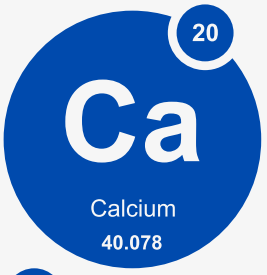
TOTAL HARDNESS

Community Science Institute
Partnering with Communities to Protect Water

WHAT IS TOTAL HARDNESS?

Total hardness refers to the concentration of dissolved minerals, mainly calcium and magnesium, in water. *Hard water* has a *high* concentration of these dissolved minerals, while *soft water* has a *lower* concentration. Total hardness calculates the concentration of both minerals, which are measured in milligrams of calcium carbonate ($CaCO_3$) equivalent per liter.



WHY DO WE MEASURE TOTAL HARDNESS?

Hard water can be good for aquatic organisms. The minerals associated with hard water are important for the formation of skeletal structures in fish larvae. Some research also demonstrates an association between harder water and mitigation of heavy metal toxicity in fish!

Like the water quality indicator alkalinity (see CSI's Alkalinity Fact Sheet for more information), water hardness can be impacted by the surrounding geology in an area. More limestone in the environment, for instance, tends to correspond to higher alkalinity and harder water.

You may have heard about water hardness as an issue in your home; many people install water softeners to avoid hard water. In this context, hard water can mean more soap is needed to form a lather or calcium deposits are left on dishes. This can be an issue for pipes and appliances, which can form buildup from hard water. However, consuming hard water does *not* negatively impact human health. The U.S. Geological Survey divides water hardness into the following categories (concentration of $CaCO_3$ equivalent):

soft: <60 mg/L
moderately hard: 61 - 120 mg/L
hard: 121 - 180 mg/L
very hard: >180 mg/L

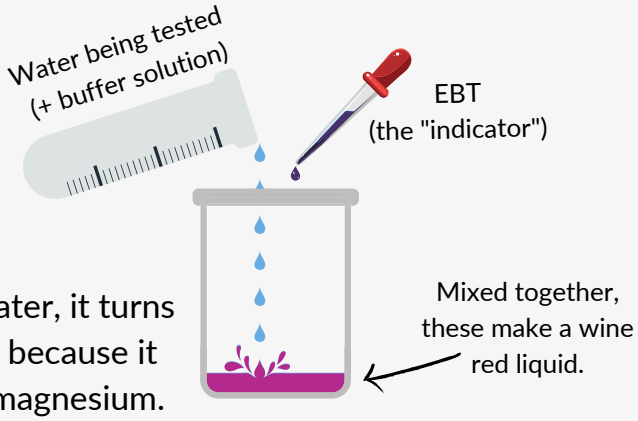
December 2023

HOW DO WE MEASURE TOTAL HARDNESS?

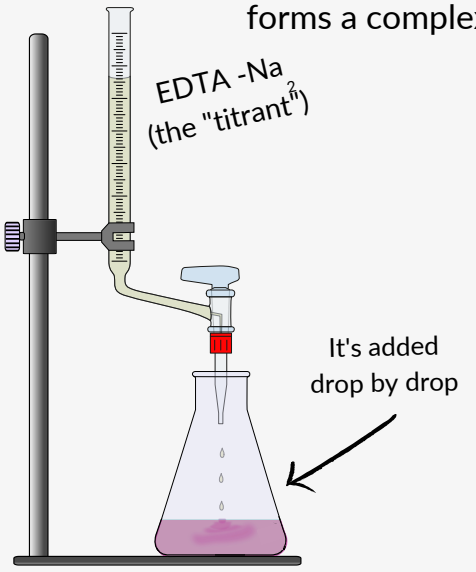
Total hardness is measured using a laboratory test that employs a buffer, an indicator, and a titrant, as illustrated below.

First, a solution called a “buffer,” made of ammonium chloride and ammonium hydroxide, is added to the water sample. The buffer raises the pH of the sample to around 10 (making it more basic). Raising the pH is important to the color change that occurs later in the test. At a high pH, the “indicator,” which is added next, will naturally be blue when magnesium and calcium are not present.

Next, a substance called “Eriochrome Black T” (EBT) is added to the water being tested for total hardness. EBT is called an "indicator" because it will cause a visible change to our mixture when the test is complete.



Though EBT is blue in more basic water, it turns the liquid wine red during this step because it forms a complex with calcium and magnesium.

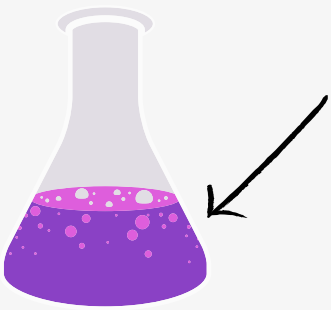


Then, a compound called EDTA disodium salt (EDTA -Na_2) is added to the mixture drop by drop.

EDTA forms a *more stable complex* with the calcium and magnesium in the water sample than the indicator (EBT) did. As the calcium and magnesium bond with the EDTA instead of the EBT, the liquid changes color. Remember, EBT is blue at a high pH when it is *not* in a complex with calcium and magnesium.

Eventually, all of the calcium and magnesium in the water have bonded to the EDTA being added.

Once this happens, the remaining indicator in the water mixture (EBT) makes the liquid turn purplish blue instead of wine red!



From there, CSI chemists calculate the **concentration of calcium carbonate ($CaCO_3$)** equivalent in the water based on how much titrant (EDTA) was needed to bind to all of the calcium and magnesium to turn the mixture purplish blue.