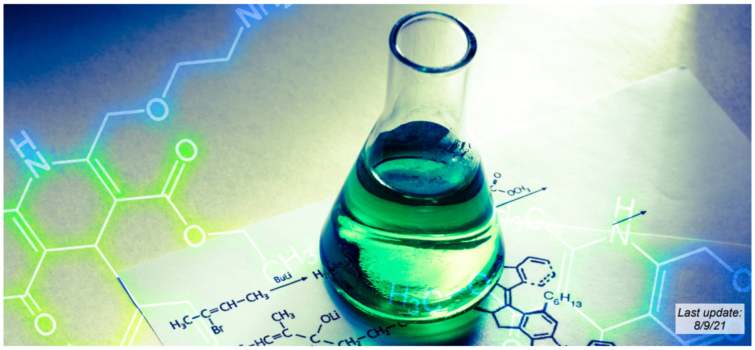
Chemistry 151: Basic Chemistry

Welcome! & Chapter 1



Welcome to Chemistry 151!

Chemistry 151 is the gateway to a successful experience in the "majors level" chemistry classes (Chemistry 221, Chemistry 222 and Chemistry 223 at Mt. Hood Community College)

CH 151 offers students the chance to acquaint themselves with chemistry, math and more before tackling the higher level (and faster paced) classes.

The *goals* of CH 151: learn chemistry, understand sig figs and dimensional analysis, explore math skills needed for chemistry, and have fun! :)

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What is Chemistry?

- "Keme" (earth)
- "Kehmeia" (transmutation)
- "Al-Khemia" (Arabic)
- "alchemy" (Europe's Dark Age)
- "chymistry" (Boyle's 1661 publication)
- "chemistry" (modern)

Khemeia - ancient Egyptian processes for embalming the dead, later extended to metallurgy

Chemistry is the study of matter and energy

Khemeia (and later chemistry) seen as "occult" by laymen, extended to modern age

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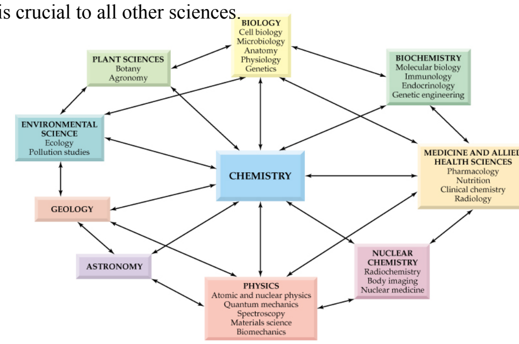
Chemistry: The Central Science

Chemistry is often referred to as "***The Central Science***" because it is crucial to all other sciences.



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The Branches of Chemistry

- **Organic - carbon, nitrogen, oxygen**
- **Inorganic - metals, everything "non-carbon"**
- **Analytical - Spectroscopy, "how much", "what kind"**
- **Physical - measurement, where physics meets chemistry**
- **Biochemical - the chemistry of life**
- **also: geochemistry, astrochemistry, radiochemistry, medicinal chemistry, etc.**

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Metric System

Scientists use the metric system to record measurements (length, mass, volume, temperature, etc.) The metric system uses prefixes which correspond to a power of ten:

COMMON METRIC PREFIXES

PREFIX	ABBREV.	MEANING	NUMERICAL VALUE	
mega-	M	one million	1,000,000	(10^6)
kilo-	k	one thousand	1,000	(10^3)
deci-	d	one tenth	0.1	(10^{-1})
centi-	c	one hundredth	0.01	(10^{-2})
milli-	m	one thousandth	0.001	(10^{-3})
micro-	μ	one millionth	0.000001	(10^{-6})
nano-	n	one billionth	0.000000001	(10^{-9})

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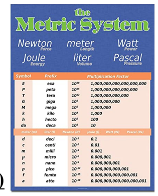
Metric System

The same prefixes are used with different types of measurements.



Length (meter, m)	Mass (gram, g)	Volume (liter, L)	Time (second, s)
megameter	megagram	megaliter	megasecond
kilometer	kilogram	kiloliter	kilosecond
decimeter	decigram	deciliter	decisecond
centimeter	centigram	centiliter	centisecond
millimeter	milligram	milliliter	millisecond
micrometer	microgram	microliter	microsecond
nanometer	nanogram	nanoliter	nanosecond

...and many more!

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Metric System

Relationships can be obtained from prefix meanings; just replace the prefix with its numerical equivalent

1 **kilo**meter = **1000** meters *(kilo = 10^3 or 1000)*

1 **deci**meter = **0.1** meters *(deci = 10^{-1} or 0.1)*

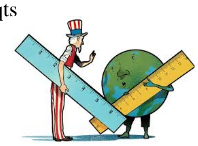
1 **centi**meter = **0.01** meters (*centi = 10^{-2} or 0.01 - note that this is equivalent to saying* **100 cm = 1 meter**)

MA

Metric System

Common "Bridges" Between English and Metric Systems

QUANTITY	BRIDGE
Length	2.54 cm = 1.00 in
	1.61 km = 1.00 mile
Mass	454 g = 1.00 lb
Volume	1.00 L = 1.06 qts



Try to use the metric system at all times!

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Physical Quantities

Measurable physical properties such as height, volume, and temperature are called ***Physical quantity***. A number and a unit of defined size is required to describe physical quantity.

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Physical Quantities

A number alone doesn't say much!

Say an average textbook weighs 1.

The question would then be asked 1 what? 1 pound? 1 kilogram? 1 ounce?

You have to mention the unit of mass *along with the number* for the statement to be meaningful.

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Physical Quantities

Physical quantities measured using many different units. Mass can be measured in pounds, kilograms, ounces, etc.

To avoid confusion, scientists around the world have agreed to use a set of standard units known as the ***International System of Units*** or ***SI units*** for some common physical quantities.

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SI Units

In **SI Units**,

- mass measured in kilograms (kg)
- length measured in meters (m)
- volume measured in cubic meters (m^3)
- time measured in seconds (s).

Many other units derived from SI units.

- speed measured in meters per second (m/s)
- density measured in grams per cubic centimeter (g/cm^3).

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Measuring Mass

Mass is a measure of amount of matter in an object.

Weight is a measure of gravitational pull on an object.

At the same location, two objects with *identical masses* have *identical weights* (gravity pulls them equally).

Thus masses of objects determined by comparing the weight of the object to the weight of a known reference.

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Measuring Length

The Meter (m) is the standard measure of length or distance in both SI and metric system. One meter is 39.37 inches.

Centimeter (cm; $^1/_{100}$ m) and millimeter (mm; $^1/_{1000}$ m) commonly used for most measurements in chemistry and medicine.

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Measuring Volume

Volume is the amount of space occupied by an object.

SI unit for volume is the cubic meter (m^3)

Liter (L) is commonly used in chemistry.

1 L = 0.001 m^3 = 1000 mL

A milliliter is often called a cubic centimeter

1 mL = 1 cm^3

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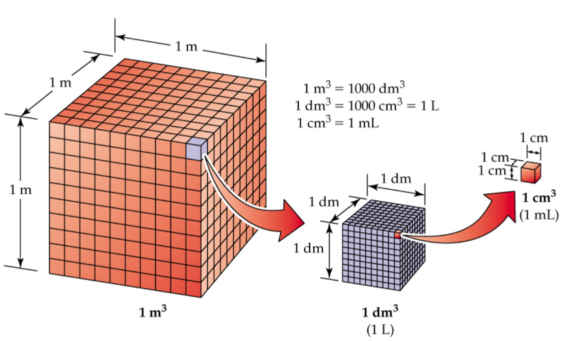

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Scientific Notation

Scientific notation used by scientists to express very large and very small numbers in a compact fashion.

To express a number in scientific notation we rewrite the quantity as a number (between 1 and 9) multiplied by 10 raised to a power (exponent) that tells us how we moved the decimal point.

- Multiply the number by 10^0. (*Remember* $10^0 = 1$)
- Move the decimal point to give a number between 1 and 10.
- Every time we shift the decimal point to the left by one place we increase the value of the exponent by one.
- Every time we shift the decimal point to the right by one place we reduce the value of the exponent by one.

$215. = 2.15 \times 10^2$

Decimal point is moved two places to the left, so exponent is 2.

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Scientific Notation

Example: Write 120,000 in scientific notation.

$120{,}000 = 120{,}000 \times 10^0 = 1.2 \times 10^5$

Example: Write 0.0000012 in scientific notation.

$0.0000012 = 0.0000012 \times 10^0 = 1.2 \times 10^{-6}$

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Scientific Notation

To express a scientific notation number as a non-exponential "regular" number:

- Move the decimal point the same number of places as the value of the exponent and eliminate the exponential part of the number.
- If the exponent is positive, we move the decimal to the right, to the same number of places as the value of the exponent. (The result should be a number greater than 1.)
- If the exponent is negative, we move the decimal to the left, to the same number of places as the value of the exponent. (The result should be a number less than 1.)

$1.56 \times 10^{-8} = 0.000\,000\,015\,6$

Negative exponent of –8,
so decimal point is moved to the left eight places.

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Scientific Notation

Example: Write 1.23×10^6 in non-exponential form.

$1.23 \times 10^6 = 1{,}230{,}000$

Example: Write 1.11×10^{-5} in non-exponential form.

$1.11 \times 10^{-5} = 0.0000111$

Remember: If we make the exponent larger we must make the number part smaller, and if we make the exponent smaller we must make the number part larger.

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Calculations Using Scientific Notation on Your Calculator

Let's see how you are at using your calculators. Try the following and don't forget about cancelling units where appropriate. Record your answers in scientific notation, rounded to one digit past the decimal. (**Rounding rule: 5 or bigger, round up.**)

1. $(1.5 \times 10^5\ in^2)(1.2 \times 10^{-2}\ in)$ = ?

   (It saves time to use your exponent button. EE, exp, 10^x)

   1.5EE5x1.2EE(-)2 [Enter] = 1800 in^3 = $1.8 \times 10^3\ in^3$ *1800 exact*

2. 4.3×10^5 ft / 5.1×10^{-6} ft = ? (try this yourself!)

   = 8.4×10^{10} *8.43137.... E10*

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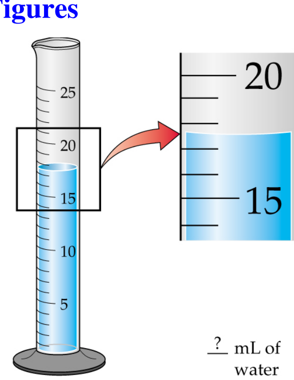
Measurement and Significant Figures

Every experimental measurement, no matter how precise, has a degree of uncertainty because there is a limit to the number of digits that can be determined.



? mL of water

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Measurement and Significant Figures

To indicate the precision of the measurement, the value recorded should use all the digits known with certainty *plus* one additional estimated digit ("doubtful digit") that usually is considered *uncertain* by plus or minus 1 (± 1)

The total number of digits used to express such a measurement is called the number of ***significant figures***.

Example: The quantity 65.07 g has four significant figures and 7 is the "doubtful digit"

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Measurement and Significant Figures

Uncertain digit

54.07 g

A mass between 54.06 g and 54.08 g (±0.01 g)

Uncertain digit

54.071 38 g

A mass between 54.071 37 g and 54.071 39 g (±0.000 01 g)

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Rules for Determining Significant Figures

1. Zeroes in the middle of a number are significant. 69.08 g has four significant figures, 6, 9, 0, and 8.
2. Zeroes at the beginning of a number are not significant. 0.0089 g has two significant figure, 8 and 9.
3. Zeroes at the end of a number and after the decimal points are significant. 2.50 g has three significant figures 2, 5, and 0. 25.00 m has four significant figures 2, 5, 0, and 0.

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Significant Figures often abbreviated as "sig figs"

Rules for Determining Significant Figures

4. Zeroes at the end of a number and before an implied decimal points may or may not be significant. 1500 kg may have two, three, or four significant figures. Zeroes here may be part of the measurements or for simply to locate the unwritten decimal point.

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Test Yourself: How Many Significant Figures?

94.072 g
0.0834 cm
0.02907 mL
138.200 m
23,000 kg

23,000. kg

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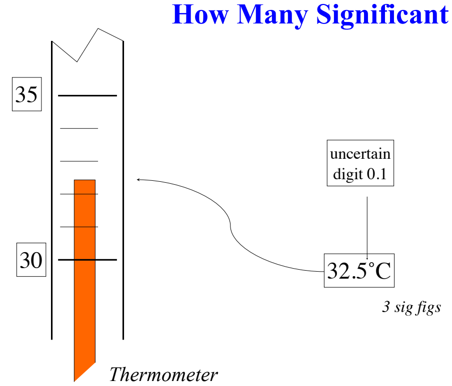
How Many Significant Figures?



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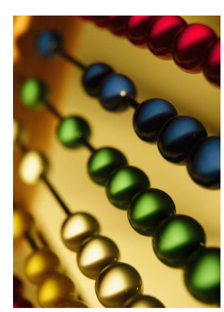
Rounding off Numbers

Often calculators produce large numbers as a result of a calculation *although* the number of significant figures is good only to a few numbers, less than the calculator has produced

In this case the large number may be rounded off to a smaller number *keeping only significant figures*.



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Rules for Rounding off Numbers

Rule 1 (For multiplication and divisions): The answer can't have more significant figures than either of the original numbers.

$$\frac{278 \text{ mi}}{11.70 \text{ gal}} = 23.8 \text{ mi/gal}$$

Three significant figures (278 mi)

Four significant figures (11.70 gal)

Three significant figures (23.8 mi/gal)

23.76068....

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Rules for Rounding off Numbers

Rule 2 (For addition and subtraction): The number can't have more digits after the decimal point than either of the original numbers.

Volume of water at start →	3.18? ?? L	← Two digits after decimal point
Volume of water addded →	+ 0.013 15 L	← Five digits after decimal point
Total volume of water →	3.19? ?? L	← Two digits after decimal point

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Rules for Rounding off Numbers

Rule 3: Once you decide how many numbers to keep, you *may* need to round off your answer:

If the first digit you remove is between 0 and 4, drop it and all remaining digits.

If the first digit you remove is between 5 and 9, round the number up by adding 1 to the digit to the left of the one you drop

Example: **2.4271** becomes **2.4** when rounded to two significant figures

Example: **4.5816** becomes **4.6** when rounded to two significant figures

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Factor-Label Method of Unit Conversions

Quantities measured in the lab usually have **units (labels)** which tell us the type of measurement made.

For example:

5.2 cm - the unit (cm) tells us the type of measurement made is length.
16.237 g - the unit (g) tells us the type of measurement made is mass.

Often we must convert one kind of unit for a measurement to a different kind. For example, we may need to convert 28 inches into a certain number of feet. The **factor-label** method (also known as the *dimensional analysis* method) uses **conversion factors** and units (**labels**) to solve problems of this type.

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Factor-Label Method of Unit Conversions

Conversion factors are fractions that relate two kinds of units. One way in which they may be obtained is from equalities.

For example: 12 in = 1 ft is an equality which leads to two equivalent fractions (conversion factors) generated by dividing one side of the equality by the other side.

$$\frac{12 \text{ in}}{1 \text{ ft}} \qquad \frac{1 \text{ ft}}{12 \text{ in}}$$

Another common conversion factor: there are 4 quarters in a dollar ($):

$$\frac{4 \text{ quarters}}{1 \text{ \$}} \qquad \frac{1 \text{ \$}}{4 \text{ quarters}}$$

And:

$$\frac{1 \text{ km}}{0.6214 \text{ mi}} \quad \text{or} \quad \frac{0.6214 \text{ mi}}{1 \text{ km}}$$

These two quantities are the same.

These two quantities are the same.

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Factor-Label Method of Unit Conversions

And yet another common example:

60 min = 1 hr is an equality which leads to two equivalent conversion factors.

$$\frac{60 \text{ min}}{1 \text{ hr}} \qquad \frac{1 \text{ hr}}{60 \text{ min}}$$

Other forms : $\frac{60 \text{ min}}{\text{per hr}}$ = 60 min/hr = $\frac{60 \text{ min}}{1 \text{ hr}}$

When you are new to the factor-label method, it is most helpful to use the form that has a numerator and denominator term (and not 60 min/hr)

Some conversion factors are considered *exact* and have *unlimited sig figs,* but most conversion factors obey sig fig rules.

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When solving a problem, set up an equation so that *all unwanted units cancel*, leaving only the desired unit. *For example*, we want to find out how many kilometers are there in 26.22 miles. We will get the correct answer if we multiply 26.22 mi by the conversion factor km/mi.

$$26.22 \not{mi} \times \frac{1 \text{ km}}{0.6214 \not{mi}} = 42.20 \text{ km}$$

42.195043....

Starting quantity (26.22 mi) — Conversion factor (1 km / 0.6214 mi) — Equivalent quantity (42.20 km)

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Some Exact Conversions

Length
1 km = 1000 m = 10^5 cm = 10^{12} nm
12 in = 1 ft 5280 ft =1 mile
1 in = 2.54 cm

Volume
1 cm^3 = 1 mL 1000 mL = 1 L

Mass
1 g = 1000 mg 1 kg = 1000 g

These conversions have ***unlimited*** sig figs by definition.
Most other conversions inexact… and follow sig fig rules!

MAR

Test yourself: How many hours in 3.5 weeks?

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Test yourself: How many quarters will a tourist need to travel 555 km? Car: 22 miles per gallon, gas: $1.37/gallon, 1.61 km = 1 mile

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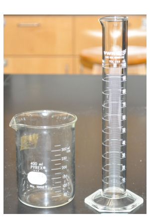
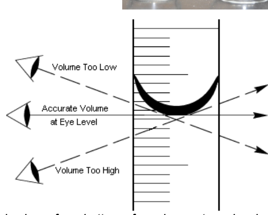
How do we measure the volume of a liquid?

volumetric flasks

Beaker (left), graduated cylinder (right)





read volume from bottom of meniscus at eye level

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Density

Density relates the mass of an object with its volume.
Density is usually expressed in:

- Gram per cubic centimeter (g/cm^3) (solids)
- Gram per milliliter (g/mL) (liquids)

$$\text{Density} = \frac{\text{Mass (g)}}{\text{Volume (mL or cm}^3\text{)}}$$

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Test yourself: Mercury has a density of 13.6 g/mL. How many L of Hg are there in 42.7 kg of Hg?

MAR

Measuring Temperature

Temperature, the measure of how hot or cold an object is, is commonly reported either in Fahrenheit (^{o}F) or Celsius (^{o}C). The SI unit of temperature is, however, the Kelvin (K).

Kelvin temperatures are ***always positive*** and they do not use the degree (^{o}) symbol.

Kelvin used in calculations, Celsius in the lab.

Temperature in K = Temperature in ^{o}C + 273.15

Temperature in ^{o}C = Temperature in K - 273.15

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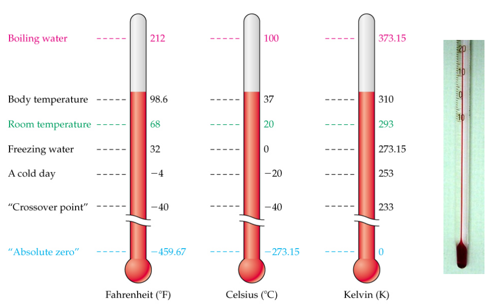

Comparison of the Fahrenheit, Celsius, and Kelvin Scales

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Converting between Fahrenheit and Celsius scales is similar to converting between different units of length or volume.

The following formulas can be used for the conversion:

^{o}F = 1.8 x ^{o}C + 32 ^{o}F

^{o}C = (^{o}F – 32 ^{o}F) / 1.8

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Test yourself: Mars often has temperatures around -70. °C. Express this in K and °F.

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End of Chapter 1