

## Measurements

Measurements are comparisons of properties against accepted standards, called units.

### ENGLISH / US SYSTEM OF UNITS:

$$1 \text{ foot} = 12 \text{ in}$$

$$1 \text{ yard} = 3 \text{ ft}$$

$$1 \text{ mile} = 1760 \text{ yd}$$

$$5280 \text{ ft} = 1 \text{ mi}$$

So what's the problem?

The English system is hard to learn because it contains lots of independent units used to measure the same thing - and they don't relate to one another in any meaningful way.

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English units are nonstandard and difficult to use. Solution?

## THE METRIC SYSTEM

Metric Base Units:

|             |           |    |
|-------------|-----------|----|
| Length      | meter     | m  |
| Mass        | *kilogram | kg |
| Temperature | Kelvin    | K  |
| Time        | second    | s  |

All metric units are made up of COMBINATIONS of BASE UNITS!

\*we usually treat the gram as if it's the base unit for mass!

- One meter is approximately 3.3 feet.
- One kilogram is approximately 2.2 pounds.

What about SIZE?

Metric units may be made larger or smaller by adding PREFIXES.

A few common metric prefixes:

|        |           |       |
|--------|-----------|-------|
| mega-  | $10^6$    | M     |
| kilo-  | $10^3$    | k     |
| centi- | $10^{-2}$ | c     |
| milli- | $10^{-3}$ | m     |
| micro- | $10^{-6}$ | $\mu$ |

Bigger units

MEMORIZE the common metric prefixes listed in the study guide

smaller units

"mc" also means  $10^{-6}$

Applying prefixes

$$1 \text{ m} = \text{m}$$

$$1 \text{ cm} = 10^{-2} \text{ m} \left( \frac{1}{100} \text{ m} \right)$$

$$1 \text{ km} = 10^3 \text{ m} \left( 1000 \text{ m} \right)$$

## Scaling units with metric prefixes ... examples

The distance between here and Columbia, SC is about 107,000 meters. What metric unit would be best suited for a distance like this?

$$k = 10^3 \text{ (1000)}$$

$$107 \text{ km}$$

By "best suited", we mean a metric unit that would represent the number without many beginning or end zeros. These kinds of numbers are easier for us to remember!

A piece of chalk is 0.080 meters long. What metric unit would be best suited for this length?

$$c = 10^{-2} \text{ (1/100)}$$

$$8.0 \text{ cm}$$

## Derived Units

- are units that are made up of combinations of metric base units with each other and/or with prefixes

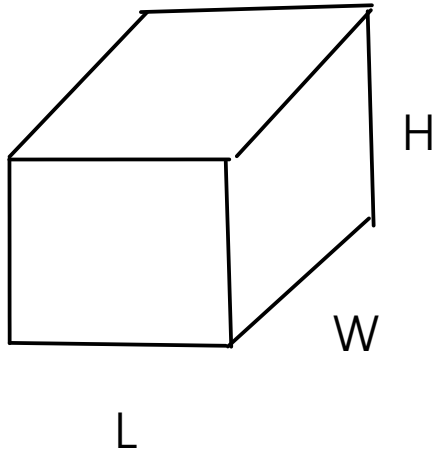
velocity:  $\frac{\text{miles}}{\text{hr}}$      $\frac{\text{km}}{\text{hr}}$      $\left(\frac{\text{m}}{\text{s}}\right)$      $\frac{\text{length}}{\text{time}}$

Two derived units are particularly important in general chemistry:

1) VOLUME

2) DENSITY

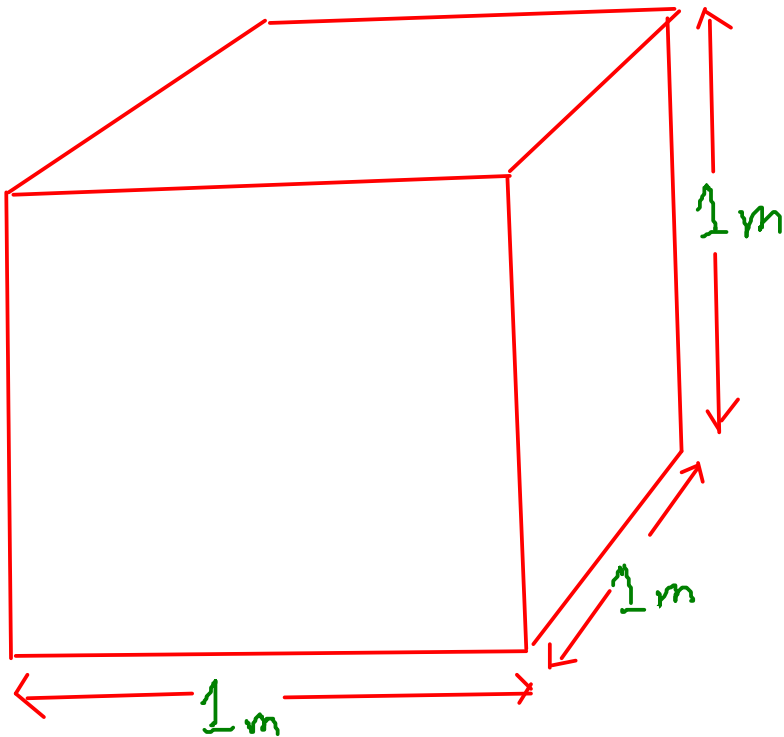
# VOLUME



$$\text{VOLUME} = L \times W \times H$$

What are the units of volume in the metric system?

$$\begin{aligned}\text{VOLUME} &= \text{meter} \times \text{meter} \times \text{meter} \\ &= \text{m}^3 \text{ "cubic meters"}\end{aligned}$$



Cubic meters are much too large for laboratory-scale or medical work.

## Practical issues for volume units

- Cubic meters are too large! A meter is very similar in length to a yard, so a cubic meter is a cube that is approximately a yard long on each side!

A smaller unit For volume?

Cubic decimeters!  $\text{dm}^3$

(decimeter =  $\frac{1}{10}$  meter)

Cubic decimeters are given the name "liters", abbreviation "L"

In the lab, we typically need an even smaller unit than the liter, so we use milliliters (mL)

$\text{mL}$   
cubic centimeter  
=  
milliliter

$$1 \text{ mL} = 10^{-3} \text{ L}$$

-or-

$$1000 \text{ mL} = 1 \text{ L}$$

## DENSITY

- Density is a measure of the concentration of matter; of how much matter is present in a given space
- Density is defined as the MASS per unit VOLUME, or ...

$$\text{Density} = \frac{\text{mass}}{\text{Volume}}$$

What are the metric units of DENSITY?

$$\text{DENSITY} = \frac{\text{kg}}{\text{m}^3}$$

← base unit of MASS

← simplest VOLUME unit

Issues with kg per cubic meter:

- 1) Cubic meters are not routinely used in the lab because they're too big!
- 2) We don't use kilograms in the lab either. A typical lab balance (analytical balance) has a maximum capacity of about 200 grams.



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In the lab, we typically measure masses as grams and volumes as milliliters, so the density unit we will use most often is:

$$\frac{g}{mL}$$

$$\left( \frac{g}{cm^3} \right)$$

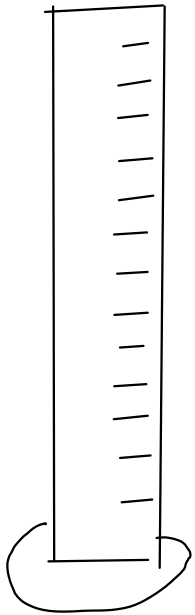
$$\left( \frac{g}{cc} \right)$$

A useful density to remember:

WATER at room temp: Density =  $1 \frac{g}{mL}$

## Measuring density

... of a liquid



1) Measure mass of empty cylinder

$$\text{mass} = 97.35 \text{ g}$$



2) Fill cylinder and measure volume of liquid

$$\text{volume} = 25.3 \text{ mL}$$

3) Measure mass of filled cylinder

$$\text{mass} = 130.55 \text{ g}$$

4) Subtract to find mass of liquid

$$\begin{array}{r} 130.55 \text{ g} \\ - 97.35 \text{ g} \\ \hline 33.20 \text{ g} \end{array}$$

5) Density = mass liquid / volume liquid

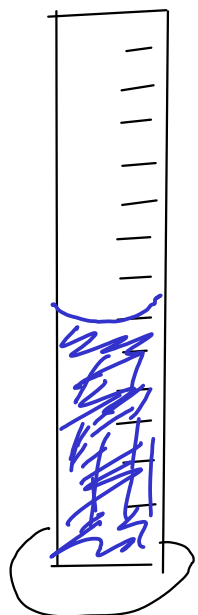
$$\text{Density} = \frac{33.20 \text{ g}}{25.3 \text{ mL}} = 1.31 \text{ g/mL}$$

...of an object



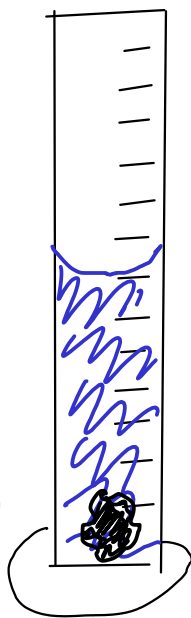
1) Measure mass  
of object

$$\text{mass} = 9.78 \text{ g}$$



2) Partially fill cylinder  
with liquid, record volume.

$$\text{volume} = 25.0 \text{ mL}$$



3) Put object into cylinder, record new  
volume

$$\text{volume} = 26.6 \text{ mL}$$

4) Subtract to find volume of object

$$\begin{array}{r} 26.6 \text{ mL} \\ - 25.0 \text{ mL} \\ \hline 1.6 \text{ mL} \end{array}$$

5) Density = mass object / volume object

$$\text{Density} = \frac{9.78 \text{ g}}{1.6 \text{ mL}}$$

$$= 6.1 \text{ g/mL}$$