Measuring Underlies Significant Figures

Human-built Instruments Always have Error

At the most basic level, chemistry (indeed all of science) depends upon experimentation; experimentation in turn requires numerical measurements. And measurements are always taken from instruments made by other human beings.

Some information about measurements:

1) Examples we will study include the metric ruler, the thermometer, the graduated cylinder, and the triple-beam balance.

2) Because of the involvement of human beings, NO measurement is exact; some error is always involved. This means that every answer in science has some uncertainty associated with it. We might be fairly confident we have the correct answer, but we can never be 100% certain we have the EXACT correct answer.

3) Measurements always have two parts - a numerical part (sometimes called a factor) and a dimension (sometimes called a label or a unit). The reason for this is that we are measuring quantities - length, elapsed time, temperature, mass, etc. Not only do we have to tell how much there is, but we have to tell how much of what.

In a mathematics class, units are inconsistently used. This is because much of mathematics discusses the relationships between pure numbers, not the use of a number which describes an amount of something. Many ChemTeam students have the unfortunate tendancy to see units are unnecessary. THEY ARE NOT.

Measuring gives significance (or meaning) to each digit in the number produced. This concept of significance, of what is and what is not significant is VERY IMPORTANT. Especially the "what is not" portion. Pay close attention to the examples presented. The concept of significant figures (or significant digits) is important and will play a role in almost every unit studied by the ChemTeam.

A measurement can be defined as the comparison of the dimensions of an object to some standard.

The dimensions of an object refer to some property the object possesses. Examples include mass, length, area, density, and electrical charge. Dimensions are often called units.

For example, the meter is the standard unit of length in science. It was first defined as one ten-millionth of the distance from the equator to the pole. Then, a standard meter was made out of a platnium-iridium alloy and kept in a carefully controlled environment in Paris. The third definition was the distance of a certain number of wave crests of a certain wavelength in the emission spectrum of krypton. The most recent definition of the meter is the length of the path travelled by light in a vacuum during a time interval of 1/299,792,458 of a second.

We will just use a ruler, thank you very much!

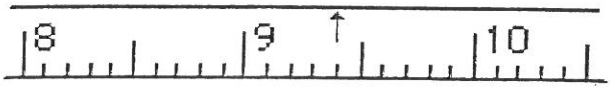
Correct answer = 4.50 cm. The arrow is pointing directly at the mark and is neither to the left nor to the right of it. At ast, according to the ChemTeam.

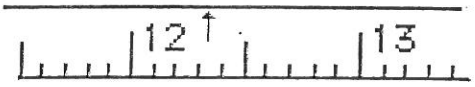
Notice that whatever the smallest division in your scale is, you can always estimate to the next decimal place after. In this case, the smallest division is in the tenth place, so we can estimate to the 0.01 place.

Be aware that there is some error, some uncertainity in the last digit of 4.50. While one should make an effort to estimate as carefully as possible, there is still some room for error.

The rule about uncertain digits is that there can be one and only one estimated or uncertain digit in a measurement. It is always the last digit in the measurement.

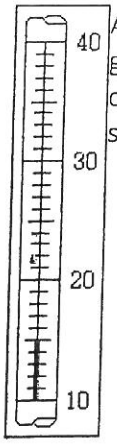
Here are two more examples of centimeter rulers. Decide what length is being shown, and record your answer.

Example #3: 

Example #4: 

Celsius thermometers used in high school typically have a scale with only whole numbers marked on the scale. The gap between each whole number does not have any register marks for tenths.

Example #1:

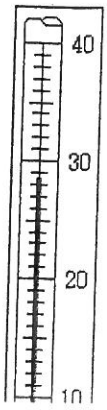


Answer = 15.0 °C. Since the line stops exactly on the 15 line and DOES NOT go any farther, we estimate that it has gone zero-tenths of the way from 15 to 16. We are allowed to include the tenth degree value and have it be considered significant. Remember that when you use thermometers in chemistry experiments. Many ChemTeam students have left off the 'point zero' and get deducted for it.

Example #2:

The indicated temperature is 28.5 °C.

Remember to mentally divide up the gap between 28 and 29, then make your best estimate of how many tenths are covered by the mark.



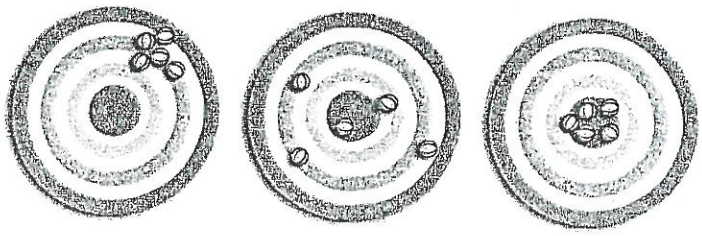
5) 101.0100 ____ 10) 2,370.0 ____

11) Why are significant figures important when taking data in the laboratory?

12) Why are significant figures NOT important when solving problems in your math class?

13) Using two different instruments, I measured the length of my foot to be 27 centimeters and 27.00 centimeters. Explain the difference between these two measurements.

Accuracy and Precision:



1. Determine the accuracy and precision represented by each group of darts in the figures above.

	Figure 1	Figure 2	Figure 3
Precision?			
Accuracy?			

2. A basketball player throws 100 free-throws; 95 of these balls go through the goal; 5 miss the goal entirely. Describe the precision and accuracy of the free-throws.

3. The same player is having an off day; 5 balls go through the goal; the other 95 balls bounce off of the rim. Describe the precision and accuracy of the throws.

Name : _____ Score : _____

Scientific Notation

Example: 1

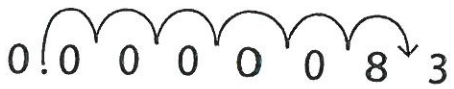
Write 514, 223 in scientific notation.

We should move the decimal point 5 places to the left. So, the exponent will be 5.

$514,223 = \mathbf{5.14223 \times 10^{5}}$

Example: 2

Write 0.0000083 in scientific notation.



We should move the decimal point 6 places to the right. So, the exponent will be -6.

$0.0000083 = \mathbf{8.3 \times 10^{-6}}$

Express each number in scientific notation.

1) 18, 451, 000 = _____

2) 0.000004826 = _____

3) 5, 820, 000, 000, 000 = _____

4) 0.000000007269 = _____

5) 350, 100, 000, 000, 000 = _____

6) 0.00000000000014 = _____

7) 71, 300, 000 = _____

8) 0.00000002164 = _____

9) 30, 000, 000, 000, 000 = _____

10) 0.0000642 = _____

METRICS AND MEASUREMENT

Name _____

In the chemistry classroom and lab, the metric system of measurement is used, so it is important to be able to convert from one unit to another.

mega	kilo	hecto	deca
(M)	(k)	(h)	(da)
1,000,000	1000	100	10
10^6	10^3	10^2	10^1

Basic Unit
gram (g)
liter (L)
meter (m)

deci	centi	milli	micro
(d)	(c)	(m)	(μ)
.1	.01	.001	.000001
10^{-1}	10^{-2}	10^{-3}	10^{-6}

Factor Label Method

1. Write the given number and unit.
2. Set up a conversion factor (fraction used to convert one unit to another).
   a. Place the given unit as denominator of conversion factor.
   b. Place desired unit as numerator.
   c. Place a "1" in front of the larger unit.
   d. Determine the number of smaller units needed to make "1" of the larger unit.
3. Cancel units. Solve the problem.

Example 1: 55 mm = _____ m

$$\frac{55 \text{ mm}}{1000 \text{ mm}} \left| \frac{1 \text{ m}}{} \right. = 0.055 \text{ m}$$

Example 2: 88 km = _____ m

$$\frac{88 \text{ km}}{1 \text{ km}} \left| \frac{1000 \text{ m}}{} \right. = 88{,}000 \text{ m}$$

Example 3: 7000 cm = _____ hm

$$\frac{7000 \text{ cm}}{100 \text{ cm}} \left| \frac{1 \text{ m}}{100 \text{ m}} \right| \frac{1 \text{ hm}}{} = 0.7 \text{ hm}$$

Example 4: 8 daL = _____ dL

$$\frac{8 \text{ daL}}{1 \text{ daL}} \left| \frac{10 \text{ L}}{1 \text{ L}} \right| \frac{10 \text{ dL}}{} = 800 \text{ dL}$$

The factor label method can be used to solve virtually any problem including changes in units. It is especially useful in making complex conversions dealing with concentrations and derived units.

Convert the following.

1. 35 mL = _____ dL
2. 950 g = _____ kg
3. 275 mm = _____ cm
4. 1,000 L = _____ kL
5. 1,000 mL = _____ L
6. 4,500 mg = _____ g
7. 25 cm = _____ mm
8. 0.005 kg = _____ dag
9. 0.075 m = _____ cm
10. 15 g = _____ mg

Name_____

Density Practice Problem Worksheet

1) A block of aluminum occupies a volume of 15.0 mL and weighs 40.5 g. What is its density?

2) Mercury metal is poured into a graduated cylinder that holds exactly 22.5 mL. The mercury used to fill the cylinder weighs 306.0 g. From this information, calculate the density of mercury.

3) What is the weight of the ethyl alcohol that exactly fills a 200.0 mL container? The density of ethyl alcohol is 0.789 g/mL.

4) A rectangular block of copper metal weighs 1896 g. The dimensions of the block are 8.4 cm by 5.5 cm by 4.6 cm. From this data, what is the density of copper?

5) A flask that weighs 345.8 g is filled with 225 mL of carbon tetrachloride. The weight of the flask and carbon tetrachloride is found to be 703.55 g. From this information, calculate the density of carbon tetrachloride.

6) Calculate the density of sulfuric acid if 35.4 mL of the acid weighs 65.14 g.

7) Find the mass of 250.0 mL of benzene. The density of benzene is 0.8765 g/mL.

8) A block of lead has dimensions of 4.50 cm by 5.20 cm by 6.00 cm. The block weighs 1587 g. From this information, calculate the density of lead.

9) 28.5 g of iron shot is added to a graduated cylinder containing 45.50 mL of water. The water level rises to the 49.10 mL mark, from this information, calculate the density of iron.

10) What volume of silver metal will weigh exactly 2500.0 g. The density of silver is 10.5 g/cm3.