

Scientific Measurements

Chapter 2

Scientific Measurements

Chemistry is both **Qualitative** and **Quantitative**.

Quantitatively chemistry considers the *amount* of a substance measured, used, or produced.

- A measurement must always consist of a **number** *and* a **unit**.
- Units tell us what scale or standard was used when the measurement was made.

Middle Ages: The King's hand determined the "unit" of measurement!

Too Inconsistent!!

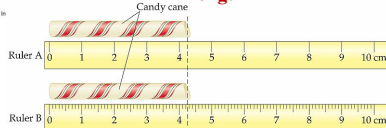
The exactness of a measurement depends on the instrument used:

Mass

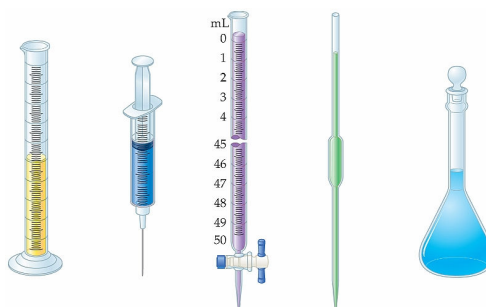


Every instrument has uncertainty!

Length



Volume



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Once we know the uncertainty in a measurement, we assign a *unit*.

1960: "Système International" –
International System of Units or **SI system**

SI System is constructed from seven base units:

1. Length	Meter	m
2. Mass	kilogram	kg
3. Temperature	Kelvin	K
4. Time	second	s
5. Amount	mole	mol
6. Electric current	ampere	A
7. Luminous electricity	candela	cd

Just For Fun!

1. The *meter* was redefined in 1983 to be equal to the distance light travels in a vacuum in 1/299,792,458 second.
2. The *kilogram* represents the mass of a platinum-iridium block kept at the International Bureau of Weights and Measures at Sevres, France.
3. The *kelvin* is 1/273.16 of the temperature interval between absolute zero and the triple point of water.
4. The *second* was redefined in 1967 as the duration of 9,192,631,770 periods of a certain line in the microwave spectrum of cesium-133.
5. The *mole* is the amount of a substance that contains as many entities as there are atoms in exactly 0.012 kg of carbon-12.

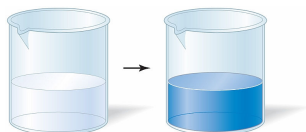
Significant Digits

When doing scientific experiments, it is very important to make **accurate** measurements and to record them correctly.

Every measurement has some degree of **uncertainty**. Another way to indicate uncertainty is to use

Significant Digits (or "Significant Figures").

The number of significant digits in a quantity is the number of digits that are known accurately **plus** the doubtful digit (*the doubtful digit is the last digit written*).



Colorless Solution
Stopwatch A: 0 s
Stopwatch B: 0.0 s
Stopwatch C: 0.00 s

Blue Solution
35 s
35.1 s
35.08 s

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Rules for Determining Significant Figures

- Nonzero Integers**
Nonzero integers **always** count as significant figures.
1, 2, 3, 4, 5, 6, 7, 8, 9
- Zeros**
 - Leading Zeros**
These are the zeros that precede all of the nonzero digits. They **never** count as significant figures.
0.00123 cm = only 3 sig. figs.
 - Captive Zeros**
These are the zeros that fall between nonzero digits. They **always** count as significant figures.
200.02 mL = 5 sig. figs.
 - Trailing Zeros**
These are the zeros at the right end of the number. They are significant **only** if the number is written with a **decimal point**.
200. g = 3 sig. figs. whereas 200 g = only 1 sig. fig.
- Exact numbers**
These are numbers determined by counting, NOT by measuring devices. Exact numbers **never** limit the number of significant figures in a calculation.
12 eggs = 1 dozen, 100 cm = 1 m, 6 test tubes

Examples

How many significant figures do each of the following measurements have?

- 34.5687 g
- 0.00365 m
- 2300 mL
- 90.300 in
- 7493 min

Rules for Using Significant Figures in Calculations

- Addition – Subtraction**
Round to the decimal place of the number with the **least** significant figures
better put – round to the answer to the first column that has a doubtful digit.

$$\begin{array}{r} 256.32 \text{ g} \\ 15.315 \text{ g} \\ 101.206 \text{ g} \\ 2.1 \text{ g} \\ + 374.931 \text{ g} \\ \hline \end{array}$$

← First column with doubtful digit.

Answer: 749.9 g (four sig. figs.)
- Multiplication – Division**
Round to the number of least significant figures.

$$(6.25 \text{ g}) \times (20.1 \text{ g}) \times (2.3 \text{ g}) \times (16.54 \text{ g})$$

3 s.f. 3 s.f. 2 s.f. 4 s.f.

$$= 4,779.0262 \text{ g}$$

$$= 4,800 \text{ g or } 4.8 \times 10^3 \text{ g (scientific notation!)}$$

Rounding Rules

- If the first digit to be dropped is less than 5, leave the digit before unchanged.
6.9926 g round to 3 sf = 6.99 g
- If the first digit to be dropped is 5 or more, increase the digit before it by one.
34.581 g round to 3 sf = 34.6 g
34.550 g round to 3 sf = 34.6 g

Perform the following calculations and write the answer with appropriate significant figures:

- 2.34 m x 5.9 m =
- 12.89 cm² / 3.51 cm =
- 204 g + 23.4 g + 1.25 g =
- 12.5 L - 0.23 L - 4.789 L =
- (12.34 m + 7.42 m) x (34.5 m - 29.68 m) =

Scientific Notation

Exponents

When a number is multiplied by itself, the process is noted by a **superscript** telling how many times the multiplication is carried out.

$$2 \times 2 \times 2 \times 2 = 2^4 = 16$$

↑ exponent
"2 to the fourth power"

Power of 10 – a number that results when 10 is raised to an exponential power.

$$10^n$$

$$10^2 = 10 \times 10 = 100 \text{ (2 zeros)}$$

$$10^3 = 10 \times 10 \times 10 = 1,000 \text{ (3 zeros)}$$

$$10^7 = 10 \times 10 \times 10 \times 10 \times 10 \times 10 \times 10 = 10,000,000 \text{ (7 zeros)}$$

$$10^{-2} = 1/10 \times 1/10 = 0.01$$

$$10^{-4} = 1/10 \times 1/10 \times 1/10 \times 1/10 = 0.0001$$

Scientific Notation is a short hand way of writing numbers that are either very large or very small.

Left for Large numbers

Right for Small numbers

Distance from the earth to the sun:

~ 93,000,000.0 miles

You move the decimal *left* (large number) until you find a number that falls between 1 and 10.

9.3 is between 1 and 10

We need to move the decimal 7 places to the left to get 9.3

9.3×10^7

Between 1 and 10 Appropriate power of 10

When going *right* for small numbers, use a *negative* exponent:

0.000006738 in scientific notation is 6.738×10^{-7}

Examples

- Round the following numbers to 3 significant figures using scientific notation:
 - 348901 g
 - 0.0340209 m
 - 10.045 L
 - 0.000012400 min
 - 30000 s

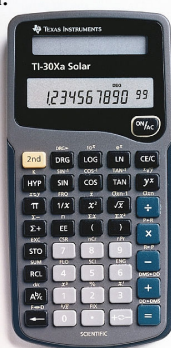
Using your calculator for Scientific Notation:

The number 234890000 in scientific notation on your calculator rounded to 3 significant figures:
 2.35×10^8

2 . 3 5 EE 8

The number 0.000456123 in scientific notation on your calculator rounded to 3 significant figures:
 4.56×10^{-4}

4 . 5 6 EE +/- 4



DO NOT type in "x 10 EE". The EE is in place of the 10!

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The Percent Concept

$$\frac{\text{One quantity}}{\text{Total sample}} \times 100\% = \%$$

$$(\text{Part/Whole}) \times 100\%$$

- A chemistry class has 24 students enrolled in it. If 7 of those 24 students is wearing red, what percent of students is wearing red?
- A coin collector has 5 rare silver dollars, 6 rare state quarters, and 3 rare Indian Head pennies. What percent of the coin collection is silver dollars?
- A math class has 750 total points for all coursework. If 35.0% of the class grade is homework, how many points is the homework worth?