

Description:

Acids and bases make a notable presence in the world around us. The pH level of our bodies as well as the foods we consume are important to our biological well-being. However, a slight shift in pH level can cause major repercussions to our bodies and the environment we live in. You are a Soil Geologist in training, and you have been assigned a project geared towards gaining basic understanding in pH properties. The pH of soil plays an important role in maintaining a healthy environment. Changing the pH of soil can impact the solubility of chemical components. This can lead to toxicity and in turn directly impact aquatic ecosystems. Your job is to test common household products and use your findings to characterize whether the solution is an acid, base, or neutral solution. Report your results and analysis to your University's Dean of the Research Department.

Students will be able to:

- Test the pH levels of an aqueous solution to determine if it is acidic or basic
- Determine which characteristics aid in differentiating an acid from a base and vice versa
- Change the pH of a solution by adding different household chemicals to a solution and record their findings
- Understand the use of litmus paper and the different meanings in color of an acid and a base
- Connect content understanding to soil acidification due to a change in pH levels to determine how damaging it could be to organisms and their environments

Students will understand:

This lesson involves learning how to read a pH scale and determine what makes a solution acidic or basic. This knowledge will allow them to determine which chemical compounds will affect the pH of their solution. Students will use litmus paper to test their solution and record their findings. This lesson will elucidate how certain substances are acidic or basic and how both possess different characteristics that influence a solution. The purpose of the lab portion is for students to apply what they learned in order to determine why an acidic environment may affect an organism's way of life. This will expand their learning in areas relating to ocean acidification and how changes in climate, such as decreases in ocean pH, can be very harmful to the ecosystem.

Key Definitions & Concepts: [1]

- **pH:** a measure of hydrogen ion concentration, a measure of the acidity or alkalinity of a solution. The pH scale usually ranges from 0 to 14. Aqueous solutions at 25°C with a pH less than 7 are acidic, while those with a pH greater than 7 are basic or alkaline.
- **Acid:** an acid is a chemical species that donates protons or hydrogen ions and/or accepts electrons. Aqueous solutions at 25°C with a pH less than 7 are acidic.
- **Base:** substances that, in aqueous solution, release hydroxide (OH⁻) ions, are slippery to the touch. Aqueous solutions with a pH greater than 7 are basic or alkaline.
- **Bronsted-Lowry Acid:** proton (H⁺) donor
- **Bronsted-Lowry Base:** proton (H⁺) acceptor
- **Arrhenius Acid:** increases (H⁺) concentration in water
- **Arrhenius Base:** increases (OH⁻) concentration in water

- **Ocean acidification:** term used to describe significant changes to the chemistry of the ocean. It occurs when carbon dioxide gas (CO₂) is absorbed by the ocean and reacts with seawater to produce acid.
- **Litmus paper:** a specially stained paper that is used to indicate the acidity or alkalinity of a substance. Blue litmus paper turns red under acid conditions, and red litmus paper turns blue under alkaline (basic) conditions.

Standards:[Copied from: 2]

3.1.10.A1: Explain the characteristics of life common to all organisms.

- The analysis within this lesson contains information pertaining to organisms in different environmental habitats. The ocean is primarily basic, rather than acidic, so this could contribute to how ocean acidification due to changes in pH levels could affect many organisms and their habitat. Decreasing pH levels could disrupt food chains and ocean environments, for example.

Background Information

Prior Knowledge:

- Familiarization with the periodic table and properties of elements
- Understanding of solubility and how concentration of molecules affects a substance's solubility
- Periodic trends, specifically electronegativity
- Familiarity with the terms: acid and base
- Solubility (Concentration of H⁺/OH⁻ ions)

Science Practices:[Copied from:

3]

- Asking questions and defining problems
- Planning and carrying out investigations
- Analyzing and interpreting data
- Constructing explanations and designing solutions
- Obtaining, evaluating, and communicating information

Core Ideas:[Copied from: 4]

- Types of Interactions
- Chemical Reactions
- The Roles of Water in Earth's Surface Processes

Cross Cutting

Concepts:[Copied from: 5]

- Cause and effect
- Energy and matter
- Structure and function
- Stability and change

Possible Preconceptions/Misconceptions:

Students may experience confusion during the discussion of acidic versus basic foods. While it is understandable that a lemon will be acidic, it can be challenging for students to label foods as basic. The instructor will be present to help students identify characteristics of basic foods, but will focus primarily on using litmus paper as a reliable indicator for pH.

Engage:

The instructor will begin the lesson by asking students if they ever tasted a slice of lime and to express how they felt about the sour taste. Everyone's taste buds are different, but when it comes to certain foods that are highly acidic or basic, people typically experience the same feeling. The instructor will use this introductory discussion as a segway to have students complete the engagement's worksheet *Food Chemistry* where they will determine which foods are acidic or basic. Based on their past experiences from tasting the food items listed, students must describe the characteristics of each food item. This assignment will allow students to qualitatively describe the difference between acids and bases. This section should take 10 minutes to complete

Explore: [6] (video), [7-8] (images)**Part I: Introduction**

The instructor will show the video *Acids, Bases, and pH* to the students. This video serves to introduce students to what pH is, how it is determined, and how the equation for determining pH is derived. This video illustrates several important characteristics of pH that must be taught to ensure deep content understanding of pH. Therefore, this video should be shown during the beginning of the lesson. If time does not allow for one or more of the following activities, then it is recommended to have the students complete the all analysis questions at home for homework. The instructor should allot 10 minutes to the showing of this video.

Part II: Benchmark Lesson: Categorizing acid and basic solutions

The instructor will distribute the worksheet *pH Analysis of Household Products*. Students will work in small groups of 2 or 3 to build on their background knowledge. They will apply learned key concepts from their previous activity discussions to investigate how to use the pH scale. Students will also be engaging in active learning and in pH testing that chemists use every day. The purpose of this worksheet is to have students pick up on the similar characteristics that differentiate acids and bases. Students should be able to characterize liquids as acidic or basic based on the color of the litmus paper, then utilize the color scale to determine its approximate pH level. This activity should take 15-20 minutes.

Part III: Investigation Lesson: Soil Acidification

At the end of the *pH Analysis of Household Products* worksheet, students will be asked to extend their knowledge to theorize about causes that impact soil acidification and ecosystems. The purpose of this question is to have students extend what they have learned from pH and apply their learning to real life applications. Students should be able to make the connection to other chemical factors (metals and corrosion) and their effect on an ecosystem. The goal here is to have students realize that soil acidification is caused by pH which then affects local ecosystems. This activity should take 10-15 minutes.

Explain:

Throughout the exploration, the students will engage in discussions that inquire their understanding and knowledge of the information at-hand. Teachers will be informally asking students to explain all topics and relevant connections throughout the entirety of this lesson. The worksheets will ask questions that require

students to engage in high-level thinking, allowing them to verbalize their understanding of the material. These worksheets also serve as a way for students to self-assess their understanding of the material.

Elaborate:[8]

This is an at-home assignment for students to complete as homework. Students will complete the worksheet titled *pH Scale* while working through a PhET simulation covering the [pH Scale](#). This activity allows students to see the effects on creating an acidic or basic solutions using household items in real-time. This activity allows for the students to choose and to create their own solutions. Through this activity, students will be able to complete the learning goals of this lesson by: understanding pH and identifying the characteristics of an acid and base. This experiment is commonly done in commercial chemistry labs, where the pH of everyday products must be tested in order to determine whether or not a product is safe to use in a home, and to also provide instructions on using the product properly as necessary. Through this activity, students will be engaged in a scenario that many career chemists follow regularly. This activity should take 10-15 minutes to complete.

Evaluate:

Throughout the entirety of this lesson, there will be both formal and informal evaluations. The informal evaluations occur throughout the exploration via leading and open-ended questioning, as well as through the open class discussions. The informal evaluations will allow for the teacher to gauge surface-level understanding of the students. By surveying the students during completion of the worksheets and activities, teachers will be able to hear and to address any misconceptions or misunderstandings as necessary. The formal evaluations of this lesson are the *pH Analyzation of Household Products* lab experiment and the exit ticket. This 5 minute, individual exit ticket tests the students on the essential knowledge of the pH scale. The exit ticket also asks students to extend their understanding and engage in critical thinking by predicting the pH of a solution based on its constituents, citric acid and water.

Enrich:

This lesson could be differentiated by having students complete a chemistry activity where they perform a titration between an acid and a base (e.g. strong acid and strong base, weak acid and strong base, weak base and strong acid, etc.). Students can also be introduced to acid base indicators and titration curves. Since the lesson focuses on pH and its properties, this allows for students extend their learning to a higher grade level and apply their gained knowledge of acids and bases. This experiment is often seen in college-level chemistry courses because of the focus on experimental procedure, chemistry techniques, and lab etiquette.

****All associated documents are attached below****

****Reference *Annotated Bibliography* on the very last page of this packet****

Name: _____ Date: _____

Food Chemistry

Directions: under the title of each food item that is listed, write a description of each item's characteristics based on taste, texture and smell. Identify which items are acidic versus basic.

1. Vinegar

2. Milk Chocolate

3. Avocado

4. Eggs

Name: _____ Date: _____

pH Analysis of Household Products [6]

1. Water is a polar molecule. Draw water molecules connected by their associated intermolecular forces, and their polar ends.

2. Two water molecules are adjacent to one another. The oxygen from one molecule “pulls off” a hydrogen from the other water molecule. What are the two byproducts of this? Include the molecules’ names and charges.

3. The amount of free hydrogen atoms floating in a sample of water is extremely rare.
 - a. What is the likelihood of a hydronium ion being present in a sample of water?

 - b. Write your answer to the above in terms of pH. Show your work.

4. You have a sample of water at a pH of 7. You place several spoonfuls of sugar in the solution, causing the amount of hydronium ions in the solution to decrease from 1 in 10 million (10^7) to 45 million (4.5^{10}). What is the pH of the sugar water solution? Show your work.

Name: _____ Date: _____

pH Analysis of Household Products

Introduction: Acids and bases make a notable presence in the world around us. The pH level of our bodies as well as the foods we consume are important to our biological well-being. However, a slight shift in pH level can cause major repercussions to our bodies and the environment we live in. You are a Soil Geologist in training, and you have been assigned a project geared towards gaining basic understanding in pH properties. The pH of soil plays an important role in maintaining a healthy environment. Changing the pH of soil can impact the solubility of chemical components. This can lead to toxicity and in turn directly impact aquatic ecosystems. Your job is to test common household products and use your findings to characterize whether the solution is an acid, base, or neutral solution. Report your results and analysis to your University's Dean of the Research Department.

Materials:

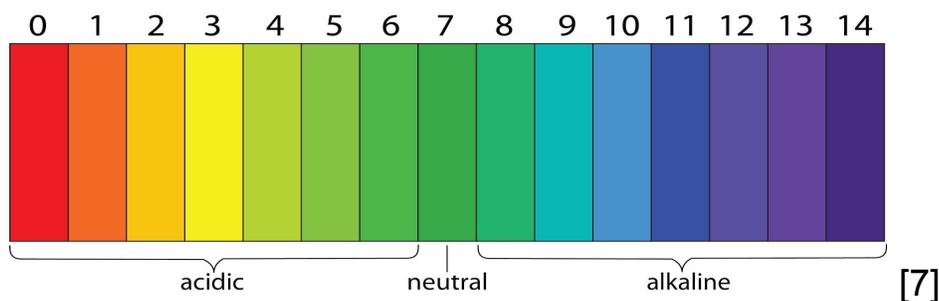
Baking Soda	Laundry Detergent	pH chart
Pepto Bismol (Bismuth Subsalicylate)	Distilled Water	6 25 ml beakers
Hydrogen Peroxide	Tap Water	Paper Towels
	Litmus paper	Gloves

Directions: For each solution sample, measure the pH level using the Litmus paper. Record your findings in the data table below as well as any observations of your solutions. Make sure to include the color indicated by the litmus paper test, the pH level determined by the pH chart, and whether the household solution is an acid, base, or neutral. Finally, answer the analysis questions to support your findings.

Observations:

Results: Data Table

Household Solution	Litmus Paper Color	pH (1 - 14)	Acid, Base, or Neutral
Baking Soda			
Pepto Bismol (Bismuth Subsalicylate)			
Hydrogen Peroxide			
Laundry Detergent			
Distilled Water			
Tap Water (Unfiltered Water)			



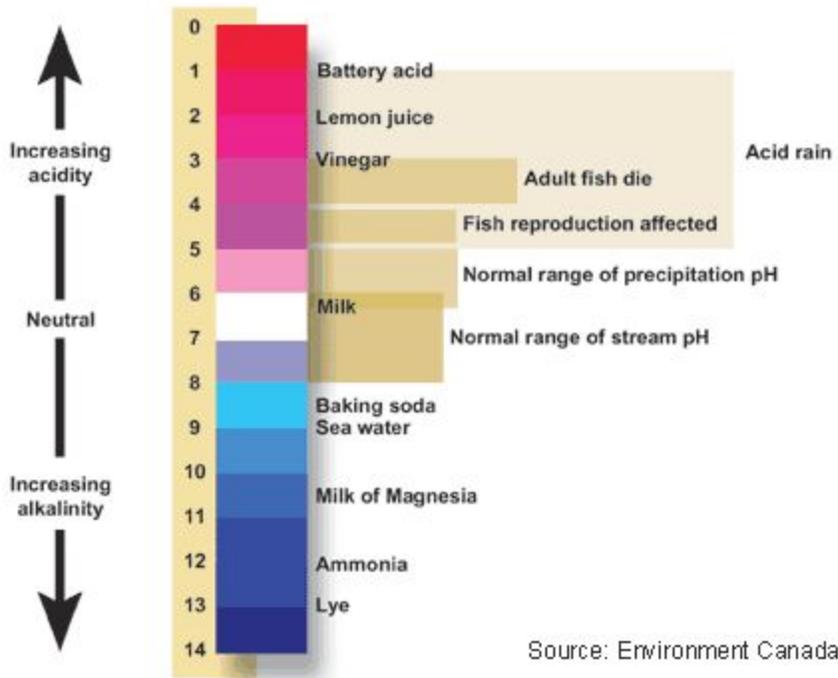
Analysis Questions:

1. Based on your observations, describe and categorize common properties (texture, taste, reactivity, color change of litmus, etc.) found in acids versus bases.

Acids

Bases

2. According to a report made by the United Utilities, the normal pH range for tap water is between 6.5 and 9.5. Was the tap water solution you tested within this range? Why is the pH of household water within a range but pure water has a pH of 7? (Think about other constituents and their effects on water).



[8]

3. Changing the pH of water can impact the solubility of chemical components. This can lead to toxicity and in turn directly impact local ecosystems. Using the chart above, explain how ocean acidification impacts these local ecosystems.

Name: _____ Date: _____

pH Scale [9]

Directions:

Complete the PhET Simulation about the [pH Scale](#) and answer the following questions based on your observations.

1. Determine if a solution is acidic or basic using:
 - a. pH
 - b. H_3O^+ / OH^- ratio (molecular size representation of just the ions in the water equilibrium)
 - c. Hydronium / Hydroxide concentration
2. Relate liquid color to pH.
3. How does diluting an acidic solution affect its pH level? Explain your reasoning.

Name: _____ Date: _____

Exit Ticket

1. Label the pH scale below by identifying which regions are acidic, neutral and basic.

0	
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	
11	
12	
13	
14	

2. Chelsea mixed a jar of lemonade using water and lemons only. What do you think the pH of the solution is? Explain your reasoning.

Name: _____ Answer Key _____ Date: _____

Food Chemistry

Directions: Under the title of each food item that is listed, write a description of what each item taste like and its characteristics using terms relating to taste, texture and smell. Identify which items are acidic or basic.

1. Vinegar:

Words to describe the taste: sharp-tasting, harsh, sour, bitter, tangy

Words to describe smell: strong, sour, unpleasant, acidic

Words to describe the texture: feels like a liquid, loose

Vinegar is an acid, it is very pungent in nature.

2. Milk Chocolate:

Words to describe the taste: sweet, rich, creamy, sugary

Words to describe smell: sweet

Words to describe the texture: smooth, lumpy, soft, hard

Milk Chocolate is acidic, though it may have characteristics that appear basic the pH of chocolate is 6. It is a dairy product but the cocoa product in chocolate makes it acidic.

3. Tomatoes:

Words to describe the taste: tangy, sour,

Words to describe smell: none

Words to describe the texture: soft, smooth, juicy

Tomatoes are very acidic in nature, they have a pH in the range of 3-4.

4. Eggs

Words to describe the taste: bland, creamy

Words to describe smell: rotten, sulfur

Words to describe the texture: smooth, lumpy, sticky, creamy

Eggs are basic in nature, they have a pH of 8-9 and they are considered a dairy product.

Name: _____ Answer Key _____ Date: _____

pH Analysis of Household Products [6]

1. Water is a polar molecule. Draw water molecules connected by their associated intermolecular forces, and their polar ends.



Two water molecules connected from the negative Oxygen end to the positive Hydrogen end by Hydrogen bonding.

2. Two water molecules are adjacent to one another. The oxygen from one molecule “pulls off” a hydrogen from the other water molecule. What are the two byproducts of this? Include the molecules’ names and charges.

Hydronium (H_3O^+) and Hydroxide (OH^-)

3. The amount of free hydrogen atoms floating in a sample of water is extremely rare.
 - a. What is the likelihood of a hydronium ion being present in a sample of water?

1 in 10,000,000 (10^7)

- b. Write your answer to the above in terms of pH. Show your work.

$$\text{pH} = -\log [\text{H}^+]$$

$$\text{pH} = -\log (10^7)$$

$$\text{pH} = 7$$

4. You have a sample of water at a pH of 7. You place several spoonfuls of sugar in the solution, causing the amount of hydronium ions in the solution to decrease from 1 in 10 million (10^7) to 45 million (4.5^{10}). What is the pH of the sugar water solution? Show your work.

$$\text{pH} = -\log [\text{H}^+]$$

$$\text{pH} = -\log (10^7)$$

$$\text{pH} = 7$$

Name: _____ Answer Key _____ Date: _____

pH Analysis in Household Products

Introduction: Acids and bases make a notable presence in the world around us. The pH level of our bodies as well as the foods we consume are important to our biological well-being. However, a slight shift in pH level can cause major repercussions to our bodies and the environment we live in. You are a Soil Geologist in training, and you have been assigned a project geared towards gaining basic understanding in pH properties. The pH of soil plays an important role in maintaining a healthy environment. Changing the pH of soil can impact the solubility of chemical components. This can lead to toxicity and in turn directly impacting local ecosystems. Your job is to test common household products and use your findings to characterize whether the solution is an acid, base, or neutral solution. Report your results and analysis to your University's Dean of the Research Department.

Materials:

Baking Soda	Laundry Detergent	pH chart
Pepto Bismol (Bismuth Subsalicylate)	Distilled Water	6 25 ml beakers
Hydrogen Peroxide	Tap Water	Paper Towels
	Litmus paper	Gloves

Directions: For each solution sample, measure the pH level using the Litmus paper. Record your findings in the data table below as well as any observations of your solutions. Make sure to include the color indicated by the litmus paper test, the pH level determined by the pH chart, and whether the household solution is an acid, base, or neutral. Finally, answer the analysis questions to support your findings.

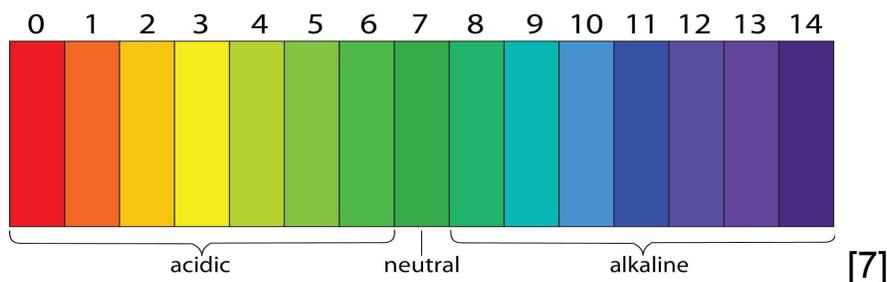
Observations:

Answers vary, but students should mention texture, smell, expected/predicted taste, and reactivity with the litmus paper.

Examples include: baking soda has a grainy texture; laundry detergent is soapy; hydrogen peroxide is a liquid; baking soda turned the litmus paper blue, etc.

Results: Data Table

Household Solution	Litmus Paper Color	pH (1 - 14)	Acid, Base, or Neutral
Baking Soda	<u>blue - green</u>	<u>9</u>	<u>Base</u>
Pepto Bismol (Bismuth Subsalicylate)	<u>green</u>	<u>5-6</u>	<u>Acid</u>
Hydrogen Peroxide	<u>green</u>	<u>4-5</u>	<u>Acid</u>
Laundry Detergent	<u>green-blue</u>	<u>7-10</u>	<u>Neutral or Base</u>
Distilled Water	<u>green</u>	<u>7</u>	<u>Neutral</u>
Tap Water (Unfiltered Water)	<u>green-blue</u>	<u>6-10</u>	<u>Acid, Base, or Neutral</u> <u>(answer varies)</u>



Analysis Questions:

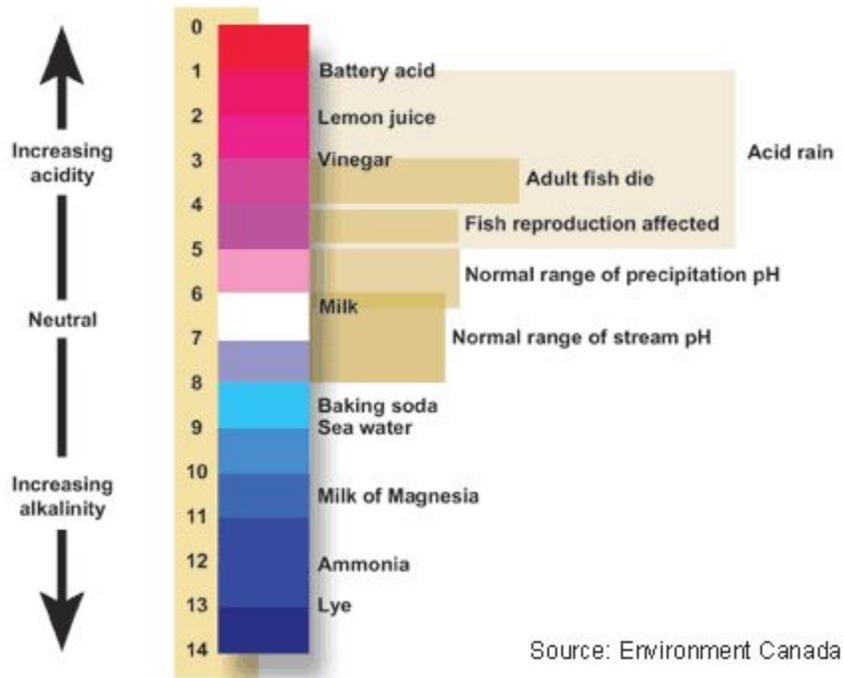
1. Based on your observations, describe and categorize common properties (texture, taste, reactivity, color change of litmus, etc.) found in acids and bases.

Acids
Sour
liquids
turns litmus paper red

Base
bitter
slippery/ soapy
can be in the form of a powder (grainy
texture)
turns litmus paper blue

2. According to a report made by the United Utilities, the normal pH range for tap water is between 6.5 and 9.5. Was the tap water solution you tested within this range? Why is the pH of tap water not 7 when compared to pure water? (Think about other constituents such as chemical and pipes and their effects on water).

The pH of tap water is not 7 when compared to pure water because the water has been treated with chemicals which can slightly alter the pH levels. In addition, the pipe in which water is carried can also alter the pH level.



[8]

3. Changing the pH of water can impact the solubility of chemical components. This can lead to toxicity and in turn directly impacting local ecosystems. Using the chart above, explain how ocean acidification impacts these local ecosystems.

The chart above shows a correlation between low pH and an increase in negative effects on health and/or the environment. At pH levels of 4-5, animals and plant life become affected causing reproductive complications and death. Soil acidification occurs when the pH of soil is lowered, which causes certain elements (mainly metals) react and cause corrosion. This causes the soil to become toxic and impact the local ecosystem which can result in death.

Name: _____ Answer Key _____ Date: _____

pH Scale [9]

Directions:

Complete the PhET Simulation about the [pH Scale](#) and answer the following questions based on your observations.

1. Determine if a solution is acidic or basic using:

a. pH

If the solution is below 7, it is acidic. If it is greater than 7, it is basic.

b. H_3O^+ / OH^- ratio (molecular size representation of just the ions in the water equilibrium)

If the value is greater than 1, meaning that there are more H_3O^+ ions than OH^- ions, then the solution is acidic. If the value is less than 1, meaning that there are more OH^- ions than H_3O^+ ions, then the solution is basic.

c. Hydronium / Hydroxide concentration

If the concentration of H_3O^+ ions is greater than the concentration of OH^- ions, then the solution is acidic. If the concentration of OH^- ions is greater than the concentration of H_3O^+ ions, then the solution is basic.

2. Relate liquid color to pH.

There appears to be no correlation between liquid color and pH.

3. How does diluting an acidic solution affect its pH level? Explain your reasoning.

If the liquid is acidic, the solution pH will increase closer to 7. The concentration of Hydronium ions in the solution is decreased since the volume of the solution is increased. Hence, this results in the solution becoming less acidic and more neutral.

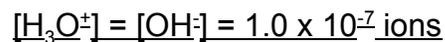
4. How does diluting a basic solution affect its pH level? Explain your reasoning.

If the liquid is basic, the solution pH will decrease closer to 7. The concentration of Hydroxide ions in the solution is decreased since the volume of the solution is increased. Hence, this results in the solution becoming less basic and more neutral.

5. Organize a list of liquids in terms of acid strength or base strength in relative order with supporting evidence.

From greatest to least pH: Drain Cleaner (13.00), Hand Soap (10.00), Spit (7.40), Blood (7.40), Milk (6.50), Chicken Soup (5.80), Coffee (5.00), Orange Juice (3.50), Soda Pop (2.50), Vomit (2.00), and Battery Acid (1.00).

6. Write the water equilibrium expression. Describe how the water equilibrium varies with pH.



As the number of $[\text{H}_3\text{O}^+]$ ions increases, the pH of the solution decreases. This is similar to the number of $[\text{OH}^-]$ ions, but as $[\text{OH}^-]$ ions increases, the pH of the solution increases.

Name: _____ Answer Key _____ Date: _____

Exit Ticket

1. Label the pH scale below by circling and identifying which regions are acidic, neutral and basic.

0	Acidic
1	
2	
3	
4	
5	
6	
7	Neutral
8	Basic
9	
10	
11	
12	
13	
14	

2. Chelsea mixed a jar of lemonade using water and lemons only. What do you think the pH of the solution is? Explain your reasoning.

Since lemons are acidic (pH of 2) and water is neutral (pH of 7), then the pH of the solution will be between 3 and 6. This is because citric acid, the acid found in lemons, is a strong acid and water is a weak base. The combination of the two would result in a slightly less acidic solution, but not neutral.

Annotated Bibliography

[1] Jircitano, A. J. (n.d.). Acid-Base Equilibria. Retrieved March, 2019, from <http://chemistry.bd.psu.edu/jircitano/acidbase.html>

This reference was used for research purposes. This reference was used to develop necessary vocabulary and lesson activities. This reference was neither adapted nor excerpted.

[2] Nsta. (n.d.). Access the Next Generation Science Standards by Topic. Retrieved January 18, 2019, from <https://ngss.nsta.org/AccessStandardsByTopic.aspx>

This website was used in each lesson in the Water Chemistry & Biology module to select proper national set standards for science subjects that each lesson is centered around.

[3] Nsta. (n.d.). Science and Engineering Practices. Retrieved January 18, 2019, from <https://ngss.nsta.org/PracticesFull.aspx>

This website used in every lesson in the Water Chemistry & Biology module to find Standards for Science and Engineering Practices that are applicable in each lesson.

[4] Nsta. (n.d.). Disciplinary Core Ideas. Retrieved from <https://ngss.nsta.org/DisciplinaryCoreIdeasTop.aspx>

This website was used in each lesson in the Water Chemistry & Biology module to select appropriate disciplinary core ideas set forth by the NSTA that are at the center of each lesson.

[5] Nsta. (n.d.). Crosscutting Concepts. Retrieved from <https://ngss.nsta.org/CrosscuttingConceptsFull.aspx>

This website was used in each lesson in the Water Chemistry & Biology module to selecting appropriate crosscutting concepts set forth by the NSTA that apply to each science lesson.

[6] Bozeman Science. (2013, May 1). Acids, Bases, and pH. Retrieved February 2019, from <https://www.youtube.com/watch?v=Xeuyc55LqiY>

This reference was used as an educational tool to introduce students to pH and its properties. The referenced video illustrates how pH is determined and how the equation for determining pH is derived.

[7] JanSan Consulting. (n.d.). PH Scale Defined - What is pH? Retrieved February, 2019, from <https://www.jansanconsulting.com/ph-scale.html>

This reference was used for excerption purposes. The image displaying the pH scale was used to illustrate the liquids that display a level of pH and the associated litmus paper colors. This image was directly excerpted from the reference.

[8] Environment and Climate Change Canada. (2013, July 17). Acid Rain. Retrieved February, 2019, from <http://www.ec.gc.ca/eau-water/default.asp?lang=En&n=fd30c16-1>

This reference was used for excerption purposes. The image displaying the pH scale was used to illustrate the liquids that display a level of pH and the effects they have on the environment. This image was directly excerpted from the reference.

[9] PhET Interactive Simulations. (n.d.). pH Scale 1.2.17. Retrieved March, 2019, from https://phet.colorado.edu/sims/html/ph-scale/latest/ph-scale_en.html

This is used in the pH lesson as part of the Water Chemistry & Biology module as an educational tool for students to explore pH. It was also used as inspiration for the creation of questions that students answer as part of the activity.