Chapter Two:Unit Conversions

Significant Figures
Clearly, when we take measurements, there is a limit as to how accurate our data can be.
For example, compare

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
<u>Non-Zero Digits</u>
All non-zero digits (1-9) are always significant.

Example: How many significant digits are there in each value below?

48.9 7231.228

<u>Leading Zeros</u>
Leading zeros are zeros to the *left* of the first non-zero digit.
Leading digits are <u>not</u> significant.
So, the zeros in 0.000825 and 0.0134 are not significant.
Why?

<u>Enclosed Zeros</u>
Enclosed zeros are zeros between other non-zero digits.
Enclosed zeros are <u>always</u> significant.
Examples of enclosed zeros:

5,002 901.0802 101

<u>Trailing Zeros</u>
Trailing zeros are those zeros which come at the end (to the right) of a value.
Trailing zeros are significant <u>if there is a decimal point in the value</u>. If there is no decimal, the zeros are ambiguous and generally not considered significant.
Why?

Practice With "Sig Digs"
How many significant digits do each of these values have?

462.0	1230	1230.	0.030900	0.0005

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

Examples:
Round 134.786 to a. the hundredths place, and b. four significant figures

Round 4,852.78 to a. the tens place, and 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 <u>least</u> number of significant digits.
Your answer will be rounded to that many significant figures.

Examples

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!

Examples

23.649 – 17.2 =

8.75 + 9.414 + 105.32 =

(6.834 × 8.32) – 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*

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

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.

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
Do not omit any significant digits!

Examples
Express these numbers in scientific notation.

23,894.

0.004289

20.000

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

$$(6.27\times10^{3})\times(9.347\times10^{-7})=$$

$$\frac{2.189\times10^{13}}{(6.45\times10^{-3})\times(9.2\times10^{14})}=$$

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

Converting Into Different Units
Consider the following well known equality:

1 foot = 12 inches

Suppose we divide both sides by 12 inches:

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

$$\frac{12\,\text{inches}}{1\,\text{foot}} \quad \textit{and} \quad \frac{1\,\text{foot}}{12\,\text{inches}}$$

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)

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

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

and

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

Consider this example, using SI units:

"How many centimeters are in 9.86 m?"

Another example using the SI system.

"How many nanoseconds (ns) are there in 2.83 milliseconds (ms)?"

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?"

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:

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 mL = 1 cm^3 = 1 cc

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

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.

Example
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 an equation

$$15\,\text{grams of iron} \doteq 100\,\text{grams of mixture}$$

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. 25.5% of a 345 gram rock is found to be pure calcite. What is

a. The mass of calcium in the rock, assuming no sources of calcium other than calcite?

b. The percent (by mass) of calcium in the rock?

Example
A mixture is composed of 52.3% aluminum sulfide and 47.7% sodium chloride. The compound aluminum sulfide is 64.1 % by mass sulfur, and the compound sodium chloride is 60.7 % by mass chlorine. Given that there is a total of 5.46 grams of aluminum in the mixture, calculate the total mass of sodium in the mixture.

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:

$$°F = (1.8 \times °C) + 32$$

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

Accuracy & Precision in Measurements

If data is accurate, 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 precise.