Acid and Bases Experiments (Standard)

$NaHCO_3$ (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 will be shown using a basic solution, universal indicator and solid CO_2. Reaction of metal and acid will be shown with Mg and Sprite. The acid/base behavior of some salts will be illustrated.

Supplies Needed

For the rocket reaction:

- empty 1 L plastic soda bottle with label removed (you provide)
- vinegar (you provide)
- Plastic powder funnel (we provide)
- cork with streamers attached by a thumbtack (we provide)
- container of tap 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 basic solution with universal indicator and CO_2:

- water
- 1 M NaOH solution (we provide)
- dry ice (solid CO_2) (we provide along with a Styrofoam container)
- dropper bottle with dark green Universal indicator (we provide)
- One 600 mL beaker (we provide)

For the Mg in Sprite reaction:

- flat Sprite or 7-up (*you provide*)
- bottle to put flat colorless soda into (we provide)
- magnesium chips (we provide)

For the salt acid/base behavior experiment:

- Three 250 ml flasks
- 3 small test tubes (labeled) with ~0.5 teaspoon of NH_4Cl (acidic), NaCl (neutral), Na_2CO_3 (basic)

Safety

Students should wear safety glasses. Most of the chemicals used are dilute (except for the 1 M NaOH) and not particularly dangerous. Needless to say, none should be consumed (except for the Sprite). If students get any of the chemicals used on their clothes or skin it can be simply washed off in the bathroom. The sodium bicarbonate is not dangerous (but should not be

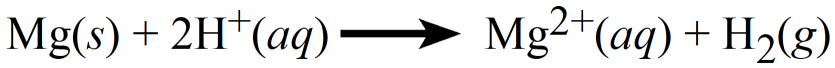
consumed) and can be used to neutralize any vinegar or NaOH solution that gets spilled. The Dry Ice (solid CO2) is very cold, -78ºC (-108ºF). It can give anyone touching it frostbite relatively quickly. **Do not let students touch or play with the dry ice!** All chemicals, except for the dry ice, can be safely washed down a bathroom sink.

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 (NaHCO3) is a base. Explain why the cork shoots out of the bottle because of the production of CO2 gas that increases the pressure in the bottle. The chemical reaction that takes place is:

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 CO2 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 basic to acidic, using a **basic solution with universal indicator and adding solid CO_2 (dry ice).** One eventually forms a $H_2CO_3/NaHCO_3/Na_2CO_3$ buffer system that will keep the pH near 7 (green color).
Finally, show them the reaction of **magnesium turnings in Sprite** and explain that the acid (carbonic and mostly phosphoric) in a soft drink can react with certain metals. Write out the below reaction on the board to show and discuss the chemistry.



Ask what metal is a soft drink can made out of? *Answer:* aluminum coated with a thin layer of plastic to ensure that it doesn't react with the acid in the soda.

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 NaHCO3 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 CO2 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).

Basic solution with universal indicator and adding CO2: Half-fill the 600 mL beaker with water. Add 4-8 drops of universal indicator. Add enough 1 M NaOH to turn the solution blue-purple (a couple of mL). Add a couple of pieces of dry ice (solid CO_2) and tell the students to observe and record the color changes and track the time. Be careful handling the dry ice!! Once the solution turns yellow, have the students record the time it took, then add ~5 mL of NaOH to turn the solution back to the blue-purple basic color. Record the time it takes the solution to turn yellow (longer this time). Repeat several times (adding more dry ice as necessary to keep a strong flow of CO_2 gas bubbling into the solution). You will have to add more and more NaOH solution each time to get the blue-purple basic color. After about the fifth time it will become quite difficult to add enough NaOH to get the basic color. This is because you are forming an increasingly concentrated $H_2CO_3/NaHCO_3$ buffer solution that has a pH around 7. Your body uses a related buffer system to keep your cellular and blood pH around 7.4.

Magnesium turnings in Sprite: Fill the jar ~ 3/4 full with Sprite (or 7-Up) the night before the demo and leave uncovered. Stir/shake occasionally to help the soda go "flat." Heating the sprite will help it go flat faster. The soda needs to be completely flat (no CO_2 bubbles present!!) for this experiment to work well. When doing the demo add a small amount of the magnesium chips and let the students observe what occurs. The gas being produced is H_2. Discuss how many of the things we drink are acidic – they are not dangerous because they are dilute and weak acids. A fun variant of this reaction is to **not** tell them what the acid is and just show it attacking the Mg and forming the $H_2(g)$. After all the students view it and you discuss how acids can dissolve many metals, you can surprise them by taking a drink of the "dangerous acid" solution (try not to drink any of the Mg chips, but they aren't toxic). Then, fill them in on its true nature.

Acid/Base Behavior of some Common Salts: Add approximately 100 mL of water to each of the three 250 mL flasks. Add 2- 3 drops of universal indicator. Add the three different salts [NH_4Cl (acidic), NaCl (neutral), Na_2CO_3 (basic)], one to each solution and dissolve. Note the color changes and discuss the meaning of the colors (universal indicator) and chemistry involved. Some students think that all salts are neutral (like NaCl). You can then add a little NaOH solution to the NH_4^+ solution to make it go basic and some dry ice to the CO_3^{2-} solution to make it go acidic to demonstrate the changes in pH.