Queer Science - October 22nd, 2023 - Acid/Base Chemistry - Georgia Tech
https://queerscience.lgbtqia.gatech.edu/

Time Required: ~ 35 minutes

Activity designed by Dr. Andrew McShan (Georgia Tech, School of Chemistry and Biochemistry)

Purpose:

Did you know that acid/base chemistry is important for the activity and function of items you encounter in your daily life? This includes the food you eat, the commercial products you use, and even components of your body's biology. The purpose of this activity is to explore acid/chemistry by directly determining the pH (remember – a measure of acidity and H^+ concentration) of everyday items. You will develop hypotheses (an educated guess that can be tested by scientific research) concerning the pH for each item, which you will then test.

Materials

- PPE (personal protective equipment)
- Goggles
- Lab coat
- Closed toe shoes
- Gloves

- pH paper - pH range 0 to 14 (Sigma Aldrich #WHA10360005)

This is a strip of paper coated with different pH indicators (molecules that change color when they contact a solution of certain pH). pH paper is an excellent way to measure pH semi-quantitatively in the absence of a speciated machine (pH meter).

- Standard solution at pH 4 (Mattler Toledo #63056121)
- Standard solution at pH 7 (Mattler Toledo #63056125)
- Standard solution at pH 10 (Mattler Toledo #63056129)

These are control solutions of known pH value. You will use these solutions to make sure the pH paper can correctly estimate pH values.

- 50 mL falcon tubes (Fischer #14-959-49A)

- Various items purchased from a standard grocery store (see Table 1)

Data collection:

- Some people suggest that acidic compounds smell sweet/sour, basic compounds smell bitter/metallic, and neutral solutions don't have a distinct smell. Using the "wafting technique", smell each of the everyday items. ***Does the item smell sweet/sour, bitter/metallic, or have no distinct smell? Fill in your observations in Table 1 (results section) in the "Smell" column.***

**** Safety note *****

Chemical odors must never be smelled directly since they can contain harmful fumes. Some chemicals should never be smelled under any circumstances (always see data safety sheet associated with the chemical). Detecting an odor in a laboratory is best done using the technique of wafting. Hold the open container a few inches from you and then use your hand or another material to push the odor towards the nose gently.

New York State

- Using the data collected from the smell test, pictures of the main chemical component for Table 1 (are these likely to donate or accept a H^+?), and your common knowledge, ***predict whether each everyday item will be acidic, basic, or neutral. Fill in your educated guess in Table 1 (results section) in the "Hypothesis" column.***

- Let's test your hypothesis. Use a strip of pH paper to semi-quantitatively measure the pH of each everyday item (use one pH paper strip per item). ***Fill in your observations in Table 1 (results section) in the "Measured pH" column.***

To semi-quantitively measured pH, dip the pH paper into the solution for 10 seconds. Take the paper out and lay it on a solid surface.

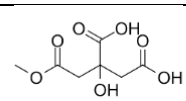
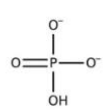
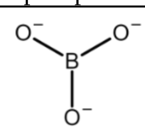
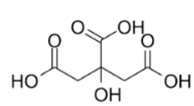
Then compare the pH strip to the reference pH strip document to estimate the pH. You will compare the entire pattern the reference.

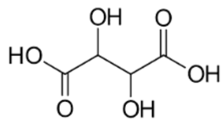
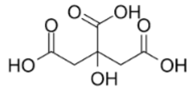
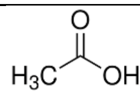
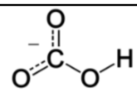
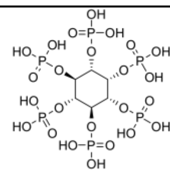
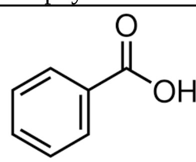
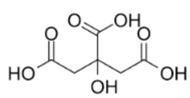
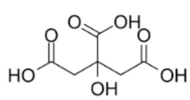
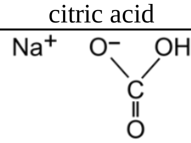
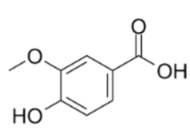
Example result for pH paper dipped in the standard pH 10 solution.

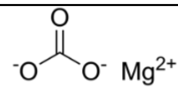
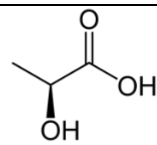
- The pH of each everyday item has been measured experimentally in a quantitative way using a pH meter. Your instructors will provide you with these measured values. ***Fill in the values in Table 1 (results section) in the "Expected pH" column.***

Results

Table 1

Everyday Item	**Smell (sweet/sour, bitter/metallic, no smell)**	**Main acid/base component**	**Hypothesis based on small and/or common knowledge (acidic, basic, neutral)**	**Measured pH (approximated by pH paper)**	**Expected pH (quantitatively measured by pH meter)**
Standard pH 4		 methyl yellow			4.01
Standard pH 7		 phosphate			7.03
Standard pH 10		 orthoborate			10.02
Lemon juice		 citric acid			1.91

Cola		 tartaric acid + citric acid			2.84
Green Tea		 citric acid			4.13
Apple cider vinegar		 acetic acid			3.12
Fiji Water		 bicarbonates			7.55
Almond Milk		 phytic acid			7.09
Tom's Mouthwash		 benzoic acid			4.19
Hand Soap		 citric acid			4.85
All purpose cleaner		 citric acid			6.34
Baking soda		 sodium bicarbonate			8.07
Vanilla extract		 vanillic acid			5.29

Alkaline Water		 magnesium carbonate			10.31
Human saliva		 lactic acid			6.71

** Different products will obviously have different ingredients. Most of the above were bought from Whole Foods Market and thus were plant-based products.*

<u>Questions:</u>

- Do you notice any trends between the pH of everyday items (*i.e,* are they mostly acidic, basic, or neutral)?

- Was there any correlation between the smell and measured pH/expected pH of the items?

- How similar are the measured pH (approximated by pH paper) and expected pH (quantitively measured by pH meter)?

- Note whether your hypotheses were mostly correct or incorrect, and what you think about the success. Any surprises?

Activity #2 – Making a rainbow with pH indicators
Time Required: ~ 20 minutes

Activity reference: Dr. Bob Porcja (Rutgers University); edited by Dr. Andrew McShan (Georgia Tech, School of Chemistry and Biochemistry)
https://chem.rutgers.edu/cldf-demos/1015-cldf-demo-rainbow-connection

Purpose:

This demonstration shows that a mixture of pH indicators can produce a color change different from that obtained with the individual indicators, resulting in the colors of the rainbow appearing and disappearing. The three indicators used are all colorless in acidic solution, but each produces a different color in basic solution. Because these colors are close to the three primary colors, colors of the rainbow can be produced by some combination of these indicators in basic solution. The indicator solutions used are very concentrated, more concentrated than standard indicator solutions, producing intense solution colors.

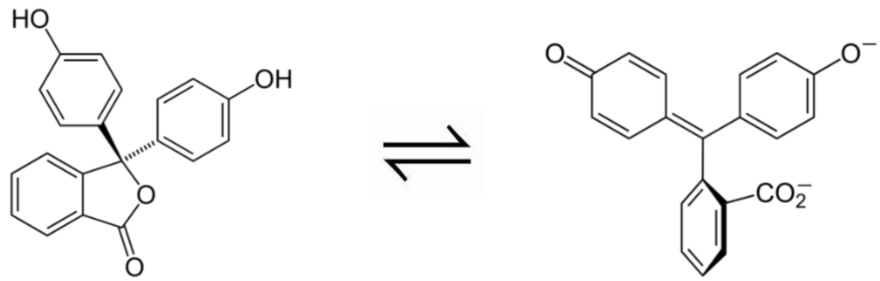
At the start of the demonstration, each beaker contains one of the six rainbow color indicator solutions along with an acid/alcohol mixture. Because the contents of the beakers are acidic, the indicators are colorless. The initial addition of base solution (sodium hydroxide) is not enough to neutralize the acid present; thus, the solution remains acidic, and the indicators remain colorless. With the second addition of base solution, an excess of base results, the solutions become basic/alkaline, and the indicators become colored. The intensity of the colors depends on the concentration of the indicator and the pH of the solution. Next, several drops of viscous acid solution (sulfuric acid/glycerin solution) are added to each beaker. The dense acidic droplets sink and are then dispersed by stirring, neutralizing the base, and converting the indicators back to their colorless form. Adding more base to each beaker again causes pH to decrease and allows the colors to redevelop. Finally, the contents of the beakers are poured into the large container containing viscous acid solution, causing the resulting solution to become acidic and converting the indicators back to their colorless form.

Materials

- Six 1 L glass beakers (KIMAX #14005-1000)
- Seven 50 mL glass bottles (PYREX #1395-50)
- One 5 L plastic beaker (Corning 1000P-5L)
- Transfer pipettes (Fisher #13-711-7M)
- 5 L carboy / pitcher (Fisher #03-313-112)
- PPE (personal protective equipment)
- Goggles
- Lab coat
- Closed toe shoes
- Gloves

Reagents

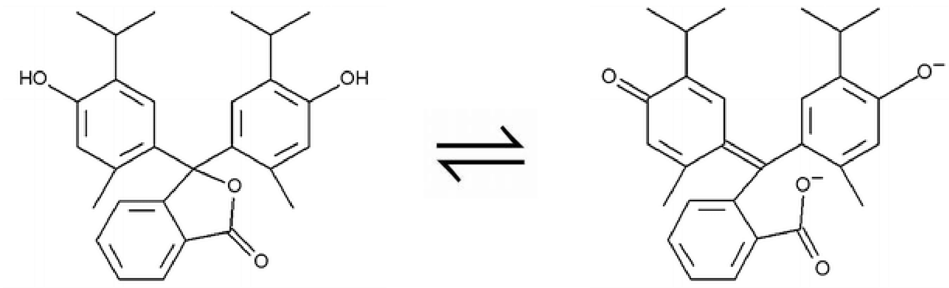
- Phenolphthalein (Sigma Aldrich #105945-100G)



pH: 0 - 8.3
Colorless

pH: 8.3 - 10
Pink/Fuchsia

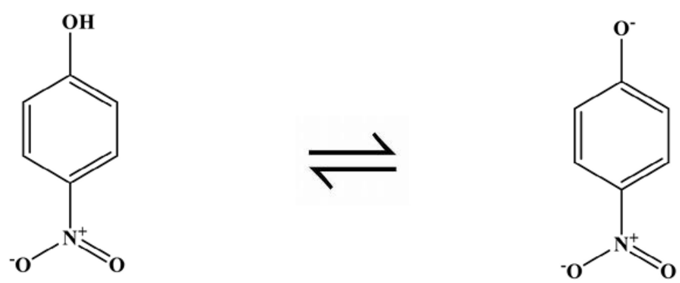
- Thymolphthalein (Sigma Aldrich #114553-50G)



pH: 0 - 9.3 Colorless

pH: > 9.3 **Blue**

- p-Nitrophenol / 4-Nitrophenol (Sigma Aldrich #241326-50G)



pH: 0 - 5.4 Colorless

pH: > 7.5 **Yellow**

- sodium hydroxide (NaOH) pellets (Sigma Aldrich #1.06482)
- sulfuric acid (H_2SO_4) (Sigma Aldrich #258105-1L-PC)
- glycerin/glycerol (Sigma Aldrich G5516-500ML)
- 100% ethanol (Fischer #A962P-4)

*** *Safety note* ****

Concentrated H_2SO_4 and ethanol are both dangerous. Wear gloves and work under a fume hood while preparing solutions. The acid/alcohol solution is flammable. Keep the container closed. Avoid flames or sparks. The acid (glycerin and acid alcohol) and base solutions can cause burns. Wear safety glasses. If you spill these solutions on yourself, wash it off immediately. Always add acid to water (not the opposite). If you add water to acid, you form an extremely concentrated solution of acid initially and the solution may boil very violently, splashing concentrated acid. If you add acid to water, the solution that forms is very dilute and the small amount of heat released is not enough to vaporize and spatter it.

Indicator solutions (final volume = 30 mL each):

- **RED:** 1.5 g phenolphthalein + 3.0 g p-nitrophenol
- **ORANGE:** 0.45 g phenolphthalein + 6.0 g p-nitrophenol
- **YELLOW:** 6.0 g p-nitrophenol
- **GREEN:** 0.6 g thymolphthalein + 6.0 g p-nitrophenol
- **BLUE:** 1.5 g thymolphthalein
- **VIOLET:** 0.9 g phenolphthalein + 0.4 g thymolphthalein

In six different 50 mL glass bottles, mix the above compound mixtures with 30 mL 95% ethanol and label the beakers with the corresponding color. Mix until the compounds dissolve. Note that here ethanol (an organic solvent) is used since the above compounds have poor water solubility.

Acid-alcohol solution (~0.03 M H_2SO_4 in 50% water/50% ethanol; final volume = 2 L):

- Under a fume hood, add 3 mL of concentrated H_2SO_4 to 1 L milliQ (or deionized) water.
- Then add 1 L of 95% ethanol.
- Mix the solution and transfer into one of the 5 L carboys. Label with "Acid-alcohol solution"

H_2SO_4-glycerin solution (~6.2 M H_2SO_4 in glycerin; final volume = 30 mL):

- Under a fume hood, in a 50 mL glass bottle, carefully add 10 mL of concentrated H_2SO_4 to 20 mL of glycerin. Label with "H_2SO_4-glycerin solution"

Base solution (~0.012 M NaOH; final volume = 5 L):

- Add 2.5 g of NaOH to 5 L milliQ (or deionized) water. Mix until dissolved. Transfer into one of the 5 L carboys. Label with "Base solution"

5 L plastic beaker preparation:

- Carefully under a fume hood, add ~25 drops of H_2SO_4-glycerin solution in the center of the 5 L plastic beaker and set it to the side.
- If the indicator solutions dry on the bottom of the beakers, they will appear cloudy. Add a few drops of 95% ethanol if this happens to keep the indicator solutions "invisible" on the bottom.

Demonstration Instructions:

- Label the six 1 L beakers with their respective colors of the rainbow. Carefully, place 2 or 3 drops of indicator solution of that color in the center of each beaker. If you add more than 3 drops, the solutions will be a very dark color, which doesn't look as pretty. Set the beakers on the light background (i.e., white towel or white sheet) in rainbow order (ROYGBV) from left to right (facing you). ***Pause for Q1.***

- Place ~50 mL of acid/alcohol solution in each of the six beakers. Observe that there is no rainbow at beginning. ***Pause for Q2.***

- Pick up the carboy of the base solution. After looking at the base solution pitcher in wonder, pour ~50 mL of solution into each glass. This is not enough to develop the colors, although you might see a quick burst of color. ***Pause for Q3.***

- Starting with red, pour in more base solution in sequence the colors of the rainbow. Into each beaker pour in enough base to develop the color (~150 mL) and display the colored solutions to the audience. If no color appears, pour in more base solution slowly until the color appears. ***Pause for Q4.***

- Present the dropping bottle of H_2SO_4-glycerin to the audience. Add ~2 drops of H_2SO_4-glycerin to each beaker.

- Using a transfer pipette, stir out the colors of the rainbow in sequence. Present the colorless beakers and take a bow. ***Pause for Q5.***

- Pick up the base solution and slowly add more to quickly redevelop the colors in all the beakers, again in rainbow sequence. You will add ~100 mL of base to each beaker.

- Remove the center two beakers (yellow and green) from the array. Replace them with the 5 L plastic beaker. Pour the contents of the beakers into the large glass container, two at a time, pouring the last two (red and violet). ***Pause for Q6.***

- Disposal: The final solution may be disposed of down the drain.

Example of what the results look like (Dr. McShan's demonstration):

Questions:

Q1: At the beginning of the demonstration, are the pH indicators, which are dissolved in the organic solvent ethanol (pH <7), already their respective expected colors or not? Why?

Q2: When the acid-alcohol solution (pH < 5) is added to the pH indicator solution, is the solution initially colored or colorless? Why?

Q3: When a small volume of base solution (pH > 9) is added to the mixture of pH indicator/acid-alcohol, is the solution colored or colorless? Why? Did you see "splashes" of color when the solution is added?

Q4: When a larger volume of base solution is added to the mixture of pH indicator/acid-alcohol/base, does the solution become colored, or does it remain colorless? Why?

Q5: When the H_2SO_4-glycerin solution (pH < 2) is added to the beakers and stirred, what happens to the color? Why?

Q6: When the solutions in the beakers are added to the 5 L plastic beaker, which contains H_2SO_4-glycerin solution, do the colors remain or do they disappear? Why?