Most chemical reactions require a solvent, to aid mixing, remove heat and consequently control reactivity. Many traditional solvents are toxic or environmentally damaging, as a result their disposal is often very costly. Our research group is particularly interested in replacing organic solvents in chemical reactions. Our strategy is to demonstrate that SCF solvent systems can give real chemical advantages as well as being environmentally more acceptable.

We have developed a versatile SCF reactor system, as part of a thriving collaboration with the fine chemicals company Thomas Swan & Co Ltd. Our flow reactor system is extremely safe and very simple. As you can see in the photograph, the apparatus is surprisingly small but it can still produce literally tons of product per year.

Although CO2 has been identified as a primary greenhouse gas, the gas that we use is isophorone, 1 gram of catalyst can hydrogenate as much as 7.5 kilos of isophorone fluid (cyclohexene) in the two glass cylinders. In another reaction, the hydrogenation of the catalyst. In only two minutes, this amount of catalyst can hydrogenate all of the liquid.

In 2002, Thomas Swan and Co. Ltd. opened a full-size plant based on our work. 1000 tons of material per year. The plant is highly flexible; you change the catalyst and you change the chemistry.

We are grateful for support from: Infrared spectroscopy provides a very characteristic fingerprint for most molecules. With the correct apparatus, the spectra can be recorded very rapidly in a millisecond of a second (picosecond) or even with high spatial resolution on the timescale of a second (picosecond). This allows us to detect compounds which are normally formed one after the other in the course of a chemical reaction. If you can detect these, you can learn about how chemical reactions occur. The chemists in the photo are using the Time-Resolved IR apparatus at Nottingham.

Our team has led the development of a national facility (PIRATE) for picosecond infrared measurements at the Rutherford Appleton Laboratory, Oxford. For example, the reaction of metal compounds with methane is becoming increasingly recognized as solvents for chemical reactions. However, a key scientific question is precisely how these unique fluids affect chemical reactions. Fast infrared spectroscopy is beginning to provide the answer.

We can now carry out these measurements in SCFs which are beginning to provide the answer.

What happens when a liquid is heated in a sealed container?

We are grateful for support from:
SCFs are gases compressed until they are nearly as dense as a liquid. Like gases, SCFs are highly compressible and can be contained in closed vessel. Like liquids, SCFs can dissolve solid materials.

For nearly 200 years, scientists have been fascinated by watching liquids being heated in sealed tubes. The photograph shows what happens; the liquid has been coloured with blue dye so that it shows up more clearly. When the liquid is heated, it expands and some of it evaporates. This makes the vapour above the liquid grow denser. Eventually, the vapour and liquid reach the same density and the meniscus between them becomes blurred and disappears. The liquid has become “Supercritical”. (Warning: this experiment involves high pressures and you should never try to do it yourself, except at the Science Museum, London).

Supercritical CO2 (scCO2) is the most widely studied SCF. It is non-toxic and Tc is close to room temperature; this means that it can be used with delicate materials, such as enzymes, which would be damaged by higher temperatures (see next page). Chemists are beginning to use scCO2 as a replacement for environmentally less acceptable solvents. scCO2 has been exploited commercially to decaffeinate coffee for several years.

SCFs are gas-like. They penetrate and swell many polymers very effectively. The picture shows two identical “O-rings”. The one at the top has been exposed to scCO2 and has swollen to twice its normal size. It takes about 20 minutes for the CO2 to come out and for the O-ring to shrink back to normal. You can see the CO2 bubbling out if you drop the swollen ring into lime water (CO2 turns the lime water milky).

We have used this swelling to load tiny “nanoparticles” of silver metal into polymers. The route involves dissolving a silver containing compound in scCO2 and then supercritically drying the polymer (impregnation). Then, the compound is carefully decomposed releasing the desired silver nanoparticles, the rest of the molecule is then washed away with more CO2 (extraction).

Silver has been shown to possess very potent antimicrobial properties. Our method of loading silver nanoparticles promises to be a better way of making medical implants that resist infection and we are now exploiting this in collaboration with medical scientists at Nottingham.

SCFs are not new!

For further reading on SCFs, see:-
- For information on any of the topics in this leaflet, contact Prof. Martyn Poliakoff FRS, Prof. Steve Howdle or Dr. Mike George, University of Nottingham, UK.

For more information about Biomaterials using SCFs, read:-