

tometer. The student has reached the limits of what can be done in a high school chemistry lab.

Don't miss the golden opportunity to emphasize:

- 1) Often questions are unanswered because of the limitations of the tools we have.
- 2) A real experiment never has a conclusion.

The Time Frame

The average class of 20 chemistry students with minimum lab skills should be able to do both demonstration and lab experiment in three class periods (one double lab period and one regular class period). An excellent follow-up experiment is a determination of the molarity of an unknown basic solution using a known acid and a student's own indicator extracted from the flowers. *Warning:* Be ready to discuss why it worked or why it did not work.

The Personal Experience

Chemistry teachers should try the students' experiments before assigning them. This experiment was developed at the Camille and Henry Dreyfus Institute held at Princeton and shows that even old and jaded chemistry teachers can get excited from this methodology. The initial idea came from a lecture given by Doris Kolb who mentioned the unusual nature of natural indicators extracted from flowers. My initial reaction was that it might be worth a try even though I was not expecting much to happen.

My initial Questions: Would this make a good experiment for high school chemistry students? How good will the indicator extracted from flowers be?

Method: Go out and pick the purple wisteria flowers growing on the walls of Frick Auditorium.

Results: (In an attempt to be as inconspicuous as possible, I started to grab the petals and place them in a beaker.) My finger was immediately stung by a bee who was also utilizing the flowers, which proves that all experiments can be dangerous.

Question: What should be used for extraction?

Method: Try denatured ethyl alcohol 95% and mix with petals.

Results: A grayish-colored alcohol solution (very uninteresting).

Question: Since the solution appears very diluted, will concentrating the solution help?

Method: Use hot plate and evaporate.

Results: A more concentrated grayish liquid.

Question: What effects do acid and base have on solution?

Method: Place two small beakers on white paper. Add 5 ml of 1 M NaOH to the first and 5 mL of 1 M HCl to the second. Then add a few drops of the concentrated wisteria indicator.

Results: Base turned bright red (the equivalent of phenolphthalein) and acid turned bright yellow (very impressive).

Question: If base side is red and the acid side is yellow, where is the blue to create a purple flower?

Method: Try titrating acid solution with base.

Results: Yellow solution turned green-blue-red.

Question: In what pH range will this wisteria indicator change?

Method: Set up a series of test tubes with different buffers to see color sequences.

Results: An entire array of different colors resulted. This indicator is almost equivalent to a universal indicator. (This is becoming interesting.)

Question: How many indicators are in this sample?

Method: Try to separate fractions using paper chromatography. Try alcohol.

Results: Separation occurs but not very good (solvent too volatile).

Question: Need a solvent system that will separate fractions slowly.

Method: Ask experts.

Results: *N*-butanol and concentrated NH_3 were suggested by visiting professor, and *n*-butanol and glacial acetic acid were suggested by lab assistant who had worked on plant extractions for 10 years.

Question: What is best system to use?

Method: Try both.

Results: *N*-butanol and concentrated $\text{NH}_3(\text{aq})(4:1)$ showed excellent separation and had distinct fraction lines.

Question: While separation lines were visible, a better way to show the different fractions is needed so student could cut out the different fractions and separate components.

Method: Try UV light.

Results: Brilliant display of at least 15 different fractions. Many shades of blue fluorescence. (Spectacular display was final surprise; I'm sold!)

In terms of my original question: "Would this make a good experiment for high school chemistry students?" The answer was obviously "yes" for the following reasons:

- 1) Each step involved new surprises.
- 2) Experiment easily holds the interest of the student.
- 3) Procedure involves use of pH, titrations, indicators, buffers, chromatography, and other basic separation techniques.
- 4) Experiment is open-ended; that is, the student could continue this experiment with more equipment.
- 5) Most important, the student is in constant dialog with unknown phenomena.

Let me encourage you to try it and enjoy yourself. Chemistry can and is fun! And, rest assured, the students will be quite attentive when pH, titrations, buffers, and Le Chatelier's principle are discussed.

An Easy DCl(g) Prep for the HCl(g)-DCl(g) IR Experiment

The HCl(g)-DCl(g) IR spectrum analysis is an excellent pedagogical exercise for undergraduates. Unfortunately, it is not always possible or practical to carry out the traditional vacuum line preparation of the DCl(g) sample using benzoyl chloride and D_2O .

Using a lecture tank of HCl(g), ≈ 10 ml of 99+% D_2O , a vacuum pump and an IR gas cell, a gaseous sample containing both HCl and DCl can be prepared in less than 10 min. To prepare the sample, place the D_2O in a 125-ml Erlenmeyer flask in a hood and saturate it with HCl gas. Place the nozzle of an evacuated IR gas cell into the flask, slowly open the stopcock to pull in the acid vapors, close the stopcock, and run the spectrum.

The solvation of HCl in D_2O is quite exothermic. Thus, to avoid getting too much D_2O vapor into the gas cell, the solution should be below room temperature before attempting to fill the cell. The warm D_2O vapor will condense in the cell when cooled and cause deterioration of the salt windows. Also, most of the HCl-DCl vapor will dissolve in the liquid. For economy of resources and time, the same DCl solution can be used for an entire class. Simply bubble the D_2O -DCl solution with HCl gas briefly before getting a new sample. The IR gas cell is opened and stored in a desiccator after each use and the D_2O solution is capped.

In addition to the easily obtained HCl(g)-DCl(g) IR sample, many interesting conversations can be initiated with students about the kinetics and mechanism of production of DCl gas by this method, as well as the nature and concentrations of the different species in the solution.

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