

SIGNIFICANT FIGURES

Two kinds of numbers are used in science:

- **Exact or Defined:** exact numbers; **no uncertainty**
- **Measured:** are subject to error; have **uncertainty**

uncertain (1)
↓
1.25 ???????? cm
↑↑ ↑
certain (2) unknown

1. Sig. Figs. - all digits obtained as the result of a correct measurement (3 SF)
 Include: - one uncertain digit (the last one); this is your guess (5)
 - all certain digits (1.2)
2. Any digit farther to the right of the uncertain digit is unknown
3. The more Sig Figs in a measurement, the greater the precision of the measurement (the smaller the uncertainty).

| | Decigram Balance 3.1 g | Centigram Balance 3.12 g | Milligram Balance 3.121 g | Analytical Balance 3.1213 g |
|-----------------------|--|--|---|---|
| Sig. Figs | 2 | 3 | 4 | 5 |
| Certain Digits | 1 | 2 | 3 | 4 |
| Accuracy | 1 g | 0.1 g | 0.01 g | 0.001 g |
| Uncertainty | ± 0.1 g | ± 0.01 g | ± 0.001 g | ± 0.001 g |

LEAST PRECISE → PRECISION INCREASES → MOST PRECISE

ZERO AS SIGNIFICANT FIGURE**1. SIGNIFICANT ZEROS:**

A) Sandwich, or captive zeros: **1.001 g** **13.02 cm**

B) Terminal Zeros : - to the right of the decimal point:

6.30 cm **90.0 cm**

- to the left of the decimal point:

39,800. m

2. NONSIGNIFICANT ZEROS:

Decimal markers: (to the left or to the right of decimal point: **0.0912 g**

3. AMBIGUOUS (DOUBTFUL) ZEROS:

Terminal zeros in a number without a decimal point: **530 m**

It is not known if the number has 2 or 3 SF's

EXAMPLES:

Determine the number of significant figures in each of the following measurements:

9.9099 g

9090. kg

0.9090 g

9×10^3 g

0.0909 g

9.0×10^3 g

9090 g

| |
|----------------------------|
| SCIENTIFIC NOTATION |
|----------------------------|

$$A \times 10^n$$

A must satisfy strict conditions:

| |
|-----------------|
| $1 \leq A < 10$ |
|-----------------|

Consider: 51,200,000,000,000 mi

Several exponential notations are possible. Which is correctly written?

$$51.2 \times 10^{12} \quad \text{mi}$$

$$512 \times 10^{11} \quad \text{mi}$$

$$5.12 \times 10^{13} \quad \text{mi}$$

$$0.512 \times 10^{14} \quad \text{mi}$$

Consider: 0.0839 g

Several exponential notations are possible. Which is correctly written?

$$839 \times 10^{-4} \quad \text{g}$$

$$83.9 \times 10^{-3} \quad \text{g}$$

$$8.39 \times 10^{-2} \quad \text{g}$$

$$0.839 \times 10^{-1} \quad \text{g}$$

- In scientific work, very large and very small numbers are commonly expressed in SCIENTIFIC NOTATION

SIGNIFICANT FIGURES IN CALCULATIONS

- THE ANSWER TO A CALCULATION CAN HAVE NO MORE SIG FIGS THAN THE LEAST ACCURATE NUMBER (**LAN**)

Multiplication and Division

LAN = number with the **fewest SIG FIGS**

Example 1:

Calculate the volume of a cylinder, given:

$$\text{Radius (r)} = 0.63 \text{ cm}$$

$$\text{Height (h)} = 6.14 \text{ cm}$$

$$V = \pi r^2 h = \pi (0.63 \text{ cm})^2 (6.14 \text{ cm}) = 7.655954 \text{ cm}^3$$

2 SF
3 SF
calculator answer

LAN

- Note: The answer can have no more than **2 SF**
- The correct answer is : **7.7 cm³**

Example 2:

Calculate the density of a liquid, given:

$$\text{Mass (m)} = 10.9837 \text{ g}$$

$$\text{Volume (V)} = 10.00 \text{ mL}$$

$$d = \frac{10.9837 \text{ g}}{10.00 \text{ mL}} = 1.09387 \text{ g/mL} \quad (\text{calculator answer})$$

6 SF
↓
↑
4 SF (LAN)

- Note: The answer can have no more than **4 SF**
- The correct answer is : **1.094 g/mL**

Addition and Subtraction**LAN = number with the fewest decimals****Example 3:**

Add the following measurements:

$$\begin{array}{r}
 212. \quad \text{g} \quad (0 \text{ decimals}) \longrightarrow \text{LAN} \\
 2.1 \quad \text{g} \quad (1 \text{ decimal}) \\
 1.88 \quad \text{g} \quad (2 \text{ decimals}) \\
 \hline
 \end{array}$$

$$\begin{array}{r}
 215.98 \quad \text{g} \longleftarrow \text{calculator answer} \\
 \hline
 \end{array}$$

- **Note: The answer can have no more decimals than the LAN (0 decimals)**
- **The correct answer is: 216 g**

Example 4:

Subtract the following measurements:

$$\begin{array}{r}
 1.0947 \quad \text{g} - \\
 1.093 \quad \text{g} \quad (3 \text{ decimals}) \longrightarrow \text{LAN} \\
 \hline
 \end{array}$$

$$\begin{array}{r}
 0.0017 \quad \text{g} \longleftarrow \text{(calculator answer)} \\
 \hline
 \end{array}$$

- **Note: The answer can have no more decimals than the LAN (3 decimals)**
- **The correct answer is: 0.002 g**

Combined Calculations

Example 5:

Given the following values, calculate the percent error in this measurement:

$$\text{Theoretical Value} = 1.0943 \text{ g}$$

$$\text{Experimental Value} = 1.0947 \text{ g}$$

$$\% \text{ Error} = ?$$

$$\% \text{ Error} = \frac{\text{Exp} - \text{Th}}{\text{Th}} \times 100 = \frac{1.0947 - 1.0943}{1.0943} \times 100 = \frac{0.0004 \text{ g}}{1.0943 \text{ g}} \times 100 = 0.036553 \% \text{ (calculator answer)}$$

1 SF (LAN)
(5 SF)

- Note: The correct answer cannot have more than **1 SF**
- THE CORRECT ANSWER IS : **0.04 %**

Example 6:

Given the following values, calculate the percent error in this measurement:

$$\text{Theoretical Value} = 2.70 \text{ g/cm}^3$$

$$\text{Experimental Value} = 3.09 \text{ g/cm}^3$$

$$\% \text{ Error} = ?$$

$$\% \text{ Error} = \frac{\text{Exp} - \text{Th}}{\text{Th}} \times 100 = \frac{\quad}{\quad} \times 100 =$$

- Note: The correct answer cannot have more than
- THE CORRECT ANSWER IS :

ROUNDING OFF

- If the rounded digit is **<5**, the digit is simply dropped. 51.2**34** → 51.2
- If the rounded digit is **≥5**, the digit is increased. 51.3**8**, 51.3**59**, 51.3**503** → 51.4

Example 1:

$$7.7776 \text{ g} \xrightarrow{\text{rounded off to 3 SF}} 7.78 \text{ g} \quad (7 > 5)$$

$$124 \text{ g} \xrightarrow{\text{rounded off to 2 SF}} 120 \text{ g} \quad (4 < 5)$$

$$14.4444 \% \xrightarrow{\text{rounded off to 2 SF}} 14 \% \quad (4 < 5)$$

$$0.02317 \text{ g} \xrightarrow{\text{rounded off to 2 SF}} 0.023 \text{ g} \quad (1 < 5)$$

- When performing calculations with multiple steps, it is often better to carry extra digits and round in the final step.

Example 2:

Calculate the volume of a cylinder, given diameter = 1.27 cm and height = 6.14 cm.

$$V = \frac{\pi d^2 h}{4} = \frac{\pi (1.27)^2 (6.14)}{4} = 7.7779598 \text{ cm}^3 \xrightarrow{\text{Round to 3 SF}} 7.78 \text{ cm}^3$$

SI UNITS

- International System of units adopted in 1960
- Is an improved metric system
- Has the major advantage of being a decimal system (all conversion factors are multiples of 10)

SI units consist of:

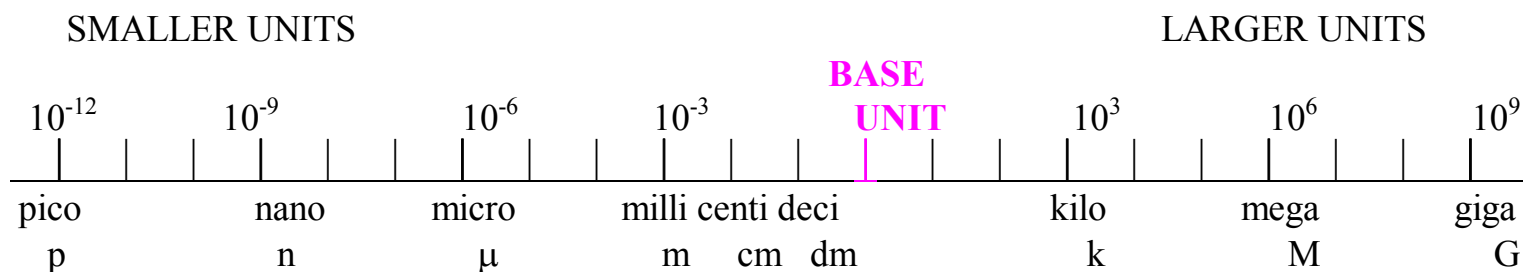
1. SEVEN BASE UNITS

| <u>Quantity</u> | <u>Unit</u> | <u>Abbreviation</u> |
|------------------------|-------------|---------------------|
| 1. Length | meter | m |
| 2. Mass | kilogram | kg |
| 3. Time | second | s |
| 4. Temperature | Kelvin | K |
| 5. Amount of substance | mole | mol |
| 6. Electric current | ampere | A |
| 7. Luminous intensity | candela | cd |

2. MANY DERIVED UNITS

| <u>Quantity</u> | <u>Unit</u> | <u>Abbreviation</u> |
|----------------------------------|------------------------------------|---------------------|
| 1. Speed = Length/Time | meter/second | m/s |
| 2. Volume =(Length) ³ | (meter) ³ | m ³ |
| 3. Density = Mass/Volume | kg/m ³ | kg/m ³ |
| 4. Acceleration = speed/time | m/s ² | m/s ² |
| 5. Force = Mass x Acc | kg m/ s ² | N (Newton) |
| 6. Pressure = Force/Area | kg/m s ² | Pa (Pascal) |
| 7. Energy = Force x Length | kg m ² / s ² | J (Joule) |

| |
|-----------------------------------|
| SI BASE UNITS AND PREFIXES |
|-----------------------------------|



MEANING:

$$1\text{m} = 1,000\text{ mm} = 10^3\text{ mm} \quad \text{OR} \quad 1\text{mm} = 0.001\text{ m} = 10^{-3}\text{ m}$$

$$1\text{mm} = 1,000\ \mu\text{m} = 10^3\ \mu\text{m} \quad \text{OR} \quad 1\ \mu\text{m} = 0.001\text{ mm} = 10^{-3}\text{ mm}$$

$$1\text{m} = 10^6\ \mu\text{m} \quad \text{OR} \quad 1\ \mu\text{m} = 10^{-6}\text{ m}$$

$$1\text{m} = 10^{-6}\ \mu\text{m} \longrightarrow \text{IS FALSE}$$

Always think : - Which unit is larger ? (m) $1\text{m} = 10^6\ \mu\text{m} \longrightarrow \text{IS CORRECT}$

- Which unit is smaller ? (μm) $1\ \mu\text{m} = 1 \times 10^{-6}\text{ m} \longrightarrow \text{IS Also Correct}$

I. BASE UNITS**1. Measurement of Length**

Base unit: The meter = m

Also commonly used in chemistry: cm, mm, μm , **nm, pm (for atomic sizes)**

$$\begin{array}{llll}
 1 \text{ m} & = & 10^2 \text{ cm} & \text{OR} & 1 \text{ cm} & = & 10^{-2} \text{ m} \\
 1 \text{ m} & = & 10^3 \text{ mm} & \text{OR} & 1 \text{ mm} & = & 10^{-3} \text{ m} \\
 1 \text{ m} & = & 10^6 \mu\text{m} & \text{OR} & 1 \mu\text{m} & = & 10^{-6} \text{ m} \\
 1 \text{ m} & = & 10^9 \text{ nm} & \text{OR} & 1 \text{ nm} & = & 10^{-9} \text{ m} \\
 1 \text{ m} & = & 10^{12} \text{ pm} & \text{OR} & 1 \text{ pm} & = & 10^{-12} \text{ m}
 \end{array}$$

Also used: the Angstrom, A

$$1 \text{ m} = 10^{10} \text{ A} \quad \text{OR} \quad 1 \text{ A} = 10^{-10} \text{ m}$$

- NOTE : The Angstrom IS NOT AN SI UNIT

2. Measurement of Mass

Base Unit: the kilogram, kg (the gram would not be practical since it is too small)

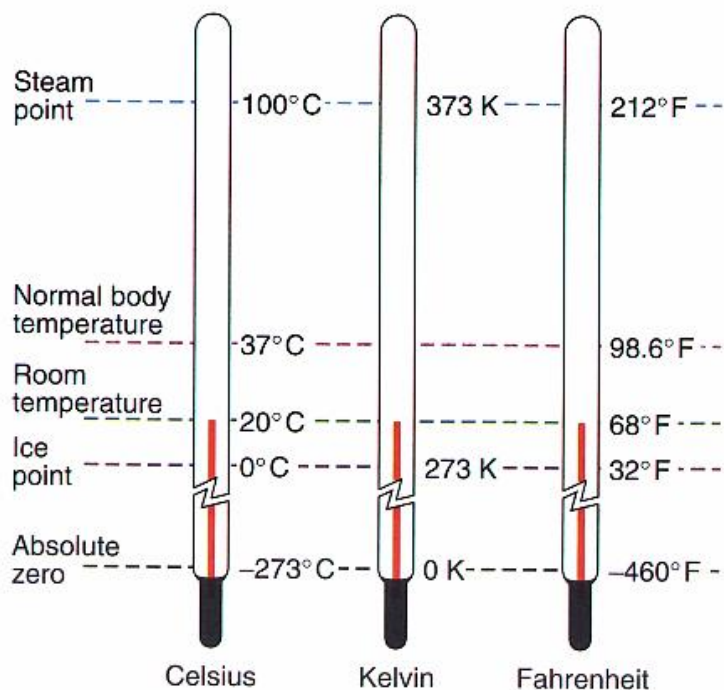
3. Measurement of Time

Base Unit: the second, s

- Conversion to minutes (60 sec/min) or hours (60 min/hr) is an exception to the decimal-based prefixes of the SI (is due to the calendar)
- Recently, nanoseconds (10^{-9} s) and picoseconds (10^{-12} s) are increasingly used in computer work

4. Measurement of Temperature

- Temperature is a measure of how hot or cold a substance is.
- It is a quantity that determines the direction of heat flow: warmer → cooler
- Three temperature scales are commonly used: **Celsius**, **Kelvin** (absolute) and **Fahrenheit**



- **To convert between Fahrenheit and Celsius;**

REMEMBER: 1.8 unit F = 1 unit C 32 °F = 0 °C

$$^{\circ}\text{F} = 32 + (1.8 \times ^{\circ}\text{C}) \quad \text{or} \quad ^{\circ}\text{C} = \frac{^{\circ}\text{F} - 32}{1.8}$$

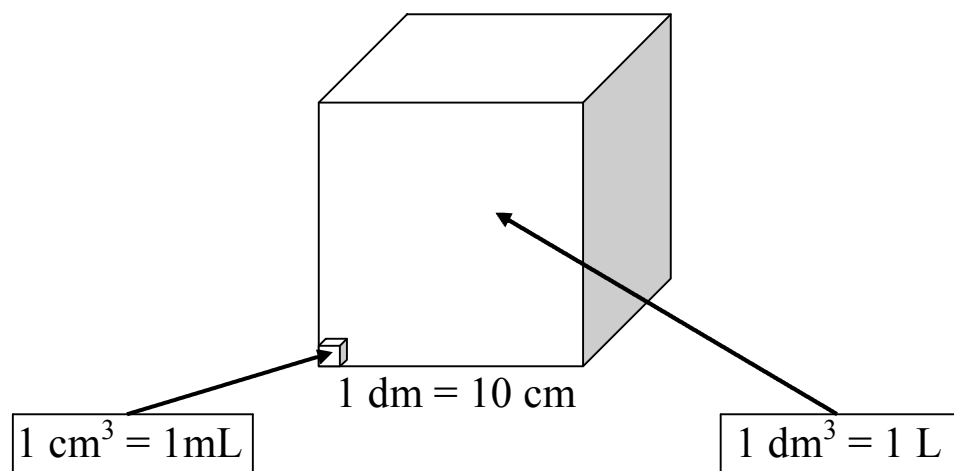
- **To convert between Celsius and Kelvin:**

REMEMBER: -The Kelvin temperature is 273 degrees higher than the Celsius

$$\text{K} = ^{\circ}\text{C} + 273 \quad \quad ^{\circ}\text{C} = \text{K} - 273$$

II. DERIVED UNITS**1. Volume**

Base Unit : m^3 Not practical because it is very large
 Commonly used: dm^3 Also called "THE LITER (L)"



NOTE: $1 \text{ dm}^3 = (10 \text{ cm})^3 = 1,000 \text{ cm}^3$
 $1 \text{ L} = 1,000 \text{ mL}$

IMPORTANT RELATIONSHIPS TO REMEMBER:

$$1 \text{ dm}^3 = 1 \text{ L} \qquad 1 \text{ dm}^3 = 1000 \text{ cm}^3 \qquad 1 \text{ L} = 1000 \text{ mL}$$

$$1 \text{ cm}^3 = 1 \text{ mL} \qquad 1 \text{ cm}^3 = 0.001 \text{ dm}^3 \qquad 1 \text{ mL} = 0.001 \text{ L}$$

2. Density (d):

Density is the mass of a unit volume

$$d = \frac{\text{mass}}{\text{volume}} = \frac{m}{V}$$

Examples:

1. Calculate the density of a piece of glass with a mass of 6.65 g and a volume of 2.95 mL.

$$m = 6.65 \text{ g}$$

$$V = 2.95 \text{ mL}$$

$$d = ?$$

2. Calculate the thickness of an Aluminum foil 15.38 cm long and 14.39 cm wide. The mass of the foil is 1.4939 g. The density of aluminum is 2.70 g/cm^3 .

(HINT: We consider the Aluminum foil to be a rectangular solid).

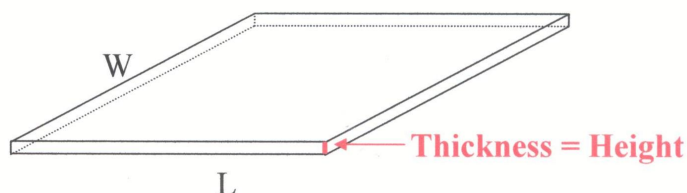
$$L = 15.38 \text{ cm}$$

$$W = 14.39 \text{ cm}$$

$$m = 1.4939 \text{ g}$$

$$d = 2.70 \text{ g/cm}^3$$

Thickness = Height = ?



$$d = \frac{m}{V} = \frac{m}{L \times W \times \text{Th}}$$

Solve the equation for the unknown (**Th**), before using numbers:

$$\text{Th} = \frac{m}{d \times L \times W} = \frac{1.4939 \text{ g}}{(2.70 \text{ g/cm}^3)(15.38 \text{ cm})(14.39 \text{ cm})} = 2.50 \times 10^{-3} \text{ cm}$$

Notes:

- The units cancel out. The units obtained for the answer are **cm**, which is to be expected.
- If the units would not be units of length, that would imply that you made a mistake in your algebra (when you solved for the unknown)

DIMENSIONAL ANALYSIS (FACTOR-LABEL METHOD)

- It is a method of calculation in which the units are carried along
- Makes word problems and chemistry calculations easy!
- Any unit can be converted into another by use of the appropriate **conversion factor**, as shown below:

$$\begin{array}{c}
 \text{beginning unit} \times \frac{\text{final unit}}{\text{beginning unit}} = \text{final unit} \\
 \uparrow \\
 \text{conversion factor}
 \end{array}$$

Examples:

1. On a picnic, **162 students** are each given **2 hot dogs**. If there are **9 hot dogs per pound**, priced at **\$ 4 per 3 pounds**, what is the cost of the hot dogs?

Note that the following conversion factors can be obtained from the text of the problem:

1 student ----- 2 hot dogs
 9 hot dogs --- 1 lb
 \$ 4 ----- 3 lbs

- To begin solving the problem, start with a known and keep your goal in mind:

$$162 \text{ students} \times \frac{2 \text{ hot dogs}}{1 \text{ student}} \times \frac{1 \text{ lb}}{9 \text{ hot dogs}} \times \frac{4 \$}{3 \text{ lbs}} = 48 \$$$

- Note that all the units (except \$) cancel out!

2. Convert 0.00250 centimeters in micrometers (μm)

? cm = ? μm Not easily remembered!

However, other relationships are easier recalled:

$$1 \text{ m} = 10^2 \text{ cm} \qquad 1 \text{ m} = 10^6 \mu\text{m}$$

- Start by what is given, and set up the units to cancel and give you the desired results:

$$2.50 \times 10^{-3} \text{ cm} \times \frac{\text{m}}{\text{cm}} \times \frac{\mu\text{m}}{\text{m}} = \mu\text{m}$$

- Next, plug in the appropriate numbers (conversion factors):

$$2.50 \times 10^{-3} \text{ cm} \times \frac{1 \text{ m}}{10^2 \text{ cm}} \times \frac{10^6 \mu\text{m}}{1 \text{ m}} = 25.0 \mu\text{m}$$

- Note that all the units cancel out, except the μm
3. A water solution containing 12.0% sodium hydroxide by mass has a density of 1.131 g/mL. What volume of this solution (in L) must be used in an application requiring 3.50 kg of sodium hydroxide?