low loading) are much higher than typical values in MOFs (around 5 kJ mol⁻¹) and are a considerable achievement. It is generally agreed that binding enthalpies of 15–20 kJ mol⁻¹ will be necessary for room-temperature hydrogen storage in MOFs, so achieving 10 kJ mol⁻¹ is an important step towards this goal.

The material reported by Schröder *et al.* does not solve the hydrogen storage problem. The surface area is rather low, which limits the ultimate capacity of the material. Moreover, the temperature and pressure at which the kinetic trapping occurs are both too low for practical application. Combining all of the desired features for hydrogen storage into one material with the required stability remains a challenge that will require

the imagination of synthetic chemists. Theory and simulation should also have an important role in elucidating the underlying structure/property relations and thus guiding synthetic efforts towards promising materials. The crystallinity of MOFs — with the resulting uniformity and detailed knowledge of the atom positions — makes it possible to apply sophisticated modelling tools to predict the thermodynamic, dynamic and structural properties of existing or hypothetical MOFs, and we can expect to see an accelerated use of molecular modelling in the future to understand and ultimately design new materials. □

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LINDAU 2009

Eyes on the prize

For six days during the summer of 2009, hundreds of young researchers gathered in Germany on the shores of Lake Constance to take part in the 59th Meeting of Nobel Laureates at Lindau — this year dedicated to the topic of chemistry.

Stuart Cantrill

Every year since 1951, groups of young scientists and Nobel Prize recipients have come together on the German island of Lindau (Fig. 1) for a unique kind of scientific conference. Rather than simply offering a venue for the dissemination and discussion of recent results, the aim at Lindau is quite different. The goal is to motivate and inspire the best of the younger generation of researchers by immersing them in a comprehensive scientific and social programme with those individuals who have previously received that early morning call from Stockholm.

It was two Lindau physicians, Gustav Parade and Franz Karl Hein, alongside Count Lennart Bernadotte of Wisborg from the island of Mainau, who established the Lindau Nobel Laureate meetings in the spirit of post-war reconciliation in Europe. The first meeting, in 1951, was focused on medicine and brought together seven Nobel Laureates with young scientists from just three countries. Over the years, the meetings have expanded in terms of size, subject coverage and global profile. The 2009 meeting — the 19th meeting dedicated specifically to chemistry — was attended by 23 Nobel Laureates and almost 600 students and young researchers from 67 different countries.

After the formalities of the opening ceremony on the first day of the 2009 meeting, the main scientific proceedings followed over the next four days. Each morning the assembled dignitaries, young researchers and media representatives were treated to short 35-minute lectures from a handful of Nobel Laureates. The afternoons and evenings were filled with much more informal interactions between the Nobelists and younger scientists — including lunches, smaller group discussions, dinners, a concert and even a traditional Bavarian get-together! The press are excluded from many of these events — particularly the afternoon discussions where small groups of students get a Nobel Laureate to themselves for a couple of hours for a question-and-answer session.

The lectures delivered by the Nobel Laureates covered a variety of different topics, and some talks represented a significant departure from what may be considered a typical presentation at a chemistry conference — but then again, the Lindau meetings are anything but typical. Nevertheless, some of the talks did focus purely on science, often giving a historical overview of the work that had ultimately led to the presenter journeying to Sweden one December. Occasionally the audience were

treated to some new and unpublished work, such as Richard Schrock's *cis*-selective alkene metathesis catalysts.

Some of the less conventional talks were the ones that stood out the most. Judging by the applause, one of the most popular talks at the meeting was delivered by Sir Harry Kroto, who gave a lecture entitled 'Science, Society and Sustainability'. He began by recounting the influences that ultimately made him become a scientist, and briefly compared his career path with that of the actor Sir Ian McKellen, who attended the same school at the same time as him. After touching on some scientific themes such as chemistry and nanotechnology, and admitting that microwave spectroscopy was the only subject he really fully understood, he moved on to discuss broader societal aspects of science. In particular, the relationship between religion and science came under sharp focus. Towards the end of his talk, the theme of sustainability — a common one at the meeting — was discussed, with Kroto suggesting that we really can't sustain our consumption of energy unless we work out a way to split water efficiently.

One lecture that nicely combined science and art was delivered by Richard Ernst. The main message of his talk was that to be

Figure 1 | A street sign on Lindau reminds passers-by of the island's association with Stockholm.

a complete and well-rounded individual, one should explore interests beyond the boundaries of science by looking to the arts and humanities. He then shared with us his pursuits outside of science, which focus on the cultural history of central Asia and, in particular, Tibetan art. After showing many examples of some quite striking paintings and explaining their meaning, Ernst brought science back into the story by revealing that he undertakes pigment analysis of some pieces in his spare time at home. He concluded by telling the young researchers that they should not become “one-sided nerds”!

Perhaps the most unconventional talk of the meeting — if we ignore the fact that most of Walter Kohn's slot was taken up by a John Cleese-narrated video¹ about solar power — was the one given by Peter Agre. Starting by telling the audience that he realized his lecture “separated them from lunch”, Agre launched into a photo-documentary of his canoeing trips in subarctic Alaska and Canada. It was a fascinating alternative to the traditional

conference lecture and the audience were treated to some stunning imagery. Nevertheless, it was hard not to go away with the feeling that we had been treated to a slideshow of someone's — albeit stunning — holiday snaps. In fairness to Agre, however, he did use the photographs to compile a compelling story of how fragile the subarctic environment is — and the significant impact that human activity is having on it.

There were many other entertaining and educational lectures given at the meeting. One session saw the three 2008 Chemistry Nobel Prize recipients — Martin Chalfie, Osamu Shimomura and Roger Tsien — tell tales of green fluorescent protein (GFP) including its discovery, structural elucidation, the practical uses to which it has been put, and the amusing trials and tribulations involved in getting some of their work published. And, although not combined in a single session, the three ‘ozone-hole’ Nobelists from 1995 — Sherwood Rowland, Mario Molina and Paul Crutzen — all made compelling cases for why anthropogenic climate change is real

and represents one of the most important problems that society faces now and in the future. The lectures from the 2009 meeting can be viewed freely online² via the official Lindau 2009 meeting website³.

As well as the lectures, one of the morning sessions featured a panel discussion about the role and future of chemistry for renewable energy. Sitting on the panel were Nobel Laureates Ertl, Grubbs, Kohn, Kroto, Marcus, Molina and Rowland. The moderator made an opening address that outlined some of the challenges we face in this particular regard and then each Nobelist was invited to respond. Gerhard Ertl suggested that our problems simply boil down to finding a way to harness the power of the sun to produce useful energy that can be stored in a practical fashion. Bob Grubbs reminded us that materials science is a crucial and enabling technology for renewable energies in terms of making energy storage and transport more efficient.

An interesting point was made by Rudy Marcus, who commented that not only is solar energy conversion an important societal challenge, but it is also a very interesting and stimulating intellectual problem. The opening statements were concluded with Molina making a case for society to double or triple its investment in renewable energy, and Rowland lamenting the fact that he had to say something original after following six other Nobel Laureates! But he did, by saying that the focus should be on removing carbon dioxide from the atmosphere. After some questions from the young researchers, much discussion ensued about the best way to tackle our energy problems.

This discussion served as a prelude to the events of the final day of the meeting, which took place on the island of Mainau — home to the Bernadotte family. After travelling by boat across Lake Constance, the delegates made their way through the beautiful gardens of Mainau, past the castle and on to an open-air panel discussion entitled ‘Global Warming and Sustainability’. The distinguished line-up of participants included Nobel Laureates Schrock and Molina, as well as Rajendra Pachauri, chairman of the Intergovernmental Panel on Climate Change, better known as the IPCC — the organization that shared the 2007 Nobel Peace Prize with Al Gore.

After much back-and-forth between members of the panel, the audience was invited to ask questions, but disappointingly there was time for only a few from the young researchers. One of the highlights, however, was when recent (GFP) Nobel Laureate Tsien stood up from the first row of the audience and challenged the panelists

to give specific examples of scientific and technological research that the assembled audience should consider working on, noting that some of the brightest young scientific minds in the world were present. There really weren't very many focused answers, but solar energy and nanotechnology were mentioned — the consensus was that work should be done in many different areas.

Following the panel discussion, the 59th Meeting of Nobel Laureates in Lindau drew to a close. Next year, 2010, the meeting will have an interdisciplinary theme, and Nobel Laureates in physics, chemistry and physiology or medicine will be in attendance. Before then, however, videos of conversations between young researchers and Nobel Laureates at the 2009 meeting will be available on the *Nature* website —

the first one scheduled to appear at the end of August. To whet your appetite for these, the Lindau meeting in 2008 — dedicated to physics⁴ — was covered in a similar fashion, and these films can be also be found on the *Nature* website⁵.

Over the years, the meetings have expanded in terms of size, subject coverage and global profile.

The atmosphere at these meetings is indeed unique and fosters a friendly and scholarly environment in which a younger generation of scientists can learn many different lessons from an older generation of scientists. In some ways, the

Nobelists are the ambassadors from the scientific futures of the younger delegates — showing them just what they can achieve and what they can become. The Nobel Laureates were careful to temper any delusions of grandeur, however, with those such as Ernst pointing out that “your goal should not be Stockholm”, and Tsien commenting that “prizes are ultimately a matter of luck, so avoid being motivated or impressed by them”. □

Stuart Cantrill is the Chief Editor of Nature Chemistry.

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CHEMICAL SENSING

Nanonose for sniffing out proteins

Diagnosing disease states relies on sensing imbalances in the quantities of markers present in biological fluids. Now a biologically compatible gold nanoparticle sensing-system that detects proteins in serum has been developed, offering great potential for medical diagnostics.

Andrew J. Wilson

The identity and the relative and absolute quantities of different proteins present in serum represent a ‘fingerprint’ suitable for detecting disease. Most current methods for protein sensing are based on the use of monoclonal antibodies or analytical techniques such as electrophoresis, both of which suffer from a range of disadvantages. Antibodies are proteins used by the immune system to recognize foreign proteins, for which they have high affinity and selectivity. However, each antibody can sense only one specific protein and its quantification can be difficult. The cost of production and manufacture of antibodies and the sensing system can therefore be significant. Analytical techniques, such as two-dimensional gel electrophoresis, use the physical properties of proteins to produce a map that describes the composition of proteins within a cell; however problems lie with slow analysis times and, again, with quantification.

Now on page 461 of this issue, Rotello and co-workers describe an approach¹ that exploits protein-surface recognition² by gold nanoparticles. Their technique can be used to identify and quantify individual

proteins when they are present at elevated levels in serum and to identify imbalances of mixtures of proteins.

The method uses a popular approach to sensing, in which the response of an array of receptors to a given analyte is used for identification and quantification³. Its advantage is that the composite response of a series of (suboptimal) receptors can provide sufficient information to permit discrimination between analytes without recourse to the time-consuming design and synthesis of specific and selective receptors. Rotello and co-workers use an array that uses ‘indicator displacement’, whereby competitive displacement of an optically active component from a binding site on the sensor results in a change in signal (Fig. 1b). The array of responses provides a ‘fingerprint’ that is diagnostic of a specific target.

In earlier work, the same group used functionalized nanoparticles as the sensor and a fluorescent poly(*para*-phenyleneethynylene) polymer as the indicator⁴. In the current work they use a more biocompatible indicator — green fluorescent protein (GFP) — that allows it to be used as a sensor in serum. Because

the nanoparticles are functionalized with groups capable of making electrostatic and hydrophobic non-covalent interactions with other molecules, GFP interacts with the nanoparticles to different extents depending on the functional groups present at the periphery of the nanoparticle (Fig. 1). The interaction results in quenching of the characteristic green fluorescence of the protein. Addition of the analyte disturbs this equilibrium and changes the fluorescence signal (Fig. 1). Part of the beauty of this approach is that it does not matter whether the analyte interacts with GFP, the nanoparticles or both. This is because the composite response of the entire array can be deconvolved using a statistical technique called linear discriminate analysis (LDA), which allows the protein target to be identified when compared with an appropriate reference.

Most significantly in this work, minute quantities of target protein spiked into serum could be identified. Serum represents both a stringent test of the method, owing to the presence of large quantities of competing species (for example, other proteins and metabolites), and, more importantly, a relevant biological medium