# Scientific Notation

Chemists are often concerned with measuring objects that range in size from the diameter of the universe to the diameter of the nucleus of an atom. For example, one gram of iron contains about 10 000 000 000 000 000 000 000 atoms of iron. Each atom of iron has a mass of approximately 0.000 000 000 000 000 000 000 1 g. Rather than writing out all those zeros each time, scientists put the number in **scientific notation**. Scientific notation is the method of expressing values as a number between 1 and 10 multiplied by a power of ten ( or an exponent).
The general form of scientific notation is ...

$$\mathbf{?.\,???\ x\ 10^{?}}$$

The general rules for expressing numbers greater than one in scientific notation is as follows:

i) Move the decimal point to the left until there is just one digit in front of it .
ii) Count the number of places that the decimal has been moved and use this number as the exponent.

Consider the number 200. This may be rewritten as $2 \times 10^2$.
This method of writing numbers can also be applied to numbers that are less than one ...

i) Move the decimal point to the right until there is just one digit ( other than zero) that remains.
ii) The exponent is given by the number of places you moved the decimal point, except the exponent is now given a negative sign.

Example: 0. 000 000 62 may be rewritten as $6.2 \times 10^{-7}$.

Generally, scientific notation is used for numbers greater than 100 or less than 0.1.

The standards of measurements used by scientists are those of the metric system. All the units are based on 10 or multiples of 10. As a result, conversions between units are easy to do. The metric system is referred to as the **International System of Units** ( abbreviated as **SI** ). The SI has seven base units ( length, mass time, electric current, temperature, amount of substance and luminous intensity). From these, other SI units of measurements such as volume, density and pressure are derived. In SI, there is an extensive system of **metric prefixes** which eliminates the need for scientific notation. Scientific notation will be a useful concept when talking about significant figures. A table of metric prefixes can be found in your text book on page 27, Table 2.2. In general, in the expression of any quantity, a metric prefix should be chosen so that the numerical value lies between 0.1 and 1000. SI does not allow double prefixes, use only one prefix with the base units.



## Multiplication and Division of Numbers in Scientific Notation

Coefficients and exponents are treated separately. The coefficients are multiplied or divided normally. In multiplication, the exponents are ______, however in division the exponents are __.
Example ... $(1.8 \times 10^2)(2.0 \times 10^3) = 3.6 \times 10^5$

## Addition and Subtraction of Numbers in Scientific Notation

Numbers that are expressed in scientific notation can only be added or subtracted if the exponents are the same.
Further information see your text section 2.3 pp 29 - 32
Homework p 44 # 10, 11, 13
Read section 2.4 pp 32 - 37

# Measurement and Significant Figures

During the laboratory sessions you will be required to measure certain quantities such as mass, temperature or volume. How we treat those numbers is important as a scientist does not want to imply any more or less precision in experimental results than is actually there.

When using instruments to take measurements in the laboratory, there is always some degree of uncertainty in every measurement, i.e. no measurement that we can ever make is perfect, or exact. All measurements have a certain degree of **uncertainty** associated with them.
When scientists report measurements they report all the digits which are accurately known plus one uncertain digit. All the accurately known digits and the one uncertain digit are called **significant digits** or **significant figures.**

The number of significant digits in a measurement is usually defined as **all of the certain digits in a measurement plus one uncertain ( estimated ) digit.** Generalized to all situations ( i.e. values from measurement or calculation) significant digits are those digits which are certain plus one uncertain digit. The uncertainty should be recorded with the measurement. Estimating the smallest division of your measuring instrument will usually indicate the place of your uncertainty.
Significant digits provide a mathematical means of expressing the precision of measured data.
**Precision** : refers to the uncertainty in a measurement and is indicated by the number of digits in the answer. Example: 25.56 $^0$C is a more precise measure of temperature than 25.6 $^0$C. By using a more precise thermometer, we would obtain a better estimate of the temperature. However, there would still be uncertainty in the measurement. Uncertainty arises from different types of errors, determinate and indeterminate. Such things as miscalibrated instruments, poor judgement on the part of the observer are considered determinate errors whereas indeterminate errors arise from things we do not know about, like fluctuating conditions ( temperature, pressure).
**Accuracy** : refers to the closeness of your measurement to the actual ( true, or accepted ) value.
**Exact Numbers** : are not uncertain and are said to have an infinite number of significant digits. These could be numbers that are defined, example, 12 is exactly one dozen; or numbers that result from counting objects, example: 32 students, 153 beakers, $ 4.95 ( exactly 495 cents).
**Homework:**
Chemistry Today 1, Whitman, Zinck, Nalepa 3rd Edition
***Read section 2.4 of your text ( pp 33 - 35 )***
***Answer : Review Your Understanding , page 44, questions 3 - 9, 14 - 16***



**<u>The Use of Plus -or-Minus Notation</u>**
Scientists sometimes use a plus-or-minus, ±, notation for describing how much uncertainty there is in a measurement. If a measurement is written as 35.25 ± 0.02 cm, it means that the measurement is correct to within 0.02 cm of 35.25 cm. That is, it might be as much as 0.02 cm greater than 35.25 cm or as much as 0.02 cm less than 35.25 cm ...

35.25 cm + 0.02 cm = 35.27 cm (largest possible value)
35.25 cm - 0.02 cm = 35.23 cm (smallest possible value)

In effect, the plus-or-minus notation describes a range within which the measured value is believed to fall. When the plus-or-minus notation is not used with a measurement, most scientists assume that there is an implied range that goes with the measurement.

# Significant Figures

All figures that are **certain** in a measurement **plus one uncertain** figure are known as the **significant figures.** The last figure shows where uncertainty begins. If a thermometer indicates a boiling point of 36.2 $^0$C, and has an uncertainty of ± 0.2 $^0$C, all figures in that 36.2 are significant, including the 0.2, which is uncertain. The notation 36.2 ± 0.2 $^0$C indicates how uncertain it is.

## Rules for the Use of Significant Figures in Data Processing

1. All measured nonzero digits are significant ( i.e. if there are no zeros in the measurement). Example: 173 has three significant figures, 2.9 has two, 125.59 has five.

2. Zero is sometimes a significant figure and sometimes not. The following rules deal with zero.

a) Zeros in between non-zero digits are significant figures.

| | |
|---|---|
| 103.33 | 5 significant figures |
| 136.02 | 5 significant figures. |
| 20.31 | 4 significant figures |

b) Zeros appearing in front of all nonzero digits are not significant. They are acting as placeholder.

| | | | |
|---|---|---|---|
| 0.02513 | 4 significant figures | 0.008741 | 4 sig. figs |
| 0.351 | 3 significant figures | 0.0255 | |
| 0.000 00123 | 3 significant figures | 0.0011525 | |
| 0.042 | 2 significant figures | 0.0112 | |

c) Zeros at the end of a number and to the right of a decimal point are significant

| | | |
|---|---|---|
| 135.30 | 5 significant figures | 0.5470 |
| 142.00 | 5 significant figures | |
| 43.00 | 4 significant figures | |
| 1.01 | 3 significant figures | |

d) Zeroes at the end of a number without a decimal point are ambiguous. Adding a decimal point indicates their significance.

| | |
|---|---|
| 3600. | 4 significant figures |
| 250 . | 3 significant figures |
| 70. | 2 significant figures |

# Significant Figures in Calculations

The result of a calculation involving physical quantities should not be given with a smaller uncertainty than the original quantities. It is poor practice , for example**,** to divide 7.8 g by 7 and give more than significant figures in the answer. Paying attention to the correct number of digits in the result of a calculation is especially important when working with electronic calculators. With the touch of a button, 7.8 divided by 7 is seen to be 1.114285714. Do not assume that all the numbers in the digital display are significant. Limit the number of digits in your answer as explained below.

## Addition and Subtraction

When adding or subtracting numbers, **the answer should have the same number of decimal places** as the measurement having the **lowest number of decimal places.**

Examples:

12.52 m + 346.0 m + 8.24 m = 369.76 m

The answer must be rounded off to one digit after the decimal point. The answer is 369.8 m or 3.698 x $10^2$ m.

74.626 m - 28.34 m = 46.286 m

The answer must be rounded off to two digits after the decimal point. The answer is 46.29 m or 4.629 x $10^2$ m.

123.45 cm + 0.3 cm =

## Multiplication and Division

When multiplying and dividing numbers, the **answer should have the same number of significant digits** as the measurement having the **least number of significant digits**. The position of the decimal point has nothing to do with the number of significant figures.

Examples:

7.55 m x 0.34 m = 2.567 $m^2$ = 2.6 $m^2$ ( 0.34 m has two significant figures)

2.4526 m ÷ 8.4 = 0.291 976 m = 0.29 m (8.4 has two significant figures)

0.365 m ÷ 0.0200 m = 18.25 m = 18.3 m (both numbers have three significant figures)

12975.6 x 423.4 =

## Sequential Calculations

When there are a series of calculations to do to obtain the final result, **do not round off until the end**. Or, if you do round off, leave at least one extra digit until the end of all the calculations.

**Homework:**

Read and make notes from section 2.4 of your text (pp 33 - 35)

Do Practice Problems 2- 4 and 2 - 5, pp 35

# **Practice**: Significant Figures in Numerical Calculations

1. Convert the following to scientific notation:

a) 2 300 cm
b) 4 174 mJ
c) 0.000 82 g
d) 0.00514 mm
e) 65 000 kg
f) 126.90 g

2. How many significant digits are there in each of the following measurements?

a) 307 g
b) 1.40082 cm
c) 0.00058900 g
d) 0.0030090087 mm
e) 4500 km
f) 350 000 cm
g) 180.00 s
h) 3.50 x $10^3$ cm
i) 1.604 x $10^{-4}$ m
j) 0.0459 x $10^3$ g

3. Express the answer to each of the following calculations wuth the correct number of significant figures.

a) 80 cm + 13.0 cm
b) 72.60 m + 0.09 50 m
c) 13.89 cm + 6.8932 cm
d) 1.30 x $10^{-2}$ cm - 2.4 x $10^{-4}$ cm
e) 750 cm - 677.4 cm
f) 10 000 m - 940 m
g) 0.0890 cm - 0.0666 cm
h) 0.340 x $10^{-1}$ g - 1.20 x $10^{-2}$

4. Express the answers to each of the following calculations with the correct number of significant figures.

a) 3.0 cm x 4.000 cm
b) 2.005 cm x 5.0 cm
c) 400 m x 87 488 m
d) 2.3 x $10^{-6}$ m x 1.45 x $10^{-2}$ m
e) $\frac{0.0045 mm^2}{0.90 mm}$
f) $\frac{120 km^2}{8.56 km}$
g) $\frac{0.7600 mm^3}{1.50 mm}$
h) $\frac{4.80 \times 10^5 m^2}{8.5 \times 10^3 m}$

5. To a beaker having a mass of 109.751 g, a student adds 10.23 g of chemical A, 0.0639 g of chemical B, and 19.1 g of chemical C. (Remember the rule about sequential calculations!)

a) What is the total mass of all of the chemicals?
b) What is the percentage by mass of chemical C in the mixture?