# SCIENTIFIC NOTATION

- Scientific Notation is a convenient way to express ***very large*** or ***very small*** quantities.

***General form:***

$$A \times 10^{n} \qquad 1 \leq A < 10 \qquad n = \text{integer}$$

***Using scientific notations:***

- Changing between conventional and scientific notation:

7**5,000,000** changes to 7.5 x $10^{7}$ (**7 to the left**)
0.**006**42 changes to 6.42 x $10^{-3}$ ( **3 to the right**)

- Addition and subtraction (NOT COVERED)
- Multiplication and division :
  1. Change numbers to exponential form.
  2. Multiply or divide coefficients.
  3. ***Add*** exponents if ***multiplying***, or ***subtract*** exponents if ***dividing***.
  4. If needed, reconstruct answer in ***standard*** exponential notation.

***Examples:***

1. Multiply 30,000 x 200,000

$$(3x10^{4})(2x10^{5}) = 6x10^{(4+5)} = 6x10^{9}$$

2. Divide 60,000 by 0.003

$$\frac{6x10^{4}}{3x10^{-3}} = \frac{6}{3}x10^{[4-(-3)]} = 2x10^{7}$$

***Follow-up Problems:***

1. $(5.5 \text{ x } 10^{3})(3.1 \text{ x } 10^{5}) =$

2. $(9.7 \text{ x} 10^{14})(4.3 \text{ x} 10^{-20}) =$

3. $\frac{2.6\text{x}10^{6}}{5.8\text{x}10^{2}} =$

4. $\frac{1.7\text{x}10^{-5}}{8.2\text{x}10^{-8}} =$

5. $(3.7\text{x } 10^{-6}) \text{ x } (4.0 \text{ x } 10^{8}) =$

6. $(8.75\text{x}10^{14})(3.6\text{x}10^{8}) =$

7. $\frac{1.48\text{x}10^{-28}}{7.25\text{x}10^{13}} =$

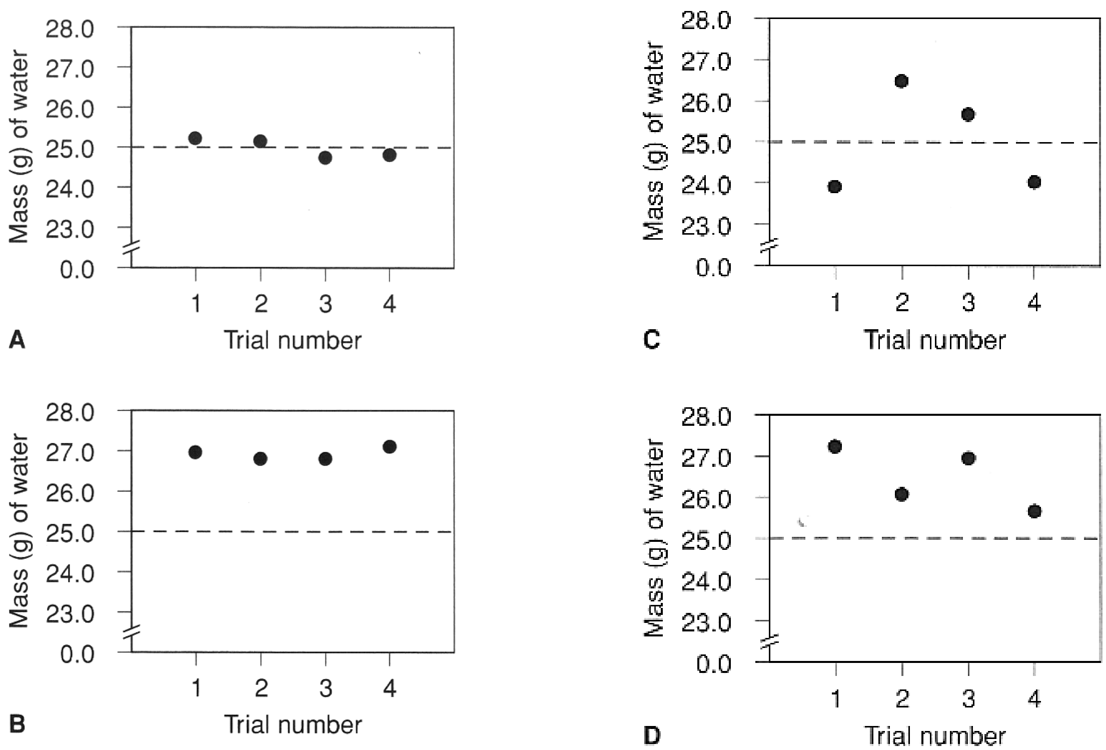
# ACCURACY & PRECISION

- For measurements to be useful, it is important that they be ***precise*** and ***accurate***.
- ***Accuracy*** is ***closeness*** of a measurement to an ***external standard***.
- ***Precision*** is ***closeness*** of a measurement to ***another similarly obtained measurement***.

Two ***types of error*** can affect measurements:

- ***Systematic errors***: those errors that are ***controllable***, and cause measurements to be ***either higher or lower than the actual*** value.
- ***Random errors***: those errors that are ***uncontrollable***, and cause measurements to be ***both higher and lower than the average*** value.

Evaluate the accuracy and precision of each set of data shown below:



# ERRORS IN MEASUREMENTS

Two kinds of quantities are used in science:

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

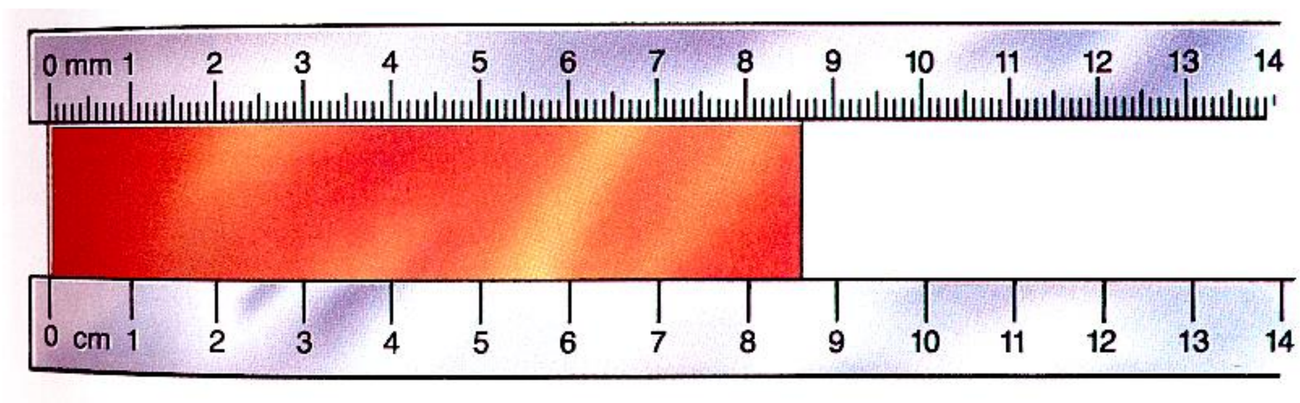
***Uncertainty in Measurements:***

- Every ***measurement*** has ***uncertainty*** because of instrument limitations, human error, and number of measurements.
- The uncertainty in a measurement appears in the last recorded digit.

15 ± 1 cm (14 cm or 16 cm)
15.3 ± 0.1cm (15.2 cm or 15.4 cm)

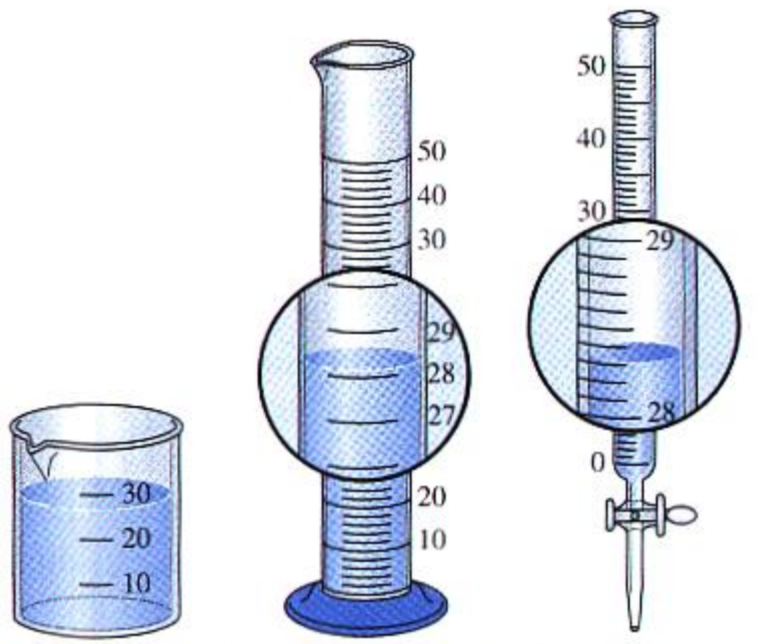
- An ***uncertainty*** of ***one unit*** is assumed in all measurements, unless otherwise specified.
- In reading a measurement scale, it is ***wrong*** to record ***more than one estimated digit***.
- The ***last*** digit is the ***estimated*** one.

8.65 cm




8.6 cm

# RECORDING MEASUREMENTS TO THE PROPER NO. OF DIGITS




(a) Beaker calibrated in 10-milliliter units (b) Graduated cylinder calibrated in milliliters (c) Buret calibrated in tenths of a milliliter

What is the correct value for each measurement shown above?

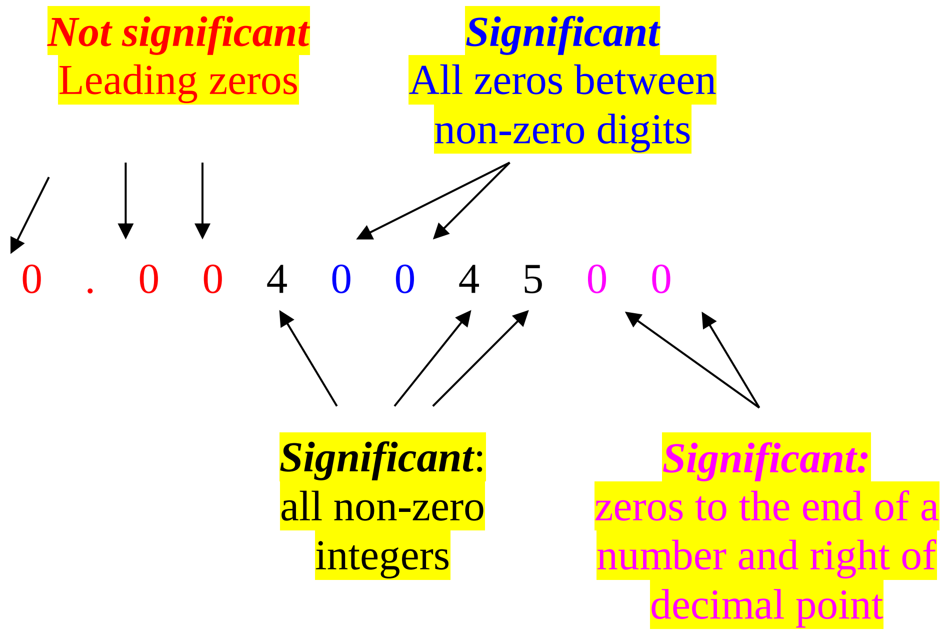
a) 28 mL (1 certain, 1 uncertain)

b) 28.2 mL (2 certain, 1 uncertain)

c) 28.31 mL (3 certain, 1 uncertain)

# SIGNIFICANT FIGURES

- Scientists use ***significant figures*** to express the ***precision*** of a measurement.
- ***Significant figures*** are the number of ***certa***in and ***uncertain digits***




***Examples:***

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

| | |
|---|---|
| 0.05082 in | 4 significant figures |
| 41.0 °C | 3 significant figures |
| 14.303 m | 5 significant figures |
| 0.00025 L | 2 significant figures |
| 150000 mg | ambiguous (should be written in scientific notation) |
| $1.5 \times 10^5$ mg | 2 significant figures |
| $1.50 \times 10^5$ mg | 3 significant figures |
| $1.500 \times 10^5$ mg | 4 significant figures |

# SIGNIFICANT FIGURES IN CALCULATIONS

***Multiplication and Division:***

- The measurement with the ***least certainty*** limits the certainty of the ***results***; or
- The answer must contain the ***same*** number of ***significant figures*** as in the measurement with the ***least number*** of significant figures.

***Examples:***

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 5.02 | x | 89.665 | x | 0.10 | = | 45.0118 | = | 45 |
| (3 sf) | | (5 sf) | | **(2 sf)** | | (calculator answer) | | **(2 sf)** |

| | | | | | | |
|---|---|---|---|---|---|---|
| 5.892 | ÷ | 6.10 | = | 0.96590 | = | 0.966 |
| (4 sf) | | **(3 sf)** | | (calculator answer) | | **(3 sf)** |

***Addition and Subtraction:***

- The answer must be rounded to the ***same number of decimal places*** as there are in the ***measurement*** with the ***fewest decimal places***.

***Examples:***

| | |
|---|---|
| 83.**5**<br>+ 23.28<br>106.**7**8 (calculator answer)<br>106.**8** (rounded answer) | 5.7**4**<br>0.8233<br>+2.651<br>9.2**1**4 (calculator answer)<br>9.2**1** (rounded answer) |
| 4.**8**<br>– 3.965<br>0.**8**35 (calculator answer)<br>0.**8** (rounded answer) | $\frac{1.039-1.020}{1.039} = \frac{0.019}{1.039} = 0.0182868 = 0.018$ |

# SIGNIFICANT FIGURES IN CALCULATIONS

**Rounding Off Rules**

When rounding to the correct number of significant figures:

- round down if the rounded digit is 4 or less.
- round up if the rounded digit is 5 or more

| | **3 sig. figs** | **2 sig. figs.** |
|---|---|---|
| 8.4234 rounds off to | 8.42 | 8.4 |
| 14.780 rounds off to | 14.8 | 15 |
| 3256 rounds off to | 3260 ($3.26 \times 10^3$) | 3300 ($3.3 \times 10^3$) |

***Examples:***
Perform the following operations to the correct number of significant figures:

1) 5.008 + 16.2 + 13.48 =

2) $\frac{3.15 \text{ x } 1.53}{0.78} =$

3) 104.45 mL – 0.838 mL + 46 mL =

4) $\frac{4.0 \text{ x } 8.00}{16} =$

# MEASUREMENTS

- ***Measurements*** are made by scientists to determine size, length and other ***properties*** of matter.
- For measurements to be useful, a measurement ***standard*** must be used.
- A ***standard*** is an exact quantity that people agree to use for ***comparison***.
- ***SI*** is the ***standard*** system of measurement used ***worldwide*** by scientists.

## *SI BASE UNITS*

| ***Measurement*** | ***Units*** | ***Symbol*** |
|---|---|---|
| Length | meter | m |
| Mass | kilogram | kg |
| Time | seconds | s |
| Temperature | kelvin | K |
| Amount of substance | mole | mol |

## *SI PREFIXES*

| ***Prefix*** | ***Symbol*** | ***Meaning*** | ***Multiplier*** |
|---|---|---|---|
| mega- | M | million | $10^6$ |
| kilo- | k | thousand | $10^3$ |
| hecto- | h | hundred | $10^2$ |
| deca- | da | ten | 10 |
| | | | 1 |
| deci- | d | tenth | $10^{-1}$ |
| centi- | c | hundredth | $10^{-2}$ |
| milli- | m | thousandth | $10^{-3}$ |
| micro- | μ | millionth | $10^{-6}$ |
| nano- | n | billionth | $10^{-9}$ |

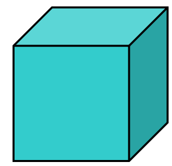
## *DERIVED UNITS*

| ***Measurement*** | ***Units*** | ***Symbol*** |
|---|---|---|
| Volume | liters | L |
| Density | grams/cc | $g/cm^3$ |

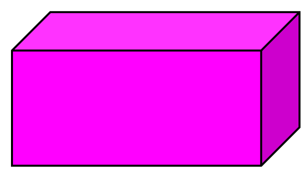
# VOLUME

- ***Volume*** is a measure of the ***amount of space*** occupied by an object.
- Volume is a ***derived*** quantity, with units of $cm^3$, $m^3$, $in^3$.
- The ***SI*** base unit of volume is ***Liter (L)*** which is equal to ***1000*** $cm^3$.
- Volume of various ***regular shapes*** can be calculated as follows:

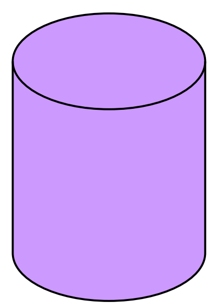
Cube $V = s \times s \times s$



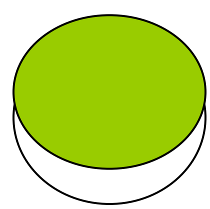
Rectangular solid $V = l \times w \times h$



Cylinder $V = \pi \times r^2 \times h$



Sphere $V = \frac{4}{3}\pi r^3$



# DENSITY

- ***Density*** is the ratio of ***mass*** of an object to its ***volume.***

$$\text{Density} = \frac{\text{mass}}{\text{volume}} \qquad d = \frac{m}{v}$$

- ***Density*** is an ***intensive*** property (i.e. ***independent*** of the ***amount*** of matter).
- ***Mass*** and ***volume*** are examples of ***extensive*** properties (i.e. dependent on the amount of matter).
- ***Density*** is a measure of how ***tightly packed*** an object's mass is.

***Examples:***

1. A copper sample has a mass of 44.65 g and a volume of 5.0 mL. What is the density of copper?

   m = 44.65 g $\qquad \mathbf{d = \frac{m}{v} =}$

   v = 5.0 mL

   d = ???

2. A silver bar with a volume of 28.0 $cm^3$ has a mass of 294 g. What is the density of this bar?

   m =

   v =

   d =

# CONVERSION FACTORS

- Many problems in chemistry and related fields require a change of units.
- Any unit can be converted into another by use of the appropriate **conversion factor**.
- Any equality in units can be written in the form of a fraction called a **conversion factor**. For example:

Equality: 1 m = 100 cm

Conversion factors: $\frac{1\text{ m}}{100\text{ cm}}$ or $\frac{100\text{ cm}}{1\text{ m}}$

**Metric-Metric**

Equality: 1 kg = 2.20 lb

Conversion factors: $\frac{1\text{ kg}}{2.20\text{ lb}}$ or $\frac{2.20\text{ lb}}{1\text{ kg}}$

**Metric-English**

- Sometimes a conversion factor is given as a percentage. For example:

Percent quantity: 18% body fat by mass

Conversion factors: $\frac{18\text{ kg body fat}}{100\text{ kg body mass}}$ or $\frac{100\text{ kg body mass}}{18\text{ kg body fat}}$

**Percentage**

# CONVERSION OF UNITS

- Problems involving conversion of units and other chemistry problems can be solved using the following step-wise method:

    1. Determine the intial unit given and the final unit needed.
    2. Plan  a sequence of steps to convert the initial unit to the final unit.
    3. Write the conversion factor for each units change in your plan.
    4. Set up the problem by arranging cancelling units in the numerator and denominator of the steps involved.

$$\require{cancel}\cancel{\text{given unit}} \times \frac{\text{final unit}}{\cancel{\text{given unit}}} = \text{final unit}$$

↑

**conversion factor**

***Examples:***

1. Convert 164 lb to kg (1 kg = 2.20 lb)

Step 1: Given 164 lb Find kg

Step 2: lb → [Metric – English factor] → kg

Step 3: $\frac{1\ \text{kg}}{2.20\ \text{lb}}$ or $\frac{2.20\ \text{lb}}{1\ \text{kg}}$

Step 4: $164\ \text{lb} \times \frac{1\ \text{kg}}{2.20\ \text{lb}} = 74.5\ \text{kg}$

2. Convert 5678 m to km.

Step 1: Given Find

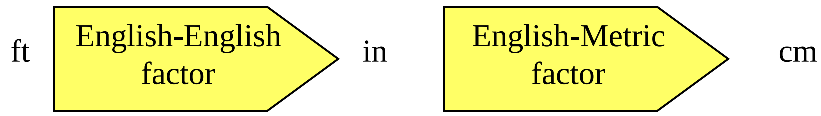
Step 2 & 3:

Step 4: m x ———— = km

3. How many centimeters are in 2.0 ft? (1 in=2.54 cm)

Step 1: Given 2.0 ft Find cm

Step 2:




Step 3: $\frac{1\ \text{ft}}{12\ \text{in}}$ and $\frac{1\ \text{in}}{2.54\ \text{cm}}$

Step 4: 2.0 ft x ______ x ______ = cm

4. Bronze is 80.0% by mass copper and 20.0% by mass tin. A sculptor is preparing to cast a figure that requires 1.75 lb of bronze. How many grams of copper are needed for the brass figure?

Step 1: Given Find

Step 2:

Step 3:

Step 4: 1.75 lb bronze x ______ x ______ = g copper

# UNITS RAISED TO A POWER

- When converting quantities with units raised to a power (e.g. $cm^3$), the conversion factor must also be raised to that power. For example:

$$2.54 \text{ cm} = 1 \text{ in}$$

$$(2.54 \text{ cm})^3 = 1 \text{ in}^3$$

$$16.387 \text{ cm}^3 = 1 \text{ in}^3$$

***Examples:***

1. A large pizza has a surface area of 110 $in^2$. What is this area in $cm^2$?

$$110 \text{ in}^2 \times \left(\frac{2.54 \text{ cm}}{1 \text{ in}}\right)^2 = 709.7 \text{ cm} \xrightarrow[\text{2 sig figs}]{\text{round to}} 710 \text{ cm}^2$$

2. How many cubic inches are there in 3.25 $yd^3$?

3. A classroom has a volume of 285 $m^3$. What is this volume in $cm^3$?

# DENSITY AS A CONVERSION FACTOR

- Density of a substance can be used as a conversion factor between mass and volume. Problems below show some examples of this.

***Examples:***

1. If the density of gold is 19.3 g/$cm^3$, how many grams does a 5.00 $cm^3$ nugget weigh?

2. The gasoline in an automobile gas tank has a mass of 60.0 kg and a density of 0.752 g/$cm^3$. What is the volume of the tank in $cm^3$?

3. If the density of milk is 1.04 g/mL, what is the mass of 0.50 qt of milk? (1L = 1.06 qt)