

Gas stoichiometry

At some point in your chemistry career (probably now), somebody (probably an instructor) will ask you to do something that combines the twin fun of gas laws and stoichiometry. And, like most students, you say to yourself, “Man, that stoichiometry sucks.” Even if you understand stoichiometry (and hopefully you do), you’ll still say that because everybody in your class will think you’re a nerd if you don’t. Nobody wants that.

In any case, let’s learn how to do some gas stoichiometry.

What is stoichiometry?

The short answer: Stoichiometry is how you figure out how much stuff will be made in a chemical reaction, or how much stuff you’ll need to use when performing a chemical reaction. The calculations that make this possible make heavy use of chemical equations. In the case of gas stoichiometry, gas laws are required in at least one of these calculations.

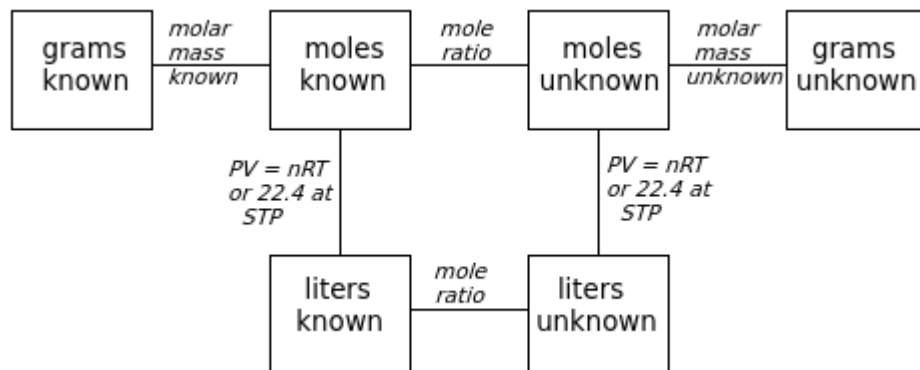


This child is upset because he doesn't yet have the mathematical knowledge to perform stoichiometric calculations.

The basics of gas stoichiometry

I want to say again that this tutorial will assume that you know how to do regular stoichiometry using grams and moles and such. If you don't, you need to go back to [this tutorial](#) to learn about it.

If you already know how to perform stoichiometry calculations, this diagram shouldn't be too scary:



Think of this as a roadmap to stoichiometry of just about any kind. To use it, figure out where you're starting from and where you're ending, and do the calculations that correspond to the journey you need to take.

Before you embark on this voyage, I want to clarify some things about this diagram to make it simple:

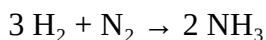
- The terms “known” and “unknown” refer to the things that you are given in the problem and the things you are trying to find, respectively. For example, if the problem says “How many liters of water vapor can you make from 2.44 grams of hydrogen when it's combined with an excess of oxygen?”, the known is 2.44 grams of hydrogen (you know how much you have from the problem) and the unknown is liters of water vapor because that's what you're trying to find.
- You need to do one calculation for each box you move across in this diagram. For example, if you go from “grams known” to “liters unknown” (as you would in the example above), you'll need to do three calculations (grams known → moles known, moles known → moles unknown, and moles unknown → liters unknown).
- STP refers to the term “standard temperature and pressure”, and is equal to 273 K (0° C) and a pressure of 1 atm. 1 mole of a gas is equivalent to 22.4 liters *only* at STP – you'll need to use $PV = nRT$ to figure out what it is for other conditions.
- As is the case in all gas law calculations, calculations should always refer to temperature in Kelvin and not in degrees Celsius. You can find Kelvin from degrees Celsius by adding 273.

In other words, this is pretty much the same blueprint as I had in the regular stoichiometry tutorial. If you understood that, you shouldn't have too much trouble. If you don't know standard grams – moles stoichiometry, you really need to go back to [this tutorial](#) to learn it.

Doing a gas stoichiometry calculation

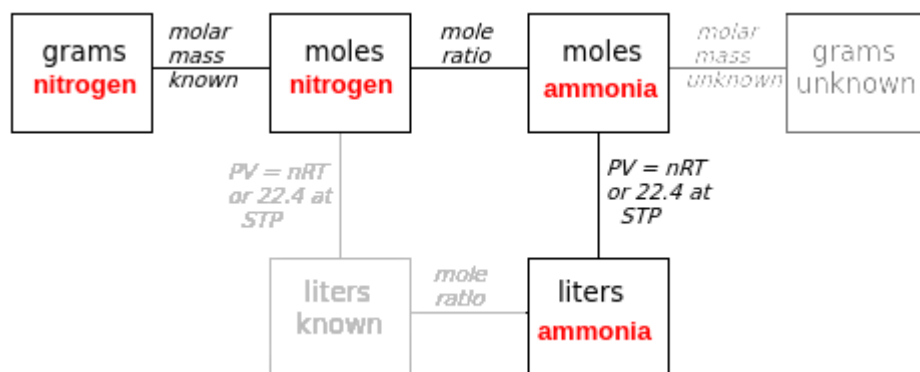
Rather than going through a bunch of steps that tell you what you ought to do, I'm going to solve problems so you can figure it out by seeing it done for real. Let's see an example:

Example: When energy is added, we see the following reaction:



All of these chemical species are gases. If I were to perform this reaction with 17.5 grams of nitrogen gas and an excess of hydrogen gas, how many liters of ammonia will I make at STP?

Solution: Our first step will be to figure out what the heck we need to do in this reaction. Let's refer back to the diagram above to make sense of it:

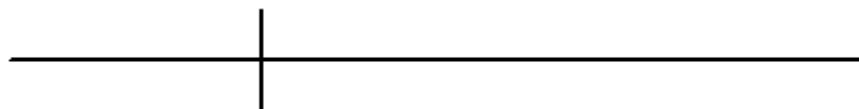


As you can tell from my subtle use of shading, we aren't going to be dealing with liters of known or grams of unknown. Instead, we'll be doing three calculations, starting with grams of nitrogen and wrapping up with liters of ammonia.

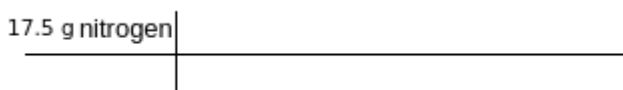
Let's see how.

Step 1: Draw a t

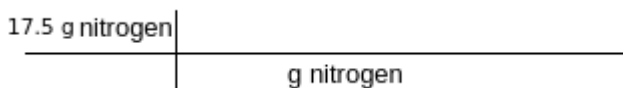
You always do this when doing either mole calculations or stoichiometry, so draw one here:



Step 2: Put whatever you're starting with in the top left part of the t:



Step 3: Put the units of whatever is in the top left on the bottom right. Since we start with "g nitrogen", we'll put that in the bottom right:



Step 4: Put the units of whatever you're trying to find in this calculation in the top right. As you can see from the cool diagram, our first step is taking us from "g nitrogen" to "moles nitrogen":

17.5 g nitrogen	mol nitrogen
	g nitrogen

Step 5: Put conversion factors in front of the units given. Here are the rules you need to follow:

- Always write the molar mass of the compound before the word "grams" in a unit conversion.
- In all steps other than the mole ratio, write "1" in front of the word "moles."
- In the mole ratio step, the numbers before each "moles" are the coefficients in each equation.

In this case, what this means is that we write "1" in front of "moles nitrogen" (it's not the mole ratio, so we *always* write "1" in front of moles) and "28.0 grams" in front of "g nitrogen" (28.0 is the molar mass of nitrogen gas):

17.5 g nitrogen	1 mol nitrogen
	28.0 g nitrogen

Step 6: The problem is now 1/3 finished, with the grams nitrogen to moles nitrogen step taken care of. I won't go through all the steps, but you basically do exactly the same thing in our second calculation:

17.5 g nitrogen	1 mol nitrogen	2 mol ammonia
	28.0 g nitrogen	1 mol nitrogen

I'll walk you through it in case you had some problems:

- First, I wrote "mol nitrogen" in the bottom right.
- Next, I wrote "mol ammonia" in the top right.
- Finally, I put the conversion factors in front of each. Because this is the mole ratio step, 2 goes in front of ammonia (check the equation!) and 1 goes in front of nitrogen (check the equation!).

Step 7: Switching gears to gases

Now that we've done some moles-grams stuff, you'll notice that our next step is to convert from moles of ammonia to liters of ammonia. This is done using our friend $PV = nRT$, or in the case of gases at STP, 22.4 L/mol.

In this example we're at STP, so we'll just continue the calculation above using "22.4 L" as our conversion factor:

17.5 g nitrogen	1 mol nitrogen	2 mol ammonia	22.4 L ammonia
	28.0 g nitrogen	1 mol nitrogen	1 mol ammonia

Step 8: Finding our answer

To find the answer to this calculation, multiply all the terms on the top together ($17.5 \times 1 \times 2 \times 22.4$) and divide by the product of the terms on the bottom ($28.0 \times 1 \times 1$). If you do the calculation accurately, you should find that you have 28.0 liters of ammonia gas. Which is the answer.

What if we're not at STP?

Let's say that we're going to do the same reaction as above, except that we'll be performing the reaction at a pressure of 1.50 atm and a temperature of 425 K. What happens then?

In the first few steps, it turns out that we do exactly the same thing that we did before. Unless we're dealing with a gas, our stoichiometry doesn't care at all what the pressure and temperature are.

What this means is that everything above is identical up through step 6:

17.5 g nitrogen	1 mol nitrogen	2 mol ammonia
	28.0 g nitrogen	1 mol nitrogen

Our last step, on the other hand, is a little different, because we can't use 22.4 liters as our conversion factor. After all, we're not at STP!

Our solution, as the big diagram suggests, is to use $PV = nRT$ to figure out our conversion factor (if you don't know how, visit [this tutorial](#)). To do this, simply put the terms from the problem into this equation, and leave the number of moles as "1". This will give you your conversion factor:

$$PV = nRT$$

$$(1.50 \text{ atm})(V) = (1.00 \text{ mol})(0.08206 \text{ L atm/mol K})(425 \text{ K})$$

$$V = 23.3 \text{ L}$$

At this point, we use 23.3 L instead of 22.4 L in our calculation to give us our final answer:

17.5 g nitrogen	1 mol nitrogen	2 mol ammonia	23.3 L ammonia
	28.0 g nitrogen	1 mol nitrogen	1 mol ammonia

= 25.5 liters
