Acids and Bases Experiments (Organic Classes)

$NaHCO_3$ (sodium bicarbonate, baking soda) and vinegar (dilute acetic acid) will be used to shoot a cork out of a bottle to show that some acid-base reactions generate gases like CO_2. All students in the class will participate in a voice-activated chemical reaction. Students will remove a stopper and speak into a flask containing base and an indicator that will change color once enough CO_2 is introduced from the students' breath. Further color changes from basic to acidic conditions are illustrated using natural and household liquids and a universal indicator prepared from red cabbage juice. Finally, conversion between colorless and colored forms of different acid-base indicators in unusual settings will be shown in the "invisible painting" experiment.

Supplies Needed:

For the **rocket reaction**:

You provide the following items indicated in red and starred:
- *** empty 1 L plastic soda bottle with label removed**
- *** vinegar (colorless)**
- Plastic powder funnel (we provide)
- cork with streamers attached by a thumbtack (we provide)
- container of de-ionized water (we provide, you refill as needed)
- sodium bicarbonate (we provide, return unused)

For the **voice-activated chemical reaction**:
- water
- 250 mL Erlenmeyer flask (we provide))
- dropper bottle with colorless phenolphtalein indicator (we provide)
- small amount of 1 M NaOH solution (we provide)
- disposable plastic droppers (we provide)

For the **universal pH indicator from red cabbage**:
- * **Red cabbage juice** (you make the day before the demo)
- * 1 lemon, 1 soap bar, Sprite, vinegar, drain cleaner
- * 7 stirring rods (e.g. plastic straws)
- ethanol (we provide)
- seven 200 mL beakers (we provide, clean and return after the demo)
- sodium bicarbonate (we provide, return unused)
- 10 mL disposable plastic syringe (we provide)

For the **invisible painting** demonstration:
- *** white poster board or cardstock, 50 x 50 cm or larger (*you provide*)**
- *** pencil *(you provide)***
- three bottles with "paints" (we provide)
  - *ortho*-cresolphthalein in ethanol (red)
  - thymolphthalein in ethanol (blue)
  - *meta*-nitrophenol in ethanol (yellow)
- spray bottle with "developing" solution (0.04% aqueous NaOH) (we provide)
- spray bottle with "erasing" solution (1% acetic acid) (we provide)
- 3 paintbrushes (we provide)

Please clean and return all materials that we provide as soon as possible. Other students may need to use this "kit" for their ChemDemo!!

Safety: **Students should wear safety glasses.** Most of the chemicals used are dilute (except for the 1 M NaOH) and not particularly dangerous. *meta*-Nitrophenol is relatively toxic when absorbed through skin and should be handled with caution. Needless to say, none should be consumed. If students get any of the chemicals used on their clothes or skin it can be simply washed off in the bathroom with plenty of water and soap. The sodium bicarbonate is not dangerous (but should not be consumed) and can be used to neutralize any vinegar or NaOH solution that gets spilled. All chemicals can be safely washed down a bathroom sink; the used poster paper can be discarded in a waste receptacle. The paintbrushes should be rinsed thoroughly with tap water and dried.

Objectives/Chemistry:

First explain to the students that scientists write down what they observe and that they must do the same when you perform the demos. As you perform the demos, you should ask the students for examples of acids and bases. If they need help, explain that every day we come into contact with some weak acids (like vinegar, citrus juices, Vitamin C and soft drinks) which are usually sour/tart tasting and weak bases (like soaps, detergents and many cleaning products) that feel slippery to the touch.

Next, explain that acids and bases are chemical opposites. When we add them together, they may react violently. Then do the **rocket reaction** (see the procedure section). Tell them that vinegar is an acid and baking soda ($NaHCO_3$) is a base. Explain why the cork shoots out of the bottle because of the production of CO_2 gas that increases the pressure in the bottle. The chemical reaction that takes place is:

$$NaHCO_3(s) + \underbrace{CH_3COOH(aq)}_{\text{acetic acid}} \rightleftharpoons CH_3COONa(aq) + \underbrace{H_2CO_3(aq)}_{\text{carbonic acid}} \rightleftharpoons CO_2(g) + H_2O(l)$$

The key here is that carbonic acid is unstable and readily decomposes to CO_2 gas and water. But carbonic acid is also formed when CO_2 dissolves in water and this is the key to the next experiment. Ask the students what gas do they exhale? It is carbon dioxide (CO_2) mixed with air. Tell them that we can use their breath to carry out an acid-base reaction. Explain that we use indicators (things that change color) to determine if we have an acid or a base or if we have something that is neutral like water. Do the **voice-activated chemical reaction** and explain that the initial color of the basic solution changes when enough CO_2 is introduced to make the solution turn more acidic. Explain that CO_2 dissolved in water makes carbonic acid and is one of the reasons that carbonated drinks are acidic. Carbonic acid reacts with basic NaOH to make $NaHCO_3$ and Na_2CO_3, which are less basic causing the indicator to change color from pink to colorless.

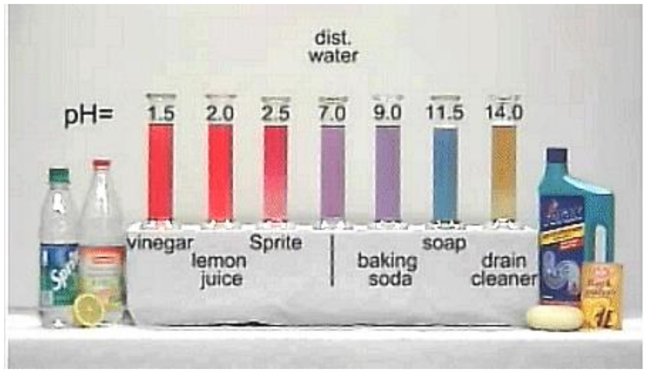
Further demonstrate the color change from acidic to basic, using a **universal indicator from red cabbage** and few typical household liquids. Explain the red cabbage pigment belongs to the group of anthocyanin dyes responsible for the red/pink and blue colors of many flowers, fruits, vegetables, and plant leaves. The anthocyanin color changes from red in acidic to blue in basic conditions. Thus, the blue color of blueberry and red color of Fuji apple skin (or red cabbage) are caused by the same pigment, but placed inside the cells with different pH.

Finally, show students the **invisible painting** demonstration. This demonstration uses synthetic acid-base indicators that are colorless in acidic or neutral conditions but colored in the basic conditions. Since these indicators require substantially basic conditions ($pH \geq 10$) to stay colored, atmospheric CO_2 (forms carbonic acid when dissolves in water) will quickly neutralize them to bring back to colorless form (especially blue color as thymolphthalein has high pK_a of 10.1). Ask students what should be done to restore the initial colors after they have faded (*answer:* spraying with basic NaOH solution again). Also discuss how the "painting" can be made invisible again (*answer:* spraying with acidic solution) and demonstrate this.

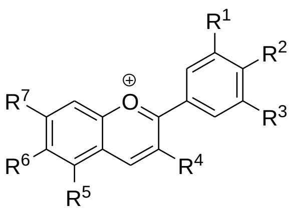
Procedures:

Rocket reaction: In a 1 L plastic soda bottle that has been rinsed and had the label removed add three teaspoons of baking soda ($NaHCO_3$) using the plastic powder funnel. When you are ready to do the demo, pour in enough vinegar to cover the $NaHCO_3$ and quickly put the cork into the mouth of the bottle. **DO NOT** aim the bottle at the students or the light fixtures. You should practice this before the demo!! The amount of $NaHCO_3$ and vinegar used may have to be adjusted especially if you are using a different size soda bottle. The class will probably want you to do it several times. Try experimenting with different amounts of $NaHCO_3$ and vinegar.

Voice-activated chemical reaction: Place 100 mL of water in the 250 mL flask (if you have a bigger flask use more water) and add about 4 drops of phenolphtalein indicator and about 1-3 drops of 1 M NaOH, just enough so that the color is an easily seen pink – do NOT add too much NaOH solution. Stopper the flask. Before you do the demo, announce to the class that this reaction can be activated by just the right person's voice. As you carry the flask around the classroom, remove the stopper for each student and let them speak to the solution. Stopper the flask and swirl after each student. The indicator color will change when enough CO_2 is blown into the flask. You can repeat this demo by adding a drop more of 1 M NaOH to turn the solution pink. You should especially practice this demo since using too much NaOH will keep the solution pink!! You can then show an accelerated version of this by adding a bit of dry ice (solid CO_2).



Universal indicator from red cabbage: **1) Preparation of cabbage juice** *(you should do this the day before the demonstration)*. Chop up finely half of a red cabbage head, and place into a 1 L bowl. Add about 800 mL of boiling water, mix thoroughly, and let the solution to cool down to room temperature. Filter the solution through a paper towel placed inside a strainer. Add approximately 5 mL of ethanol; the indicator liquid should be of dark reddish-purple color. Keep in refrigerator before the demonstration. **2) Demonstration experiment:** First, prepare 7 solutions in separate beakers: (1) 130 mL of vinegar, (2) juice of 1 lemon in 130 mL of water; (3) 130 mL of Sprite; (4) 130 mL of water; (5) ~0.15 g (tip of a spatula) of sodium bicarbonate in 130 mL of water; (6) ~0.2 g (few shavings) of soap in 130 mL of water; (7) 15 mL of drain cleaner in 130 mL of water. Stir solutions of soap and sodium bicarbonate until the solids dissolve. Using a plastic syringe, add ~12 mL of the red cabbage juice solution to each of the beakers, stir. Observe the color of each solution (your colors should be similar to those shown on the picture). Explain to the students that many household products contain acids and bases. pH is the measure of acidity/basicity, and red cabbage juice is the natural pH indicator. Thus, the juice will change to different colors when added to solutions of various pH. The natural pigments responsible for color change are called *anthocyanins*, and they are responsible for the red/pink or blue colors (depending on intracellular pH) of many flowers, fruits (apples, grapes, blueberries, raspberries), vegetables (peppers, olives, cabbages), and other plants (autumn red-colored leaves). These compounds belong to the class of common natural and synthetic dyes and pigments called *flavonoids*. Show to the class the general formula of anthocyanins and explain how millions of natural organic compounds can be "built" from just few elements (carbon, hydrogen, oxygen, nitrogen, etc.) connected in different ways.



anthocyanins *(R's are carbohydrate residues)*

Invisible painting: "Paint" a picture on the poster board using a separate brush for each color (lightly drawing the outline of your picture with a pencil will make painting easier as your painting is invisible at this stage). In addition to three provided colors (red, blue, and yellow), other colors can be obtained by painting over a previously painted region with a different color after the previous color has completely dried (practice this before the demonstration). Since your painting has to dry completely before you use it in the demonstration, it may be a good idea to paint it at the beginning of the demonstration, and let students wait anxiously to see what you are going to do with it until the end. Display the prepared board and spray it lightly with the "developing" NaOH solution but avoid spraying too heavily as the colors will run (**<u>CAUTION:</u> stay on a reasonable distance from the observers and do not allow the spray to get on yourself or any observers!!!!** If you let a student in class to spray the painting, make sure he/she wears gloves and safety goggles and check that he/she points the spraying nozzle in the right direction.) The painting will appear. After about a minute, the colors (blue in particular) will fade – they can be restored upon spraying again. You can also spray the painting with an "erasing" acidic solution to turn it invisible.