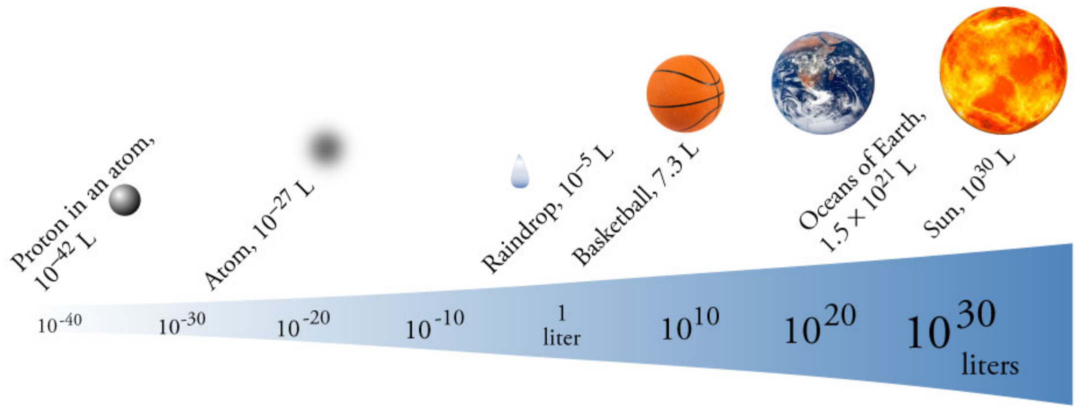
Table of Prefixes for SI Units

prefix	abbreviation*	power of 10	decimal form	word form
tera-	T	10^{12}	1,000,000,000,000	trillion
giga-	G	10^{9}	1,000,000,000	billion
mega-	M	10^{6}	1,000,000	million
kilo-	k	10^{3}	1,000	thousand
hecto-	h	10^{2}	100	hundred
deka-**	da	10^{1}	10	ten
deci-	d	10^{-1}	0.1	tenth
centi-	c	10^{-2}	0.01	hundredth
milli-	m	10^{-3}	0.001	thousandth
micro-	μ	10^{-6}	0.000001	millionth
nano-	n	10^{-9}	0.000000001	billionth
pico-	p	10^{-12}	0.000000000001	trillionth
femto-	f	10^{-15}	0.000000000000001	quadrillionth

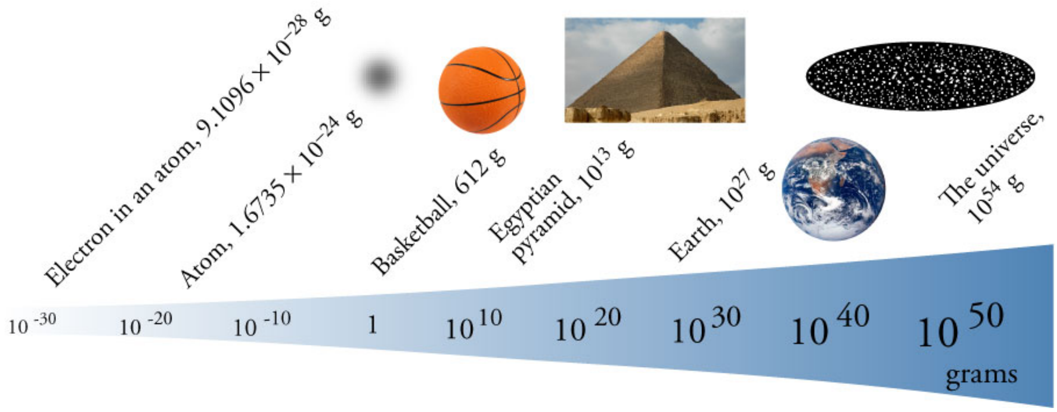
Range of Lengths



Range of Volumes



Range of Masses



Temperature

- Temperature is a measurement of the average kinetic energy of a body.
  - Kinetic Energy is the energy of motion, so the molecules in hot water are, on average, moving more rapidly than those in colder water.
  - Note, temperature is *not* the same as heat (which is measured in Joules)!

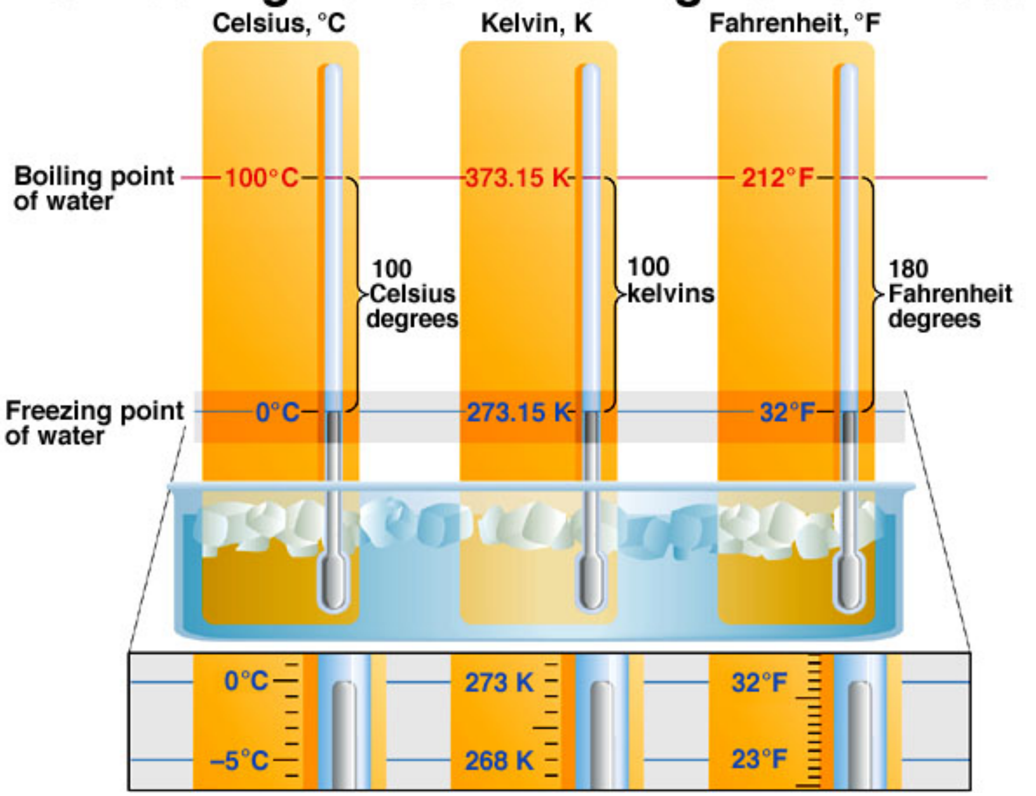
Units of Temperature

- Fahrenheit (°F)
  - Commonly used to measure temperatures in the U.S., but not very practical for scientific use.
- Celsius (°C)
  - Unit most commonly used in determining temperature in the laboratory.
- Kelvin (K)
  - The SI unit of temperature.
  - 0 K is called "absolute zero." It is impossible to for a system to have a temperature of 0 K (or lower).

The Temperature of the Freezing and Boiling Points of Water

Temperature Scale	Freezing Point	Boiling Point
°F	32	212
°C	0.00	100.00
K	273.15	373.15

The Freezing Point and Boiling Point of Water



Converting Into Different Units

- Consider the following well known equality:

  1 foot = 12 inches
- Suppose we divide both sides by 12 inches:

$$\frac{1\,\text{foot}}{12\,\text{inches}} = \frac{12\,\text{inches}}{12\,\text{inches}} = 1$$

- We know the following rule from algebra:

  1x = x

  From this we can conclude that multiplying by the first fraction is the same as multiplying by one. You are not changing the quantity!
- Also, note that units cancel out just like numbers do!

Conversion Factors

- Conversion factors are fractions which have different units in the numerator and denominators
- The value in the numerator and denominator are equivalent, so multiplying be a conversion factor does not ultimately change the value of a measurement
- For example, we can get the following conversion factors from the equation below:

12 inches = 1 foot

$$\frac{12\,\text{inches}}{1\,\text{foot}} \qquad \frac{1\,\text{foot}}{12\,\text{inches}}$$

Unit Conversions

- Consider the following problem:
  "Convert 18.5 feet to inches."
- We need a conversion factor which will cancel out feet, and leave us with inches.
  - Strategy: Divide by feet (in denominator), multiply by inches (in numerator)

$$18.5\,\cancel{\text{ft.}}\left(\frac{12\,\text{in.}}{1\,\cancel{\text{ft.}}}\right) = 222\,\text{in.}$$

Conversion Factors using SI Units

- Before attempting conversion problems using SI units it is essential that you know the power of ten which corresponds to each prefix
- You must be able to write each relationship between a prefixed unit and its base unit in two different ways
- For example, consider the following units and their conversion factors:
  - Prefixed unit: centimeters (cm)
  - Base unit: meter

1 cm = 10^{-2} m
and
10^{2} cm = 1 m

$$\frac{1\,\text{cm}}{10^{-2}\,\text{m}} \qquad \frac{10^{-2}\,\text{m}}{1\,\text{cm}}$$

$$\frac{1\,\text{m}}{10^{2}\,\text{cm}} \qquad \frac{10^{2}\,\text{cm}}{1\,\text{m}}$$

Unit Conversions

- Consider this example, using SI units:
  "How many centimeters are in 9.86 m?"

$$9.86\,\cancel{\text{m}} \times \left(\frac{1\,\text{cm}}{10^{-2}\,\cancel{\text{m}}}\right) = 986\,\text{cm}$$

Unit Conversions

- Another example using the SI system.
  "How many nanoseconds (ns) are there in 2.83 milliseconds (ms)?"

$$2.83\ \text{ms}\left(\frac{10^{-3}\ \text{s}}{1\ \text{ms}}\right)\left(\frac{1\ \text{ns}}{10^{-9}\ \text{s}}\right) = 2.83 \times 10^{6}\ \text{ns}$$

Conversion Factors Between SI and English Units

Type of Measurement	Probably Most Useful to Know	Others Useful to Know		
Length	$\frac{2.54\ \text{cm}}{1\ \text{in.}}$	$\frac{1.609\ \text{km}}{1\ \text{mi}}$	$\frac{39.37\ \text{in.}}{1\ \text{m}}$	$\frac{1.094\ \text{yd}}{1\ \text{m}}$
Mass	$\frac{453.6\ \text{g}}{1\ \text{lb}}$	$\frac{2.205\ \text{lb}}{1\ \text{kg}}$		
Volume	$\frac{3.785\ \text{L}}{1\ \text{gal}}$	$\frac{1.057\ \text{qt}}{1\ \text{L}}$		

Multiple Unit Conversions

- In many measurements, such as in this problem, there are units in both the numerator and the denominator:
  "A car is traveling at 60. miles per hour. How fast is this in centimeters per second?"

$$\frac{60\text{ miles}}{1\text{ hour}}\left(\frac{5280\text{ ft.}}{1\text{ mile}}\right)\left(\frac{12\text{ in.}}{1\text{ ft.}}\right)\left(\frac{2.54\text{ cm}}{1\text{ in.}}\right)\left(\frac{1\text{ hour}}{60\text{ min}}\right)\left(\frac{1\text{ min}}{60\text{ sec}}\right)=2682\,\frac{\text{cm}}{\text{s}}$$

$$=2.7\times10^{3}\,\frac{\text{cm}}{\text{s}}$$

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.

A Side Note…

- By now you have noticed that units can be factored (or divided out) just like numbers
- You should also note that
  - Units also can be multiplied
    2 ft × 2 ft = 4 (ft × ft) = 4 ft^2
    3 ft. × 2 lbs. = 6 ft.·lbs. (read "foot pounds")
- You can only add and subtract measurements with the <u>same</u> units!
  - Before adding and subtracting, perform any unit conversions to make the measurements have the same units (of course, they must be the same *type* of measurement!).

Area & Volume

- Translating length to area involves squaring the units as well as the values which accompany them.
- For example, what is the area of a square which is 5.0 cm on each side?
  5.0 cm × 5.0 cm = 25 cm^2
- Let's convert that to square meters:

$$25\ \text{cm}^2\left(\frac{10^{-2}\ \text{m}}{1\ \text{cm}}\right)^2 = 25\,(10^{-4}\ \text{m}^2) = 2.5\times 10^{-3}\ \text{m}^2$$

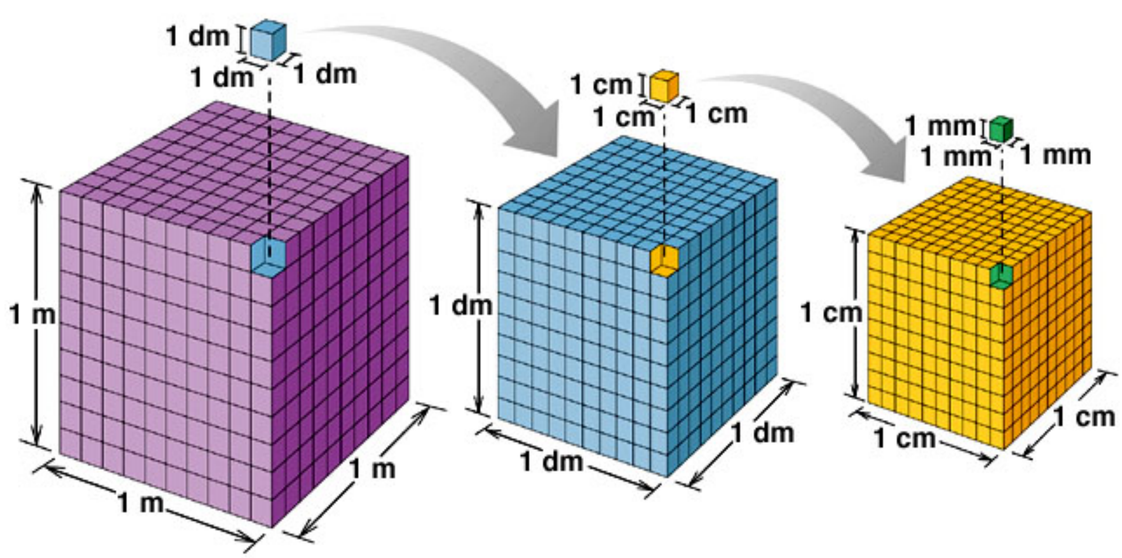
Area & Volume

- Common units of volume you should know
  - Liter(L) – the SI unit of volume
  - milliliter(mL) – another common unit
  - Cubic centimeter (cm^3 or cc) – a unit equivalent to the milliliter

$$1 \text{ mL} = 1 \text{ cm}^3 = 1 \text{ cc}$$

- Dealing with volumes involves a similar procedure to that of areas.

Some Volume Relationships in SI



A Volume Problem

A rectangular block is 14.6 in. by 7.2 in. by 6.8 in. What is its volume in cm^3?

Density

- Density (d) is the ratio between mass (m) and volume(V):

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

- Units of density for liquids are usually g/mL.
- For solids, we use the equivalent g/cm^3.
- If something has high density, then a small volume of it will have a large mass.

A Density Problem

The mass of an empty graduated cylinder is found to be 22.57 g. 7.25 mL of a liquid is added to it. The graduated cylinder and liquid have a combined mass of 30.79 g. What is the density of the liquid?

One More Density Problem

A 73.43 g cube of gold is dropped into a graduated cylinder whose volume reads 27.8 mL. After the cube sinks to the bottom, what volume reading will the graduated cylinder have? Note that gold has density 19.3 g/cm^3.

Percentages

- Many chemical calculations involve the use of percentages
- In words, percent means "for every 100 parts of the whole"
- For example, say that we have a mixture with 15% iron by mass
- We know from this that, for every 100 grams of the mixture, 15 grams of it is iron, or, as a ratio
  15 grams of iron : 100 grams of mixture
- We can generate the following conversion factor (and its reciprocal) for this example:

$$\frac{15\text{ grams of iron}}{100\text{ grams of mixture}}$$

Example

- The mineral calcite is 40.0% calcium by mass.

  a. What mass of calcium is contained in a 1.55 kg block of calcite?

  b. What is the mass of a block of calcite which contains 13.5 grams of calcium?

Converting Temperatures

- To convert between Celsius and Kelvin, use the following relationship:

$$T(\text{in K}) = T(\text{in °C}) + 273.15$$

- To convert between °C and °F, use the equation:

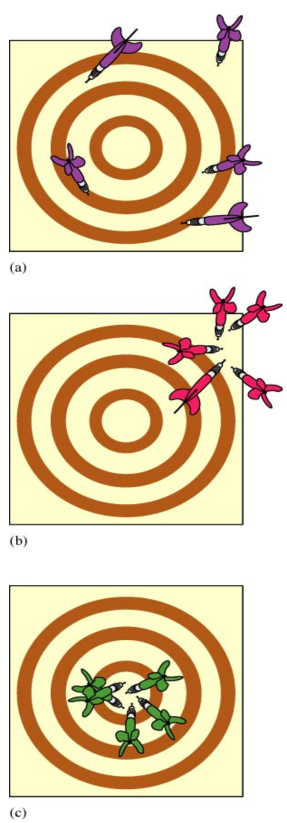
$$°\text{F} = (1.8 \times °\text{C}) + 32$$

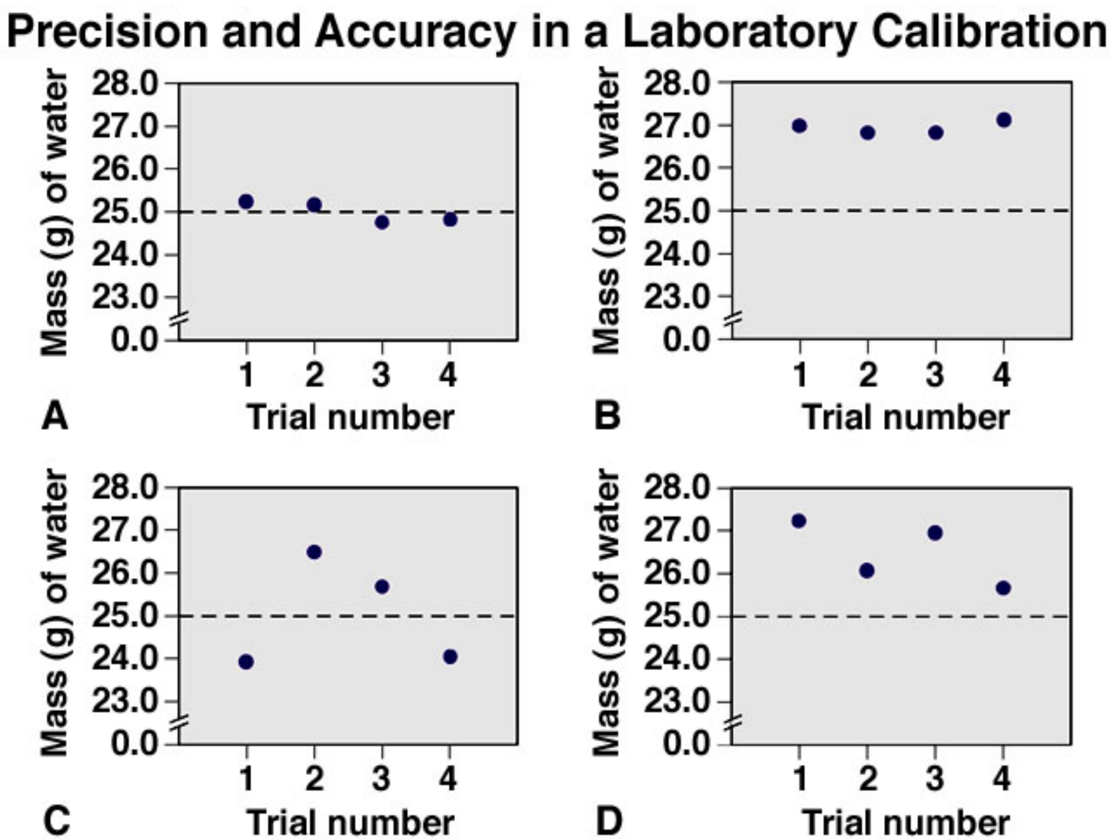
A Temperature Problem

The temperature in Paris is 23 °C. What is the equivalent temperature in Kelvin? In Fahrenheit?

Accuracy & Precision in Measurements

- If data is <u>accurate</u>, this means that the results obtained are close to the "true and correct" value(s).
- If a group of measurements give data which are close in value, these measurements are said to be <u>precise</u>.





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/cm³
3. Write down the appropriate **Conv. Factor and Equation**.	**CF & Equation:**	1 mL = 1 cm³ $d = \frac{m}{V}$
4. Write a **Solution Map**.	**Solution Map:**	*m, V* → *d* $d = \frac{m}{V}$
5. Follow the solution map to **Solve** the problem.	**Solution:** V = 37.8-25.0 = 12.8 mL	$12.8\,\text{mL} \times \frac{1\,\text{cm}^3}{1\,\text{mL}} = 12.8\,\text{cm}^3$ $d = \frac{100.0\,\text{g}}{12.8\,\text{cm}^3} = 7.8\underline{1}25\,\text{g/cm}^3$
6. Significant figures and round.	**Round:**	7.8125 g/cm³ = 7.81 g/cm³ 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/cm³ ∴ 11.3 g Pb = 1 cm³ Pb
- How much does 4.0 cm³ 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 → g → cm^3

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

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

Solution Map:

kg → g → cm^3

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

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

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:**	$m \rightarrow V$; $\frac{1\ cm^3}{4.00\ g}$
5. Follow the solution map to **Solve** the problem.	**Solution:**	$100.0\ \cancel{g} \times \frac{1\ cm^3}{4.00\ \cancel{g}} = 25\ cm^3$
6. Significant figures and round.	**Round:**	25 cm^3 = 25.0 cm^3 3 significant figures
7. Check.	**Check:**	Units and magnitude are correct.

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: $m, V \longrightarrow d$

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

Trio's "Introductory Chemistry", Chapter 2

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.

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

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

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

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 = 5.59×10^4 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.

$$57.2\,\cancel{L} \times \frac{1\,m\cancel{L}}{0.001\,\cancel{L}} \times \frac{1\,cm^3}{1\,m\cancel{L}} = cm^3$$

$= 5.72 \times 10^4$ 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 = 5.59×10^4 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.

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

$= 0.9772727\ g/cm^3$

$= 0.977\ g/cm^3$

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:

$$d = 0.977 \text{ g/cm}^3$$

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.