# 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**<br>**3.1 g** | **Centigram Balance**<br>**3.12 g** | **Milligram Balance**<br>**3.121 g** | **Analytical Balance**<br>**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

## ZEROASSIGNIFICANTFIGURE

### 1. SIGNIFICANTZEROS:

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. NONSIGNIFICANTZEROS:

Decimal markers: (to the left or to the right of decimal point: **0.0 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 | 9x$10^3$ g |
| 0.0909 g | 9.0 x$10^3$ g |

9090 g

# SCIENTIFIC NOTATION

$\mathbf{A} \times 10^n$

**A** must satisfy strict conditions:

$$\boxed{\mathbf{1 \le A < 10}}$$

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

Several exponential notations are possible. Which is correctly written?

$51.2 \times 10^{12}$ mi

$512 \times 10^{11}$ mi

$5.12 \times 10^{13}$ mi

$0.512 \times 10^{14}$ mi

Consider: 0.0839 g

Several exponential notations are possible. Which is correctly written?

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

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

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

$0.839 \times 10^{-1}$ 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**)

## Multiplicationand Division

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

**Example1:**

Calculate the volume of a cylinder, given:

Radius (r) = 0.63 cm
Height (h) = 6.14 cm

$$V = \pi\ r^2\ h = \pi\ \underset{\substack{\text{2 SF}\\ \textbf{LAN}}}{(0.63\text{ cm})^2}\ \underset{\text{3 SF}}{(6.14\text{ cm})} = \underset{\text{calculator answer}}{7.655954\text{ cm}^3}$$

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

**Example2:**

Calculate the density of a liquid, given:

Mass (m) = 10.9387 g
Volume (V) = 10.00 mL

$$d = \frac{\overset{\overset{\text{6 SF}}{\downarrow}}{10.9837\text{ g}}}{\underset{\underset{\text{4 SF (LAN)}}{\uparrow}}{10.00\text{ mL}}} = 1.09387\text{ g/mL} \qquad \text{(calculator answer)}$$

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

## AdditionandSubtraction

**LAN = number with the fewest decimals**

**Example3:**

Add the following measurements:

**212. g ( 0 decimals) ————————> LAN**
2.1 g (1 decimal)
1.88 g (2 decimals)

215.98 g <———————— calculator answer

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

**Example4:**

Subtract the following measurements:

1.0947 g –
1.093 g **(3 decimals) ————————> LAN**

**0**.0017 g <———————— (calculator answer)

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

## CombinedCalculations

**Example5:**

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

Theoretical Value = 1.0943 g
Experimental Value = 1.0947 g
% Error = ?

$$\% \text{ Error} = \frac{\text{Exp - Th}}{\text{Th}} \text{x}100 = \frac{1.0947 - 1.0943}{1.0943} \text{x } 100 = \underset{\textbf{(5 SF)}}{\overset{\textbf{1 SF (LAN)}}{\frac{0.0004 \text{ g}}{1.0943 \text{ g}}}} \text{x}100 = 0.036553 \ \% \ \text{(calculater answer)}$$

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

**Example6:**

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

Theoretical Value = 2.70 $g/cm^3$
Experimental Value = 3.09 $g/cm^3$
% Error = ?

$$\% \text{ Error} = \frac{\text{Exp - Th}}{\text{Th}} \text{x}100 = \frac{\qquad\qquad}{} \text{x } 100 =$$

- 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. 51.234 → 51.2
- If the rounded digit is ≥5, the digit is increased. 51.38, 51.359, 51.3503 → 51.4

**Example1:**

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

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

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

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

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

**Example2:**

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:

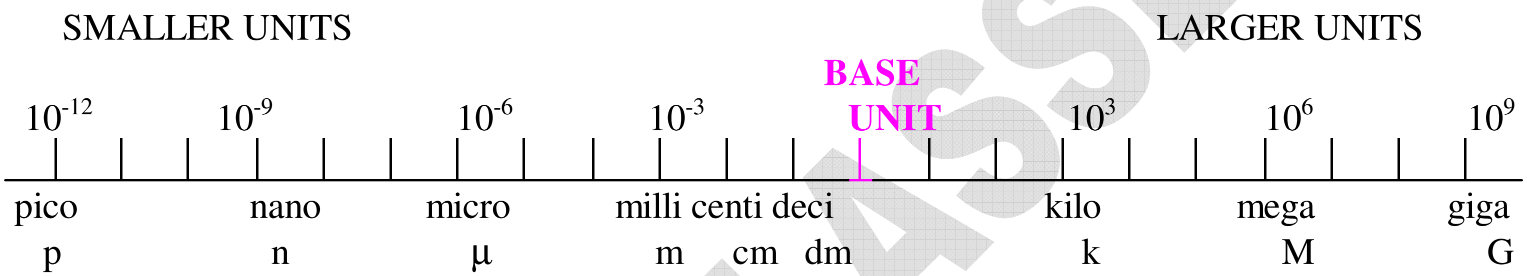
## 1. SEVENBASEUNITS

| | **Quantity** | **Unit** | **Abbreviation** |
|---|---|---|---|
| 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. MANYDERIVEDUNITS

| | **Quantity** | **Unit** | **Abbreviation** |
|---|---|---|---|
| 1. | Speed = Length/Time | meter/second | m/s |
| 2. | Volume =$(\text{Length})^3$ | $(\text{meter})^3$ | $m^3$ |
| 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:

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

1mm = 1,000 µm = $10^3$ µm OR 1 µm = 0.001 mm = $10^{-3}$ mm

1m = $10^6$ µm OR 1 µm = $10^{-6}$ m

**1m = $10^{-6}$ µm ⟶ IS FALSE**

Always think : - Which unit is larger ? (m) **1m = $10^6$ µm ⟶ IS CORRECT**

- Which unit is smaller ? (µm) **1 µm = 1 x $10^{-6}$ m ⟶ IS Also Correct**

## I. BASEUNITS

### 1.MeasurementofLength

Base unit: The meter = m

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

1 m = $10^2$ cm OR 1 cm = $10^{-2}$ m

1 m = $10^3$ mm OR 1 mm = $10^{-3}$ m

1 m = $10^6$ μm OR 1 μm = $10^{-6}$ m

1 m = $10^9$ nm OR 1 nm = $10^{-9}$ m

1 m = $10^{12}$ pm OR 1 pm = $10^{-12}$ m

Also used: the Angstrom, A

1 m = $10^{10}$ A OR 1 A = $10^{-10}$ m

- NOTE : The Angstrom IS NOT AN SI UNIT

### 2. MeasurementofMass

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

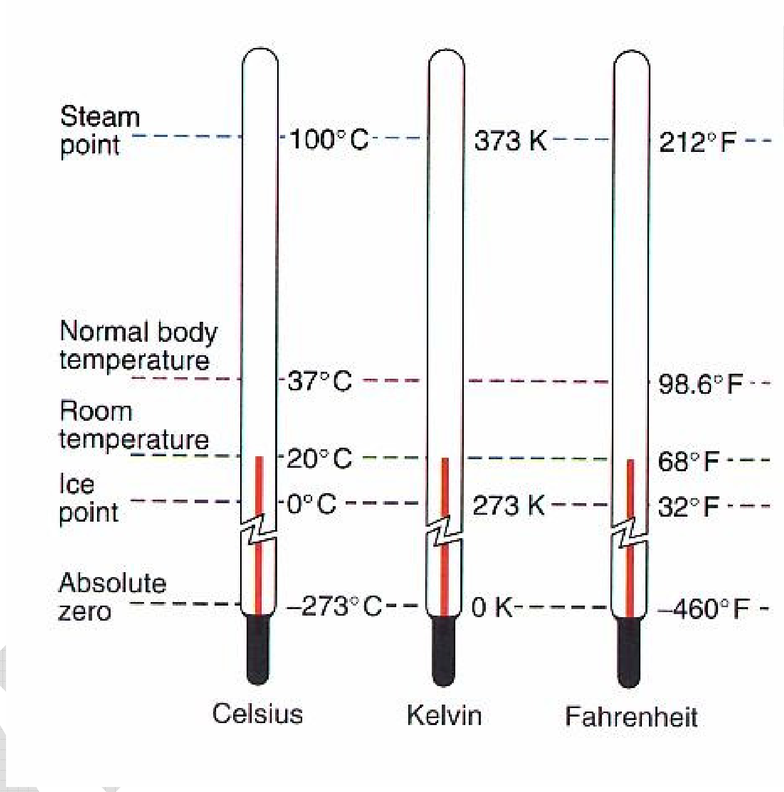
### 3. MeasurementofTime

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. MeasurementofTemperature

- 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

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

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

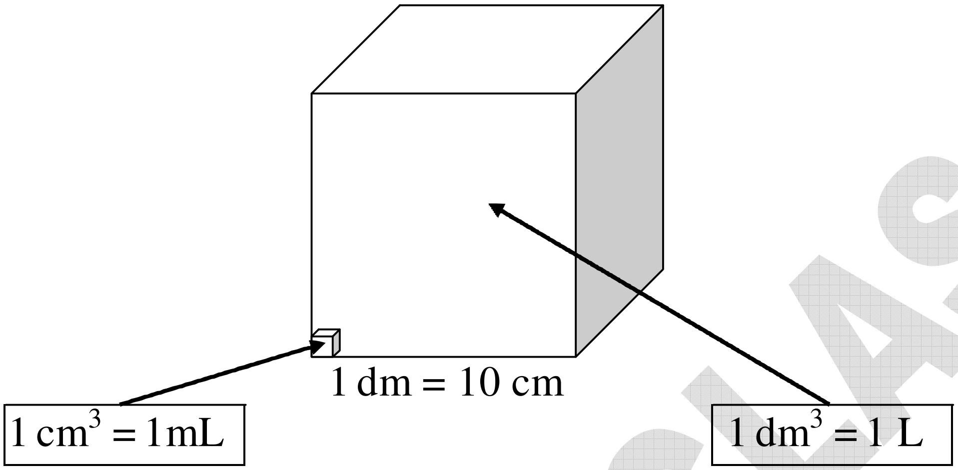
REMEMBER: -The Kelvin temperature is 273 degrees higher than the Celsius

$$K = {}^{o}C + 273 \qquad {}^{o}C = K - 273$$

## II. DERIVED UNITS

### 1. Volume

| | | |
|---|---|---|
| Base Unit : | $m^3$ | Not practical because it is very large |
| Commonly used: | $dm^3$ | Also called "THELITER(L)" |



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

$1\ L = 1{,}000\ mL$

**IMPORTANT RELATIONSHIPS TO REMEMBER:**

$1\ dm^3 = 1\ L$ $1\ dm^3 = 1000\ cm^3$ $1\ L = 1000\ mL$

$1\ cm^3 = 1\ mL$ $1\ cm^3 = 0.001\ dm^3$ $1\ mL = 0.001\ L$

### 2. Density (d):

Density is the mass of a unit volume

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

**Examples:**

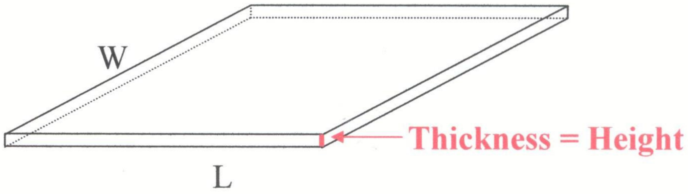
1. Calculate the density of a piece of glass with a mass of 6.65 g and a volume of 2.95 mL.

   m = 6.65 g
   V = 2.95 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 cm
   W = 14.39 cm
   m = 1.4939 g
   d = 2.70 g/cm$^3$

   **Thickness = Height = ?**



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

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

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

**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:

$$\cancel{\text{beginningunit}} \text{ x } \frac{\text{final unit}}{\cancel{\text{beginningunit}}} = \text{final unit}$$

↑

**conversion factor**

**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:

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

- 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:

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

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

$$\mathbf{2.50 \text{ x } 10^{-3}}\ \cancel{\text{cm}} \text{ x } \frac{\cancel{\text{m}}}{\cancel{\text{cm}}} \text{ x } \frac{\mu\text{m}}{\cancel{\text{m}}} = \mu\text{m}$$

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

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

- 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?