1.3 Water: Hardness in Water and Solubility

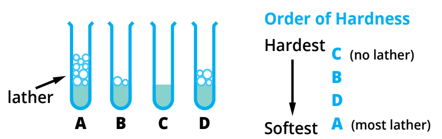
wjec cbac

Hardness in Water:

- Hardness in water is caused by dissolved **calcium (Ca^{2+}) and magnesium (Mg^{2+})** ions.
- These ions come from minerals that dissolve as the water passes slowly through soil and rocks and into underground sources.
- These ions are **not removed** during the water treatment processes because they are dissolved **in the water**.

Measuring Hardness:

Hardness in water is measured using **soap solution**. Hard water **does not** easily form a lather when shaken with soap solution.



To ensure a fair test

- same volume of each sample
- same volume of soap
- shake for the same length of time.

- The method can be inaccurate because:
  - » the lather quickly disappears
  - » it is difficult to ensure consistent shaking.
- A variation on this method is to measure the **volume of soap solution needed** to produce a **permanent lather** with each sample.
- Comparing results **before and after boiling** each sample also allows identification of permanent and temporary hardness.

Hardness – Good or Bad?

- There are advantages and drawbacks to living in an area where the water is hard:

Advantages

- Strengthens teeth and bones
- Lowers risk of heart disease
- Improves brewing and baking
- Better taste

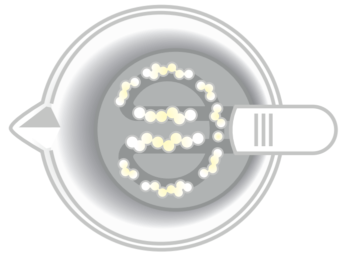
Negative effects

- Forms limescale on appliances
- Furs up pipes
- Reduces efficiency of appliances
- Wastes soap

Temporary Hard Water:

- Temporary hard water is caused by dissolved **calcium hydrogencarbonate** or **magnesium hydrogencarbonate**.
- When the water is boiled, the hardness is removed as the hydrogencarbonate decomposes.

calcium hydrogencarbonate	→	calcium carbonate	+	water	+	carbon dioxide
$Ca(HCO_3)2$ (aq)		$CaCO_3$ (s)		H_2O (l)		CO_2 (g)



*Calcium carbonate forms when the water is boiled. It is **insoluble** and forms **limescale** on kettles and in pipes.*

Permanent Hard Water:

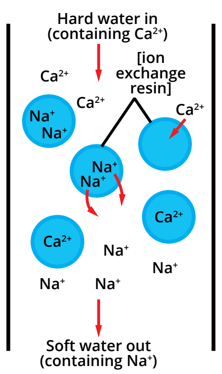
- Permanent hardness is caused by dissolved **calcium sulfate** or **magnesium sulfate**. It can be removed in two ways.

Washing soda

Washing soda contains **sodium carbonate**, Na_2CO_3. *When added to permanent hard water, the carbonate ions react with the dissolved calcium ions, forming a **precipitate** of **calcium carbonate**.*

Ca^{2+} (aq) (from the water)	+	CO_3^{2-} (aq) (from the washing soda)	→	$CaCO_3$ (s) (limescale)

- The large quantities of washing soda used makes this an **expensive method**. It also leads to the formation of limescale and its problems!



Ion exchange

*The hard water continually passes through the column. Each calcium (or magnesium) ion is exchanged for **two sodium ions**.*

This technique is more convenient than using washing soda because it is **continuous**. However, ion-exchange columns are expensive, and the resin often needs **regenerating with salt solution**.

Solubility:

- Solubility is a measurement of **how much solute can be dissolved** in a fixed volume of a solvent.

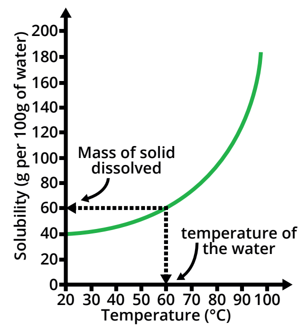
Term	Meaning
Solution	Mixture where a solid has been dissolved in a liquid
Solute	The solid that gets dissolved
Solvent	The liquid that dissolves the solid
Soluble	Able to dissolve
Saturated	When no more solid can be dissolved

Measuring Solubility:

To find the solubility of a solute, add a **known excess** mass of solute to a **fixed volume of water** at the required temperature (not all will dissolve). Filter, dry and weigh the excess solute to determine how much has dissolved.

Solubility Curves:

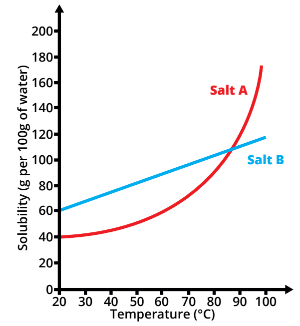
- Every solute has a fixed solubility at a given temperature



The solubility usually increases as the temperature of the water increases.

A solubility curve is used to show how the solubility of a solute changes with temperature. It can be used to find the mass of crystals formed when a solution is cooled.

- Solubility curves can be used to **compare the solubilities of different solutes**



The curves show that:

- The solubility of both salts increases as temperature increases.
- As temperature increases, the solubility of salt A increases more than that of salt B.
- The solubility of both salts is the same where the curves cross (approximately 110g per 100g of water at about 85°C).

Note – solubility is usually measured over a range from 0-100°C because that is the range when water is a liquid!