

Experiment 12

Molar Mass of a Gas

19 November 2019

If we can figure out the molar mass, we can possibly identify the gas.

C_4H_{10} MM = 58.1 g/mol

CO_2 MM = 44.0 g/mol

O_2 MM = 32.0 g/mol

CH_4 MM = 16.0 g/mol



I like shiny things.

Objectives: Use the ideal gas law to determine the molar mass of an unknown gas.



We end this semester with an experiment that utilizes the ideal gas law in both of its forms.

We will use this to determine the molar mass of a gas.



Overview:

1. From the ideal gas law to molar mass
2. The two experiments
3. Data collection and calculations
4. Procedure: What we do today
5. Your lab report



We can do this???

1. From the ideal gas law to molar mass

So starting with the equation for the ideal gas law, we substitute in for moles, n . Then rearrange to solve for molar mass, MM ...



... using a little trick we call math.



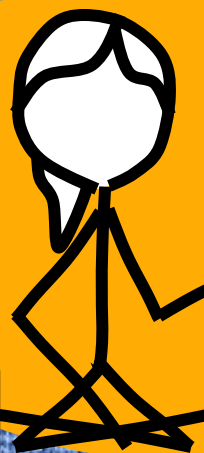
$$P V = n R T$$

$$n = \frac{m}{MM}$$

$$P V = \frac{m R T}{MM}$$

$$MM = \frac{m R T}{P V}$$

And R is the gas constant, $0.0821 \text{ L atm mol}^{-1} \text{ K}^{-1}$



So if we knew the mass of a gas, its temperature, volume and pressure, we'd have everything we needed to calculate MM ! This is one method we will use today.



**Info for
Introduction**

1. From the ideal gas law to molar mass

Here's the other way we'll do it... Solve for R and realizing R is a constant, we can write the equation in the green box, where A and B are different conditions, and in our case, different gases!

$$P V = n R T$$

$$R = \frac{P V}{n T}$$

$$\frac{P_A V_A}{n_A T_A} = \frac{P_B V_B}{n_B T_B}$$

$$n = \frac{m}{MM}$$

$$\frac{\cancel{P}_A \cancel{V}_A MM_A}{m_A \cancel{T}_A} = \frac{\cancel{P}_B \cancel{V}_B MM_B}{m_B \cancel{T}_B}$$

$$\frac{MM_A}{m_A} = \frac{MM_B}{m_B}$$

Sub in m/MM for n and then cancel P , V and T because they will be the same on the same day using the same vessel.

Info for
Introduction

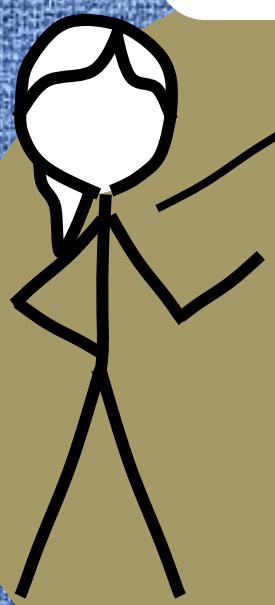
Ooo! Ooo!
The **P**eas and
Vegetables on
the **n**ice **T**able
equation!

Leaving us a
pretty simple
equation that
we will use
today!

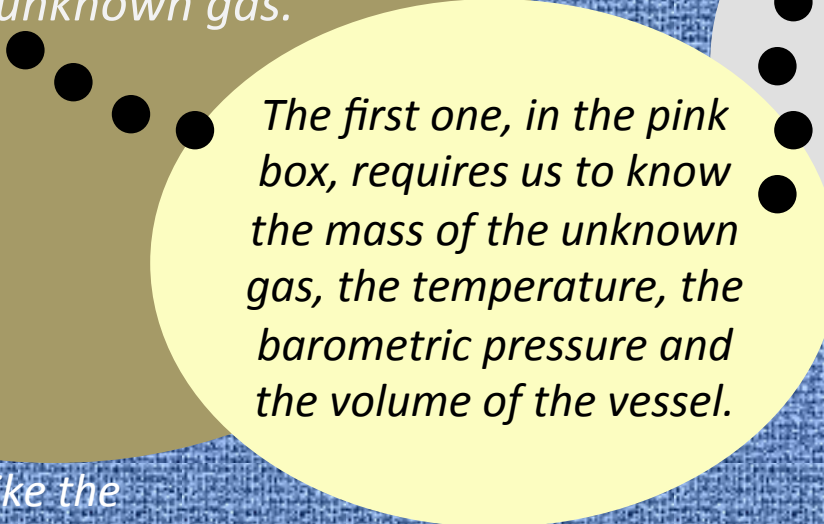
2. The two experiments

$$MM = \frac{m R T}{P V}$$

$$\frac{MM_A}{m_A} = \frac{MM_B}{m_B}$$




So here are the two equations that will give us the molar mass of an unknown gas.



The first one, in the pink box, requires us to know the mass of the unknown gas, the temperature, the barometric pressure and the volume of the vessel.



I like the word vessel.



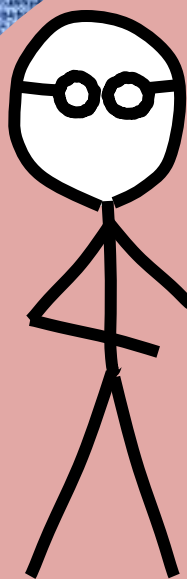
We can easily measure the

- *temperature with a thermometer.*
- *We'll need to flip it into kelvin, but that's easy peasy.*

3. Data collection and calculations

$$MM = \frac{m R T}{P V}$$

$$\frac{MM_A}{m_A} = \frac{MM_B}{m_B}$$



*Reading the volume is done **where the black seal meets the gas**. You should be able to squeak 3 sig figs out of it, but the syringe is probably only accurate to two*




*Right here:
58.0 mL*

3. Data collection and calculations

$$MM = \frac{m R T}{P V}$$

$$\frac{MM_A}{m_A} = \frac{MM_B}{m_B}$$



The pressure is read with a barometer. We have one in the Chemistry Department, but only a few souls have ever seen it or know where it is. Here is a picture of it that we took for you. It looks like it may have been built by Evangelista Torricelli himself. But probably not...

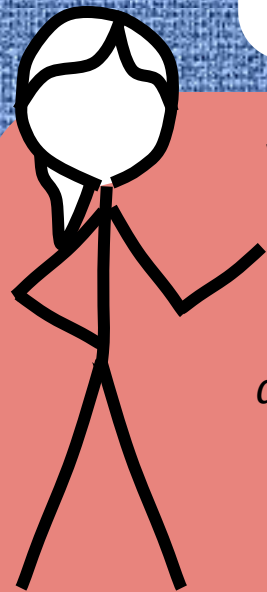
Sooo, why can't we just google the current barometric pressure in Omaha?

We can! And that is what we'll do! But there is a little hitch.

3. Data collection and calculations

$$MM = \frac{m R T}{P V}$$

$$\frac{MM_A}{m_A} = \frac{MM_B}{m_B}$$

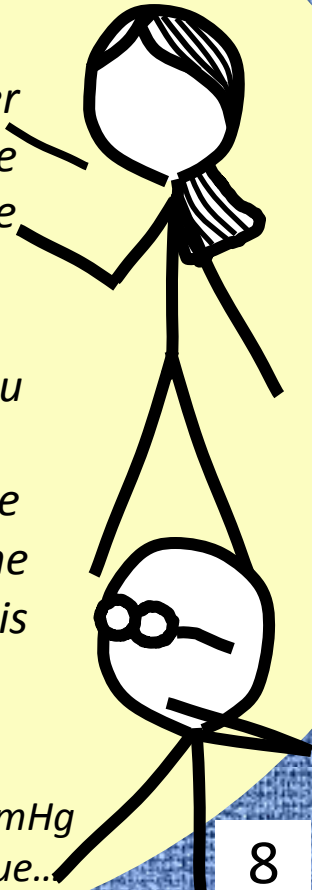


You can find the current barometric pressure in Omaha on-line. It is probably not given in atmospheres – it may be in inches of mercury. Start by converting the pressure into mmHg.



1 inch = 25.4 mmHg – an exact number, BTW.

*Then things get weird. The barometric pressures given by the National Weather Service and all other weather outlets are elevation adjusted – to give the pressure as if Omaha were at sea level. A nice thought. The weather people have a reason for doing this. So the number you get from the internet is **27.2 mmHg higher than the actual pressure** because of Omaha's elevation. For example, if the value you get from the Weather Service is 768.9 mmHg, the actual pressure in Omaha is $768.9 - 27.2 = 741.7$ mmHg*

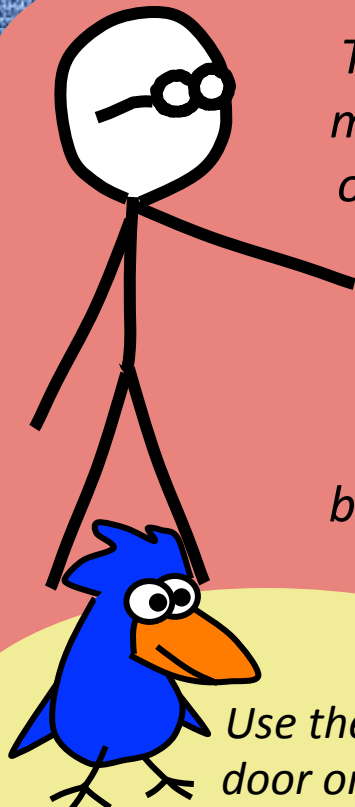


So... I subtract 27.2 mmHg from the internet value...

3. Data collection and calculations

$$MM = \frac{m R T}{P V}$$

$$\frac{MM_A}{m_A} = \frac{MM_B}{m_B}$$



That leaves us with measuring the mass of the gas. See how the syringe can stand on its little cap? This lets us place it on the balance standing on its cap!

Use the balance door on the top!



Measure the mass of the syringe with the gas, then shoot the gas out and mass it again under vacuum. Use the same balance and cap and nail.

Filling the syringe with a vacuum, whatever that means, takes two people.



3. Data collection and calculations

We measure the masses with the best balance we can find – using all decimal places.

$$MM = \frac{m R T}{P V}$$

Pressure comes from the internet converting to mmHg and subtracting 27.2 mmHg due to the elevation correction...

... then convert to atmospheres for use with R.

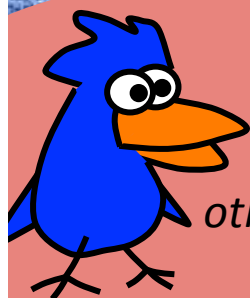
And volume is read from where the black seal meets the gas. Oh, and convert to liters.

We measure the temperature as carefully as possible – two significant figures. When we convert to kelvin we get three sig figs, due to the rule for adding numbers.

3. Data collection and calculations

$$MM = \frac{m R T}{P V}$$

$$\frac{MM_A}{m_A} = \frac{MM_B}{m_B}$$



On to the other method!

Compare the measurements we need to make for the second equation with the first.

We'll do it both ways and see which gives the best results.

With the second equation, we just need two masses and a known molar mass.

When we study our unknown using the second equation, we use CO_2 , with $MM = 44.01 \text{ g/mol}$ as our known.



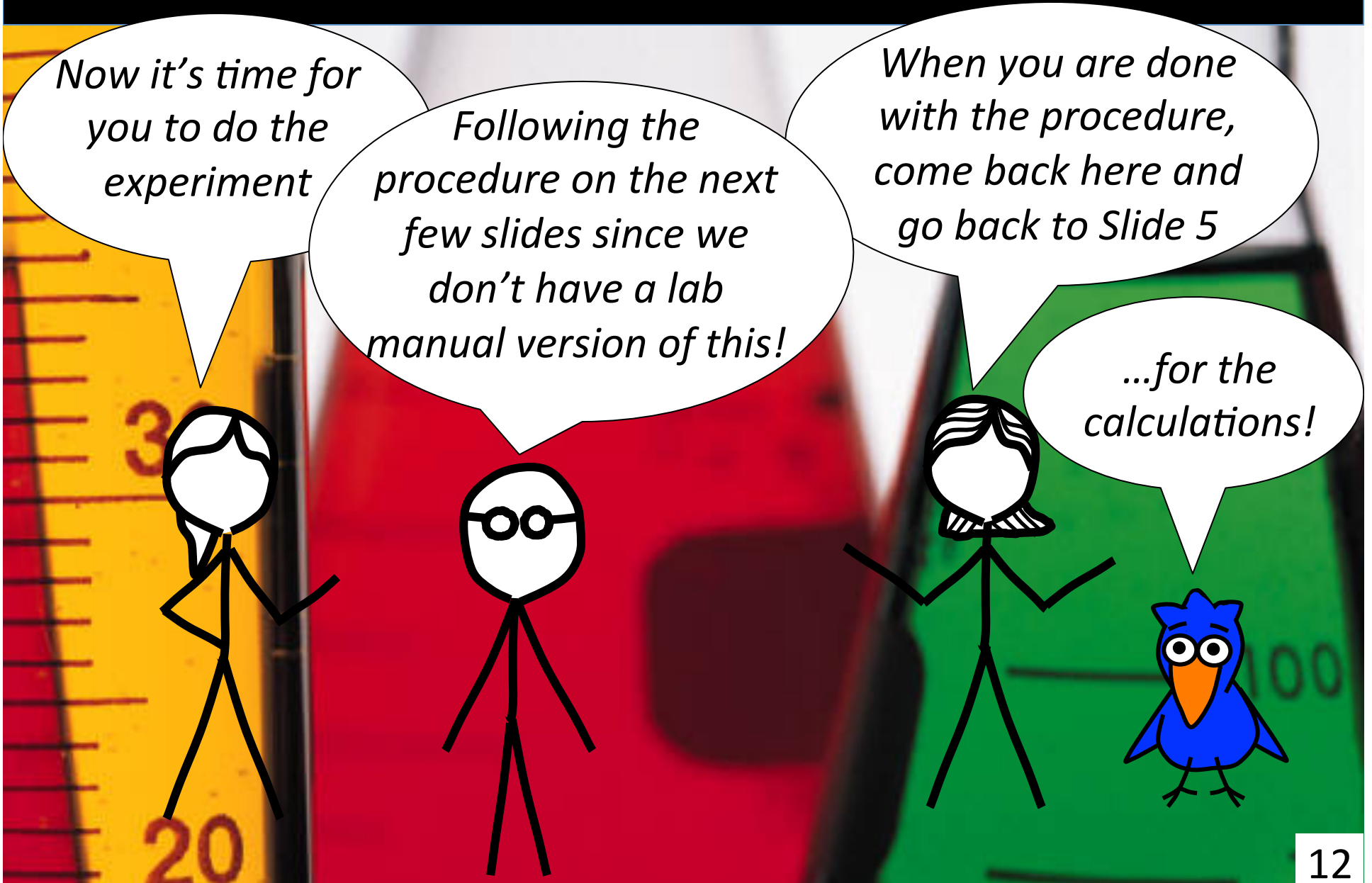
4. Procedure: What we do today

Now it's time for you to do the experiment

Following the procedure on the next few slides since we don't have a lab manual version of this!

When you are done with the procedure, come back here and go back to Slide 5

...for the calculations!

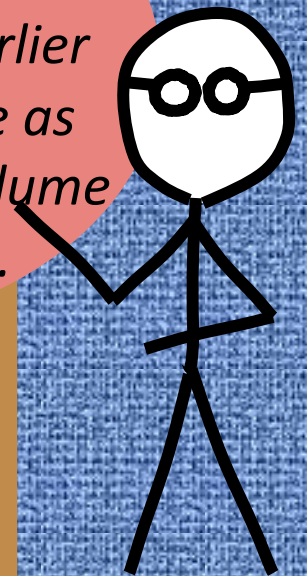


4. Procedure: What we do today

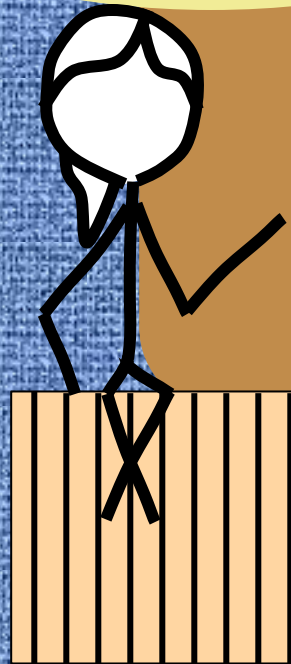


In addition to the measurements mentioned on Slide 10 (temperature, pressure and volume), we need to measure four masses. Check out the back of your cover sheet!

Measure temperature, and pressure as described on the earlier slides. Be as precise as possible. We'll do volume on the next slide.

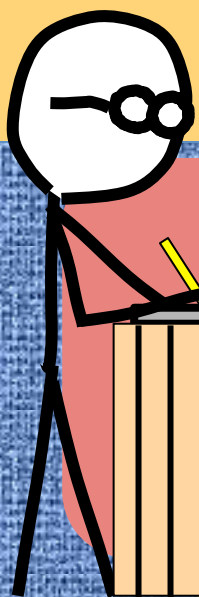


So, about those four masses... These can be measured in any order, but we must always use the same equipment.



Same syringe barrel. Same syringe plunger. Same syringe cap. Same nail. Same. Same. Same Bird. Everything the same.

4. Procedure: What we do today



Mass measurements are done on the analytical balance with as many significant figures as possible.

*Don't forget to **tare** the balance before adding the syringe apparatus.*



An important mass that we will need is the mass of the empty syringe filled with a vacuum, whatever that means. Our TAs and Dr M will show you how to do this.

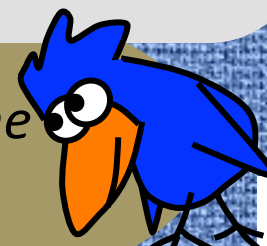
Another mass we need is of the syringe apparatus filled with CO_2 . And the final mass is of the syringe filled with the unknown gas – the mystery gas. We measure the mass of the mystery gas twice.

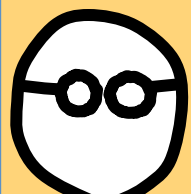


Also...read the volume using this evacuated syringe. Do this as carefully as possible.



Now go do the calculations.





4. Procedure: What we do today

- ① *Wearing your safety glasses is always prudent, but today we will not be enforcing it. No special attire needed today. We are not making a mess.*
- ② *Take time writing an introduction in your own words before lab.*
- ③ *We follow the procedure part of the lab manual carefully today.*
- ④ *Record observations and details as carefully as possible. Show your calculations (both ways) with formulas, units, and significant figures!*
- ⑤ *Write your conclusions in your own words. Take time to do this carefully and with thought. In your conclusions, address percent error given by the formula:*

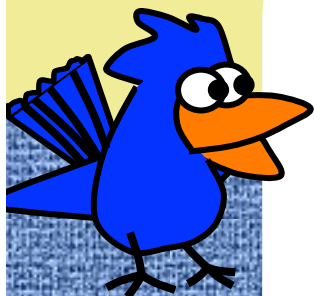
$$\% \text{ error} = 100\% \times |\text{Actual} - \text{Experimental}| / \text{Actual}$$

The little red || marks mean absolute value. Percent error is always positive.



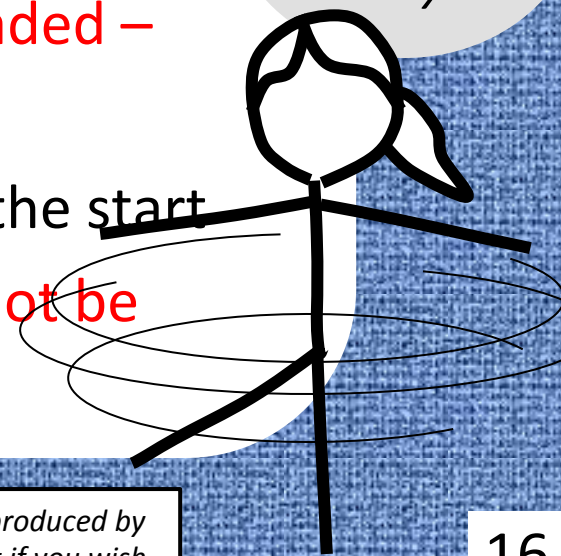
5. Your lab report

Read this!



- ① First, the cover page with TA initials.
- ② Next, the trimmed copy pages from your lab notebook stapled together. Staple all together.
- ③ **On-line results** due at the end of class today. **Late submissions are not graded – see the syllabus.**
- ④ Turn in lab report **today** or **before** the start of class tomorrow. **Late labs may not be graded – see the syllabus.**

Yippee! This lab was easy!



Stick people inspired by xkcd cartoons by Randall Munroe (www.xkcd.com)

Chem Lab with the Stick People and Bird was created and produced by Dr. Bruce Mattson, Creighton Chemistry. Enjoy it and share it if you wish.