Derived Units

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

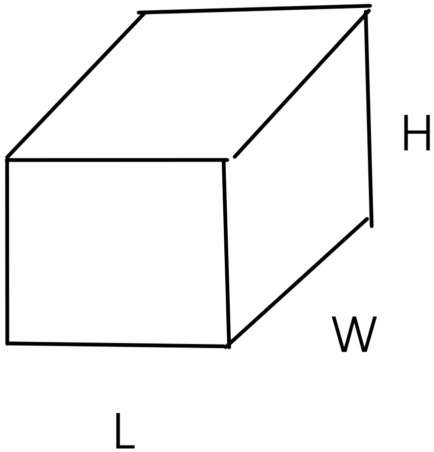
Example: speed $\frac{miles}{hr}$, $\frac{Km}{hr}$ $\left(\frac{length}{time}\right)$, $\frac{m}{s}$

Two derived units are particularly important in introductory chemistry:

1) VOLUME

2) DENSITY

VOLUME



VOLUME = L × W × H

What are the units of volume in the metric system?

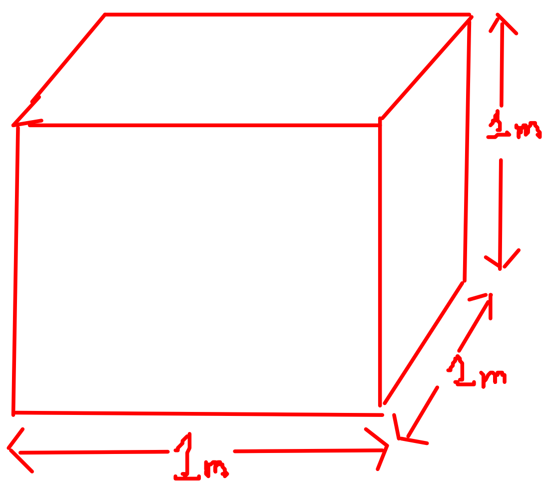
L = LENGTH. Base unit of length: METER (m)

W = WIDTH. Also a length unit; METER

H = HEIGHT. Also a length unit; METER

VOLUME = (m) × (m) × (m) = m^3 "cubic meter"

(L) (W) (H)



... but the CUBIC METER is a LARGE unit for lab-scale work. We would like to use a more friendly unit.

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! dm^3

(decimeter = 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)

"cc"
cubic centimeter
=
milliliter

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

-or-

$1000\ mL = 1\ L$

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?

mass: kilograms (kg)

volume: cubic meter (m^3)

So, density unit = $\frac{kg}{m^3}$

We don't usually use either kilograms or cubic meters in the lab, since both are large units. Instead, we scale these down.

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

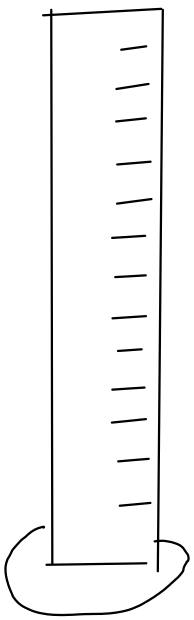
$$\frac{g}{mL}$$ same as $$\frac{g}{cm^3}$$

A useful density to remember:

WATER at room temp: Density = 1 g/mL

Measuring density

... of a liquid



1) Measure mass of empty cylinder

mass = 97.35 g

2) Fill cylinder and measure volume of liquid

volume = 25.3 mL

3) Measure mass of filled cylinder

mass = 130.55 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

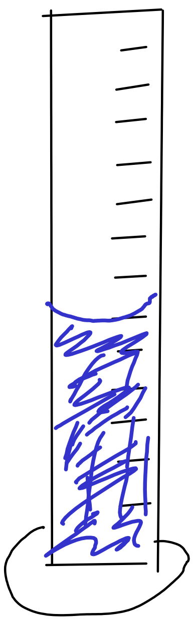
$$\text{Density} = \frac{33.20\ \text{g}}{25.3\ \text{mL}}$$

$$= \boxed{1.31\ \text{g/mL}}$$

...of an object

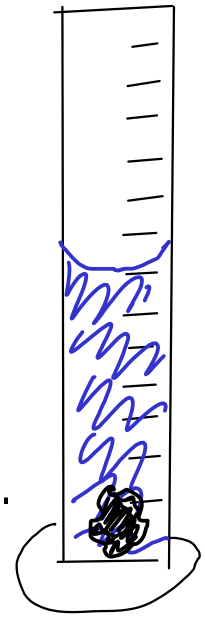
1) Measure mass of object

mass = 9.78 g



2) Partially fill cylinder with liquid, record volume.

volume = 25.0 mL



3) Put object into cylinder, record new volume

volume = 26.6 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

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

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

Converting from one unit to another

We will use the method of dimensional analysis, sometimes called the factor-label method.... or, the "drag and drop" method!

Dimensional analysis uses conversion factors to change between one unit and another

What's a conversion factor? A simple equality.

Example

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

Conversion factors in metric

In the metric system, conversion factors between units may always be made from the metric prefixes!

For example, "kilo-" means 10^3

$$k = 10^3$$

so

$$km = 10^3 m$$

$$kg = 10^3 g$$

$$ks = 10^3 s$$

$$kL = 10^3 L$$

Just apply the prefix to the base unit!

How do we actually USE a conversion factor?

$$cm = 10^{-2}\,m$$

Convert 15.75 m to cm

$$15.75\,m \times \frac{cm}{10^{-2}\,m} = 1575\,cm$$

DRAG AND DROP!

Put what you want to cancel on the bottom, then ...

... put what it equals on the top!

Convert 0.01893 kg to g

$$kg = 10^{3}\,g$$

$$0.01893\,kg \times \frac{10^{3}\,g}{kg} = 18.93\,g$$

Convert 14500 mg to kg

$mg = 10^{-3}g \qquad kg = 10^{3}g$

$$14500\ mg \times \frac{10^{-3}\ g}{mg} \times \frac{kg}{10^{3}\ g} = \boxed{0.0145\ kg}$$

Cancels mg

Cancels g

If you have TWO prefixes in your problem, you will apply TWO conversion factors in your solution!

Convert 0.147 mm to μm

μ — micro-

$mm = 10^{-3}m \qquad \mu m = 10^{-6}m$

$$0.147\ mm \times \frac{10^{-3}\ m}{mm} \times \frac{\mu m}{10^{-6}\ m} = \boxed{147\ \mu m}$$