Finding the molar mass:

A chemical compound is a combination of two or more elements that bond together in a specific ratio of atoms. As we now know, atoms, molecules, ions, and formula units are really really small.

Examples:

a) What is the molar mass of hydrogen chloride?

$$\text{H} = \frac{1.01g}{1\ mol} \times 1\ mol = 1.01g$$

$$\text{Cl} = \frac{35.45\ g}{1\ mol} \times 1\ mol = 35.45\ g$$

$$1.01\ g + 35.45\ g = 36.46\ g$$

So the molar mass of HCl (hydrogen chloride) is 36.46 grams per mole $\left(\frac{36.46\ g\ \text{HCl}}{1\ mol\ \text{HCl}}\right)$.

b) What is the molar mass of beryllium sulfate?

$$\text{Be} = \frac{9.01g}{1\ mol} \times 1\ mol = 9.01g$$

$$\text{S} = \frac{32.07g}{1\ mol} \times 1\ mol = 32.07g$$

$$\text{O} = \frac{16.00g}{1\ mol} \times 4\ mol = 64.00g$$

$$9.01g + 32.06 + 64.00g = 105.07g$$

So the molar mass of $BeSO_4$ (beryllium sulfate) is 105.07 grams per mole $\left(\frac{105.07\ g\ BeSO_4}{1\ mol\ BeSO_4}\right)$.

c) What is the molar mass of $Ga_2(CO_3)_3$?

$$2\ mol\ \text{Ga} \times \frac{69.72g}{1\ mol\ \text{Ga}} + 3\ mol\ \text{C} \times \frac{12.01g}{1\ mol\ \text{C}} + 9\ mol\ \text{O} \times \frac{16.00g}{1 mol\ \text{O}} = 319.74g$$

So the molar mass of $Ga_2(CO_3)_3$ (gallium carbonate) is $319.74\ {}^{g}\!/_{mol}$.

Your turn. Using the same steps as above, find the molar mass of each of the following compounds. Don't let the large molecules fool you; the same steps are used in each calculation. You might also want to try naming the compounds to help with nomenclature (except numbers 6, 9, 13, and 14).

1) H_2O
2) HgO
3) Hg_2O
4) I_2
5) I^-
6) CH_3OH
7) $Ca(NO_3)_2$
8) $Al(OH)_3$
9) $C_{12}H_{22}O_{11}$
10) $Ba_3(PO_4)_2$
11) $Sr(MnO_4)_2$
12) $(NH_4)_2Cr_2O_7$
13) $PtCl_2(NH_3)_2$
14) $C_{23}H_{40}N_7O_{17}P_3S$

Dealing with moles:

Avogadro's number is the key to this type of problem. Everyone knows what is meant when someone says they have a dozen somethings. It is automatic that a dozen means there are 12 of whatever somethings are being talked about. Avogadro's number is the same thing except a little bigger and is used to describe the number of particles in one mole of substance. If I told you that I had a dozen pencils and asked you to tell me how many pencils I have, this is what you would do to find out:

$$3\ \textit{dozen} \times \frac{12\ \text{pencils}}{1\ \textit{dozen}} = 36\ \text{pencils}$$

You can also find how many dozen pencils you have if you have 60 pencils:

$$60\ \text{pencils} \times \frac{1\ \textit{dozen}}{12\ \text{pencils}} = 5\ \textit{dozen}$$

Just as 1 dozen pencils contains 12 pencils, 1 mole of particles contains 6.022×10^{23} particles. These particles can be anything, but in this class, they will always be atoms, molecules, or formula units. A problem asking how many atoms there are in a certain number of moles will be set up EXACTLY the same way as the proceeding example of 3 dozen pencils.

Examples:

a) How many atoms are there in 5.62 moles of potassium?

$$5.62\ \textit{mol}\ \mathbf{K} \times \frac{6.022 \times 10^{23}\ \textit{atoms}\ \mathbf{K}}{1\ \textit{mol}\ \mathbf{K}} = 3.38 \times 10^{24}\ \textit{atoms}\ \mathbf{K}$$

b) How many moles are there in 1.16×10^{22} molecules of Br_2?

$$1.16 \times 10^{22}\ \textit{molecules}\ \mathbf{Br_2} \times \frac{1\ \textit{mol}\ \mathbf{Br_2}}{6.022 \times 10^{23}\ \textit{molecules}\ \mathbf{Br_2}} = 0.0193\ \textit{mol}\ \mathbf{Br_2}$$

Again it is your turn. As a hint for this review, as well as your tests and quizzes, EVERY time you see the phrase "how many atoms…" or "how many molecules…" in a question, you WILL use Avogadro's number!

1) How many moles are there in 1.0000 mol of moles?
2) How many atoms are there in 7.42 moles of tin?
3) How many molecules are there in 3.14 moles of water?
4) How many ATOMS are there in 8.22 moles of H_2 molecules?
5) How many moles are there in 5.87×10^{24} formula units of NaCl
6) How many moles are there in 9.46×10^{18} formula units of $AgNO_3$?

Now for a little twist. These will be basically the same questions with one added step. In this case, you will be asked how many atoms or moles are represented by one PART of a molecule.

Examples:

a) How many sodium atoms are there in 3.75 moles of Na_3PO_4?

The first step is to determine the number of sodium moles in one mole of Na_3PO_4. Look at the subscript to find out. There are 3 sodium moles in each mole of the compound. So:

$$3.75\ \textit{mol}\ \mathbf{Na_3PO_4} \times \frac{3\ \textit{mole}\ \mathbf{Na}}{1\ \textit{mol}\ \mathbf{Na_3PO_4}} \times \frac{6.022 \times 10^{23}\ \textit{atoms}\ \mathbf{Na}}{1\ \textit{mole}\ \mathbf{Na}} = 6.77 \times 10^{24}\ \textit{atoms}\ \mathbf{Na}$$

b) How many sulfur atoms are there in .512 moles of SO_2?

Once again, how many moles of sulfur are there in each mole of SO_2? Looking at the subscript, we see that there is one mole of sulfur for each mole of SO_2. So:

$$0.512\ \textit{mol}\ \mathbf{SO_2} \times \frac{1\ \textit{mol}\ \mathbf{S}}{1\ \textit{mol}\ \mathbf{SO_2}} \times \frac{6.022 \times 10^{23}\ \textit{atom}\ \mathbf{S}}{1\ \textit{mol}\ \mathbf{S}} = 3.08 \times 10^{23}\ \textit{atom}\ \mathbf{S}$$

c) If there are 7.84x10^{24} atoms of oxygen in a sample of hydrogen peroxide (H_2O_2), then how many moles of hydrogen peroxide are present?

This is the last question, only in reverse. First find the number of moles of oxygen atoms in each mole of H_2O_2, which from the subscript, is 2. So:

$$7.84\times10^{24}\,\textit{atoms}\ \mathbf{O}\times\frac{1\,\textit{mol}\ \mathbf{O}}{6.022\times10^{23}\,\textit{atoms}\ \mathbf{O}}\times\frac{1\,\textit{mol}\ \mathbf{H_2O_2}}{2\,\textit{mol}\ \mathbf{O}}=6.51\,\textit{mol}\ \mathbf{H_2O_2}$$

NOTE: The number of moles of one substance over the number of moles of another substance is called the mole to mole ratio. In the preceding example, the mole to mole ratio is 1:2, meaning there is one mole of H_2O_2 for every two moles of O. The mole to mole ratio is used in the majority (but not all) of the chemical calculations you will do in this class, so learn it well!

d) How many moles of magnesium nitrate are present in a sample containing 1.14x10^{25} atoms of oxygen?

First, find the mole to mole ration for oxygen to magnesium nitrate. There are 6 mole of O for each one mole of $Mg(NO_3)_2$ so the mole to mole ratio is 6 to 1. How did I know this? Look at the subscript OUTSIDE the parentheses, it is a 2. Now multiply that but the number of oxygen INSIDE the parentheses (which is 3) and you get a TOTAL of 6 oxygen for each $Mg(NO_3)_2$. So:

$$1.14\times10^{25}\,\textit{atoms}\ \mathbf{O}\times\frac{1\,\textit{mol}\ \mathbf{O}}{6.022\times10^{23}\,\textit{atoms}\ \mathbf{O}}\times\frac{1\,\textit{mol}\ \mathbf{Mg(NO_3)_2}}{6\,\textit{mol}\ \mathbf{O}}=3.16\,\textit{mol}\ \mathbf{Mg(NO_3)_2}$$

That's right… your turn yet again. Think the problems through. They are all done the same way, but don't just go through the motions, think about them and understand them!

1) If a 1 liter flask contains 55.4 moles of H_2O, how many atoms of hydrogen are in the flask?
2) A sample has 1.93x10^{20} atoms of Iron. How many moles of Fe_2O_3 would this make?
3) How many atoms of carbon are there in 6.15x10^{-8} moles of $(CH_3CH_2CO_2)_2C_6H_4$
4) How many moles of $Ra(CN)_2$ are present if you have 8.34x10^{27} atoms of N
5) How many atoms of hydrogen are there in 1.23x10^{-4} moles of Aspartame, $C_{14}H_{18}N_2O_5$
6) Calculate the mass (in grams) of 4.97x10^{24} molecules of sulfur dioxide.

You have just gone over how to go back and forth between particles and moles. The next step is to start or end with a mass. The same methods will be used for this type of problem as were used in the last problems, but now a molecular or atomic mass will also be used. At this point, it may also help to start writing out a game plan for yourself before doing each problem. When you write a game plan, think about what is takes to get from one step to the next. If you are going from grams to moles, you will ALWAYS use the molar mass. Going from moles of one substance to moles of another will ALWAYS require a mole to mole ratio. Going from moles to grams will ALWAYS require a molar mass. If you write out a games plan for each problem, and now what each step requires, you are set to get the problem correct!

Examples:

a) How many atoms of oxygen are there in 52.6 g of $(NH_4)_3PO_4$?

Game plan: grams $(NH_4)_3PO_4$ → mol $(NH_4)_3PO_4$ → mol O → atoms O

$$52.6\,g\ \mathbf{(NH_4)_3PO_4}\times\frac{1\,\textit{mol}\ \mathbf{(NH_4)_3PO_4}}{140.04\,g\ \mathbf{(NH_4)_3PO_4}}\times\frac{4\,\textit{mol}\ \mathbf{O}}{1\,\textit{mol}\ \mathbf{(NH_4)_3PO_4}}\times\frac{6.022\times10^{23}\,\textit{atoms}\ \mathbf{O}}{1\,\textit{mol}\ \mathbf{O}}=9.05\times10^{23}\,\textit{atoms}\ \mathbf{O}$$

b) How many grams of mercury (II) bromide are present if you have 8.52x10^{19} atoms of mercury?

Game plan: atoms Hg → mol Hg → mol $HgBr_2$ → grams $HgBr_2$

$$8.52\times10^{19}\,\textit{atoms}\ \mathbf{Hg}\times\frac{1\,\textit{mol}\ \mathbf{Hg}}{6.022\times10^{23}\,\textit{atoms}\ \mathbf{Hg}}\times\frac{1\,\textit{mol}\ \mathbf{HgBr_2}}{1\,\textit{mol}\ \mathbf{Hg}}\times\frac{358.59\,g\ \mathbf{HgBr_2}}{1\,\textit{mol}\ \mathbf{HgBr_2}}=0.0507\,g\ \mathbf{HgBr_2}$$

c) What mass of fluorine is in 5.78x10^{24} formula units of $NaBF_4$?

Game plan: formula units $NaBF_4$ → mol $NaBF_4$ → mol F → grams $NaBF_4$

$$5.78\times10^{24}\,\textit{form. units}\ \mathbf{NaBF_4}\times\frac{1\,\textit{mol}\ \mathbf{NaBF_4}}{6.022\times10^{23}\,\textit{form. units}\ \mathbf{NaBF_4}}\times\frac{4\,\textit{mol}\ \mathbf{F}}{1\,\textit{mol}\ \mathbf{NaBF_4}}\times\frac{19.00\,g\ \mathbf{F}}{1\,\textit{mol}\ \mathbf{F}}=729\,g\ \mathbf{F}$$

Your tu…. Never mind, you know what to do.

1) What mass of rubidium is in $2.39x10^{20}$ molecules of Rb_2SO_4?
2) How many sodium atoms are there in 6.53kg of $NaHCO_3$?
3) What is the mass of iodine in $8.52x10^{20}$ molecules of CeI_3?
4) How many oxygen atoms are in $1.2x10^{-3}$ grams of testosterone, $C_{19}H_{28}O_2$?
5) What is the mass of a snowflake (think) containing $2.67x10^{19}$ atoms of hydrogen?
6) How many nitrogen atoms in $1.05x10^{21}$ molecules of caffeine, $C_8H_{10}N_4O_2$?
7) What is the mass of a Vitamin C tablet that has $5.13x10^{21}$ atoms of oxygen? The formula for Vitamin C is $C_6H_8O_6$.
8) A sample of calcium acetate contains $5.98x10^{23}$ atoms of oxygen. What mass of hydrogen does it contain?
9) Home many iodine atoms are there in 28.3mg of carbon tetraiodide?