Part I: The Mole – An Introduction

The mole, not to be confused with the animal, is what is known as a "counting unit." One common counting unit you've likely come across in your day to day life is a *dozen*. We know that when we have 1 dozen of something, that means we have 12 of that something. So for example, if we want to make a good first impression at a new office job, we may stop by a donut shop and ask for 2 dozen donuts. We know that 1 dozen is equal to 12 donuts so 2 dozen would equal 24 donuts. This unit, just like other units we've used previously, can be used as a conversion factor.

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

The "mole" unit is used by chemists just as a baker would use dozen. The difference, however, is that 1 mole of donuts would be a lot of donuts , 6.022×10^{23} donuts to be exact (that means everyone would get 74 TRILLION donuts EACH). So, it goes without saying that 1 mole is a very large number. The reason for this is that objects are made of an outstanding number of atoms and molecules. For example, a 20.0 fl. oz bottle of water contains 2.22×10^{25} water molecules!

<u>Example 1</u>

For our first example, let's determine how many individual donuts are in 3.5 dozen.

a. 1 dozen can be used as a conversion factor to know how many individual donuts we have in 3.5 dozen donuts.

$$3.5 \text{ dozen} \times \frac{12 \text{ donuts}}{1 \text{ dozen}} = 42 \text{ donuts}$$

<u>Example 2</u>

Now apply the same concept used to determine how many individual donuts we had in 3.5 dozen to calculate how many donuts we have in 3.5 moles donuts.

a. Use mole as a conversion factor to know how many individual carbon atoms we have in 3.5 moles of carbon.

$$3.5 \text{ moles carbon} \times \frac{6.022 \times 10^{23} \text{donuts atoms}}{1 \text{ mole donuts}} = 2.1 \times 10^{24} \text{ donuts}$$

Part II: Counting by 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.

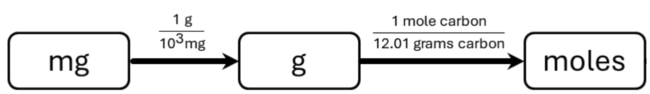
Chemistry is another example where the "things" (i.e. the atoms and molecules) are too small to directly count so scientists use molar mass instead. We can look up the atomic mass (in amu) of any element on the periodic table and directly figure out its molar mass by changing the units to g/mol.

For example, the atomic mass of carbon (C) is $\frac{\text{12.01 grams of carbon}}{\text{1 mole Carbon}}$

Example 3

Use molar mass as a conversion factor to determine how many carbon atoms there are in a diamond, which is pure carbon, that weighs 400 mg.

a. Make a flowchart showing how you will go from mg to grams, then grams to moles, and finally moles to atoms. Include the necessary conversion factors (this includes the atomic mass of carbon and atoms per mole). *Remember, 1 mole = 6.022 x 10 ^{23}*



b. Convert 400 mg to grams.

$$400 \text{ mg carbon} \times \frac{1 \text{ g carbon}}{10^3 \text{ mg carbon}} = 0.400 \text{ g carbon}$$

c. Calculate the number of moles there are in your answer from **3a**.

$$.400 \text{ g carbon} \times \frac{1 \text{ mol carbon}}{12.01 \text{ g carbon}} = 0.0333 \text{ mole carbon}$$

2. The largest gold nugget thought to have been discovered has a mass of 70.76 kg! How many moles of gold is this? The atomic mass of gold is 196.97 g/mol.

We can apply mass to moles calculations to molecules as well. The only difference is that we will use *molar mass* in place of *atomic mass*.

For example, the molar mass of H_2O is $\frac{\text{18.02 grams of water}}{\text{1 mole water}}$

3. A glass of water is filled with 500 grams of water. How many molecules of water are in the glass?

a. Make a flowchart to determine how many moles of water there are in the 500 g.

b. Calculate the number of moles of water there are in 500 g glass.

Part III: *How* Many Atoms?!

We've discussed that the mole unit is used due to the enormous number of atoms and molecules make up even the smallest observable object to the human eye.

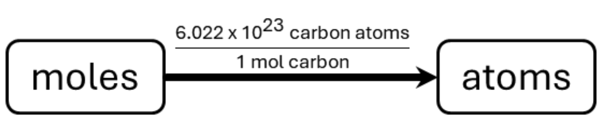
Now have a use for Avogadro's number!

$$\text{Avogadro's Number} = N_A = \frac{6.022 \times 10^{23} \text{ carbon atoms}}{\text{1 mole carbon atoms}}$$

__**Example 4**__

Determine how many carbon atoms there are in a 0.0333 mole carbon sample.

c. Make a flow chart going from mole C to C atoms



d. Determine how many individual atoms of carbon there are in a diamond made up of 0.0333 mole carbon.

$$.0333 \text{ mole carbon} \times \frac{6.022 \times 10^{23} \text{carbon atoms}}{\text{1 mol carbon}} = 2.01 \times 10^{22} \text{carbon atoms}$$

4. Calculate the number of water molecules there are in 27.7 moles of water
    a. Make a flow chart going from moles of water to individual water molecules.

    b. How many water molecules are there in 27.7 moles of water?

At times we will be asked to determine the quantity of a particular atom there is in a sample.

   c. How many hydrogen atoms are there in each molecule of water?____________

   d. Use your answer from **4c** to determine how many hydrogen atoms there are in 600 g of water.

5. How many oxygen atoms are there in iron (III) oxide, Fe_2O_3 (159.69 g/mol)?

Part IV: It's All Coming Together Now

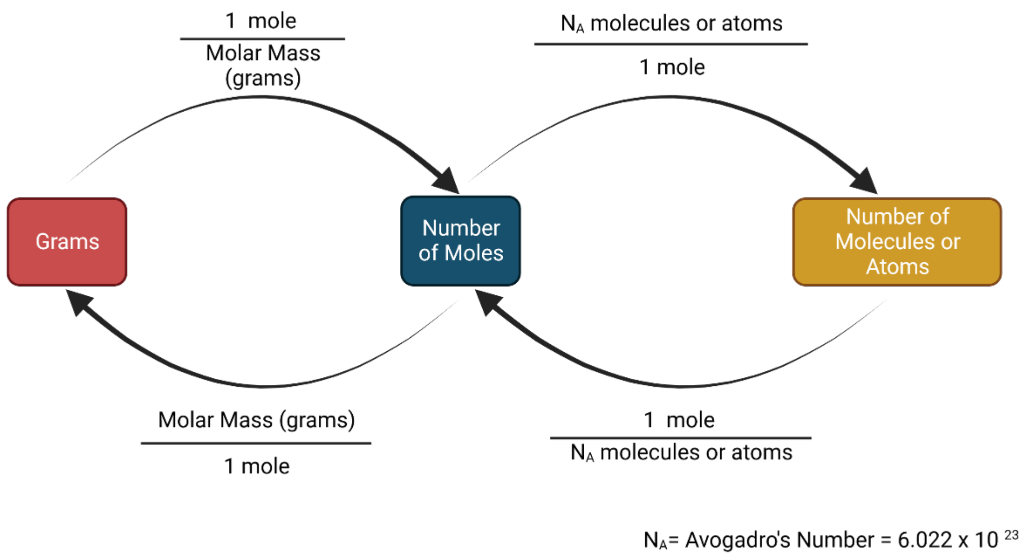
When the previous examples involving the diamond are combined you can see that it is possible to go from grams of carbon to number of carbon atoms.

Example 5

How many carbon atoms are there in a diamond which has a mass of 400 mg?

$$.400 \text{ g carbon} \times \frac{1 \text{ mol carbon}}{12.01 \text{ g carbon}} \times \frac{6.022 \times 10^{23} \text{ carbon atoms}}{1 \text{ mol carbon}} = 2.01 \times 10^{22} \text{ carbon atoms}$$

A flowchart or map can be used to navigate your way around these calculations as you become more familiar with the concept of the mole and using it as a conversion factor in combination with Avogadro's number. Here is the Mole Map which you may have seen in your class (or something similar).



6. Use the map above to determine how many hydrogen atoms are there in 500 g of water. Show all of your work including your own flowchart and include units for every step.

Part V: Going From Number of "Things" to the Mass

These calculations can go back and forth as needed. Mass can be determine from the number of atoms of molecules.

7. Calculate the mass of tungsten carbide (WC), in grams, of a sample which is made up of 1.75 mole WC. The molar mass of WC is 195.85 g/mol. *Hint:* use the flowchart given in **Part IV** as a guide.

8. Calculate the mass of ammonia, in grams, if there are 1.75×10^{23} ammonia molecules.

9. Calculate the mass of water, in grams, if there are 3.16×10^{26} hydrogen atoms.

Part VI: Additional Mole Calculations

Remember all of the steps covered in the above examples as you work on these additional examples. Refer to the Mole Map if you get stuck and remember to include units in every step. If your units don't cancel out like they should then take a step back and figure out why. Some of these examples will require additional conversion factors.

10. Calcium nitrate is used in fertilizers, wastewater treatment, and in making concrete. How many ions are in 45 kg of calcium nitrate?

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

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

13. Approximately how many water molecules are in the body of someone weighing 175 lbs? Assume 60% of your body mass is due to water.

14. 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.

15. How many carbon atoms are there in a container which holds 2 liters acetone (C_3H_6O)? The density of pure acetone is 0.7845 g/mL.