<u>Chemistry</u>
Basic Science Concepts

Chemistry: the study of matter.

Matter: anything that has mass and occupies space.

Observations: are recorded using the senses. Examples: the paper is white; the air is cold; the drink is sweet.

Instruments: are devices that increase detail or enhance the senses when an observation is made. Examples: A thermometer can determine the temperature of water more accurately than a human finger; a ruler can determine the length of an object better than just looking at it. There are many instruments used to measure things in science. These include graduated cylinders (for volume), rulers (for length), balances (for mass), and thermometers (for temperature). There are many more.

Inference: is an interpretation based on observations. Example: You may infer that the grass died because of a lack of rain.

Prediction: is the use of observations and records to foretell future events. Example: Meteorologists predict the weather based on observations from weather instruments and past occurrences.

Accuracy: describes how close a measurement is to the true value.
Example: If a rock is known to have a mass of 15.0 kilograms and a balance measures the rock's mass as 15.0 kilograms the measurement is considered accurate. If the balance measured the rock's mass as 10.0 kilograms the measurement would be considered inaccurate.

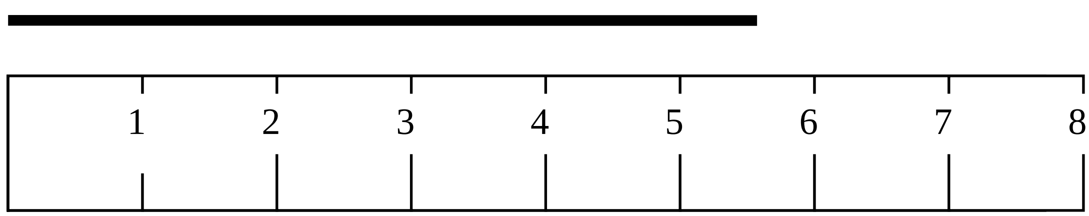
Precision: describes how close a series of measurements are to each other.
Example: If a table with a known length of 1.5 meters was measured 3 times with a ruler resulting in the following measurements: 1.2, 1.2, and 1.2. The ruler would be considered precise because all 3 measurements were close to each other. **However:** The ruler would be considered inaccurate because the measurements were not close to the known value.

Uncertainty in Measurement

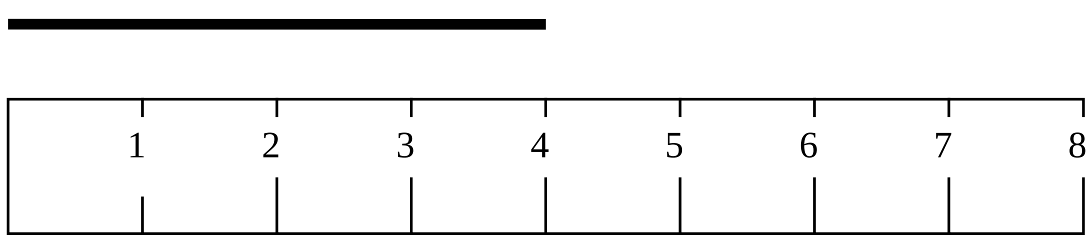
It is an important concept in chemistry that all measurements contain some uncertainty. Such data is reported in significant figures to inform the reader of the uncertainty of the measurement. Significant figures are also known as significant digits. When these measured values are used in calculations, it is vital that the answers are not misleading, and therefore, rules for addition, subtraction, multiplication, and division should be followed.

Recording Measurements

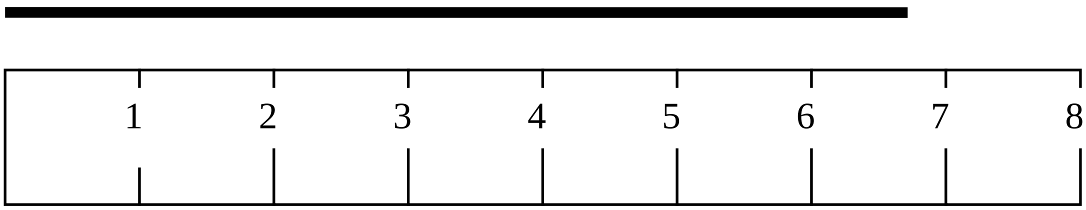
Since all measurements are only as good as the measuring device there must be a way to properly record measurements. The rule is simple! **Record all known values plus one estimated value.** This results in **significant digits** also known as **significant figures**. Significant digits are used to express the reliability of a measurement.
Example: If the following line were measured with the accompanying ruler the measurement could be: 5.6, 5.5 or 5.7. **Why?** Because the line is definitely as long as 5 units but less than 6 units. The last digit is an estimate open to the interpretation of the person recording the measurement.



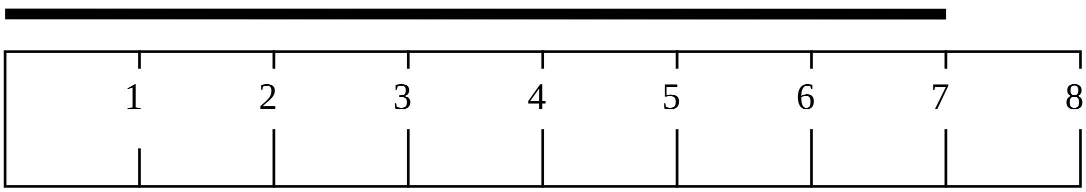
If the line is directly on a measuring increment you will add a zero to the measurement. Example: How long is the following line? 4.0 **Why?** Because the line appears to be exactly 4 increments long but is open to interpretation by the person making the measurement.



Measure the line below. _______________



Measure the line below. ______________________



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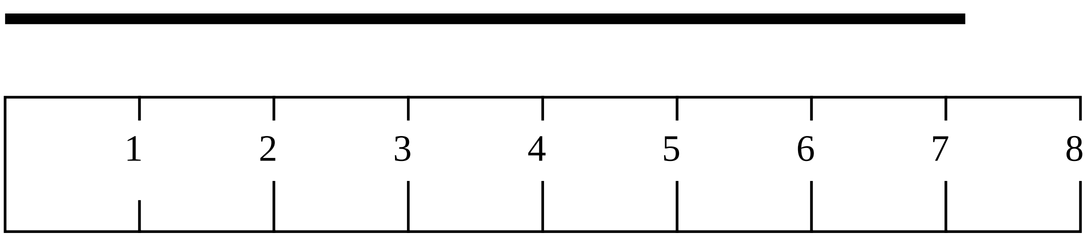
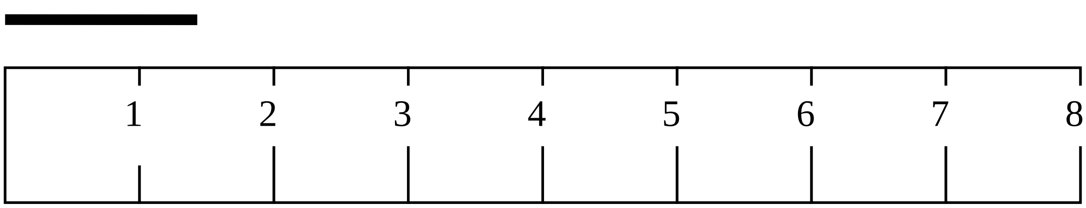


Measure the line below. _________________



Determining the number of significant digits in a measured value is important because it is needed to properly express accuracy and round the answers from calculations involving *division or multiplication*.

Method for counting significant figures in a measured number.

1. All numbers either have or don't have a decimal. Determine if the number has a decimal.

If the number contains a decimal the digits will be counted from left to right. →

Memory helper! A decimal looks like a period in a sentence. A sentence is read from left to right.

If the number does not contain a decimal the digits will be counted in the opposite direction, from right to left. ←

2. Count all digits beginning with the first nonzero number and count all numbers including zeros until the end.

Examples: Determine the number of significant digits in the following numbers.

a) 100.0 This number has a decimal, therefore; digits will be counted from left to right beginning with the first nonzero number. Answer: **4** significant digits.

b) 53.5 This number has a decimal, therefore; digits will be counted from left to right beginning with the first nonzero number. Answer: **3** significant digits.

c) .0005 This number has a decimal, therefore; digits will be counted from left to right beginning with the first nonzero number. Answer: **1** significant digit.

d) .0051500 This number has a decimal, therefore; digits will be counted from left to right beginning with the first nonzero number. Answer: **5** significant digits.

e) 515 This number does not have decimal, therefore; digits will be counted from right to left beginning with the first nonzero number. Answer: **3** significant digits.

f) 5050 This number does not have decimal, therefore; digits will be counted from right to left beginning with the first nonzero number. Answer: **3** significant digits.

g) 1001000 This number does not have decimal, therefore; digits will be counted from right to left beginning with the first nonzero number. Answer: **4** significant digits.

h) 100000000000 This number does not have decimal, therefore; digits will be counted from right to left beginning with the first nonzero number.
Answer: **1** significant digit.

Determine the number of **significant digits** in the following.

a) 743.1

b) 2000

c) 33.335

d) 5056

e) 222980

f) .000345

g) 1000000000000000000000

h) 100001

i) 4.3001

j) 735.0010

k) .000000017

l) 34.7

m) 34.70

n) 34.700

o) 37400

Rounding for Multiplication or Division

Rule: Round the answer to have as many **significant digits** as the factor with the least number of significant digits. Exact numbers such as counted numbers (5 chickens), conversion factors (12 inches in a foot), or constants (gravity 9.8 m/s^2) are considered to have an infinite number of significant digits and are not a limiting factor.

Example: Correctly round the following: 5.53 X 10.31

Procedure:

1. Determine the number of significant figures of each factor. 5.53 has **3** and 10.31 has **4**. Obviously, 3 significant figures are less than 4 significant figures.
2. Put the numbers in the calculator as they appear (don't round yet).
3. Observe the number that appears in the window of the calculator. For this example it is 57.0143. Our answer must only have 3 significant figures. It is rounded to 57.0

Remember from 4th grade! The first number that gets cut off determines if the number rounds up or down. A number below 5 rounds down, a number above 5 and above rounds up.

Example: Correctly round the following: 25.73 ÷ 1.21

Procedure:

1. Determine the number of significant figures of each factor. 25.73 has **4** and 1.21 has **3**. Obviously, 3 significant figures are less than 4 significant figures.
2. Put the numbers in the calculator as they appear (don't round yet).
3. Observe the number that appears in the window of the calculator. For this example it is 21.2644628. Our answer must only have 3 significant figures. It is rounded to 21.3

Remember from 4th grade! The first number that gets cut off determines if the number rounds up or down. A number below 5 rounds down, a number above 5 and above rounds up.

Correctly round the following. Follow rules for significant figures!

a) 33.005 X 10.3134

b) 67.66 ÷ 4.21

c) 109.87 ÷ 22.6

d) 56.6578 X 23.459

e) 7 ÷ 3

f) 33.234 ÷ 101

Rounding for Addition or Subtraction

Rounding for *addition or subtraction* is based on the number of occupied decimal places not significant figures.
Rule: Round the answer to have as many occupied decimal places as the item, which has the least.
Example: Correctly round the following problems.

40.8451	this number has 4 occupied decimal places
+ 300.2	this number has 1 occupied decimal place. Obviously, 1 is less than 4
341.0451	this number must be rounded to 1 decimal place

341.0 final rounded answer

Remember from 4th grade! The first number that gets cut off determines if the number rounds up or down. A number below 5 rounds down; a number above 5 rounds up.

Example:

600034.89	2 occupied decimal places
- 56.567	3 occupied decimal places
599978.323	answer is rounded to 2 occupied decimal places

599978.32 final rounded answer

Complete the following problems.

a) 23.54 - 5.67

b) 45.0 - 56.98

c) 819.1 -45.673

d) 678.982 + 34.75

e) 12.4 + 39.10005

f) 99.9972 - 52.78

g) .0012 - .000

PERCENT ERROR

Students often assume that each measurement made in the laboratory is true and accurate. Likewise, they often assume that the values that they record through experimentation are very accurate. However, equipment limitations or human error often prevent students from being as accurate as they would like. **Percent error calculations** are used to determine how close to the true values, or how accurate, their experimental measured values really are.

The value that the student records is usually called the **measured value**, or the **experimental value**. A value that can be found in a reference table or textbook is usually called the **accepted value**, or the **true value**. The **percent error** can be determined when the **accepted value** is compared to the **measured value** according to the equation below:

$$\textbf{Percent Error} = \frac{\textbf{Measured Value - Accepted Value}}{\textbf{Accepted Value}} \times 100\%$$

Let's look at an example of how the formula would be used in a real-life situation.

Ex. 1 A student measures the mass and volume of a piece of copper in the laboratory and uses the data to calculate the density of the metal. According to his results, the copper has a density of 8.37 g/cm^3. Curious about the accuracy of the results, the student consults a reference table and finds that the accepted value for the density of copper is 8.92 g/cm^3. What would be the student's percent error?

Solution:

Step 1 Determine which values are known.

The students result, or the measured value = 8.37 g/cm^3.

The accepted, or true value = 8.92 g/cm^3.

Step 2 Substitute these values in the percent error calculation, as shown below:

$$\textbf{Percent Error} = \frac{\textbf{Measured Value - Accepted Value}}{\textbf{Accepted Value}} \times 100\%$$

$$\textbf{Percent Error} = \frac{(8.37\ g/cm^3 - 8.92\ g/cm^3)}{8.92\ g/cm^3} \times 100\%$$

Step 3 Solve for the unknown, and round to correct significant digits.

Percent Error = - 6.17%

Please note! The negative sign does not mean that the error was less than zero, which would be impossible. It shows that the student's calculated value was actually too low.

Practice Percent Error Calculations   Show All Work

$$\textbf{Percent Error} = \frac{\textbf{Measured Value - Accepted Value}}{\textbf{Accepted Value}} \times 100\%$$

1. Working in the laboratory, a student found the density of a piece of pure aluminum to be 2.85 g/cm^3. The accepted value for the density of aluminum is 2.699 g/cm^3.

   What is the student's percent error?

2. A student experimentally determines the specific heat of water to be 4.29 J/g x ^oC. He then looks up the specific heat of water on a reference table and finds that is 4.18 J/g x ^oC.

   What is the percent error?

3. A student uses a lab balance to find the mass of an object with an accepted mass of 200.000 grams. The student records the mass of the object as 196.500 g.

What is the percent error?

Density

Density describes the amount of mass per unit volume. Another way to describe density is “compactness”. Substances such as lead or gold have high densities since a small volume has a high mass. A substance such as Styrofoam has a low density since a large volume will have a little mass. Density is a physical property that depends on the nature of the material itself. For example: the density of granite is the same whether the granite is a pebble or a boulder. All matter whether; solid, liquid, or gas has a density. In this chemistry class the units of density are grams per cubic centimeter, represented as g/cm^3.

The formula to determine density is: $d = \frac{m}{V}$

d = density   If any 2 values are known the 3rd value can be calculated.

m = mass

V = volume

Example:
Determine the density of an object if its mass is 50.0g and its volume is $12.5cm^3$

Solution: Substitute the given information into the density formula.

$d = \frac{50.0g}{12.5cm3}$ Answer: $d = 4.00g/cm^3$

Example:
Determine the mass of $40.0\ cm^3$ of material if its density is $8.00g/cm^3$

Solution: Substitute the given information into the density formula. $d = \frac{m}{V}$

$8.00g/cm^3 = \frac{m}{40.0cm3}$ Cross multiplying will solve for m

Any number can be changed into a fraction by dividing it by 1.

$\frac{8.00g/cm3}{1} = \frac{m}{40.0cm3}$ Answer: m = 320g

Example:
Determine the volume of 150.000g of lead if its density is $11.350 g/cm^3$

Solution: Insert the given information into the density formula. $d = \frac{m}{V}$

$11.350 g/cm^3 = \frac{150.000g}{V}$ Cross-multiplying and dividing will solve for V

Any number can be changed into a fraction by dividing it by 1.

$\frac{11.350g/cm3}{1} = \frac{150.000g}{V}$ Cross multiply $11.350 g/cm^3 V = 150.000g$

Divide $V = \frac{150.000g}{11.350g/cm3}$ Answer: $V = 13.216 cm^3$

Practice density problems: **ShowAll Work**

1. Determine the density of an object if its mass is 130.0g and its volume is $10.5cm^3$.

2. Determine the mass of 80.0 cm^3 of material if its density is $16.00g/cm^3$.

3. Determine the volume of 150.000g of silver if its density is $10.500g/cm^3$.

Metric System

Measuring is a central concept in science. To say something has a length of 1 is meaningless. Is it 1 foot, 1 mile, 1 meter, 1 millimeter? All measured quantities must include a unit. The units of science are **SI** units. We will refer to these units as **metric units**. Many people are more familiar with the English System. The English System uses units such as pounds for weight, feet for length, and gallons for volume. The metric system uses grams for weight, meters for length, and liters for volume. There are 2 main advantages for using the metric system. One advantage is that the metric system is used **worldwide**. Another advantage is that the metric system is based **on prefixes indicating factors of ten, making the math of conversions easier**.

List 2 advantages of using the metric system.

1.

2.

Metric Units

Symbol	**Name**	**Quantity**
m	meter	length
kg	kilogram	mass
Pa	pascal	pressure
K	kelvin	temperature
mol	mole	amount of substance
J	joule	energy, work, or heat
s	second	time
L	liter	volume
ppm	parts per million	concentration
M	molarity	solution concentration

Metric Prefixes

Factor	**Prefix**	**Symbol**
10^3	kilo-	k
10^{-1}	deci-	d
10^{-2}	centi-	cm
10^{-3}	milli-	m
10^{-6}	micro-	u
10^{-9}	nano-	n
10^{-12}	pico-	p

Examples:

kilo $10^3 = 1000$

centi $10^{-2} = .01$ or $\frac{1}{100}$

milli $10^{-3} = .001$ or $\frac{1}{1000}$

Combining a metric prefix with a metric unit results in units such as:

Kilometer – 1000 meters

Centimeter - $\frac{1}{100}$ or .01 meter

Millimeter - $\frac{1}{1000}$ or .001 meter

Conversions

In chemistry it is often necessary to convert from one metric prefix to another.
Example: 2.7 liters is equal to how many milliliters?

1. You must know the relationship between the prefixes to be converted.
2. Use a ratio.

1000 mL = 1 L $\frac{x}{1000mL} = \frac{2.7L}{1L}$

3. Cross-multiply to solve: x = 2700 mL.

Convert the following.

1. 753mm = ___________cm

2. 55cm = ___________m

3. 1.3 km = ____________cm

4. 45.3 mg = ___________g

5. 1.89g = ___________mg

6. 2.34L = ___________mL

7. 1409.3 mL = ___________L

Scientific Notation is a method used to express very large or very small numbers. Chemistry students are expected to know scientific notation already but here is a reminder.

Numbers such as .000000078 or 6.0200000000000000000000
are difficult to read or express in words.
Scientific notation is useful for these types of numbers.

Scientific notation takes the following form: $\mathbf{M} \text{ X } \mathbf{10^n}$

M stands for mantissa. It is a number between 1 and 10.

n is the exponent that can be +,-, or 0.

Examples:

Number	**Sci notation**
100	$1 \text{ X } 10^{2}$
1000	$1 \text{ X } 10^{3}$
1500	$1.5 \text{ X } 10^{3}$
.01	$1 \text{ X } 10^{-2}$
.0053	$5.3 \text{ X } 10^{-3}$
.000000078	$7.8 \text{ X } 10^{-8}$
6.0200000000000000000000	$6.02 \text{ X } 10^{23}$

Complete the following:

Number	Sci notation
1. 110	______________
2. ______________	1.51×10^{3}
3. 12000	______________
4. .00017	______________
5. ______________	4.53×10^{-6}
6. .009	______________
7. 175000	______________
8. ______________	3.5×10^{2}
9. ______________	1.21×10^{-3}
10. .0093	______________