Syllabus

CHM115H Laboratory Syllabus
Chemistry 115 H Honors Laboratory
Inorganic/Environmental Chemistry Integrated Science II (1 hr)

Spring 2008
Chasteen's Office Hours

10-11 am MWF	9am to 11am TTh	or by e-mail appointment anytime (chm_tgc@shsu.edu)

- The first Chemistry 115H laboratory will be on Thursday afternoons in the semester (yes **Thursday**) in Chemistry\Forensic Science 107 (CFS107) at 1:30 pm. The first lab's date will be announced in class.

Bring Lab Glasses

You can buy them from the chemistry club in room CFS 310 or at the tables set up on the ground floor of CFS or at home improvement stores like Home Depot.
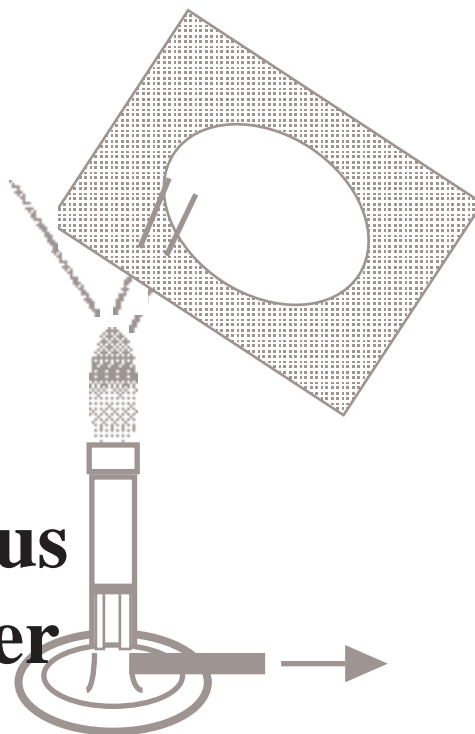
The labs will be on Thursday afternoons, 1:30 to 3:30 PM starting on the date announced in class. The first lab day let's meet in our normal classroom in CFS and I'll show you the laboratory.

Bring Lab Glasses

You are responsible for getting your lab glasses and having them for the first lab.

Honors Chemistry

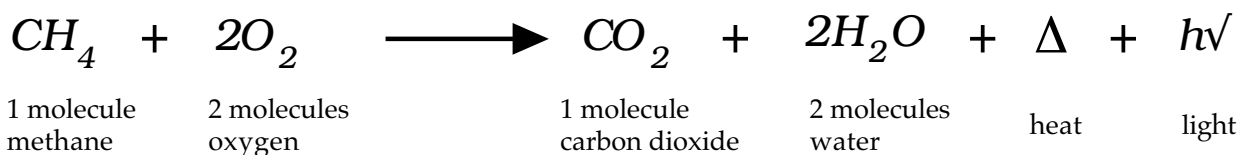
The Ubiquitous Bunsen Burner

Objectives

You will examine the structure and function of the Bunsen burner and the effects that the air and gas flow controls have upon the color and hotness of the flame. Time and materials will also be available for experimenting with glassworking.
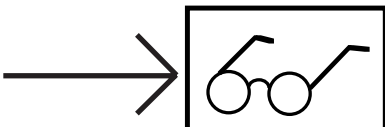
Background

Those pieces of laboratory equipment that visions of the proverbial white-smocked, bespectacled chemist conjures up in most people's mind would have to be the test tube—and the Bunsen burner. What self-respecting chemist indeed would be caught in any Hollywood movie without them! Although the Bunsen burner has been around ever since Robert Bunsen developed it back in 1855, it is still a workhorse in the lab for many heating jobs that require neither careful heat control, nor involve flammable chemicals.

Burning is a chemical process and involves a chemical reaction whereby a substance commonly combines with oxygen in the air to produce new substances. These new substances, while containing all of the same original atoms, have entirely new physical and chemical properties. None of the atoms representing elements have changed their fundamental identity, but they have undergone a chemical change which is accompanied by drastic alterations in their properties. Thus the paraffin wax in a candle "burns" (reacts with oxygen) to produce carbon dioxide gas, water, light and heat energy. Decaying organic matter such as leaves and humus also "burn," only not usually so fast that the heat is sufficient to cause ignition. Iron, too, slowly "burns" in air to produce rust—a new chemical compound of iron combined with oxygen.

The actual substance burned in the Bunsen burner is principally a gaseous paraffin hydrocarbon called methane (marsh gas or natural gas). A chemically correct equation for this reaction would read: methane and oxygen in air react to produce carbon dioxide, water and energy. In chemist's formula notation, this would become:

$$CH_4 \;+\; 2O_2 \quad\longrightarrow\quad CO_2 \;+\; 2H_2O \;+\; \Delta \;+\; h\sqrt{}$$

| 1 molecule methane | 2 molecules oxygen | 1 molecule carbon dioxide | 2 molecules water | heat | light |

The actual design of the Bunsen burner is in principle the same as for other types of gas flames, whether in a home gas stove or a welding torch. The purpose of this design is to premix the gas and oxygen (air) before ignition. This permits the combustion process to be more efficient, thereby producing more heat as well as a particular "hot zone" defined by the shape of the burner mouth. The flame color is an indication of how complete the burning has been. A yellow color in the flame is due to microscopic incandescent carbon particles (soot); this condition is undesirable because **any carbon atoms escaping as soot and not ending up as carbon dioxide reduce the efficiency and hence heat of the flame**. But these are things you are to observe and verify in this experiment.

This means ⟶ 👓

Procedure (**Put on your lab glasses now!**)

1. Determine where the gas control is for your particular type of burner. Some may have a thumbscrew control underneath the base, but in any case the gas flow can always be adjusted back at the main valve at your desk station. The air control consists of vents at the base of the tall cylindrical chimney and can be opened and closed either with a circular slip-ring or by rotating the chimney itself. Turn on the gas and light the Bunsen burner. If the flame keeps blowing itself out, cut back a bit on the gas flow valve. Don't use the wing top on the burner now. That's for bending glass.

2. *Shut off the air vents.* In many burners this can only be done completely by tightly gripping the bottom of the chimney and wrapping your hand around it using your ring and little fingers. Yes, it is safe to handle the Bunsen burner

while it is lit if you are careful. But you MUST shut off the air vents to obtain valid observations. **Repeat: you must shut off the air vents to obtain valid observations.** Any blueness to your flame means that you have *not* completely shut off the air. Your lab instructor can demonstrate.

Figure 1. Examining methane flame using an evaporating dish.

(a) You should now have seen a dramatic change in the nature of the flame. Note the color and shape of your flame on the report sheet.

(b) Briefly (20–30 seconds) using your tongs, hold a white porcelain evaporating dish filled with cold water over the very top of this flame and observe any deposit formed on the underside of the dish.

(c) Hold your wire gauze (**not** a thermometer) for about 10 seconds at various levels in the flame in a horizontal position and pass it up and down through the flame. Does the wire glow red hot at any location in the flame? (If the gauze has a white ceramic center, heat the bare metal at the corners.)

3. *Now completely open the air vents.* If your flame goes out, you may have to cut back slightly on the gas flow and relight the burner.

Figure 2. Examining methane flame using a wire gauze.

(a) You should at this point be able to discern a relatively colorless flame with two distinct conical sections. If in doubt, ask for help from your lab instructor.

(b) Repeat the heating test with your evaporating dish as in 2(b).

(c) Check the hotness (temperature) of your flame as in 2(c).

(d) Draw a temperature profile sketch (at the bottom of page 4), showing the general form of the flame and its coldest and hottest parts.

4. (Optional). Your lab instructor can demonstrate how to seal the end of glass tubing and then blow out (not *blow up!*) sections of this glass. Please be careful if you undertake this. If you have any questions just ask.
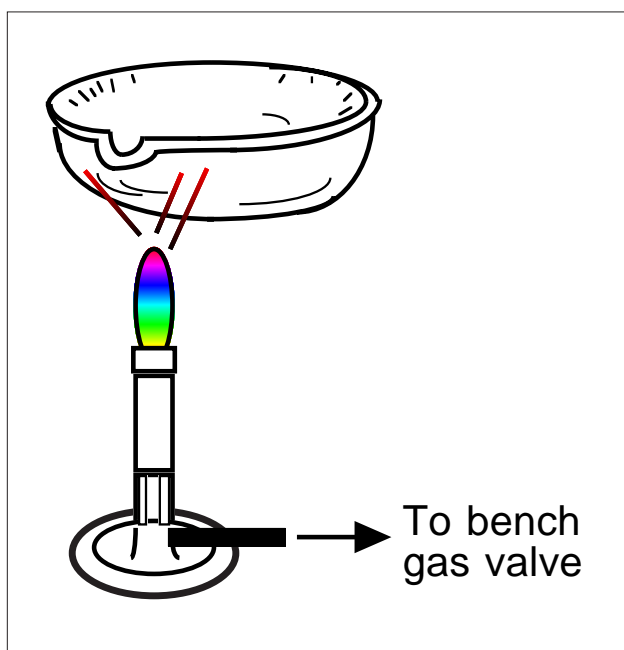
The Bunsen Burner

(Don't forget to turn this page in with your answered questions.)

Name: _____

1. Observations on Bunsen burner set-up

       Gas control located _____.

       Air control located _____.

2. Air vents closed

       (a) Appearance of flame _____.

       (b) Nature of deposit, if any, on dish (identify) _____.

       (c) Did your gauze glow red anywhere in flame? _____.

3. Air vents open

       (a) Appearance of flame _____.

       (b) Nature of deposit, if any, on dish _____.

       (c) Did your gauze glow red anywhere in flame? _____.

       (d) Draw the shape and temperature profile sketch of your flame below.

The Bunsen Burner
(answer on a separate piece of paper)

Staple and write your name on what you turn in.

1. Societally, over the past 200 years, what is the most important product of methane combustion? Explain.

2. Where do the carbon atoms come from in this experiment that are found in soot?

3. What percent or fraction of air is pure oxygen, O_2? What comprises most of the rest? (Use the InterNet and key phrases "visual geometric albedo" and "oxygen" and find the earth's atmospheric composition.

4. Why does mixing air with gas before ignition give a hotter flame?

5. In glassblowing, the flame temperatures must be even hotter than those that can be obtained with your bunsen burner. Using the same fuel (methane), suggest how hotter flame temperatures are reached in a commercial glassblowers shop (hint: think about question #3).

6. What happens to the waste products from the Bunsen burner's flame?

7. Which one of the waste products from the Bunsen burner's flame contributes to a global environmental problem? What is the name commonly given to this problem? What kinds of fuels contribute to this problem? Give some examples of these fuels?

8. What's the big hubbub regarding global warming? Who cares if the planet's average temperature rises by a few degrees?

9. What's the big hubbub about making changes that will decrease the effects of global warming? Aren't the adjustments that can be made easy and painless? Why?

10. Using a Web Browser, find 2 (two) InterNet sites that discuss **combustion**. Read what you find at each site, copy the site's address, and provide a three sentence summary in your own word of each site you visited.

11. Using the logic that we described as being part of the **scientific method** describe how you would explain to someone who says that components from the air are NOT involved in the process occurring in a Bunsen burner's flame that you think they (the components of air) <u>are</u> involved. You could imagine that you are trying to describe an experiment to someone who thinks that the flame is magic! This is one of the most important questions; don't blow it off. Be imaginative and explicit in your description of the conversation.

Honors Chemistry

Ammonium, Potassium, and Sodium
and
Acid Rain and The Ion Pump

INTRODUCTION

Three cations that we will examine in today's laboratory are ammonium (NH_4^+), potassium (K^+) and sodium (Na^+). Unlike most cations which are singly charged particles and therefore referred to a monatomic (one atom), **ammonium** is a polyatomic cation, NH_4^+—a particle with five atoms bonded together—and, like both K^+ and Na^+, it is found everywhere in our environment. All three of these species play many important roles in the environment and in biological systems. You will be introduced to some of the environmental chemistry of these cations before their qualitative analysis is detailed.

AMMONIUM EXCRETION
AND
ACID RAIN

The role that ammonium cation plays in our lives starts in our bodies and ultimately influences not only our immediate surroundings but to some degree even the pH of the atmospheric layer of air closest to the earth. Nitrogen atoms are a significant component of all amino acids, the molecular precursors of proteins. Since excess ingested amino acids cannot be stored, the nitrogen atoms in them are either recycled in the biosynthesis of other nitrogen containing molecules or the excess nitrogen is excreted from the body in the waste stream. If this process goes awry it can be very dangerous for the organism. In humans, a condition that causes lethargy and in extreme cases retardation has been documented and labeled **hyperammonemia**. It involves a high concentration of ammonium ion in the blood because of a defective excretion cycle possibly originating in a damaged liver.

Most animals release excess nitrogen as urea or uric acid; however, many aquatic animals just simply discharge NH_4^+ to keep their waste cycles in balance. This means that one way or the other, NH_4^+ is a significant component of most animal wastes. As almost anyone knows who has been near an area where a large collection of animals lives or near a few days old diaper pail, one of the major degradation components released by these compounds in the environment is ammonia, NH_3. In fact, a major source of gaseous ammonia into the atmosphere is from animal wastes; however, there are other sources as well. Figure 1 on the next page shows a generalized diagram for the ammonium cycle. The important processes involve ammonium production. This in-
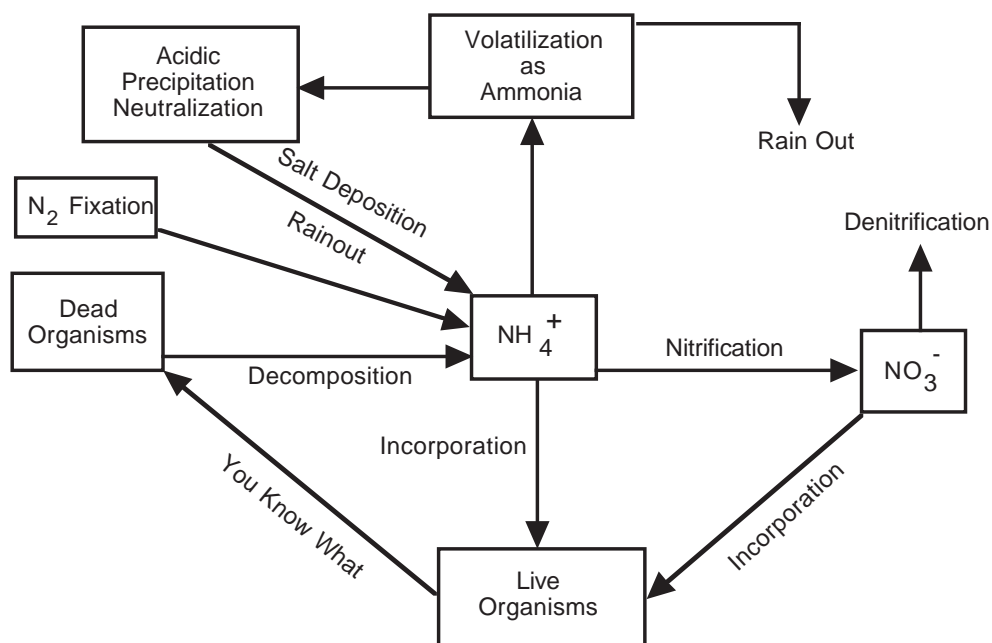
Figure 1 Ammonium cycle of production and loss.

cludes the decomposition of organisms (including their wastes), nitrogen fixation and nitrification by bacteria, and deposition and rainout of ammonium salts. These sources can be contrasted with the prominent ammonium losses via denitrification and organismic uptake and incorporation.

The role of ammonia once it escapes into the air is unique among atmospheric constituents. Ammonia (NH_3) is the only basic gaseous component in the atmosphere; that is, basic in a pH sense. This is in contrast to the many acidic components present in the air surrounding the earth: Nitric acid (HNO_3), sulfuric acid (H_2SO_4), hydrochloric acid (HCl), and carbonic acid (H_2CO_3) all play significant roles in the pH of clouds and the precipitation that falls to the earth. Low **pH** precipitation (pH <5.4) is called **acid rain** or acid snow and both of these affect soil, water and wildlife. Some lakes in the Northeastern United States, Eastern Canada, and Scandinavia have pH readings 10 to 50 times more acidic than their normal pH would be without the effects of acidic precipitation. This problem is vastly complicated by the influence that the soil and underlying rock play in their interaction with the deposited acids. Some acid deposition can be partially neutralized by the ground and some can't. This means that some geological areas fair better than others even though the pH of the precipitation is still much lower than normal. Geology plays a large role in the ultimate effects of acid rain.

Gaseous ammonia can react with atmospheric acids and neutralize them in cloud water or on small particles. And as noted above, NH_3 is the only gas that can do this in the atmosphere. Here's the reaction of ammonium hydroxide and sulfuric acid similar to a neutralization reaction that takes place in clouds: $NH_4OH + H_2SO_4 \longrightarrow (NH_4)_2SO_4 + H_2O$. The products of this neutralization interaction are rained out as salts like ammonium sulfate, ammonium chloride, or ammonium nitrate. This can, therefore, short circuit the acid rain problem before it touches the ground.

Unfortunately the large amount of gaseous acids in the Northern hemisphere, created to a large degree by the release of sulfur and nitrogen oxides from the combustion of fossil fuels, is *not* completely neutralized by ammonia, and environmental damage varies from region to region. The effects of acid rain are wide spread in many of the industrialized nations and their down-wind neighbors: many lakes can no longer support fish; plant and crop damage has been documented; and forest damage in Germany may even terminally threaten the Black Forest. Experiments have been underway for many years in lakes in Scandinavia, with varying success, designed to neutralize the acid in natural lakes by the addition of neutralization reagents.

POTASSIUM, SODIUM AND YOUR NERVES

Potassium metal, K^o, and sodium metal, Na^o, are so intent on losing their lone s electrons and thereby so reactive that they will react with water to produce elemental hydrogen. This reaction can be used as a spectacular demonstration by tossing a small piece of either metal into a pan of water. Because the hydrogen gas produced often catches on fire, the reacting metal runs around on top of the water continuously reacting and putting out a flame to boot! However, the reactive characteristic of potassium and sodium are actually an unusual episode in the life of an average potassium or sodium metal. Reactivity of these pure metals is such that very little of these species exists naturally. Instead the most common state of these elements is missing that last valence electron and forming the +1 ion. Furthermore, the solubility of compounds containing potassium and sodium are so great that these ion are found almost everywhere in the environment. Like sodium, the distribution of potassium on the earth is approximately 2 to 3 %. And finally, the great solubility of these compounds means that we will not use a precipitation reaction as a means to isolate potassium or sodium from a mixture of our cations. Instead we will depend, on flame tests. The complication of overlapping light emissions from these species will be discussed below.

Potassium and sodium ions not only take the role of escorting dissolved anions around in our environment, they also play an important part in the ionic pumps in our bodies. Their job of controlling the ionic potential across neural membranes is extremely important.

The sensation of touch felt by your finger is actually an electronic signal transmitted via nerve cells or axons that are bundle together by tissue into a structure we call a nerve. The electronic signals flowing through nerve cells, passing information to the central nervous system, are actually transmitted by shifting the distribution of ions between the interior and exterior of the axon itself. The relative distribution of sodium and potassium on either side of the cell wall directly affects the amount of signal that will cause the nerve cell to "fire."

Through a series of biochemical reactions, cell walls have the ability to move or pump ions (and other species) from one side of the wall to another. In the resting or unexcited state, the nerve cell's success at pumping K^+ and Na^+ is such that sodium preferentially builds up outside the cell and potassium inside. Since each of these cat-

ions is normally balanced electrostatically by a counter-ion (anion—negatively charged ion), this preferential buildup means that the inside of the axon has an excess negative charge relative to the outside (usually about -70 millivolts). This electrochemical energy gradient or potential means that the cell is, in effect, cocked and ready to fire. This electrochemical potential is called the resting potential.

If the axon's potential is disturbed strongly enough the result is a chain reaction that triggers the electrical disruption of all the axons along the nerve bundle, that is, serial firing. We call this traveling electrochemical event a nerve signal or nerve impulse, and the stimulus for it can be a touch on the skin or a signal from a nearby nerve.

Now you may see the importance of maintaining the correct concentration of cations in and around cells. If the wrong concentration of a cation like calcium distorts the electrochemical gradient of the nerve cell, the result is a change in the resting potential. A *lower* resting potential means that it takes less of a disruption on the nearby axon to cause the cell to fire. The result is that the nerve either fires too easily or even fires with no stimulus at all. This could lead to a very dangerous situation if the job of that nerve is to tell the heart muscle when to contract.

If the resting potential is *increased* by the chemical imbalance then the result is an inhibition of nerve impulses and lethargy, stupor, or possibly even death as the lungs stop working or the heart stops pumping blood.

ATOMIC EMISSIONS

Remember that we mentioned above that the flame tests for sodium and potassium were a little more complicated than usual? In many flame tests we can simply excluded interfering compounds that were not in the group under study so that we can clearly see the emission features (think colors) of our cations, for instance: strontium—carmine, calcium—orange-red, barium—yellow-green, and tin—blue. With the members of the NH_4^+, K^+, and Na^+ group this is impossible because both potassium and sodium are in the same group. Since we are not going to use precipitation (for separation) we must be able to distinguish between the light given off by sodium and potassium excited in a flame. Figure 2 has two parts: 2a and 2b are the *emission* spectra in the visible region of sodium and potassium in a flame.
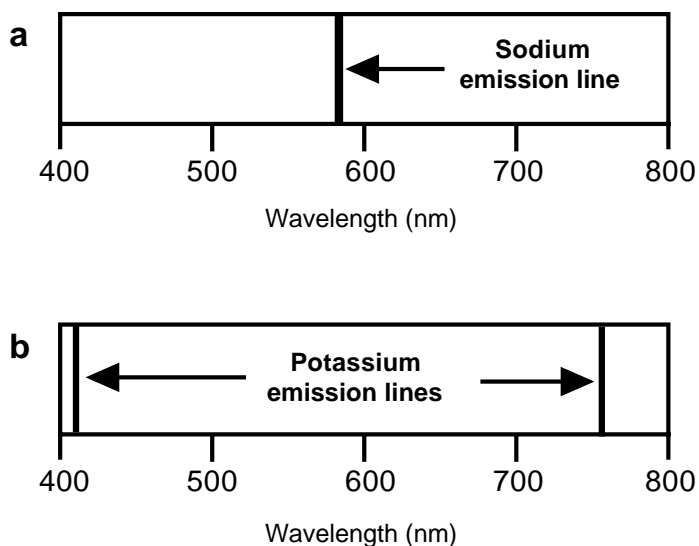
The light given off by sodium has basically one strong emission line in the visible, at about 589.3 nm (actually two closely spaced emission lines above and below this point). Potassium has two less intense lines at 405 nm and approximately 768.5 nm (this last wavelength is again two closely spaced lines). The result of a sodium flame test is a bright yellow light.

Figure 2 Emission spectra of sodium and potassium.

The result of a potassium flame test is a weaker reddish-violet light that unfortunately is completely masked by the emission of almost any sodium if it is present. What can you do to resolve this dilemma? If you said a monochromator you would in fact be correct. If you had an atomic absorption spectrometer you could indeed use that instrument (and its flame) to determine the presence of either of these species using its monochromator to isolate the elemental emission lines that you desired without having to use a hollow cathode lamp. (This would actually be atomic emission spectroscopy.) But there is an easier method of qualitatively solving this problem that has been used for years: a simple filter.

Figure 3 shows the wavelength region that is transmitted by cobalt blue glass. Remember, this is the transmission spectrum, that is, a plot of light that will be allowed to pass through the filter. Notice that "shoulders" at either end of the filter's transmission spectrum allow potassium's emission lines to pass to a large degree and that the flat center portion of lowest transmission **blocks** the sodium emission line. If sodium and potassium are present in the same sample, examining the flame without the filter will undoubtedly reveal the presence of Na since its emission line is so intense. When it comes time to test for potassium, with the filter between your eyes and the flame, almost all of this sodium emission will be blocked and you will see some light that will indicate the presence of potassium. Though this one takes a little practice, working with the filter can be fun, and it is substantially cheaper than a $20,000 spectrometer!

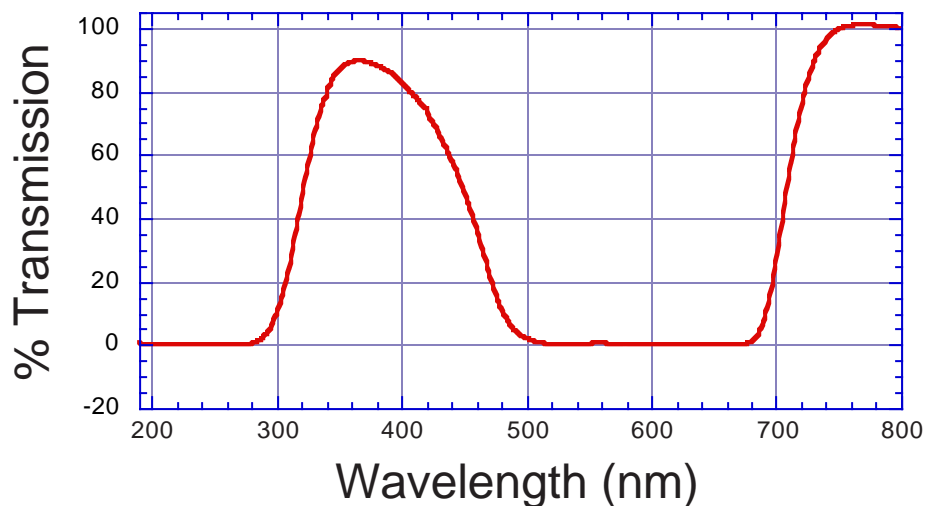## Transmission Spectrum of Cobalt Blue Glass

Figure 3 Transmission spectrum of cobalt blue glass.

QUALITATIVE ANALYSIS

OF

NH$_4$$^+$, K$^+$, AND Na$^+$

We are, in general, not approaching the entire Qualitative Analysis scheme by starting with a mixture of all of the possible dissolved cations and then separating each out for identification; however, even an abridged qual scheme involves fourteen or fifteen elements, so you could imagine how challenging that task might be in the complete classical scheme.

This lab focuses on those cations that would traditionally slip through all of the other Qual Group analyses of selective dissolution, oxidation, decantation, reconcentration, and precipitation and that finally end up in the last Qual Group, Group V, the soluble cations. Since environmental samples almost invariably contain potassium and sodium (see above) these analyses have, in general, only passing importance in environmental chemistry. The importance of ammonium determination is more significant in environmental samples such as those collected from precipitation; however, that analysis undoubtedly involves a quantitative measure not a qualitative one because of the ubiquity of this ion in the biosphere.

The potassium and sodium analyses that you will use are, as detailed above, flame tests, augmented by the use of a glass filter to isolate the potassium emission. The ammonium test is likewise relatively simple. It involves an odor test and can be double checked by the detection of very small amounts of ammonium by its conversion to ammonia with strong base and its absorption and subsequent color change on litmus paper.
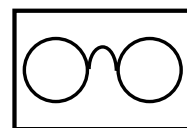
Sodium and potassium flame tests

You will need a Nichrome wire flame probe for these tests; a glass rod made of sodium borosilicate won't work as the flame probe. Why?

Dissolve a small amount of sodium chloride (NaCl, from the reagent bottle made available to you by your lab instructor) in 20 drops of distilled water and mix it by tapping the test tube's bottom with your finger (will holding the top of the test tube with your other hand). Add a few more drops if it doesn't dissolve in 30 seconds. Dip your pre-cleaned Nichrome wire into the NaCl solution and place it in the flame. The bright yellow color of sodium (Na) will be prominent. Repeat this test three or four times. On one run view the emission through one thickness of cobalt blue glass. Next view the Na emission through two thicknesses of cobalt blue glass. The emission level will be substantially attenuated (decreased) by the filter.

Dissolve 1 small scoop of potassium chloride (KCl) in 20 drops of distilled water; add a few more dropd of DI water if necessary. Let's call this the KCl STOCK solution. Clean your flame probe with repeated flame heatings and dipping in distilled water until no more sodium emissions are detectable on the probe. Next dip your pre-cleaned Nichrome wire into the KCl solution and place it in the flame. The reddish-violet flame of the element potassium will be evident, especially if you put the probe in the lower, less blue part of the methane cone. Potassium's emission does not last as long as

sodium's so you will have to repeat this test many time to become familiar with the emissions from this excited element (OK OK read color). After this, repeat the test a few more times while looking at the K emissions through the cobalt blue glass. The attenuation that you noticed with the sodium line should be substantially less with this test because of the transmission characteristics of the cobalt blue filter (see Figure 3).

Try different mixtures of solutions of the potassium and sodium salts and perform the flame test as described above. Start with a pure potassium chloride solution and, beginning with a single drop, add a drop of the sodium chloride solution to the test tube containing a **fresh** KCl stock solution; perform the flame test looking careful for potassium's emissions; add another drop of NaCl solution; test again; add; test, etc. Perform the flame tests between each addition. The idea here is to gain confidence in detecting potassium in solution that have lots of sodium. When you stop this practice is your call.

Ammonium/ammonia odor test

If this is your first smell test, follow the instructions exactly as they are written. *You are responsible for your own safety in the laboratory*, and while a strong whiff of ammonia is not permanently damaging, it is somewhat unpleasant.
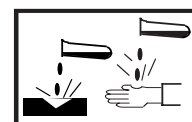
Put a small scoop of ammonium chloride (chemical formula NH_4Cl) solid in a test tube.

Add 20 drops of deionized water to the test tube. Tap the test tube's bottom with your finger (will holding the top of the test tube with your other hand) until the NH_4Cl all dissolves. Add a few more drops of water if you need to to dissolve all the solid. Lets call this the ammonium chloride STOCK solution.

Next add 5 drops of concentrated sodium hydroxide (NaOH) to that same test tube. Do not let any drops of the NaOH touch the upper part of the test tube. Make sure the drop falls all the way to the bottom of the test tube. After your NaOH addition, gently tap the test tube's bottom with your finger a few time to mix the ingredients.

Here's the reaction that takes place: NH^{4+} + NaOH ----> **NH_3** (gas)

Carefully—very carefully—hold the test tube in front of you over the lab bench twelve inches or more from your nose. Slowly fan your hand over the test tube and toward your nose and smell. Continue this process, slowly moving and fanning the test tube toward your nose until you smell ammonia. Put the test tube in your test tube rack. Repeat this test until you are sure that you know what a positive test for ammonia smells like. The ammonia was created by the reaction of sodium hydroxide with the ammonium cation.

Tear a one inch piece of red litmus paper in half and moisten one piece with deionized water. Put the moist litmus paper inside the top of the test tube and stick it against the glass. If the ammonia being released is in high enough concentration the litmus will turn blue. Red litmus turns blue in contact with a base like ammonia.

Make another NH_4Cl stock solution as above but this time dilute that stock

ammonium chloride solution by a factor of two with distilled water by adding <u>about</u> 10 drops of the stock solution to <u>about</u> 10 drops of distilled water in a clean test tube. Label this solution "**first dilution**." Add 5 drops of concentrated sodium hydroxide and repeat the odor and litmus test.

Dilute this "first dilution" solution by adding 10 drops of it to 10 drops of deionized water in yet another clean test tube. Add 5 frops of NaOH and repeat the smell and litmus test. This is a 1:2 dilution. If you run out of test tubes dump the contents of an old test in the beaker marked wastes and rinse the test tube with water and finally with deionized water.

Continue carrying out the odor test and the litmus test and serial dilutions until you can no longer smell the ammonia given off and then continue the litmus test until it gives a negative result. Number each of your dilutions so you can answer the questions posed below. Clearly label each tube with its new concentration. For very dilute solutions to get a positive smell or litmus test you may need to heat your test tube in a Bunsen burner's flame for a few seconds after the NaOH addition to volatilize enough ammonia to cause the litmus to react. (The process of heating decreases the solubility of the ammonia in solution and it bubbles out as a gas.) What is the dilution number of the last test <u>that you can smell</u>? What is the dilution number that will cause a positive litmus test? recorn both of these on the last page of this lab.

Dispose of the material left over after your tests in the appropriate waste container(s). Ask your lab instructor if you do not know where or what the correct container is. Also make sure that your Bunsen burner is turned off and free of any dried salts that you might have spilled accidently.

Unknowns

Get a test tube containing an unknown from your lab instructor. Record the unknown number. Assume that your unknown contains all the members of this group, ammonium, potassium, and sodium cations. Perform the flame and odor test on small portions of your unknown dissolved in deionized water. Repeat the known confirmation tests (real Na^+, K^+ ,and NH_4^+ samples) if you are allowed to and if the need arises because of indistinct results from the tests. **Report to your instructor all of the cations present in your unknown in the section at the end of your written answers to the questions on the next page. Also report your unknown number.**

Answer on a separate sheet in complete sentences.

1. What is the source of the nitrogen that is excreted by animals?

2. What is hyperammonemia?

3. What is the only **basic** gaseous component of the atmosphere? What is its chemical formula?

4. Write down the names and formulae of three **acidic** atmospheric components.

5. Write down the balanced neutralization reaction between sulfuric acid and ammonium hydroxide.

6. Why does a low pH rain not always result in a low pH runoff?

7. Most of the lowest pH rain that has been detected in the earth's atmosphere is in the Northern hemisphere. Why?

8. What is the wavelength of sodium's single emission line? What color is this light?

9. What are the wavelengths of potassium two emission lines? What colors are these? Why do you think that the color of the potassium flame is purplish?

10. What wavelength regions does a cobalt blue filter transmit best?

11. If you draw it, what does the transmission spectrum of clear, colorless window glass look like?

12. What does the *absorption* spectrum of a cobalt blue filter look like?

13. The sodium flame test cannot be performed using a glass rod as a flame probe. Why?

14. The potassium flame test cannot be performed using a glass rod as a flame probe. Why?

15. Why is the potassium emission so easily swamped by such a low concentration of sodium in your mixed Na/K salt test?

16. Given that baby's diaper pails smell stronger in the summer than the winter, why do you think that it is necessary to heat a sample that contains a very low concentration of ammonium to get a positive test?

17. Pretend that your audience is a 17th century American who believes that the cobault glass that filters light is magic. In complete sentences write down the words that you would use to explain why the cobalt blue glass filters out a particular wavelength of light. Beyond common words clearly define—for your sceptical 17th century audience—the terms that you use. This question is weighted heavily. Don't blow it off.

Your Unknown Number _____

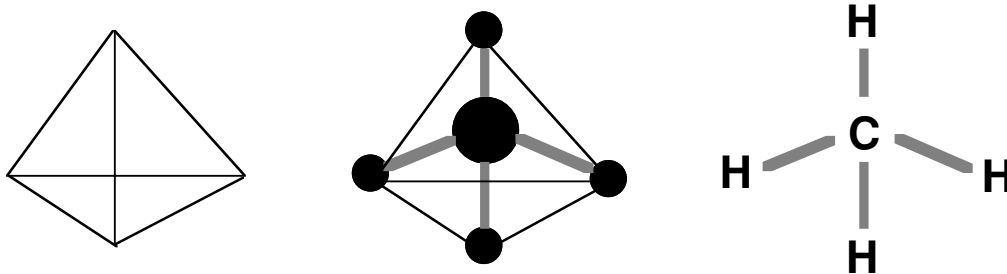**Cations from this group in YOUR unknown are** _____ **;
the possibilities are ammonium, potassium, and sodium.**

From the procedure on Page 8:

What was the last ammonium dilution number that produced a positive smell test when that tube was heated? _____

What was the last ammonium dilution number that produced a positive litmus test when heated? _____

Honors Chemistry

Chemical Model Building

Objectives

The physical distances, angles, and number of atoms in molecules gives them their structures and helps to determine their physical state. Using commercial "stick and ball" modelling kits you will build a few simple examples of common molecules.

Background

The sizes of atoms are so small that they cannot possibly be seen with the naked eye. In fact, even after you build one molecule with hundreds of thousands of atoms, the result is still too small to see. You need millions and millions of most molecules before you would even begin to see anything at all. However just because these objects and the arrangements of the parts of these objects are too small to see doesn't mean that they are not important.

In fact, the physical arrangement of atoms is one of the most important things that scientists have learned about the molecules that make up the matter in the universe. For instance, the arrangement of the three atoms in a water molecule give it special characteristics that make this molecule useful in dissolving salts that your body needs for life.

At the same time, this same molecular structure is the reason why an oil spill takes a long time to disappear from the surface of the ocean—and why a spill like this is so damaging to the environment in the long run. The structure of the molecules that make crude oil is distinctly different from water's.

Finally, the arrangement of the atoms in the molecules in the genetic material in my DNA also determines whether or not I have red hair. In short, the major differences between two different molecules are, of course, the kind of atoms that are present, but also the arrangement of the atoms that make up those molecules.

The simplest molecules are made of at least two atoms joined together in such a way that the atoms share two electrons. We call this process of sharing two electrons **a bond**. A very simple example of this is the two-atom molecule hydrogen, H_2. This molecule is referred to as *di*atomic because it has two atoms. It is also designated a *homo*nuclear diatomic because both of its atoms are the same and, of course, the atoms are identical in size and mass. The first molecule that you will build is diatomic hydrogen. This molecule is very light and has a very even (symmetrical) distribution of the electrons around the atoms that make it up. This molecule is referred to as a **nonpolar** molecule because of the kind of atoms, identical on each end of the bond, and because of the distribution of electrons or electron density among the atoms.

If one of the atoms of molecular hydrogen were replaced by nature (or by an inquisitive student) with a chlorine atom, things change. The second molecular model that you will build for this laboratory experiment will be HCl. This diatomic molecule has neither identical atoms nor a symmetrical electron distribution now. The atoms still share electrons but two things (in our simple treatment) have changed: First the size of the atoms have changed (a chlorine atom is much larger than an atom of hydrogen), and secondly, the distribution of electrons has changed too; many more electrons are concentrated near the chlorine atom than near the hydrogen atom. The number of electrons that atoms bring to molecules is just equal to their atomic number appearing in the periodic table (1 for H and 17 for Cl); however we will not spend too much time concentrating on the electrons for this experiment. Chemists label HCl a *hetero*nuclear diatomic and also call this type of molecule **polar** because of, in part, the unequal electron distribution.

The next molecular model that you will build contains just two different kinds of atoms (similar to HCl), but instead of just two atoms in the molecule, there are five atoms. This molecule is methane, CH_4. The key to understanding the structure of this molecule is to stop thinking "on the page" and to start to think in three dimensions. After all, the universe is not a two dimensional thing and neither are molecules.

Methane, CH_4, can of course, be drawn on the page like H_2 and HCl. But this is the first time that the drawings on the page really don't adequately represent reality. Instead of methane looking like that two dimensional cross in a square, with a hydrogen on each

side of the square and (a larger) carbon atom in the middle, the truth is that the physical forces that make up the CH_4 molecule make the structure a *three dimensional shape* called a tetrahedron. The tetrahedron has four sides. Each side has a face like a triangle. If you think of the methane molecule as being inside of the tetrahedral shape, then the carbon atom would be in the center and the four hydrogen atoms would each be at a vertex or corner.
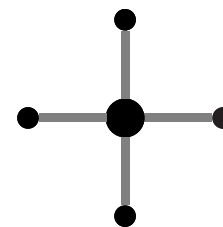
The reason why the three dimensional methane molecule is not flat, with all the atoms in the same plane as in BF_3, is because of the attractions and repulsions between the forces in the molecule. More specifically, the electron pairs in the bonds that make up the molecule stay as far away from each other as possible (see Question 7). In methane, these repulsions are most successfully balanced, with the lowest overall "conflict" being represented by a tetrahedral structure, not a planar "cross." In BF_3 a trigonal planar structure satisfies these requirements best.

If you are starting to think that the amount of effort necessary to describe with words and draw these 3D molecules is getting out of hand, you are right. It is much easier to build them using chemical model kits and that is exactly what we will do in this experiment.
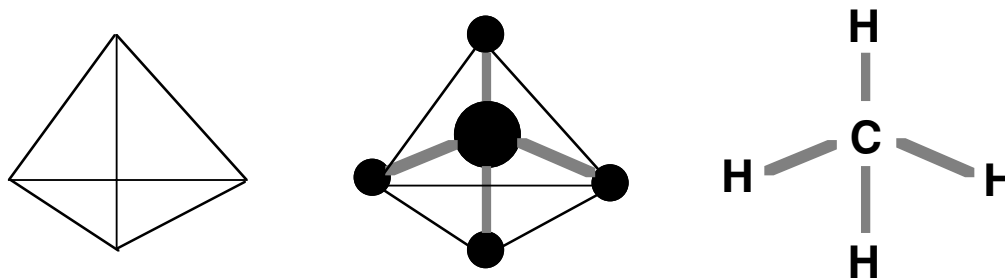
Your lab instructor has kits for you to use and will tell you how to put the models of the molecules together. Please be careful with the atoms and the bonds since they are generally somewhat fragile and have to be connected and disconnected over and over again. Some models have different colors to represent different kinds of atoms, and some have different length bonds; usually any bond to hydrogen is shorter than bonds between other atoms.

Procedure

1. Diatomic Molecules

The first molecule you will build is hydrogen. Connect two identical atoms together using the shortest bond available. There may not be any different bond lengths available; however, most molecular modelling kits do have different size or color atoms. Use the kit's instructions or check with your lab instructor—hydrogen is usually the most numerous atom in the kit. *Hydrogen can only form one bond*; this is an important rule. Other atoms like carbon can form more than one bond. In this lab we will assume that *carbon always forms four bonds*.

Notice that the H_2 molecule that you built is symmetrical. If you passed a mirror (a pane of glass) perpendicularly through the bond between the atoms with each hydrogen atom completely on either side of the mirror, then the reflection of an atom (and half of the bond left on that side of the mirror) would look exactly like the whole molecule without the mirror present. This mirror test for symmetry means that one side of the molecule is an exact mirror image of the other half. Since there are only two atoms in this molecule it is also automatically linear—it has no chance for another shape.

Hydrogen chloride is built exactly like H_2 except that one of the atoms is a different color and/or size than hydrogen. Use the atom specified by the modelling kit or your lab instructor for chlorine (or any halogen); don't use the kit's carbon atom. Remove one of your H atoms from H_2 and build HCl. (Like H, *chlorine only forms one bond*.) The fat side and thin side of the HCl molecule (that is, the large and small atoms on either side of the bond) show that the mass and electrons in the molecule are not symmetrically distributed and therefore there is more electron density at one end of the bond than at the other. This *polar* molecule would not pass the imaginary mirror image test if the mirror were passed directly between the two atoms because the molecule is not symmetrical. The reflection in the mirror (on either side) does not look like the original molecule.

Record all the molecules you've built on the Report Sheet.
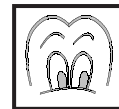
2. Trigonal Planar Molecules

Though relatively uncommon compared to linear or tetrahedral molecules, there *are* molecules that have a central atom with three connected atoms all lying in the same plane, that is, flat as it they were all lying on a page. One of these molecules is BF_3. Build boron trifluoride with three fluorine atoms connected to the central boron atom. Note that you cannot use the tetrahedral atoms (see below). For the three fluorine atoms use an atom like chlorine that you used in HCl, something that is larger than hydrogen and can connect to only one other atom. The strictly tetrahedral connectors will *not* allow you to make a molecule with three atoms connected to the central atom all in the same plane. (Hint: The angle between each of the three bonds in this molecule is 120 degrees.)

3. Tetrahedral Molecules

Now you will build your first tetrahedral molecule. Methane is often used as the primary example of this shape of molecule and we will also start here. Build CH_4 using one tetrahedral connector (the central carbon atom) and four hydrogens. Remember that carbon forms four bonds and hydrogen only one. Make sure that you use the carbon atom as specified by your lab instructor or the modelling kit's instructions. Notice that the molecule is inherently NOT FLAT like the simple 2D drawing of methane in this lab's introduction. As a matter of fact, if you are a good artist you might put the methane molecule down on the table top and try to draw it. (See the report sheet.) Estimate the angle between two bonds in methane; that is, what is the angle made between three points made up of a hydrogen atom, carbon, and a second hydrogen atom? Notice that it is smaller than that of the trigonal angle but larger than 90°. What would you estimate that angle to be?

The reason for the bond angles we have seen in the trigonally (120°) and tetrahedrally bonded central atom has to do with electron repulsion. The electrons in the bonds are trying to stay between the (positively-charged) atoms in the bond that they are attracted to yet stay as far away from each other as possible, because electrons in different bonds repel each other. If the central atom in methane had four hydrogens bonded to it and their bonds were all in thr same plane the result would be four 90° angled bonds. By existing in three dimensions, the bonds can increase their distance from other electrons in other bonds. See?

Other alternative tetrahedral molecules can be constructed by exchanging one or more of the hydrogen atoms for other atoms. Using the same kind of atom that you used for chlorine in HCl (and other than what you used for carbon or hydrogen), construct each of the following molecules in turn: CH_3Cl, CH_2Cl_2, $CHCl_3$, and CCl_4. What is the difference between CCl_4 and CH_4?

A second "level" of tetrahedral molecules can be made by joining two tetrahedral (carbon) centers together to form a longer molecule. If the only atoms used are hydrogen and carbon, these molecules are simply called hydrocarbons. Try removing one hydrogen from each of two different methane models and joining those two (CH_3-) pieces together. Most modelling kits have a longer bond connector for bonds that are not to hydrogen. Use the longer bond length if you can.

You have now built ethane (2 carbons), variously written as C_2H_6 or CH_3CH_3 or sometimes H_3C-CH_3. These different ways of writing the formulae help describe which atoms are connected together. Again notice that each carbon has four bonds and each hydrogen has only one; however, now one of the bonds is a carbon/carbon bond instead of a carbon/hydrogen bond.

Can you build the next member of this hydrocarbon family, propane, with three carbons? The carbons are "all in a row" and the center carbon is connected to one carbon on either side. All the other bonds are to hydrogen, and as before each carbon has four bonds and each hydrogen only one.

Record all the molecules you've built on the Report Sheet.

4. Chemical Nomenclature

Let's play around with some chemical nomenclature. We'll start with 1, 2, and 3 carbon hydrocarbon compounds with different numbers of chlorines and end up with the very specific way that chlorofluorocarbons are name by the "Rule of 90."

The family of molecules were going to build and name and then modify and name are called the linear (or normal) alkanes.

You've already built methane (1 carbon), ethane (2Cs) and propane (3Cs), and these names hold for those molecules even when some of the hydrogens are replaced by atoms like bromine, but the name has to be augmented to inform of the presence of the new atom. For example if one hydrogen is replaced by a bromine atom the name then becomes bromoethane. If the substitutent is a chlorine atom the molecule would be chloroethane, etc.

Name the following molecules, all normal alkanes:

C_2H_6 _____

C_2H_5Br _____

C_2H_5F _____

OK but now when we substitute onto the the propane molecule we have to differentiate between the substituent (called a "heteroatom" because it neither carbon nor hydrogen) on the first carbon or the second (the third can just as easily be thought of as the first atom if we have only one substituent so...well see below).

Therefore the following molecules have different names. Even though they have the same formula they are different molecules; they are isomers.
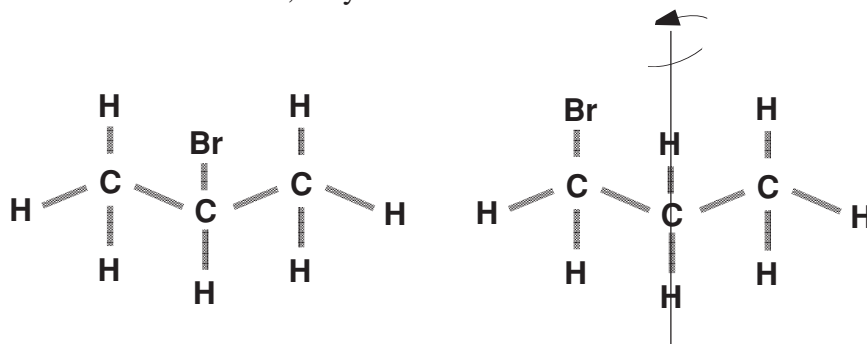
These guys are different molecules with different physical characteristics likemelting points, boiling points, and even toxicities. The molecule on the left is therefore named 2-bromopropane (C_3H_7Br) and the one on the right 1-bromopropane (C_3H_7Br). If you rotate the right molecule 180° the way the arrow suggests you don't get 3-bromopropane because rotating the molecule doesn't change its structure and make it a different molecule. Therefore there *is* no 3-bromopropane.

Report Sheet   *Honors Chemistry Lab*

Molecular Model Building

Date _____   **Section** _____   **Name**_____

1. Linear models

List the linear diatomic molecules that you built (page 4). Write down their chemical names and their formulas.

2. Trigonal planar models

What is the chemical name and formula of the trigonal planar molecule that you built while reading page 4? Do the best you can at drawing this molecule in the space below. Use letters to represent the atoms and lines for the bonds.

3. Tetrahedral models

List the chemical formulae of all of the tetrahedral molecules (page 5) that you built that contained one carbon. Draw methane in the space below to the best of your ability. Try to make your drawing look as three dimensional as possible on the page. You will not be graded on your artistic ability.

4. "Joined" tetrahedral structures

List the name and formulae of two of the models that you built that had two or more carbons (page 5). Write each of the formulae two different ways. Make sure that at least one formula for each shows *which carbons are connected together*. Draw two-dimensional pictures of ethane and propane.

5. Butane

Write down the formula of the next logical member in this series of hydrocarbons, butane. This molecule has four carbons in a row and follows the same pattern that you saw for methane (1 C), ethane (2 Cs), and propane (3 Cs). How many hydrogens are necessary if you follow the pattern started with ethane?

6. The **Rule of 90**

Simple hydrocarbons with chlorine and fluorine replacing some or all of the hydrogens are the basis of chemicals called chlorofluorocarbons (surprise). Commercially for a long time they were called Freons® and were used in refrigerators and air conditioners as working fluids which were used to move heat through the system using a series of compression and expansion steps. The simplest and most widely used chlorofluorocarbon has the formula $CFCl_3$. Notice that like methane if has four bonds to the central carbon; fluorine and chlorine never double bond. This compound is named CFC-11 using the Rule of 90. Here's how it works.

Take the CFC number and add 90 (ergo the Rule of 90): 11 + 90= 101

That resulting sum represents the number of the atoms in the molecule: the three digit number, 101, represents the number of carbon, hydrogen, and fluorine atoms in the molecule--in that order. Whatever bonds to the carbon are left over (remember carbons always have four bonds) are connected to chlorine atoms (remember, no double chlorine or fluorine bonds are allowed).

Therefore 101 represents a CFC with 1 carbon, 0 hydrogens, and 1 fluorine. All the rest of carbon's bonds are made to different chlorine atoms. That leaves three unfilled carbon bonds so there are three chlorines.

So the formula of CFC-11 is $CFCl_3$.

Here's one more: The formula of CFC-140 is $C_2H_3Cl_3$. **Why?**

Molecular Model Building

(Staple together all you turn in.)

Date _____   **Section** _____   **Name**_____

1. What is the term given to two electrons shared by two atoms?

2. Give examples (name and formulae) of three different *homo*nuclear diatomic molecules using only atoms from Group VII of the periodic table. What is the angle between the bonds in all of these molecules? What was the angle between the bonds in the trigonal planar molecules that you built in step 2 of the lab procedure?

3. Give examples (name and formulae) of three different *hetero*nuclear diatomic molecules using hydrogen and atoms from only Group VII of the periodic table. Names can be found here: webbook.nist.gov/chemistry/form-ser.html .

4. An even, symmetrical distribution of the mass and the electron density in a molecule creates a _____ molecule.

5. Polar diatomic molecules are made of two _____ atoms joined by a bond.

6. Build the methane molecule with your modelling kit and get an approximate angle between any two of the bonds in this molecule. In other words, what is the angle made between three points made up of a hydrogen atom, carbon atom, and a second hydrogen atom? Is the angle less than or more than 90°? What is the largest angle possible between four bonds in a three dimensional molecule like methane?

7. If the angle that you measured in Question number 6 were greater than 90°, do you think that that would decrease the repulsion between the electrons in two adjacent bonds or increases it when compared to a bond angle of 90°? Why? What is the "advantage" to the molecule of having bonds farther apart as opposed to closer together?

8. Write down the correct formula for each of these compounds using the Rule of 90:

CFC-11   **CFC-12**   **CFC 113**

CFC-123   **CFC-141**   **CFC-10**

9. Review the definition of isomer and then **draw and name** the structures of all of the possible isomers of the following molecules. They are all normal alkanes. Use an additional sheet of paper.

C_3H_7Cl C_4H_9Br $C_5H_{11}F$ $C_3H_6Cl_2$

Honors Chemistry

O_2 Content of Air

Objectives

The percentage of oxygen in normal atmospheric air will be determined using a simple method. This technique makes use of the catalyzed oxidation (rusting) of iron in a closed atmosphere.

Background

The oxygen content (molecular oxygen, O_2) of our atmosphere is something that we seldom think about, yet something that is very important. A large number of living things on this planet depend on the oxygen in the air for life. Some organisms remove oxygen from water solutions simply by the diffusion of dissolved oxygen through the membranes of the organism's cells (for example, protozoa and some kinds of worms). Larger life forms need a more specialized way to transfer oxygen into their bodies and to get waste products like carbon dioxide out of their bodies. Many marine animals have gills for this purpose to extract dissolved oxygen from the water that they live in. Some gills (like those that starfish have) are passive absorbers of oxygen and rely on water that is passing by to come in contact with the gill surface to supply the needed oxygen. Other kinds of fish (like sunfish and catfish) optimize this situation by pumping water through their gills. This process is assisted by the fish's movement through the water.

The largest animals on the planet need an even more efficient means of extracting the oxygen that they need from the air (instead of O_2 dissolved in water). Lungs have evolutionarily developed for this purpose. They get the oxygen they need directly, by breathing air into their lungs and selectively removing the oxygen from the other gases (mainly nitrogen and a small amount of carbon dioxide). Human beings, obviously, fall into this last class, and we too are extremely dependent on the oxygen content of the air we breathe.

People who go snow skiing only once a year often have a headache during their first day on the slopes. The reason for this is that most ski slopes are in the mountains at relatively high elevations (the new Japanese artificial slopes in Tokyo notwithstanding). As you move higher and higher into the atmosphere the air gets less and less dense; the heaviest air is near the bottom of the atmosphere at the surface of the earth, and the lightest air is at the top of the atmosphere. Some of the "missing" density at higher altitudes is due to a lower oxygen content in the air. Performing a relatively high impact activity like snow skiing demands a lot of oxygen. Although skiers may not consciously notice the lower oxygen content, their bodies often do and respond with a headache. People who have spent an extended time in this lower oxygen atmosphere have developed additional lung capacity to increase their ability to extract the oxygen that they need from the thinner air.

The rusting (oxidation) of iron usually takes place slowly. This process is <u>accelerated</u> by moisture, acidity, and heat. The procedure in this experiment takes advantage of catalysts. Catalysts are <u>reagents</u>—chemical substances—that speed up a reaction but are not used up by the reaction itself and can therefore often be recycled. The temperature, that is the heating of the reaction mixture, though <u>not a catalyst</u> is important. Most chemical reactions occur faster at higher temperatures.

Time management is an import aspect of this experiment. You need to get all four runs completed in two hours and average the results.

The controlled oxidation of iron in this experiment is performed in a moist, slightly acidic atmosphere, and the amount of oxygen necessary for the reaction is measured by the "reverse displacement" of water. As oxygen is taken out of the air by the rusting iron, the vacuum produced sucks water up into the inverted graduated to take its place. Scientists are happier if you say that the higher pressure outside the cylinder PUSHES the water into the lower pressure space. The percentage of oxygen in the air can then be calculated from the "sucked up water volume" compared to the original air volume of the graduated cylinder. Read the experiment's steps *before you start* and you will surely see the effects of rusting with your own eyes in a few minutes time.

Read the experiment's steps *before you start*.

Procedure
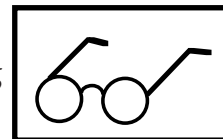
1. Determine the weight of a piece of weighing paper or plastic weighing boat.   Record the weight to 0.01 g.

2. Wash your hands with soap and water and dry them. Get a piece of steel wool about $^1/_4$ as large as your fist from the supply cart or stockroom. Pinch off a single piece between two fingers and roll it into a little ball in the palm of your hand.   Place approximately 0.75 g of steel wool rolled into a ball on the weighing paper and record the total weight to 0.01 g. (This piece should be about as large as the end of your thumb, but the size of the ball actually depends on how tightly you roll the ball. And be careful, the steel wool can cut you.) This weight shouldn't be any larger than 1.0 g and no less than 0.5 g. If you end up with a larger or smaller steel wool bgÑl, pinch off a piece or add a small piece to your ball to get approximately 0.75 g. Don't weigh the small pieces that break off. Throw these away and return the larger pieces that you don't use to the supply cart or stockroom.

 3. Measure 35 mL of 0.3 *M* acetic acid with a graduated cylinder and pour this entire volume into a 50 mL beaker. Keep the beaker in the vent hood. Unfold and "exercise the steel wool so that you expose as much surdace area as possible. *Using your tweezers*, put the steel wool ball weighed out in Step 2 into the acetic acid making sure it is completely covered by the acid. You may have to press down on the ball to completely submerge it.

4. Leave the steel wool in the acid for 1 minute. Remove the acid dipped steel wool from the acetic acid solution with your tweezers, put it in a clean 50 mL beaker, and take it back to your work station or bench top.   Do not wash off the steel wool after the acid dip. Before Step 5, make the steel wool ball's surface area larger by spreading it out with your fingers or your tweezers. The idea is to make it into a diffuse "tube"—not a tight ball as before. If you use your fingers then wash them off with water at the sink after you finish step adding the first aliqout of water in step 5.

Read Steps 5-7 before you begin Step 5. You now have to do a number of things correctly to get the best results. A partner can help here especially if you are working in a group.

5. As quickly as possible, remove the acid dipped steel wool ball from your 50 mL beaker using your tweezers and *loosely* pack the steel wool down into the *bottom* of a 25 mL graduated cylinder. <u>Try to expose as much of the steel wool cylinder to the air in the graduate as possible.</u> Invert the graduate and set it down into an *empty* 250 mL beaker. Using your wash bottle, add water to the beaker until the lip of the graduated cylinder (including the pour spout) is just covered by water. BE CAREFUL NOT TO KNOCK OVER THE INVERTED GRADUATE.

Figure 1. *Taking the initial reading.*
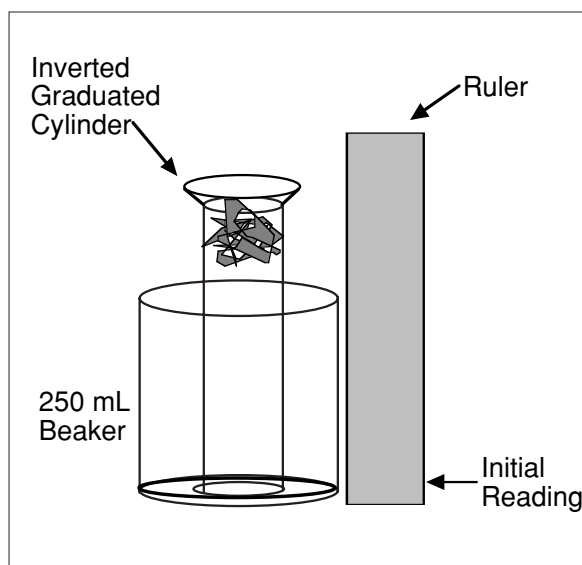
A "group acid beaker" under the hood may be used instead.

This is a very important step!

For this next step use a ruler marked in mm. Set the ruler on the bench top next to the beaker containing the inverted graduate and measure the distance from the bench top to the top of the water that you have added to the beaker. You will need to place a ruler on the bench top outside of the beaker and sight from the water level in the beaker over to the ruler's marks. Use the millimeters side of the ruler instead of the inches side. This will be a small number, probably less than 10 mm. This is your *initial water height*. (See Figure 1.) Record this value on the report sheet in the appropriate place.

As the oxidation (rusting that you have initiated by moistening the steel wool with water and acid) begins, the reaction will use up oxygen in the air inside the graduated cylinder. You will be able to see this because the water level *inside* the graduate will creep up: Oxygen will be used in the reaction and the volume of gases inside the graduate will decrease, pulling water up into the graduate from the beaker. This change in volume will be quickest at the beginning and slower later on. Why?

6. Start watching the clock as soon as you have inverted the graduate and finished measuring the initial water level. About every two minutes, carefully add water to the beaker with your wash bottle to make the water level *inside the graduated cylinder* and the water level in the beaker exactly level with each other. DO NOT LET THE WATER DROP BELOW THE GRADUATE'S SPOUT. (If the water level starts to move so radically that there is a chance that the water level *in the beaker* will drop below the spout of the inverted graduate and will allow air to get sucked into the graduate instead of water, carefully add water to the beaker with your wash bottle before the next minute mark.) After about 10 minutes, stop making water additions with your wash bottle every minute and instead add water to even out the water levels only every five minutes. Again, be careful not to tip over the inverted graduate. Continue adding water every five minutes until the reaction stops (about 20 minutes total), and the level of water inside the graduate does not rise any more. For your next trial get some food coloring from your TA and see if adding a <u>two drops</u> to the water in your beaker (not in the wash bottle) helps you visualize the water levels easier.

7. When the reaction is completed (no more change in water level since your last leveling addition of water), measure the height of the present water level in the graduate *above the bench top*. In other words, get the height of the water level above the start of the ruler. Place the ruler on the bench top outside of the beaker and sight from the final water level in the beaker over to the ruler's marks (which will exactly match the height inside the graduate if you made your last addition carefully—See Figure 2.) Record this reading in millimeters on the report sheet in the appropriate place. The difference between the initial and final readings will therefore be the distance that the water has travelled up into the graduated cylinder during the whole reaction time.
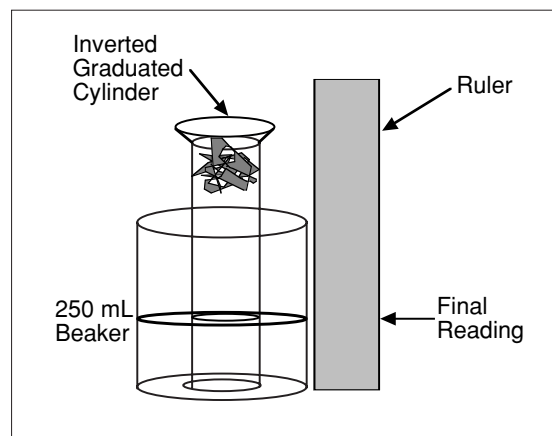

Figure 2. *Taking the final reading.*

After you have successfully measured the distance that the water level has travelled, remove the steel wool from the graduated cylinder and discard it in the appropriate waste container. With your ruler measure the total height of the cylinder *from the lip to the top of the base*. (See Figure 3.) Record this value in millimeters on the report sheet as the height of the graduated cylinder.

8. Repeat the experiment from Step 1. Use a fresh, newly weighed ball of steel wool; however, you *may* use the acetic acid left in the 50 mL beaker from before to acid rinse the steel wool. Record all of your data on the report sheet for the second run.
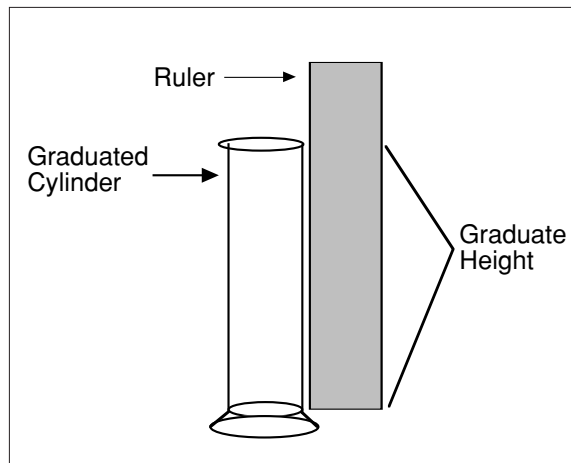

Figure 3. *Measuring the total height of the graduated cylinnder.*

O_2 *Content of Air*

1. Data table

	Run # 1	Run # 2
Mass of Steel Wool + Paper		
Mass of Paper		
Mass of Steel Wool		
Height of Graduated Cylinder (mm)		
Final Height of Water in Graduated Cylinder (mm)		
Initial Height of Water		

2. Calculations

	Run #1	Run #2

a) Height of graduated cylinder .... _____ mm   _____ mm.
   (from data table)

b) Calculate the change in height
   of the column of water during the experiment
   (subtract the initial ruler reading
   from the final ruler reading) .... _____ mm   _____ mm.

c) Calculate the percentage of oxygen in air
   (divide 2b by [2a minus initial height]
   and then multiple by 100) [all units in mm] .... _____ % O_2 _____ % O_2.

d) Repeat the procedure for an additional two runs and record the data on the fol-
   lowing page. Average all four runs at the bottom of that page and in the box..

O_2 *Content of Air*

1. Data table

	Run # 3	Run # 4
Mass of Steel Wool + Paper		
Mass of Paper		
Mass of Steel Wool		
Height of Graduated Cylinder (mm)		
Final Height of Water in Graduated Cylinder (mm)		
Initial Height of Water		
Average % Oxygen Content in Air	**%**	←
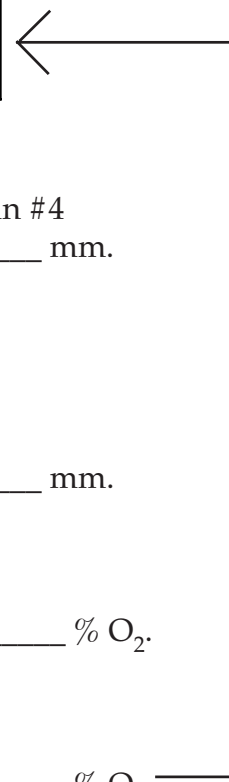
2. Calculations

                                   Run #3   Run #4

   a) Height of graduated cylinder .... _____ mm   _____ mm.
      (from data table)

   b) Calculate the change in height
      of the column of water during the experiment
      (subtract the initial ruler reading
      from the final ruler reading) .... _____ mm   _____ mm.

   c) Calculate the percentage of oxygen in air
      (divide 2b by [2a minus initial height]
      and then multiple by 100) [all units in mm] .... _____ % O_2 _____ % O_2.

   d) Record the average of these four percentages
      on the data table above. .... Average   _____ % O_2.

O_2 *Content of Air*

Answer in complete sentences on a separate sheet.

1. The percentage of oxygen in the air at sea level is approximately 20.6%. Calculate the percent error for your experiment: subtract your average experimental % O_2 **from** 20.6 (accepted value - experimental = difference) and then divide this result by 20.6 and then multiply by 100. This is your average % error. If your % error was greater than 10% provide three thoughtful reasons why the error is so high.

2. What is a catalyst? Are there any catalysts used in this experiment? If so, what are they?

3. The oxygen content of the atmosphere has a very important effect on forest and prairie fires. What would you expect might happen to the severity and number of fires on the earth if the oxygen content of the atmosphere (near the surface) increased from approximately 20.6 % to 25 %? Conversely what would you expect might happen if the natural atmospheric oxygen content became 15 %?

4. Catalytic converters are installed in all automobiles sold in the United States. These devices are placed "in-line" in the exhaust pipe, and all gases that are exhausted by the engine pass through the catalytic converter. Use the World Wide Web to determine what chemicals react in an automobile's catalytic converter. Write down at least two of the reactions using chemical formulae (not words) and balance your equations.

5. Could a mouse live by breathing the gases left in the graduated cylinder at the end of the experiment? Explain your answer for credit.

6. The condition of metal objects that have been retrieved from deep oceanic ship wrecks is often quite good; the process of rusting still occurs at these depths but at a much slower rate than at the oceans surface. Why? (pH, that is, acidity content is not part of this answer.)

7. What would happen to your experiment if the acetic acid "dip" were left out of your procedures?

8. What would happen to your experiment if the reaction vessel (the graduated cylinder and beaker) were cooled by using ice water instead of room temperature water. What about using hot water?

9. The process of eutrophication is dangerous for fish that live in bodies of water that normally "support fish." Find the definition of eutrophication, write it down and explain why this process is bad for fish.

10. Google for a definition of the "dead zone" in the US Gulf of Mexico. Write your own definition and a short explaination of the cause of the dead zone.

11. Write a description to your chemistry professor about the strengths of the experimental procedure you performed in this lab (BS not appreciated, i.e. "I learned a lot....") Follow that by a description of the procedure's failures. You are trying to improve the process for future Honors non-major chemistry students. Be constructive and thorough.