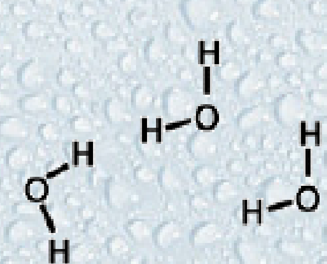
Changes in State and Latent Heat

Physical States of Water   Latent Heat

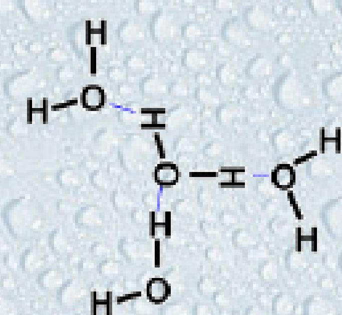
Physical States of Water

The three physical states of matter that we normally encounter are solid, liquid, and gas. Water can exist in all three physical states at ordinary temperatures on the Earth's surface.



When water is in the vapor state, as a gas, the water molecules are not bonded to each other. They float around as single molecules.

When water is in the liquid state, some of the molecules bond to each other with hydrogen bonds. The bonds break and re-form continually.



When water is in the solid state, as ice, the molecules are bonded to each other in a solid crystalline structure. This structure is six-sided, with each molecule of water connected to four others with hydrogen bonds. Because of the way the crystal is arranged, there is actually more empty space between the molecules than there is in liquid water, so ice is less dense. That is why ice floats.

Latent Heat

Each time water changes physical state, energy is involved.

In the vapor state, the water molecules are very energetic. The molecules are not bonded with each other, but move around as single molecules. Water vapor is invisible to us, but we can feel its effect to some extent, and water vapor in the atmosphere is a very important factor in weather and climate.

In the liquid state, the individual molecules have less energy, and some bonds form, break, then re-form. At the surface of liquid water, molecules are continually moving back and forth from the liquid state to the vapor state. At a given temperature, there will be an equilibrium between the number of molecules leaving the liquid, and the number of molecules returning.

In solid water--ice--the molecules are locked together in a crystal structure: a framework. They are not moving around, and they contain less energy.

How do you make water evaporate? Here is a bowl of water. Make the water evaporate. Go ahead.

How did you make the water evaporate? Probably you added heat. You might have set it out in the sun, or possibly put it over a fire. To make water evaporate, you put energy into it. The individual molecules in the water absorb that energy, and get so energetic that they break the hydrogen bonds connecting them to other water molecules. They become molecules of water vapor. Evaporation is the change of state from liquid to vapor. In the process of evaporation, the molecule absorbs energy. This energy is latent heat. Latent means hidden, so latent heat is "hidden" in the water molecule--we can't feel it, but it is there. Wherever that individual molecule of water vapor goes, it takes that latent heat with it. To get the molecule of water vapor to become liquid again, we have to take the energy away, that is, we have to cool it down so that it condenses (condensation is the change from the vapor state to the liquid state). When water condenses, it releases latent heat.

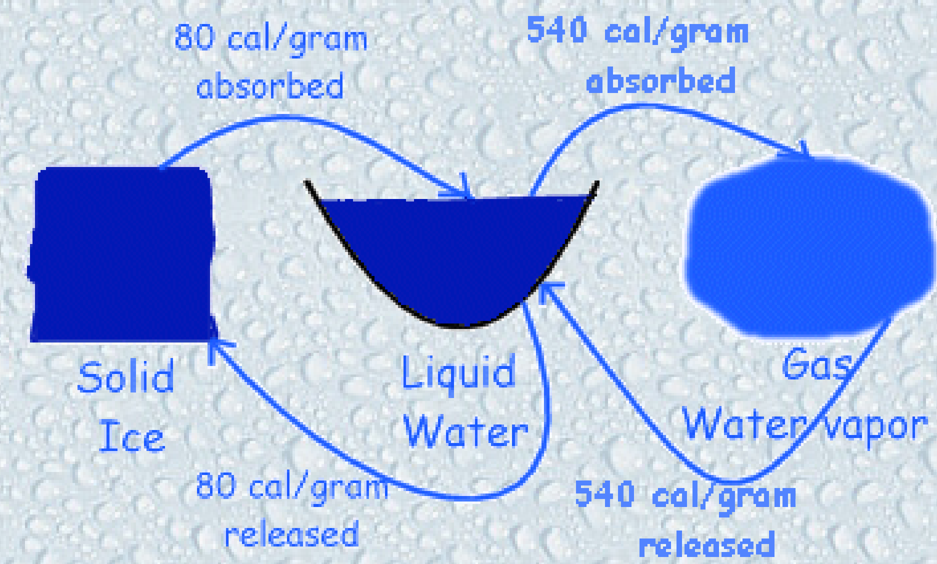
Now, how do you make ice melt? Here is a block of ice, water in the solid state. Make it melt. Go ahead.

Again, you probably melted the ice by adding energy. The additional energy was absorbed by the individual molecules of water, which became so energetic that they broke some of the hydrogen bonds holding the ice crystal together, and became liquid (that is, the ice melted). This energy is also latent heat, and each molecule of the liquid water is holding that latent heat. To change the liquid water back to ice, you have to take that latent heat away, or in other words, cool the water.

Water could change directly from the frozen state to the vapor state without passing through the liquid state first. This process is called sublimation. Water can also change from the vapor state to the frozen state without passing through the liquid state. This is usually called deposition, and is what you see when frost forms on grass or windows on a cold night. (Sometimes the term sublimation is used when water changes state in either direction, that is, from solid to vapor, or vapor to solid).

The really important thing to remember is that each time water changes state, energy is absorbed or released. This energy is latent heat. Latent heat is the energy absorbed or released when a substance changes its physical state. Latent heat is absorbed upon evaporation, and released upon condensation to liquid (as in clouds). Latent heat is also absorbed when water melts, and released when it freezes.

How much heat does it take to get water to change state? If the water is at a temperature of 100 degrees C (that is, the boiling point, or 212 degrees F) it takes an additional 540 calories of heat to convert one gram of water from the liquid state to the vapor state. When the vapor converts to the liquid state, 540 calories of energy will be released per gram of water. If you are converting solid water (ice) to liquid water at 0 degrees C, it will require about 80 calories of heat to melt one gram of ice, and the 80 calories will be released when the liquid water is frozen to the solid state.



Water does not have to be at the boiling point to evaporate. If you don't believe this, set a pan of water out in the sun and watch it slowly disappear. The sun's heat is not boiling the water, but it is evaporating it. In a given amount of water at a given temperature, some molecules of water will have more energy than others, so some molecules will be able to evaporate, while others remain in the liquid state. The lower the temperature of the water, the more energy is required for evaporation. If the water is liquid at a temperature of 0 degrees C, the latent heat of vaporization is 597 cal/g, compared to 540 cal/g at 100 degrees C. In between, at 50 degrees C, an input of 569 cal/g would be required for evaporation.

It will take a total of about 720 calories per gram to sublimate water, that is change it directly from ice at 0 degrees C, to vapor at 100 degrees C: this includes 80 calories from latent heat of fusion (melting) + 100 calories to raise the temperature of the water 100 degrees C + 540 calories to make the liquid water evaporate (latent heat of vaporization). Similarly, about 720 calories per gram will be released when water is changed directly from vapor to ice, the process called deposition.

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