Hard Water Lab

AP Environmental Studies Lesson Summary

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NSF GK-12 Vibes and Waves in Action
AP Environmental Science

Summary of lesson:
This lesson is intended to provide the students with a deeper understanding of the concept of water hardness as it relates to water quality. This is accomplished through a laboratory activity that gives students hands on experience with assessing water quality. After completing the lab, the students will evaluate the quality of the results that they obtain to provide a deeper understanding of the typically iterative processes involved with science and engineering.

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Prelab – Theoretical Hardness

Hard water is simply water that contains minerals, such as calcium and magnesium. When water passes through areas rich in calcium and magnesium it becomes hard. Theoretical hardness provides a way to calculate the theoretical concentration of minerals in a sample of water. It is expressed with respect to a specific compound, in this lab $CaCO_3$, so that different minerals may be compared to one another.

Theoretical hardness is calculated with the following equation:

$$\begin{matrix} Hardness \\ as\, CaCO_3 \end{matrix}\left(\frac{mg}{L}\right) = \frac{\left[\begin{matrix} Cation \\ Concentration \end{matrix}\left(\frac{mg}{L}\right)\right] * \left[\begin{matrix} Equivalent \\ Weight\ of\ CaCO_3 \end{matrix}(mg)\right]}{\left[\begin{matrix} Equivalent \\ Weight\ of\ Cation \end{matrix}(mg)\right]}$$

Determine the theoretical hardness for the three samples that we will be working with today. Record the results in the following table:

Sample	Theoretical Hardness
100 $\frac{mg}{L}$ of Magnesium in water	
100 $\frac{mg}{L}$ of Calcium in water	
50 $\frac{mg}{L}$ of both Magnesium and Calcium in water	

You should make use of the following equivalent weights:

Component	Equivalent Weight
Magnesium	12.15 mg
Calcium	20 mg
Calcium Carbonate	50 mg

Laboratory Safety

Ensure that you are wearing the following personal protective equipment for the duration of the lab:

- Lab Coat
- Safety Goggles
- Gloves

Also, ensure that you do not accidentally drink any of the laboratory chemicals (even the water!), or allow any of them to come into contact with your skin, eyes or clothing. While most of the materials used in this lab are quite harmless, we should follow the same practices for handling all chemicals to prevent any accidents.

Do not horse around while handling chemicals or the laboratory equipment.

Laboratory Procedure

1. Verify that your experimental setup has the following equipment:
   - Burette and Burette Stand
   - Erlenmeyer Flask
   - Magnetic stir plate and stir bar
   - Graduated cylinder
   - Disposable pipettes

2. Ensure that your experimental setup has the following equipment:
   - Sample (one of three at each station)
   - Buffer solution (handle with care, contains Ammonia)
   - EBT (the dye)
   - EDTA (the titrant)

3. Using the graduated cylinder to measure the volume, add 50 mL of sample water to the Erlenmeyer Flask. Record the exact volume in the table at the end of the instructions (estimate where the meniscus falls in between the tick marks on the graduated cylinder).

4. Using a disposable pipette, add 2 mL of the buffer solution to the Erlenmeyer Flask.
   - Ensure that this step is done under the fume hood. It is safe for the Erlenmeyer Flask containing water and the buffer solution to be exposed to the air in the classroom, but it's not safe for the buffer solution by itself to be exposed to the air.
   - Leave the pipette under the hood for the next group to use.

5. Using a disposable pipette, add 2 drops of the EBT to the Erlenmeyer Flask.

6. Place the Erlenmeyer Flask on the magnetic stir plate and place the magnetic stir bar inside of the flask. Turn on the stir plate and set its speed to be high enough to keep your mixture well mixed.

7. Place the burette directly over the Erlenmeyer Flask.
8. Add 30 mL of EDTA to the burette. Record the exact initial volume of the EDTA in the table at the end of these instructions.
   - Recall that the burette is numbered from the top, not the bottom.
   - Recall that measurements are taken from the lowest point of the meniscus.

9. Twist the stopcock located at the base of the burette until a slow, but steady, stream of EDTA is pouring into the Erlenmeyer Flask.

10. Monitor the extent of the scavenging reaction, and twist the stopcock until the EDTA no longer flows when the reaction is finished.
    - Remember, the difference between almost finished and finished is a matter of seconds, not minutes. Be ready to twist the stopcock the instant that you see some color change in your mixture.
    - After the first 10 mL or so of the EDTA has been dispensed, it may be beneficial to slow the flow to a drip. This will allow for more accurate results.

11. Record the final the exact final volume of the EDTA in the table at the end of these instructions.
    - Recall that the burette is numbered from the top, not the bottom.
    - Recall that measurements are taken from the lowest point of the meniscus.

12. Dilute your sample until it is clear and then wash it down the drain. Clean out your glassware for the next group.

13. Repeat the procedure, starting from Step 1, for the two other stations.

Sample	**Sample Volume (mL)**	**Initial EDTA Volume (mL)**	**Final EDTA Volume (mL)**
100 $\frac{mg}{L}$ Mg			
100 $\frac{mg}{L}$ Ca			
50 $\frac{mg}{L}$ each, Mg and Ca			

Determining Experimental Hardness

Determine the experimental hardness using the following equation:

$$\begin{matrix} Hardness \\ as\, CaCO_3 \end{matrix}\left(\frac{mg}{L}\right) = \frac{\left[\begin{matrix} Cation \\ Concentration \end{matrix}\left(\frac{mg}{L}\right)\right] * \left[\begin{matrix} Equivalent \\ Weight\ of\ CaCO_3 \end{matrix}(mg)\right]}{\left[\begin{matrix} Equivalent \\ Weight\ of\ Cation \end{matrix}(mg)\right]}$$

Record your results in the following table:

Sample	Experimental Hardness
100 $\frac{mg}{L}$ Mg	
100 $\frac{mg}{L}$ Ca	
50 $\frac{mg}{L}$ each, Mg and Ca	

Evaluating Our Results

1. Combine your results with the measurements of the other two groups, record their results in the table below. You should now have a total of three measurements for each of the three samples.

2. Determine the mean value for each of the three samples, (average the three measurements together).

3. Determine the standard deviation for each of the three samples.

4. Determine the relative standard deviation for each of the three samples.

$$Relative\ Standard\ Deviation = \frac{Standard\ Deviation}{Mean} * 100$$

5. Determine the percent recovery for each of the three samples.

$$Percent\ Recovery = \frac{Mean\ Experimental\ Hardness}{Theoretical\ Hardness} * 100$$

6. Ideally, relative standard deviation would have a value of 0. This would occur if each group came up with the exact same experimental hardness. In the space underneath the table on the following page, explain why we are not able to achieve a value of 0 for relative standard deviation.

7. Ideally, percent recovery would have a value of 100%. This would occur if our experimental hardness was exactly equal to the theoretical hardness. In the space underneath the table on the following page, exlain why we are not able to achieve a value of 100% for percent recovery.

Sample	Group 1	Group 2	Group 3	Mean	Standard Deviation	Relative Standard Deviation	Percent Recovery
100 $\frac{mg}{L}$ Mg							
100 $\frac{mg}{L}$ Ca							
50 $\frac{mg}{L}$ each, Mg and Ca							

6.)

7.)