Water hardness

Keywords: hard water, soap, soft water

Meta Description

The formation of lather on the addition of soap with water is an easy and practical method for a comparative review on water hardness.

Learning Objectives

To get familiar with the different classifications of water.

To be able to understand the role of soap in distinguishing hard from soft water.

To understand how water hardness can be removed.

Key Terms

Epsom salt

A powder of magnesium sulfate

Hard water

Water has a relatively high amount of minerals, mainly magnesium and calcium carbonates which make it difficult for lather to form.

Limescale

A chalky hard white substance mainly of calcium carbonate ($CaCO_3$)

Permanent hardness

The hardness that will not be removed by boiling. Consist of chlorides, nitrate and sulfates of calcium and magnesium.

Temporary hardness

Hard water that is easily turned into soft water by boiling. It consists of dissolved magnesium and calcium ions.

Soft water

Water that has no calcium or magnesium salts dissolved.

Method

Step 1

Fill the bottles with equal amounts of distilled water.

Step 2

To one of the bottles add 2 teaspoons of Epsom salts. Seal the bottle with the cap and shake vigorously for a few seconds.

Step 3

Remove the cap from the bottle and add a few drops of dishwashing detergent to each bottle.

Step 4

Seal both bottles with their caps and shake them both vigorously for a few seconds.

Step 5

Place both bottles on the table and observe what happens.

Alternative Method

Try different amounts of Epsom salts in each bottle and see how that affects the amount of lather produced.

Try leaving the bottles of Epsom salts to settle for different times before adding the soap and shaking, do you see any difference in the amount of lather produced?

Precautions

Ensure the caps are on tightly before you shake the bottles

Avoid touching your face while doing this experiment, if you get soap in your eye, wash face with lukewarm clean water.

Narrative

Have you ever been on holiday or a different area and drank a glass of water, to notice that it tastes different to what you are used to? This might be due to the minerals which are dissolved in the water, as a result of the geology and rocks that the water had passed through during the water cycle, also known as “Hard water”. You decide to try and make a cup of tea with the water, and you slowly notice that some grey crust is developing inside of the kettle. This is the dissolved minerals in the water leaving solution and settling on the kettle. But is there a way to determine if the water is hard or soft without tasting it?

Questions

What is the difference between soft and hard water?
Hard water has minerals such as magnesium and calcium ions while soft water does not.

Name the two types of water hardness.
Temporary and permanent hardness

What is the difference between temporary and permanent water?
One consists of dissolved calcium/magnesium hydrogen carbonate and one of calcium/magnesium sulfate respectively.

How to remove temporary hardness?

By boiling the water to form a layer of limescale.

How to remove permanent hardness?

By ion exchange resin

How is soap helpful in distinguishing between the two?
Soap form lather in soft water and a cloudy solution in hard water.

Brief Explanation

Have you ever noticed that sometimes lather does not seem to form when you are cleaning with soap?

This is because of the hardness characteristic of water, the difference between hard and soft water is determined by the amount of mineral content dissolved within the water, mainly calcium and magnesium. When present in water, these minerals combine with soap and prevent any lather from forming. Therefore, soap only lathers in hard water once it has reacted with all of the calcium and magnesium ions, in other words, when the water becomes soft.

To distinguish between hard and soft water, the lack of lather formation from detergent can be a quick and easy test.

Detailed Explanation

After the experiment, the difference between the two bottles should be very clear. The bottle which had the Epsom salts was added to it will have less bubbles compared to the bottle without Epsom salts.

Hard water is produced when magnesium or calcium ions are dissolved in the water. Initially the water is distilled, meaning that the water is pure and would have no additional solutes present, however, when you add Epsom salt and shake the water, you are dissolving magnesium ions into the water. These magnesium ions react with the detergent added to form lime soaps or soap scum which is insoluble. Lime soaps will prevent lather from forming and also is not useful in the washing process. This means that hard water requires a larger amount of soap to form any lather. In addition to this, the use of hard water can also reduce the effectiveness of appliances that use water, due to the formation of scale. Soft water does not contain magnesium or calcium in any significant amounts that would hinder the function of the detergent.
http://www.water-research.net/index.php/water-treatment/tools/hard-water-hardness

$M^{2+} + 2C_{17}H_{35}COONa$ (sodium stearate/ soap) ==== $(C_{17}H_{35}COO)_2 M$ (soap scum) + $2Na^+$

Where M is either Mg or Ca

There are two types of water hardness, temporary and permanent hardness. Temporary hardness happens when the water has dissolved bicarbonate minerals as calcium hydrogen carbonate Ca(HCO3)2 and magnesium hydrogen carbonate Mg(HCO3)2, which can be removed by the addition of washing soda or simply by boiling to form limescale (CaCO3).

Permanent hardness has dissolved calcium sulfate in the water and is relatively more difficult to remove. Boiling the water will not be enough, instead, an ion exchange resin is needed to reduce this type of water hardness. Ion-exchange resin consists of sodium ions that exchange their place with the calcium ions present in the hard water. The resin has to be charged over a period of time.

http://www.bbc.co.uk/schools/gcsebitesize/science/triple_ocr_gateway/chemistry_out_there/hardness_of_wa

Applications and Research

Applications

Water is an essential resource that obviously has a wide range of applications, in domestic, industrial, and even agricultural function. However, hard water can be problematic in the industry as it increases the chance of breakdowns in boilers and cooling towers.
https://en.wikipedia.org/wiki/Hard_water
It is important to monitor water hardness used in industrial processes, as low calcium levels in water can result in cause corrosion of metal equipment, which would eventually need to be resurfaced. On the other hand, high calcium levels result in limescale to build up in pipes and plumbing, which can cause blockages. http://www.lamotte.com/en/blog/test-factors/75-measuring-water-hardness

Research

Water treatment technologies focus on removing undesired contaminants from water, such as metal and minerals. Bioremediation technology is a developing process in which the contaminants are eliminated in an eco-friendly manner by biological catalyzes, like fungi. The organisms bind with the metal ions and eliminate them from the water. In such studies, the influence of pH, calcium concentration, and the temperature was investigated to determine the optimum conditions for toxic metals removal by three different fungal species.
http://oaji.net/articles/2017/2154-1489116400.pdf

Investigation

Try it with different types of water as rainwater, tap water, and seawater, and see if there is a difference in the number of bubbles produced.

Boil some tap water and compare the hardness between boiled and unboiled tap water. Boiled water should have some of its hardness removed hence form more lather than unboiled tap water.

Add more Epsom salt and notice the difference. The more one adds the fewer bubbles are formed.

Subject

Chemistry

Education

Primary
Secondary
Informal

Time Required

~10 minutes
Preparation: 2 mins
Conducting: 5 mins
Clean Up: 2 mins

Cost

0 – 10 €

Recommended Age

6 – 9
10 – 12
13 – 16

Number of People

1 participant

Supervision

Required

Location

Indoors
Laboratory

Materials

2 empty plastic bottles with caps
Epsom salts
Dish washing liquid
Distilled water

Contributors

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Sources

Chemistry for engineers page 83 by Dr. B.K. Ambasta

To Test for Water Hardness, Soap Test

Hard vs Soft Water Soap Test

Hard & Soft Water | Environmental Chemistry | Chemistry | FuseSchool

Learn How To Turn Hard Water Into Soft Water | Environmental Chemistry | Chemistry | FuseSchool

IonExchange

Additional Content

Hard water (Beginner)

Hard & Soft Water | Environmental Chemistry | Chemistry | FuseSchool (Intermediate)

Water Softening (Advanced)

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