For RSC website

Opening Remarks by Professor David Phillips CBE, President of the Royal Society of Chemistry

Solar Fuels and Artificial Photosynthesis: Global initiatives and opportunities

May 17th, Burlington House, London

Good afternoon. It is my pleasure to welcome you all to the Chemistry Centre for this special event to mark the launch of our report *Solar Fuels and Artificial Photosynthesis: Science and innovation to change our future energy options*.

This meeting is part of a two-day event organised in partnership with the UK Global Science Innovation Network and with Imperial College London where, tomorrow, there will be an international scientific discussion meeting. I would like to welcome the Science Innovation Network representatives Liesbeth Bouwhuis and Muzinee Kistenfeger.

The report, which is in your delegate folders, is part of a programme of activities which the RSC science team has developed with advice from members of our scientific divisions. This began about a year ago following suggestions from – you will forgive me if I don't use titles - James Durrant, from Imperial College London and a member of our Environment Sustainability and Energy Division Council, as well as Tony Harriman from Newcastle University who is the RSC solar energy champion. We are very grateful for their input and for that from many members of the scientific community, in particular Jim Barber who has also played a central role.

The main conclusion of our report is that there is a real need to consider a coherent strategy to advance solar fuels research and innovation in the UK and in Europe. So the primary goal for this meeting is to create an opportunity to think in a coordinated way by bringing together people with a range of perspectives that will be important in developing any such strategy.

Looking at the participant list today you will see that indeed each person brings a particular kind of expertise and experience. Among us are:

- researchers working on different approaches to solar fuels production;
- representatives from different industrial sectors and funding bodies and
- experts in energy, science, research and innovation policy.

I think that it is important for us to have a conversation now about solar fuels for three interconnected reasons, which I will give in the order reflected by today's programme.

One reason to talk about solar fuels now is recent scientific progress and the first session today is all about science. The idea of producing solar fuels has been around for many decades, including some of the early work by British Nobel Laureate Sir George Porter. There have been fluctuations in the levels of research support and rates of progress, but the field has witnessed substantive advances during the past 10-15 years.

For example, there have been many advances in the design and production of nanostructured materials providing a new avenue to simultaneously optimise the efficiency with which light can be captured and electrons utilised for fuel formation. Recent advances in semiconductor nanomaterials and their geometry include the work of Nathan Lewis at Caltech and we are also joined today by Subodh Mhaisalkar who leads, among other initiatives, the Center for Nanostructured Photosystems at Nanyang Technological University in Singapore. Nano-structuring is also very important for catalysis and for novel electrode design. From the UK we have also today Chris Pickett from the Energy Materials Lab at the University of East Anglia.

Another area where there have been breakthroughs is the development of photocatalytic materials, with benchmark work in 2006 by Kazunari Domen from the Department of Chemical Engineering at Tokyo University demonstrating the feasibility of solar hydrogen production by an inorganic material using visible light. Materials-based approaches are being pursued by various groups in the UK including Junwang Tang who is with us today from the Department of Chemical Engineering at UCL as well as other members of the UK Semiconductor Photochemistry Network chaired by Andrew Mills who joins us from Queens University Belfast.

Moving to the interface between Chemistry and Biology we see many breakthroughs in our understanding of photosynthesis, including the work of Jim Barber and Bill Rutherford. We are also very glad to have with us Richard Cogdell, Director of the Institute of Molecular Cell and Systems Biology at the University of Glasgow, whose research includes both fundamental insights into light harvesting and reaction centres in photosynthesis, and their application to solar fuels. One example of a remarkable discovery from fundamental research at the interface between chemistry, biology and physics is the recent discovery by Graham Fleming, a chemist at the University of California at Berkeley, of coherence among the light harvesting units in natural photosynthesis. This was the first observation of quantum effects in biology with potentially far-reaching implications for other fields of science.

A final example of an area that has witnessed substantial progress is molecular approaches to catalysis, in part stimulated by the deepening of our understanding of the molecular mechanisms of natural photosynthesis. Experts here today include Ally Aukauloo from the University of Paris-Sud, Bruno Robert from the CEA in Saclay, Antoni Llobet from the Institute of Chemical Research of Catalonia and Licheng Sun of the KTH Royal Institute of Technology in Stockholm. This field has seen increases by several orders of magnitude in the efficiency of catalysts for different steps required for solar fuels production, as well as the discovery of catalysts based on inexpensive constituents such as Nickel, Cobalt and even Iron.

These examples illustrate the role being played by researchers from diverse subfields within Chemistry and Chemical Engineering including physical, materials, organic and inorganic chemistry as well as chemical biology. They also make clear the inter-disciplinary nature of this research involving collaboration across not just the chemical sciences, but also physics, materials science and nanoscience, biology and engineering. In this context I am very glad to welcome colleagues from the Institution of Chemical Engineers, the Royal Society and the Institute of Physics.

A second reason to talk about solar fuels now is because there is an opportunity now to create conditions whereby economies, both nationally and globally, would benefit from future wealth creation opportunities associated with solar fuels. This means thinking now about supporting research, about links between research initiatives globally, about the next generation of researchers, about connections with existing industries and how to secure business opportunities across the spectrum from intellectual property to manufacturing to deployment.

So the second session today is a panel discussion about routes to solar fuels innovation, with panellists bringing perspectives from policy, industry and academia.

Recently there has been the evolution of new activities globally, including the examples that we will hear about in Session 1. We had hoped today to have a talk also from Can Li, director of the large new Dalian National Laboratory for Clean Energy in China, but difficulties with the timescale for his visa meant that he had to change his plans. We are very glad however to welcome Cheng-Guan Michael Quah, Deputy Director of the National University of Singapore's Energy Office which is involved in significant initiatives such as the Solar Energy Research Institute of Singapore. It is also my pleasure to welcome Alfred Holzwarth, the director of a new clean energy centre at the Max Planck Institute in Mullheim, Germany.

We also see what may be thought of as seeds creating the impetus for larger initiatives in Europe. An example is the Joint Programme on Advanced Materials and Processes for Energy Application which was recently established by the European Energy Research Alliance. Bruno Robert is one of the coordinators of the Artificial Photosynthesis Network.

The importance of solar fuels was recognised some time ago by European Cooperation for Science and Technology with a collaborative network focussed on molecules an molecular devices chaired by Tony Vlcek who joins us from Queen Mary University of London. COST is now considering a proposal for a new collaborative network dedicated entirely to photochemical splitting of water using supramolecular catalysis. I would like to particularly thank Matthias Haury from the COST office in Brussels for joining us on a national holiday, along with several other participants including Jasper Reijnders from the Foundation for Fundamental Research on Matter in The Netherlands.

I look forward very much to the discussion in Session 2 and to hearing thoughts from people working in different industrial, policy and funding sectors.

The third reason why I think it is important to talk about solar fuels now is climate change. This is something that I know that members of the chemical sciences community working on solar fuels care about deeply and is one of the factors underlying their commitment and their determination. I will have the pleasure of introducing our keynote lecture by Nathan Lewis later and so leave some thoughts on the implications of solar fuels for sustainable energy until then.

The charter of the RSC includes as its purpose both the advancement of the chemical sciences and serving the public interest. In the spirit of the latter it is important to be clear that while there are functioning laboratory prototypes, at present there is no commercial solar fuel production

technology. So what we are talking about today is potential and the future. As you all know, the history of science and engineering provides convincing evidence of their capacity to lead to benefits for humanity on a global scale, but it is also difficult to, as it were, "exactly programme a breakthrough".

It is my view, however, reflecting that of our scientific divisions, that the case for pursuing a solar fuels technology is a compelling one because of:

Firstly: the urgency of the need to address climate change
Secondly: the momentum created by recent scientific progress
And thirdly: the need to think long-term about wealth creation

I can think of many questions including how such a mission would be funded, how it would be organised, how it would build most effectively on existing expertise and who would have ownership of any technology. There are many other questions around anticipating the benefit of solar fuels for the global energy system and the nature of associated business opportunities.

So, my expectation is that the question of the nature of a coherent strategy for solar fuels research and innovation in the UK and in Europe is not one to which we will arrive at a single answer today. I am confident however that, given the depth and breadth of expertise here today, we will leave with some overarching themes for the continuation of this conversation and concrete directions for future action.

[Excerpts from introduction to keynote lecture]

Good evening. I would like to welcome those of you who have just joined us at the Chemistry Centre and also those of you joining us via webcast for this special lecture which is a highlight of today's meeting to mark the launch of our report "Solar Fuels and Artificial Photosynthesis: Science and innovation to change our future energy options".

In 2009 the Royal Society of Chemistry, after consultation with our members, produced a roadmap "Chemistry for Tomorrow's World", highlighting the role of the chemical sciences in addressing major global challenges such as food and water security, health and energy. The chemical sciences have an important part to play in many of the avenues that need to be pursued in the development of a sustainable global energy system. For example, new materials for coating and insulating will make a contribution to reducing the demand for energy. Chemical scientists are also making important contributions to next generation technologies which be key to the enhancement of existing renewable energy options in areas such as photovoltaics, batteries and fuel cells.

Production of solar fuels on a large scale would constitute an additional, completely new, element in the energy landscape in several ways. It would provide an alternative to fuels and feedstocks produced from oil, coal and natural gas. Using sunlight to drive the production of fuels would also be a way of storing solar energy when the sun is shining so that it can be transported and used anywhere and anytime.

Of course fuels, for transport by land, air and sea, are central to everyday life and to the global economy. They are also crucial as feedstocks for industries for production of key goods such as the fertilisers, pharmaceuticals and plastics.

This afternoon we have focussed on celebrating recent scientific advances in solar fuels research and also discussed routes to solar fuels innovation and therefore wealth creation. The purpose of this lecture is to help us to view solar fuels in the context of climate change and sustainable energy.

So it is a great pleasure to introduce our keynote lecture on "Global Energy Perspectives" and our lecturer Professor Nathan S Lewis. We are honoured that Nate Lewis has a special connection with the RSC because of his role as the Editor-in-Chief of the interdisciplinary journal "Energy and Environmental Science" of which we are very proud. He was also awarded our Electrochemistry Group's Faraday Medal in 2008.

Nate Lewis is the George L. Argyros Professor of Chemistry at the California Institute of Technology. He has also served as the Principal Investigator of the Beckman Institute Molecular Materials Resource Center at Caltech since 1992. He is the Principal Investigator of the Joint Center for Artificial Photosynthesis, a US Energy Innovation Hub in Fuels from Sunlight, which we have heard about also this afternoon. Nate was on the faculty at Stanford from 1981-1986 and received his Ph.D. in Chemistry from the Massachusetts Institute of Technology.

Nate has received many scientific honours including an Alfred P. Sloan Fellowship, a Camille and Henry Dreyfus Teacher-Scholarship, and a Presidential Young Investigator award. He received the Fresenius Award in 1990, the ACS Award in Pure Chemistry in 1991, the Orton Memorial Lecture award in 2003 and the Princeton Environmental Award, also in 2003. He has published over 300 papers.

In addition to being a world-leading chemist, Nate is a renowned international speaker and authority on energy. He was a member of the Panel on Electricity from Renewable Resources as part of the America's Energy Future study led by the US National Academies. He has also served as a member of the California's Clean Energy Future panel and participated as a speaker in the Davos World Economic Forum and the Aspen Ideas Festival. He has advised members of the US House of Representatives, US Senate and staffers. He also advises corporate sectors including venture capitalists and major energy companies such as BP, Hess and Chevron, regarding clean energy technology and energy policy. In 2009 Nate was listed by Rolling Stone magazine as number 17 in the top 100 Agents of Change in the United States.

I would like to welcome Nate to the Chemistry Centre, to thank him for taking the time to come to London to be with us today, and to invite him now to present his lecture on Global Energy Perspectives.