**Purpose:** To review the procedure for calculating one unit of measurement when given another. This becomes increasingly important in chemistry as we consider how much product will be obtained from a reaction or how much reactant will be left over. Much like baking a batch of cookies, we can have a strong sense of what our outcomes should look like if we’ve followed directions and combined the proper amounts of ingredients.

## Practice drawing out the road map from memory and from your notes:

$$Grams \leftrightarrow Moles \leftrightarrow Particles$$

Questions to ask yourself as we go along:

* What do the arrows represent?
* What do the letters represent?
* Why do we have to go through the mole in order to get from grams to particles and visa versa?

## Particles $\leftrightarrow $ Moles

*When we look at a chemical reaction, we can say that 1 atom of zinc reacts with 1 atom of sulfur to form 1 molecule of zinc sulfide: Zn + S 🡪 ZnS. However, when we’re doing experiments in lab, it becomes impractical to talk about individual atoms, so we need a different measure of scale that is more realistic.*

*Without changing the 1:1 relationship between the reactants (Zn and S), we could say talk about different quantities of material used:*

 *1 dozen Zn atoms + 1 dozen S atoms 🡪 1 dozen ZnS molecules*

 *1 ream Zn atoms + 1 ream S atoms 🡪 1 ream ZnS molecules (1 ream = 500,remember!)*

 *1 mole Zn atoms + 1 mole S atoms 🡪 1 mole ZnS molecules*

*Now, Avogadro determined that 1 mole of anything is equal to 6.02x1023 particles/units of whatever it is we’re talking about. It’s another counting number! And one that is very convenient for chemistry lab.*

*Example problem:*

1. How many dollars do you have in your bank account if your account balance reads 0.4 moles dollars?

*Conversion factors and keeping our units straight is very important with these problems, because these allow us to examine our work and determine if our process (and thus our answer!) is correct.*

*The conversion factor that we need for this problem?* I need to go from moles to “particles”, so I’ll need to use Avogadro’s number.

 *What information am I starting with? # moles:* This will go in the **numerator**.

*What information do I need to find? # dollars:* This will eventually be in the **numerator** as well.

Thus, my work will look like:

$$0.4 moles dollars×\frac{6.02x10^{23} dollars}{1 mole dollars}=2.4x10^{23} dollars$$

Notice that moles cancels based on my arrangement of the conversion factor and I am left with “number of dollars” which is what the question asked me to find.

1. How many grains of sand are present on a beach that contains 4.3 moles of sand? (ans. 2.6x1024 grains)

*Remember that Avogadro’s number is a counting number, like dozen and reams- it will always be the same! We just have to figure out how to arrange it so that we get the units we’re solving for.*

$$4.3 moles sand×\frac{6.02x10^{23} grains of sand}{1 mole sand}=2.6x10^{24} grains of sand$$

1. If you have 2.14 x 1024 atoms of carbon, how many moles is this? (ans. 3.55 mol C)

$$2.14×10^{24} atoms C×\frac{1 mole C}{6.02x10^{23} atoms C}=3.55 mol C$$

1. In a beaker, there are 4.1 x 1019 formula units of Copper (II) nitrate, how many moles of Copper (II) nitrate are contained in that beaker? (ans. 6.8x10-5 mol)

$$4.1×10^{19} form u Cu(NO\_{3})\_{2}×\frac{1 mole Cu(NO\_{3})\_{2}}{6.02x10^{23} form u Cu(NO\_{3})\_{2}}=6.8×10^{-5} mol Cu(NO\_{3})\_{2}$$

1. How many molecules of water (H2O) are present in a cup that contains 12.42 moles of water? (ans. 7.477x1024 molecules)

$$12.42 moles H\_{2}O×\frac{6.02x10^{23} molecules H\_{2}O}{1 mole H\_{2}O}=7.477×10^{24} molecules H\_{2}O$$

## Grams $\leftrightarrow $ Moles

*Remembering back to the “Measure a mole” lab, we saw that the mass of a mole of a substance depends on the composition of that substance. For instance, the mass of a mole of water will be the sum of the mass of 2 moles of hydrogen and the mass of 1 mole of water (H2O). This is called the* ***molar mass*** *of water and is equal to:*

 *(2 x 1.0079 g H) + 15.9994 g O = 18.0152 g H2O per 1 mole H2O*

*For compounds that contain heavier atoms, such as copper (molar mass of Cu = 63 g/mol- look at the periodic table for these values!), their molar mass will be much larger than that of water. Like 1 dozen boulders will weigh more than 1 dozen eggs, 1 mole of Cu(NO3)2 will weigh more than 1 mole H2O, even though we have the same number of particles of each (6.02x1023 formula units of Cu(NO3)2 and 6.02x1023molecules of H2O)!*

Example problem:

1. How many moles of water are present in 352 g water?

*The conversion factor that we need for this problem?* I need to go from moles to grams, so I’ll need to use the molar mass (g/mol) of water in some way.

 *What information am I starting with? # grams:* This will go in the **numerator**.

*What information do I need to find? # moles:* This will eventually be in the **numerator** as well.

Thus, my work will look like:

 **a. Determine the molar mass of water.**

 **b. Use factor label method to convert from grams to moles.**

$$352 g H\_{2}O×\frac{1 mol H\_{2}O}{18.0152 g H\_{2}O}=19.5 mol H\_{2}O $$

Notice that moles cancels based on my arrangement of the conversion factor and I am left with “number of moles” which is what the question asked me to find.

1. How many moles of Copper (II) nitrate are present in 352 g Cu(NO3)2? (ans. 1.88 mol)

*Use the 2 steps outlined above to determine number of moles of* Copper (II) nitrate. Notice the difference in number of moles Copper (II) nitrate when compared with number of moles H2O present in 352 g H2O. Does this different make sense? Which would you expect to have the higher number of moles?

$$352 g Cu(NO\_{3})\_{2}×\frac{1 mol Cu(NO\_{3})\_{2}}{187.56 g Cu(NO\_{3})\_{2}}=1.88 mol Cu(NO\_{3})\_{2}$$

1. Calculate the number of grams of aluminum present in 0.112 moles aluminum foil. (ans. 3.02 g Al)

$$0.112 moles Al×\frac{26.98 g Al}{1 mole Al}=3.02 g Al$$

1. Calculate the number of grams (i.e. how much would it weigh on a lab scale) of table salt, NaCl, you would need for a reaction if it calls for 0.45 mol NaCl. (ans. 26 g NaCl)

$$0.45 moles NaCl×\frac{58.44 g NaCl}{1 mole NaCl}=26 g NaCl$$

1. Determine the number of moles of carbon atoms present in a diamond, which is composed only of carbon, that weighs 0.35 grams. (ans. 0.029 mol C)

$$0.35 g C×\frac{1 mol C}{12.011 g C}=0.029 mol C$$

1. Determine the number of moles of Lead (II) sulfate are present in 174 g of this substance. (ans. 0.859 mol)

$$174 g PbSO\_{4}×\frac{1 mole PbSO\_{4}}{303.26 g PbSO\_{4}}=0.574 mol PbSO\_{4}$$

## Grams $\leftrightarrow $ Particles

*Unfortunately, there is no direct way to go from grams to particles or visa versa. It would be very cumbersome to come up with conversion factors for* each *element and compound we know of! This is where the mole really comes in handy. Since we now know how to convert from particles to moles and moles to grams, we can start to connect the work we’ve done with writing out chemical names and reactions to the work we’ve done in the lab!*

*The factor label method is the easiest way to ensure that we’re using our conversion factors properly, so work on becoming comfortable with writing out your work and units in this structure.*

*Example problem:*

1. How many molecules of PCl5 are present in 25g phosphorous pentachloride?

*The conversion factor that we need for this problem?* I need to go from grams to moles and then from moles to molecules, so I’ll need to use the molar mass (g/mol) of PCl5 AND Avogadro’s number in some way.

*What information am I starting with? # grams:* This will go in the **numerator**.

*What information do I need to find? # molecule:* This will eventually be in the **numerator** as well.

Thus, my work will look like:

 **a. Determine the molar mass of PCl5.**

Molar mass of PCl5 = (5x 35.453 g/mol Cl) +30.97 g/mol P = 208.24 g PCl5

 **b. Use factor label method to convert from grams to moles**

**c. Use factor label method to convert from moles to molecules.**

$$25 g PCl\_{5}×\frac{1 mol PCl\_{5}}{208.24 g PCl\_{5}}×\frac{6.02x10^{23}molecules PCl\_{5}}{1 mol PCl\_{5}}=7.23x 10^{22} molecules PCl\_{5}$$

Notice that moles cancels based on my arrangement of the conversion factor and I am left with “number of molecules” which is what the question asked me to find.

1. How many atoms of carbon are present in a diamond weighing 0.35 grams? (ans. 1.8x1022 atoms C)

$$0.35 g C ×\frac{1 mol C}{12.011 g C}×\frac{6.02x10^{23} atoms C}{1 mole C}=1.8x10^{22}atoms C$$

1. How many formula units of Aluminum oxide are present in 49 grams of Al2O3? (ans. 2.9x1023 formula units)

$$49 g Al\_{2}O\_{3} ×\frac{1 mol Al\_{2}O\_{3}}{101.96 g Al\_{2}O\_{3}}×\frac{6.02x10^{23} form u Al\_{2}O\_{3}}{1 mole Al\_{2}O\_{3}}=2.9x10^{23}form u Al\_{2}O\_{3}$$

1. How many grams will 2.23x1022 molecules glucose (C6H12O6) weigh? (ans. 6.67 g)

$$2.23×10^{22} molecules C\_{6}H\_{12}O\_{6}×\frac{1 mole C\_{6}H\_{12}O\_{6}}{6.02x10^{23} molecules C\_{6}H\_{12}O\_{6}}×\frac{180.16 g C\_{6}H\_{12}O\_{6}}{1 mole C\_{6}H\_{12}O\_{6}}=6.67 g C\_{6}H\_{12}O\_{6}$$

1. How many grams of baking soda (NaHCO3) are present in 1.34x1025 formula units of baking soda? (ans. 1.87x103 g)

$$1.34×10^{25} form u NaHCO\_{3}×\frac{1 mole NaHCO\_{3}}{6.02x10^{23} form u NaHCO\_{3}}×\frac{84 g NaHCO\_{3}}{1 mole NaHCO\_{3}}=1.87x10^{3} g NaHCO\_{3}$$

1. How many atoms of mercury are present in 14.1 grams of mercury? (ans. 4.23x1022 atoms)

$$14.1 g Hg ×\frac{1 mol Hg}{200.59 g Hg}×\frac{6.02x10^{23} atoms Hg}{1 mole Hg}=4.23x10^{22}atoms Hg$$

1. Practice writing your own problem for going from grams 🡪 atoms.
2. Practice writing your own problem for going from molecules 🡪 grams.

Percent composition and empirical formulas

1. Calculate the percentage composition by mass of each element in the following compounds:
	1. NaH2PO4

$$\% \left(by mass\right) Na= \frac{22.99 g Na}{119.98 g NaH\_{2}PO\_{4}}×100\%=19.2 \% Na$$

$$\% \left(by mass\right) H= \frac{2(1.0079 g H)}{119.98 g NaH\_{2}PO\_{4}}×100\%=1.7 \% H$$

$$\% \left(by mass\right) P= \frac{30.97 g P}{119.98 g NaH\_{2}PO\_{4}}×100\%=25.8 \% P$$

$$\% \left(by mass\right) O= \frac{4(15.9994 g O)}{119.98 g NaH\_{2}PO\_{4}}×100\%=53.3 \% O$$

* 1. (CH3)2CO

$$\% \left(by mass\right) C= \frac{3(12.011 g C)}{58.08 g (CH\_{3})\_{2}CO}×100\%=62.0 \% C$$

$$\% \left(by mass\right) H= \frac{6(1.0079 g H)}{58.08 g (CH\_{3})\_{2}CO}×100\%=10.4 \% H$$

$$\% \left(by mass\right) O= \frac{15.9994 g O}{58.08 g (CH\_{3})\_{2}CO}×100\%=27.5 \% O$$

1. Phencyclidine is C17H25N.  A sample suspected of being this illicit drug was found to have a percentage composition of 83.71% C, 10.42% H, and 5.61% N.  Do these data acceptably match the theoretical data for phencyclidine?

$$83.71 g C×\frac{1 mole C}{12.011 g C }=6.97 mol C$$

$$10.42 g H×\frac{1 mole H}{1.0079 g H }=10.3 mol H$$

$$5.61 g N×\frac{1 mole N}{14.01 g N }=0.400 mol N$$

$$\frac{0.400 mol N}{0.400 mol N}=1 mol N$$

$$\frac{6.97 mol C}{0.400 mol N}=17.4 mol C$$

$$\frac{10.3 mol H}{0.400 mol N}=25.75 mol H$$

Close, but not perfect. It would be better to multiply by 4 to get whole number ratios: C70H103N4

1. A substance was found to be composed of 22.9% Na, 21.5% B, and 55.7% O.  What is the empirical formula of this compound?

$$22.9 g Na×\frac{1 mole Na}{22.99 g Na }=0.996 mol Na$$

$$21.5 g B×\frac{1 mole B}{10.81 g B }=1.98 mol B$$

$$55.7 g O×\frac{1 mole O}{15.9994 g O }=3.48 mol O$$

$$\frac{0.996 mol Na}{0.996 mol Na}=1 mol Na×2=2 mol Na$$

$$\frac{1.98 mol B}{0.996 mol Na}=1.99 mol B×2=4 mol B$$

$$\frac{3.48 mol O}{0.996 mol Na}=3.49 mol O×2=7 mol O$$

 The empirical formula for this compound is Na2B4O7.

Balancing equations

1. Write the equation that expresses in acceptable chemical shorthand the following statement: “Iron can be made to react with molecular oxygen (O2) to give iron oxide with the formula Fe2O3”

Fe(s) + O2 (g) 🡪 Fe2O3 (s)

1. Balance the following reactions:
2. Ca(OH)2 + 2HCl  CaCl2 + 2H2O
3. 2AgNO3 + CaCl2  Ca(NO3)2 + 2AgCl
4. Fe2O3 + C  2Fe + CO3
5. 2NaHCO3 + H2SO4  Na2SO4 + 2H2O + 2CO2
6. C4H10 + 9O2  4CO2 + 5H2O
7. Mg(OH)2 + 2HBr  MgBr2 + 2H2O
8. Al2O3 + 3H2SO4  Al2(SO4)3 + 3H2O
9. 2KHCO3 + H3PO4  K2HPO4 + 2H2O + 2CO2
10. C9H10O + 11O2  9CO2 + 5H2O