Derived Units

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

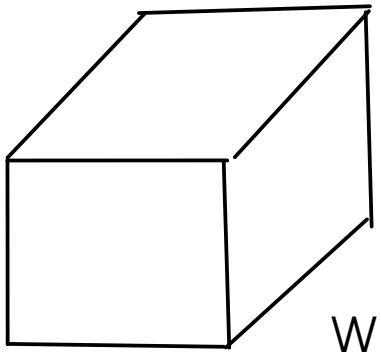
velocity: $\frac{\text{miles}}{\text{hr}}$ $\frac{\text{km}}{\text{hr}}$ $\left(\frac{\text{m}}{\text{s}}\right)$ $\frac{\text{length}}{\text{time}}$

Two derived units are particularly important in general chemistry:

1) VOLUME

2) DENSITY

VOLUME

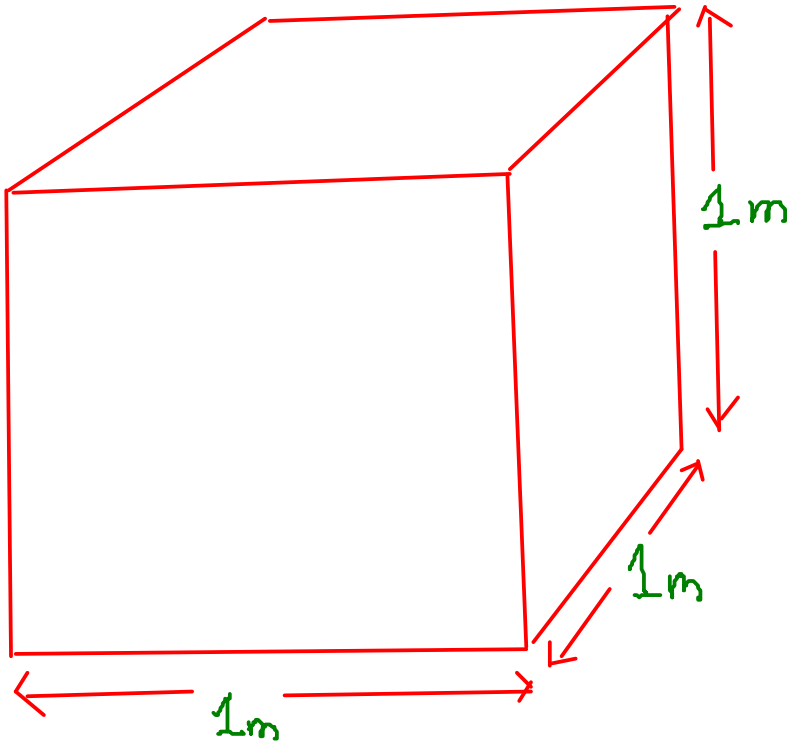


VOLUME = L × W × H

What are the units of volume in the metric system?

VOLUME = (m) × (m) × (m)

= m^3 ("cubic meters")



CUBIC METERS are a large unit. They're too large for typical lab-scale work. We need to scale the volume unit down for everyday 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! 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?

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

Base unit of mass

Simplest volume unit

... but we typically don't measure mass in kilograms or volume in cubic meters in the lab! (A typical laboratory balance has a maximum capacity of 200 g - 0.2 kg...)

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

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

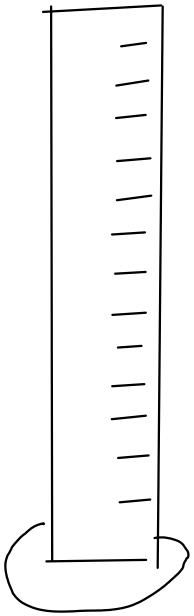
$$\left(\frac{g}{cm^3}\right) \quad \left(\frac{g}{cc}\right)$$

A useful density to remember:

WATER at room temp: Density = 1 g/mL

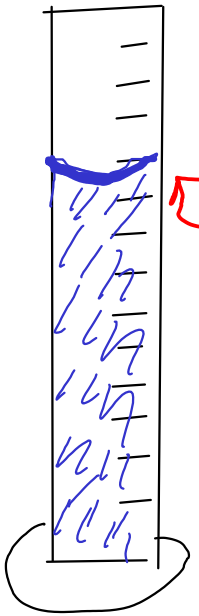
Measuring density

... 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

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

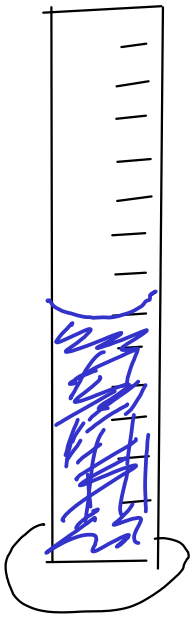
5) Density = mass liquid / volume liquid

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

...of an object

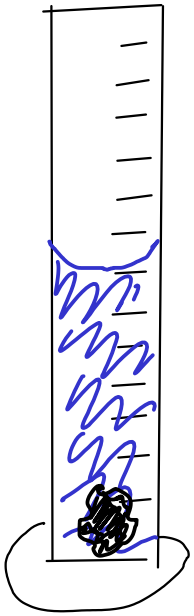
1) Measure mass of object

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

$$k_g = 10^3\ g$$

$$k_m = 10^3\ m$$

$$k_L = 10^3\ L$$

$$k_s = 10^3\ s$$

Just apply the prefix to the base unit!

How do we actually USE a conversion factor?

Convert 15.75 m to cm

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

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

* Similar to...

If X = 2, then

$$\frac{X}{2} = 1$$

15.75 / EE −2 .. on TI-83

* This fraction equals one, so multiplying by it does not change the VALUE of the number, only its UNITS!

Convert 0.01893 kg to g

$1\ kg = 10^{3}\ g$

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

DRAG AND DROP

- Drag the part of the factor that you want to cancel out to the BOTTOM.
- Then, drag the other half of the factor to the TOP

Convert 14500 mg to kg

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

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

Convert 0.147 cm^2 to m^2

$cm = 10^{-2} m$

$cm^2 = (10^{-2})^2 m^2$

.. .same as applying the factor twice

$$0.147\ cm^2 \times \frac{10^{-2} m}{cm} \times \frac{10^{-2} m}{cm} = 1.47 \times 10^{-5}\ m^2$$

$0.0000147\ m^2$

For squared units, we have to convert BOTH PARTS of the unit, so we use the factor twice. Think of square centimeters as:

$cm \times cm$

For cubed units, apply the factor three time.

8.45 kg to μg

$kg = 10^{3}\ g$ $\quad \mu g = 10^{-6}\ g$

$$8.45\ kg \times \frac{10^{3}\ g}{kg} \times \frac{\mu g}{10^{-6}\ g} = 8450000000\ \mu g = 8.45 \times 10^{9}\ \mu g$$

88100 kHz to MHz

$kHz = 10^{3}\ Hz$ $\quad MHz = 10^{6}\ Hz$ | $Hz : s^{-1}$ (Frequency)

$$88100\ kHz \times \frac{10^{3}\ Hz}{kHz} \times \frac{MHz}{10^{6}\ Hz} = 88.1\ MHz$$