

The Chemistry of the Platinum Group Metals

A REPORT OF THE EIGHTH INTERNATIONAL CONFERENCE

By John Evans

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The themes of the Eighth International Conference of the Chemistry of the Platinum Group Metals (PGM8), held at the University of Southampton, from 7th to 12th July 2002, covered a broad spectrum from the chemistry of these fascinating elements, ranging through:

- Organometallic chemistry
- Coordination and supramolecular chemistry
- Biological and medicinal chemistry
- Surfaces, materials and crystal engineering
- Photochemistry and electrochemistry
- Catalysis and organic syntheses, to
- Theoretical chemistry and physical methods.

The attendees also found time to cruise down Southampton Water (in mist and rain), visit Stonehenge and Salisbury (only a little rain), walk through in the New Forest (totally dry!), and dine under King Arthur's Round Table in the Great Hall in Winchester.

But the open and challenging atmosphere was the most apparent hallmark of PGM8. Scientists with a breadth of approaches shared their differing experience and targets around common chemical foci, and these can be exemplified by an overview of the reports of the invited speakers.

The well-established antitumour activity of cis-platin and carboplatin, and the onset of tumour resistance to them, was discussed by Lloyd Kelland (St. George's Hospital Medical School, London, U.K.); and here there still remain many important targets. Phase I trials of a ruthenium(III) complex were reported by Gianni Sava (University of Trieste, Italy), and these show promise for a selective effect on lung metastases. Indeed, ruthenium complexes occupied a significantly important position in the biological and medicinal chemistry theme, with Jackie Barton (Caltech, U.S.A.) using them to monitor electron transfer ranges and identify the effect of oxidative damage on the conductivity of DNA. Peter Sadler (University of

Edinburgh, U.K.) described how his work on coordination spheres interacted with DNA bases is being extended to organometallic centres.

Control and exploitation of coordination spheres was preeminent in the programme. Many examples were elegant, such as the helicate complexes of open chain tetra- and hexa-dentate phosphines (Bruce Wild, Australian National University, Canberra) and osma-benzenes and fused osma-aromatics (Warren Roper, University of Auckland, New Zealand), while others challenged conventional thinking, such as the careful design of complexes with monodentate phosphines acting as bridging ligands (Helmut Werner, University of Würzburg, Germany). Probably the 'simplest' ligand sets were presented by Gary Schrobilgen (McMaster University, Canada) who compared the high oxidation states of osmium and xenon (these elements have the widest +8 oxidation state chemistry). The simplicity of the formulae belied the technical challenges of unravelling this chemical frontier.

For the most part, ligand sets were chosen to engender attractive physicochemical properties. These included the luminescent properties of terpyridyl complexes of iridium and ruthenium (Gareth Williams, University of Durham, U.K.), and the non-linear optical materials based upon dendrimeric oligomers of ruthenium(II) bipyridyls (Hubert Le Bozec, Université de Rennes 1, France). Dendrimers and other polymeric architectures (rings, chains and helices) have been synthesised with impressive control by Shigetoshi Takahashi (Osaka University, Japan), and Ian Manners (University of Toronto, Canada) described his control over the synthesis of different types of ferrocenyl polymers.

Catalysis was one of the recurring reasons for ligand design, with Duncan Bruce (University of Exeter, U.K.) demonstrating that metallorganic

Platinum Metals in Biological and Medicinal Chemistry

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The Eighth International Conference on the Chemistry of the Platinum Group Metals provided an ideal opportunity for researchers to report their latest results on research and development in the field of biological and medicinal chemistry with respect to the platinum metals. A number of exciting new directions have emerged in this field, and these are summarised below.

Professor J. K. Barton (Caltech, U.S.A.) opened the proceedings, describing the elegant use of metal-intercalators to probe charge migration through DNA. DNA base mismatches and drug lesions (including those from cisplatin) on DNA can be characterised using this method. Her research group is currently embarking on exciting *in vitro* cell studies using these novel probes.

The current status of several platinum drugs in clinical studies was reviewed by L. R. Kelland (St. George's Hospital Medical School, London, U.K.) who described the challenge of drug resistance that needs to be faced in future drug development. While cisplatin and oxaliplatin remain successful in the clinic, novel drugs such as JM216 and BBR3464 are currently under evaluation. Professor T. G. Appleton (University of Queensland, Australia) described the complex reactions with endogenous thiols that contribute to tumour resistance, and their examination using NMR techniques.

While platinum drugs are the major research

thrust of platinum metals in medicinal chemistry, the emergence of several promising ruthenium complexes with antimetastatic and antitumour activity was described by Professors G. Sava (University of Trieste, Italy) and P. J. Sadler (University of Edinburgh, U.K.), respectively. Complexes trialled by Sava have been shown to localise in the lung basement membranes, not in DNA like many platinum drugs, thus preventing lung cancer metastasis. Sadler described the development of Ru(II) arene complexes with reduced toxicity, non-cross-resistance and a different spectrum of activity to platinum compounds. Structure-activity relationships have been developed and highly selective DNA binding has been demonstrated. While it is clear that the development of further platinum chemotherapeutics is an ongoing endeavour, the emergence of active ruthenium compounds with the potential to enter clinical trials demonstrates that the medicinal chemistry of the platinum metals now has even wider potential.

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Matt Hall is the joint winner of the *Platinum Metals Review* PGM8 conference student article competition.

liquid crystals could act as templates for the synthesis of heterogeneous metal catalysts based on mesoporous silicas. Jan Bäckvall (University of Stockholm, Sweden) demonstrated the use of allenes as nucleophiles in palladium-catalysed coupling reactions, and the emphasis of palladium mediated C–C coupling reactions was continued by Hans de Vries (DSM Research, Geleen, The Netherlands) who presented thoughtful developments of Heck reactions. An alternative approach to C–C coupling, namely hydroformylation, was also stressed, with Kyoko Nozaki (University of

Tokyo, Japan) describing very effective asymmetric hydroformylation catalyst systems, and Eric Hope (University of Leicester, U.K.) showing how fluororganic groups can be exploited in green chemistry: to enhance the solubility of rhodium and ruthenium complexes in supercritical CO₂, and also utilising fluorous phases themselves as supercritical solvents.

More detailed fundamental studies relating to homogeneous catalytic processes were a feature of the programme. The elegant and penetrating studies of Bob Bergman (University of California,

U.S.A.) provided great insight into C–H bond activation processes, and Zhenyang Lin (Hong Kong University of Science and Technology) showed how theoretical studies can add to the insight in an incisive way. Sylviane Sabo-Etienne (Laboratoire de Chimie de Coordination, Toulouse, France) described the activation of boranes and silanes, demonstrating the main group elements to hydro-

gen bonds as η^2 -ligands. Richard Eisenberg (University of Rochester, U.S.A.) reported the power of parahydrogen-induced polarisation to track through the mechanistic pathways of H_2 through a catalytic cycle, while Jon Iggo (University of Liverpool, U.K.) reported on impressive technical developments with a flow cell to allow *in situ* NMR under high pressures, without

An Equilibrium in Catalyst Optimisation and Development?

By G. R. Owen, Department of Chemistry, Imperial College, South Kensington, London SW7 2AY, U.K.

A number of the presentations at the Eighth International Conference on the Chemistry of the Platinum Group Metals focused on catalysis. One of the major issues addressed was the cost involved in the design, synthesis and optimisation of new catalysts. Why spend so much money and time on the preparation of expensive ligands and complicated techniques when triphenylphosphine with $PdCl_2$, under standard conditions, works well?

As the conference progressed through imaginative and stimulating presentations it became clear that the search for more efficient catalytic processes requires the involvement of both academia and industry. While the optimisation of the processes can be left to the industrialist, academics should dedicate their time to design and enhancement of novel systems that might involve unprecedented chemistry.

There were a number of fascinating and inspiring presentations. Professor B. R. James (University of British Columbia, Canada) provided an amusing advertisement for the paper industry, describing the requirements for new strategies in the hydrogenation of lignin found in wood pulp, particularly one using a $RuCl_3 \cdot 3H_2O$ and trioctylamine catalyst. This was a call to academia for some fresh ideas.

There were also some examples of novel routes for the overall development of catalytic systems. Two interesting presentations on the use of dendrimer catalysts by the van Koten group (G. P. M. van Klink and R. J. M. Klein Gebbink, Utrecht University, The Netherlands) were given. Organic products could be separated from the reaction

mixture by recently developed nanofiltration techniques. Careful choice of catalyst, the strong chelation of the pincer ligands in these cases, prevented catalyst leaching.

An important puzzle was also highlighted by Professor P. S. Pregosin (ETHZ, Switzerland) in his talk on the '*meta-dialkyl effect*'. This interesting contribution showed that greatly improved enantiomeric excesses are obtained when *meta-dialkyl* substituted ligands are used. The reasons for this dramatic effect were discussed and studies have shown that in Pd-phosphino-oxazoline allyl complexes, the observed *trans*-influence of both the N and P donors were the same. This remarkable '*leveling effect*' clearly needs further investigation and may have many implications for reactivity.

The conference has shown that there is a great deal of chemistry which is available for study, and in particular platinum group metals can be used to study a wide range of reactions. Pure curiosity and application-driven research will continue to be essential for the development of exciting and novel chemistry. In both cases, real investment will be required to achieve the challenging aims ahead.

The Author

Gareth Owen is working towards a Ph.D. in organometallic chemistry at Imperial College, under the supervision of Dr Ramón Vilar. His thesis will concentrate on the palladium-mediated reactivity and insertion chemistry of carbon-heteroatom multiple bonds, such as isocyanides, imines and heterocumulenes. His research interests include the design of novel supramolecular ligands and their uses in the control of selectivity in catalysis.

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the attendant problems of slow gas dissolution due to poor mixing. This direct observation of homogeneous catalysis, such as hydroformylation and carbonylation, can be achieved under representative conditions.

Although many of the complexes and materials describes above were oligomeric and polymeric, few had direct metal–metal interactions. However, these were evident in the heterogeneous catalysts described by Stan Golunski (Johnson Matthey, U.K.). He emphasised the ability of metals, especially palladium, to mediate the transfer of oxide ions from an oxide surface to a catalysis substrate.

Two talks, though, demonstrated differing but fascinating properties of nanoscopic metal structures; Phil Bartlett (University of Southampton, U.K.) described how liquid crystals and solid microspheres (of polystyrene and silica) could be used as templates for the chemical and electrochemical formation on mesoporous metals. These materials provide large surface areas, like those of the nanoparticles in heterogeneous catalysts, but the area within is a concave, rather than a convex, surface and generates different types of metal surface sites. It might also be expected that the large arrays that comprise mesoporous metals may be less prone to sintering than the clusters within a high dispersion metal catalyst. So novel chemical applications of these materials in catalysis, electrocatalysis and sensors can be anticipated.

The other approach was that of Günter Schmid (University of Essen, Germany). His ligand-stabilised clusters lie at the boundary of molecular complexes and colloids. The Au₅₅ type of cluster with PPh₃ and the predominant protecting ligand was reported to form 2-dimensional monolayers at a water-CH₂Cl₂ boundary, and 1-dimensional structures with different templates. A supramolecular chemistry was established between these high nuclearity cluster materials. The electrical conductivity across a single cluster molecule was also measured. In the junction to the nanoelectrodes, the ligand sheath acted as an insulating layer. The metal core itself behaved as a coulomb well with properties attributable to quantum size effects, rather than being merely a segment of an extended metal array.

It is unfair to the excellent contributed papers and to the poster presenters that I have concentrated on the contributions of the invited speakers. In many ways they accentuated the perception that platinum metals chemistry is a mature, but still youthful science, with new vistas opening. Indeed, that view was expressed by Helmut Werner in his thanks to Günter Schmid. The boundaries of platinum metals chemistry are still there to be probed in a fundamental way, aided by the great array of structural, spectroscopic, imaging and analytical techniques now available to us.

Indeed, the platinum group metals themselves are now part of the array of analytical techniques, used for example in understanding the effects of damage within DNA, and the capability for effective functioning is continually being extended. Ligand design and synthesis are developing apace, and can be used to construct clefts at single metal atoms, helicate grooves in oligomers, and complex surfaces in dendrimers and polymers. As yet we do not understand these new structures well enough to predict the applications in molecular electronics, optoelectronics and catalysis. However, we can see extended arrays of metal nanostructures that have a totally untapped potential. Perhaps even less do we understand how such complexes interact with living tissue. That they can do so to therapeutic benefit is a major impetus to research. The conference demonstrated that the range of complexes and materials that could be tested comprise a vast array of types. And, as always, development of the underlying theory of all of these interactions is essential to orient further synthetic developments.

We are grateful for the organisation provided by the Royal Society of Chemistry, and also to our sponsors: Johnson Matthey, Syntex, BP Chemicals and Nycomed Amersham. On behalf of the National and Local Organising Committees, we would like to thank all of the attendees for a memorable scientific meeting.

The Author

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