DNAZone Classroom Kit

Classroom kits created by Carnegie Mellon University and the University of Pittsburgh
The Center for Nucleic Acids Science and Technology

Kit title	What is the pH? Chemistry of Acids and Bases
Appropriate grade level	Upper high school, AP Chemistry
Abstract	The concept of acids and bases is an important topic in any introductory chemistry course. It is also a crucial part of standardized exams. Because acids and bases are so prevalent in real life applications, learning the concept through hands-on experiments will enhance a student's understanding of these topics and evoke curiosity and interest. The teaching plan of this kit follows the PPP model, which, stands for presentation, practice and production. The included set of activities involves using pH indicators to characterize the acidity of common household items and to gain understanding of the importance of acids and bases in controlling homeostasis in biological systems.
Time	Two 40-minute class periods
PA Department of Education Standards	**Process Standards** **3.4.12 A.** Apply concepts about structure and properties of matter • Characterize and identify important classes of compounds (e.g. acids, bases, salts) **Content Standards** **3.1.12 B.** Apply concepts of models as a method to predict and understand science and technology **3.1.12 C.** Assess and apply patterns in science and technology
Kit adapted from:	A Demonstration of Acid Rain. http://www.ied.edu.hk/apfslt/v5_issue1/fongmw/index.htm#contents (accessed June 29, 2012). Exploring Acids and Bases. http://scifun.chem.wisc.edu/homeexpts/ACIDBASE.html (accessed June 29, 2012). Guare, Linette. The Magic Pitcher. http://www.elmhurst.edu/~chm/demos/MagicPitcher.html. Elmhurst College (accessed November 12, 2014).
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“What is the pH? Chemistry of Acids and Bases” Overview

Educational Objectives

- Students will learn the observable properties of acids, bases and salts.
- Students will learn the definitions of acids and bases according to the Arrhenius and Bronsted-Lowry models.
- Students will be able to identify acids and bases using pH indicators.
- Students will be able to relate the concepts learned to real life applications.

Teacher Preparation Time

Approximately 1 hour 10 minutes:

- Prepare cabbage juice the day before the activity (30 minutes)
- Go over the skit for the magic pitcher and prepare (30 minutes)
- Get the magic pitcher ready for demonstration before class (10 minutes)
- Review the teacher kit and the background information

Class Time

Two 40-minute class periods

1st period: 5 minutes to put the class into groups of four and have each group guess the topic
20 minutes to go over the presentation.
15 minutes to go over the magic pitcher demonstration.
(Total: 40 minutes in the first period)

2nd period: 5 minutes for warm up (post-it note activity)
20 minutes for pH determination of household products with red cabbage
5 minutes for denaturation of milk activity
15 minutes for acid rain activity
(Total: 40 minutes in the second period)

Materials Needed

- Electronic or printed copies of student worksheets from this document (labeled Student Page)
- Cabbage juice (<u>not included in the kit</u>---must be prepared by the teacher the day before the activity)
- Distilled water (not included in kit)
- One teacher kit:
    - plastic pitcher
    - dropper bottle of phenolphthalein
    - pH paper
    - Post-it notes
    - lighter
    - box of matches
    - blue tack
    - dropper bottle of methyl orange indicator
    - 2 large glasses
    - 2 watch glasses

    - dropper bottle of universal indicator
    - 4 small glasses
    - 100 mL bottle of saturated baking soda solution
    - large (14-16 fl. oz.) bottles of:
        - milk of magnesia
        - isopropyl alcohol
        - vinegar
        - lemon juice
        - household ammonia

- Twelve student kits:
    - 10 clear plastic cups
    - 2 plastic disposable pipettes
    - Permanent marker
    - 3 small (20 mL) glass vials with cap
    - small (20 mL) glass vials or dropper bottles of:
        - vinegar,
        - lemon juice
        - milk of magnesia
        - isopropyl alcohol
        - saturated baking soda solution
        - distilled water

Prior Knowledge of Student

- Chemical reactions (formulas for basic chemical compounds)
- Molarity and concentration

Part I: Introduction to Acids and Bases

Educational Objectives:

- Know the general definition of acids and bases
- Differentiate between Arrhenius and Bronsted-Lowry acids and bases
- Calculate the pH mathematically and by indicators
- Understand the importance of acids and bases for real life applications

Background Information:

1. General Definition of Acids and Bases
   a. Acids:
      i. Function as strong/weak electrolytes in aqueous solution
      ii. Have a sour taste
      iii. Change color of litmus from blue to red
      iv. React with certain metals to produce gaseous H_2
      v. React with bases to form water and a salt
      vi. May be corrosive

   b. Bases:
      i. Function as strong/weak electrolytes in aqueous solution
      ii. Have a bitter taste
      iii. Change color of litmus from red to blue
      iv. Are slippery to the touch
      v. React with acids to produce salts

2. Difference between Arrhenius, Bronsted-Lowry, and Lewis definitions of acids and bases
   a. Arrhenius defintion:
      i. An acid gives off hydrogen ions (H^+) in solution, while a base gives off hydroxide (OH^-) in solution.
   b. Bronsted-Lowry defintion:
      i. An acid donates protons (hydrogen ions – H^+), while a base accepts protons.
   c. Lewis defintion:
      i. An acid accepts electron pairs, while a base donates electron pairs – this definition is not covered in this lecture.

3. pH
   i. pH stands for "power of Hydrogen."
   ii. The pH is a measure of the concentration of hydrogen ions. pOH, which is less frequently used, measured the concentration of hydroxide.
   iii. $\mathbf{pH = -log_{10}[H^+]}$ and $\mathbf{[H^+] = 10^{-pH}}$, where $[H^+]$ is the molarity of hydrogen ions in the solution.
   iv. In neutral water, $[H^+] = [OH^-] = 10^{-7}$ moles/L, so the pH is **7** for a neutral solution.
   v. $[H^+]x[OH^-] = 10^{-14}$ always, so if $[H^+]$ increases, $[OH^-]$ must go down, and if $[OH^-]$ increases, $[H^+]$ must go down.

vi. In acidic solutions, the concentration of hydrogen ions is higher than the concentration of hydroxide, so the pH is lowered.
vii. In basic solutions, the concentrations of hydrogen ions is lower than the concentration of hydroxide, so the pH is increased.

4. Indicators:
   i. Indicators give an estimate of pH by changing color over a certain pH range.
   ii. Different indicators are available for different pH ranges
   iii. Litmus paper: changes to red in acids and to blue in bases
   iv. Methyl orange: changes from yellow to orange in acidic solutions
   v. Phenolphthalein: changes from colorless to pink in basic solutions
   vi. Red cabbage juice: changes from purple to a variety of colors depending on pH
   vii. Universal indicator: changes to the different colors of the rainbow over a wide pH range

Day 1: Teaching and Learning Activities- Introduction to Acids and Bases

Procedure	Teaching-Learning Activities	Time (min)	Materials& Tips
Introduction Motivation	Divide the class into groups of four **Teacher:** "Hello class! In your groups of four, look at this slide and see if you can guess the topic of today's lesson. I will give you one minute to come up with an answer." (Ask each group their guesses)	5	• PowerPoint • Projector
Lecture	**Teacher:** "Group ___ got it right. Today's topic is acids and bases, which is a very important part in chemistry and definitely shows up on the AP chemistry and SAT II chemistry exams. Even if you are not interested in those, as you saw on the slide, acid-base chemistry is so prevalent in everyday life that it is good to know how to distinguish and characterize acids and bases, and why they're important. If you pay attention, you may be able to figure out the magic trick that I'll show you later today." (Go through the Power Point slides and make sure the students know how to calculate the pH and $[H^+]$)	20	Power Point

Demonstration 1: Magic Pitcher (20 minutes)

Reference: http://www.elmhurst.edu/~chm/demos/MagicPitcher.html

Materials:

- Magic pitcher observation worksheets (to be handed out before demonstration)
  - Page 8 of this kit
- Clear plastic pitcher
- Water (tap or distilled)
- Phenolphthalein indicator
- Vinegar
- Saturated baking soda solution
- 4 clear plastic or glass cups:
  Cup A – leave empty
  Cup B – 5 drops of baking soda solution
  Cup C – 10 drops of vinegar solution
  Cup D – 15 drops of baking soda solution

Preparation:

Before class, fill the pitcher with water to the 1L line and add approximately 50 drops of phenolphthalein indicator. Up to 100 drops can be added to get a strong pink color. The solution in the pitcher should then be brought to the point that adding just 1-2 drops of baking soda solution turns the entire solution bright pink. You may have to adjust it, especially if using tap water, by adding either drops of vinegar or baking soda solution to get the solution to this point.

Essentially, this activity involves adding drops of baking soda solution until the solution in the pitcher just turns pink, then adding 1-2 drops of the vinegar to bring it back to colorless. Before class, with no one watching you, dry out the cups, and then add drops of solution to the bottoms so when viewed from the side they are not noticeable:
nothing to cup A, 10 drops of baking soda solution to cup B, 20 drops vinegar solution to beaker C, and 30 drops baking soda solution to cup D.

(Hand out the observation worksheet; explain to them to fill out the worksheet and write down the observations and answer the question at the end of the demonstration)

The following is a skit script that can be followed for the magic pitcher demonstration. If you'd like to perform the demonstration in a different way, the basic steps are:
- Pour approx. 200 mL from pitcher into cup A – should be colorless.
- Pour approx. 200 mL from pitcher into cup B – should turn dark pink.
- Pour cups A and B back into the pitcher – should turn pitcher pink.
- Pour 200 mL from pitcher into cup A and cup B – should remain pink.
- Pour 200 mL from pitcher into cup C – should turn colorless.
- Pour cups A, B, and C back into the pitcher – should turn pitcher colorless.
- Pour 200 mL from pitcher into cups A, B, and C – should be colorless.
- Pour 200 mL from pitcher into cup D – should turn dark pink.

Teacher:
"So I don't know whether you knew this about me before but back when I was in high school I used to wait tables at a restaurant for some extra cash. We didn't have a lot on the menu, very basic things like burgers, pizza, fries and such and had even more limited beverage options; just water and watermelon Kool-Aid.

Even with these limited choices, it seemed I was always in need of a third hand: one to carry a pitcher of water, one to carry a pitcher of Kool-Aid and one to carry the pen and pad to take orders. One day, in the chemistry lab, I came up with an ingenious way to solve my problems. I invented my very own magic pitcher [hold it up proudly], capable of pouring out either water or watermelon Kool-Aid on command. It was very popular with the customers and all the waiters were jealous. They begged me to let them borrow it, but I told them that if they did not have a strong foundation in chemistry, the pitcher would not work for them.

The pitcher came in especially handy one day when I had an unusually fickle group of four gentlemen sit at one of my tables. I remember it quite well…

The first asked for water. No problem, I told the pitcher water, and out came his water [pour about 200 mL from the pitcher into cup A; it should be colorless].

The second asked for Kool-Aid. No problem, I told the pitcher Kool-Aid and out came his Kool-Aid [pour about 200 mL from the pitcher into cup B; it should turn dark pink as it hits the cup].

Well, the first guy tried his water, said it tasted funny, and wanted to change his to Kool-aid too. No problem, I took back his water [pour beaker A back into the pitcher], and took back the second guy's Kool-aid [pour cup B back into the pitcher], and then I poured them both out the Kool-aid they wanted, [pour out pink Kool-aid into cups A and B].

Well, you all know what the third guy wanted: that's right, water. So I told the pitcher water, and out came his water [pour about 200 mL from the pitcher into cup C; it should turn colorless – most impressive!]

Well, wouldn't you know it: now the first two guys said they thought that water looked mighty fine, and asked if I wouldn't mind changing theirs back to water. By then I was getting a little frustrated, but I was trying not to show it. So I took back their two Kool-Aids [pour cup A and B back into the pitcher], and of course I had to take back the third guy's water [pour beaker C back into the pitcher], then I poured all three out the water they wanted [pour out colorless water into beakers A, B, and C].

And what do you suppose the fourth guy wanted? You got it: Kool-Aid. So I told the pitcher Kool-Aid, and out it came [pour about 200 mL from the pitcher into cup D; it should turn dark pink.]"

Name____________________________

Date____________________________

Magic Pitcher Demonstration Worksheet

Student Page

1. Write down your observations of what happened during the magic pitcher demonstration.

2. What do you think might be causing the color changes?

3. Based on your observations, propose a hypothesis that explains the color changes that took place.

Part II: Review and pH Activities

Reference: http://scifun.chem.wisc.edu/homeexpts/ACIDBASE.html

Purpose

The purpose of the second period of acid and bases demonstration is to review the concepts learned in the first period and to apply those concepts in real life applications. There is a hands-on experiment on measuring the pH of common household goods, and there is a demonstration on acid rain that shows the importance of pH in environmental systems.

Background

In nature, there are many organisms that are very sensitive to pH, and some will change color dramatically in response to varying pH. Hydrangeas are one of several flowers that are sensitive to pH, and will change color to pink or purple depending on the acidity of the soil.

Figure 1. Hydrangeas with different colors

Red cabbage juice exhibits similar properties. Red cabbage contains an anthocyanin pigment called flavin that is highly sensitive to pH changes. The juice will be purple in neutral pH, red-pink in acidic pH, and green, blue or even yellow in the basic pH range. Cabbage juice will, however, turn colorless in very basic solutions as the flavin will break down.

In this activity, the instructor will have the red cabbage juice already prepared, and the students will use the juice to measure the pH of common household goods. Several household goods are included in the activity kit, and the instructor may optionally hand out additional household goods for testing, or ask students to bring in their own. Clear, colorless liquids or solutions are ideal, but light coloration should not be an issue.

Preparing the red cabbage juice indicator:

(This is done the night before the lecture)

Materials:

- Red cabbage, water, stove, pot

Procedure:

1. Take off the cabbage leaves by whole or cut them into slices (see next page).
2. Bring water to boil
3. Boil cabbage leaves for at least 30 minutes
4. Cool to room temperature and store in a container for the next class. Cabbage juice indicator should stay usable for at least two days after preparation if refrigerated, but effectiveness will decrease after this.

			
Figure 2. Red cabbage	Figure 3. Take off the cabbage leaves by whole	Figure 4. Boil cabbage leaves for at least 30 minutes and	Figure 5. Cool and strain the deep purple juice

Day 2: Teaching and Learning Activities- Review and pH Activities

Procedure	Teaching-Learning Activities & Tips	Time (min)	Materials
Introduction Review	Warm up (Before class starts, make a table for acids and bases on the blackboard) Hand out the post-it notes from the Teacher kit as students walk into the class Teacher: You have five minutes to determine whether the post-it note you got today is a characteristic of a base or an acid. Please put your post-it notes on the respective columns on the blackboard	5	Post-it notes
Practice Production	pH determination of Household Products Cabbage juice activity (Partner Activity) To reduce activity time: instead of having students label cups, label the cups for each household good for each group before class – then the teacher can dispense the each household items in the cups while the students are doing the warm up activity. After they're done with the warm up activity, have one person from each group come up to get all the materials -Explain background on the cabbage juice and the students can work on the activity by themselves afterwards following their worksheet	20	Student Kits Worksheet Drinking cups from Teacher's kit
Practice Production	Acid Rain Activity -Explain the background on Acid Rain -Students can follow the activity with their worksheets	20	Student Kit Worksheet Lighter(in Teacher's kit)

Name______________________
Date_______________________

Finding the pH of Common Household Goods by Cabbage Juice Indicator

Student Page

Materials:

- One plastic cup for each product to be tested, with one cup labeled for each product
- Container for cabbage juice – large beaker or Erlenmeyer flask
- Cabbage juice – approximately 5 mL for each product to be tested
- Disposable pipette for cabbage juice

WARNING: ⚠

- Cabbage juice indicator **<u>will stain clothes</u>**. Use caution when handling this indicator.
- Use caution when handling the household goods, as some can be dangerous, particularly ammonia and strong cleaning agents such as Drano.

Instructions:

1. Take your labeled plastic cups to the teacher and have them filled with the household good samples
2. In the data table, indicate your prediction for each of the household goods
3. Using the disposable pipette, add one pipetteful of cabbage juice to each sample cup.
4. Note the color change that occurs for each material and measure its pH according to the pH scale indicator below. Record in the data table.
5. Align the household items from most acidic to least acidic
6. Compare your ordering to the orders other groups have figured out to make sure your pH determination is accurate. If any part of your ordering disagrees with another group's ordering, retest the products on which you disagree using new product samples.

Student Page

pH of Common Household Products- Data Table

Household Product	**Prediction (Acid, Base, or Neutral)**	*Initial color of product*	*Initial color of indicator*	*Final color of indicator*	**Estimated pH Values**	**Acid**	**Base**	**Neutral**
1. Vinegar								
2. Water								
3. Lemon Juice								
4. Baking Soda								
5. Isopropyl Alcohol								
6. Ammonia								
7. Milk of Magnesia								
8.								
9.								
10.								
11.								
12.								
13.								

Student Page

Homework:
Fill one of the empty glass vials with some of the remaining red cabbage juice indicator. Take it home, test two other household products, and record your observations in the data table. Use the cabbage indicator today if possible, or tomorrow otherwise. You may not get any results if you wait longer than this.

Questions

1. Slowly add the vinegar to the baking soda cup. Write down your observation below. Why do you think this occurs? Write the chemical reaction that takes place.

2. List the products that you tested from the most acidic to the least acidic.

3. Does the data page indicate that most foods are basic or acidic? Provide a possible explanation for this phenomenon.

4. Does the data page indicate that most cleaning supplies are basic or acidic? Provide a possible explanation for this phenomenon.

5. In living things, pH is maintained within a narrow range. Why is pH important in maintaining homeostasis?

6. Write at least 1 paragraph to explain how your results support or reject your hypothesis.

7. a. Did your results disagree with any other group's results? If so, provide a possible explanation for why this might have happened.

   b. If your results disagreed with another group's, did the results agree when you retested the products on which you disagreed? If not, provide a possible explanation for what might be happening.

Activity 2: Acid Rain

Reference: http://www.ied.edu.hk/apfslt/v5_issue1/fongmw/fongmw3.htm#three

Purpose: This activity is intended to demonstrate the importance of acids and bases in real life applications. Through this experiment, the student will learn how acid rain develops both as an environmental process and in chemical terms.

Background: The gases carbon dioxide and sulfur dioxide can both dissolve in water to form acidic compounds, lowering the pH of the water. Carbon dioxide is naturally present in the atmosphere, and dissolves in rainwater, giving most rain a slightly acidic pH of about 5.6. Rain with a pH below this level is called "acid rain."

Sulfur dioxide, however, is much more soluble in water than carbon dioxide, and lowers the pH of rain much further. Since sulfur dioxide is produced from the combustion of many fossil fuels, including coal, oil, and gasoline, the concentration of sulfur dioxide in the air has increased greatly since the Industrial Revolution, which has resulted in acid rain becoming prevalent in many areas – in some industrial areas, rain with a pH as low as 2.4 has been reported.

Acid rain is a serious issue with a number of adverse effects. Humans do not have acute reactions to acid rain, but prolonged contact will contribute to heart and lung problems including asthma and bronchitis. Acid rain can also be very toxic to plants and aquatic life – prolonged periods of acid rain can result in the formation of "dead lakes," in which much of the aquatic life has died off. Acid rain also corrodes metals, particularly bronze, iron, and steel, and other building materials, including marble, which results in the defacement of statues and gravestones.

Figure 6. Trees Killed by Acid Rain

Figure 7.Since 1998, Harvard University has wrapped some of the bronze and marble statues on its campus with waterproof covers every winter to protect them from acid rain.

Reference for the figures:
http://en.wikipedia.org/wiki/Acid_rain#History_of_acid_rain_in_the_United_States

Acid Rain Activity

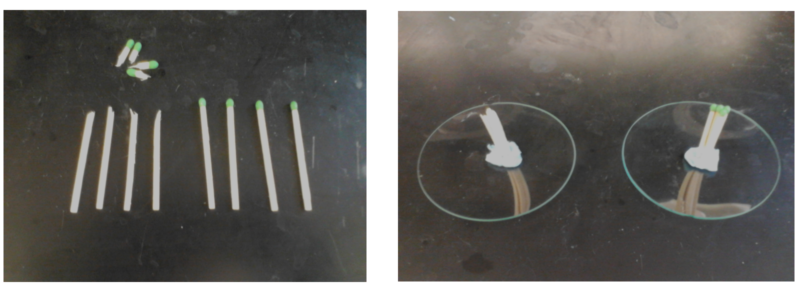
Materials:

- 2 glass cups
- 2 watch glasses
- Matches
- Blue tack
- Methyl orange indicator

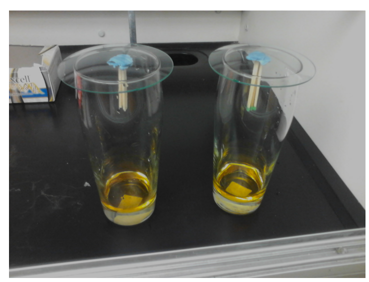
Instructions:

1. Add 10mL of water to each glass.
2. Add 5 drops of indicator to each glass.
3. Stick four wooden matches closely together to a watch glass with blue tack as shown below.
4. Scrape or break the heads off of four other matches, and stick them to a watch glass in the same manner.
5. Hold the watch glass up with the matches hanging down to ensure that they're firmly attached.
6. Place the watch glass over the glass with the matches pointing down, as shown.
7. Use the long lighter to light the matches as shown, removing the lighter as quickly as possible.
8. Let the matches burn out with the watch glass in place, as shown.
9. Write down your observations and answer the following questions.

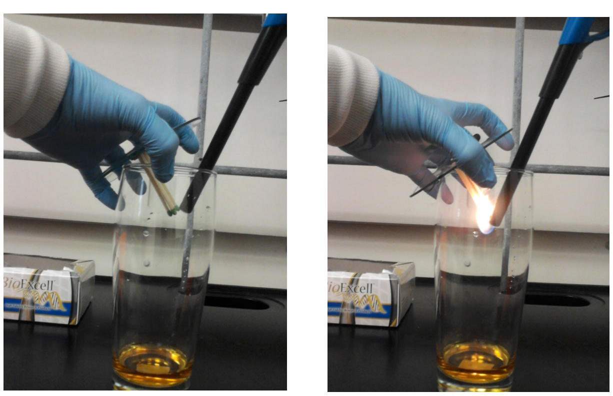
Experimental Setup



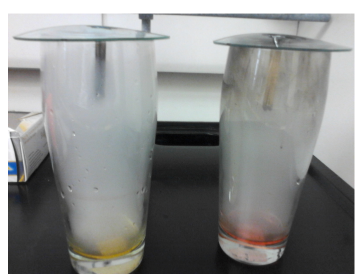
Steps 3 and 4: Breaking and attaching matches.



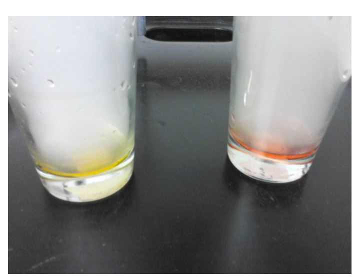
Step 6: Assembly.



Step 7: Lighting matches.



Step 8: Matches burning.



Step 9: Color change visible.

Acid Rain Activity Questions and Discussion

Student Page

1. Methyl red indicator's pH range is 3.2-4.4. It will have a yellow color when the pH is above 4.4 and will turn red when the pH is below 3.2. What color change did you observe in this experiment?

2. What acid caused this color change?

3. Where did this acid come from?

Hint:
The head of the match is composed of sulfur and potassium chlorate (V). As you light the match, sulfur dioxide is produced as a result of oxidation of sulfur, which is shown in the following reaction.

$$3S(s) + 2KClO_3(s) \text{ -----> } 3SO_2(g) + 2KCl(s)$$

	Sulfur dioxide	Carbon dioxide
Henry's Law Constant	1.2 $molL^{-1}atm^{-1}$	3.38×10^{-2} $molL^{-1}atm^{-1}$
Acid Dissociation Constant	1.7×10^{-2}	4.45×10^{-7}

This data illustrates that sulfur dioxide is significantly more soluble in water than carbon dioxide.