

Microwaves and Water

You can do a startling experiment in a microwave oven with two Pyrex measuring cups, ice and water.

In one cup, put dry cubes of water ice that have been previously chilled in a deep freezer to remove any surface moisture. In the other cup put about an equal amount of tap water. After 90 seconds in the oven, remove the cups with oven mitts.

The water will be boiling but the ice cubes will not even have started to melt! In fact, if you look closely, you will see that needles of frost have grown on the ice cubes.

To understand why the ice did not melt, and how microwave ovens work, we need to know about water molecules.

They are smaller, by far, than the wavelengths of the light our eyes can detect and so we can never see an individual water molecule with our "very own" eyes.

One ice cube weighs about 18 grams and contains six hundred thousand billion billion water molecules (6 followed by 23 zeros or 6^{23}).

To get an idea of the shape of a water molecule, imagine cutting a ping-pong ball in half and gluing the halves, flat side down, on a tennis ball, like ears on a cat's head. The ping pong ball halves would represent the two hydrogen atoms, and the tennis ball, the oxygen atom, in the molecule of H_2O .

Atoms in the water molecules are glued together with pairs of electrons, the infinitely small units of negative electricity. These electrons are clustered around the big oxygen atom and this leaves a positive electrical charge on the small hydrogen atoms.

The positive (hydrogen) end of one water molecule attracts the negative (oxygen) end of a neighboring water molecule. Since there are two hydrogen atoms per molecule, each one can attract another water molecule and a whole 3D network of "sticky" water molecules is set up. This network holds the water molecules in place in the crystals of ice. They can vibrate but they do not move about. In liquid water, the network is constantly breaking up and reforming as the molecules tumble and collide.

Microwaves are alternating positive and negative electric fields. When they encounter liquid water, they cause the water molecules to tumble (rotate) faster and faster. This heats the water until it boils and the molecules escape from the liquid and form steam.

Microwaves cannot rotate the water molecules in ice because they are held tightly in the 3-D network of electrical attractions. So the ice cubes do not melt in the microwave oven. However, if the ice cubes get wet, then the heated wetness will melt them.

In microwave cooking, the heating is from the inside out because the food has liquid water in the centre. Professor of Engineering N. Kurti of Oxford University has invented a microwave dessert he calls "inverted baked Alaska". This has a gooey filling and a frozen icing so in the microwave oven, it bakes inside, but remains frozen outside. This is just the opposite of real baked Alaska where ice cream is coated with cake and baked in a regular oven without melting.