UNIVERSITY OF OREGON

STEM core

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Title: pHun with pH

Synopsis

The audience will be introduced to the main concepts of the pH scale. They will learn the definition of pH and the logarithmic pH scale. They will also have a chance to determine the pH of common household items using pH paper and chemical indicators. A natural pH indicator that can be extracted from red cabbage will be used to investigate pH as well. Finally, the purpose of buffers in biological systems to balance pH will be explained using a titration demonstration.

Audience

6-12th grade

Learning Goals

To introduce participants to the pH scale as a logarithmic scale that can be used to determine how acidic or basic a solution is, and that organisms use organic buffers as a way for biological systems to maintain constant pH.

Materials

- Computer/laptop with display screen
- pH paper
- Universal pH indicator
- Household acids and bases (soda, orange juice, Windex/ammonia based cleaners, milk of magnesia, vinegar, etc.)
- Water (deionized)
- Ring stand
- 2 glass burets
- 1M NaOH
- Tris buffer pH 7.0 (or other biological buffer pH 7.0)
- 1M HCl
- Red cabbage

- 4 glass Erlenmeyer flasks (~250 mL)
- Sleeve of clear plastic cups
- Nitrile gloves (optional)

Preparation and Set-up

Prepare red cabbage indicator (before demo)

Shred red cabbage leaves, place in microwave safe bowl, and add enough water to cover the leaves. Microwave about 2 minutes or until water is deep purple. Carefully strain the indicator into container and cover with a lid.

Prepare Demo Space (Day of Demo)

Set up computer and display screen with interactive pH demo. Set out household items in easily accessible area with a clear plastic cup in front of each solution. Place ~10-15 strips of pH paper in front of each item as well, and designate an extra cup as pH strip garbage. Universal indicator should also be nearby, however do not place indicator within reach of audience—only the demonstrator should use indicator. Set up burets in ring stand. Fill each buret with 50 mL of 1M NaOH. Pour ~100 mL of either 1M HCl or Tris pH 7.0 in separate Erlenmeyer flasks and place under each buret. Fill 2 Erlenmeyer flasks with ~50 mL of red cabbage indicator (can also scale down if you don't have much indicator—5 mL in a scintillation vial will work). Have 1M NaOH and 1M HCl nearby (but out of reach of participants) for demonstration.

Guiding Questions

- Are you familiar with pH?
- Do you know what a logarithmic scale is?
- What are some acidic/basic things that you know of?
- Do you think [household item] is acidic or basic?

Activity Description

Start out by asking the audience if they are familiar with the pH scale. If they are, ask if they understand the inverse logarithmic nature of the pH scale. If so, you can move on to household items and buffers. If they are not familiar with pH and logarithmic scales, use the interactive pH scale app on the computer for a visual explanation how OH^- and H_3O^+ ions are affected as you move up and down the pH scale. Make sure the “show molecules” button is checked when you do this, so the ions are visible. Once they understand pH scale, you can ask what acids and bases they know of and then relate this to the common household items you have present. Introduce methods of determining pH, starting with pH strips. You can also talk about how pH strips are used not only by scientists in the lab, but also for pool or spa maintenance, etc. You can then invite audience members to use the pH strips themselves to investigate the pH of the common household items you have present. Discuss with audience members what the colors of the pH strips mean and you can also explain why certain items are acidic/basic (ex—vinegar is dilute acetic acid, household cleaners have the strong base ammonia, orange juice contains citric acid, milk of magnesia is magnesium hydroxide [OH^-], etc.). You can then move onto the buffer demo by explaining how the cells in our bodies maintain pH through buffering solutions. Turn on both burettes at the same time and then indicate how the pH is only changing in the solution without buffer. Then if it is appropriate for your audience, explain how buffers work discussing the ideas of weak acids and their conjugate bases. Then explain to them how they can extend these lessons by making their own pH indicator at home using red cabbage and a microwave. Encourage them to then explore any questions they have about pH at home.

Teaching Strategies

Engage students by asking questions listed above. Use the indicator to create a rainbow of solutions of varying pH to attract and entice participants. Explore the concept of pH by using the household items and pH strips. Then explain and the evaluation phase can be initiated by asking participants why certain household items are acidic or basic. The elaboration phase can later be initiated by inviting the students to create their own pH indicators at home using red cabbage, and then encouraging them to explore other pH questions they might have.

Vocabulary

- pH— scale of concentration of H_3O^+ ions in solution. This is the –log (concentration of H_3O^+).
- Logarithmic scale— Similar to the Richter Scale, where the values correspond to orders of magnitude instead of a linear scale. In this scale 1 is 10, 2 is 100, 3 is 1000 so on and so forth.
- Indicator— usually a dye that is used in pH tests that has the ability to accept and/or donate hydrogen atoms. Based upon donation or acceptance the dye will change color indicating the pH of the solution.
- Buffer— A solution composed of a weak acid and its conjugate base. Because the solution contains both an acid and base it is able to have an external acid or base added to it without changing pH. Buffers resist changes in pH.
- Universal Indicator—A complex mixture of different pH indicator dyes to give a rainbow like correlation from acids to neutral to bases.

Science Content Background and Additional Resources

The Concept of pH

In chemistry, pH is a way to understand if a solution is acidic or basic. If an acid is added to a solution, the acid is able to donate a hydrogen atom to water, making H_3O^+ (hydronium ion). If a base is in solution, the base is able to take a hydrogen atom away from water making OH^- (hydroxide ion). A solution is acidic when the concentration of H_3O^+ ions is greater than the concentration of OH^- ions. The reverse is also true for basic solutions. When a solution is neutral, the concentration of H_3O^+ ions is equal to the concentration of OH^- ions, or the solution has a pH of 7.

pH Scale

The pH scale is between 0 and 14, where 7 is neutral, below 7 is acidic and above 7 is basic. The best way to think about pH is the potential of a solution to take hydrogen atoms. If a solution is acidic it has a low potential, or a lot of hydrogen atoms present and is not able to take on other hydrogen atoms. If a solution is basic, it doesn't have very many hydrogen atoms and has a high potential for hydrogen atoms. This relationship is caused by the fact that pH is an inverse logarithmic scale, very similar to the Richter Scale. This means that when the pH of a solution goes from 2 to 1, the number of H_3O^+ ions increases by a factor of 10, but if a solution goes from 3 to 1 the number will increase by a factor of 100.

pH Indicators

A lot of different pH indicators are routinely used. For the purposes of this demo we are using both pH paper and in-situ indicators. Both of these indicators operate off of the same principle; they have a dye that has groups that can take a hydrogen atom or donate one. If the dye is able to donate a hydrogen atom easily the solution is basic and will change color. If the dye is able to receive a hydrogen atom the solution is acidic and will also change color. Chemists use a wide variety of different kinds of pH probes, some of which use the conductivity of a solution to get very accurate pH readings.

Buffers

It is important for biological systems to maintain a constant pH. This is generally done by the presence of complex buffers in our bodies. A buffer is generally composed of a weak acid and its conjugate base. Since the weak acid and base are constantly in equilibrium with each other, when acids or bases are added to the solution the pH resists change. This is because if an acid is added it will react with the base already in solution and be neutralized. If a base is added it will react with the acid in solution and be neutralized as well. In nature there are a lot of different buffers present like milk. The lactate and lactic acid ions in milk are in constant equilibrium ultimately giving it the ability to resist changes in pH. Other ions like phosphates and sulfates can also be used as buffering agents in biological systems.

http://phet.colorado.edu/en/simulation/ph-scale
http://en.wikipedia.org/wiki/PH
http://en.wikipedia.org/wiki/Logarithmic_scale