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?

Km = 10^3 m (1000 m)

107 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?

cm = 10^{-2} m (1/100 m)

8.0 cm

Derived Units

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

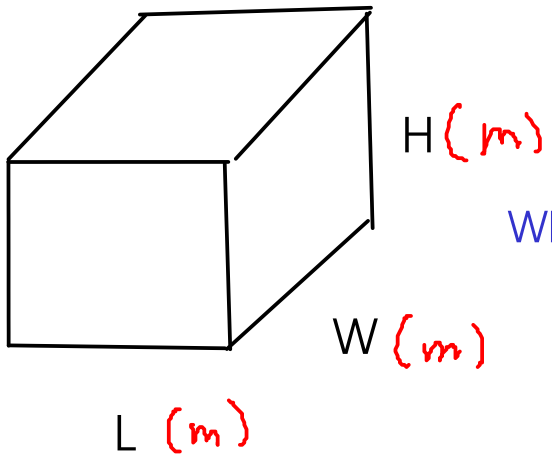
velocity: $\frac{miles}{hr}$ $\frac{km}{hr}$ $\left(\frac{m}{s}\right)$ $\frac{length}{time}$

Two derived units are particularly important in general chemistry:

1) VOLUME

2) DENSITY

VOLUME

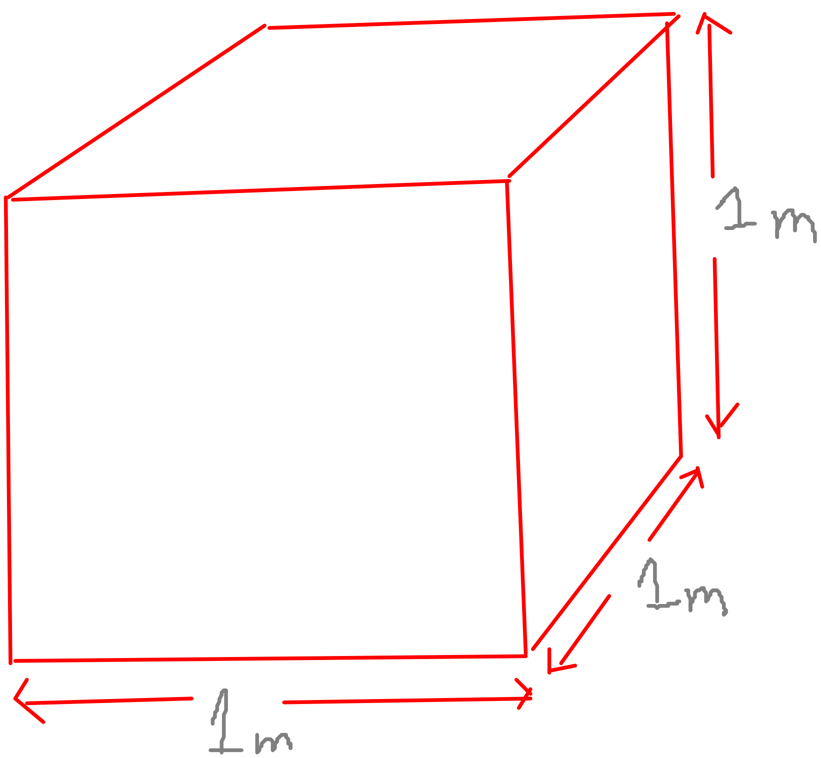


VOLUME = L × W × H

What are the units of volume in the metric system?

VOLUME = (m) × (m) × (m)

= m^3 "cubic meters"



CUBIC METERS are far too large for laboratory (and medical) work, so we will scale the unit down to something more usable.

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?

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

kg ← Base unit of mass

m^3 ← Simplest volume unit

.. but we typically don't measure volumes in cubic meters in the lab. We also don't usually measure masses in kilograms, either!

(A typical laboratory analytical balance has a maximum capacity of about 200 grams!)

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

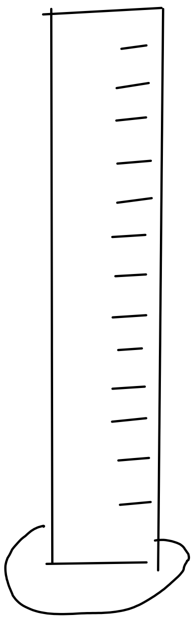
$$\frac{g}{mL} \quad \left(\frac{g}{cm^3}\right) \quad \left(\frac{g}{cc}\right)$$

A useful density to remember:

WATER at room temp: Density = 1 g/mL

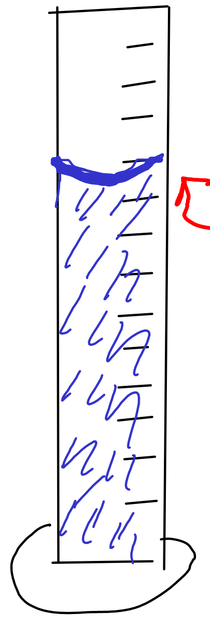
Measuring density

... 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

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

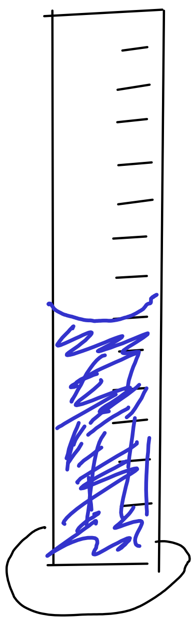
5) Density = mass liquid / volume liquid

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

...of an object

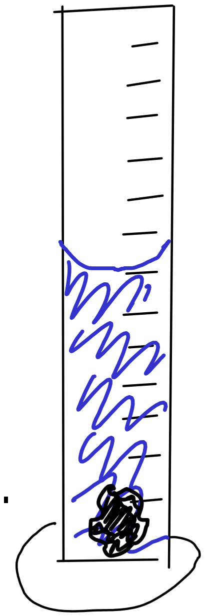
1) Measure mass of object

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 in = 1 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

$$kg = 10^3 g$$

$$km = 10^3 m$$

$$kL = 10^3 L$$

$$ks = 10^3 s$$

Just apply the prefix to the base unit!

How do we actually USE a conversion factor?

Convert 15.75 m to cm

$cm = 10^{-2} m$

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

* Similar to...

If X = 2, then

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

$15.75 / \boxed{EE} -2$ .. 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

$kg = 10^{3} g$

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

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

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

$$14500\,mg \times \frac{10^{-3}\,g}{mg} \times \frac{kg}{10^{3}\,g} = 0{,}0145\,kg$$

Convert 0.147 cm^2 to m^2

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

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

For squared units, we have to convert BOTH PARTS of the squared unit!
Think of square centimeters as

$cm \times cm$

... and it makes sense. For cubed units, just apply the factor THREE times!

8.45 kg to μg

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

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

$8.45 \times 10^9\ \mu g$

88100 kHz to MHz

$Hz = s^{-1}$
(frequency)