Hard Water Lab

Thursday, September 23, 2021 10:56 AM

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Hard Water Lab.docx

Hard Water Lab Timeline:
1/24-25: Background and planning
1/26-27: Complete pre-lab and begin lab work
1/28 - 1/31: Lab work
2/1-2: Complete lab work and work on client letter
2/3-4: Client letter due at the beginning of class

Supplies and Materials:

- Erlenmeyer flasks
- Graduated cylinders
- Beakers
- Funnel
- Filter paper
- Balances

- Deionized water
- Water samples (200 L concentrated to 1 L) - may contain up to 200 mg $CaCl_2$ per 10 mL of sample
- 0.1M Na_2CO_3 solution

What Makes Hard Water Hard?

Central Challenge

Samples of tap water have been collected from faculty members who live in different cities, and counties. Some are from municipal water sources; others are from wells. The water will be analyzed for their quantities of water hardness through principles of metal ion precipitation and separation.

Context for This Investigation

When relocating, there are many factors that go into choosing where to buy a house. One of those factors is water quality – it is advantageous to find a location where a water softener will *not* be needed. Hard water costs more for detergent, plumbing repairs, and appliance maintenance and replacement. Having water that is already soft is preferred to installing a water softening system. You, the students, will identify which of the areas around King County have the lowest hard water quantities by ranking the hardness of the water in the areas.

Safety and Disposal

All solutions can be rinsed down the drain. Normal laboratory precautions, including always wearing goggles, should be taken as these solutions may be harmful if swallowed and can irritate the eyes.

Prelab Guiding Questions/Simulations

1. Watch the following video:
http://www.youtube.com/watch?v=YcZSNcaHHN8&feature=youtube_gdata_player
After watching the video, describe what you believe to be "hard water."

2. Examine some ways that water can be softened. Some helpful sites include, but are not limited to:
http://www.chem1.com/CQ/hardwater.html
https://www.ag.ndsu.edu/publications/home-farm/water-softening-ion-exchange

3. Using the SDS, identify the potential health risks and the appropriate measures for first aid for the following chemicals and write them into your lab notebook:

- **a.** calcium chloride
- **b.** sodium chloride
- **c.** sodium carbonate, anhydrous

4. Answer the following in your lab notebook: What minimum volume (in mL) of 0.5 M Na_2CO_3 solution is needed to completely react with 220 mg of $CaCl_2$?

Explanation to Strengthen Student Understanding

Have you ever had difficulty lathering soap or find that the scum in your shower constantly needs to be removed? These are signs of “hard water.” Soap does not lather well in hard water because metal ions, such as Ca^{2+}, form precipitates, creating “soap scum.” A *precipitate* is an insoluble compound that forms when soluble ions in separate solutions are mixed. Because this happens, soap is a less effective cleanser in hard water. Even laundry can appear dingy or feel rough when washed in hard water.

While these metal ions are generally harmless, hard water has other disadvantages, such as “boiler scale.” Boiler scale is a scaly buildup of calcium carbonate, $CaCO_3$, produced when the calcium ions in hard water have precipitated with dissolved carbonate ions, $CO3^{2-}$. This scale can build up on the inside of water pipes and coffee makers. One of the biggest problems boiler scale creates is that it reduces the operating efficiency in water heaters. Even a thin layer of scale inside a water heater can reduce the energy efficiency by 10 percent or more. Scale can also result in the failure of boiler tubes as they become clogged. Once these insoluble salts form a deposit, other metal ions present in the water can become bound to the deposit, increasing the thickness of the boiler scale layer.

The best way to control the formation of boiler scale is through water pretreatment, such as installing a water softener. Water softeners typically replace the Ca^{2+} ions with soluble Na^{+} salts. Other water softeners cause the calcium carbonate to form before the water is circulated to the water heater. Because metal ions enter water when it travels through rocks and soil en route to a home, the amount of water hardness varies. When the hard water within your home is 120–150 mg/L as $CaCO_3$, it is recommended that a water softener is installed. If the hardness falls between 60–120 mg/L as $CaCO_3$, the hardness is considered acceptable (moderately hard) and no water softener is needed.

Hard water can contain various metal ions, including Ca^{2+}, Mg^{2+}, and Fe^{3+}. To fully determine the hardness of the water, each ion must be isolated separately. When a particular ion species, an *analyte*, needs to be isolated, it is possible to use the tendency of that ion to form an insoluble compound by a precipitation reaction.

When the analyte ion is formed into a precipitate, it can be collected through a process called *gravimetric analysis*, during which the precipitate is isolated, purified, dried, and weighed. From the mass and the known composition of the precipitate, the amount of the analyte in the original solution can be calculated stoichiometrically. When done properly, gravimetric analysis provides an extremely precise quantitative analysis of the analyte. Since hard water is commonly expressed as the milligrams of $CaCO_3$ per liter of solution, the quantity of Ca^{2+} in the water identifies how hard the water is. This analyte can be isolated by mixing it with a solution of Na_2CO_3 to form the slightly soluble salt $CaCO_3$.

$$Ca^{2+}\ (aq) + Na_2CO_3\ (aq) \rightarrow 2\ Na^{+}\ (aq) + CaCO_3\ (s)$$

When completing a gravimetric analysis, an important consideration is that the analyte is completely precipitated. This can be accomplished by ensuring that the analyte acts as the limiting reactant in the precipitation reaction. Once the salt has precipitated, it can be collected through filtration. All the impurities should be removed from the precipitate through washing and drying.

Investigation helpful hints

Students should determine the unknown quantity of Ca^{2+}, as milligrams of $CaCO_3$ per Liter of solution, in a water sample by designing their own procedure.

You may perform the optional practice with known quantities for the hard water lab to help determine an estimated percent yield. With the assumption that your technique is consistent, you can use that percent yield with your hard water sample to determine concentration of Ca^{2+} in your hard water unknown sample. You can do BOTH of these on the same day so that they can dry overnight together.

Students should consider what data are needed to obtain the concentration of the Ca^{2+} ions; this should be clearly exhibited in the step-by-step procedure and the creation of their data table. They should present a detailed, step-by-step procedure, a list of materials needed, and a data table for measurements and observations.

Procedures should indicate how the sodium carbonate solution will be used in excess, as well as how often and for how long the precipitate will be dried. Once teachers have approved the students' proposed procedures, they may begin the data collection.

Procedure

Students will design their own procedures. Students should use the materials provided them but should check before deciding to use additional materials.

Data Collection and Computation

Students must answer the following questions in their analysis.

1. How many grams of precipitate was collected?
2. What is the hardness, in mg/L as $CaCO_3$, of the water sample evaluated? (Note: samples have been concentrated from 200 L of sample.)