University of Glasgow

School of Chemistry

Heterogeneous Catalysis Section

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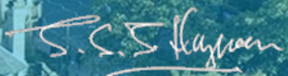
The School of Chemistry at the University of Glasgow has a long tradition of research in heterogeneous catalysis. This research has developed and grown over the years and has resulted in the Heterogeneous Catalysis Section, which have some of the best-equipped labs in the UK and has attracted strong industrial support from a range of international companies including: Johnson Matthey, BP, Syngenta, SABIC, Saudi Aramco, Huntsman, Sasol, Invista and Innospec.

The School has very recently developed an exciting and unique MRes programme entitled "Industrial Heterogeneous Catalysis", that is designed to give students the appropriate practical research skills and theoretical knowledge to embark on a future career in industry or academia.

Professor Justin Hargreaves



Head of School.

Contents

MRES:

M.Res. Industrial Heterogeneous Catalysis

Course format choice:

1 year taught masters:

- 4 weeks of lectures
- 2 research projects
- Small group tutorials
- Frontiers of Catalysis

Continuous Professional Development (CPD) 1 week courses

- Catalyst testing and industrial process development
- Catalyst Activation and Deactivation
- Preparation of Catalytic Materials
- Catalyst Structure and Function

Lecture courses

1. **Catalyst testing and industrial process development**
   Introduction to catalysis; Catalyst testing; Feedstock purification; Active sites; Promotors/poisons; Process examples

Prof David Jackson

Dr John Birtill

2. **Catalyst Activation and Deactivation**
   Activation from lab to plant; Deactivation; Techniques for analysis; Case studies

Prof Stewart Parker

Lecture courses

3. Preparation of Catalytic Materials

Structure, Solids and surfaces ; Supports; Methodologies; Forming


Prof David Jackson


Dr Martin Fowles


Prof Justin Hargreaves

4. Catalyst Structure and Function

Characterisation; Reaction Engineering; Laboratory Testing


Prof Stewart Parker


Dr Emma Gibson


Dr Martin Fowles


Prof David Lennon

Example research projects

- Hydrogenation of 2'-Nitroacetophenone.
- The addition of CO_2 to the syngas feed stream over Fe-based Fischer-Tropsch Synthesis catalysts
- The synthesis and reactivity of ternary and quaternary nickel containing nitrides possessing the η-6 carbide structure.
- *In situ* Raman spectroscopy capability to study propane oxidative dehydrogenation catalysts.

Frontiers in Catalysis

A programme which will develop your skills in analysing scientific literature, giving presentations, and writing reports and papers.

Small group tutorials

Small group tutorials will be used to build on lecture courses and allow you to ask your lecturers more detailed questions.

Dr. John Birtill

Dr Birtill was an industrial research scientist at ICI and Air Products for 24 years, specializing in catalytic processes. He is now a consultant scientist with his own company and an Honorary Senior Research Fellow at the University of Glasgow. He is an internationally recognized expert in the investigation of process catalyst performance and catalyst deactivation.

Dr. Martin Fowles

Dr Fowles has 33 years of industrial experience working for ICI and Johnson Matthey on many aspects of syngas catalysts and technology development. He has wide ranging experience of heterogeneous catalyst testing and catalyst manufacturing, preparation and forming and a particular interest in carbon formation during syngas reactions.

Prof. Stewart Parker

Prof Parker is the Catalysis Scientist at the ISIS Pulsed Neutron and Muon Source in Oxfordshire. He joined the ISIS Facility in 1993 after eight years working for BP Research. His interests are in the use of neutron scattering techniques (including diffraction, vibrational spectroscopy and diffusion studies) to better understand the species present on, and in, heterogeneous catalysts.

University of Glasgow

Prof. David Jackson

Prof. Jackson spent 18 years with ICI plc, developing new catalytic processes before joining University of Glasgow in 2000. His research interests include syngas chemistry, hydrogenation, catalyst deactivation and reaction mechanisms.

Prof . David Lennon

Prof. Lennon joined the University of Glasgow in 1995. His research efforts are concentrated on surface chemistry and heterogeneous catalysis, examining phenomena at the gas/solid and liquid/solid interfaces. He makes extensive use of spectroscopic probes, in particular vibrational spectroscopy (*i.e.* infrared spectroscopy, Raman scattering and inelastic neutron scattering).

Prof. Justin Hargreaves

Prof. Hargreaves joined the University of Glasgow in 2002 where he is currently Professor of Catalytic Materials Chemistry. His research interests centre upon structure activity relationships particularly in relation to activation of small molecules such as nitrogen and methane.

Dr. Emma Gibson

Dr Gibson moved to the University of Glasgow on a Lord Kelvin Adam Smith Research Fellowship in 2017. Her interests lie in applying synchrotron techniques and vibrational spectroscopy to study heterogeneous catalysts under reaction conditions.

Heterogeneous Catalysis Section

Project with BP

S. Blain, E. Ditzel, S. D. Jackson, *Catalysis Science & Technology*, (2012), **2**, 778–783

In the synthesis of C_{2+} oxygenates over methanol synthesis catalysts it would be of interest to determine how higher oxygenate species interact on the surface of the catalyst under working conditions. In this study it was decided to investigate the effects of the presence of higher oxygenates on the synthesis of methanol over an unmodified commercial catalyst operating under realistic industrial conditions. Acetic acid was selected as a suitable probe molecule. Isotopic labelling of the acid was used to determine the mechanism.

Project with Johnson Matthey

C. Gillan, M. Fowles, S. French, S. D. Jackson: *Ind. Eng. Chem. Res.*, (2013), **52**, 13350−13356 , *International Journal of Industrial Chemistry*, (2017), **8**, 235-240,

Recent studies have indicated that the activity of platinum in steam reforming is similar to that of rhodium and both are well-known to be more active than nickel, although not yet commercially used. Nevertheless there has long been interest in using precious metals and platinum in particular as sulfur tolerant steam reforming catalysts. In this study a low loading of platinum (0.2% (w/w)) was chosen as this was viewed as a more realistic loading for a commercial precious metal catalyst, while from the a wide range of possible sulfur containing species we chose the general motif of R-SH, looking initially at hydrogen sulphide (H-SH) and methanethiol (CH_3-SH). The sulfur concentration was chosen at ~10 ppm as this value both was realistic and gave the opportunity to follow any deactivation over a sensible period of time.

Project with Sasol

N.G. Hamilton, I.P. Silverwood, R. Warringham, J. Kapitán, L. Hecht, P.B. Webb*, R.P. Tooze, S.F. Parker, D. Lennon, *Angewandte Chemie International Edition*, (2013) **52**, 5608-5611.

This partnership with Sasol Technology UK Ltd applied inelastic neutron scattering (INS) to investigate the matter of hydrogen partitioning in iron based Fischer-Tropsch synthesis (FTS) catalysts. Whereas there is a huge volume of work on FTS catalysts, the majority of that work tends to concentrate on the elemental partitioning of iron, oxygen and carbon; there is surprisingly little information on how the hydrogen co-reagent explicitly interacts with the evolving catalyst matrix. INS provides the capability to speciate and quantify hydrogeneous moieties retained by heterogeneous catalysts; thereby providing new information on the functionality of the catalyst in maintaining sustained turnover. Furthermore, post-reaction industrial grade catalysts tend to contain significant quantities of metal and/or to be very black in colour. These properties conspire to make it very difficult to interrogate spent catalysts by optical techniques such as infrared or Raman spectroscopy. In contrast, INS is proving particularly useful in obtaining the vibrational spectrum (20-4000 cm^{-1}) of these commercially relevant materials.

Project with Syngenta

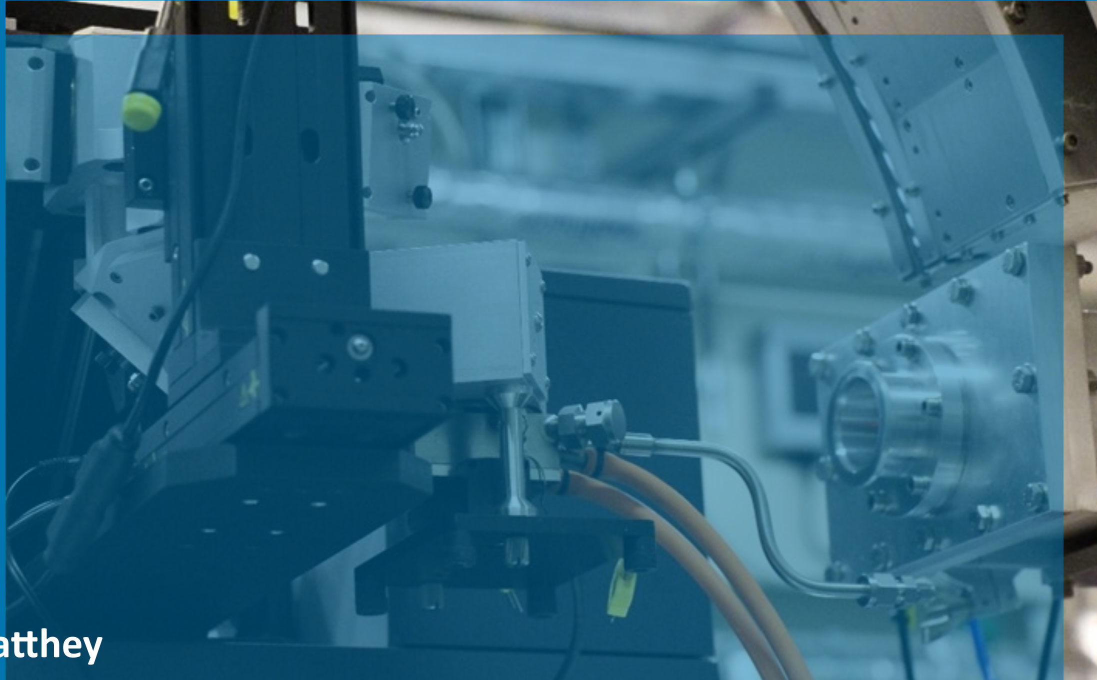
M.I. McAllister, C. Boulho, C. Brennan, P.J. Sidebottom and D. Lennon, *Molecular Catalysis*, (2020) **484**, 110720.

This article represents output resulting from a medium-term partnership with Syngenta that examines the heterogeneously catalysed liquid phase hydrogenation of aromatic cyanohydrins to selectively produce primary amines that have direct application in the argi-chemical industry. Via a series of Ph.D. studentships, the group have developed a comprehensive mechanistic understanding of the reactions accessible to this particular reaction system. This heightened understanding of fundamental physico-chemical concepts has enabled process intensification/process optimisation strategies to be realised, so that deactivation issues previously associated with the large-scale unit operation have now been significantly minimised.

Projects with BP

L. J. France, D. C. Apperley, E. J. Ditzel, J. S. J. Hargreaves, J. P. Lewicki, J. J. Liggat, D. Todd, *Catal. Sci. Technol.*, (2011) **1**, 932–939,
N. A. Spencer, E. J. Ditzel, J. S. J. Hargreaves, S. Sproules, *J. Mater. Chem. A*, (2016) **4,** 7036

Supported by BP Chemicals, in a series of projects JSJH has undertaken an investigation of zeolite catalysis. These have predominantly focussed understanding the nature of carbonaceous species in relation to mordenite catalysed methanol conversion where the nature of the species has been of direct relevance. Other interests have involved the investigation of catalyst configurations to obtain acetic acid and methyl acetate from methanol only feed streams using heterogeneous catalysts in the absence of halide promoters.



Project with Johnson Matthey

E.K. Dann, E. K. Gibson, R. H. Blackmore, C. R. A. Catlow, P. Collier, A. Chutia, T. Eralp Erden, C. Hardacre, A. Kroner, M. Nachtegaal, A. Raj, S. M. Rogers, S. F. R. Taylor, P. Thompson, G. F. Tierney, C. D. Zeinalipour-Yazdi, A. Goguet, P. P. Wells, *Nature Catalysis,* (2019) **2**, 157–163

Using a combined XAFS-DRIFTS cell the selective oxidation of NH_3 to N_2 was investigated, as a possible solution to the release of unused NH_3 from diesel exhausts. By combining these techniques the different catalyst structures observed during three temperature regimes could be correlated to surface species and selectivity by following the evolved gases by mass spectrometry.

1451 THE UNIVERSITY IS ESTABLISHED

1776 ADAM SMITH PUBLISHES *THE WEALTH OF NATIONS*

1848 **LORD KELVIN** PROPOSES AN ABSOLUTE TEMPERATURE SCALE, NOW CALLED THE KELVIN SCALE

1867 **JOSEPH LISTER** INTRODUCES ANTISEPTIC IN SURGERY

1896 **JOHN MACINTYRE** OPENS THE WORLD'S FIRST X-RAY DEPARTMENT

1913 NOBEL PRIZEWINNER **FREDERICK SODDY** DISCOVERS ISOTOPES

1926 **JOHN LOGIE BAIRD** INVENTS TELEVISION

1958 **IAN DONALD** SHOWS US THE FIRST ULTRASOUND IMAGE OF A FOETUS

1967 **JOCELYN BELL BURNELL** DISCOVERS RADIO PULSARS

1974 **GRAHAM TEASDALE** AND **BRYAN JENNETT** CREATE THE GLASGOW COMA SCALE

2015 **SHEILA ROWAN** LEADS THE GLASGOW TEAM THAT FIRST DETECTED GRAVITATIONAL WAVES

2017 NAMED SCOTTISH UNIVERSITY OF THE YEAR

To find out more and apply for the 1 year taught MRES program please visit:

https://www.gla.ac.uk/postgraduate/taught/industrialheterogeneouscatalysis/

To apply for the CPD please contact Prof David Jackson (david.jackson@glasgow.ac.uk)