WATER FORMS HYDROGEN BONDS

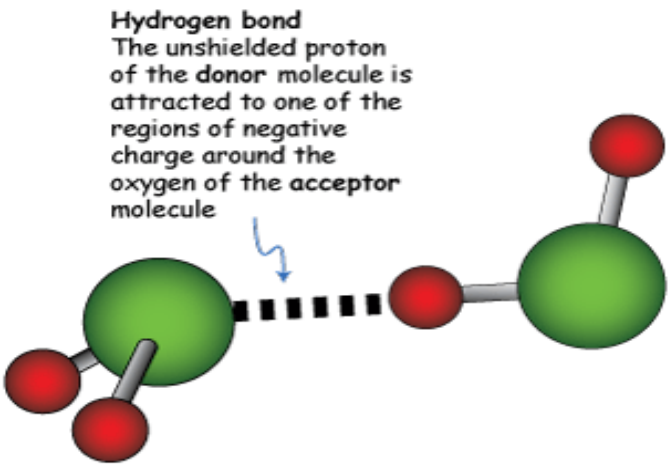
The charge distribution of water lends to the easy formation of **hydrogen bonds**. Hydrogen bonding among water molecules and between liquid water and **solutes** has profound implications on all kinds of chemistry. The near **tetrahedral** geometry of that charge distribution also gives solid water (ice) a beautiful hexagonal crystal structure.

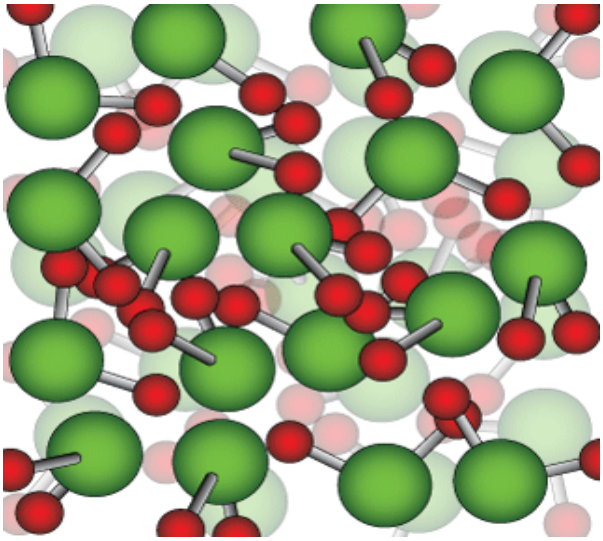
A Hydrogen Bond

In certain experiments, two water molecules, bound together by a hydrogen bond, have been observed unperturbed by any surrounding molecules. The structure of the water **dimer** looks something like this →

The distance between oxygen atoms is about 3.5Å (1Å = 10^{-10} m). A hydrogen bond is weak compared to a covalent bond: The H-bond energy is less than 1/10 of the energy of the O-H bond in water.

The water molecule that contributes its proton to the H-bond is called the H-bond **donor**, the other the **acceptor**.





Liquid Water: Transient H-bonds

In the liquid phase, water molecules possess enough **kinetic energy** (the energy of movement) to easily break H-bonds just by their constant motion. But the closeness of the molecules in the liquid, and the fact that each water can form four H-bonds at once (two as donor, two as acceptor), makes re-formation of H-bonds very likely.

In the liquid, H-bonds between water molecules are constantly forming and re-forming — they are **transient**. On average, each water has at least one H-bond to another at any given instant.

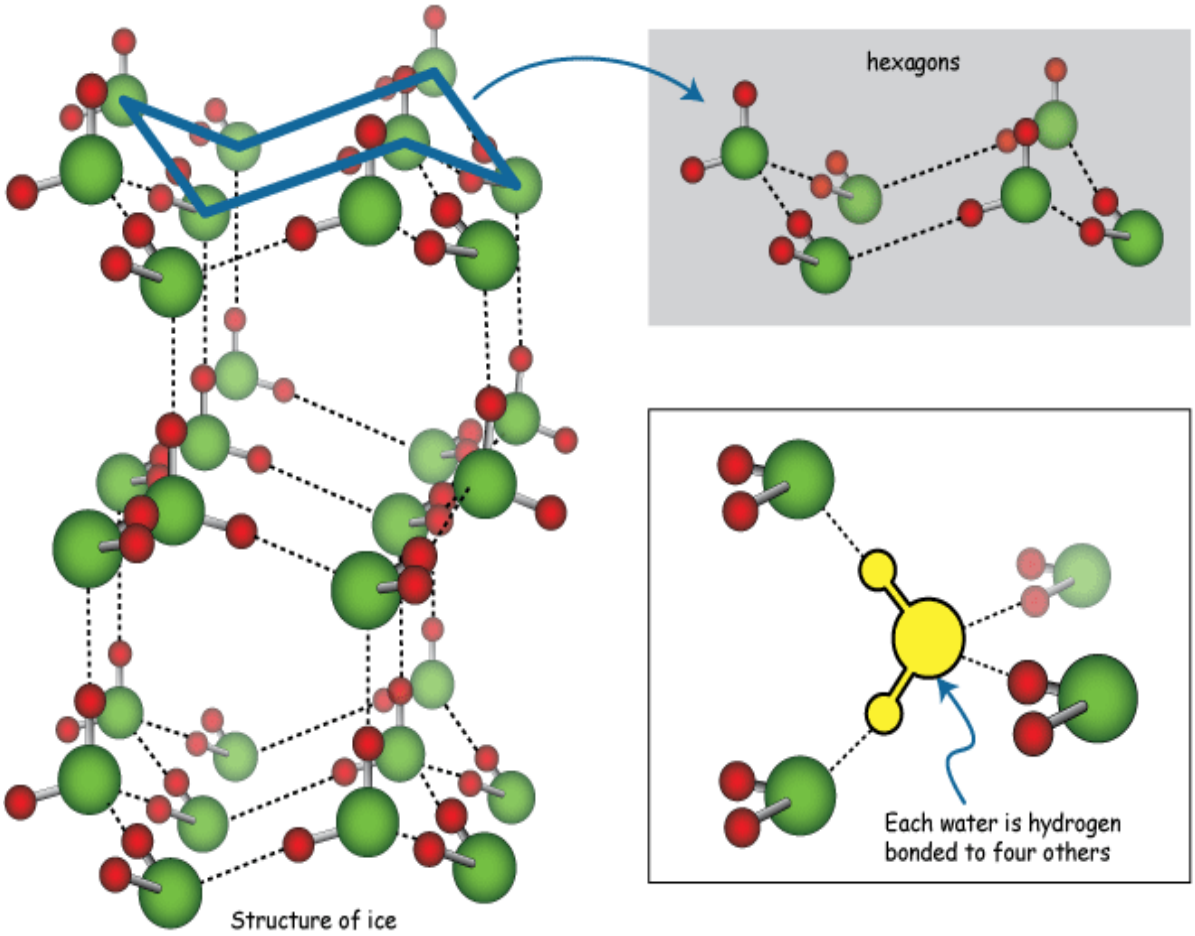
As we remove energy from water, the molecules slow down.
They **translate** and **rotate** much more slowly. At temperatures close to room temp., they are already vibrating about as slowly as they can.

Ice: H-bonds locked in

Water turns to **ice**, its solid form, when enough energy has been removed that small vibration and rotations of the molecules can no longer overcome the (relatively low) strength of the hydrogen bonds. Each water molecule is bonded to four others in a near-tetrahedral arrangement (lower right, below). Water ice has a hexagonal structure. Along many directions, six-membered rings of water molecules (upper right in the figure below) can be identified.

Most substances can exist in gas, liquid and solid forms. When most substances fuse into their solid forms, they become more dense than the liquid. Solid iron sinks in liquid iron; solid CO_2 (dry ice) sinks in liquid CO_2, and so on, because the solid is more dense than the liquid. But when water freezes it becomes *less* dense than its liquid. As you are aware, ice *floats* on liquid water.

That is so because formation of the extensive H-bonding network creates a lot of open space in the ordered crystal lattice of ice. In fact, the maximum density of water occurs at about 4˚C.



Source: http://www.drcruzan.com/Water.html