Name: ___________________________________ Date Due: _____________

Lab #25: Determining the Relationship between the Volume and the Temperature of a Gas

Pre-Lab Activities

1. Welcome back to the Lab! Survey the bold headings to familiarize yourself with this lab. The Lab **Introduction** and **Materials and Methods** sections in Level II are packed with information for which you will be held accountable on quizzes and other assignments. You absolutely will need to read and re-read these labs a few times in order to understand the concepts—that is the nature of non-fiction reading. The Pre-Lab Activities will guide you.

2. Read the **Introduction** from start to finish, ***talking to the text*** and answering prompts as you go. Review the list of techniques we brainstormed in class that you can use to ***talk to the text***.

3. Re-read the **Introduction** a third time**,** picking 3 new terms, underlining them, and defining them in your own words in the margins on this sheet. These terms do not need to be "science" words.

4. Read the **Materials and Methods** from start to finish, ***talking to the text*** as you go.

5. Set up your lab notebook for Lab #25. This includes a heading, purpose, and a section labeled "Safety Precautions". Transfer any important safety information and/or safety symbols into this section.

6. As a group, create a hypothesis about the relationship between the temperature and the volume of a gas assuming the number of moles and pressure of the gas remain constant. Represent this relationship graphically and in words in your lab notebooks in a section labeled "Hypothesis."

7. Familiarize yourself with the new lab techniques during your Lab Technique Discussion. Record any notes to yourself.

8. Decide which data you will be gathering during this lab, and construct data tables.

Introduction

In Bio-Chem II, we will be referencing labs we completed last year, and ideas that we have already studied. Some of them you will remember quickly, and some of them you may need to go back and study a bit. This is natural in any learning process, so try to be patient with your self. It is likely that you will need to stop to re-read paragraphs to yourself until they make sense. Remember that this is not a story, but rather a series of explanations that you need to internalize. For these reasons, it is important to continue to complete the tasks in the text so that the connections to past concepts come more easily.

In Bio-Chem I we looked at the relationship between temperature, vapor pressure and the state of matter. What are the states of matter, and how would you characterize them?

We are going to focus on the gaseous state of matter in Lab #25. The gaseous state can be described by four variables: *pressure*, *temperature*, *volume* and *moles* (amount of matter). Through our activities we will be studying the relationship between the temperature and pressure of a gas, as well as the temperature and volume of a gas. These relationships will help us understand the abiotic factors that can impact an ecosystem.

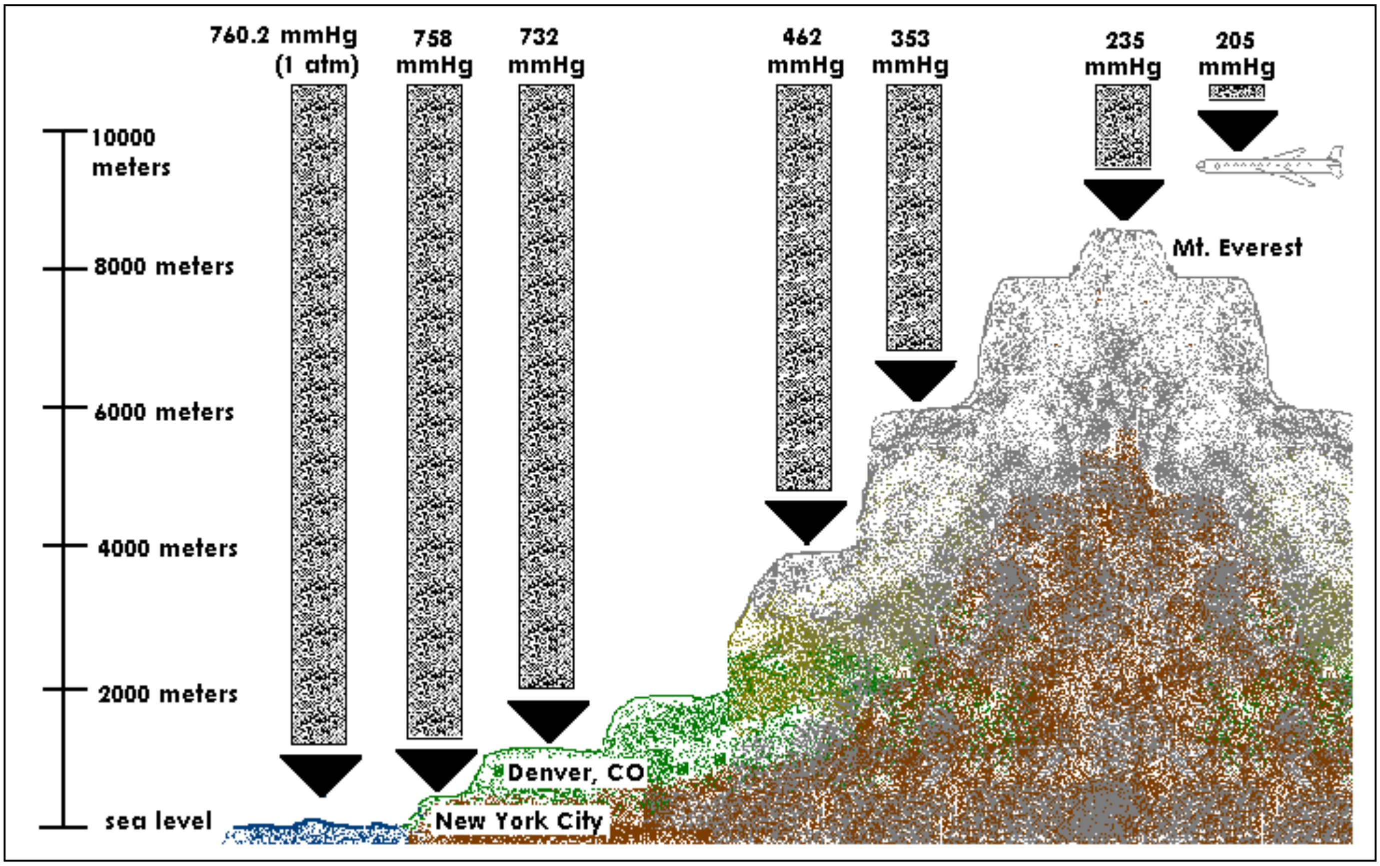
Air Pressure

You probably learned that gravity is the force that keeps us from floating up into the clouds when we walk down the street. Our atmospheric gases consist of abiotic particles of matter that are also kept on Earth due to gravity. Imagine a column of the atmosphere that extends from Earth's surface to the top of Mt. Everest, which now stands 8850 meters above sea level. If you were at the bottom of the air column, which is what we call *sea level*, all of that atmospheric matter is on top of you. You will experience greater pressure there than you would if only half of the column is on top of you. There is simply more matter in the longer column. For our purposes, let us consider this air column as representative of *air pressure*.

Suppose you are in New York City, which is 26 meters above sea level. There is less atmospheric matter on top of you since now some of the matter is below you. Fewer particles exert less force, and the air pressure decreases. However, the difference between New York City's elevation and sea level is not great enough to warrant different organismal adaptations. The same bird can happily fly from sea level to Times Square without feeling much of a change in air pressure.

If you have ever been on an airplane, you may have felt your ears "pop." This is due to the fact that you ascend so rapidly that even the pressurized cabin takes a moment to catch up with the pressure differential. As we level off, we feel relatively comfortable because the cabin is pressurized to standard conditions of 760 *mmHg*, air pressure as measured at sea level. For longer flights, cruising altitude is usually around 9754 meters, and the air pressure outside is 205 mmHg. Thus, at higher elevations, there is less air pressure (See **Figure 1**). You may have noticed that there aren't too many red-breasted robins alighting on the airplane's wings at this elevation. This is because their lungs are not adapted to such low air pressures, even if they could physically fly that high. As we fly in the airplane, Mt. Everest and the biosphere lie below.

Figure 1. The Change in Atmospheric Pressure at Increasing Altitudes



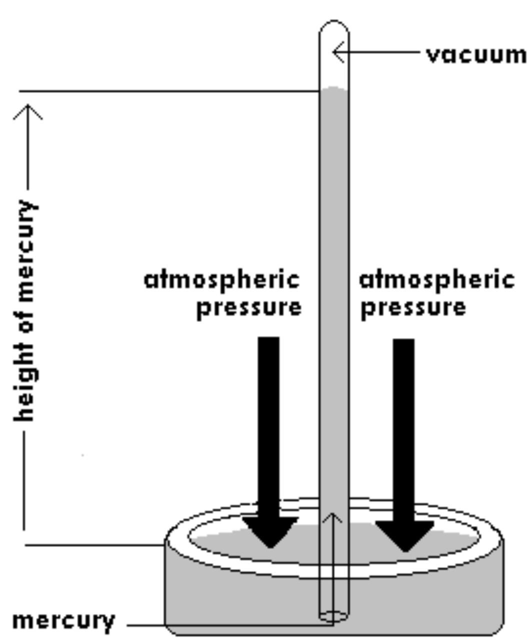
Meteorologists are interested in changes in air pressure since it relates to changes in weather patterns. They measure air pressure using a *barometer*, an instrument that utilizes a column of liquid that responds to changes in air pressure. Due to their chemical properties, barometric liquids such as mercury (Hg) readily respond to changes in air pressure, making them useful indicators in our instrument. As the air pressure increases, the barometric liquid moves farther up the tube (See **Figure 2**). 760 mmHg corresponds to an English System measurement of 1 *atmosphere*, or 14.7 pounds per square inch (in^2). Think of these as conversion factors:

760mmHg = 1 atm

1 atm = 14.7 pounds per square inch (psi)

When 1 atm of pressure pushes down on a dish of mercury, the mercury will rise 760 mm in the vacuum tube. Referring to Figure 1, determine the height of mercury in a barometer placed on the summit of Mount Everest:

Figure 2. A Mercury Barometer



Human bodies are adapted to function at a pressure of 1 atm, and if this pressure were to change drastically over a short period of time, our bodies would have a very difficult time adjusting. However, humans have gotten very good at *acclimatizing* to the lower air pressures found at higher altitudes. Think about individuals who live in Denver, Colorado. Denver is 1609 meters (1 mile) above sea level, and as a result, the air pressure exerted on objects there is significantly less than the pressure exerted on objects at sea level. The reduction in air pressure is a direct result of the decreasing number of air molecules present as the elevation increases. The bodies of individuals living at this elevation *acclimatize*, or adjust, to the decreasing number of oxygen molecules by increasing the number of hemoglobin molecules in the blood. In this way there are more oxygen-binding sites, making each breath more productive.

This is not to be confused with an *adaptation* that is a permanent change in the genotype of an organism. If an individual who has been living in Denver were to move to New York City (which is about 26 meters above sea level), the levels of hemoglobin in his blood would eventually reduce to levels that are in line with other New York City residents. The column of air pressing down on individuals living in Denver, CO is simply not as high as the air pressing down on New York City residents. A smaller column of air means fewer molecules of air. The result is a reduction in the overall air pressure (See **Figure 1)**. Consequently, people living in Denver, CO need to make adjustments in certain things they do such as cooking (see *Bio-Chem I The Quest For Energy—HW--High Altitude Cooking*) or even how they exercise. **If you were boiling a pot of water in Denver, do you think the water would boil at 100oC, below 100oC, or above 100oC? Explain your reasoning.**

Other organisms have developed *adaptations* via *natural selection* that allow them to live at higher elevations. For example, llamas live in the Andes Mountains in South America. These animals are born having blood with a higher affinity for oxygen than animals living at lower altitudes. This means that a liter of blood of a llama can hold more oxygen than a liter of blood of a cow, which is advantageous for the llama since there is less oxygen available at higher altitudes. The llamas are adapted to their habitat because their *genotype* codes for increased hemoglobin production. Humans are not adapted to living in Denver since it is simply a temporary response to a changing environment that is not passed on to offspring. Acclimatization is a form of *homeostasis*, a self-regulation mechanism. Adaptation involves a change in actual genetic makeup that is often the product of natural selection. **In the space below, summarize the difference between adaptation and acclimatization.**

Altitude, Latitude, and World Ecosystems

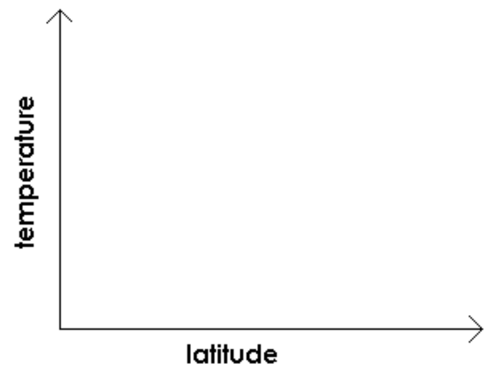
As the moles of air decrease, air pressure decreases, just as **Figure 1** illustrates. This happens as elevation, or *altitude*, increases. But there is another interesting relationship that comes into play. As one climbs a mountain, for example, it gets colder. So why do skiers get sunburned, yet still need to keep warm? The answer actually relates to moles and pressure. There are fewer molecules, therefore fewer moles of molecules, to absorb the Sun's radiation at higher altitudes. Remember that a decrease in pressure at higher elevations is a result of a decrease in moles of atmospheric matter per square inch. The decreasing number of air molecules is directly proportional to the amount of thermal energy (infrared radiation) absorbed and held by the atmosphere as whole. As a direct result of the less dense air (lower number of moles per square inch), UV radiation has more direct contact with unprotected human skin. As you increase in altitude, you will experience a corresponding decrease in temperature but, an increased risk of UV damage. These relationships are crucial to consider when we study organisms that nest and feed in mountainous regions. These organisms must be able to withstand lower temperatures and lower air pressure.

Interestingly, as one travels north from the equator, temperature decreases—but for different reasons. Higher *latitudes* have lower average temperatures. The Sun's rays that travel to the higher latitudes are simply not as direct as those reaching more equatorial regions. Even if we take into account the tilt of Earth on its axis, electromagnetic radiation destined for high latitudes must travel through more moles of air molecules than those destined for lower latitudes. Some of the radiation is absorbed or reflected, and consequently only a small percentage of the radiation leaving the Sun actually reaches Earth's surface. And, of that small percentage, the radiation reaching Earth at higher latitudes is relatively less than that reaching lower latitudes.

In **Figure 3**, graph the linear relationship between latitude and temperature, assuming that altitude remains the same.

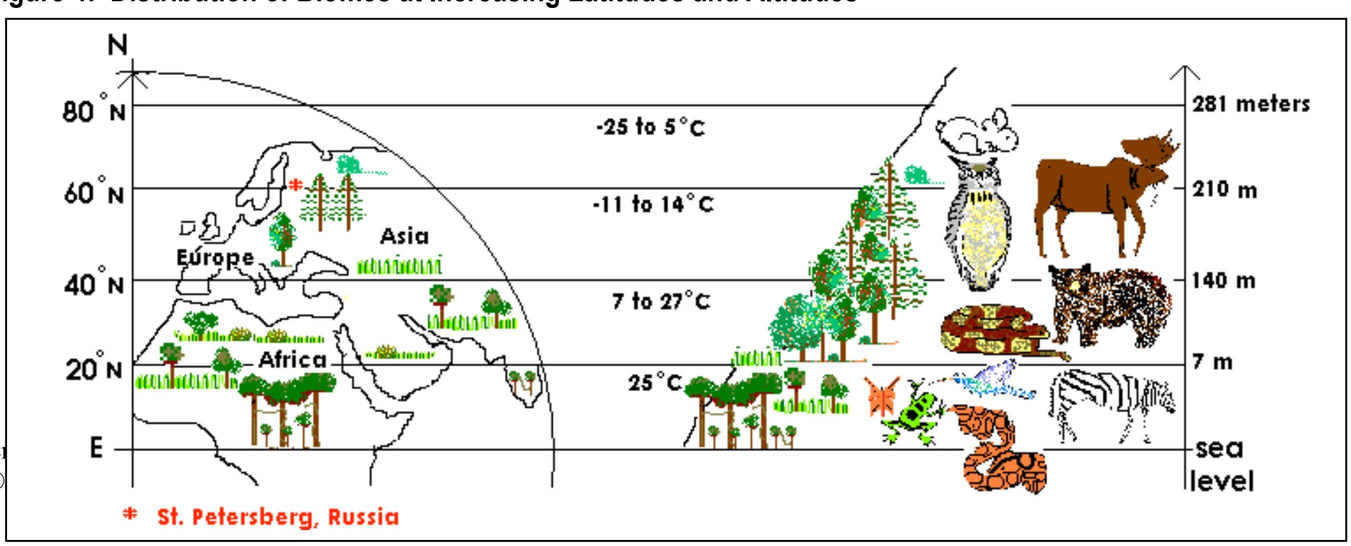
This latitude-temperature relationship describes how abiotic factors help set the stage for different world ecosystems. In general, the world ecosystems associated with higher latitudes, such as the taiga and the tundra, have lower average temperatures than the biomes associated with lower latitudes, such as tropical rainforests. The average temperatures throughout the year for each of the major biomes are graphed at the following Web site: http://www.chs.k12.nf.ca/science/b3201/WebCT-Copy/images/lesson-images/lesson02/temperature.gif .

Figure 3. Relationship Between Temperature and Latitude At the Same Altitude



Interestingly, this same relationship between average temperature and world ecosystems can be observed when traveling up the side of a mountain. Remember that as altitude increases, air pressure decreases, and consequently temperature decreases. This relationship describes the fact that there are fewer molecules of air to act as insulators and also to help hold on to the Sun's infrared energy. In addition, the presence of fewer molecules also results in less conduction of thermal energy, so overall there is a decrease in air temperature as compared to an area at a lower altitude but the same latitude.   So imagine you are climbing up a mountain such as Denali, AK (formerly known as Mt. McKinley). As you climb higher and higher the temperature drops. This drop in temperature will affect what type of flora and fauna are present in a similar way as if you were traveling up through the latitudes (See **Figure 4).**

Figure 4: Distribution of Biomes at Increasing Latitudes and Altitudes

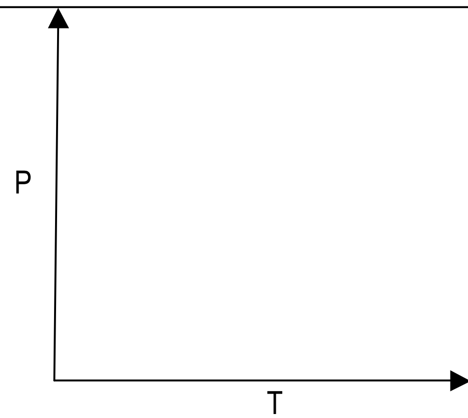


Gay-Lussac's and Charles' Gas Laws

The relationship between the temperature and the pressure of a gas is very apparent when climbing a mountain. Rock climbers and hikers need to consider this when they prepare their ascent. Depending on the altitudes ultimately traversed, they may need to pack a change of clothes! As we have seen in our study of different altitudes, as the pressure of a gas decreases the temperature of that gas decreases. This is known as a *direct proportion*, meaning that as one factor decreases in value, another factor also decreases in value. This relationship holds true under all circumstances where the amount/number of moles of the gas and the volume of the gas are held constant, and is known as *Gay-Lussac's Law*. <u>In the space provided, indicate which factors are constant and which are variables in Gay-Lussac's Law. Then, sketch the relationship between temperature and pressure on the axis provided.</u>

Variables for Gay-Lussac's Law:

Constants for Gay-Lussac's Law:



Gay-Lussac's Law can be studied as we climb *up* a mountain face. However, when we are traveling *north* through increasing latitudes, for example from Mexico to Fairbanks, AK, our air pressure remains reasonably constant as long as we stay below 4,000 feet above sea level. Thus, while Gay-Lussac's Law is an important pressure-temperature relationship, it is not as easily observed or studied in a school laboratory. But air temperature is slowly decreasing over the increasing latitudes, and enabling us to study the relationship between the temperature and the volume of a gas, otherwise known as *Charles' Law*. <u>How do we define volume? Write your own definition below:</u>

<u>Just as you did with Gay-Lussac's Law, define which factors would remain constant and which are variable in Charles' Law.</u>

Variables for Charles' Law:

Constants for Charles' Law:

Materials and Methods

In Lab #25 we will model the relationship between the temperature and the volume of a gas. We will do this using balloons filled with air that are placed in "environments" of different temperatures. By determining the volume of the air at these different temperatures we will be able to establish the relationship between temperature and volume of a given amount of gas.

We are using balloons because they are flexible and will therefore expand if necessary while remaining sealed. In addition, a balloon has a physical surface that can be measured so that the volume can be determined. The formula for the volume of a sphere is:

$$\mathbf{(4/3)\pi r^3}$$

In this equation, like any other, π is equal to 3.14 and **r** represents the radius of the sphere. It is somewhat difficult to measure the radius of a sphere experimentally; with the radius being half the diameter (**Figure 4**) we would have to cut the balloon in half to get and accurate measurement—but as soon as we did that our volume of air would be lost.

To solve the problem from another angle, we will determine the radius mathematically using the following formula:

$$\mathbf{r = \frac{C}{2\pi}}$$

First, the circumference of the balloon (**C**) will be determined. Since rulers do not conform to the shape of a sphere, we have to use an alternative measuring technique. A piece of string will be used to encircle the sphere, and then laid flat to determine the length using a meter stick.

For all of this to work we will need to start by making two additional assumptions; 1) the inflated balloon is a perfect sphere and 2) the thickness of the balloon is negligible. <u>Why do you think these two assumptions are necessary to proceed?</u>

You and your lab partner will determine the volume of a fixed amount of gas at varying temperatures. You will be able to graph that data and comment on the trends that you observe. From there you will be able to experimentally determine and state Charles' Law.

Materials per Team of 4

2 large plastic buckets or dishpans	balloons
Hot Plate	string
1 Thermometer	ruler
1000 mL beaker(s)	Ice

Post-Lab Activities

1. Lab Debrief including explanation of the application of *Charles' Law*.
2. Was your hypothesis supported by your data? Why or why not?
3. How accurate do you feel your results are based on the initial <u>assumptions</u>?
4. How do adaptation and acclimatization differ?