AP Chem Properties of Gases and Gas Laws Lab

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1 Background Information

The behavior of gases can be determined across variations in temperature, pressure, and volume assuming a gas is ideal. A gas is ideal if it has the following characteristics:

1. The collisions between molecules are elastic
2. The total volume of the individual molecules is insignificant compared to the volume of the container they are in
3. There are no inter-molecular forces acting on or between the gaseous molecules
4. The molecules are constantly in motion
5. The distance between two molecules is significantly large than the size of an individual molecule

Assuming a gas is ideal, it follows Boyle's Law($p \propto \frac{1}{V}$) relating pressure and volume inversely, Charles' law($V \propto T$) relating volume and temperature directly, Gay-Lussac's Law($P \propto T$) relating pressure and temperature directly, and Avogadro's law($V \propto n$) relating volume and the number of molecules directly. These are combined into the catchall ideal gas law which addresses the proportionality as well with $PV = nRT$ where R is a constant.

With these direct and inverse relationships in mind as well as kinetic-molecular theory relating mass of molecules and their speed($K_e = \frac{1}{2}mv^2$), this lab's overall purpose is to explore the real-world applications of gas properties and laws, and their meaning to every-day objects. To do this, the lab uses four activities, each with a different individual purpose.

1. The purpose of this activity is to observe the interaction of separated liquid ammonia and Phenolphthalein indicator made possible by their existence as vapors.
2. The purpose of this activity is to observe the power of air pressure by heating, then cooling a can to make the pressure inside the can less than atmospheric pressure, and watch it crunch itself.
3. The purpose of this activity is to explore the relationship between pressure and volume of a gas by observing change in the volume of air in a syringe as the pressure outside the syringe changes.
4. The purpose of this activity is to explore the relationship between pressure and temperature by observing a difference in volume of air in a syringe at different temperatures.

2 Data

2.1 Activity 1

For this activity, ammonia was placed on one half of a divided petri dish while Phenolphthalein was placed in the other half along with distilled. Phenolphthalein is an indicator which turns violet in basic solutions from its colorless standard color. Immediately when the ammonia was added, the Phenolphthalein side turned bright violet indicating the presence of a base despite having no physical contact with the ammonia.

2.2 Activity 2

In this activity, about 10ml of water was heated in an aluminium can, then the can was inverted into a plate of room temperature water. Nothing changed visibly about the can as it heated it up, yet as soon as it was inverted, it collapsed in on itself. This demonstrates what happens to the volume of air when it is cooled rapidly. When the water in the can was heated to a boil, it made the air inside the can significantly more voluminous(See Charles' law: $T \propto \frac{1}{V}$), and when it left the can, the air cooled rapidly, decreasing in volume. As the only opening in the can was submerged in water, the volume of the can decreased accordingly.

2.3 Activity 3

The reading of the gauge pressure on the bike pump began at zero, yet the local barometric pressure was recorded as 29.92 inHg, which converts to $\frac{29.29}{2.036} = 14.70psi$. Due to this, the "zero" pressure reading on the bike pump is likely actually the local barometric pressure, and convert all bike pump readings as follows: $60.psi + 14.70psi = 75psi$.

Gauge Pressure(psi)	Adjusted Gauge Pressure(psi)	Volume in Syringe(mL)
60	75	1.5
55	70	1.8
50	65	2.0
45	60	2.2
40	55	2.4
35	50	2.5
30	45	2.9
25	40	3.2
20	35	3.5
15	30	4.1
10	25	4.3
0	15	8.6

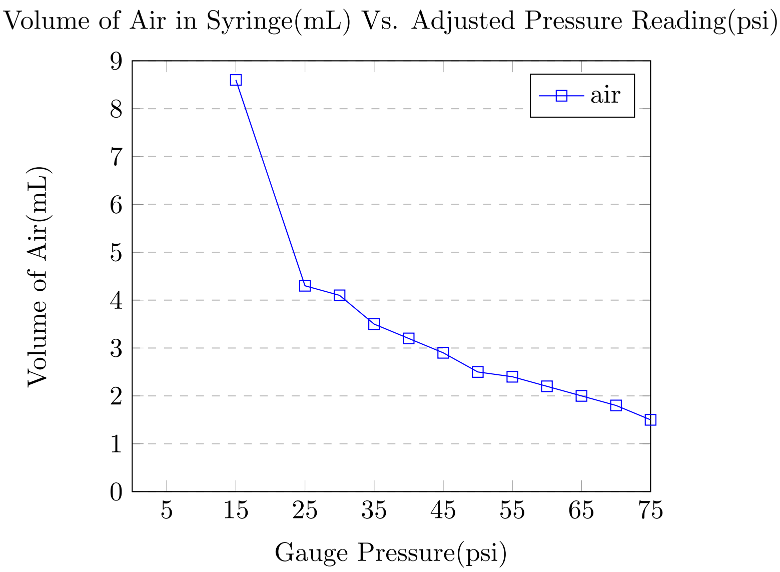

Figure 1: Inverse relationship between gauge pressure and volume
Figure 2: Linear relationship between the inverse of volume and gauge pressure
This shows the inversely proportional affect of changing the pressure of a gas on its volume per Boyle's law. The high r$\hat{2}$ value in the relationship between 1/Volume and Pressure demonstrates that this relationship is truly inverse.

2.4 Activity 4

In order to be used for the gas laws, it is best for the values to be in kelvin, with absolute units of temperature, so the units are converted like follows: $22°C + 273.15 = 295$

	Temp. ($°C$)	Temp. (K)	Syringe Volume(mL)
Ambient	22	295	17
Saltwater-Ice	0	273	12
Ice Only	10	283	15
Hot Water	76	349	20

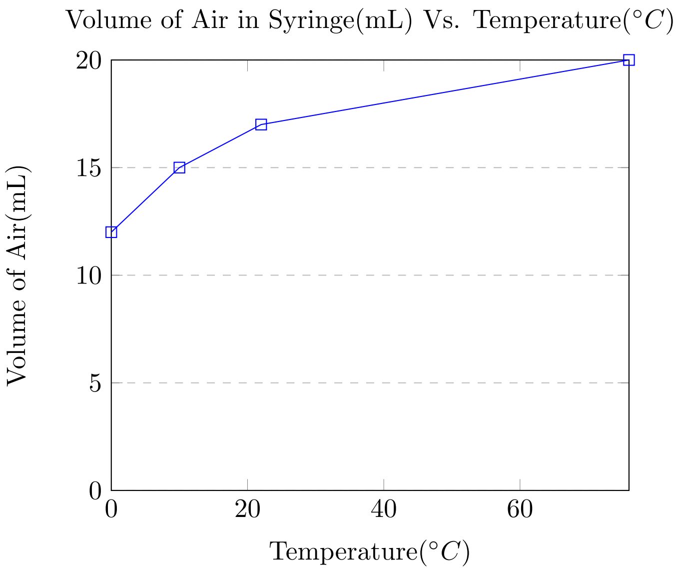

Figure 3: Linear relationship between temperature and volume
Figure 4: Linear relationship between temperature and volume
This shows the affect of changing the temperature of a gas on its volume per Charles' law.

3 Discussion

3.1 Activity 1: Diffusion of Gases

1. The design of the divided petri plate ensures that the liquid ammonia cannot pass into the compartment with the Phenolphthalein indicator as it may not pass through the plastic barrier in liquid form. However, as some particles with greater random velocity exit the ammonia compartment and enter the Phenolphthalein half of the petri dish, they make the Phenolphthalein turn violet.

2. One example of this is the smell of liquids like isopropyl alcohol. Isopropyl alcohol has a very low boiling point, so it is easy for liquid particles to be in gaseous form and a larger proportion of particles are in this gaseous and smell-able phase at one time. Another example of this is the smell of the ocean, which has various smell-able particles which exit and travel with the wind as gases so we can smell what we associate with the ocean.

3.2 Activity 2: Crush the Can

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As I explained above, the volume of air getting smaller inside the can made the can get smaller to accommodate this smaller volume. The actual force changing the volume is the atmospheric air pressure, and the "want" of air pressure inside the can and outside to be the same, or in equilibrium. Volume decreases to equalize this pressure, as $P \propto \frac{1}{V}$

The air in the can was heated, so per Charles' law, the volume of the air got larger. The can had an opening for it to escape, so when the air's volume got larger than the can, it took the path of least resistance and effused at a high rate. In a way, the boiling water drove the air out of the can as quickly-moving water molecules caused the heating of the air itself, however, the water itself didn't 'push' the air out as much as the air effused.

There was less pressure after it was cooled because the temperature decreased and per Gay-Lussac's law($T \propto P$), pressure should decrease as well. The pressure decreases because the particles aren't moving as fast so they're colliding with the container's walls less frequently.

3.3 Activity 3: Boyle's Law

1. The 10-mL syringe decreased in volume because the pressure on the molecules was increasing. On a molecular level, the same number of particles are colliding with the container more frequently at the same temperature(average speed per kinetic-molecular theory), so the only remaining factor to change is volume. When volume gets smaller, the pressure must increase as there are fewer non-collision-with-container places for the particles to be, so the number of collisions increases.

2. We observed the syringe first get smaller as we pumped up the bottle, increasing the air pressure, and then get larger as we let air out, decreasing the air pressure. This simple observation alone indicates that air pressure is inversely proportional to volume, but the quantitative results really confirm it. Boyle's law states that $P \propto \frac{1}{V}$, so volume decreasing as pressure increased confirmed it.

3. The general inverse shape of the Volume-Pressure graph suggested an inverse correlation, but the linear nature of the 1/Volume by Adjusted Pressure graph with a high coefficient of determination indicates that this correlation is present and very strong. Boyle's law states that $P \propto \frac{1}{V}$, so we would expect an inverse relationship between the two, and that is certainly what we observe.

3.4 Activity 4: Charles' Law

1. The mathematical relationship between temperature and volume of a gas is best described by Charles' law($T \propto V$), which says that pressure and volume are proportonal. This means that as one increases the other increases and that as one decreases, the other decreases. It also means that the amount of increase/decrease in one value per one unit increase in the other value is the same no matter what value.

2. This makes sense in terms of kinetic-molecular theory because as temperature increases, the average velocity of the particles increases, which means that they will hit the walls of the container more often just by virtue of being in different places more often. Pressure is defined by the rate at which a particle hits the walls of its container, so pressure increases with temperature.