Solvent properties of water

Why water makes a good solvent, and what kinds of molecules dissolve best in it.

Introduction

Has life ever given you lemons? If so, you've no doubt followed the old adage and made lemonade - involving, of course, a lot of sugar! If you've stirred sugar into lemonade (or tea, or any other water-based drink) and watched it dissolve, then you've already seen the solvent properties of water in action. A **solvent** is simply a substance that can dissolve other molecules and compounds, which are known as **solutes.** A homogeneous mixture of solvent and solute is called a **solution**, and much of life's chemistry takes place in **aqueous solutions**, or solutions with water as the solvent.

Because of its polarity and ability to form hydrogen bonds, water makes an excellent solvent, meaning that it can dissolve many different kinds of molecules. Most of the chemical reactions important to life take place in a watery environment inside of cells, and water's capacity to dissolve a wide variety of molecules is key in allowing these chemical reactions to take place.

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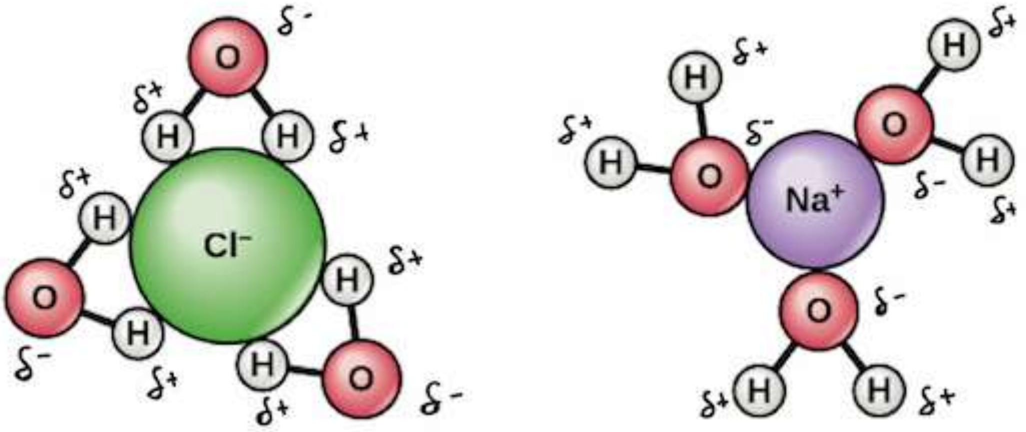
Thanks to its ability to dissolve a wide range of solutes, water is sometimes called the "universal solvent." However, this name isn't entirely accurate, since there are some substances (such as oils) that don't dissolve well in water. Generally speaking, water is good at dissolving ions and polar molecules, but poor at dissolving nonpolar molecules. (A **polar** molecule is one that's neutral, or uncharged, but has an asymmetric internal distribution of charge, leading to partially positive and partially negative regions.)

Water interacts differently with charged and polar substances than with nonpolar substances because of the polarity of its own molecules. Water molecules are polar, with partial positive charges on the hydrogens, a partial negative charge on the oxygen, and a bent overall structure. The unequal charge distribution in a water molecule reflects the greater electronegativity, or electron-greediness, of oxygen relative to hydrogen: the shared electrons of the O-H bonds spend more time with the O atom than with the Hs. In the image below, the partial positive and partial negative charges on a water molecule are represented by the symbols $\delta+$ and $\delta-$ respectively.

Because of its polarity, water can form electrostatic interactions (charge-based attractions) with other polar molecules and ions. The polar molecules and ions interact with the partially positive and partially negative ends of water, with positive charges attracting negative charges (just like the + and - ends of magnets). When there are many water molecules relative to solute molecules, as in an aqueous solution, these interactions lead to the formation of a three-dimensional sphere of water molecules, or **hydration shell**, around the solute. Hydration shells allow particles to be dispersed (spread out) evenly in water.



Water molecules forming hydration shells around Na+ and Cl- ions. The partially positive ends of the water molecules are attracted to the negative Cl- ion, while the partially negative ends of the water molecules are attracted to the positive Na+ ion.

Image modified from "Water: Figure 3," by OpenStax College, Biology (CC BY 3.0).

How does the formation of a hydration shell cause a solute to dissolve? As an example, let's consider what happens to an ionic compound, such as table salt (NaCl), when it's added to water.

If you stir table salt into water, the crystal lattice of NaCl will begin to dissociate into Na^+ and Cl^- ions. (**Dissociation** is just a name for the process in which a compound or molecule breaks apart to form ions.) Water molecules form hydration shells around the ions: positively charged Na^+ ions are surrounded by partial negative charges from the oxygen ends of the water molecules, while negatively charged Cl^- ions are surrounded by partial positive charges from the hydrogen ends. As the process continues, all of the ions in the table salt crystals are surrounded by hydration shells and dispersed in solution.

Nonpolar molecules, like fats and oils, don't interact with water or form hydration shells. These molecules don't have regions of partial positive or partial negative charge, so they aren't electrostatically attracted to water molecules. Thus, rather than dissolving, nonpolar substances (such as oils) stay separate and form layers or droplets when added to water.