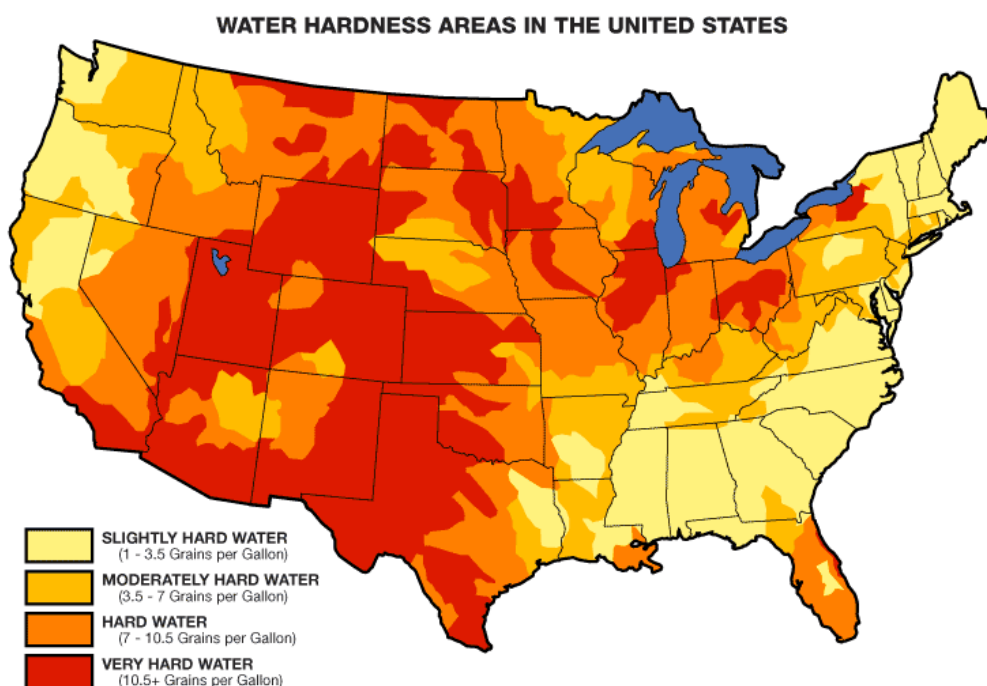


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Water Hardness Reading

Water in different parts of the United States varies in the amount of dissolved mineral ions it contains. This determines whether it is hard or soft water. There are advantages and disadvantages to each, but the damage that can be caused to water pipes and appliances by hard water means that water may need to be softened.



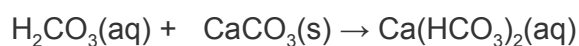
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Hard and soft water

Rainwater is naturally weakly *acidic* because it contains carbonic acid, formed by the reaction between water and carbon dioxide in the atmosphere. When the rain falls, it flows over rocks or soaks into the ground and then passes through layers of rock. *Compounds* from the rocks dissolve into the water.

Hard water contains dissolved compounds, usually calcium or magnesium compounds. For example, limestone contains calcium carbonate, CaCO_3 . Carbonic acid in rainwater reacts with this to produce soluble calcium hydrogencarbonate:

carbonic acid + calcium carbonate \rightarrow calcium hydrogencarbonate



¹ "Water Hardness Map of the United States - H2O Distributors." 2010. 12 Jun. 2014
<<http://www.h2odistributors.com/water-hardness.asp>>

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Water Hardness Reading

The presence of calcium *ions* and magnesium ions in the water makes it hard. *Soft water* readily forms lather with soap, but it is more difficult to form lather with hard water. The dissolved calcium ions and magnesium ions in hard water react with the soap to form *scum*, so more soap is needed. Soapless detergents do not form scum with hard water.

The types of rocks found in different regions determines how hard or soft the water will be.

The water in some parts of the country is soft because it has low levels of dissolved calcium and magnesium compounds, while the water in other parts of the country is hard because it has higher levels of dissolved calcium and magnesium compounds.

There are varying degrees of hardness in water - from slightly hard to very hard.

Measuring hardness

One way to measure the hardness in water is to perform a *titration* with soap solution.

A known volume of water is put into a conical flask. Soap solution is added to it from a burette or pipette. The mixture is swirled to help it form lather. The volume of soap solution that needs to be added to form permanent lather is recorded. The harder the water, the greater the volume of soap solution needed.

The benefits and drawbacks of hard water

You need to be able to evaluate the environmental, social and economic aspects of water hardness.

Hard water has some benefits compared to soft water. For example, the dissolved calcium compounds in hard water:

- can improve the taste of the water
- are good for the development and maintenance of bones and teeth
- can help to reduce heart disease

But hard water also has some drawbacks compared to soft water. For example:

- More soap is needed to produce lather, which increases costs. This happens with temporary or permanent hardness.
- The scum produced is unsightly - spoiling the appearance of baths and shower screens, for example.

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Water Hardness Reading

- Temporary hardness can reduce the efficiency of kettles and heating systems. This is because limescale (a solid containing calcium carbonate) is produced when the water is heated. It coats the heating element in kettles, and the inside of boilers and hot water pipes. This means more energy is needed to heat the water, again increasing costs. Pipes may become blocked by limescale - causing the heating system to break down.

Softening hard water

The damaging effect that hard water can have means that it may be beneficial to soften the water. Methods for softening hard water involve the removal of calcium *ions* and magnesium ions from the water.

There are two methods for softening hard water:

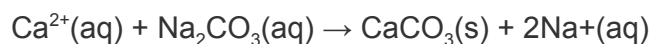
- adding sodium carbonate to the water
- using ion exchange columns

Adding sodium carbonate

Sodium carbonate, Na_2CO_3 , is also known as **washing soda**. It can remove temporary and permanent hardness from water. Sodium carbonate is soluble but calcium carbonate and magnesium carbonate are insoluble.

The carbonate ions from sodium carbonate react with the calcium and magnesium ions in the water to produce *insoluble precipitates*. For example:

calcium ions + sodium carbonate → calcium carbonate + sodium ions



The water is softened because it no longer contains dissolved calcium ions and magnesium ions. It will form lather more easily with soap.

However, the calcium carbonate and magnesium carbonate precipitates to form *limescale*. As well as being unsightly on your taps, it can also clog up pipes in heating systems (causing them to break down). This makes treatment with sodium carbonate suitable for softening water **only** in certain circumstances - such as softening water for hand washing clothes.

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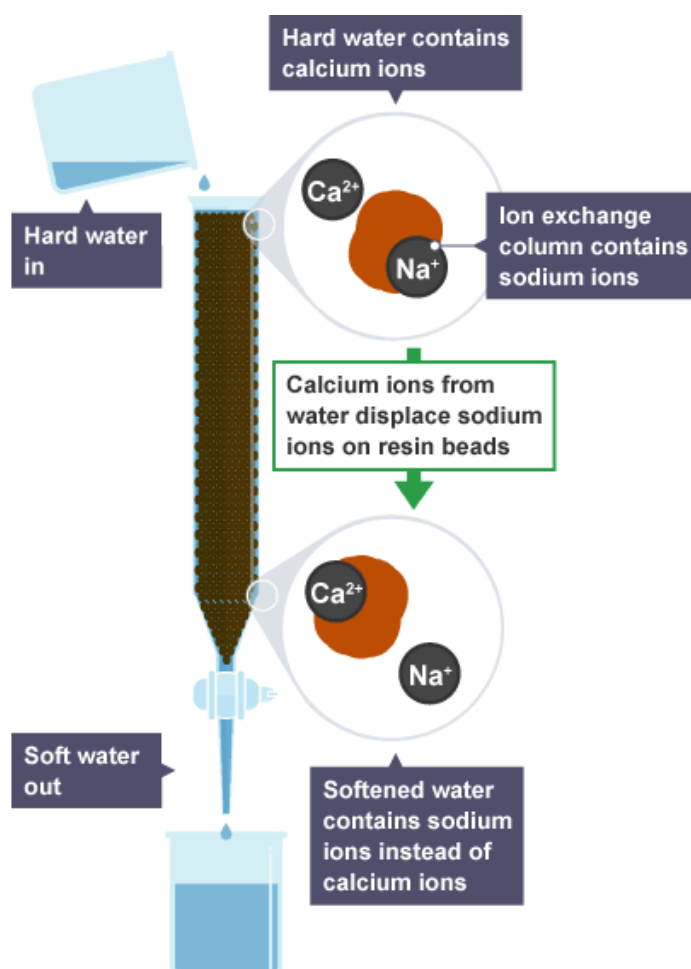
Water Hardness Reading

Ion exchange columns

Commercial water softeners often use ion exchange *resins*. These substances are usually made into beads, which are packed into cylinders called **ion exchange columns**. These can be built into machines, such as dishwashers, or plumbed into water systems to continuously soften the water.

The resin beads have sodium ions attached to them. As the hard water passes through the column, the calcium and magnesium ions swap places with the sodium ions.

The calcium and magnesium ions are left attached to the beads, while the water leaving the column contains more sodium ions. The hard water is softened because it no longer contains calcium or magnesium ions. Some ion exchange resins use hydrogen ions instead of sodium ions.



An ion exchange column: calcium ions in hard water get replaced with sodium ions to produce soft water

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Water Hardness Reading

Once the resin beads in **dishwashers** become saturated with calcium and magnesium ions, they must be *regenerated* by adding sodium chloride (common salt). The sodium ions it contains replace the calcium and magnesium ions on the beads. Sodium chloride is cheap and widely available, making this a convenient and cost-effective system.²

Questions

1) Find where you live on the map and state what type of water your area has.

2) How does water become hard? What causes this?

3) How can you tell the difference between hard and soft water?

4) How can you soften water? Briefly explain how each of the two methods works.

² "BBC - GCSE Bitesize Science - Hard and soft water : Revision." 2013. 12 Jun. 2014

<http://www.bbc.co.uk/schools/gcsebitesize/science/triple_aqa/water/hard_soft_water/revision/1/>