Shattering sounds

Ultrasound shows promise of enabling chemical reactions to be carried out more efficiently. Researchers using the technique have been able to produce reactions at or near room temperature that would normally require a temperature of several hundred degrees centigrade.

Ultrasound consists of sound waves at frequencies higher than those the human ear can hear. A dog whistle employs ultrasound, while ultrasound cleaners are commonly used in laboratories (and in medicine) to clean delicate or oddly shaped objects that would be difficult to wash. Chemical reactions can be produced by the same method.

Ultrasound cleaners work as follows. When passed through a liquid, the ultrasound causes cavitation—the formation of tiny gas vacuoles or bubbles. As the bubbles burst, temperature and pressure around them soar to an estimated 10,000°C and 10,000 atmospheres of pressure. This lasts for a mere millisecond. But it produces shock waves that knock dirt particles off solid surfaces immersed in the liquid.

To produce liquid chemical reactions, Dr Kenneth Suslick of the University of Illinois has been working with a commonly used catalyst: an iron carbonyl known as $Fe(CO)_5$. In Dr Suslick's experiments, ultrasound breaks bits off the iron carbonyl. The residue has more catalytic power than iron carbonyl normally has.

At the University of North Dakota, Dr Philip Boudjouk and Mr Byung-Hee Han are using ultrasound to improve the efficiency of solid catalysts. They have observed increased reaction rates, lower temperature requirements, increased yields and purer products. They have looked at five types of reaction, all of them used extensively in making pesticides, petrochemicals or drugs.

The reaction rates are thought to be increased via the cleaning action of ultrasound. If a piece of catalytic wire is immersed in a solution of chemicals, the shock waves caused by cavitation shake off dirt and oxide impurities from the wire. Molecules in the solution then have a larger, cleaner surface of catalyst available to them.

In the production of beta-hydroxy esters, which are used for making pharmaceuticals, far fewer toxic by-products are generated, so purification is simpler. But the most important difference in all the reactions carried out by the North Dakota team is that they take place at or near room temperature.

The chemical engineer often has to compromise between yield and cost. The high temperature and pressure that produce the best yield may be prohibitively expensive in terms of energy required. Ultrasound may be a way round that difficulty. Cutting even a few degrees from the temperature of a reaction can save millions of dollars.