15. pH of Household Chemicals

Driving Questions

Many of the products you use at home can be classified chemically as acids or bases. What makes one chemical an acid and another chemical a base? How can you determine if a household chemical is an acid or a base?

Background

Pure water is able to autoionize, or dissociate into hydrogen ions (H^+) and hydroxide ions (OH^-).

$$H_2O(l) \rightarrow H^+(aq) + OH^-(aq)$$

At the molecular level, an acid is a substance that donates a hydrogen ion (H^+). The donated H^+ ion quickly bonds with a water molecule to form the hydronium ion (H_3O^+).

$$H^+(aq) + H_2O(l) \rightarrow H_3O^+(aq)$$

Compared to pure water, an acidic solution contains a larger number of H_3O^+ ions than OH^- ions. Acids are ranked in a continuum from strong acids to weak acids based on the ease with which they give up their H^+ ions and form H_3O^+. A strong acid is one that readily and completely dissociates; every acid unit breaks into a hydrogen ion and an anion. In contrast, a weak acid is one that only partially dissociates; only a fraction of the available acid units break into a hydrogen ion and an anion.

A base is the complement of an acid. A base is a substance that accepts a hydrogen ion. Compared to pure water, a basic solution contains a smaller number of H_3O^+ ions than OH^- ions. The more readily a chemical substance bonds with H^+ ions, the stronger the base.

Substances that contain equal amounts of H_3O^+ ions and OH^- ions, such as pure water, are considered neutral solutions.

The pH scale provides a numerical measure of the H_3O^+ ion concentration in an aqueous solution. The pH scale is a base 10 logarithmic scale.

$$pH = -\log [H_3O^+]$$

Substances with a pH less than 7 are classified as acids. Substances with a pH greater than 7 are classified as bases. And substances with a pH equal to 7 are classified as neutral.

Materials and Equipment

For each student or group:

- Data collection system
- pH sensor
- Beaker (2), 50-mL
- Graduated cylinder, 50-mL
- Graduated cylinder, 10-mL
- Test tube (10), 15-mm x 100-mm
- Test tube rack
- Wash bottle and waste container
- Buffer solution pH 4, 25 mL
- Buffer solution pH 10, 25 mL
- White vinegar (~5% acetic acid), 5 mL
- Lemon Juice, 5 mL
- Soft drink, 5 mL
- Window cleaner, 5 mL
- Tap water, 5 mL
- Milk, 5 mL
- Coffee, 5 mL
- 0.5 M Sodium bicarbonate (baking soda), 5 mL
- Liquid soap, 5 mL
- Bleach, 5 mL

Safety

Add these important safety precautions to your normal laboratory procedures:

- Many household chemicals are skin, eye, and respiratory irritants, including window cleaner, vinegar, lemon juice, and bleach.

Sequencing Challenge

The steps below are part of the Procedure for this lab activity. They are not in the right order. Determine the proper order and write numbers in the circles that put the steps in the correct sequence.

◯	◯	◯	◯
Graph pH versus hydronium ion (H_3O^+) concentration.	Place 5 mL of each household chemical in a clearly labeled test tube.	Calculate the hydronium (H_3O^+) ion concentration for each household chemical using the measured pH values.	Measure the pH of each household chemical.

Procedure

After you complete a step (or answer a question), place a check mark in the box (☐) next to that step.

Note: When you see the symbol "" with a superscripted number following a step, refer to the numbered Tech Tips listed in the Tech Tips appendix that corresponds to your PASCO data collection system. There you will find detailed technical instructions for performing that step. Your teacher will provide you with a copy of the instructions for these operations.

Set Up

1. ☐ Start a new experiment on the data collection system. (1.2)

2. ☐ Connect a pH sensor to your data collection system. (2.1)

3. ☐ Place 25 mL of pH 4 buffer solution in a 50-mL beaker and 25 mL of pH 10 buffer solution in a second 50-mL beaker. Use these solutions to calibrate the pH sensor.(3.6)

4. ☐ Using the terms "accuracy" and "precision," explain why is it necessary to calibrate the pH sensor?

_____

_____

5. ☐ Configure the data collection system to manually collect pH for different household chemicals in a table. Define household chemicals as the manually entered text data. (5.2.1)

6. ☐ Obtain 10 clean, dry test tubes.

7. ☐ Label each test tube with a household chemical name. The household chemicals are listed in Table 1 in the Data Analysis section below.

8. ☐ Add 5 mL of each household chemical to the appropriately labeled test tube. Each test tube should be approximately one third full.

9. ☐ Does the amount of liquid used in each test tube need to be exact? Explain.

_____

_____

_____

Collect Data

10. ☐ Start a new manually sampled data set. (6.3.1)

11. ☐ Place the pH sensor into the first sample. Make sure the bulb of the pH sensor is fully submerged.

12. ☐ Leave the pH sensor in the solution until the reading stabilizes (about 1 minute) and then record the data point.(6.3.2)

13. ☐ Remove the sensor from the sample and thoroughly rinse it with clean water.

14. ☐ Repeat the steps above to determine the pH for all the samples.

Note: Remember to thoroughly rinse the pH sensor with clean water after testing each solution.

15. ☐ Why is it necessary to rinse the pH sensor after each sample is tested?

_____

_____

16. ☐ When you have recorded all of your data, stop the data set.(6.3.3)

17. ☐ Save your data file and clean up according to the teacher's instructions.(11.1)

Data Analysis

1. ☐ Calculate the hydronium ion (H_3O^+) for each of the household chemicals using the measured pH value. Follow the steps below to do this on your data collection system.

   a. Enter the equation given below into your data collection system's calculator. (10.3)
   concentration = 10^–(pH)

   b. Add a column to the table on your data collection system to display the calculated hydronium (H_3O^+) ion concentration. (7.2.2)

2. ☐ Copy the pH and H_3O^+ ion concentration data from your data collection system to the corresponding columns in Table 1 below.

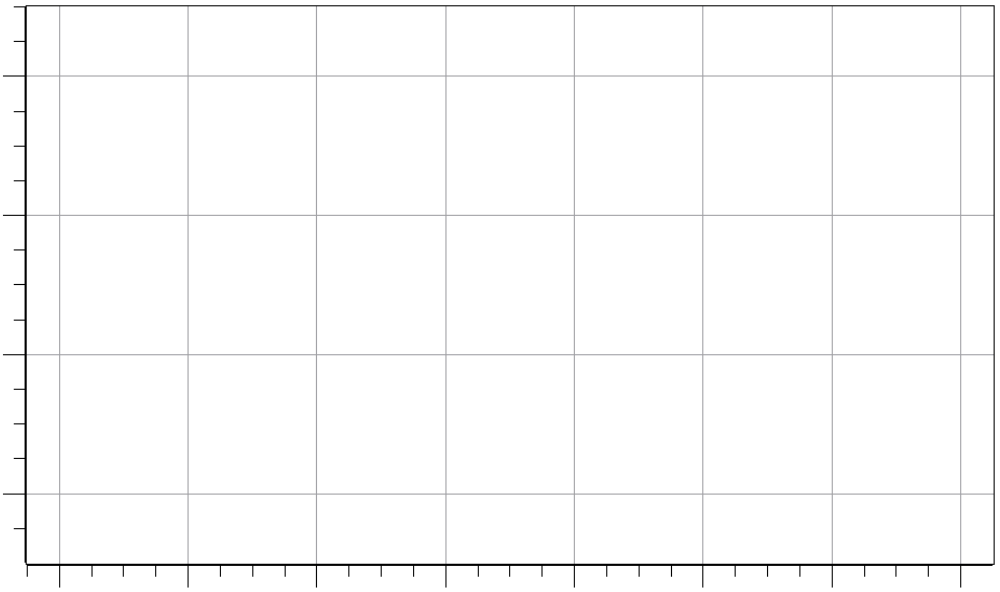
Table 1: Household chemicals, their pH and H_3O^+ concentrations

	Household Chemical	**pH**	**$[H_3O^+]$ (M)**
1	Vinegar		
2	Lemon juice		
3	Soft drink		
4	Window cleaner		
5	Tap water		
6	Milk		
7	Coffee		
8	Baking soda		
9	Liquid soap		
10	Bleach		

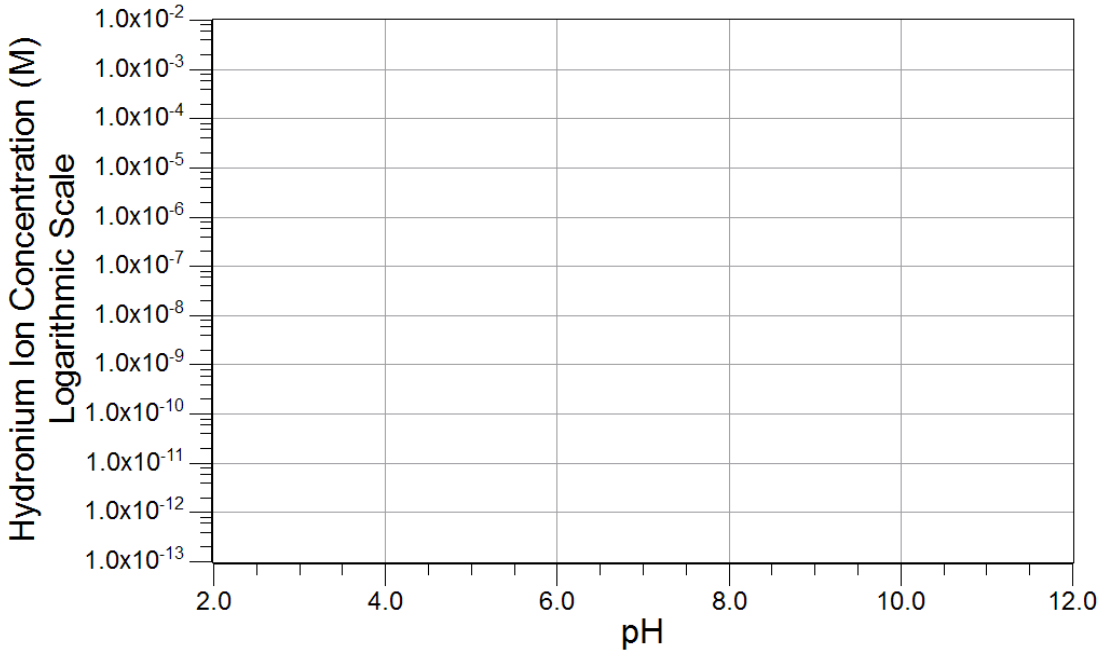
3. ☐ Display H_3O^+ concentration versus pH on a graph. (7.1.1)

Note: To graph a scatter plot of the data points hide the connecting lines between data points feature. (7.1.8)
If needed, adjust the scale of the graph to show all the data points. (7.1.2)

4. ☐ Plot or print a copy of the graph of H_3O^+ Concentration (M) versus pH. Label the overall graph, the x-axis, the y-axis, and include units on the axes. (11.2)



5. ☐ Draw a scatter plot of H_3O^+ ion concentration versus pH on a logarithmic scale.



Analysis Questions

1. **What is pH and why is the pH scale used?**

2. **Explain the relationship between pH and H_3O^+ ion concentration.**

3. **Define the term "acid" and explain the why there are strong and weak acids.**

4. **Identify which of the household chemicals tested are acids and list them in order from the lowest to highest pH.**

5. **Define the term base and explain why there are different strengths of bases.**

6. **Identify which of the household chemicals tested are bases and list them in order from highest to lowest pH.**

Synthesis Questions

Use available resources to help you answer the following questions.

1. **A nitric acid solution has a pH of 1 and a hydrochloric acid solution has a pH of 3. Which acid solution is more concentrated and by how much?**

2. **What is pOH and how is it related to pH?**

3. **If an acid is added to a basic solution, what do you expect to happen to the pH of the basic solution? Why?**

Multiple Choice Questions

Select the best answer or completion to each of the questions or incomplete statements below.

1. **Why is a 0.1 M hydrochloric acid solution a stronger acid than a 0.1 M acetic acid solution?**

   A. Because more of the H^+ ions dissociate into the solution
   B. Because less of the H^+ ions dissociate into the solution
   C. Because there are equal numbers of H^+ ions in the two solutions
   D. Because there are equal numbers of OH^- ions in the two solutions

2. **How is an aqueous solution of a base different from an aqueous solution of an acid?**

   A. A basic solution conducts electricity and an acidic solution does not
   B. A basic solutions will cause an indicator to change color and an acid will not
   C. A basic solution has a greater concentration of H_3O^+ than OH^-
   D. A basic solution has a lower concentration of H_3O^+ than OH^-

3. **Pure water has a pH of 7 and toothpaste has a pH of 10. The water contains how many times the number of H_3O^+ ions as toothpaste?**

   A. 1/100
   B. 3
   C. 10
   D. 1000

4. **An unknown solution has an H_3O^+ concentration of 6.0×10^{-10} M. This solution is:**

   A. Acidic
   B. Basic
   C. Neutral
   D. Concentrated

5. **An unknown solution has a pH of 4.0. This solution is:**

   A. Acidic
   B. Basic
   C. Neutral
   D. Concentrated

Key Term Challenge

Fill in the blanks from the list of words in the Key Term Challenge Word Bank.

1. _____ are found in numerous substances all around us such as soft drinks, salad dressing, and rain water. Acids taste _____, cause indicators to change color, and react with certain _____ to form hydrogen gas. At the molecular level, an acid is a substance that _____ a hydrogen ion (H^+) which will form an increased concentration of the hydronium ion (H_3O^+) when the acid is dissolved in water. _____ acids dissociate fully in water, whereas _____ acids only partially dissociate. Acids have pH values _____ 7. The lower the pH, the _____ acidic the solution.

2. Bases may not be as familiar to you, but they are just as numerous as acids. _____ are found in personal hygiene products, cleaning products, and food. Bases taste _____, feel slippery, and react with oil and grease. At the molecular level, a base is a substance that _____ or bonds with a hydrogen ion (H^+). By bonding with the H^+ ion, a base causes the concentration of the hydronium ion (H_3O^+) to _____. _____ bases have a strong force of attraction and readily bond with H^+ ions which reduces the H_3O^+ ion concentration in solution. Bases have _____ values greater than 7. The _____ the pH, the more basic the solution.

Key Term Challenge Word Bank

Paragraph 1

accepts
acids
bases
bitter
donates
greater than
less than
metals
more
sour
strong
weak

Paragraph 2

accepts
acids
bases
bitter
decrease
donates
higher
increase
lower
pH
reduces
sour
strong