# Fun with Stoichiometry!

I know what you're thinking: You hate stoichiometry. You can't pronounce it, you can't spell it, and it involves all kinds of calculations that drive you crazy. Your friends all hate it, too, and your teacher keeps using the word "stoichiometry" like it's some kind of magic word.

OK… take a deep breath. We're about to start over from scratch, so forget everything you know about stoichiometry (that is, if you knew anything to start with), because we're going to start over.

## What is stoichiometry, anyway?

The best definition for stoichiometry is this: It's a way of figuring out how much stuff you're going to make in a chemical reaction, or how much stuff you'll need to make a chemical reaction do what you want.
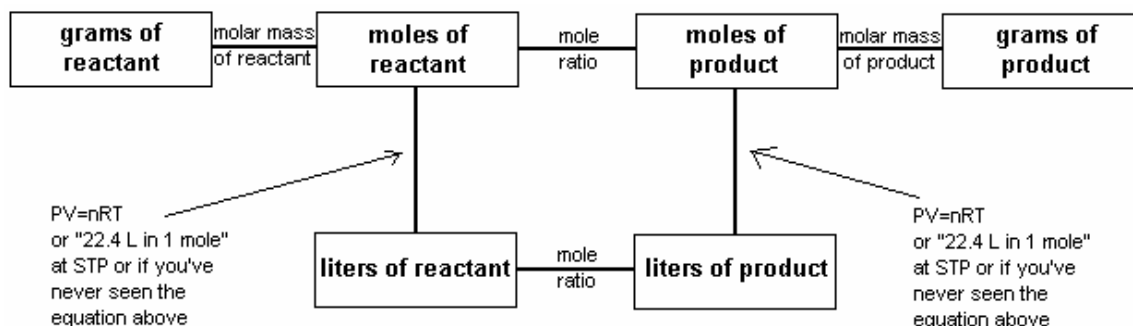
This isn't scary at all. Let's think of my favorite chemical reaction: Making peanut butter and jelly sandwiches (OK… maybe it's not a chemical reaction, but the idea is the same). When I'm really hungry, I do stoichiometry during this process. For example, if I have ten pieces of bread in my house, stoichiometry converts the amount of break I have (ten pieces) into the number of sandwiches I can make (five). This is **exactly** the same thing that you do in chemistry, except that the conversion factors are a little bit more challenging.

## How do I get started?

Before I can even answer this question, you'll need to understand how I do calculations. Since stoichiometry calculations are exactly the same thing as unit conversions, you should review how to do T-chart unit conversions at http://misterguch.brinkster.net/unitconversions.html before continuing. I'll wait patiently here while you do that.

OK… I know you didn't visit that link. Seriously, go visit that link, or my explanation won't make any sense. You'll be just as frustrated as you were before, and you don't want *that*, do you? Of course not! Go visit that link, learn how to do unit conversions using my fancy method, and then come on back.

Now that you understand how to do unit conversions using my handy dandy method, I'm going to throw a big scary diagram at you. Please don't freak out – it's a lot easier to use than it looks:

grams of reactant | molar mass of reactant | moles of reactant | mole ratio | moles of product | molar mass of product | grams of product

liters of reactant | mole ratio | liters of product

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Believe it or not, this is the ONLY thing you have to memorize to do stoichiometry calculations (assuming you actually followed the link I gave you earlier – if you didn't do it then, do it now or you won't understand what I'm talking about later). Before we do anything, let's go through what all the chemical terms on this diagram mean.

**reactant**: The thing that you start with in the reaction. For making PB&J sandwiches, bread is a reactant. For the equation $2 H_2 + O_2 \rightarrow 2 H_2O$, both $H_2$ and $O_2$ are reactants.

**product**: The thing you make in the reaction. For making PB&J sandwiches, the sandwich is your product. For the equation $2 H_2 + O_2 \rightarrow 2 H_2O$, water is your product.

**mole ratio**: The ratio of the product and reactant in a chemical reaction. The numbers that fit into this ratio are pulled *directly* out of the balanced equation for the reaction. I realize that this doesn't make any sense to you yet, so don't worry too much about this right now.

**PV=nRT (and all the stuff written around it)**: If you've studied the gas laws, you already know how to convert liters to moles (using pressure and temperature and whatnot). If you need a review of how to do this, visit my handy tutorial page at http://misterguch.brinkster.net/gaslaws.html – if you've never seen it before, then the only thing you need to know about this are the words "22.4 L in 1 mole."

**molar mass**: The molar mass is also known as the "molecular mass", "molecular weight", and "gram formula mass." If you don't remember what this means, check out my tutorial page on the subject at http://misterguch.brinkster.net/molarmass.html.

**That's great, Mr. Guch – but now what do I do?**

Hey, I'm getting to that! The diagram I gave you is nothing more than a map that explains how to get from what you've been given in the problem to what you've

been asked to figure out.  (To see how this works using a simpler diagram, take a look at http://misterguch.brinkster.net/molecalculations.html).

The idea is simple.  Given the problem you're trying to solve, figure out what box in the diagram is your starting point and which diagram in your box is the ending point.  Then, using the T-chart method that we use for such things (once again, a more complete description of this is at http://misterguch.brinkster.net/unitconversions.html), we convert stepwise from our starting box through each intermediate step until we reach our destination box.

The best way to understand how this works is to just do an example.

**Example:  How many grams of water can I make from 25 grams of hydrogen gas and an excess of oxygen gas, using the reaction 2 $H_2$ + $O_2$ $\rightarrow$ 2 $H_2O$?**

**Answer:**  Let's take this one step at a time!

**Step 1:  Figure out our starting and destination boxes.**
Since we were given 25 grams of hydrogen in the problem, and hydrogen is a reactant in this reaction, we will start at "grams of reactant" as our starting box.  Since we're trying to figure out how many grams of water we can make and water is a product, "grams of product" is our destination box:
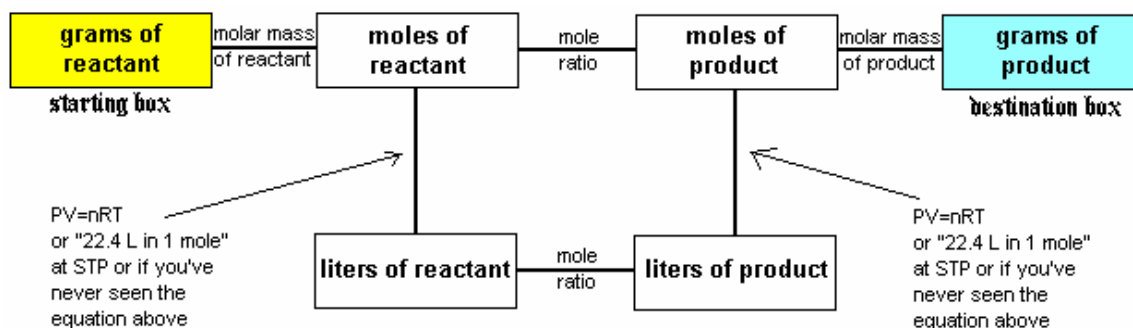


One thing that students always find challenging is the term "excess of [whatever]."  When you see that in a problem, all this means is that there's so much of that reactant around that you don't need to worry about it.  Focus on the other reactant.  When we get to limiting reactant problems, *then* we'll worry about it!

**Step 2:  Move one box toward the destination box, doing the necessary calculation.**
In this case, we're going to move from the "grams of reactant" box to the "moles of reactant box."  Since we already know how to do this (from converting from grams to moles using the T-chart method, as mentioned above and as described

in gory detail at http://misterguch.brinkster.net/molecalculations.html), we can see that this is done like this:

| 25 grams hydrogen | 1 mole hydrogen |
|---|---|
| | 2 grams hydrogen |

### Step 3: The dreaded mole ratio!

What's a mole ratio? Don't worry about that yet. What we'll do is simply set up our calculation from "moles of reactant" to "moles of product" just like we do with every T-chart calculation and not even worry about the numbers we need for our conversion factors. When we do that, we end up with:

| 25 grams hydrogen | 1 mole hydrogen | moles water |
|---|---|---|
| | 2 grams hydrogen | moles hydrogen |

Of course, we need to know what numbers to put in front of "moles water" and "moles hydrogen." These numbers are the numbers from in front of each formula in the balanced chemical equation for this reaction. In our case, the reaction is $2 H_2 + O_2 \rightarrow 2 H_2O$, so the number in front of "moles water" is "2" and the number in front of "moles hydrogen" is also "2". Putting these numbers into the equation, we end up with:

| 25 grams hydrogen | 1 mole hydrogen | 2 moles water |
|---|---|---|
| | 2 grams hydrogen | 2 moles hydrogen |

### Step 4: Move to the destination box.

If you understood all of this so far, then you probably understand what I mean here. Do the calculation from "moles product" to "grams product", which should look like this:

| 25 grams hydrogen | 1 mole hydrogen | 2 moles water | 18 grams water |
|---|---|---|---|
| | 2 grams hydrogen | 2 moles hydrogen | 1 mole water |

### Step 5: Do the math

To do the math, simply multiply all the numbers on the top of the T together and divide it by the multiplied numbers from the bottom.  When you do this, you end up with 225 grams of water.  That's your answer!

**Limiting reagent problems:**
Now that you know how to do regular problems of this sort, it's time to figure out how to do limiting reagent problems.  These problems are of this general variety:

**Problem:  How many grams of water can I make from 22 grams of hydrogen and 195 grams of oxygen?**

**Answer:  Do <u>two</u> stoichiometry calculations!**

The idea here is simple.  Do two stoichiometry calculations.  One will convert 22 grams of hydrogen to grams of water and the other will convert 195 grams of oxygen to water.  The answer which gives the smallest amount of product will be the correct answer, and the reactant which gives you this answer is the "limiting reagent" (because it ran out before the other one did).

Conceptually, we can see how this works with sandwiches.  If I make a very boring sandwich from 2 slices of bread and 1 slice of cheese, I can ask myself a limiting reagent problem like this:

**How many cheese sandwiches can I make using 500 slices of bread and 2 slices of cheese?**

Now, this is a pretty simple question that you can solve in your head, but the idea is the same.  If you examine how you solve problems like this, you find that your mental process figures out how many sandwiches you can make from 500 slices of bread (250 sandwiches) and how many you can make from 2 slices of cheese (2 sandwiches).  Because you run out of cheese after 2 sandwiches, you can only make 2 sandwiches no matter how much bread you have.  In this question, cheese was our "limiting reactant."

Using your stoichiometry knowledge, do the calculation to see how much water we can make from 22 grams of hydrogen and 195 grams of oxygen.  I'll wait here.

OK… when you do this calculation, you end up with two different answers.  Let's see those two calculations (I won't go through each step because you already know how to do this kind of problem):

$$\frac{22 \text{ grams hydrogen}}{} \cdot \frac{1 \text{ mole hydrogen}}{2 \text{ grams hydrogen}} \cdot \frac{2 \text{ moles water}}{2 \text{ moles hydrogen}} \cdot \frac{18 \text{ grams water}}{1 \text{ mole water}} = 198 \text{ g water}$$

$$\frac{195 \text{ grams oxygen}}{} \cdot \frac{1 \text{ mole oxygen}}{32 \text{ grams oxygen}} \cdot \frac{2 \text{ mole water}}{1 \text{ mole oxygen}} \cdot \frac{18 \text{ grams water}}{1 \text{ mole water}} = 220 \text{ grams water}$$

Since 198 grams of water is smaller than 220 grams of water, our answer is 198 grams of water.  Because hydrogen was the reactant that caused us to get this answer, it is the limiting reagent.

I hope this helped you!  I've got many handy stoichiometry worksheets for your practicing pleasure on this page: http://misterguch.brinkster.net/pra_equationworksheets.html.