Stoichiometry

We have all heard of Autoliv in our community and know that they make air bags. But have you ever wondered how the air bag actually works? It is all controlled by simple chemistry, a part of chemistry referred to as stoichiometry. Stoichiometry is the study of the actual numbers of atoms or molecules involved in a chemical reaction. In the air bag it is extremely important that the bag is inflated with just the right amount of atoms, so that the bag does not over or under inflate. Engineers can keep track of these atoms through stoichiometric equations. The reaction that takes place in the air bag is shown below.

$$2\ NaN_3(s) \quad \text{-----}> \quad 2\ Na(s) \quad + \quad 3\ N_2(g)$$

You will recall that the number in front of the symbols represents the number of moles that are used in a reaction, there are two moles of $NaN_3(s)$, two moles of Na(s), and three moles of $N_2(g)$. The little g at the end of N_2 means it is a gas; this is the gas that inflates the air bag. Today we are going to learn how to use these numbers to calculate the exact number of grams that I need to produce those three very important moles of N_2 gas. Let's see how this process is done.

We know from the reaction that there are three moles of N_2 produced. This means if I can find the molar mass of N_2, then I can easily find the number of grams of N_2 that are needed to inflate the air bag.

$$2\ NaN3(s) \quad \text{-----}> \quad 2\ Na(s) \quad + \quad 3\ N2(g)$$

From my periodic table I can see that that the molar mass of Nitrogen is 14 g, but in this case there are two nitrogens, N_2. Therefore I must take that mass and multiply it by two since there are two N's in every molecule. Thus the molar mass of N_2 is 28 grams/mole. This is the molar mass proportion. I now use this to solve the problem.

I am given three moles of N_2 and I want to know how many grams that is. I know that one mole of N_2 is 28 grams, so I can easliy set this up using a picket fence. You will recal how to use picket fences this from earlier lab books.

$$3\ \cancel{\text{mole } N_2} \ \Big|\ \frac{28 \text{ grams}}{1\ \cancel{\text{mole } N_2}} = 84 \text{ grams } N_2$$

This is a typical stoichiometric equation. They are simple in that if you follow the steps it is next to impossible to make a mistake. These are the types of problems that you will be expected to solve at the end of this instruction. You will be shown the steps in more detail and will have plenty of practice. You will be able to confidently and easily solve stoichiometric equations in no time.

Stoichiometry is a step by step process. You will be shown each step. At the end of each section you will need to do the practice problems to see that you are on the right track. At any time you may go back if you are lost. It is very important that you understand a step before moving on to the next step.

Step 1
Objective: Locate the molar mass of an element using a periodic table.

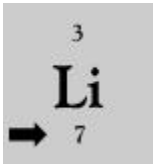
Chemists have devised a means of keeping track of the amount of Matter involved in chemical reactions. This method uses the gram formula mass better known as the **MOLAR MASS** or **MOLE** for short.

In each element box on the periodic table are two numbers - the molar mass of an element is the **LARGER** of these two numbers. For example:

The molar mass of carbon is **12** grams/mole
(Rounded off)

Take out your periodic table and find Lithium, its symbol is **Li**. To find the molar mass you find the bigger of the two numbers in the element box. So let's look at Lithium.

It is easy to see that seven is the bigger number, so the molar mass of Lithium is 7 grams.



The same will be true for all elements. The molar mass is always the bigger number in the elemental symbol box. Let's do some practice.

Using your periodic table write the molar mass of the following elements next to their corresponding symbol. As always, be sure to include the unit (grams). Check your answers in the back of the instruction. If you miss any, review the above and try again.

1. He

2. Ne

3. Fe

4. Hg

5. O

Step 2
Objective: Calculate the molar mass of a compound using a periodic table and a calculator.

Now that you can find the molar mass of an element ,it is time to find the molar mass of a compound. You will recall that a compound is two or more elements that are chemically combined. To find out what the mass of a molecule is you must first count up the different **TYPES** and **KINDS** of atoms. For example:

$CuSO_4$ ---> 1 copper atom + 1 sulfur atom + 4 oxygen atoms

HINT: The small number at the end of chemical symbols is applied only to the symbol that it follows. A small number outside parenthesis applies only to the elements inside the parenthesis. A large number at the beginning of a compound applies to all the elements after.

Let's work through number nine together to see that we get the hint.

$Ca(NO_3)_2$ ---> 1 calcium atom + 2 nitrogen atoms + 6 oxygen atoms

Count up the number and types of atoms in the following molecules:

6. H_2--->

7. $AlCl_3$--->

8. $C_6H_{12}O_6$--->

9. $Ca(NO_3)_2$--->

10. $2H_2SO_4$--->

Next, we **MULTIPLY** the number of each type of atom by the molar mass of the element. (The bigger number in the element box) For example:

$CuSO_4$---> (1 X 63.5 g/mole) + (1 X 32 g/mole) + (4 X 16 g/mole) = 159.5 g/mole

Calculate the molar mass for each of the following molecules: Check your answers in the back of the instruction. If you miss any, review the above and try again.

11. H_2--->

12. $AlCl_3$--->

13. $C_6H_{12}O_6$--->

14. $Ca(NO_3)_2$--->

Step 3
Create proportions for the molar mass of compounds.

You now know how to construct a **PROPORTION** for the molar mass of a substance:

$$\text{Molar Mass} = \frac{\text{grams}}{\text{mole}}$$

$Ca(NO_3)_2$ ---> 1 calcium atom + 2 nitrogen atoms + 6 oxygen atoms

$$(1 \times 40) + (2 \times 14) + (6 \times 16) = 164 \frac{\text{grams}}{\text{mole}}$$

This proportion, 164 $\frac{\text{grams}}{\text{mole}}$ is what we will use later.

HINT: Proportions are useful to us in the picket fence. We will align these proportions to eliminate the undesired units in the answer by using the property of division so that if I have a unit in the numerator and in the denominator, they will cancel each other out.

Using a calculator and the periodic table, write the molar mass for the following molecules in proportion format. Check your answers in the back of the instruction. If you miss any, review the above and try again.

15. H_20--->

16. HCl--->

17. CO_2--->

18. $CaCl_2$--->

Step 4
Determine the desired unit in the answer.

The key to determining the desired unit in the answer is reading the problem and determining what is being asked for. For example

How many **grams** are in 3 moles of HCl?

Well, what is the desired unit in the answer? The problem asks for **grams**, so the unit we have in the answer is **grams**.

One more example,

How many **moles** are in 65 grams of H_2O?

Once again, what is the desired unit in the answer? The problem asks for **moles**, so the unit we have in the answer is **moles**.

Indicate by underlining the unit that is asked for in the answer. Check your answers in the back of the instruction. If you miss any review above and try again.

19. How many grams are in 13 moles of H_2?

20. How many moles are in 26 grams of H_2?

21. How many moles are in 57 grams of HCl?

22. How many moles are in 390 grams of NaCl?

Step 5

Objective: Solve gram to moles problem using a periodic table and a calculator.

We can now use these proportions in a picket fence to calculate the number of moles in a certain mass of a substance. Here we will put all the steps together to set up the problem.

1. Find the molar mass of the element or molecule.
2. Determine the units desired in the answer.
3. Set up the proportions and check that units cancel out.
4. Do the math.

Let's do one together.

1. How many moles are in 26 grams of H_2?

First we need to find the molar mass of H_2. We see that there are two H's in H_2. Looking at the periodic table I see that the molar mass of H is 1g/m. So I must now multiply the molar mass by the number of atoms.

$$\underset{\text{Hydrogen atoms}}{2} \times \underset{\text{molar mass}}{1\text{g/mole}} = 2 \text{ grams/mole of } H_2$$

So every mole of H2 has a mass of 2 $\frac{\text{grams}}{\text{mole}}$. This is my proportion that I will place in the picket fence.

I want moles in my answer, so I must eliminate grams in the picket fence.

$$\frac{26 \cancel{\text{grams}} \mid 1 \text{ mole}}{\mid 2 \cancel{\text{grams}}} = 13 \text{ moles}$$

Using a calculator and the periodic table, calculate the number of moles in the following problems. Check your answers in the back of the instruction. If you miss any, review the above and try again.

23. How many moles are in 107 grams of $C_6H_{12}O_6$?

24. How many moles are in 127 grams of $PbCl_3$?

25. How many moles are in 45 grams of HCl?

26. How many moles are in 540 grams of HgO?

Step 6
Solve mole to grams problem using a periodic table and a calculator.

This will be the same basic process as we used in step five. We will need to just flip the proportion so that we eliminate moles this time in the picket fence.

1. Find the molar mass of the element or molecule.
2. Determine the units desired in the answer.
3. Set up the proportions and check that units cancel out.
4. Do the math.

Let's do one together.

1. How many grams are in 6 moles of KCl?

First we need to find the molar mass of KCl. We see that there are two elements, K and Cl. Both are just 1 atom each. So all I need to do is to find the mass of K and Cl and then add the two masses together. Looking at the periodic table I see that the molar mass of K is 39 grams/mole and the mass of Cl is 35.5 grams/mole. I now add the two masses together..

$$39 \text{ g/mole} + 35.5 \text{ g/mole} = 74.5 \text{ grams/mole of KCl}$$

So every mole of KCl has a mass of $\frac{74.5 \text{ grams}}{\text{mole}}$. This is my proportion that I will place in the picket fence.

I want grams in my answer, so I must eliminate moles in the picket fence.

$$\frac{6 \cancel{\text{ moles}}}{} \left| \frac{74.5 \text{ grams}}{1 \cancel{\text{ mole}}} \right. = 447 \text{ grams}$$

Using a calculator and the periodic table, calculate the number of grams in the following problems. Check your answers in the back of the instruction. If you miss any, review the above and try again.

27. How many grams are in 1.89 moles of HgO?

28. How many grams are in 8.3 moles of $Mg(NO_3)_2$?

29. How many grams are in 5.3 moles of HNO_3?

30. How many grams are in .56 moles of $FeCl_3$?

Congratulations! You are now ready to engineer airbags! Ok, maybe you should hold off on engineering life saving materials, but you are ready to solve stoichiometric problems. You should feel good about your ability to solve difficult problems and to use a step by step process to arrive at an answer. Please take the following test to see if you really get it.

Answer Key

1. He ---> 2 grams

2. Ne ---> 20 grams

3. Fe ---> 56 grams

4. Hg ---> 201 grams

5. O ---> 16 grams

6. H_2---> 2 H

7. $AlCl_3$---> 1 Al, 3 Cl

8. $C_6H_{12}O_6$---> 6 C, 12 H, 6 O

9. $Ca(NO_3)_2$---> 1 Ca, 2 N, 6 O

10. $2H_2SO_4$---> 4 H, 2 S, 8 O

11. H_2---> 2 grams / mole

12. $AlCl_3$---> 133.5 grams / mole

13. $C_6H_{12}O_6$---> 180 grams / mole

14. $Ca(NO_3)_2$---> 164 grams / mole

15. H_20---> 18 grams / mole

16. HCl---> 36.5 grams / mole

17. CO_2---> 44 grams / mole

18. $CaCl_2$---> 111 grams / mole

19. How many <u>grams</u> are in 13 moles of H_2?

20. How many <u>moles</u> are in 26 grams of H_2?

21. How many <u>moles</u> are in 57 grams of HCl?

22. How many <u>moles</u> are in 390 grams of NaCl?

23. How many moles are in 107 grams of $C_6H_{12}O_6$? .59 moles

24. How many moles are in 127 grams of $PbCl_3$? .40 moles

25. How many moles are in 45 grams of HCl? 1.23 moles

26. How many moles are in 540 grams of HgO? 2.48 moles

27. How many grams are in 1.89 moles of HgO? 410.13 grams

28. How many grams are in 8.3 moles of $Mg(NO_3)_2$? 1,228.4 grams

29. How many grams are in 5.3 moles of HNO_3? 333.9 grams

30. How many grams are in .56 moles of $FeCl_3$? 91 grams

1.0 **H** 1																	4 **He** 2
7 **Li** 3	9 **Be** 4											11 **B** 5	12 **C** 6	14 **N** 7	16 **O** 8	19 **F** 9	20 **Ne** 10
23 **Na** 11	24 **Mg** 12											27 **Al** 13	28 **Si** 14	31 **P** 15	32 **S** 16	35.5 **Cl** 17	40 **Ar** 18
39 **K** 19	40 **Ca** 20	45 **Sc** 21	48 **Ti** 22	51 **V** 23	52 **Cr** 24	55 **Mn** 25	56 **Fe** 26	59 **Co** 27	59 **Ni** 28	63.5 **Cu** 29	65 **Zn** 30	68 **Ga** 31	73 **Ge** 32	75 **As** 33	79 **Se** 34	80 **Br** 35	84 **Kr** 36
85 **Rb** 37	88 **Sr** 38	89 **Y** 39	91 **Zr** 40	93 **Nb** 41	96 **Mo** 42	99 **Tc** 43	101 **Ru** 44	102 **Rh** 45	106 **Pd** 46	108 **Ag** 47	112 **Cd** 48	115 **In** 49	119 **Sn** 50	122 **Sb** 51	128 **Te** 52	127 **I** 53	131 **Xe** 54
133 **Cs** 55	137 **Ba** 56	139 **La** 57	178 **Hf** 72	181 **Ta** 73	184 **W** 74	186 **Re** 75	190 **Os** 76	192 **Ir** 77	195 **Pt** 78	197 **Au** 79	201 **Hg** 80	204 **Tl** 81	207 **Pb** 82	209 **Bi** 83	210 **Po** 84	210 **At** 85	222 **Rn** 86
223 **Fr** 87	226 **Ra** 88	227 **Ac** 89	261 **Rf** 104	262 **Db** 105	263 **Sg** 106	262 **Bh** 107	265 **Hs** 108	266 **Mt** 109	269 **Uun** 110	272 **Uuu** 111	272 **Uub** 112						

atomic number ---> (number of protons)

1.0 **H** 1 <---- atomic mass (protons + neutrons)

140 **Ce** 58	141 **Pr** 59	144 **Nd** 60	147 **Pm** 61	150 **Sm** 62	152 **Eu** 63	157 **Gd** 64	159 **Tb** 65	163 **Dy** 66	165 **Ho** 67	167 **Er** 68	169 **Tm** 69	173 **Yb** 70	175 **Lu** 71
232 **Th** 90	231 **Pa** 91	238 **U** 92	237 **Np** 93	244 **Pu** 94	243 **Am** 95	247 **Cm** 96	247 **Bk** 97	251 **Cf** 98	252 **Es** 99	257 **Fm** 100	258 **Md** 101	259 **No** 102	262 **Lr** 103