Part A: The "Mole" is an example of a "Counting Unit"

"Counting units" are words that represent a given number of things. For example a *dozen* is always 12 things. Once you know what a dozen means, you can have a dozen of anything: a dozen donuts, a dozen books, a dozen cars.... Counting units can be turned into useful conversion factors, for example:

$$\frac{1\,\text{dozen donuts}}{12\,\text{donuts}}$$

The problem with using *dozens* when we are doing chemistry is that chemists very rarely deal with such a small number of atoms or molecules. For example, a 20.0 fl oz bottle of water contains 2.0×10^{25} water molecules!!!

To have a "counting unit" that will be useful in chemistry, scientists have come up with *Avogadro's number* which is also called a *mole*. Reported to 4 significant figures, the *mole* = 6.022×10^{23} things. The *mole* allows us to make very useful conversion factors, for example:

$$\frac{1\,\text{mole } H_2O \text{ molecules}}{6.022 \times 10^{23}\ H_2O \text{ molecules}}$$

As with a *dozen*, technically you can have a *mole* of anything, however the *mole* is only practical when dealing with incredibly tiny things, like atom and molecules.

1) How many moles of water molecules did you consume if you drank 2.0×10^{25} water molecules? Show all your work including flowchart, units, and significant figures.

2) A 1.0 L bottle of water contains 56 moles of water molecules. How many water molecules is this? Show all your work including flowchart, units, and significant figures.

Part B: Counting by Mass (Using Molar Mass)

Your textbook explains that when dealing with small things that you need a lot of, it is easier to "count by mass". For example, you'd never go to the grocery store and buy 29,000 grains of rice. It would take forever to count them and the exact number isn't that important, so instead we buy a pound of rice.

Chemistry is another example where the "things" (i.e. the atoms and molecules) are too small to directly count so scientists use *molar mass* instead. We can look up the *atomic mass* (in amu) of any element on the periodic table and directly figure out its *molar mass* by changing the units to *g/mol.*

For example, *molar mass* of C is: $\frac{12.01\,\text{g C}}{1\,\text{mole C}}$

3) Use the molar mass of Fe (from the periodic table) as a conversion factor to determine the mass of 2.8 mol of Fe? Show all your work including flowchart, units, and significant figures.

4) Use the molar mass of Sn to determine how many moles of Sn are in 65 g of Sn? Show all your work including flowchart, units, and significant figures.

We can also determine the mass of one mole of any compound (i.e. the compound's *molar mass*) if we calculate the *formula mass* (in amu) of that compound and change the units to *g/mol*.

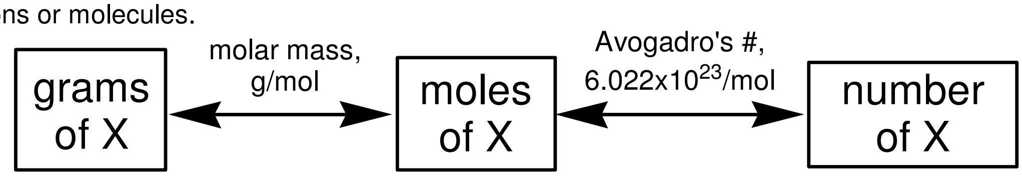
For example, the *molar mass* of NH_3: $\frac{17.03\,\text{g}\,NH_3}{1\,\text{mol}\,NH_3}$

Notice that, like the textbook author, we always show what we are talking about in our units, so we write "g NH_3/mol NH_3" rather than just writing "g/mol". This will be VERY important when we start converting between different compounds using a balance reaction, so get in the habit of doing it now.

5) How many NH_3 molecules are in 85.0 g of NH_3? Show all your work including your flowchart, all units, and significant figures.

Part C: Putting it all together

We are now ready to pull together *Avogadro's number* and *molar mass*. These two tools will allow us to convert from mass ↔ number of things. This is illustrated in the following flowchart, where X can be atoms, ions or molecules.



Use the periodic table and the above flow chart to answer the following questions.

6) What is the *molar mass* of CO_2?

7) What is the mass of 1.06×10^{20} CO_2 molecules? Show all your work including your flowchart, all units (for example, write "mol of CO_2" rather than just "mol"), and significant figures.

8) How many CO_2 molecules are in 74 g? Show all your work including your flowchart, all units (for example, write "mol of CO_2" rather than just "mol"), and significant figures.

Part D: Lots of Additional Practice if You Have Time

For the following problems, be sure to follow the steps we practiced in the previous questions (i.e. write a flowchart with units, write all your conversion factors with units and then solve the problem).

9) Calcium nitrate is used in fertilizers, waste water treatment and in making concrete. How many formula units of calcium nitrate are there in 45 kg of calcium nitrate? Note: remember that when we talk about *ionic compounds* we refer to *formula units* rather than *molecules*.

10) Acetic acid is the main component of vinegar. Determine the mass, in ng, of 5.00×10^{22} acetic acid molecules.

11) The chemical formula for aspirin is $C_9H_8O_4$. How many aspirin molecules are in 325 mg of pure aspirin?

12) Approximately how many water molecules are in your body? Assume 60% of your body mass is due to water.

13) A roll of aluminum foil is 12 inches wide. If you tear off a piece of foil that is 36 inches long, how many aluminum atoms are there in that piece? Note: Searching the internet tells us that aluminum has a density of 2.7 g/cm^3 and that household aluminum foil is 0.016 mm thick.