Honors Chemistry   Chapter 2 Measurements and Calculations

Section 1 pg. 29-32   Scientific Method

Objectives:

1. **Describe the purpose of the scientific method**
2. **Distinguish between qualitative and quantitative observations.**
3. **Describe the differences between hypothesis, theories, and models.**

Vocabulary: Define the following here.

1. **scientific method--**

2. **system--**

3. **hypothesis--**

4. **model--**

5. **theory--**

The scientific method is a series of steps that attempt to answer questions about the world we live in. There may be many steps included in the scientific method. In general these steps can be summarized as:

1. Observing and Collecting Data.

Observations may be quantitative and qualitative.

What is a quantitative observation?

Answer:

What is a qualitative observation?

Answer:

2. Formulating Hypotheses.

Look at fig. 2 pg. 30 in your text. Is this valid hypothesis?

Answer:

What can you predict what the data for a 75% phosphorus addition would do?
Answer:

3. Testing Hypotheses. All experiments performed with the scientific method contain a <u>variable</u> (may be a group) and a <u>control</u> (may also be a group).
Both groups are exposed to the same set of conditions. The variable is one factor which is changed and is the only difference from the control group.
If there is a difference between the groups at the end of an experiment then one can be sure that the difference is caused by the variable which has been changed.
4. Theorizing
5. Publishing Results.
See pg. 31 in your text.
Models are used often in science. Models may be visual, verbal, or mathematical. Give an example of a model from your textbook.
<u>Answer</u>:

Which of the following are quantitative observations and which are qualitative?

1. **Water boils at 100ºC.**

2. **Oil floats on water.**

3. **23 zebras**

4. **A red rose.**

<u>Section 2 Pgs. 33-43 Units of Measurement</u>

<u>Objectives:</u>

1. **Distinguish between a quantity, a unit, and a measurement standard.**
2. **Name and use SI units for length, mass, time, volume, and density.**
3. **Distinguish between mass and weight.**
4. **Perform density calculations.**
5. **Transform a statement of equality into a conversion factor.**

<u>Vocabulary</u>: Define the following here.

1. **quantity--**

2. SI--

3. weight--

4. derived unit--

5. volume--

6. density--

7. conversion factor--

8. dimensional analysis--

The Metric System

The metric system is used in science. Today the metric system is called the International System of Units (SI). There are seven base units listed on pg. 34. *****Memorize the first five.

Other common units are derived units. Students sometimes confuse base units with derived units since these units are often mixed together.
As the name indicates derived units come from base units. Know the difference between the two.

Consider the following problem. A student fills a hollow cube with water. The sides measure 10 cm on a side.
What is the volume?

What is the cube's surface area?

Note:* *Always show all your work in chemistry when solving any mathematical problems. Answers without work will not receive credit.

As you can see the surface area and volume were derived from the base unit of length. Surface area and volume are therefore derived units.
In general the most common measurements used in chemistry are: length, mass, volume, density, mole, temperature, and time. Which of these are base units and which of these are derived units?
Answer:
Base Units:

Derived Units:

The three most common units of measure used in the SI system are length, mass, and volume.
Length
The unit of length is the meter, (m); a base unit.
Mass
The unit of mass is the kilogram, (kg); a base unit.
Volume
The unit of volume is the cubic meter, (m^3); a derived unit. Note: most texts use the liter as the unit of volume, which was the case in the early metric system, but was later revised in the SI system to m^3.

While length is a fairly obvious unit of measure that needs no explanation, mass and volume need some further explanation which follows.

Mass and Weight

Many students believe the basic unit of mass is the gram when it is actually the kilogram. The explanation is that in relationship to other common measures the gram is too small. To achieve some relative size relationship the kilogram is used instead.
Mass is the actual amount of material in an object. The amount of material is the number of atoms. As an object is moved from place to place the number of atoms remains constant; its mass does not change.
Weight on the other hand is a measure of how strongly the object is pulled by g-ravity. Weight changes with its location.
Answer the following.
An object with a mass of 500 kg at sea level is moved first to a high mountain and then to a valley below sea level.
Has the mass changed?

Has the weight changed, and if so how did it change?

Volume

Volume is the amount of space an object occupies. Volume is derived from length by the formula: V = l x w x h.
Though volume's bases unit in the SI system is m^3, the liter is more commonly used because it is more practical. Memorize the following conversions.
********* $1{,}000cm^3$ = 1,000cc = 1,000mL = 1 liter**
1,000 liters = 1 cubic meter (m^3)

Metric Prefixes

The common metric prefixes are found on pg. 35, Table 2 in your text.
Though you will encounter all of these prefixes in this course of study and should be familiar with <u>all</u> of these, the most important four are kilo, deci, centi, and milli. Three other less used prefixes are micro, nano, and pico.
A simple method that can be used to convert one metric unit to another is based on a number line. In this method each number represents a power of 10 (this means to move the decimal place once for each power, either left or right). If the given measurement is smaller than the requested measurement move the decimal left. If the given measurement is larger than the requested measurement move the decimal to the right or more simply stated:

<u>small to large go left</u>
<u>large to small go right</u>
Number line method.

pico	nano	micro	milli	centi	deci	*base	kilo
-12	-9	-6	-3	-2	-1	0	+3

***The base means the one of the major words meter, gram, liter, seconds, etc. Refer to Appendix A p. 828 and p.13.**

Example 1
Change 52.1 micrograms to picograms.
The difference in positive numbers between micro and pico is 6. Since micro is larger than pico (-6 larger than -12) move the decimal place 6 places to the right.
Answer: 52.1 micrograms = 52,100,000 picograms.
Example 2
Change 23.54 centimeters to kilometers.
The difference between centi and kilo in positive numbers is 5, (centi is -2 and kilo is +3)
Since centi is smaller than kilo move the decimal place 5 places to the left.
Answer: 23.54 centimeters = 0.0002354 kilometers
Refer to Appendix A p. 828 and p.13.

Now try the following!

1. **62 centimeters (cm) to meters (m)_________**
2. **152 meters to kilometers (km)_________________**
3. **26 millimeters (mm) to centimeters _________________**
4. **4623 picograms (pg) to nanograms (ng) ______________**
5. **57 cubic centimeters (cm^3) to milliliters (mL)______________**
6. **2.5 millimeters to micrometers (um)________________**
7. **0.7562 milligrams (mg) to grams (g)_________________**
8. **0.00273 kilograms (kg) to centigrams (cg) _________________**
9. **0.032 m^3 to liters ___________________**
10. **65 s to nanoseconds ___________________________**

Density

Density is the ratio of one measurement divided by a measurement of length, area, or volume? In a physical science such as chemistry, the density of an object is determined by dividing the mass of an object by its volume or stated by the equation; D = m/V.

Density is usually expressed in grams/cm^3 or g/mL, (Remember: 1.0 cm^3 = 1.0 mL).

Problems: Always show your work!

1. **What is the density of an object with a volume of 8.0 cm^3 and a mass of 2.0 grams?**

2. **What is the volume of iron when given a mass of 5.00 grams and a density of 7.86 g/mL?**

3. What is the mass of aluminum given a volume of 25.6 mL and a density of 2.70 g/mL?

Conversion Factors

Conversion factors are ratios obtained from an equality between two different units, for instance 1 foot = 12 inches.
When using metric conversions you may use either the number line method or dimensional analysis. However for conversions other than metric you must use dimensional analysis.

Dimensional Analysis (Factor-Label Method)

Dimensional analysis is a means of changing one measurement into another measurement when conversion factors are known. Conversion factors are found in your textbook on pg. 35 and pg.854 Appendix A at the back of your book and the conversion handout given in class.**Know where to find these conversion factors!**
Dimensional analysis depends most importantly on the units of measure given, such as seconds, meters, cm^3, etc. Dimensional analysis depends entirely on the ability to cancel these types of identical units of measure.
Look at the following conversion factor.

60 seconds = 1 minute

Since this is a conversion factor it can be written as follows.

$$\frac{60 \text{ seconds}}{1 \text{ minute}} \quad \text{or} \quad \frac{1 \text{ minute}}{60 \text{ seconds}}$$

This is allowed because both forms have the same meaning as 60 seconds = 1 minute. It is this fractional form that allows cancellation of units.
Consider the following:
Change 120 seconds to minutes.
The problem gives a starting unit of measure and the ending unit of measure required. The starting unit of measure always has a number associated with it. The ending unit of measure does not have a number. The first step would appear as follows.

$$120 \ \underline{\text{seconds}} \quad = \quad \underline{\text{minutes}}$$

Since these are to be written in fractional form we can add a 1 in the denominator so that the solution now appears as

$$\frac{120 \text{ seconds}}{1} \quad = \quad \frac{\text{minutes}}{1}$$

Every entry from here on must be a known conversion factor which cancels a unit of measure. The solution appears as

$$\frac{120 \text{ seconds}}{1} \times \frac{1 \text{ minute}}{60 \text{ seconds}} = \frac{2 \text{ minutes}}{1}$$

Cancellation of like labels only can be from top to bottom. If the same measure appears top to top or bottom to bottom simply flip it so that the cancellation is correct. For instance the following is incorrect, because seconds and seconds are both on the top.

$$\frac{120 \text{ seconds}}{1} \times \frac{60 \text{ seconds}}{1 \text{ minute}} = XX \quad \frac{\text{minutes}}{1}$$

Notice that once the cancellation of the identical measures (second to second) is complete the measure of minute on the left side f the equation is the same as minute on the right side. When these measures are the same the mathematical operations can be performed, which is 120 divided by 60 equals 2.

Sample Problem #2
Change 2.75 meters to centimeters.

$$\frac{2.75 \text{ meters}}{1} \times \frac{100 \text{ centimeters}}{1 \text{ meter}} = \frac{275 \text{ centimeters}}{1}$$

Refer to conversion handout to answer the following. Show all work!!!

1. Change 1,250. seconds to hours.

2. Change 52 millimeters to kilometers.

3. Change 68.4 centimeters to inches.

4. Change 572.6 centimeters to miles.

Notice all of these conversions were in the same category, such as time to time or length to length. You cannot change time to length because there are no conversions for this.

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To demonstrate that dimensional analysis is a valuable tool that will supply a correct answer even when working with unfamiliar measurements or values try the following.

3 Dodos = 7 Turkeys
4 Turkeys = 5 Nerds
9 Nerds = 11 Bozos

Change 9 Dodos to Bozos. Show all work!!!!!

Answer ________________________.

A problem can be solved in which there is more than one category of measurement such as a rate problem which includes a distance over time, ex. 65 miles/hour. Each category must be converted into its compliment before the second category is converted. This process can be completed on the same line as follows.

Sample Problem:

A snail moves at the rate of 1.5 mm per second. What is its rate in meters per minute?

Step1:

$$\frac{1.5\text{mm}}{\text{s}} = \frac{\text{meters}}{\text{min}}$$

Step 2:

Your choice; you may either change mm to meters or seconds to minutes. (Remember you must complete the conversion of one value before you change the second value). Let's do mm to meters first.

$$\frac{1.5\text{ mm}}{\text{s}} \times \frac{1\text{ m}}{1{,}000\text{ mm}} = \frac{\text{meters}}{\text{min}}$$

If the problem was ended here the answer would be in meters/s, which was not asked for. Let's continue the solving process.

Step 3: This step converts the second measurement on the same line.

$$\frac{1.5\ \text{mm}}{\text{s}} \times \frac{1\ \text{m}}{1{,}000\ \text{mm}} \times \frac{60\ \text{s}}{1\ \text{min}} = \frac{\text{meters}}{\text{min}}$$

After all of the labels have been cancelled, the only labels on the left side that remain should be the same as those on the right side. When they match the math portion can now be performed.

1) (Multiply the numbers in the numerator) 1.5 x 1 x 60 = 90

2) (Multiply the numbers in the denominator) 1 x 1000 x 1 = 1000

3) (Divide the numerator by the denominator $\frac{90}{1000}$ **= .090**

The completed problem is:

$$\frac{1.5\ \text{mm}}{\text{s}} \times \frac{1\ \text{m}}{1000\ \text{mm}} \times \frac{60\ \text{s}}{1\ \text{min}} = \frac{0.090\ \text{m}}{\text{min}}$$

Try the following. You must show all work.

1. Change 52.7 centimeters per minute to inches per hour.

2. Change 2.02 meters per hour to centimeters per year. (Use 365 days/yr)

3. Change 120. mL per hour to liters per day.

Try using dimensional analysis in the following word problem.

Sammy the snail slimes along at a rate of 1.5 mm per second. How many meters does Sammy travel in a day? Show all work.

Section 3 pgs. 44-57 Using Scientific Measurements

Objectives:

1. **Distinguish between accuracy and precision.**
2. **Determine the number of significant figures in measurements.**
3. **Perform mathematical operations involving significant figures.**
4. **Convert measurements into scientific notation.**
5. **Distinguish between inversely and directly proportional relationships.**

Vocabulary: Define the following here.

1. **accuracy--**

2. **precision--**

3. **percentage error--**

4. **significant figures (digits)--**

5. **scientific notation--**

6. **directly proportional--**

7. **inversely proportional--**

Uncertainty in Measurement

All measurements are uncertain because of flaws in the instruments and because all measurements have estimations of the last unit. In a digital display instrument as well as non-digital instruments, the last number is the estimated number.

Reliability

Reliability includes two terms; accuracy and precision.

<u>Precision</u> means that a number of measurements are very close to each other. If the measures are about the same, the measurements are highly precise. For example a student obtains the following four measurements of the width of a table: 2.51 cm, 2.52cm, 2.53cm, and 2.52cm. These measurements would be considered precise.
<u>Accuracy</u> is obtained by comparing the measurements to some standard. A high accuracy is one that is close to some accepted (standard) value. For instance the density aluminum is 2.70 g/cm^3. If a student obtained a density of 2.69 g/cm^3, a decision must be made as to whether this is accurate or not.
See pg. 44 Figure 8 in your text for a very good example using a dart board showing accuracy and precision.

Percents and Percent Error

<u>Percent</u>

<u>Never</u> leave your answer as a fraction. This is <u>always</u> considered an incomplete response. In science you should always express your answer as a decimal. Why?
Answer

If your answer is a fraction divide the bottom into the top to obtain the decimal equivalent and if asked for a percent, multiply the decimal by 100,
or simply move the decimal place two places to the right.
For example 1/4 becomes 0.25 or 25%.

<u>Percent Error</u>

To find a percent error use the following formula.

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

As an example of percent error refer back in your notes the example concerning accuracy. In that example the student obtained a value of
2.69 g/cm^3 as the density of aluminum whereas the accepted value from tables is 2.70 g/cm^3.
What is the percent error?

Answer _________.

Your textbook states that one may obtain a negative percent error, however, most textbooks (other than yours) usually prevent this by taking the absolute value of the answer to make the answer always positive. Thus the value $|-25\%| = 25\%$.

In general a 3% percent error or less is acceptable. Anything greater than this indicates that there is something incorrect with the measurement or the procedure used to obtain the measurement.

Consider the following:

A student tosses a penny 10 times and obtains 3 heads and 7 tails. The student predicted 50% heads and 50% tails.

What was the percent error? Answer ____________.

What does this type of error tell the student? Answer ____________.

How might the percent error obtained, lead the student to change the procedure? Answer ______________.

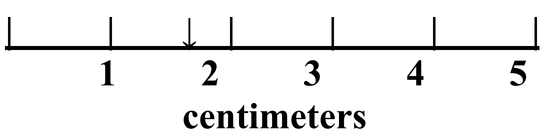
Significant Digits or Significant Figures

There is uncertainty in any measurement due to flaws in the instrument and flaws in estimation (human error). When many measurements, each with its own uncertainties, are combined it poses a dilemma as to what measurements are acceptable and to what extent are they acceptable.

Significant digits attempt to bring some order to these uncertainties.

All measurements have certain digits and an uncertain digit. The uncertain digit is the last digit of the measurement, which is always estimated.

Example



What is the measurement at the arrow? Answer: _______

Could your estimate of the last digit be different than someone else? Answer: ____

Are you certain that the object is at least 1 centimeter long? Answer: ______

One measurement might be 1.7 cm.

Which is the certain digit? Answer: ____

Which is the estimated digit? Answer: _____

The certain digit(s) and the estimated digit are the significant digits of a measurement.

Examples

48.6 g, 11.2 milliliters, and 151 s. All of these measurements have three significant digits; two certain digits and the last digit which is always an estimate.

Rules for Significant Digits

All numbers other than zero are significant.

Zeros may or may not be significant depending on their location and the presence or absence of a decimal point.

For instance, look at the measurements of 250 centimeters and 250. centimeters. One measurement has a decimal point and the other does not. Both measurements

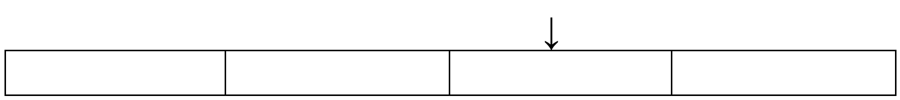
appear to be the same but one of the two measurements is more reliable. To scientists significant digits tell the reader what each division on the instrument is measured in. In the previous example, the 1.7 cm tells the reader that the ruler was marked in whole centimeters and the .7 was estimated because it was between measured lines. Tenths of centimeters were not given and had to be estimated. The measurement of 250 cm tells the reader that the object being measured is probably around 250 cm, but it could be 240 cm or 260 cm. The instrument was marked every 100 centimeters with no units of ten given. The <u>five</u> of the 250 was the estimate.

The measurement of 250. tells the reader that the instrument in this case was measured in tens as indicated by the use of the decimal. The decimal point tells the reader that the <u>zero</u> was the estimate and is significant.

This is how these two measures might have looked.

Ruler A

Measurement of 250 cm



0 100 200 300

Centimeters

Measurement of 250. cm

Ruler B

↓

┴ I I I II I I I II I I I II I I I II I I I II I I I II I I I II I I I II

0 100 200 300

Centimeters

Which instrument was more accurate?

Answer: ____

What is the smallest unit of measure in each?

Ruler A _______ Ruler B _______

The ± value is the value a person estimates. For instance if the instrument is marked in units then the estimate is in tenths and the ± is tenths or ± 0.1

What is the ± estimate in Ruler A? Answer: ______

What is the ± estimate in Ruler B? Answer: ______

Example: 7.8 mL the ± is 0.1, meaning the reading could be 7.7 mL or 7.9mL.

<u>Atlantic-Pacific Rule</u>

This rule helps to explain whether zeros are significant digits or not.
The Pacific Ocean is on the left side of the United States; the Atlantic Ocean is on the right side of the United States. The letter "p" in Pacific is taken to mean a decimal point is present. If a decimal is present count from the left until a digit other than zero is reached. Zeros before this digit are not significant. All digits, including zeros, after this digit are significant. If there is no decimal point in the measurement, count from the right side until a digit other than zero is reached. Zeros before this digit are not significant while zeros after this are significant.
Example: 250 cm and 250. cm.
250 cm has no decimal point. Count from the Atlantic side (right) until a digit other than zero is reached. Therefore there are two significant digits, the 2 and the 5. The 0 is not significant.
250. cm has a decimal point. Count from the Pacific side (left) all digits afterwards, including zeros, are significant. Therefore there are three significant digits.
Calculate the correct number of significant digits in the following measurements.

1) 0.0056 s __________ 2) 2.0079 cm __________
3) 10 g ___________ 4) 105.0 m _________
5) 8.1 moles _______ 6) 4050.10 kg ________
7) 102 mL _________ 8) 520 pg _________
9) 0.99 km _________ 10) 10. L ____________

Note: 1) Numbers used in counting have an infinite number of significant digits.
2) Numbers used in a definition or conversion have an infinite number of significant digits.
Examples:
11) There are 1,000 meters in 1 kilometer. How many significant digits are there in 1,000 meters in this example? Answer ___________
12) There are 20 students in a classroom. How many significant digits in 20 students in this example? Answer ___________

<u>Rounding</u>

Copy the five rules for rounding found on page 48 into your notes here.

1.

2.

3.

4.

5.

In general if before the 5 the digit is odd go up/ if even stays the same.

Significant Digits in Calculations

Multiplication and Division

The measurement with the least number of significant digits determines the number of significant digits in the answer.

Example:

Area = length x width

What is the area of a flat surface with a width of 5.3 cm and a length of 40.2 cm? The numerical answer is 213.06 cm^2. Since the least number of significant digits in the problem is two (5.3 cm^2) then the answer must be rounded to two significant digits or 210 cm^2. Remember to first perform the mathematical operation as given and then round the answer.

Addition and Subtraction

The answer can be no more accurate than the least accurate measurement in the problem.

Example:

5.01 g + 2.1 g = 7.11 g. The least accurate measure was the 2.1 g so that the answer can only be recorded to the tenth, which makes the correct answer 7.1 g. Remember to round so that if the number before the number to be rounded is 5 or greater go up; if less than five leave the number as it is.

Examples:

1) 6.23 cm x 5.2 cm x 2.0 cm = ________________

2) 15.0 g ÷ 3.0 g = ________________

3) 0.002 m x 43 m = __________________

4) 15.2 kg + 1.67 kg + 10 kg = ______________

5) 15.2 kg + 1.67 kg + 10. kg = ____________
6) 5060 s - 1095. s = ___________________

When addition or subtraction are combined with multiplication or division, the answer is given in the least number of significant digits found in the problem.
Example:

$$\frac{2.52\text{ g} + 8.486\text{ g}}{2.1\text{ g}} = 5.241\text{ g} = 5.2\text{ g}$$

Scientific Notation

Very large or small numbers in science are written in scientific notation.
A number written in scientific notation is broken down into two parts; a number between 1 and 10 and a power of 10. The number part only contains the significant digits. The exponent of 10 is found by counting the number of decimal places that are moved to obtain a value between 1 and 10.
Example: The number 1506 has a decimal point after the 6 whether it is inserted or not. To make 1506 between 1 and 10 the decimal point is moved from behind the 6 to between the 1 and the 5 (1.506). 1.506 is between 1 and 10. Next count the number of decimal places the decimal point was moved to the left, which is 3 places. The three becomes the exponent of 10. The correct scientific notation for 1506 is 1.506×10^{3}.
Moving the decimal place to the right gives a negative exponent. For example 0.001506 is written as 1.506×10^{-3}.
To change a number from scientific notation to a whole number move the decimal point in the scientific notation in the direction indicated by the exponent. A positive exponent moves the decimal point to the right and a negative exponent moves the decimal place to the left.
Examples:
1) $2.072 \times 10^{3} = 2{,}072$
2) $5.89 \times 10^{-4} = 0.000589$

Change the following numbers into correct scientific notation or change the scientific notation into a whole number.

A) 751 = ___________________ **B) 0.0051 =_________________**
C) 4,050 = __________________ **D) 4,050. = ________________**
E) 6.57×10^{3} = _______________ **F) 5.71×10^{-4} = _____________**
G) 1.10×10^{1} = _______________ **H) 1.1×10^{1} = _______________**
J) 5.62×10^{0} = ________________ **K) 1.500×10^{-2} = ____________**

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<u>Direct and Indirect Proportions</u>

In general a direct proportion means that as one value increases or decreases the other value increases or decreases in the same ratio.

For instance, if the temperature of a gas doubles than the volume doubles, (Charles' law).

An indirect proportion means that as one value increases or decreases the other value increases as the opposite or reciprocal.

For instance, if the pressure on a gas doubles than the volume becomes ½ the original volume, (Boyle's law).