Sonochemistry

In the 1920s it was first discovered that ultrasound – sound with a frequency above 18 kHz – produces chemical effects. The study of sonochemistry, as it is called, did not really take off until the 1980s, when reliable and inexpensive ultrasound generators became readily available. Now, there is a host of interesting and important applications of ultrasound in chemistry.

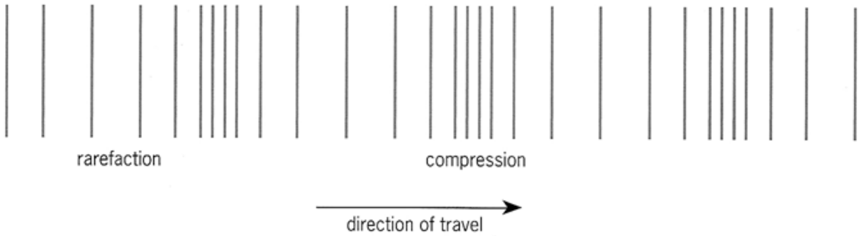

Fig 26.9 The propagation of a sound wave through a liquid. As the wave travels through the liquid, it creates alternate regions of high pressure (compression) and low pressure (rarefaction). These travelling pressure changes are exceptionally rapid when the liquid is excited by ultrasound

When a liquid is excited by ultrasound, the rapid changes in pressure (see Fig 26.9) produce an effect known as cavitation. As the rarefactions travel through the liquid, they pull its molecules apart to produce tiny cavities or bubbles. The compressions cause the bubbles to collapse, which releases tremendous amounts of energy. It has been estimated that the temperature near the collapse may be about 7000 K, which is the temperature at the surface of the Sun. Even higher temperatures – up to 2×10^6 K – may be generated as cavitation bubbles implode. The pressure created could make a gas as dense as a metal. However, the rate of cooling is astonishing at 10^{10} K per second, so overall the liquid does not become hot.

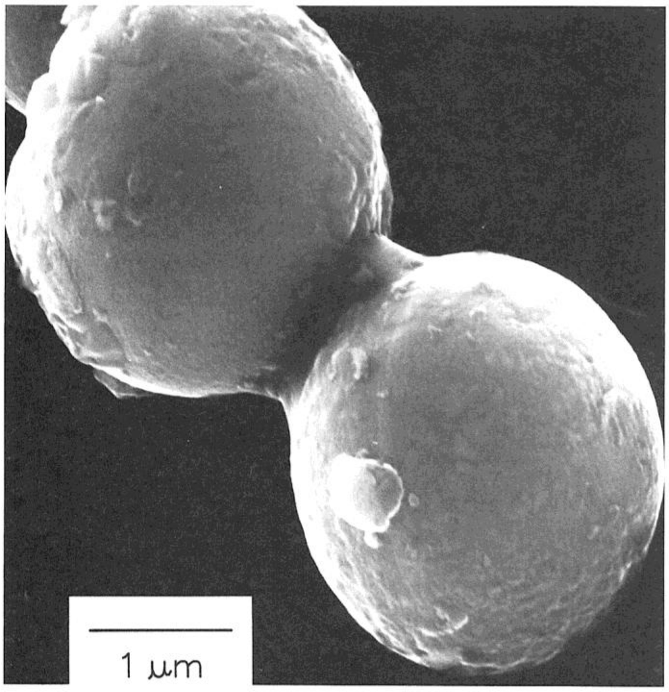

Fig 26.10 Cavitation bubbles produced by ultrasonic waves

These localized energy hot spots are used to increase the rates of chemical reactions. They also produce highly reactive radicals. For example, the water molecule can be torn apart to produce H• and OH• radicals. Radicals have unpaired electrons, which makes them highly reactive. So these radicals can combine to produce hydrogen gas and hydrogen peroxide. The OH• radical is also a potent oxidizing agent, which can react with other chemicals placed in the water.

Early on, sonochemistry led to the production of catalysts that have particles so minute that they are called nanostructured catalysts. (A nanometre is 10^{-9} metres.) The surface area of these catalyst particles is huge. Nowadays, special combinations of metals in catalysts produced with the aid of ultrasound are making chemical processes more efficient, and it is likely that alternatives to platinum-based catalysts will be found.

Tailoring polymer molecules with ultrasound to enhance particular properties is another exciting prospect. The polymer chains are dissolved in a solvent, in which they are subjected to the awesome energy of cavitation bubbles. The chains break into smaller structures that, under the action of the bubbles, recombine to form different monomers in blocks along the chains.

There is so much unexplored potential in sonochemistry. Another possibility is that some organochlorine pollutants in water supplies could be broken down by ultrasound into harmless products. In a contrasting application, tiny haemoglobin spheres have been synthesized and may make it possible to produce artificial blood.