And the Award goes to…TAML

Lesson

Teacher Background Information:

Chlorine is used in pools and drinking water because it is a great **disinfectant**. It is able to kill bacteria and algae, among other things. Chlorine also makes a great stain remover, but not because of the chlorine itself. Natural stains (as well as dyes) produced by everything from mildew to grass come from chemical compounds called **chromophores**. Chromophores can absorb light at specific wavelengths and therefore cause colors. Wood is made of approximately 28 % lignin (varies with tree variety), which degrades to a chromophore, causing paper to brown with age. When chlorine reacts with water, it produces hydrochloric acid and atomic oxygen. The oxygen reacts easily with the chromophores to eliminate the portion of its structure that causes the color. Hydrogen peroxide works in much the same way, with the hydroxyl radical (OH) breaking up the chromophores. The peroxide is not as effective as the chlorine bleach, but is able to be easily broken down to water and oxygen as the only benign byproducts versus chlorinated organic molecules like dioxin for the bleach.

Safety Information:

Teacher demonstration utilizes 30% hydrogen peroxide, a strong oxidizer. Contact with other materials my cause a fire. Harmful if inhaled. Corrosive. Causes eye and skin burns. May cause severe respiratory tract irritation with possible burns. May cause severe digestive tract irritations with possible burns.

Educational Goals:

To reinforce the scientific method through careful manipulation of variables to develop a rich understanding of the bleaching process through an inquiry based activity.

Student Objectives:

Students will …

- Examine hard water treatment
- Compare the efficiency of soap in hard and soft water
- Discover the use of activators to increase the efficacy of a chemical
- Examine how hydrogen peroxide works to oxidize the lignin in wood pulp in the paper making process to make paper white
- Understand that Green Chemistry techniques are being used in industry in products which affect our everyday lives
- One piece of printer paper
- One piece of all-natural, non-bleached paper
  Test tubes – 9 per lab group
- Test tube stoppers – 9 per lab group

- Test tube racks – one per lab group
- Droppers – 4 per lab group
- 60 mL of hard water sample per lab group (recipe in prep section of lab)
- 30 mL of soft water per group (distilled/deionized)
- Epsom Salt (Magnesium Sulfate)
- 3 mL sodium carbonate per lab group (recipe in prep section of lab)
- Environmentally friendly colorless dish soap such as seventh generation – 1 ml per lab group
- 50 ml of 30% hydrogen peroxide
- MSDS sheets for hydrogen peroxide – one per group
- MSDS sheets for Bleach – one per group
- 1 cup of Saw dust –free in the saw area at your local hardware store
- 5 Erlenmeyer flasks (125 mL)
- 5 watch glasses
- Distilled water
- Source of Catalase (potatoes used here)
- pH paper/Universal Indicator
- Small labels or sharpie pens

Time Required:

1 x 45-60 minute class period + 10 minutes on a previous day

NGSS:

- Develop a model based on evidence to illustrate the relationships between systems or between components of a system.(HS-PS1-8)
- Use a model to predict the relationships between systems or between components of a system.(HS-PS1-1)
- Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence, and in the design: decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly. (HS-PS1-3)
- Communicate scientific and technical information (e.g. about the process of development and the design and performance of a proposed process or system) in multiple formats (including orally, graphically, textually, and mathematically). (HS-PS2-6)

Chemistry concepts//STEM concepts:

Solutions and solubility – dissolved ions in water
pH of compounds
Hard water science

Teacher Prep:

Will need approximately 100mL of each solution per student group.
Make hard water using the following recipe:

- Add 5 grams of Epsom salts to 100mL of water
- Make sodium carbonate solution by combining 12 g of sodium carbonate decahydrate with 100m L
- Soft water is just distilled/deionized water.

Make 4, 25mL solutions of hydrogen peroxide with concentrations of 30%, 15%, 7.5%, and 3.75%

Keys for Success:

Lesson takes 10 -15 min at the start of one period to introduce and start bleaching the samples. These samples are then left overnight until the next class period. Should see some significant bleaching of the samples with 30% and 15% hydrogen peroxide solutions, but the more dilute solutions will be relatively unchanged from the control. For these lower concentrations to work as a bleaching agent, an activator must be used. This introduces the concept of using one molecule to increase the efficiency or efficacy of a second molecule.

Procedure:

Day 1 – 10 minutes at the end of the class period.

- Intro to students that tomorrow they are going to be talking about paper making.
- Reinforce that many industrial processes take time to develop the final product, and paper making is no exception. The process must start 24 hours minimum before the paper is ready to be made.
- Demonstrate the following procedure:
    - Place 1 gram of saw dust into each of the 5 Erlenmeyer flasks.
    - To these, add 25 mL of H_2O_2 at the different concentrations (30%, 15%, 7.5 % and 3.75%) and pure water to the 5^{th} as a control.
    - Cover them with watch glasses and place them somewhere where they will be undisturbed. The longer they sit, the more bleaching will occur.

Day 2

- Show students two pieces of paper: one regular white printer paper and one all natural, non-bleached paper.
- Ask students a series of questions:
    - If you were applying for a job, which piece of paper would you submit your resume on?
    - If you were using a laser printer which piece of paper would you use in your printer?
    - What might you use the other piece of paper for? What value does it have?
- Explain to the students that although the all-natural paper is more friendly to the environment, it is not what people want to use for most purposes, therefore it is not as effective.
- Ask students what bleach does to materials.

- Show them an example of a piece of clothing that has gotten accidentally bleached.
- Ask students what has happened here to the dye, bleach and clothing to make this happen.
- Explain that bleach is an oxidizing agent and the pigment is oxidized in order to make the stain colorless.
- Check for understanding of oxidizing/reducing agents and explain that this is the process which is also used to make white paper.
- Explain how the piece of white paper is made using bleach to remove the lignins from the pulp.
- Conventional bleaching of pulp often takes place by the Kraft Process. This consists of a series of chemical processing steps using alkali, acid, hydrogen and sodium peroxide, oxygen, dithionite salts, sodium bisulfite, and wash water processes followed by chlorinating treatments to remove any residual lignin. The chlorinating treatments make use of either chlorine gas, hypochlorite salts and/or chlorine dioxide. Unfortunately, while this method produces bright white paper, it also causes environmental problems through the production and release of organochlorine compounds. These compounds are formed by the reaction or of organics present in the pulp with the chlorine-containing oxidizing agents. The reaction of chlorine and lignin produces chlorinated aromatic rings. Among the organochlorines that are produced are 2,3,6,7-tetrachlorodibenzo-4-dioxin (TCDD, also known by the generic term dioxin) and furans.4,5 TCDD is the most common and most toxic dioxin produced in paper manufacturing

  (Baird, Colin, Environmental Chemistry, 2nd ed., W. H. Freeman: New York, 1999)

  - Explain to the students that this process has been identified by green scientists as a problem that chemistry needs to solve.
  - Have students look at the MSDS sheet for bleach. Consider why we have decided that bleach is not very green.
  - Explain to the students that chemists have solved this problem by increasing the potency of a chemical which has similar properties as bleach.
  - Explain that this process uses a very similar idea as the process we use to soften hard water.
  - Ask students to get into lab groups
  - Hand out student lab procedure
  - Review as needed and have students complete the lab
  - Discuss the student answers to the questions.
  - Brainstorm other examples of chemicals that are made more efficient using additives:
    - Peroxide in toothpaste
    - Nitrous oxide in a race car
    - MSG in food – flavor enhancer and preservative
  - Explain to the students that historically paper was made white and smooth by using bleach. Green chemists have identified that using bleach in the huge amounts that are needed to process this type of paper is not sustainable. Chemists identified that hydrogen peroxide works in a similar way as bleach in terms of the way it takes the pigment out of a material but it did not do the job as effectively therefore it does

not adhere to green chemistry principles number 4 in terms of providing the same level of efficacy.

- Green chemists therefore looked at ways to increase the efficacy of the hydrogen peroxide by using an additive.
- The key here is that the additive does not actually do the job of making the paper white, but it helps the hydrogen peroxide to do the job better. It is like a surgeon and a nurse. The nurse doesn't actually perform the appendectomy but he does make the doctor work faster and more effectively.
- Show the students the saw dust and hydrogen peroxide mixture that you made the previous day.
- Explain to the students that you have succeeded in bleaching the pulp that might be used for making paper. Filter the pulp from the liquid. However you still have the 30% hydrogen peroxide to deal with.
- Demo the sawdust and hydrogen peroxide and then show how to make the hydrogen peroxide benign.
    - Take the sawdust/30% peroxide solution and filter out the solids
    - Test the pH of the peroxide using Universal Indicator or pH Paper
    - Use the catalase to make the hydrogen peroxide benign. Pour peroxide over finely diced potato cubes. Can check pH to verify that only water is present, and no acidic peroxide. (can extend this activity by checking for the presence of molecular oxygen using a glowing splint test)
- Show the TAML PowerPoint presentation.

Extension activity:
Use the pulp that you have bleached with the Hydrogen Peroxide to make homemade paper. Follow the directions for homemade paper at the following website:
http://www.pioneerthinking.com/makingpaper.html

Disposal Information: Bleached sawdust can be rinsed, strained and placed in a solid waste. All hydrogen peroxide solutions should be reacted with catalase (potato) and disposed of down the drain. Aluminum sulfate/sodium carbonate solutions should be filtered. Solids disposed of with solid waste, and aqueous solutions with liquid waste.

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Student Sheet

Materials:

- 9 test tubes
- 9 stoppers
- 1 test tube rack
- 4 droppers
- 60 ml of hard water sample
- 30 ml of soft water sample
- 3 ml of sodium carbonate solution
- approximately 1 ml of clear dish soap
- 9 small labels or a sharpie pen

Objective:

- Test the efficiency of soap in different types of water.

Procedure:

_ Put tubes into test tube rack
_ Label test tubes A1 – A3 and B1 – B3 and C1 – C3
_ Add 10 ml of hard water to test tube A1-A3 and C1 – C3
_ Add 10 ml of soft water to test tubes B1-B3
_ To test tubes – C1 – C3 add 1 ml Sodium Carbonate
_ To each test tube:
  - o Place 1 drop of soap in A1, B1 and C1
  - o Place 2 drops of soap in A2, B2 and C2
  - o Place 3 drops of soap in A3, B3 and C3

_ Shake each test tube for 10 seconds
_ Complete observation table.
_ Complete student questions for thought below.

Observation Table

Test tube #	Amount of soap	Cloudiness (turbidity) of solution with the soap	Height of suds
A1			
A2			
A3			
B1			
B2			
B3			
C1			
C2			
C3			

Lab Analysis

Answer the following questions in the spaces provided

1. Compare the hard water to the soft water. What did you notice about the height of suds and cloudiness of the solutions?

_____
_____
_____

2. What effect does hard water have on the cleaning action of the soap?_____
_____

3. What would this mean to a family who lived in an area where the water supply is hard?

_____
_____

4. What did you see when the sodium carbonate was added to the hard water? In your answer the net ionic chemical reaction, including states of matter.

_____
_____

5. How did the hard water and the hard water with the sodium carbonate compare? What did you notice about the height of suds and cloudiness of the solutions?

_____
_____
_____

6. Read the following paragraph:

Hard water ions (calcium and magnesium) interfere with the cleaning action of soap and detergent. They do this by combining with soap molecules and forming a scum that does not dissolve in water, because the ions react with soap and detergent. Magnesium and calcium ions interfere with the soap and detergent thereby reducing the effectiveness of these cleaning agents. This can be overcome by adding more soap and detergent, however the scum that is formed can adhere to what is being washed making is appear dingy.

Based upon your observations, what does Sodium Carbonate do to these hard water ions?_____
_____
_____
_____

7. What effect did the addition of the sodium carbonate have on the efficiency of the soap as a cleaning agent?_____
_____

Lab Analysis – Teacher Answer Key

1. Compare the hard water (test tubes A) to the soft water (test tubes B). What did you notice about the height of suds and cloudiness of the solutions?

   The water in test tubes A had less soap bubbles at the top than those in test tube B . Each solution in A and B was equivalent in cloudiness.

2. What effect does hard water have on the cleaning action of the soap?

   The hard water ions interfere with the soaps ability to bind with dirt/oil, therefore decrease its efficiency as a cleaning product

3. What would this mean to a family who lived in an area where the water supply is soft?

   The family would be able to use less soap to be able to wash their clothes, dishes, hair, etc. This would add to considerable cost savings over the period of a year.

4. What did you see when the sodium carbonate was added to the hard water? Explain this using a chemical reaction including states of matter.

   A milky white precipitate formed. This could have been the magnesium and calcium ions present in the solutiuon (note: Students unaware that hard water was spiked with Magnesium alone). The reaction is: $Ca_2{}^{+}{}_{(aq)}$ /$Mg_2{}^{+}{}_{(aq)}$ + $CO_3{}^{2-}{}_{(aq)}$ ==> $CaCO_{3(s)}$/$MgCO_{3(s)}$

5. How did the hard water (test tube A) and the hard water with the sodium carbonate (test tube C) compare? What did you notice about the height of suds and cloudiness of the solutions?

   Test tubes A had significantly less soap suds on top, but the test tubes with the sodium carbonate added were significantly cloudier than the untreated

6. Read the following paragraph:

Hard water ions (calcium and magnesium) interfere with the cleaning action of soap and detergent. They do this by combining with soap molecules and forming a scum that does not dissolve in water because they react with soap and detergent they remove the soap and detergent thereby reducing the effectiveness of these cleaning agents. This can be overcome by adding more soap and detergent, however the scum that is formed can adhere to what is being washed making is appear dingy.

Based upon your observations, what does sodium carbonate do to these hard water ions?

The sodium carbonate precipitated out all the hard water ions, leaving behind softened water that was able to make the most out of the use of the soap.

7. What did the addition of the sodium carbonate have on the efficiency of the soap as a cleaning agent?

The addition of the sodium carbonate increased the efficiency of the soap, meaning less was required to clean and produce the bubbles.