pH

Fall 2007

GOAL To introduce students to acids, bases and the pH scale.
Fits Metro Davidson County Science Academic Standards for 5th and 8th grades.
Text reference – none.

LESSON OUTLINE

I. Introductory Demonstration, Mystery Liquids.
Use litmus paper to test three "mystery" liquids, and note colors. Then add red cabbage juice to the "mystery" li

II. Discussion of Acids and Bases.
Some general properties of acids and bases are discussed.

III. Explanation of the pH Scale.
Write the letters pH on the board, and give brief explanation. Give each group one of the laminated pH charts and an instruction sheet. Point out the acid, neutral and base regions.

IV. Construction of a pH Scale Using Known pH Solutions.

A. Demonstration of pH = 1 and pH = 14.
Mention that students will be using red cabbage juice as an indicator. Demonstrate the color changes for pH=1 and pH=14 by adding some cabbage juice to some pH = 1 and pH=14 solutions.

B. Color Changes for Known pH Solutions Using Red Cabbage Juice.
One person from the VSVS team should put the Known pH Solution Chart on the board while students observe colors for 12 known pH solutions when red cabbage juice is added. An answer key is given that lists the colors the students should observe.

V. Testing the pH of Household Items.
One person from the VSVS team should put the Household Items Chart on the board. Students test several household items with cabbage juice and record the colors they observe. Each group matches these colors with their known solutions and records the pH for the known solution that gives the best match.

VI. Analyzing Introductory Demonstration.
Ask students if they can identify the liquids in the glasses from Demonstration I as acids, bases, or neutrals based on the colors.

VII. Demonstration, Magic Foam.
The demonstration uses milk of magnesia, red cabbage juice, pH Down (sodium bisulfate), and pH Up (sodium carbonate). Follow the directions carefully. The first step involves putting the milk of magnesia in the cut-off bottle, followed by the bottle of red cabbage juice. This produces a green color. Adding pH Down solution causes the color to eventually turn red. Adding pH Up solid produces a foam (carbon dioxide gas) and a rainbow of different colors as the pH in different regions of the foam changes.

VIII. Review.
Discuss review questions in the context of vocabulary words.

MATERIALS

1 plastic bottle with the top cut off (Magic Foam)
1 clear plastic container with a ziploc bag containing: (Magic Foam)
  1 large (8-oz) bottle of red cabbage juice (right dilution for Magic Foam)
  chemicals - milk of magnesia, solution of sodium bisulfate, sodium carbonate solid
  1 plastic spoon
2 4 –oz bottles of red cabbage juice (Parts I, IV)
6 10 oz. clear plastic glasses (4 for introduction - Magic Liquids, two for Step IV demonstration)
1 4 oz. bottle white vinegar - labeled V (for introduction - Mystery Liquids)
1 4 oz. bottle of water - labeled W (for introduction - Mystery Liquids)
1 4 oz. bottle of water with 1/4 tsp. baking soda mixed in - labeled B (Mystery Liquids)
3 strips of red litmus paper (for introduction - Mystery Liquids)
3 strips of blue litmus paper (for introduction - Mystery Liquids)
16 dropper bottles of red cabbage juice (2 per group)
8 24 well trays
8 plastic bags containing
  12 dropper bottles with pH solutions 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13
8 plastic bags containing
  4 dropper bottles with Milk of Magnesia suspension, Sprite,tap water, and vinegar
  2 wide mouth bottles with baking soda solid and laundry detergent solid
  2 scoops
1 4 oz. bottle of pH = 1 for demonstration in Step IVA
1 4 oz. bottle of pH = 14 for demonstration in Step IVA
32 pH observation sheets
16 pH charts in page protectors
32 Instruction Sheets (in sheet protectors)

Give each student one of the Observation Sheets before doing the Mystery Liquids demonstration, and ask them to record their observations.

While one team member does the Mystery Liquids demonstration, another team member should write the following vocabulary words on the board:

litmus paper	**pH**
neutral	**indicator**
acids	**vinegar**
bases	**baking soda**

I. INTRODUCTION DEMONSTRATION – Mystery Liquids

This demonstration is designed to capture student interest and make students curious about the color changes they observe. As the lesson progresses they will see how color change can be useful to scientists. At the end of today's lesson, return to these demonstrations to see if the students can identify acids and bases by the color changes and if they can identify the liquids used in the demonstration.

Materials

1 small (4-oz) bottle of red cabbage juice
4 10 oz. clear-plastic glasses
1 4 oz. bottle of vinegar - labeled V
1 4 oz. bottle of water - labeled W
1 4 oz. bottle of water with 1/4 tsp. of baking soda - labeled B

3 strips red litmus paper
3 strips blue litmus paper

- Have 2 VSVS volunteers hold the 4 clear plastic glasses up so students can see them.
- Tell the students that you have some mystery liquids.
- Pour the contents of the bottle labeled V into the first glass.
- Pour the contents of the bottle labeled W into the second glass.
- Pour the contents of the bottle labeled B into the third glass.
- Pour all of the cabbage juice into the fourth glass.
- Have a student describe the four liquids they see.

Note: Students should not be close enough to smell the liquids. Describe liquids based on visual cues only. Students may assume that all three glasses contain water. At this point that is an appropriate assumption based on visual cues alone. Since the liquids were in different containers, the students may think that the liquids are different.

Ask students if they have ever heard of litmus paper. If so, what is it used for?
Litmus paper is used to test whether something is acidic or basic.

Test each glass of clear liquid by dipping first the red and then the blue litmus paper into the liquid and
noting what changes, if any, occur.
•Ask students to record the changes on their observation sheets.
Then, one at a time, hold each glass of clear liquid up for the students to observe as you pour cabbage juice into each of the liquids until the color is strong enough for students to see.
•Ask students to record the color changes.
Note: Do not identify the liquids at this point. The vinegar should turn pink or red; the water should dilute the cabbage juice to a lighter shade of purple; and the baking soda water should turn blue-green.

Explain to students: In this experiment, the liquids turned different colors because one is an **acid**, one is a **base**, and one is a **neutral** (neither an acid nor a base). The cabbage juice was the **indicator** used to cause this color change. **Indicators** are substances that change colors when mixed with an acid or base. Indicators are a safe way to help scientists identify whether a substance is an acid or a base. Litmus paper is an indicator which can also identify whether a substance is an acid or a base.

Do not identify the liquids in the glasses at this time. Set the glasses aside. Tell the students that you will see if they can tell you what was in each of the glasses after they do the experiments in today's lesson.

II. DISCUSSION OF ACIDS AND BASES

Ask: *What do you know about acids?*
(You might ask students to name some acids.)
Responses may include references to battery acid, acid indigestion, stomach acid, acid rain, citrus acid, and chemicals in a lab.
Ask: *What do you know about bases?*
(You might ask students to name some bases.)
Most students know less about bases than acids. The most common response here is a

reference to bases in softball or baseball. Accept that response if it is given and tell students, “Yes, that is one kind of base, but not the one we are going to focus on today.”

EXPLAIN ACIDS AND BASES USING SOME OF THE FOLLOWING INFORMATION:

(Note:Select the information that is appropriate for the class you are teaching. Try to keep the information on a level that the students can understand. Feel free to add other appropriate information. Keep this discussion brief.)

ACIDS and BASES are two important classes of compounds.

ACIDS

Weak acids like the natural acids in food give foods a sour, sharp flavor (like lemons).
Strong acids can burn your skin.
Many acids are corrosive. They eat away metals and other substances.
Some acids can be helpful. The acid in your stomach aids in digestion.
Two acids (sulfuric acid and nitric acid) cause damage in acid rain.
An acid releases hydrogen ions (H^+) in water.
Acids can neutralize bases.

BASES

Bases taste bitter and feel slippery.
Weak bases are used to settle upset stomachs.
Detergents and many cleaning solutions are basic.
Strong bases can burn the skin.
A base releases hydroxide ions (OH^-) in water.
Bases can neutralize acids.

III. EXPLANATION OF THE pH SCALE

Ask: *How can scientists tell which solutions are more acidic or basic than other solutions?*
(Based on the first experiment, some students may be able to reason that scientists could use different shades of color to tell how acidic or basic a solution is.)

EXPLAIN the pH SCALE USING THE FOLLOWING INFORMATION:

Refer to the letters pH on the board.

Scientists developed a way to measure the acidity or basicity when small amounts of acids or bases are present in water. This is called the pH scale. The pH scale ranges from 0 to 14 and was designed to measure acidity or basicity of weak solutions of acids and bases. Students will be testing several common chemicals found in the home that are examples of solutions or solids that have pH values within this range.

For VSVS team information: In 1909, the Danish biochemist S.P.L. Sorenson devised a scale that would be useful in his work of testing the acidity of Danish beer. This scale became known as the pH scale from the French *pouvoir hydrogene*, which means hydrogen power.

MATERIALS : **16 laminated pH Scale charts**

Give a laminated pH chart to each group and use your copy to briefly point to acid, neutral, and base regions on the chart as you explain the pH scale (acids 0-6, neutrals 7, bases 8-14).

On the pH scale, 0 is the most acidic solution and 14 is the most basic solution. More concentrated solutions of acids and bases exist that go beyond either end of this scale.

<u>**Note for VSVS information only:**</u> **A pH of 0 is a dilute solution of a strong acid such as 1M hydrochloric acid. A pH of 14 is a dilute solution of a strong base such as 1M sodium hydroxide.**

Like the Richter scale used to measure the extent of ground movement in earthquakes, the pH scale isa logarithmic scale. This means that a substance at pH 6 is ten times more acidic than a substance of pH 7, a substance at pH 5 is one hundred times more acidic than a substance of pH 7 and so on.

Note: The important concept at this grade level is to understand the 0-14 scale that identifies which substances are acids and bases. It is not necessary to spend lots of time explaining the logarithmic aspect of the scale.

IV. CONSTRUCTION of a pH SCALE USING SOLUTIONS OF KNOWN pH

Explain that they will be using solutions of known pH to construct a colorful pH scale. It is very important that the solutions are not mixed or contaminated. If this happens, the pH of the solution could no longer be used as a reference.

Scientists use a variety of chemicals to determine the pH of substances. These chemicals are called indicators. In this lesson, we will use red cabbage dye as an indicator. Each numbered solution on the pH scale will turn a different color and these colors will be used later in the lesson to determine whether household items are acids or bases.

<u>Organize the class into 8 groups of 3-4 students. Give each student one of the instruction sheets. A VSVS team member will still need to give instructions, but the students can refer back to the instruction sheet as they are doing the experiments. You will still need to guide them through the procedures, making sure they understand the instructions.</u>

A. Demonstration of pH = 1 and pH = 14

Materials: **2 10 oz. glasses**
1 4 oz. bottle of pH = 1
1 4 oz. bottle of pH = 14
1 small (4 –oz) container of red cabbage juice

- Add the 4 oz bottle of pH = 1 solution to a 10 oz. glass.
- Add <u>**half**</u> of the cabbage juice. (Note: color should be red).
- Ask students to check the pH chart to see what solution in their body has a pH of 1 (stomach acid).
- Explain that the acidic solution in their stomach helps to break down the food they eat into forms their body can use during the process of digestion.

- Add the 4 oz bottle of pH = 14 solution to the other10 oz. glass.
- Add <u>**the rest**</u> of the cabbage juice. (Note: color should be green at first and then change to yellow).
- Ask students to check the pH chart to see what solution has a pH of 14 (lye).

B. Color Changes for Known pH Solutions Using Red Cabbage Juice

Materials

8 sets of dropper bottles with known pH solutions 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13
16 dropper bottles of cabbage juice (2 per group)
8 24-well plates
32 pH observation sheets

•Organize the class into groups of four.
•Distribute the following materials to each group.
1 well plate, 2 dropper bottles of cabbage juice, 1 set of dropper bottles with known pH solutions, 4 pH observation sheets (or 1 per student).

- Tell students in each group to remove the pH solution dropper bottles from the bag and line them up in numerical order (2-13).
- Tell the students to place the well plate beside the Instruction sheet. The template on the bottom of the Instruction sheet tells which pH standard or household item should be added to which well.
- Demonstrate how to squeeze the bottle to add several squirts of cabbage juice into the well. (The well should be about 1/2 full.) DO NOT FILL THE WELLS.

Hint: For better classroom management, assign numbers (1-4) [or letters A-D] to each group member. Tell all the students who are #1 to add the cabbage juice to 12 wells. Student #2 can add the pH standards to the cabbage juice. Students #3 and #4 will test the household items in the next section of the lesson.

- Tell student #1 to add several squirts of cabbage juice to the first (TOP) 6 wells in one of the well-plates and then the BOTTOM 6 wells, until the wells are about 1/2 full.
- Tell student # 2 to add a squirt of solution pH 2 into the first well. Remind students that The dropper bottle should not touch the cabbage solution, since this would cause contamination. Tell all the students to record the color change on their observation sheets. Tell student # 2 to continue adding the pH solutions to the wells in the order on the diagram, and for all students to record each color change as it occurs. Make sure that the red caps are placed back on top of each dropper bottle after it is used.
- Put the Known pH Solutions chart on the board (without colors filled in). Have students report their findings to the VSVS student who is completing the chart on the board. (Accept other color names as long as they are similar to those on the chart.

Known pH Solutions - Answer Sheet

pH Number	Color (after cabbage juice is added)
1	red
3	reddish-pink
4	pale pink
5	pinkish-lavender
6	purple
7	light purple
8	blue (blue-green)
9	gray
10	green
11	light green
12	greenish-yellow
13	yellow

14	yellow

The students now have a pH scale to use as a reference guide in determining the pH of household items.

Ask students, *"When red cabbage juice is used as the indicator, what color do the acid solutions turn?"* (shades of pink or red).

Ask students, *"When red cabbage juice is used as the indicator, what color do the base solutions turn?* (shades of blue or green, except #9 turns grey and #13 and 14 which turn yellow.)

V. TESTING THE pH OF HOUSEHOLD ITEMS

Materials per group: 1 bag containing 1 bottle each of

Milk of Magnesia suspension	**laundry detergent solid**
Sprite	**tap water**
baking soda solid	**vinegar**

- Tell students that they will test several household items to determine if they are acids, bases, or neutrals.
- Put the Testing Household Items chart on the board (<u>not the answers</u> - leave 2nd and 3rd column blank)

Testing Household Items - Answer Sheet

Item	Actual Color Change	Result of Test
	(pink, red, purple, blue, green)	(acid, base, neutral, and closest pH #)
1 baking soda solid	Answer: blue	Answer: base, 8
2 Milk of Magnesia	Answer: green	Answer: base, 12
3 Sprite	Answer: pinkish lavender	Answer: acid, 4
4 tap water	Answer: purple	Answer: neutral, 7
5 vinegar	Answer: red or pink	Answer: acid, 3
6. Laundry detergent solid	Answer: green	Answer: base, 10

- Tell student #3 to add several squirts of cabbage juice to 6 of the wells in the 2nd row of the well plate.
- Tell student #4 to add either a squirt of the liquid household chemical, or a small scoop of solid.
- Students should look at the color changes on the observation sheet, compare the color of the household solution with the known pH solutions and the laminated pH color chart and decide on a pH value based on the closest match. Then they should record the pH for the known solution that most closely matches the household solution.

VI. ANALYZING INTRODUCTORY DEMONSTRATION

Get the three glasses of mystery liquids from the introductory demonstration I.

•Ask students to use their observations from today's experiment to determine (1) whether the liquids are acid, base, or neutral, and (2) what they think the liquids are. Have them record their

predictions in the right column of the table at the top of the observation sheet
After they have finished their predictions, go over the observation chart from Demonstration I with them.

VII. DEMONSTRATION - Magic Foam

Materials

- **1 tall plastic bottle with the top cut off**
- **1 clear plastic container (to catch overflow)**
- **1 ziploc bag with containers of red cabbage juice, milk of magnesia, pH Up solid, pH Down solution and one plastic spoon**

Note: pH Down = sodium hydrogen sulfate, $NaHSO_4$, also known as sodium bisulfate
pH Up = sodium carbonate, Na_2CO_3

• Tell students to use their best powers of observation as they watch this demonstration.
• Place the cut-off bottle in the center of the clear plastic container.
• Pour **<u>all</u>** of 8-oz container of red cabbage juice from the ziploc bag into the tall bottle so that the bottle is about 1/3 full.
• Have another VSVS volunteer carefully hold the plastic container with the bottle in front of the class so all students can see the experiment as the chemicals are added.

NOTE: Be sure to hold the container with the bottle level since foam will come over the top of the bottle at various times during the demonstration.

• Shake up the milk of magnesia and add the contents to the cabbage juice. Slowly swirl the bottle.

Ask students what color the cabbage juice is now. (green)

Add all of the pH Down solution (sodium hydrogen sulfate) and swirl. Be sure students note The color change. (changes to red)

BE PREPARED FOR FOAMING (and awe from audience) IN THE NEXT STEP!

• Add two plastic spoonfuls of the pH Up solid (sodium carbonate). The foam will form quickly and reach the top of the bottle and probably overflow a little. The solution will change colors, showing blue, purple, and pink at different places in the foam.

NOTE: EYE OR SKIN CONTACT WITH PH UP OR PH DOWN SOLID SHOULD BE AVOIDED. IF CONTACT OCCURS, IMMEDIATELY FLUSH WITH WATER.

Ask students, *Why does the solution foam?*

The pH Up chemical is sodium carbonate, Na_2CO_3, which reacts with acid (the pH Down chemical, $NaHSO_4$ in this case) to form the gas, carbon dioxide, CO_2. This produces foam. The color changes in the foam are a result of the mixing of the acid and base to give different colors as they neutralize each other. Local colors of pink or blue are caused by a greater concentration of acid or base in that region.

<u>CLEANUP: One of the VSVS volunteers should take the magic foam demonstration bottle to the nearest sink and pour the contents out. Wash down the drain with lots of water and rinse out the bottle. Be sure to return the bottle with the kit.</u>

Information for VSVS students: (Share with the class if time permits.)

At the beginning of the magic foam experiment, milk of magnesia turned the cabbage juice green because it is a base. Milk of magnesia was then neutralized by the pH Down (acid, sodium hydrogen sulfate), going through several colors to give a reddish-pink color because an excess of acid has been added. When the pH Up (base, sodium carbonate) was added, carbon dioxide gas was produced from the reaction with the acid, sodium hydrogen sulfate. pH Up and pH Down can be purchased at stores, such as Home Depot, that handle chemicals for adjusting pH in spas, hot tubs, and swimming pools.

The color changes will depend on how many spoonfuls of pH Up were added. If the amounts used were as given in the directions, then the observations will be as described above. However, be prepared for different observations of color changes if different amounts of acid or base have been added.

VIII. Questions for Review – Discuss review questions in the context of the vocabulary words.

What scale is used to determine how acidic or basic a dilute solution of an acid or base is?
pH scale

How is this scale useful to scientists?
It provides a comparison that is universally recognized, not only by scientists but by the informed public.

On the pH scale, what numbers represent acids?
0 - 6

On the pH scale, what number represents a neutral?
7

On the pH scale, what numbers represent bases?
8-14

When using red cabbage juice as the indicator, what color do acid solutions turn?
shades of pink or red

When using red cabbage juice as the indicator, what color do base solutions turn?
shades of blue and green, except pH #14 which turns yellow

Is there an advantage to using red cabbage juice instead of litmus paper to test acids and bases?
Yes, litmus paper only undergoes one color change to indicate whether something is acidic or basic. Red cabbage juice has a range of color changes that indicate the range of acidity or basicity. For example, red cabbage juice will show that Sprite is not as acidic as vinegar, even though both are acids. Litmus paper would show that both were acids, but would not distinguish which one was more acidic.

Reference: Fun with Chemistry, Vol. 2, 2nd edition; Sarquis, M; Sarquis, J. Eds., Publ. 91-005, Institute for Chemical Education, University of Wisconsin: Madison, 1991; pp. 53-62.

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