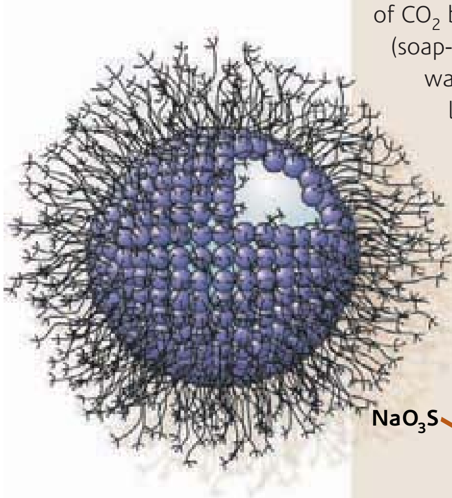
CO_2 gets a designer makeover

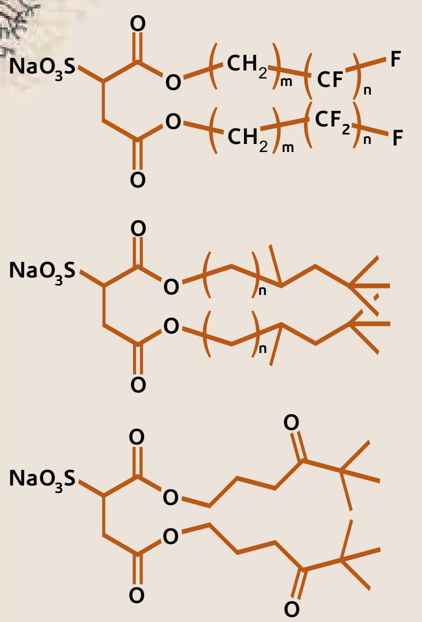
How to turn carbon dioxide into a working 'green' solvent for industry.

Carbon dioxide is readily converted under pressure into a dense liquid or supercritical fluid (with properties ranging from gas-like to liquid-like). Being cheap, abundant, non-toxic and easily disposed of, CO_2 is potentially an interesting medium for processing foods, drugs, and chemicals. The snag is that it is a rather uncooperative solvent and dissolves only tiny levels of water, for example.

Chemists have, therefore, been looking at ways to modify the properties of CO_2 by adding suitable surfactants (soap-like molecules) that would coax water to disperse within it. These long-chain, polymer molecules must be chemically attractive to both media, self-assembling into 'micelles' which encapsulate the water molecules within the CO_2 solvent.



Schematic of a surfactant-stabilised water-in-CO_2 microemulsion droplet, stablised by novel surfactants such as the molecules shown.



Another goal is to find materials that would thicken CO_2, rather as gelatine converts water into a jelly in foods. The modified CO_2 could then be used in wells to pump out the last remaining oil or natural gas, currently not recoverable. In the long term, the technology could prove invaluable in carbon-capture schemes to store CO_2 underground.

Sarah Rogers (now at Diamond) performing high-pressure SANS experiments with CO_2 on LOQ at ISIS.

SANS reveals all

Unfortunately, most surfactants show little liking for CO_2. Those containing fluorine are CO_2 soluble but are both uneconomic and environmentally unacceptable, and so the hunt is now on for more suitable candidates. Julian Eastoe at the University of Bristol and David Steytler at the University of East Anglia have been chemically customising surfactants to make them more CO_2 friendly, and – using small angle neutron scattering (SANS) – have been exploring how effectively they disperse water in CO_2. SANS can reveal the presence of molecular assemblies such as micelles. The studies were carried out at ISIS in a specially designed cell which kept the CO_2 at pressures between 60 and 500 atmospheres – more than 100 times that in a car tyre.

Two chemical strategies were adopted. Taking the structure of a commercial surfactant called Aerosol OT as a starting point, the researchers added three hydrocarbon 'fingers' (tertiary butyl groups) to the ends of the chains to make the molecule more 'CO_2-friendly'. The SANS data confirmed that micelles formed. The researchers then made a triple-chain version which turned out to be the most CO_2-soluble material to date. Inserting oxygen links into the chains further promoted the CO_2-attraction.

This preliminary work successfully points the way forward to unlocking the vast potential of CO_2 as a green processing and separation medium.

Further information:

Hydrocarbon surfactants for CO_2: an impossible dream?, J Eastoe, S Gold and DC Steytler, Current Chemistry, Aust. J. Chem. 50 (2006) 1.

Surfactants for CO_2, J Eastoe, S Gold and DC, Steytler, Langmuir 22 (2006) 9832.

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