Chemistry 110
Spring 2011
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Supplemental Experiments 1 and 3 – Refrigerant and Pollutant Gases

Prelab Lecture

What is the purpose of this experiment?

We are trying to understand some of the properties of four gases – SO_2, sulfur dioxide; NH_3, ammonia; a standard CFC replacement gas and NO_2, nitrous oxide.

What properties are we trying to understand regarding these gases?

The gases used in the first experiment are gases that were used in refrigeration before the advent of CFC's and the CFC replacements that are currently used. In the case of these gases SO_2, NH_3 and the CFC replacement, we're trying to understand something about their odor, and three aspects of their reactivity – their ability to dissolve in water, their acidity or basicity, and their tendency to be involved in oxidation-reduction reactions – reactions in which electrons are transferred from one molecule to another.

In the second experiment we're looking at SO_2 again, as well as NO_2. We'll take a more detailed look at the tendency of these molecules to make acids when dissolved in water, and their effect on some unicellular animals found in pond water, called Blepharisma.

Why do we care if these gases are acidic or basic?

For experiment 1, the acidity or basicity is important because acids or bases can corrode the tubes which make up the coils on the back of the refrigerator. Because sulfur dioxide and ammonia are toxic at high concentrations this is dangerous, as well as severely limiting the lifetime of the refrigerator.

In addition, SO_2 and NO_2 are atmospheric pollutants from automobile exhaust and burning dirty coal and oil. Studying their reactions with water and testing the resulting pH can help us understand their role in acid rain.

Why do we care about oxidation-reduction reactions?

These are another mechanism for corrosion. For example the formation of rust from wet iron is the result of an oxidation reduction reaction between the oxygen in the air, water and iron.

How can we tell if the gases do oxidation-reduction reactions?

We look to see if they remove the color from a sample of potassium permanganate. If there is no electron transfer reaction, the potassium permanganate stays purple, but if there is an electron transfer reaction, it turns colorless.

Why do we look for the effect of SO_2 and NO_2 on the Blepharisma?

It's a way of evaluating the toxicity of the gases.

How do we tell if the molecules are acidic or basic?

In experiment 1 we use one of two indicators. An indicator is a substance that changes color upon a specific reaction. An acid-base indicator is one that changes color when the system reaches a certain acidity.

In experiment 1 you'll use phenolphthalein, a substance that is clear when acidic and turns pink when basic.

The other indicator you'll use in experiment 1, bromthymol blue, is yellow when acidic, blue when basic, and is sort of an ugly green for neutral solutions.

In experiment 3, you'll use an indicator called a universal indicator, that has several different colors depending on how acidic or basic the solution is. As part of experiment 3, you'll determine how the color of the universal indicator changes as the acidity of a solution changes.

What is acidic and what is basic?

A neutral solution at 298K has concentrations of H_3O^+ and OH^- that are equal at 1.000×10^{-7} moles of solute per liter of solution. A solution that has a higher concentration of H_3O^+ is considered to be acidic, and one that has lower concentrations of H_3O^+ are considered to be basic.

Are the concentrations of H_3O^+ and OH^- independent or interrelated?

They are interrelated. At 298 K, the relationship is given by

$$[H_3O^+]\,[OH^-] = 10^{-14}.$$

What this implies is that when the concentration of H_3O^+ increases, the concentration of OH^- decreases and vice versa.

Are concentration units the only way that we measure the acidity of a sample?

No, we frequently use a system of units called pH.

What is pH?

pH is defined as the –log [H_3O^+]. Therefore the higher the concentration of acid the lower the pH. A neutral solution has a pH of 7. An acidic solution will have a pH less than 7 and a basic solution will have a pH greater than 7.

Does each increase of a pH by 1 mean the same increase in the amount of H_3O^+?

No, because pH is a logarithmic scale, each time the pH increases by 1, we have 10 times as much acid. Thus a pH of 7 means an acid concentration of 10^{-7} moles/liter, while a pH of 4 is 10^{-4} moles/liter, a concentration a thousand times higher. A pH between 6 and 7 is only very slightly acidic, and a pH between 7 and 8 is only slightly basic. pHs between 6 and 8 deviate so slightly from neutrality that they can be considered (from an environmental point of view) neutral for all practical purposes.

Are natural water sources neutral?

Actually natural water sources, depending on where they are from, vary from a pH of 6.5 to a pH of 8.5, so they are typically very close to neutral, but not exactly neutral.

How do we obtain our gases?

We use chemical reactions to synthesize them.

How do we get SO_2?

We use two different reactions:

In experiment 1, we use the reaction

$$Na_2SO_3 + 2HCl \rightarrow 2NaCl + H_2O + SO_2$$

In experiment 3, we use a similar reaction but use sulfuric acid, H_2SO_4, instead of hydrochloric acid.

How do we get NH_3?

We use the reaction

$$NH_4OH(aq) + heat \rightarrow H_2O + NH_3$$

How do we get NO_2?

We do this in three steps. First we generate NO, using the reaction:

$$H_2SO_4 + 3NaNO_2 \rightarrow Na_2SO_4 + H_2O + NaNO_3 + 2NO$$

Then we generate oxygen from hydrogen peroxide using yeast as a catalyst:

$$2H_2O_2 \xrightarrow{yeast} 2H_2O + O_2$$

Finally, we combine the oxygen and the nitric oxide to get NO2:

$$2NO + O_2 \rightarrow 2NO_2$$

Experimental Hints:

1) Safety : Both acids and the base are highly corrosive. Take care not to get them on your skin. Use gloves if you desire. Eye protection should be on at all times.

2) Safety again: All three gases are mucous membrane irritants. This means you should avoid inhaling them in bulk, and if you are asthmatic, inhaling them at all.

Make sure that all gas generation steps take place in the hoods, and as many of the other steps involving the gases should also be done in the hood. Asthmatic students should skip the step involving smelling the gases

3) Safety again: For the rest of you, when you smell the gases, don't stick your head over them and inhale. Instead, use your hand to waft some of the gas toward you.

4) The directions for synthesis of the SO_2 tell you to use just a few drops of HCl. This isn't sufficient. About a half a pipetteful from the micropipette is necessary.

5) Use the balances in the next room to measure out the masses of your solid samples. Use the following techniques:

A. Take a piece of weighing paper and fold it in four (crosswise twice).
B. Open the door of the balance and put the paper on the tray, then close the door of the balance.
C. Record the mass of the weighing paper.
D. Open the door and with your scoopula or spatula add your chemical until the mass is greater than the weighing paper by the desired amount. Do not try to get exactly the amount specified. It is more important to precisely measure the amount you use than to use exactly the amount specified. So for an experiment requesting a gram of material, usually any amount from 0.9 g to 1.1 g is fine.
E. Close the door again, and record the mass of chemical plus paper.
F. The mass of your substance is the difference between the two masses.

6) When making the NO_2, be aware that opening the oxygen bag inside the SO_2 bag is difficult. You should practice this before putting your chemicals in.

7) When using the pipette to remove NO_2 from the bag, you need to be careful to open the bag the absolute minimum amount, or your gas will escape. Practice this too.

8) The refrigerant gas is one that is used as a propellant in an aerosol can. To fill your collecting bulb with the gas, keep the collecting bulb open side up, and put the canister rightside up to get the propellant out.
Make sure that you write down the name of the propellant. It's on the can.

9) To make the experiment go faster, you'll work in groups of four. One group will prepare the experimental setups for the refrigerants lab, while simultaneously, the other will put together the setups for the pollutants lab (but keep the liquids separate untuseil you're ready to use them. Then the four students will carry out all of the studies together. This should make the experiment go more quickly.

9) Make sure you follow the cleanup instructions in the manual, both for safety and for environmental responsibility. Make sure that you clean up the weighing room as well.

Lab Report:

Data sheets on pages 9 and 10 of each experiment, and questions on page 8.

Make sure that you keep careful notebook records, and that you use the proper correction methods.