

# Gravimetric Analysis of Calcium and Hard Water

## AP® Chemistry Big Idea 1, Investigation 3

### An Advanced Inquiry Lab

#### Introduction

In certain areas of the country, the presence of hard water poses significant problems in water supply systems. Various water softening techniques are used to remove the cations responsible for water hardness. This investigation involves the application of gravimetric analysis to test samples for the amount of water hardness and calcium ions.

#### Concepts

- Water hardness
- Double replacement reactions
- Gravimetric analysis
- Stoichiometry

#### Background

Water from natural sources may contain a number of dissolved substances. The amount and nature of these dissolved substances varies depending on the geography of the area and the journey the water has taken. As water travels through the ground or over the surface of the land, it can dissolve naturally occurring minerals. As minerals dissolve in the water, the compounds separate into their respective cations and anions. Common cations in water include  $\text{Na}^+$ ,  $\text{Ca}^{2+}$  and  $\text{Mg}^{2+}$ , and  $\text{Fe}^{3+}$ , while the principal anions in water are  $\text{Cl}^-$ ,  $\text{HCO}_3^-$ ,  $\text{NO}_3^-$ , and  $\text{SO}_4^{2-}$ . The main ions contributing to water hardness are  $\text{Ca}^{2+}$ ,  $\text{Mg}^{2+}$  and, to a lesser extent,  $\text{Fe}^{3+}$ . Their presence makes it difficult for soaps to lather and also causes a "scum" to form. Equation 1 (where R is a long hydrocarbon chain) shows the precipitation reaction between alkyl sulfate anions in a typical soap with calcium ions in hard water. The main problem due to water hardness in industrial pipes or boilers is the buildup of solid  $\text{CaCO}_3$ , which precipitates out and causes thick deposits to form in pipes and other appliances.



There are many different ways to "soften" water. One of the most common ways to remove ions is by ion exchange. The ion exchange process uses a resin to replace some of the ions that cause hardness with ions that do not. Hardness is commonly measured in units of grains per gallon or milligrams per liter (also known as parts per million), and is classified by the U.S. Department of the Interior and the Water Quality Association as follows:

Classification	mg/L or ppm	grains/gal
Soft	0–17.1	0–1
Slightly hard	17.1–60	1–3.5
Moderately hard	60–120	3.5–7.0
Hard	120–180	7.0–10.5
Very Hard	180 and over	10.5 and over

Although several ions contribute to water hardness, the units of mg/L or ppm are defined in terms of the equivalent mass (milligrams) of  $\text{CaCO}_3$  that would be present per liter of water. In this investigation, gravimetric analysis will be used to precipitate and isolate solid  $\text{CaCO}_3$  from water samples and determine water hardness. Many municipal water treatment plants use soda

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**Jane D. Smith, George R. Hague**



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