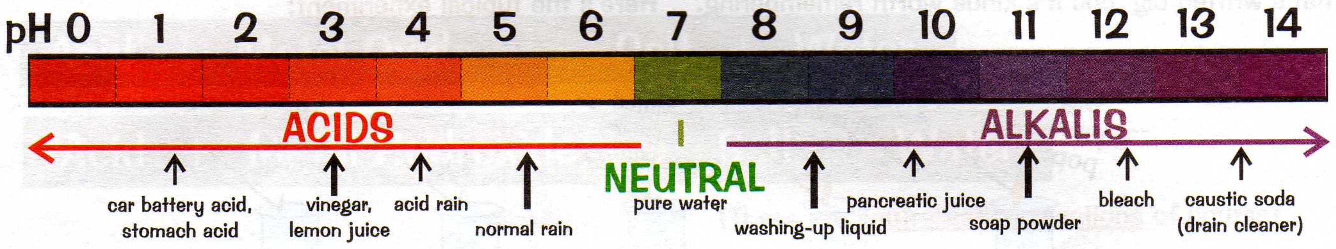
Acids and Alkalis

Testing the pH of a solution means using an indicator — and that means pretty colours...

The pH Scale Goes From 0 to 14

1) The pH scale is a measure of how acidic or alkaline a solution is.
2) The strongest acid has pH 0. The strongest alkali has pH 14.
3) A neutral substance has pH 7 (e.g. pure water).



An Indicator is Just a Dye That Changes Colour

The dye in the indicator changes colour depending on whether it's above or below a certain pH.
Universal indicator is a combination of dyes which gives the colours shown above.
It's very useful for estimating the pH of a solution.

Acids and Bases Neutralise Each Other

An ACID is a substance with a pH of less than 7. Acids form H^+ ions in water.
A BASE is a substance with a pH of greater than 7.
An ALKALI is a base that dissolves in water. Alkalis form OH^- ions in water.
So, H^+ ions make solutions acidic and OH^- ions make them alkaline.

The reaction between acids and bases is called neutralisation. Make sure you learn it:

$$\text{acid} + \text{base} \rightarrow \text{salt} + \text{water}$$

Neutralisation can also be seen in terms of H^+ and OH^- ions like this, so learn it too:

$$H^+_{(aq)} + OH^-_{(aq)} \rightarrow H_2O_{(l)}$$

Hydrogen (H^+) ions react with hydroxide (OH^-) ions to produce water.

When an acid neutralises a base (or vice versa), the products are neutral, i.e. they have a pH of 7.
An indicator can be used to show that a neutralisation reaction is over (Universal indicator will go green).

State Symbols Tell You What Physical State It's In

These are easy enough, so make sure you know them — especially aq (aqueous).

(s) — Solid (l) — Liquid (g) — Gas (aq) — Dissolved in water

E.g. $2Mg_{(s)} + O_{2(g)} \rightarrow 2MgO_{(s)}$

Interesting(ish) fact — your skin is slightly acidic (pH 5.5)...

The neutralisation reaction's a great one to know. If you have indigestion, it's because you've got too much hydrochloric acid in your stomach. Indigestion tablets contain bases that neutralise some of the acid.

Hardness of Water

Water where you live might be hard or soft. It depends on the rocks your water meets on its way to you.

Hard Water Makes Scum and Scale

1) With soft water, you get a nice lather with soap. But with hard water you get a nasty scum instead — unless you're using a soapless detergent. The problem is dissolved calcium ions and magnesium ions in the water (see below) reacting with the soap to make scum which is insoluble. So to get a decent lather you need to use more soap — and because soap isn't free, that means more money going down the drain.
2) When heated, hard water also forms furring or scale (mostly calcium carbonate) on the insides of pipes, boilers and kettles. Badly scaled-up pipes and boilers reduce the efficiency of heating systems, and may need to be replaced — all of which costs money. Scale can even eventually block pipes.
3) Scale is also a bit of a thermal insulator. This means that a kettle with scale on the heating element takes longer to boil than a clean non-scaled-up kettle — so it becomes less efficient.

Hardness is Caused by Ca^{2+} and Mg^{2+} Ions

1) Most hard water is hard because it contains lots of calcium ions and magnesium ions.
2) Rain falling on some types of rocks (e.g. limestone, chalk and gypsum) can dissolve compounds like magnesium sulfate (which is soluble), and calcium sulfate (which is also soluble, though only a bit).

Hard Water Isn't All Bad

1) Ca^{2+} ions are good for healthy teeth and bones.
2) Studies have found that people who live in hard water areas are at less risk of developing heart disease than people who live in soft water areas. This could be to do with the minerals in hard water.

Remove the Dissolved Ca^{2+} and Mg^{2+} Ions to Make Hard Water Soft

There are two kinds of hardness — temporary and permanent.
Temporary hardness is caused by the hydrogencarbonate ion, HCO_3^-, in $Ca(HCO_3)_2$.
Permanent hardness is caused by dissolved calcium sulfate (among other things).

1) Temporary hardness is removed by boiling. When heated, the calcium hydrogencarbonate decomposes to form calcium carbonate which is insoluble. This solid is the 'limescale' on your kettle.

   e.g. calcium hydrogencarbonate → calcium carbonate + water + carbon dioxide

   $$Ca(HCO_3)_{2(aq)} \rightarrow CaCO_{3(s)} + H_2O_{(l)} + CO_{2(g)}$$

   This won't work for permanent hardness, though. Heating a sulfate ion does nowt.
2) Both types of hardness can be softened by adding washing soda (sodium carbonate, Na_2CO_3) to it. The added carbonate ions react with the Ca^{2+} and Mg^{2+} ions to make an insoluble precipitate of calcium carbonate and magnesium carbonate. The Ca^{2+} and Mg^{2+} ions are no longer dissolved in the water so they can't make it hard.

   e.g. $Ca^{2+}_{(aq)} + CO_3^{2-}{}_{(aq)} \rightarrow CaCO_{3(s)}$
3) Both types of hardness can also be removed by running water through 'ion exchange columns' which are sold in shops. The columns have lots of sodium ions (or hydrogen ions) and 'exchange' them for calcium or magnesium ions in the water that runs through them.

   e.g. $Na_2Resin_{(s)} + Ca^{2+}_{(aq)} \rightarrow CaResin_{(s)} + 2Na^+_{(aq)}$

   ('Resin' is a huge insoluble resin molecule.)

And if the water's really hard, you can chip your teeth...

Hard water — good thing or bad thing... Well, it provides minerals that are good for health, but it creates an awful lot of unnecessary expense. All in all, it's a bit of a drag. But you still need to learn it.

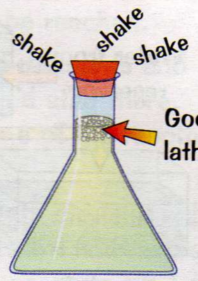
Hardness of Water

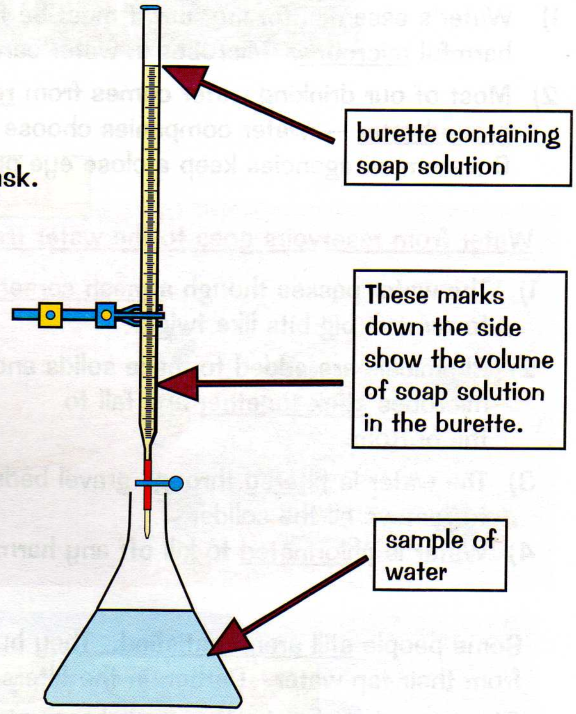
If you live in an area of hard water you might already know about it because you sometimes get a grimy layer of scale floating on the top of your tea and you get through more shampoo than you can shake a stick at...

You Can Use Titration to Compare the Hardness of Water Samples

Method

1) Fill a burette with 50 cm^3 of soap solution.
2) Add 50 cm^3 of the first water sample into a flask.
3) Use the burette to add 1 cm^3 of soap solution to the flask.
4) Put a bung in the flask and shake for 10 seconds.
5) Repeat steps 3 and 4 until a good lasting lather is formed. (A lasting lather is one where the bubbles cover the surface for at least 30 seconds.)
6) Record how much soap was needed to create a lasting lather.
7) Repeat steps 1-6 with the other water samples.
8) Next, boil fresh samples of each type of water for ten minutes, and repeat the experiment.





Results

This method was carried out on 3 different samples of water — distilled water, local tap water and imported tap water. Here's the table of results:

Sample	Volume of soap solution needed to give a good lather	
	using unboiled water in cm^3	using boiled water in cm^3
Distilled	1	1
Local water	7	1
Imported water	14	8

The results tell you the following things about the water:

1) Distilled water contains little or no hardness — only the minimum amount of soap was needed.
2) The sample of imported water contains more hardness than local water — more soap was needed to produce a lather.
3) The local water contains only temporary hardness — all the hardness is removed by boiling. You can tell because the same amount of soap was needed for boiled local water as for distilled water.
4) The imported water contains both temporary and permanent hardness. 8 cm^3 of soap is still needed to produce a lather after boiling.
5) If your brain's really switched on, you'll see that the local water and the imported water contain the same amount of temporary hardness. In both cases, the amount of soap needed in the boiled sample is 6 cm^3 less than in the unboiled sample.

My water's harder than yours...

One thing that I've never understood is that they sell water softeners in areas that already have soft water. Hmm... Anyhow, the usual message here. There is an exam coming up, and any of this hard water stuff could be on it. Read through any experimental data they give you carefully — don't drop the easy marks.

Water Quality

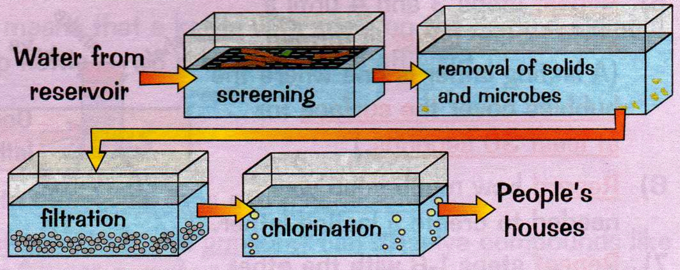
It's easy to take water for granted... turn on the tap, and there it is — nice, clean water. The water you drink's been round the block a few times — so there's some fancy chemistry needed to make it drinkable.

Drinking Water Needs to Be Good Quality

1) Water's essential for life, but it must be free of poisonous salts (e.g. phosphates and nitrates) and harmful microbes. Microbes in water can cause diseases such as cholera and dysentery.
2) Most of our drinking water comes from reservoirs. Water flows into reservoirs from rivers and groundwater — water companies choose to build reservoirs where there's a good supply of clean water. Government agencies keep a close eye on pollution in reservoirs, rivers and groundwater.

Water from reservoirs goes to the water treatment works for treatment:

1) The water passes though a mesh screen to remove big bits like twigs.
2) Chemicals are added to make solids and microbes stick together and fall to the bottom.
3) The water is filtered through gravel beds to remove all the solids.
4) Water is chlorinated to kill off any harmful microbes left.



Some people still aren't satisfied. They buy filters that contain carbon or silver to remove substances from their tap water. Carbon in the filters removes chlorine taste and silver is supposed to kill bugs. Some people in hard water areas buy water softeners which contain ion exchange resins (see p.78).

Totally pure water with nothing dissolved in it can be produced by distillation — boiling water to make steam and condensing the steam. This process is too expensive to produce tap water — bags of energy would be needed to boil all the water we use. Distilled water is used in chemistry labs.

You'd use pure water to make a solution of (say) KBr, because you wouldn't want any other ions mucking it up.

Adding Fluoride and Chlorine to Water Has Disadvantages

1) Fluoride is added to drinking water in some parts of the country because it helps to reduce tooth decay. Chlorine is added to prevent disease (see above). So far so good. However...
2) Some studies have linked adding chlorine to water with an increase in certain cancers. Chlorine can react with other natural substances in water to produce toxic by-products which some people think could cause cancer.
3) In high doses fluoride can cause cancer and bone problems in humans, so some people believe that fluoride shouldn't be added to drinking water. There is also concern about whether it's right to 'mass medicate' — people can choose whether to use a fluoride toothpaste, but they can't choose whether their tap water has added fluoride.
4) Levels of chemicals added to drinking water need to be carefully monitored. For example, in some areas the water may already contain a lot of fluoride, so adding more could be harmful.

The water you drink has been through 7 people already...

Well, it's possible. It's also possible that the water you're drinking used to be part of the Atlantic Ocean. Or it could have been drunk by Alexander the Great. Or part of an Alpine glacier. Aye, it gets about a bit, does water. And remember... tap water isn't pure — but it's drinkable, and that's the main thing.