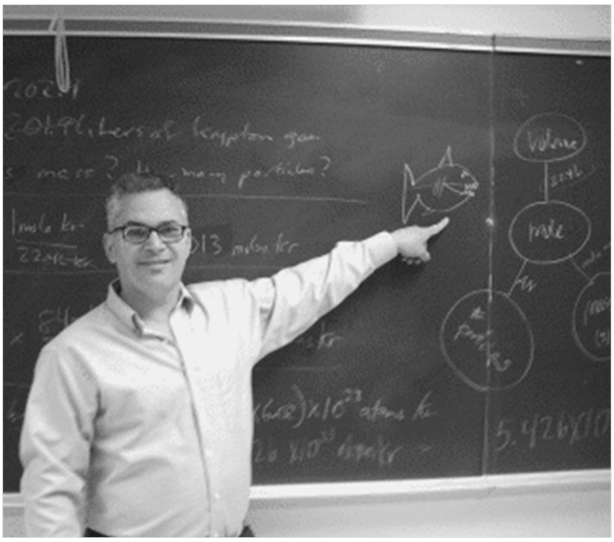
MOLES & Percent Comp by Mass BASICS

MOLES



Any time that you get to draw a shark in chemistry class is a good day. Fishing is not one of my favorite "sports", but I do enjoy fishing at Wegmans for shark (and for salmon). This is your teacher in the fall of 2006, it's the first picture of me on the website!

There's the shark on the map how to do all of this math. It shows how moles are related to mass, volume, and to the number of particles.

The Mole is central to your understanding much more chemistry; you must work hard to truly grasp the significance of moles.

Avogadro's number sets the basic ratio between the mole and how many particles it is. Like a dozen is twelve, a mole is exactly 6.02×10^{23} particles. Particles can be atoms, or molecules, or even FU's.

Half of a dozen is six, and half of a mole is one half of Avogadro's Number, or 3.01×10^{23} particles. This relationship of moles to an exact number of particles allows us to mathematically connect masses of substances to the number of particles present.

Particles can be atoms if the substance exists as atoms, like the noble gases, or the metals. Sometimes particles can be FU's, or formula units - if the substance is an ionic compound. Particles can also be molecules - when if the substance is a molecular compound. Particles can even be ions, if you want to count how many ions are present in a substance. Having a mole of anything of "real" size is a problem. A mole of atoms is a huge number but they are so small. A mole of atoms is also pretty small.

Besides the "mole to number of particles" ratio, there is a special mass relationship between atoms on the periodic table and the concept of moles. If you look at your Periodic Table, and see that one atom of Helium has an atomic mass of 4.00260 amu (which we round to 4 amu), the mass of ONE MOLE OF HELIUM is 4.00260 grams, or 4 grams. An easy switcheroo.

The units change between atoms (amu's) and moles (grams), but the periodic table provides the numbers. We can use these numbers to determine how many grams one mole of any element is, and to determine the MOLAR MASS of any compound (by just adding up individual atomic mole masses by the ratios of atoms in the compound - see below) Examples include

atom	atomic mass	molar mass
niobium	93 amu	93 grams/mole
zinc	65 amu	65 grams/mole
sulfur	32 amu	32 grams/mole
silicon	28 amu	28 grams/mole
NaCl	23 + 35 = 58 amu	58 grams/mole
NaOH	23 + 16 + 1 = 40 amu	40 grams/mole
$C_6H_{12}O_6$	72 + 12 + 96 = 180 amu	180 grams/mole

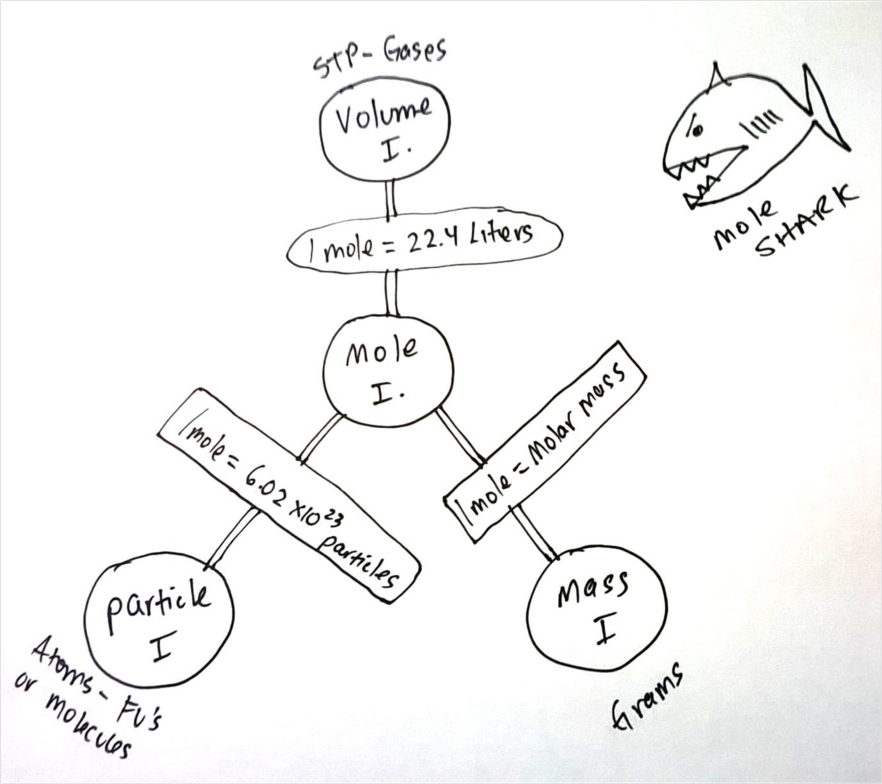
With gases, the mole to volume relationship is the "simplest" to connect. At standard temperature and pressure (zero centigrade and one atmosphere pressure), one mole of any gas is equal to 22.4 Liters of volume. In our class the gas parameters of pressure and temperature will be at STP until we study gases later in the year. So, the number to remember is 22.4 Liters. Examples include

gas	formula		volume at STP
1 mole of helium	He	1 x 22.4 L =	22.4 liters
1 mole of carbon dioxide	CO_2	1 x 22.4 L =	22.4 liters
2 moles of krypton	Kr	2 x 22.4 L =	44.8 liters
one half mole neon	Ne	0.5 x 22.4 L =	11.2 liters
1.0 mole nitrogen dioxide	NO_2	1.0 x 22.4 L =	22.4 liters
3.0 moles iodine gas	I_2	3.0 x 22.4 L =	67.2 liters

Mole Islands… The drawing below describes the connection between MOLES in the middle, with the "islands" that surround it. The only way to make your way from any island to another is to take the ONLY BRIDGE available, and PAY THE TOLL as indicated. Use the tolls to make your conversions factors. If you "cheat" and try to skip the mole conversion, the sharks will eat you. Stay on the "BRIDGES"!

Going from one part of the diagram to another (going from one island to another) you may only use the bridges as shown.

Each bridge has its own toll to pay, indicated in THE MIDDLE OF THE BRIDGE. Use these "tolls" to convert from one unit to another (for example, from LITERS TO MOLES, or MOLES TO GRAMS, or MOLES TO NUMBER OF PARTICLES).



If you try to take a short cut, the MOLE SHARK will eat you, and it won't be pretty. There are NO SHORT CUTS. That said, the biggest mole problem is just 2 conversions at most.

Mole Math Problems always start on one island, you either start with a known number of grams, or a known number of particles, or a known number of liters of a gas. You could even start with a known number of moles. No matter what, you will do some conversions. Only do the steps in the order that the bridges show you. If you ever try to go from liters (top) to grams (bottom right) straight away, you are in the ocean and in danger!

Moles are central to chemistry and this diagram will help you keep it all straight. Everything can be converted to moles, moles can be converted to all other units you will ever need (or want!) It will require practice, and if you don't practice, it will become very apparent.

MOLAR MASS

By definition, how many grams exactly one mole of a substance weighs. If it is just an element, read the atomic mass on the periodic table, and change the "AMU" units to "GRAMS" instead. If it is a compound, write the PROPER FORMULA of the compound, and multiply the number of atoms by the proper atomic masses, and then add them all up. Units will be GRAMS PER MOLE.

Determine the MOLAR MASS of sodium Na	Put your finger into box 11 on the periodic table. Atomic mass is 23 AMU, so molar mass is 23 grams/mole
Determine the MOLAR MASS of sodium hydroxide NaOH It has 3 atoms, one each of sodium, oxygen, and hydrogen.	Molar Mass of NaOH Na - sodium 1 x 23 = 23 O - oxygen 1 x 16 = 16 H - hydrogen 1 x 1 = 1 sum = 40 grams/mole
Determine the MOLAR MASS of sulfur trioxide SO_3 It has 4 atoms, one sulfur, and 3 oxygen atoms.	Molar Mass of SO_3 S - sulfur 1 x 32 = 32 O - oxygen 3 x 16 = 48 sum = 80 grams/mole

% Composition by Mass

When you make a good fruit salad (I think) it should be big and include about five pounds of bananas, one pound of strawberries, three pounds of blueberries, one pound of ripe peaches, and two pounds of melon. A nice twelve pound fruit salad just right.

If I asked you, what percent of the fruit salad is bananas, would you be able to figure that out?

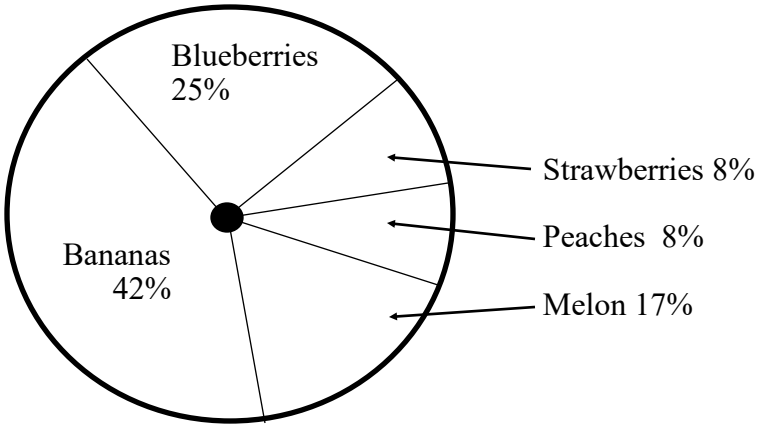
You would divide 5/12 and say it's about 42% bananas.

The blueberries make up 3/12 pounds, so they make up 25% of the fruit salad.

1/12 of the salad is about 8%, so we can say that it's about 8% strawberries and 8% peaches.

Finally, the melon is 17% of the total salad.

That sums to 100% of the salad. Chemistry can be like making fruit salad (and doing math to it).



What is the percent composition by mass of magnesium in magnesium hydroxide? Do this…

$Mg(OH)_2$			% Comp			
Mg	1 x 24 g =	24 g	Mg	24/58	X 100% =	41.4%
O	2 x 16 g =	32 g	O	32/58	X 100% =	55.2%
H	2 x 1 g =	2 g	H	2/58	X 100% =	3.4%
		58 g/mole				100%

$Mg(OH)_2$ is 41.4% magnesium by mass. It's also 55.2% oxygen, and 3.4% hydrogen. Importantly, the sum of the three parts equals 100%, just like it should. Always do the whole problem, even if you are just asked for one part of the compound. Check yourself always.

Percent Composition by Mass

On the back of the reference table you see this formula:

Percent Composition

$$\% \text{ composition by mass} = \frac{\text{Mass of part}}{\text{Mass of whole}} \times 100\%$$

Another example… Find the % composition of chlorine in hydrogen monochloride (HCl).

HCl			% Comp			
H	1 x 1 g =	1 g	H	1/36	X 100% =	2.8%
Cl	1 x 35 g =	35 g	Cl	35/36	X 100% =	97.2%
		36 g/mole				100%

HCl is only 2.8% hydrogen, and 97.2% chlorine by mass.

Another problem…. If you have 50.0 grams of HCl, how many grams would be chlorine?

50.0 grams HCl X 0.972 = 48.6 grams is chlorine [97.2% = 0.972 AS A DECIMAL]
and
50.0 grams HCl X 0.028 = 1.4 grams hydrogen [2.8% = 0.028 AS A DECIMAL]

48.6 g + 1.4 g = 50.0 grams total.

And Another example…

If you have 312 grams of HCl, how many grams would be chlorine?

312 grams HCl X 0.972 = 303.26 grams

312 grams HCl X 0.028 = 8.74 grams 303.26 + 8.74 = 312.00 grams (the whole amount, of course!)

For HCl, the proportions are constant based upon the percent comp by mass math.
No matter how much stuff you have, if it's HCl, it's always 97.2% chlorine and 2.8% hydrogen— by mass.

EMPIRICAL FORMULAS

An empirical formula is a math concept more than a chemistry one. It really is the lowest ratio of atoms or ions that make up a formula.

You are familiar with glucose, $C_6H_{12}O_6$, and the ratio of atoms in that is of course 6:12:6, which can be reduced to 1:2:1.

The EMPIRICAL FORMULA for glucose is just CH_2O.

The ratio has NOTHING to do with the actual chemistry, density, molar mass, etc. It is a way to categorize groups of compounds, and to make you think.

Formulas	Empirical Formulas
$C_5H_{10}O_5$	CH_2O
C_2H_2	CH
C_4H_{10}	C_2H_5
C_8H_{18}	C_4H_9
$MgSO_4$	$MgSO_4$ (this formula cannot be reduced to a lower ratio)
H_2O	H_2O (this formula cannot be reduced to a lower ratio)
CH_4	CH_4 (this formula cannot be reduced to a lower ratio)
$C_{44}H_{88}O_{44}$	CH_2O

Empirical formulas are about the LOWEST RATIO.

Often the "lowest ratio formula", such as CH_2O, is not even a real compound, and if it can even exist chemically, it certainly is not the compound you started with.

An EMPIRICAL FORMULA is more an IDEA than a real thing. Sometimes Empirical Formulas are the same as the formula of the real compounds, like with magnesium sulfate, water, or methane gas. This is nutty.

The last example shows that no matter how big the numbers, the lowest ratio makes the empirical formula.

Types of mole problems… (answers on next page)

There's a limited number of kinds of mole problems. Using your mole island map, you can easily do all of them.

Problems for practice. Answers below in order.

1. How many grams are in 1.0 moles of $NaHCO_3$, which is baking soda?
2. How many moles are in 25.0 grams of baking soda?
3. How many moles is 145.6 liters of helium gas at STP?
4. If you have 2.75 moles of CO_2 gas, how many liters does it take up at STP?
5. If you have 2.75 moles of CO_2 gas, how many particles is that?
6. If you have 3.50×10^{27} atoms of neon gas, how many moles is that?
7. If you have 175 grams $Cl_{2(G)}$, how many molecules AND how many liters does it take up at STP?

1 The molar mass of $NaHCO_3$, sodium hydrogen carbonate is 84 g/mol.

2 $\frac{25.0 \text{ g baking soda}}{1} \times \frac{1 \text{ mole baking soda}}{84 \text{ g baking soda}} = 0.298 \text{ moles baking soda}$

3 $\frac{145.6 \text{ liters He}}{1} \times \frac{1 \text{ mole He}}{22.4 \text{ liters He}} = 6.50 \text{ moles He}$

4 $\frac{2.75 \text{ moles } CO_2}{1} \times \frac{22.4 \text{ liters } CO_2}{1 \text{ mole } CO_2} = 61.6 \text{ liters } CO_2$

5 $\frac{2.75 \text{ moles } CO_2}{1} \times \frac{6.02 \times 10^{23} \text{ molecules } CO_2}{1 \text{ mole } CO_2} = 16.555 \times 10^{23}$ changes to

$= 1.66 \times 10^{24}$ molecules CO_2

6 $\frac{3.50 \times 10^{27} \text{ atoms Ne}}{1} \times \frac{1 \text{ mole Ne}}{6.02 \times 10^{23} \text{ atoms Ne}} = \frac{3.50}{6.02} \times \frac{10^{27}}{10^{23}} = 0.581 \times 10^4$ changes to

$= 5.81 \times 10^3$ moles Neon

7 $\frac{175 \text{ grams } Cl_2}{1} \times \frac{1 \text{ mole } Cl_2}{70 \text{ grams } Cl_2} = 2.50 \text{ moles } Cl_2$ go to the next line

Now change those moles of chlorine into molecules. A different conversion here.

$\frac{2.50 \text{ moles } Cl_2}{1} \times \frac{22.4 \text{ liters } Cl_2}{1 \text{ mole } Cl_2} = 56.0 \text{ liters } Cl_2$

$\frac{2.50 \text{ moles } Cl_2}{1} \times \frac{6.02 \times 10^{23} \text{ molecules } Cl_2}{1 \text{ mole } Cl_2} = 15.05 \times 10^{23}$ molecules Cl_2

$= 1.51 \times 10^{24}$ molecules Cl_2