Teacher Tune-up

Quick Content Refresher for Busy Professionals

What is the difference between physical and chemical change?

Chemistry is the study of the transformation of matter. Broadly speaking, there are two such kinds of change: physical and chemical.

Physical changes alter materials without changing what substance they are. For example, when liquid water freezes or evaporates, it remains water. It just changes its **state** (or phase). State changes (between solid, liquid, and gas) are some of the most important kinds of physical change.

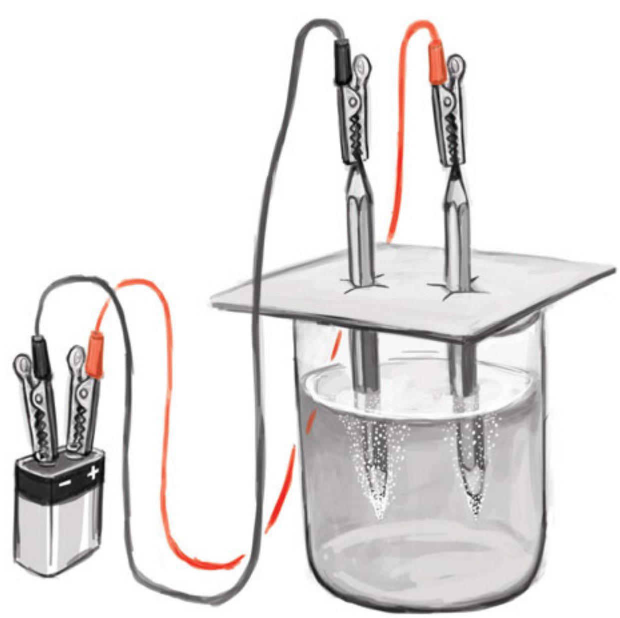
Other changes that leave a substance with the same chemical identity are also physical changes. The pressure of a gas can change without its chemical composition changing. If a block of ice breaks, it is still ice and it is still water. If a piece of wood is crushed and splintered, the cellulose and other chemicals in it don't change. These changes are all physical.

But if the same wood is burned, its cellulose is transformed into carbon dioxide, water, and other new chemicals. And if water is subjected to an electrical current so that H_2O molecules are broken apart and their atoms recombine into hydrogen gas and oxygen gas, that too is a chemical change. This so-called electrolysis reaction might look a bit like water boiling—bubbles are formed in the water—but it's entirely different.

Any list of macroscopically perceptible signs of a chemical reaction needs to be taken with a grain of salt. Potential signs that commonly appear in such lists include

- Change of color
- Production of light (as with fire)
- Change of temperature
- Production of gas
- Production of solid (as when a precipitate forms from liquid reactants)

But as you can see, some of these events can also occur in a state change. How do we know whether liquid water is boiling to produce steam or being electrolyzed to produce hydrogen and oxygen gas? We see bubbles in both cases, so we need to consider the wider context. Is the water heating up to its known boiling point? Production of heat is sometimes a sign of a chemical reaction, but in this case, production of bubbles in water *without* a dramatic rise in temperature argues in favor of electrolysis, a chemical change. (Of course, those two electrodes in the water hooked up to a nearby battery are another other big hint!)



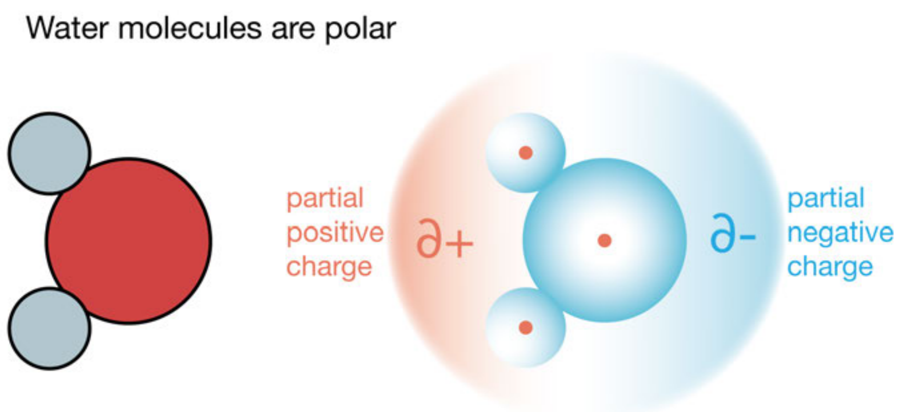
Simple electrolysis demonstration using pencils for electrodes (the graphite is electrically conductive and the wood is insulating) and a 9-volt battery. For best results, dissolve Epsom salt in water to improve conductivity.

The deeper distinction between physical and chemical change lies beyond the limits of our unaided senses. The question is, when matter changes, *which kinds of bonds are changing?* And that begs the question, *what kinds of bonds are there?*

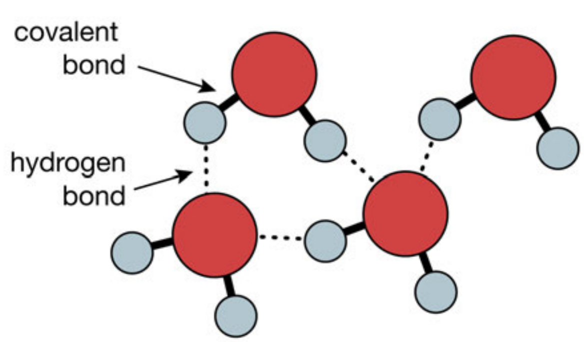
What kinds of bonds change in physical and chemical changes?

We need to consider the various kinds of connections between and within water molecules in order to understand what makes boiling a physical change and electrolysis a chemical change at the particulate level.

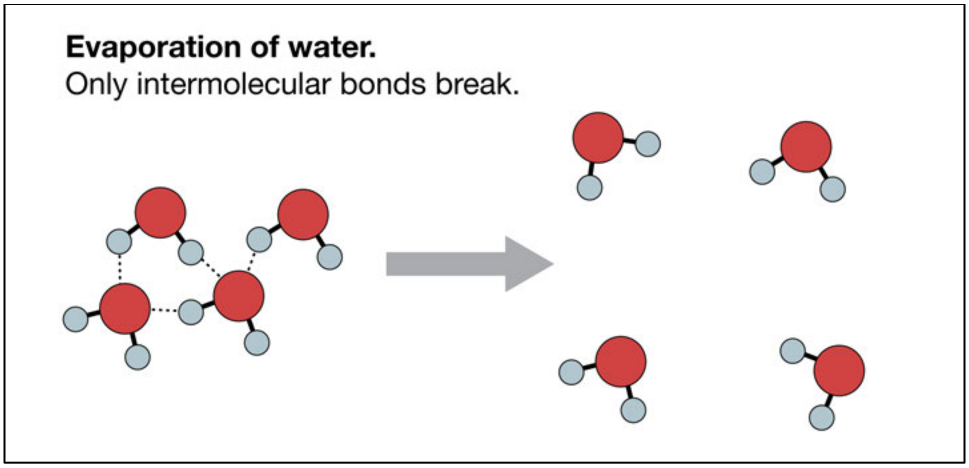
A water molecule is made of an oxygen atom bonded to two hydrogen atoms. These bonds are **covalent,** which means that the atoms are sharing electrons. (The atoms do this in order to obtain full, stable valence electron shells, as discussed in M1t2, “What does atomic structure have to do with how atoms bond with each other?”) In the case of water and certain other molecules, those bonding electrons are not shared equally. Instead, the oxygen atom pulls them a little closer than the hydrogen atoms do. This uneven sharing gives the oxygen side of a water molecule a slightly more negative charge than the hydrogen side of the molecule. This skewed electrical charge makes water a **polar** molecule. The ∂+ and ∂- (delta plus and delta minus) labels in the illustration bellow indicate that these charges are partial, i.e. lower in magnitude than an electron or a proton.

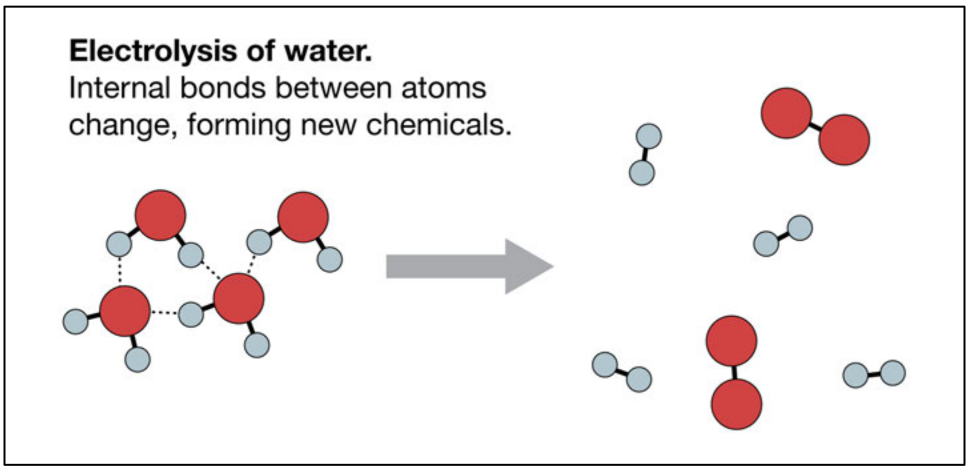


Because of their polarity, water molecules tend to stick to each other. The partial positive charges on the hydrogen atoms of water molecules are attracted to the partial negative charges on the oxygen atoms of neighboring molecules, an attraction known as **hydrogen bonding.**



Now we’re in a position to consider two different kinds of changes that water can go through: changes to its hydrogen bonds and changes to its covalent bonds. The hydrogen bonds are *intermolecular* bonds, bonds *between* the molecules. The covalent bonds are *internal* bonds, bonds *within* the molecules. If the intermolecular bonds change, we have a physical change. If the internal bonds change, we have a chemical change.





We can generalize from the example of water. When bonds between atoms *within* chemicals change, we have a chemical change. When intermolecular bonds change (leaving the basic chemical unit of a substance unchanged), we have a physical change.

Hydrogen bonds are a relatively strong kind of intermolecular bond, but there are others. Nonpolar molecules also experience intermolecular forces, but these tend to be much weaker. That is why nonpolar substances like oxygen gas and hydrogen gas are so much more volatile than water: they need to be extremely cold (or under extremely high pressure) in order to be able to cling to each other and condense into a liquid.