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?

$km = 10^3 m$ $(1000 m)$

$\boxed{107\ km}$

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?

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

$\boxed{8.0\ cm}$

Derived Units

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

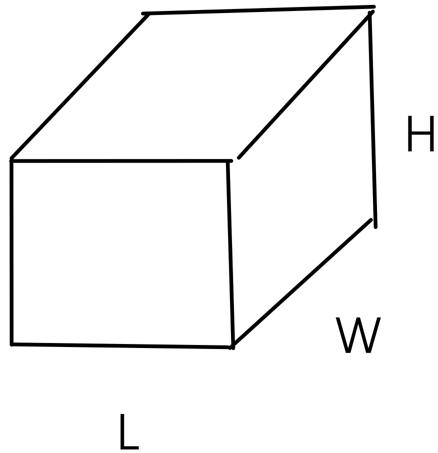
Example: speed $\frac{\text{miles}}{\text{hr}}$, $\frac{\text{km}}{\text{hr}}$ $\left(\frac{\text{length}}{\text{time}}\right)$ $\frac{\text{m}}{\text{s}}$

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?

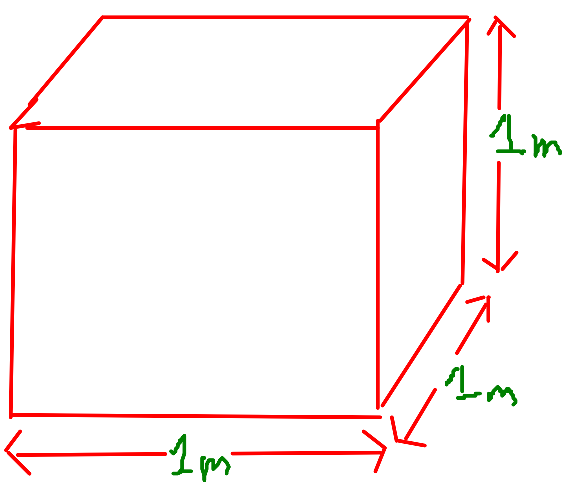
L = LENGTH. = m (meter) Base unit of length is the meter

W = WIDTH. = m ... also a length

H = HEIGHT. = m ... also a length

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

= m^3 "cubic meters"



... but the CUBIC METER is much too large for routine laboratory and medical 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?

$\boxed{\text{cubic decimeters!}}$ 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 : kilogram (kg)

volume : cubic meter (m^3)

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

We don't usually measure mass in kilograms (or volume in cubic meters) in the lab! In fact, our lab balances can handle only 200 grams MAXIMUM!

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

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

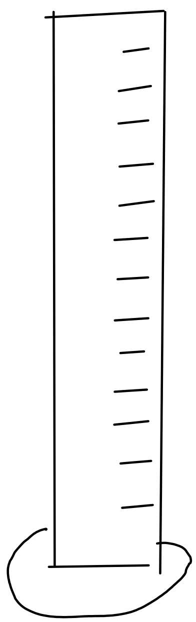
same as $\frac{g}{cm^3}$ or $\frac{g}{cc}$

A useful density to remember:

$$\boxed{\text{WATER at room temp: Density} = 1\ g/mL}$$

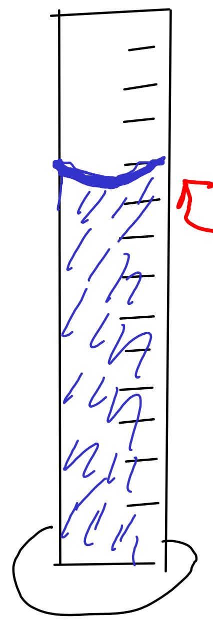
Measuring density

... 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

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

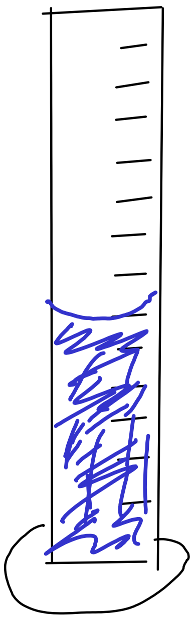
5) Density = mass liquid / volume liquid

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

...of an object

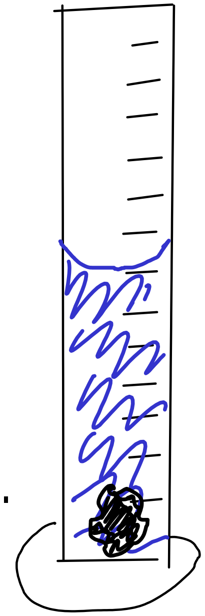
1) Measure mass of object

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

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

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

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

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

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

$$km = 10^3 m$$

$$kL = 10^3 L$$

$$ks = 10^3 s$$

$$kg = 10^3 g$$

Just apply the prefix to the base unit!

How do we actually USE a conversion factor?

Convert 15.75 m to cm

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

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

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

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

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

Convert 14500 mg to kg

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

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

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-

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

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

Convert 38.47 in to m, assuming 2.54 cm = 1 in

$2.54\ cm = in \qquad cm = 10^{-2}\ m$

$$38.47\ \cancel{in} \times \frac{2.54\ c\cancel{m}}{\cancel{in}} \times \frac{10^{-2}\ m}{c\cancel{m}} = \boxed{0.9771\ m}$$

Even though English units are involved, we can solve this problem the same way we solved the previous problem where only metric units were used!

20 Even if you're unfamiliar with the metric units involved in a problem, you can still do conversions easily.

88100 kHz to MHz

$kHz = 10^3 Hz \quad MHz = 10^6 Hz \qquad Hz = \text{hertz } (1/s)$

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

0.004184 kJ to J

$kJ = 10^3 J \qquad J = \text{joule (energy)}$

$$0.004184 \cancel{kJ} \times \frac{10^3 J}{\cancel{kJ}} = \boxed{4.184\ J}$$

Practical applications of dimensional analysis: Drug calculations.

Example: A patient is ordered 40 mg of codeine phosphate by subcutaneous injection. 50 mg in 1 mL liquid is available. How much of this liquid should be adminstered?

We're trying to convert the amount to be administered (40 mg) to a volume!

So what's the conversion factor?

We can use "50 mg in 1 ml" as a conversion factor ... it tells us how many mL of solution contain a certain amount of drug!

$$50 \text{ mg drug} = 1 \text{ mL}$$

$$40 \cancel{\text{mg drug}} \times \frac{1 \text{ mL}}{50 \cancel{\text{mg drug}}} = \boxed{0.8 \text{ mL}}$$

Hint: Conversion factors often contain words like "in" or "per"!

Mileage

A car (averaging 17.5 miles per gallon) is traveling 50 miles per hour. How many gallons of gas will be used on a trip that lasts 0.75 hours?

$17.5\ mi = gal \qquad 50\ mi = hr$

$$0.75\ \cancel{hr} \times \frac{50\ \cancel{mi}}{\cancel{hr}} \times \frac{gal}{17.5\ \cancel{mi}} = 2.1\ gal$$

If gas is $3.45 per gallon, what is the cost of the trip?

$\$3.45 = gal$

$$2.1\ \cancel{gal} \times \frac{\$3.45}{\cancel{gal}} = \boxed{\$7.39}$$