Preparation and Properties of Pollutant Gases[1]

Objective: In this experiment you will prepare and examine the properties of four atmospheric gases, carbon dioxide (CO_2), oxygen (O_2), sulfur dioxide (SO_2), and nitrogen dioxide (NO_2). You will compare the impact of these gases when dissolved in solution and study the solution acidity as well as and effect on one-cell organisms.

Background: SO_2 and NO_2 are both highly toxic and have irritating odors. They are formed during burning or combustion processes and enter into the atmosphere. Sulfur dioxide is primarily formed when coal or oil that contains elemental sulfur as an impurity is burned at an electric power plant. Nitrogen dioxide is primarily formed in automobile engines that are running at high temperatures. In these engines, nitrogen (N_2) from the air reacts with oxygen (O_2) to form a variety of toxic nitrogen oxides. These pollutants can be controlled by using low sulfur coal and by having car engines tested and properly tuned.

You will not be using combustion processes to synthesize nitrogen dioxide and sulfur dioxide gases in the lab. You will be running reactions in Ziploc bags in order to be able to collect the gases you produce. It may be necessary for you to do a practice run through the gas generating procedures before you will be able to collect a gas sample. Remember that one of the properties of gases is that they rapidly diffuse; this means that the gas you produce will rapidly leave the bag and normal atmospheric gases will enter the bag if you carelessly open it.

Carbon dioxide will be prepared using a common technique, acidifying a bicarbonate or carbonate.

$$NaHCO_3(s) + H^+(aq) \rightarrow Na^+(aq) + H_2O(l) + CO_2(g)$$

Oxygen will be prepared by the catalytic decomposition of hydrogen peroxide.

$$2H_2O_2(aq) \rightarrow 2H_2O(l) + O_2(g)$$

You will produce SO_2 via the reaction of sodium sulfite and sulfuric acid.

$$H_2SO_4(aq) + Na_2SO_3(s) \rightarrow Na_2SO_4(aq) + H_2O(l) + SO_2(g)$$

Lastly, nitrogen dioxide will be produced in a multi-step process. First, nitric oxide (NO) will be formed by the reaction of sulfuric acid with sodium nitrite to produce sodium sulfate, water, sodium nitrate and nitric oxide.

$$H_2SO_4(aq) + 3NaNO_2(aq) \rightarrow Na_2SO_4(aq) + H_2O(l) + NaNO_3(aq) + 2NO(g)$$

Second, the oxygen and the nitric oxide will be combined to produce nitrogen dioxide.

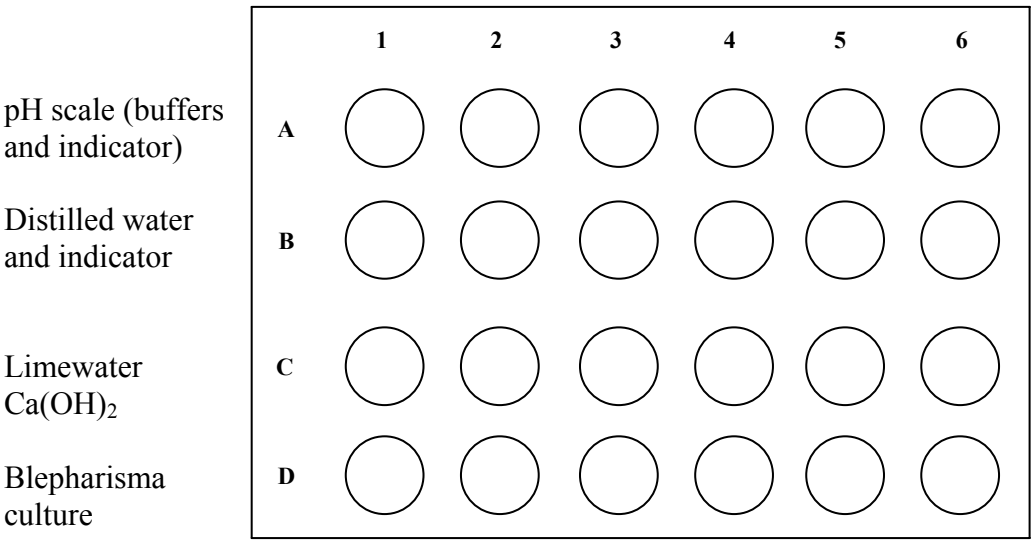
$$2NO(g) + O_2(g) \rightarrow 2NO_2(g)$$

Procedure:

Safety Note: The acids and the hydrogen peroxide used in this lab are corrosive materials and should be handled cautiously. In addition, SO_2 and NO_2 are toxic gases and should not be allowed to escape into the lab. Work with these gases in the fume hood. Do not open the bag containing the gas outside of the hood.

[1] Adapted from *Chemistry in Context Laboratory Manual*, ACS, Wm. C. Brown, Dubuque, IA, 1994.

Setup



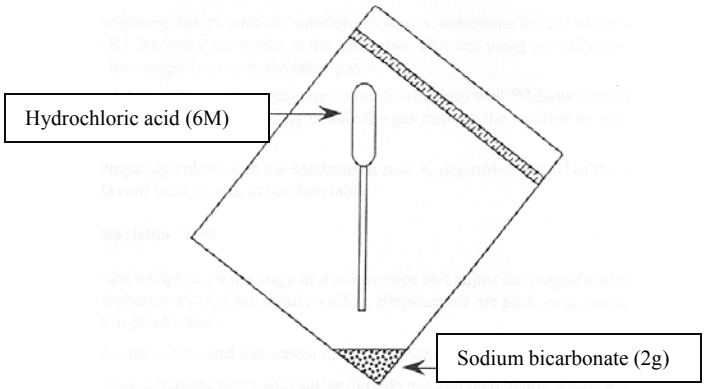
The reaction wellplate setup

1. Add 20 drops of pH 3 solution in well A1, 20 drops of pH 4 solution in A2, etc. through pH 8 solution.
2. Add 1 drop of universal indicator to each well containing a pH solution. These solutions are your comparison standards. To prevent contamination, seal them with a strip of cellophane tape.
3. In row B of the wellplate place 20 drops of distilled water and 1 drop of universal indicator in wells B1, B2, B3, B4, and B5.
4. In row C of the wellplate add 10 drops of limewater (calcium hydroxide solution) to wells C1, C2, C3, C4, and C5. For a CO_2 test only, add some limewater to well C6 too.
5. In row D of the wellplate add several drops of the Blepharisma culture (or pond water) to wells D1, D2, D3, D4, and D5. (Note: Since living cells will be in these wells, the wells must be clean and free of any chemical contamination from previous experiments.)

Generating the Gases and Determining their Properties

Carbon Dioxide

1) Place about 2 grams of sodium bicarbonate ($NaHCO_3$) in the bottom corner of a 1-pint Ziploc bag.
2) Fill a plastic transfer pipet with 6 molar (M) hydrochloric acid (HCl). Hydrochloric acid is highly corrosive, be careful not to drip it on yourself.
3) Place the transfer pipet with the hydrochloric acid in the bag with the sodium bicarbonate. Smooth out the bag so it contains a minimum amount of air and then seal the bag without squeezing the pipet.
4) Hold the sealed plastic bag as shown in the diagram and slowly squeeze the pipet so that the acid drops onto the $NaHCO_3$. What do you observe? Keep the bag sealed.



Properties of Carbon Dioxide

1) Squeeze the bulb of the pipet to expel the air and keep it squeezed. Slowly push the tip of the pipet against a corner of the zip seal. Push the tip gently into the bag and release the bulb taking care not to have the tip of the pipet contact the liquid or solid in the bag. As you withdraw the pipet reseal the Ziploc bag. Place the tip of the carbon dioxide filled pipet into a well plate containing distilled water (B1). Slowly bubble the gas through the water by gently squeezing the pipet. Compare the color with the solutions in row A to determine the pH of the gaseous solution in B1. We will discuss pH in much greater detail later in the term. For now it will suffice that a pH of seven is neutral, a pH less than seven is acidic and a pH greater than seven is basic.
2) Repeat this process of expelling carbon dioxide gas into the limewater (C1). What do you observe? In a test for CO_2 only, expel some CO_2 into well C6. Follow by adding a drop of hydrochloric acid to this well. What did you observe?
3) Again, repeat the process by gently squeezing a puff of carbon dioxide gas at the water containing the Blepharisma (D1) while you observe the life forms on the microscope.
4) Ignite the end of a wood splint. After it has burned for a few seconds, blow out the flame. Continue to blow on the embers so that they glow. Hold the pipet full of carbon dioxide so that the tip is very near the glowing ember and quickly squeeze a puff of gas directly at the glowing portion. What do you observe?

Oxygen

1) Place about 1 gram of yeast in the bottom corner of a 1-pint Ziploc bag.
2) Fill a plastic transfer pipet with 6% hydrogen peroxide. Hydrogen peroxide is highly corrosive.
3) Place the transfer pipet with the hydrogen peroxide in the bag with the yeast. Smooth out the bag so it contains a minimum amount of air and then seal the bag without squeezing the pipet.
4) Hold the sealed plastic bag and slowly squeeze the pipet so that the H_2O_2 drops onto the yeast. What do you observe? Keep the bag sealed.
5) Repeat the processes used for carbon dioxide to determine the properties of oxygen using wells B2-D2.

Sulfur Dioxide

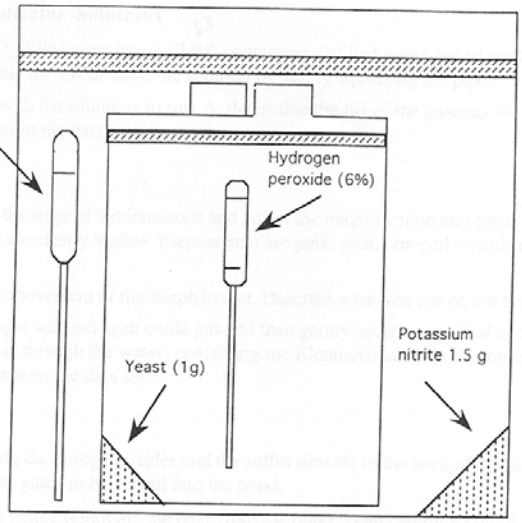
1) Place about 2 grams of sodium sulfite (Na_2SO_3) in the bottom corner of a large Ziploc bag.
2) Fill a plastic transfer pipet with 6 M sulfuric acid (H_2SO_4). Sulfuric acid is highly corrosive, be careful not to drip it on yourself.
3) Place the transfer pipet with the sulfuric acid in the bag with the sodium sulfite. Smooth out the bag so it contains a minimum amount of air and then seal the bag without squeezing the pipet.
4) Hold the sealed bag and slowly squeeze the pipet. What do you observe? Keep the bag sealed.
5) Repeat the processes above to determine the properties of sulfur dioxide using wells B3-D3.

Nitrogen Dioxide

1) Weigh out 1.5 grams of potassium nitrite and place it in the bottom of a *large* Ziploc bag.
2) Fill a transfer pipet with 6 M sulfuric acid and place it in the bag with the potassium nitrite.
3) Place about 1 gram of yeast in the bottom corner of a 1-pint Ziploc bag.
4) Fill a transfer pipet with 6% hydrogen peroxide and place it in the bag with the yeast. Smooth out the bag so it contains the minimum amount of air and then seal the bag.
5) Place the <u>smaller bag into the larger bag</u>. Smooth out the larger bag so it contains the minimum amount of air and then seal the bag. Your bags should look like the picture below.
6) In the fume hood, slowly squeeze the pipet containing hydrogen peroxide in the smaller bag to generate oxygen. Then slowly squeeze the pipet containing sulfuric acid in the larger bag to produce

NO and maybe some NO_2. What do you observe? Finally open the smaller inner bag while keeping the larger outer bag sealed to make NO_2. What did you observe?

7) Keep the two-bag setup in the fume hood, as nitrogen oxides tend to be able to diffuse through plastic.
8) Repeat the processes above to determine the properties of nitrogen dioxide using wells B4-D4.



Lastly, in order to make sure you are comparing apples to apples, you need a standard. You should take a pipet filled with <u>air</u> and see what the properties of air are by blowing this gas into the wells (B5-D5). What happens in the wooden splint test?

Disposal & Clean Up

When your work is complete open the bags in the fume hood. Fill the bags with water in the fume hood and then carefully pour the water into the sink. The bags can now be placed in the trash. The wellplates should be washed, rinsed with distilled water, and allowed to dry.

Write Up

Complete the write up sheet posted at the web page.

Questions:

1) Rank the acidity of the five gases.
2) Limestone ($CaCO_3$) is commonly found in the Midwest and it helps to keep the bodies of water from becoming too acidic. Can you use the results from well C6 to explain this?
3) How do CO2 fire extinguishers work?
4) What possible effects could be expected to occur in a lake that is downwind from a coal-fired power plant that burns high sulfur coal?
5) Nitrogen oxide emissions occur in cities with large numbers of automobiles (that means all cities in the US). Which urban pollution and health problems are likely to be made worse by nitrogen oxide emissions?
6) If you were careful when you made the observations of the effects of the gases on Blepharisma, you may have noticed that the Blepharisma began to swell as the gas was introduced. Speculate on the reason for this. (Hint: Look up osmotic pressure in a biology or general chemistry textbook.)