Environmental Clean-up with “Frozen Smoke”.

A gel is a sort of inside out solid/liquid solution. In a regular solid/liquid solution, a solid material is dispersed throughout a liquid (for example, when you dissolve sugar in water, sugar molecules are spread throughout the water). In a gel, liquid is dispersed throughout a solid – all of the solid part is linked together, forming a kind of microscopic 3-D superstructure (a ‘skeleton’), and the liquid fills in the spaces. This solid structure gives the gel some of the rigidity of a solid – Jell-O is an example of a gel.

An aerogel is made by starting with a gel and then removing the liquid, leaving just the solid structure behind (air takes the place of the liquid). Most of the mass of a gel is due to the liquid, so removing the liquid leaves behind a very lightweight, 3-D solid skeleton (Fig. 1). The structure of the

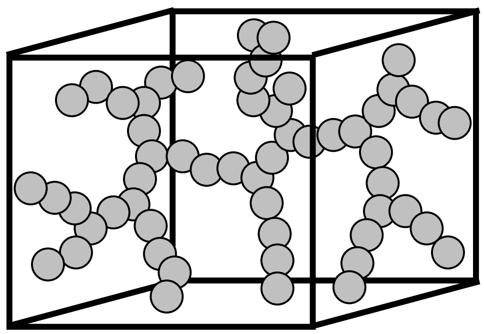

Fig. 1. The microscopic ‘skeleton’ structure of an aerogel.

solid is too small to see in detail, and looks like wispy smoke to the naked eye. Consequently aerogels are translucent and sometimes referred to as ‘frozen smoke’.

Aerogels have some very interesting properties; they are incredibly lightweight, consisting largely of air; they have a very low thermal conductivity (air is a poor conductor of heat); and the large amount of empty space inside them allows them to absorb liquids (and gases) like a sponge. It is the last property that is of particular interest to environmental scientists, who would like to use hydrophobic aerogels to soak up environmental oil spills.

The solid part of a hydrophobic aerogel is made from a material that repels water (like wax) because it is unable to form hydrogen bonds with water. Water molecules prefer to remain surrounded by other water molecules with which they *can* form strong hydrogen bonds (Fig. 2) rather than stick to the hydrophobic aerogel via much weaker London dispersion forces (LDF) (Fig. 3).

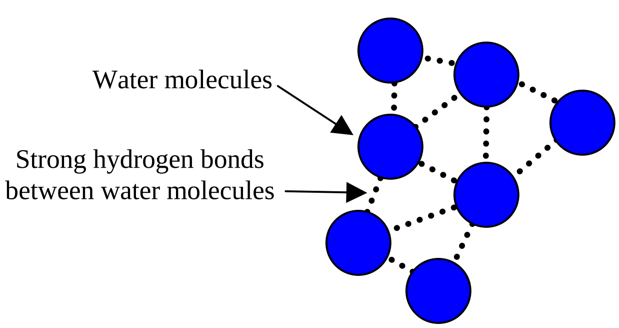

Fig. 2. Interactions of water molecules in a water sample.

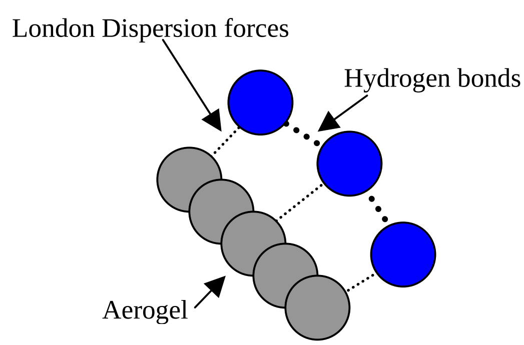

Fig. 3. Interactions of water molecules with hydrophobic aerogel.

Oil molecules, however, cannot form hydrogen bonds and instead stick together using the same LDF (Fig. 4) with which they can also attach to the hydrophobic aerogel (Fig. 5). The oil molecules are therefore just as happy to cling to the surface of the aerogel as they are to stick to each other.

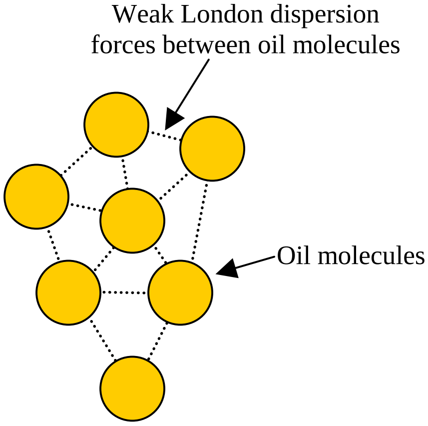

Fig. 4. Interactions of oil molecules in an oil sample.

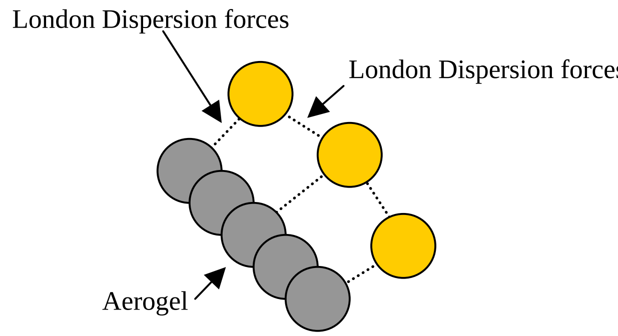

Fig. 5. Interactions of oil molecules with hydrophobic aerogel.

When an oil/water mixture comes into contact with the hydrophobic aerogel, the oil sticks, but the water does not. However, unlike a flat hydrophobic surface (for example, the surface of a wax candle) that can only pick up a small amount of oil from an oil/water mixture, an aerogel has a huge internal hydrophobic surface (a 1 cm^3 block of aerogel has roughly the same surface area as about 3 tennis courts) that can soak up large quantities of oil from an oil/water mixture. The absorption of the oil turns the aerogel back into a gel, with oil filling the spaces inside the solid structure. This gel can then be removed from the river, lake, or ocean surface, and the oil can be recovered and re-used.