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ICE, ICE, BURNING HOT !

Water, perhaps the most abundant compound on earth, is peculiar in many ways, says S.Ananthanarayanan.

It is stable, free flowing, the water cycle sustains the earth as we know it, the first thing we ask about an alien world has to be whether it has water. Water dissolves more substances than any other and it is the base of cellular life, or life as we know it. Yet, it has peculiarities that set it apart and, incredible as it sounds, scientists have recently created a form of ice at many hundreds of degrees above boiling point!

Peculiarities

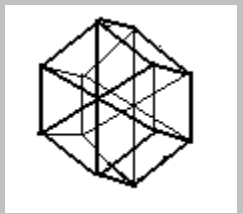
An important peculiarity of water is the way it behaves when it freezes. Like all other materials, in the gas form (vapour) and the liquid form, and even as ice, water normally expands when heated and contracts when cooled. But when liquid water is cooled nearly to freezing point, down to 4º C, it suddenly starts expanding! And it keeps expanding till it reaches 0º C, when it begins to freeze. The ice that forms at 0º C is thus bulkier, and hence less dense than water and that is the reason that icebergs float. A useful consequence is that when water in a pond cools below 4º C, the cool water stays on top and the depths of the pond stay warmer, for the fish to survive. This peculiar conduct of water, incidentally, is shared by iron, when it forms from the melt at 1535º C.

Pressure and temperature

Whether a substance will change from a liquid to solid (freezing) or vice versa (melting) or go from liquid to a vapour (evaporation) or vice versa (condensing) depends on the pressure and the temperature. If the pressure is high, the temperature of freezing gets depressed. This is the reason a knife can go through a slab of ice. The ice melts where the knife presses down and freezes back above the knife, where there is no pressure.

Conversely, in evaporation, it is when the pressure is low that water evaporates at a lower temperature. This is the reason that water boils at less than 100 0º C at high altitudes and alpinists have problems brewing tea!

Different forms of ice

The reason for the strange behaviour of water and ice is the atom-scale, crystal structure of the ice. The ice that we encounter, which is the most common form, has a crystalline shape made up of hexagons, or six sided shapes, as shown in the picture. It turns out that this is the shape that allows the hydrogen and oxygen atoms, of which water is made, to settle most efficiently as the water cools and the molecules display less agitation. And this shape happens to be more ‘spread out’ than the way the molecules are packed when the water is warmer.	

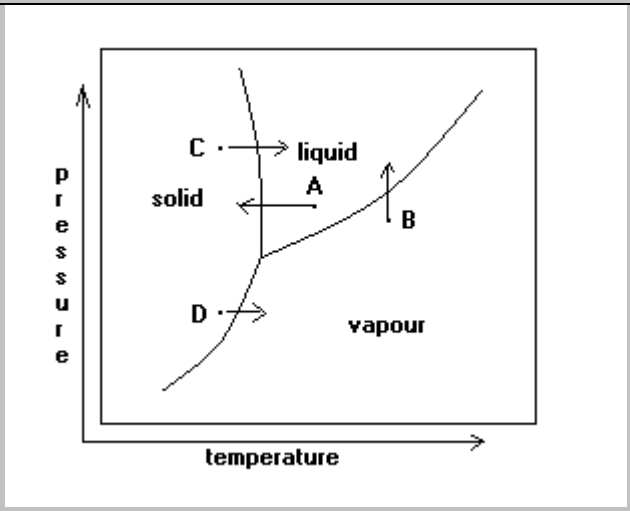
But once ice has formed, it behaves like any solid and packs closer as it cools and contracts when cooled.

But this is not the only form of ice. If ice is made to form at different temperatures and pressures, other crystal patterns are possible. In fact, 14 different forms are known, with different patterns and disposition of the hydrogen and oxygen atoms. Under tremendous pressures, for instance, there is a form of ice called ice VII, a 'cubic' crystal, which is the form which scientists have now produced at high temperatures. The common, hexagonal crystal type, incidentally, is the only kind of ice that is less dense than water. Hence if any other form of ice should melt, it would expand!

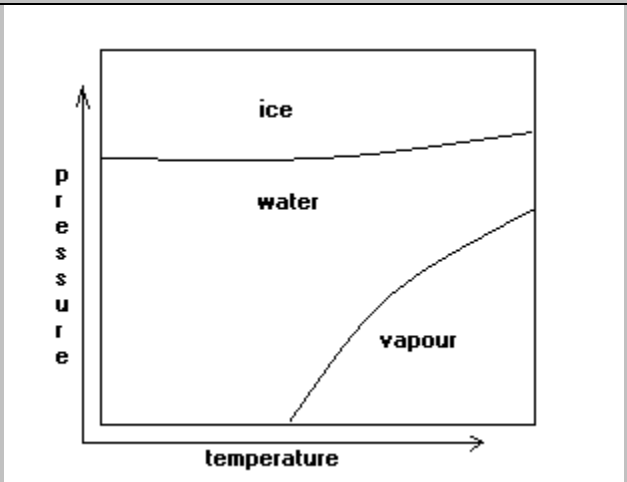
Phase change

The conditions when vapours change to liquids, liquids to solids or even vapours directly to solids (when water vapour forms frost, without the water stage) are studied with the help of diagrams like the one shown.

The lines represent the borders of areas of different phases. We can see that if solid at C is warmed, it changes to liquid. Vapour at B will condense if the pressure is increased. Liquid at A will freeze if cooled. But solid at D will go directly to vapour if warmed!



In the case of water, there is such a diagram for each form of ice involved. It is found that for ice VII, the diagram is something like the second picture.
In this, if the pressure is more than 70,000 times the pressure of the earth's atmosphere, ice VII could never find a way to expand and melt, no matter how hot! Conversely, if water, no matter how hot, is at just below this pressure, it would instantly freeze when the pressure is increased!



This is what has been done by scientists working with equipment to create ultra-high temperatures and pressures, towards attaining conditions for nuclear fusion. When water was compressed rapidly, it produced all the kinds of ice, except the common kind, which expands on freezing. And ice VII, when the pressure was increased beyond the critical value, formed in nanoseconds!