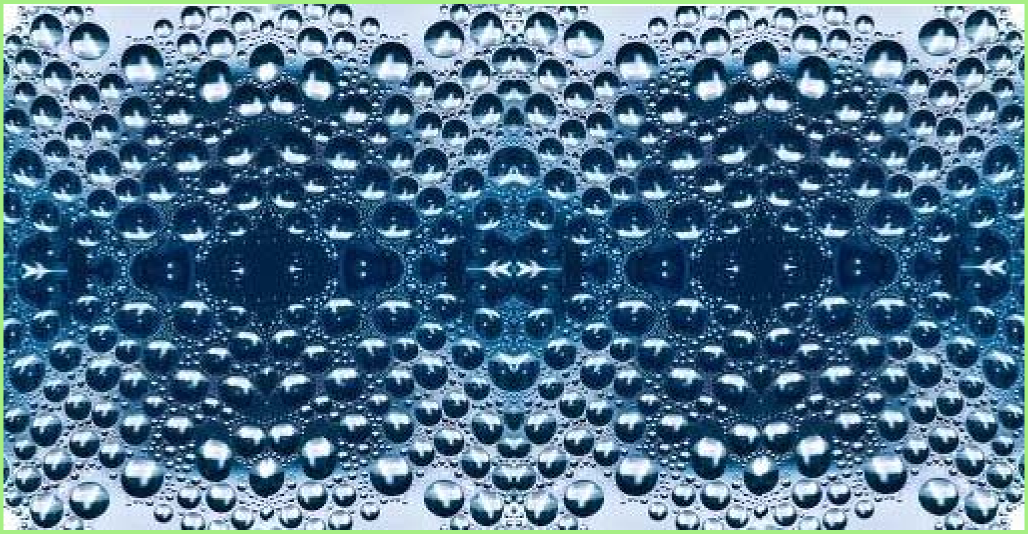
appeared on 6th Aug 2009



Liquids rock at the surface!

A property of matter in the liquid state has a lot to do with our world, says S.Ananthanarayanan.

The liquid state is an intermediate state - it comes between the solid and the gaseous states. For the very existence of life, which needs myriad chemical processes to take place, and still be confined within the body of an animal or plant, it is essential that important chemical components exist in the liquid state. If any planet is too cold, so that things are frozen, the chemical reactions cannot take place in that planet. If the planet is too hot and things are gases or vapours, then again, things like animals or plants cannot exist.

Atomic nature

The reason for this is that in the solid state, atoms are fixed and are not free to combine with other atoms. But when solids are heated and the atoms get more energetic, they break free, to flow like liquids and when heated even more, they fill the whole space available, as gases. And in the liquid or gas state, atoms and molecules are not confined and they can make liaisons with other atoms, through chemical reactions.

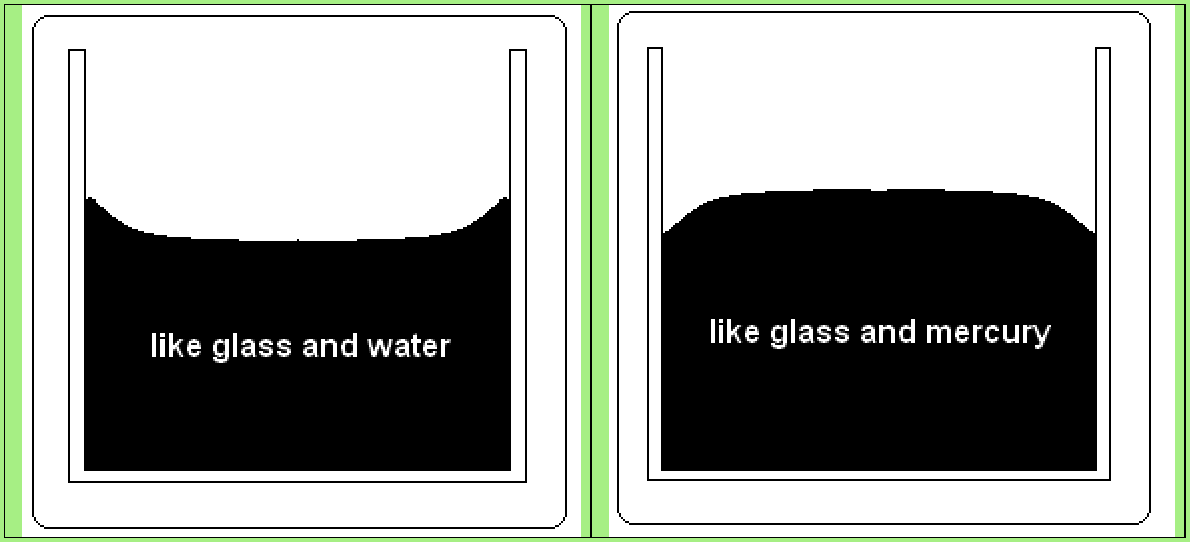
But of these two reactive states, the liquid state has the advantage of being of practically of fixed volume, confined by gravity and yet able to take the shape of an irregular container. Liquids are thus the more effective medium for life processes, which must take place within the confines of a body or plant.

Surface tension

One of the special properties of liquids is that they have unique upper surface. A solid can have any shape and a gas takes the full shape and space of its container. But a liquid, which also bends and fills voids, must remain rooted to the ground and its upper surface is horizontal. The reason that this happens is that the surface represents the combined attraction exerted by all molecules of the liquid on the surface and also the force of gravity, if any, on all molecules. The collection of molecules hence try to have the least possible energy of elevation against gravity and the shape that uses the least energy at the surface. Under gravity, this is the horizontal surface, and in free fall, it is the sphertical shape of the sphere.

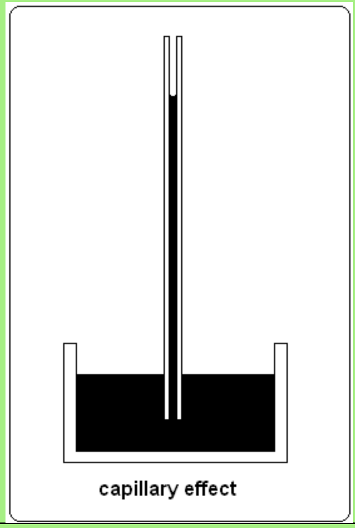
Contact with other materials

Where the surface of a liquid touches another material, like its container, the liquid faces another set of forces, of attraction or repulsion by the material of the container. When water is in a glass container, the force is attractive and the water edge likes to be close to the glass and tries to creep up the sides of the container. But the surface is also attached to the mass of water, which must stay down, by gravity, and the surface is a curve, as shown in the picture.



But when the liquid is not water but mercury, the force when in contact with glass is one of repulsion. The surface then tries to turn towards itself, rather than associate with glass, and the surface bulges like in the second picture. In the first case, the attraction for glass is kept down by gravity and in the second, the repulsion for glass tries to pull the mercury down and down and causes the middle to bulge.

Surface tension in nature



We can see that if the container is narrow, then the weight of the column of liquid to be supported is less. In narrow containers, then, the column is liquid can actually rise quite high, just because of the attraction of the liquid for the material of the container. This height of liquid column can become very large in the case of very narrow containers, or tubes called ***capillaries*** (from the Latin word for ***hair***).

This effect, in fact is what lifts the oil up the wick of a lamp or which causes a mop to draw water off the floor. A more widely encountered instance is the rising of the sap and nutrients up plants and trees, from the ground and up to the leaves, against the force of gravity. It is just this capillary effect that is the basis of all plant life!

Harnessing surface tension

A bird called the phalarope makes use of surface tension to its advantage. It is a slender necked shorebird with a long, narrow beak, which does not catch fish or larger prey and feeds on small insects or crustaceans. While foraging in a pond, the phalarope raises these nutrients to the surface by creating a small whirlpool by swimming in rapid circles. But how does the phalarope work these tidbits from the tip of its beak to its mouth?

It has been found that when the phalarope closes its beak around nutrient-rich water, the water moves up the beak and into the mouth by the force of surface tension! The phalarope has learnt to adjust the diameter of the tube that the beak forms in such a way that the water moves up and up, along with its load of insects. It has been shown that the effect is purely surface tension driven, not squeezing, like the action that moves food down the gullet or around the intestines.

Other uses

Other uses that nature makes of surface tension is the way some insects can walk on the surface of ponds. Their feet are coated so that they water does not ‘wet’ them and the surface resists deformation. There is one insect, in fact, that uses different levels of ‘wetting’ of its forefeet and hind feet, to use surface tension to move it along the surface, like an outboard motor!

Another interesting application of surface tension is in the alveoli, or tiny breathing cavities inside our lungs. Alveoli expand and fill with air when the outside pressure is reduced, when the diaphragm moves down. The question is, how do they stop expanding, why do they not expand so much that they rupture?

The answer is in surface tension. Alveoli are moist and expansion implies the increase in the extent of air–water interface, which is resisted unless the water ‘wets’ the alveoli surface. The cavities contain a ‘wetting’ agent that is concentrated when the cavity is small. But when the cavity expands, the concentration drops and surface tension increases, which stops the alveolus from growing too much!