CHE 1301

Basic Principles of Modern Chemistry I

Week 13

Hi! Thanks for checking out the weekly resources for Chemistry 1301! This resource covers topics typically taught by professors during the 13th week of classes.

Visit our website, https://baylor.edu/tutoring, to sign up for appointments and check out additional resources for your course! You'll find helpful links with the following titles:

- "Online Study Guide Resources" – The pace of your course may vary slightly from what's shown in this document. If you don't see the topics you're learning right now, use this link to find the weekly resources for the rest of the semester.
- "How to Participate in Group Tutoring" - See if there is a Chemistry 1301 group tutoring session being hosted this semester. These are weekly question/answer sessions taught by our master tutors!
- "View tutoring times for your course" or "Schedule a private 30-minute appointment!"

You can also give us a call at (254)710-4135, or drop in! Our hours are Monday-Thursday 9 am – 8 pm on class days.

KEY WORDS: Properties of Gases, Boyle's Law, Charles' Law, Avogadro's Law, Ideal Gas Law

TOPIC OF THE WEEK: Properties of Gases

When discussing properties of gases, it's important to think of them on the molecular level. These definitions will explain the relationships that Boyle, Charles, and Avogadro turned into laws.

Let's start with a list of things that we could measure that would describe a gas:

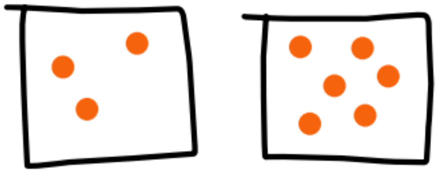
1. Number of molecules of gas
2. Volume of gas
3. Temperature of gas
4. Pressure of gas

To focus in on that last one:

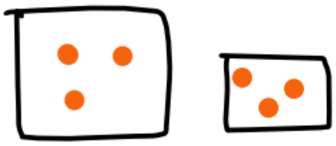
> Pressure, mathematically, **is F/A, or force per unit area**. In other words, how much are the gas molecules pushing on the outside of their container? This is determined by how often the molecules hit the outside of the container. If they're **moving faster**, or if they're **closer together**, they'll hit the wall **more often**.

So, let's look at how 1-3 could affect pressure!

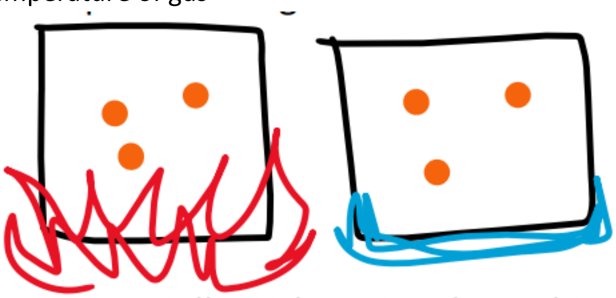
1. Number of molecules of gas



   Which container has the higher pressure? (Think: In which situation will the molecules hit the walls of the container more?) **The second one**! There are more molecules, so they bump into each other and force each other toward the walls.
2. Volume of gas



   Which container has the higher pressure? It's **the one on the right**. The molecules have less space to move around, so they hit the walls of the container more.
3. Temperature of gas



   This one is especially tricky. It involves a bit of physics—we have to think about the effects of increasing temperature on the speed of the molecules. Speed of molecules depends on a type of energy called kinetic energy…and heat is the transfer of energy. When a container is heated, the kinetic energy of the molecules increases, and they move more quickly. If they move more quickly, they hit the walls of the container more often, which means that pressure is **greater in the situation on the left**.

- Calculating force: F=ma
  - To calculate pressure, use P = F/A. Sometimes, you won't be given the force that's applying pressure, but you will be given a mass of the gas above the location for which you're trying to calculate.
  - This mass is being pulled by gravity. Gravity is a type of acceleration equal to 9.8 m/s^2.
  - Calculate force: F=ma. Then, plug force into P=F/A to determine pressure.

Keep these molecular-level explanations in mind as you look over the next few relationships!

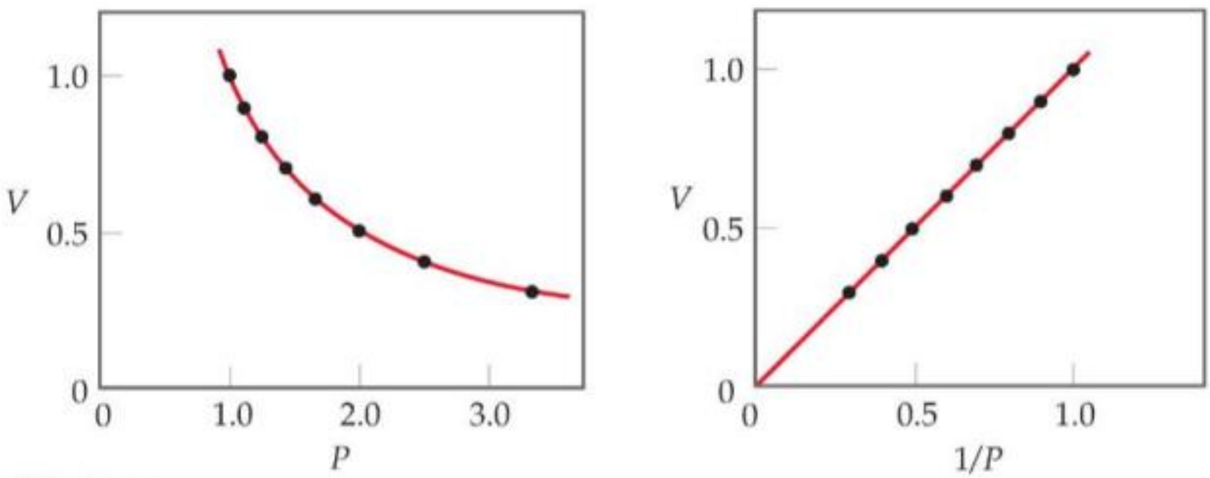
Highlight 1: Boyle's Law

Boyle investigated the relationship between pressure and volume. He found that they are inversely related: as pressure increases, volume decreases. As volume increases, pressure decreases. (Why is this the case? See above!) This relationship can be described as follows: V=k/P

Or,

$V_1P_1=V_2P_2$

Notice that V and P are inversely related! Think of it this way: **if pressure were increased, to keep the equation true, V would have to decrease, because k doesn't change**.

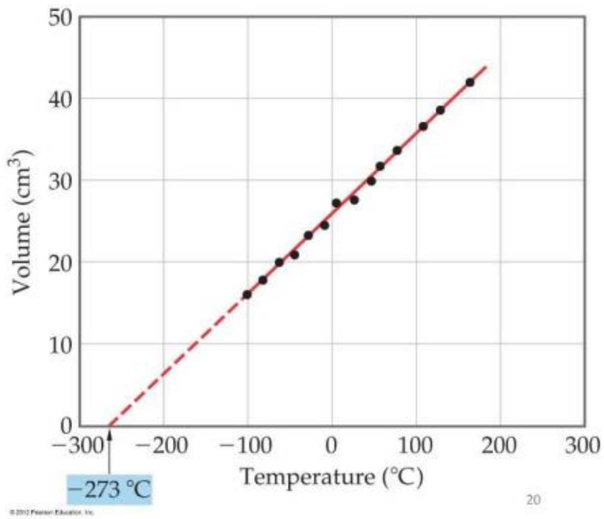


Highlight 2: Charles' Law

Charles discovered that as volume increases, temperature must also increase to keep pressure constant. In other words, volume and temperature are directly related… their ratio is a constant.

$V_1/T_1=V_2/T_2$

Or, we could say that V=k/T



Highlight 3: Avogadro's Law & The Ideal Gas Law

The **volume of gas is proportional to the number of moles of gas.** The way that Avogadro figured this out was this type of observation:

First, guess how many "volumes" of water (proportionally) these two should form

2 volumes of H_2

+ 1 volume of O_2

Doesn't it seem like it should be 3 volumes? But the correct answer is 2. *Why?* 2 moles of H_2 and 1 volume of O_2 combine to make 2 moles of water. And since the number of volumes is proportional to the number of moles, 2 moles means 2 volumes.

This relationship can be represented as:

V=constant*n, where n is the number of moles

The Ideal Gas Law:

Combining all of these relationships yields the following

PV=nRT

Pressure and volume are on the same side of the equation; volume and temperature are on opposite sides of the equation. Since volume and temperature are on opposite sides of the equation, pressure and temperature must also be on opposite sides of the equation.

This last equation is the only one that you need to memorize! Boyle's law can be derived:

"before" equation: $P_1V_1 = n_1RT_1$

"after" equation: $P_2V_2 = n_2RT_2$

If everything but pressure and volume are kept constant, then $P_1V_1 = P_2V_2$

Similarly, Charles' law can be derived.

Two gases:

So, given info about a gas, you can calculate other info. Let's add one more piece. If you know the stoichiometric ratio between the gases, then… given info about one gas, you can calculate info about another. For example:

Given: Pressure, temperature, and volume of gas A; 2A+3B → 2C

PV=nRT can be used to calculate moles of gas A

Moles of gas B = moles of gas A * (3/2)

Density:

A different application of the ideal gas law: Say that you were trying to calculate density given a gas's pressure and temperature. Do you have enough info? Well, density is equal to mass divided by volume…PV=nRT.

n/V could be turned into m/V if you converted moles to grams. And how would you do that? Try multiplying both sides of the equation by the molecular mass. PVM=mRT, where M is molecular mass, and m is the mass of the gas.

Now, divide both sides by V. PM=m/V*RT… or PM=DRT, where D = density.

So, D=PM/RT.

Here's a great explanation of the ideal gas law: https://www.khanacademy.org/science/ap-chemistry-beta/x2eef969c74e0d802:intermolecular-forces-and-properties/x2eef969c74e0d802:ideal-gas-law/v/ideal-gas-equation-pv-nrt

The key to this one is definitely practice problems—here are a couple of links!

https://chem.libretexts.org/Courses/Oregon_Tech_PortlandMetro_Campus/OT_-_PDX_-_Metro%3A_General_Chemistry_I/07%3A_Ideal_Gas_Behavior/7.03%3A_Applications_of_the_Ideal_Gas_Law_and_Partial_Pressures/7.3.01%3A_Practice_Problems-_Applications_of_the_Ideal_Gas_Law

https://www.khanacademy.org/science/ap-chemistry-beta/x2eef969c74e0d802:intermolecular-forces-and-properties/x2eef969c74e0d802:ideal-gas-law/e/ideal-gas-law

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Check Your Understanding

1. If pressure doubles, volume:
    a. Doubles
    b. Is cut in half
    c. Quadruples

    d. Is cut in four
2. If temperature quadruples, volume:
    a. Doubles
    b. Is cut in half
    c. Quadruples
    d. Is cut in four
3. Determine the pressure of 1 mol of gas at 273 K and 1 atm.

Things You May Struggle With

1. Cause/effect relationships go both ways. Boyle's Law doesn't just mean that changing pressure changes volume… it also means that changing volume changes pressure!
2. Make sure you know which variables are directly related (pressure and temperature) and which are inversely related (pressure and volume). Think about what they mean molecularly (decreasing volume will force the molecules to bump the walls of the container more often). Memorizing the ideal gas law can allow you to determine Boyle's and Charles' laws, too!

That's all this week! Please reach out if you have any questions and don't forget to visit the Tutoring Center website for further information at www.baylor.edu/tutoring. Answers to Check Your Learning are below.

1. B *Try figuring this out without looking at Boyle's Law—use the ideal gas law! \
2. C
3. 22.4 L *This is a number that's good to memorize—it will be used often, and it saves time to skip calculating it.