

## INTERACTIVE DEMONSTRATIONS

*The goal is to expand and extend demonstrations to include the entire class. We first saw Ed Brogie of Laurel H.S., in Wayne, Nebraska use this method. It became a major part of the Chem 5 program that Ed, Bob Lewis (Downer's Grove North H.S., Illinois), George Gross (Union H.S., New Jersey), and I presented for six years, under the auspices of Woodrow Wilson National Fellowship Foundation. Thanks to Bob for putting the material into a workable format.*

### I. PINK PANTHER BREATH!

#### A SMALL-SCALE LABORATORY AND A MACROSCALE DEMONSTRATION OF GAS DIFFUSION AND SOLUBILITY OF GASES IN LIQUIDS.

**Concepts:** Scientific method, diffusion, properties of ammonia, indicators, gas-liquid miscibility, density, surface tension, and some other stuff that I forgot.

**Description:** A large-mouth bottle, filled with liquid and covered with a piece of filter paper is inverted above another, apparently-empty bottle. After a short time, swirls of pink color begin to float up into the liquid in the inverted bottle.

#### A. THE DEMO

**Materials:** Two wide-mouth bottles, 250-mL or larger (gas collection bottles are great, if you have them); concentrated (15 M) aqueous ammonia (you can substitute non-sudsing household ammonia, which is about 10 M); phenolphthalein solution, filter paper, water. An overhead projector or light box is helpful.

#### Preparation

1. Mix in a separate container: 4-5 drops of prepared phenolphthalein solution and enough water to completely fill one of the wide mouth bottles. Pour the mixture into one of the bottles.
2. Cut a piece of filter paper so that it is just a half-centimeter larger than the mouth of the filled bottle.
3. In the second bottle, place a few drops of concentrated aqueous ammonia. Cover the bottle until you are ready to do the demonstration.

#### Performing the Demonstration

1. Using the filter paper, cover the filled bottle. It is crucial that the bottle be filled to a convex meniscus, so that no air bubbles are trapped between the water and the paper.
2. Uncover the bottle with the ammonia solution. Holding the filter paper on the filled bottle, invert it over the bottle containing the ammonia. If you are lucky (or very skillful) the paper will effectively hold the water in the bottle. Don't count on it.

To better display the color change that results as the ammonia diffuses up into the phenolphthalein, place the two-bottle system on an overhead projector or light box. As the light shines up from below, the pink color is highlighted more effectively

## B. LABORATORY EXTENSION

### Materials:

8- or 12-well strips (Flinn AP 1724 or AP 1446)

thin-stem Beral-type pipettes

concentrated aqueous ammonia or household ammonia

water with phenolphthalein

6-mm x 50-mm test tubes (Flinn GP6060)

latex tubing, about 6 mm diameter.

### Preparation:

1. Add about 10 drops of phenolphthalein to about 500 mL of water.
2. Fill a number of thin-stem pipettes with the water/phenolphthalein mixture. Fill a second set with aqueous ammonia, and label both sets of pipettes. Ideal is to have 1 set for each 1 or 2 students.
3. Cut the latex tubing into small rings, about 2 mm wide; you need one ring per student or 2-student team.

### Instructions to students

*Safety goggles must be worn at all times in the laboratory, and this is a laboratory setting.*

*You have just seen a demonstration that illustrates diffusion and solubility of gases. Use the materials you have been given to study these principles. In about 15 minutes, you will be asked to share your findings with the class.*

You will need to show your students how to set up the system to simulate the demonstration. Below is a drawing that illustrates it. No filter paper is needed, since the small diameter of the test tube precludes dripping.

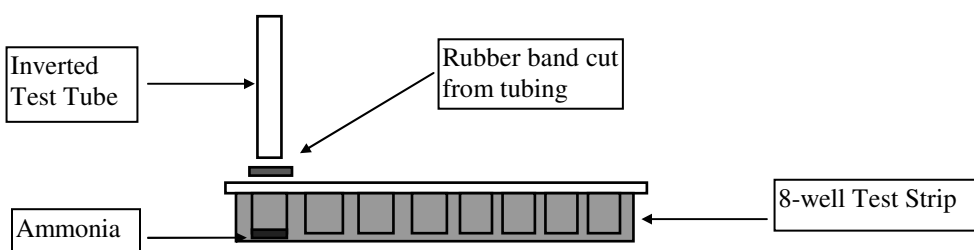


Figure 1: Student Set-up

**Do not over-instruct students.** Show them the setup, but don't tell them where to place either solution. They will determine that by trial and error if need be. Setup is so easy that repeat trials are the norm and should be encouraged.

### Discussion:

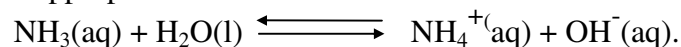
Students may try any number of variations, from changing the location and amounts of solutions to varying the size of the air space between the drop(s) of ammonia in the well and the solution in the tube. Seek out as many variations as time permits. Here are some typical initial responses:

1. The ammonia solution “smells.”
2. The water and phenolphthalein turns pink.
3. The water and ammonia do not have to be touching for it to work.
4. The number of drops of ammonia solution does not seem to change the speed of color diffusion.
5. Diluting the ammonia does slow the diffusion rate.

**Hazards:** Ammonia is a strong base with an unpleasant odor. Care must be taken to protect skin and eyes. Vapor can be absorbed by contact lenses. Perform both the demonstration and experiment only in well-ventilated areas.

### Background

Ammonia gas is very soluble in water; at room temperature, 700 volumes of the gas will dissolve in one volume of water. Depending on where you are in the course, discussions of hydrogen bonding and ionization reactions may be appropriate:



As ammonia vapor escapes from the concentrated solution, it travels into the water above it, causing the phenolphthalein to change color. “Plumes” of color will be in evidence; they are due to the density gradients produced by dissolving ammonia. If you use household ammonia for the demo, the reaction will be a bit slower, but will work.

### Disposal

All solutions may be flushed down the drain with water.

## **II. THE MAGIC AIR BUBBLE.**

### **A SMALL-SCALE LABORATORY AND A MACROSCALE DEMONSTRATION OF SOLUTION PROPERTIES AND INTERMOLECULAR FORCES.**

**Concepts:** Observation skills, solutions, endothermic and exothermic processes, hydrogen bonding, molecular structure, density, miscibility, Raoult's Law, vapor pressure and boiling point, mol fractions.

**A. Laboratory Portion** (This part should be done first.)

#### **Materials:**

Glass tubing, 8-10 mm dia, in lengths of 18-20 cm. One per student or pair.

Corks to fit the tubing, probably #00 or 0.

Food coloring, blue and yellow

Ethanol (anhydrous preferably; 95% works well enough); methanol may be substituted

20-30 thin-stem pipettes

#### **Preparation:**

##### **Solutions:**

\*Note: colors do matter in this case; some yellow food coloring does not mix well with alcohol.

**1 L of water**, to which you have added 10-15 drops of yellow food coloring. Try for a reasonably intense color.

**1 L of alcohol**, to which you have added 10-15 drops of blue food coloring. Ethanol or methanol will work.

#### **Materials**

- Place about half the pipettes in the yellow liquid, half in the blue. Do not identify the liquids to the students. Remind them of precautions that are to be taken when handling unknown substances.
- Make sure each tube has two corks that fit tightly. Set all materials in a convenient location for student access.

#### **Instructions to Students**

*Safety goggles must be worn at all times in the laboratory, and this is a laboratory setting.*

*To day you are going to do a mini-experiment. I want you to put each of the two liquids, blue and yellow, into the glass tube. The only requirements are that you fill half the tube with each color, and that you fill the tube to the top, so that no air bubble is present when you insert the second cork. You may repeat the process several times, if you like. Record all of your observations and be ready to share your findings with the rest of the class in 15 minutes.*

#### **Hazards**

Tubes will leak if not stoppered tightly. Alcohol is flammable; no open flames should be in the area.

#### **Disposal**

Flush the liquids down the drain with water.

## Results

When alcohol and water are mixed, the resulting volume is less than the sum of the original volumes. The decrease can be attributed to the greater degree of hydrogen bonding that exists between alcohol and water, as compared with alcohol and alcohol. This is a non-ideal solution, and exhibits a negative deviation from Raoult's Law. (You might want to pursue this with an advanced or AP class.) The smaller water molecules fit into the spaces between larger alcohol molecules.

If students add the blue liquid first, they will discover that mixing takes place immediately when the yellow liquid (water) is added. The more dense water sinks to the bottom and the mixture quickly becomes green throughout. If the yellow liquid is added first, addition of the blue (alcohol) results in formation of two distinct layers, which mix only very slowly unless the tube is inverted repeatedly. When the tube is inverted, a bubble appears, no matter how carefully students filled the tube. This bubble is the result of the non-additive volumes.

An interesting question concerns the make-up of the bubble; the most common answers are "a vacuum" and "air." Both are probably partially correct. When the liquids first combine, a partial vacuum is produced as the volume decreases. The space is quickly filled with water vapor and alcohol vapor (the latter predominates). There is also likely to be a small amount of dissolved air that is released from both liquids, but this cannot be a significant volume, given the solubility of oxygen as about 9 ppm, with nitrogen much less. The actual composition of the bubble would be determined by Raoult's Law, using the respective mol fractions of alcohol and water.

$$P_{\text{total}} = \chi_A P_A^{\circ} + \chi_B P_B^{\circ},$$

where  $P(\text{total})$  is the total vapor pressure of the mixture,  $\chi_A$  and  $\chi_B$  are the mol fractions of the two, and the  $P^{\circ}$  values are the individual vapor pressures at the ambient temperature. Because this system is non-ideal, only approximate values can be obtained, however. It is also important to recognize that these two liquids mix exothermically (some students may detect a warming); this, too, must be considered when Raoult's Law is applied.

## B. MACROSCALE DEMONSTRATION (Do this after students have shared their findings.)

### Materials

Long (100 cm or so) glass tube, 25 mm diameter approximately, standard wall or heavier. (Flinn's GP9146 "Magic Wand" is suitable, but if you can find a tube that's 4 ft by 1 in. diameter, that's best.)

Two rubber stoppers (solid) to fit the ends of the tube

400 mL (approx. ) each of the blue and yellow solutions. (You may be able to just use what remains from the student experiment, but identify the liquids this time.)

### Procedure

Stopper one end of the long glass tube. Fill the tube about halfway with the (yellow) water, then carefully fill it the rest of the way with the (blue) alcohol. Try to avoid mixing the liquids during filling. Place the stoppered (bottom) end firmly on the floor or other hard surface (such as a lab stool), then stopper the open end. Carefully slide your finger over the bottom stopper and hold the tube up so that

students see you must press firmly to keep the stoppers in place. Begin slowly turning the tube end over end.

For the first few turns, you need to keep firm pressure on both stoppers to avoid “eruptions.” As the two liquids mix, however, attractive forces between molecules will cause the expected reduction in volume; this drops the internal pressure and holds the stoppers in. You may or may not detect the pulling in of the stoppers. As you continue to turn the tube, the color will become green and the size of the bubble will increase. The center of the tube becomes warm, due to the exothermic mixing of alcohol and water.

### **Extension**

Lately, we have used the Vernier Pressure Sensor, connected to LabPro or CBL2, as a final stage of the demo. This is especially effective with honors and AP-level classes, as students see the expected rise in pressure as the stopper and sensor are inserted into the full tube. Then as the demonstrator tilts the tube back and forth, the pressure drops dramatically to about half an atmosphere (350-400 mmHg) as the bubble forms. Over time, the pressure returns to its initial level. Our theory is that the methanol is boiling, as shown by the large number of very small bubbles appearing near the middle of the tube and the fact that the area of mixing becomes palpably warm. This is displayed on a TI ViewScreen.

**Hazards:** Alcohol is flammable. The glass tube is breakable. Stoppers may pop out from the tube; goggles and lab coat should be worn. Do not do this demonstration too close to students.

### **Disposal**

Flush down the drain with water.

### **Discussion**

On a large scale, many of the observations are more pronounced: the tube becomes distinctly warmer; the bubble here is definitely too large to result from dissolved air; tiny bubbles (boiling alcohol?) can be seen the length of the tube, apparently starting from nowhere.

The possibility of a vacuum can be demonstrated (well, it usually works) if you hold the tube very close to a student’s ear (goggles!) as you carefully remove the (top) stopper. It is usually possible to detect a sound that is suggestive of an inrush of air.

(We first saw the macro demonstration from Sheldon Knoespel, in 1987.)

### III. THE RAINBOW COLUMN:

#### A SMALL-SCALE LABORATORY AND A MACROSCALE DEMONSTRATION OF DENSITY, PH AND MIXING.

##### CONCEPTS

Scientific Method, diffusion in liquids, indicators, and relative densities of solutions.

##### A. LABORATORY PORTION (This part should be done first.)

##### MATERIALS:

**Glass tubing**, 8-10 mm diameter, in lengths of 18-20 cm. One per student or pair.

**Corks** to fit the tubing, probably #00.

**0.1 M hydrochloric acid, HCl**, containing enough Universal indicator to give a distinct red color, about 5 mL per student or pair. Add 2.1 mL of concentrated acid to distilled water to make a volume of 250 mL. Set out in thin-stem pipettes.

**2.0 M potassium carbonate, K<sub>2</sub>CO<sub>3</sub>**, about 0.5 mL per student or pair. Dissolve 28 g of anhydrous solid or 35 g of the dihydrate in 100 mL of distilled water. Sodium carbonate may be substituted, but its solubility is not as great as that of potassium; a saturated solution may be less than 2.0 M depending on temperature, so the diffusion won't be as distinct. Set out in micro-tip pipettes.

##### Instructions to Students

*Safety goggles must be worn at all times in the laboratory, and this is a laboratory setting. The reagents you will be using consist of a dilute acid and a mildly skin-corrosive solution, so wash your hands thoroughly before you leave the room.*

*Today, you will do a mini-experiment. I want you to fill the corked glass tube to about 2 cm from the top with the red liquid using the thin-stem pipette. Add enough of the clear, colorless liquid from the microtip pipette to fill about half the remaining space in the tube. Record your observations and be ready to share your findings with the rest of the class in about 10 minutes.*

##### HAZARDS

Tubes may leak if not tightly corked. If the ends of the tubes are not fire-polished, there is some risk of injury. As mentioned in the instructions, there is a dilute acid (0.1 M HCl) and a mildly caustic solution (2 M K<sub>2</sub>CO<sub>3</sub>), so students should wash up spills on skin and clothing.

##### RESULTS

As the clear, colorless carbonate solution runs down the inside of the tube, it produces a purple color at the bottom, with layers of blue, green, yellow, orange and finally red at the top. This is due to neutralization of the acid by the strong base, carbonate ion. The density of the carbonate solution is sufficiently high to make it fall fast enough that only a small amount of mixing takes place.

One interesting feature of the experiment is the length of time that the color layers will persist. Another is the very sharp break, especially between the yellow and red layers, that often results. It is not uncommon for the orange color to either not be observed at all or to not last very well.

With an advanced class, this is a good opportunity to discuss hydrolysis and buffer action. For first-year students, you will want to focus on density and the pH effects that are evident in the similar system that is used in the demonstration that follows.

## **B. MACROSCALE DEMONSTRATION** (Do this after students have shared their findings.)

### **MATERIALS**

**Long glass tube (100 cm or so)**, approximately 15-25 mm diameter, standard or heavy wall.

(Flinn's GP9146 "Magic Wand" is suitable, but as before, use a larger one if you have it, especially if you are in a large room.)

**Rubber stoppers (2)** for the ends of the tube.

**Distilled water**, about 400-500 mL, with enough **Universal Indicator** to give a distinct color, adjusted to green (neutral).

**Hydrochloric acid, HCl**, 0.3-0.5 M, 1-2 mL. For 0.5 M, dissolve 4 mL of concentrated reagent in 96 mL of distilled water.

**Sodium hydroxide, NaOH**, 0.3-0.5 M, 1-2 mL. For 0.5 M, dissolve 2 g of solid pellets in 100 mL of distilled water. Allow to cool before using.

**(N.B. The Concentrations of HCl and NaOH should be equal, or nearly so.)**

### **THE DEMONSTRATION**

Stopper one end of the tube securely. Fill the tube to within 4-5 cm of the top with the (green) mixture of water and universal indicator. Allow air bubbles to work their way to the top, then add 15-20 drops of the base (enough to give a distinctly purple color to the top of the tube). Stopper the tube and rotate it 180°. Remove the stopper that is now on top and add about 15-20 drops of the acid, to make that end distinctly red. Replace the stopper and slowly rotate the tube 180° again. Now rotate the tube 90°, so that it is parallel with the floor. The full range of colors of the indicator should be evident.

Discuss with students the reasons for the various colors, making particular note of the fact that the experiment clearly demonstrates the slowness with which liquids mix. This is in accord with our understanding of the spacing between the molecules (and ions) in a liquid. The mean free path in liquids is quite short, especially in comparison to gases, and is only slightly greater than that in solids.

As with so many demonstrations, I attribute this one to Bob Becker. You can also try doing the sodium carbonate-0.1 M HCl as a long tube. It works reasonably well, but has the disadvantage of using a large volume of acid, albeit dilute acid.

### **DISPOSAL**

The contents of the tube will fall within the range of pH 6-8, so can be safely disposed of in the sink.