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

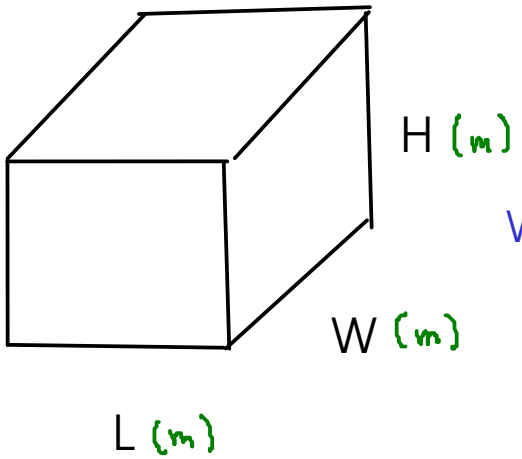
velocity: $\frac{\text{miles}}{\text{hr}}$ $\frac{\text{km}}{\text{hr}}$ $\left(\frac{\text{m}}{\text{s}}\right)$ $\frac{\text{length}}{\text{time}}$

Two derived units are particularly important in general chemistry:

1) VOLUME

2) DENSITY

VOLUME

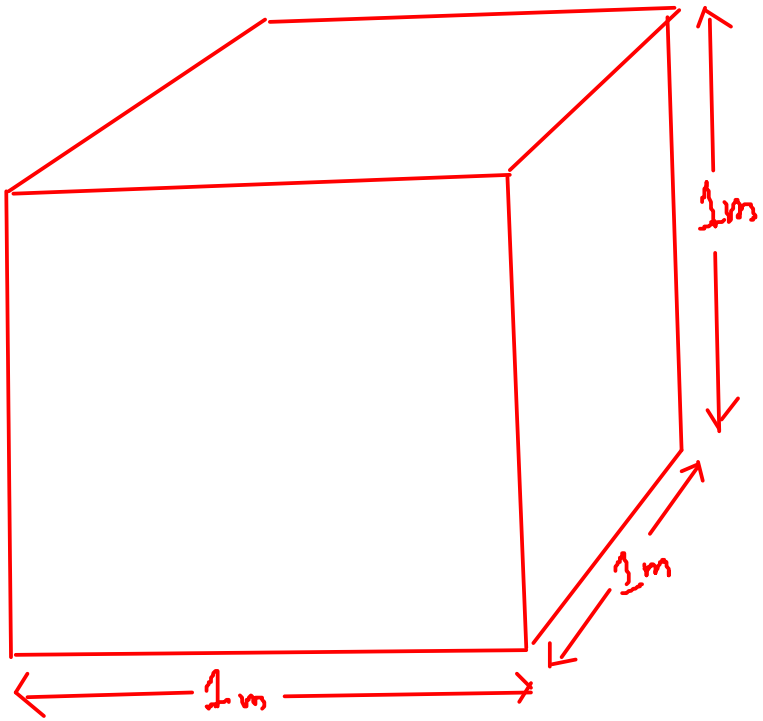


VOLUME = L × W × H

What are the units of volume in the metric system?

VOLUME = (m) x (m) x (m)

= m^3 (cubic meters)



CUBIC METERS are too large for lab-scale work.
We need a smaller 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?

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

Kg ← base unit of mass

m^3 ← volume

... but these are not the units you would typically use in a lab. Our lab scales can weigh a maximum of about 0.200 kg.

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

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

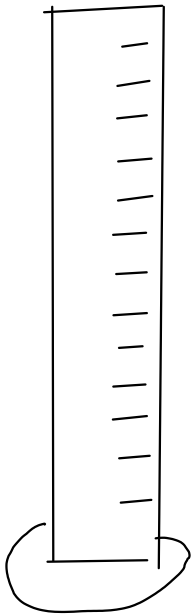
$$\left(\frac{g}{cm^3}\right)$$

A useful density to remember:

WATER at room temp: Density = 1 g/mL

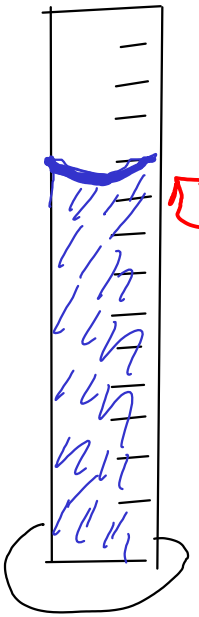
Measuring density

... 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

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

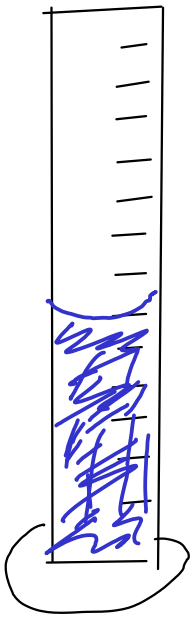
5) Density = mass liquid / volume liquid

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

...of an object

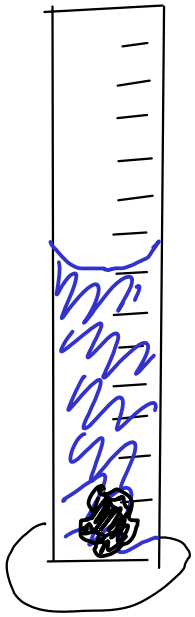
1) Measure mass of object

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

$$k_m = 10^3\ m$$

$$k_g = 10^3\ g$$

$$k_s = 10^3\ s$$

$$kL = 10^3\ L$$

Just apply the prefix to the base unit!

How do we actually USE a conversion factor?

Convert 15.75 m to cm

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

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

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

* Similar to...

If X = 2, then

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

15.75 / EE −2 .. on TI-83

Convert 0.01893 kg to g

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

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

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

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

Convert 0.147 cm^2 to m^2 $\quad cm = 10^{-2} m$

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

$$(0.0000147\ m^2)$$

Always use the BASE here, not squared or cubed units...

or

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

NOT

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

We have to use the factor twice to convert BOTH PARTS of the squared unit: $cm^2 = cm \times cm$

For CUBED units, use the factor three times!