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Carbon Dioxide Chemistry

The current importance of carbon dioxide and its chemistry cannot be overstated. A wide range of processes essential for our daily lives all lead to production of carbon dioxide somewhere in the supply chain, be it electricity generation from power stations, petrol to drive cars, or preparation of raw materials for consumer goods. Although in the long term, low carbon alternatives are being developed, most still have a long way to go, and it is matter of debate whether they will ever be able to satisfy current demands, let alone those of the future. Our research group has an underlying theme of sustainability and the environment throughout all its projects. In the case of CO_2 chemistry, we have a variety of project areas underway, summarised below.

Carbon capture and storage (CCS) is a key strategy for reducing atmospheric CO_2 levels. Rather than being released into the atmosphere, CO_2 produced by large scale industrial processes, is selectively captured, concentrated, and then transported for storage in geologically suitable sites such as saline aquifers and depleted oil wells. However, the capture and concentration of CO_2 represents a huge challenge, particularly in terms of scale, given that a large power station can produce over 50,000 tonnes of CO_2 per day. Current technology utilises amines, predominantly monoethanolamine (MEA) to selectively capture the CO_2 as a carbamate salt, which then on heating liberates almost pure CO_2 suitable for storage. However, there remain significant problems with this technology. Firstly, it is very energy intensive and significantly reduces the efficiency of power stations; secondly, the use of MEA is far from ideal as it decomposes over time to give large volumes of potentially hazardous material which will require disposal; and thirdly, it has never been demonstrated on such a large scale. Our group are working on a number of relevant projects in this area:

- Understanding the reactions responsible for CO_2 capture and amine degradation.[1]
- Investigating the role of CCS within Bioenergy with CCS towards negative CO2 emissions (through the Bioenergy CDT).[2]
- Developing new CO_2 absorbers which alleviate many of the problems inherent with MEA.[2] Much of this work is through our spin out company, *C-Capture Ltd*. which is currently commercialising our recently patented technology for carbon dioxide capture.

Carbon dioxide in Synthesis. Our original interest in carbon dioxide chemistry stems from very successful work which utilised high pressure CO_2 as a solvent for organic chemistry. In addition to the environmental aspects of not requiring potentially hazardous solvents, we also found that reaction selectivity could be controlled to an extent not possible in conventional solvents, particularly in terms of diastereoselectivity and enantioselectivity.[3] We are currently working on investigating a variety of other reactions in CO_2, and trying to understand the unique influence CO_2 has on reactivity. We are also utilising CO_2 in novel crystallisation processes by formation of crystalline carbamate derivatives of amines and related species, exploiting chemistry similar to that which occurs in carbon capture processes for CCS, in the purification of high value intermediates such as pharmaceuticals.[1] A closely related project recently initiated through the Institute of Process Research and Development at Leeds, is focused on utilising CO_2 in reaction product processing rather than the reaction itself, including novel aspects of biotransformations, as part of the major international CHEM21 IMI project.[4]

The availability of funding for projects varies; if you wish to discuss the chemistry in more detail, and potential opportunities in any of these areas, please contact Professor Rayner directly.

References and notes.

1. With James Wheatley.
2. With Diarmaid Clery, Prof. Jenny Jones (Engineering), Dr Douglas Barnes and Dr Gergely Jakab (C-Capture Ltd).
3. C.M. Rayner, *Org. Proc. Res. Dev.,* 2007, **11**, 121.
4. With Balazs Kulic and Prof. Nick Turner (University of Manchester).