In the future, our energy systems will need to be renewable and sustainable, efficient and cost-effective, convenient and safe. Hydrogen has been proposed as the perfect fuel for this future energy system. Produced from water and sunlight in nearly inexhaustible quantities, hydrogen could supply the energy needs of all sectors of the economy. But, the technologies needed for the so-called Hydrogen Economy are not technically mature or are too costly to compete with other energy forms.
scientists was given by C.P. Snow in a series of lectures which he delivered at Harvard in 1960 (see ‘Science and Government,’ Oxford University Press, 1961). The protagonists were Professor F.A. Lindemann, who in 1942 became Viscount Cherwell, and Sir Henry Tizard, an Oxford physicist. In chemical kinetics, Lindemann’s name is usually associated with the first successful explanation of the mechanism of first order reactions, but he is now generally remembered for his close association with Winston Churchill during World War 2. This curious relationship was recorded by Sir John Colville (Churchill’s Private Secretary) in his Downing Street Diaries, ‘The Fringes of Power’ (Sceptre, 1986). It is apparent that Lindemann was a strange character: the fact that he was an extreme vegetarian and never drank alcohol makes it all the more remarkable that he enjoyed such a close relationship with Churchill.

As chairman of an important government committee on air defence, Tizard was largely responsible for the organization of the early pre-war work on radar. According to Snow’s account things went well until at Churchill’s request Lindemann was given a place on the Tizard Committee. It seems that Lindemann’s presence led to constant bickering and disharmony and at one stage there was a serious risk that the development of radar would be impeded. It became evident that these two eminent scientists found it impossible to work together and eventually the committee was disbanded and reconstituted under Tizard and without Lindemann.

The first round in the Tizard-Lindemann duel thus went to Tizard, but things changed when Churchill became Prime Minister in 1940. As Colville has recorded, Lindemann was Churchill’s adviser on all technical matters (both scientific and economic) and was given a senior position in the war Cabinet. As a consequence, Tizard was pushed out of the inner circle. Further conflict developed in 1942 over the predicted effect of the strategic bombing of Germany. Lindemann estimated in 1940 to 1970. It is fashionable now to belittle the value of Snow’s work in science, literature and politics. The importance of his books and lectures was perhaps overestimated at the time of their publication or delivery, but they still give a vivid description of the motivation of gifted scientists and the machinations of government committees.

These few examples – and there are many others – illustrate the difficulties that scientists experience in trying to live up to the high ideals of science. Are these illusory and what exactly do we mean when we speak of ‘science’? If we go back a few hundred years, we find that the word ‘science’ had a much broader meaning than it has today. In accordance with its Latin origin, it originally covered the entire spectrum of human knowledge. Gradually the word began to mean knowledge of the universe and thus in the English speaking countries it became identified with natural science, but until the end of the nineteenth century many preferred to use the term ‘natural philosophy.’ There was obviously a good deal of confusion in the use of these and other related terms as exemplified by the definition of ‘naturalist’ in Dr. Samuel Johnson’s famous 1755 dictionary as ‘A student in physics or natural philosophy.’

It is now generally accepted that there are no sharp boundaries between the primary scientific disciplines of chemistry, physics and biology: indeed, it is in the nature of science that there are no permanent disciplinary boundaries. Furthermore, some of the most important research problems are of an interdisciplinary nature. However, we natural scientists run into difficulties when we consult the Oxford English Dictionary and find that the social sciences, economics and psychology are to be regarded as legitimate scientific disciplines. If this is so, we must accept that there are some fundamental differences between the various areas of scientific activity.

Another complication is the rate of advancement of science. Long gone are the days when a chemist could speak with authority on all aspects of inorganic or organic chemistry. In physical chemistry there is a widening gulf between the vocabulary of the theorician and the experimentalist. An added complication has been the rapid growth of computer simulation as a kind of intermediate hybrid between theory and experiment. This ever-increasing degree of specialization is inevitable, but it is worrying that communication is becoming more difficult...
Science and Scientist, (cont.)

even within established areas of research (e.g. in surface science, between chemists and physicists).

Nothing could, or should, be done to stop the flow of scientific research. Moreover, ‘good’ research can emerge from small groups as well as large ones. However, the rate of proliferation of mediocre research literature is alarming. Something should be done to hold back the creation of new journals and reverse the present tendency to publish fragments of ongoing work! In my view, unless an important breakthrough has been made, the publication of a piece of research should not be rushed. Every effort should be made to present the findings as clearly and concisely as possible.

The debate will continue: I shall look forward to hearing the views of others.

Dr. Sing is the co-author of the well-known book “Adsorption, Surface Area and Porosity” by Gregg and Sing and of the recently published book “Adsorption by Powders and Porous Solids” by Rouquerol, Rouquerol and Sing. Until his semi-retirement in 1990, Sing was Professor of Chemistry at Brunel University, England. He may be reached by email at: kwsing@eclipse.co.uk.

Back to the Future, (cont.)

The availability of a reliable and cost-effective supply of hydrogen will be essential for a Hydrogen Economy. Whereas most hydrogen is now produced from steam reforming of natural gas, renewable and sustainable resources will be the sources of choice. Getting from the current production paradigm to this idyllic future will require a transitional phase that exploits our abundant fossil resources in new ways, and challenges our sustainable technologies to reduce costs and improve efficiency and convenience.

In its Hydrogen Program, the U.S. Department of Energy (DOE) conducts R&D for the development of safe, cost-effective hydrogen production technologies that support and foster this transition. Although the long-term focus is on renewable technologies, the introduction of hydrogen into the transportation and utility sectors will require the availability of inexpensive hydrogen - most likely relying on fossil fuels.

Hydrogen Economy purists frequently express dismay at the notion of using fossil fuels to produce hydrogen in the transition to a hydrogen-based energy system. The argument focuses on the contamination of the hydrogen utopia - where hydrogen produces no pollution in the production, storage, transportation, and use cycles. Producing unholy hydrogen from fossil fuels results in the production of anthropogenic CO₂, which cannot be (easily) recycled to produce more fuel. Note that carbon emissions are not necessarily evil; CO₂ produced in a biomass-based system is recycled during the biomass growth phase, resulting in net (nearly) zero CO₂ emissions.

But we are faced with economic realities - hydrogen is pretty cheap when produced in large steam methane reformers. Renewable-based technologies are not ready for commercialization, and face significant economic hurdles when they get there. Therefore, it will not do us much good to develop these renewable production technologies if there are no viable end uses for hydrogen. Pragmatists look to fossil fuels as stepping stones to the future, providing hydrogen at reasonable costs for evolving end users. That doesn’t mean we cannot improve upon today’s technologies to provide the cleanest hydrogen possible. The DOE Hydrogen Program is dedicated to developing improved production technologies that provide fossil-based hydrogen in the near-term at competitive prices, and renewable-based hydrogen in the mid- and long-term. The production of hydrogen from natural gas is an integral part of the strategy to introduce hydrogen into the transportation and utility energy sectors, by reducing the cost of conventional and innovative hydrogen production processes that rely on cheap fossil feedstocks.

Air Products and Chemicals is modifying the conventional steam methane reforming process to include incorporation of an adsorbent in the reformer to remove CO₂ from the product stream. This ‘upset’ to the reaction equilibrium drives the reaction to produce additional hydrogen at lower temperatures than conventional reformers. The cost of hydrogen is expected to be 25-30% lower, primarily due to reduced capital and operating costs. In addition, the adsorption of the CO₂ in the reforming stage results in a high-purity CO₂ stream from the adsorbent regeneration step. This has interesting implications in a carbon-constrained world.

The Program supports efforts at the Massachusetts Institute of Technology in the development of a compact plasma reformer for hydrocarbon fuel reforming for industrial, distributed utility, and vehicular refueling applications. Improvements to the process are expected to result in a reduction in specific energy consumption.

In a project cosponsored by the Hydrogen Program and the Office of Fossil Energy, Air Products and Chemicals is developing a ceramic membrane reactor for the simultaneous separation of oxygen from air and the partial oxidation of methane. If successful, this process could result in improved production of hydrogen and/ or synthesis gas compared to conventional reformers.

The thermal processing of plant material (biomass) and fossil fuels are similar, with a number of the downstream unit operations being essentially the same for both feedstocks. Hydrogen Program R&D focuses on the processing units that are feedstock-dependent, leveraging the vast experience on the common unit operations. Using agricultural residues and wastes, or biomass specifically grown for energy uses, hydrogen can be produced via pyrolysis and gasification. Biomass pyrolysis produces a liquid product (bio-oil) that, like petroleum,
contains a wide spectrum of components that can be separated into valuable chemicals and fuels. Unlike petroleum, bio-oil contains a significant number of highly reactive oxygenated components derived mainly from constitutive carbohydrates and lignin. These components can be transformed into products, including hydrogen. The bio-oil is catalytically steam reforming using Ni-based catalysts. At the National Renewable Energy Laboratory (NREL) and the Jet Propulsion Laboratory, research and modeling are underway to develop processing technologies that take advantage of the wide spectrum of components in the bio-oil, and address reactivity and reactor design issues.

In a supercritical water gasification process at the Hawaii Natural Energy Institute (HNEI), a slurry containing 15 wt% biomass is pumped at high pressure (>22 MPa) into a reactor, where hydrothermolysis and reforming occur. Catalysts have been identified that are suitable for the steam reforming operation.

The use of solar energy to split water into oxygen and hydrogen is an attractive means to directly convert solar energy to chemical energy. Biological, chemical, and electrochemical systems are being investigated within DOE as long-term, high-risk, high-payoff technologies for sustainable production of hydrogen.

In nature, algae absorb light and utilize water and CO2 to produce cell mass and oxygen. Of interest is a class of enzymes known as hydrogenases that can combine protons and electrons obtained from water oxidation to release molecular hydrogen. Normally, these hydrogenases are quickly deactivated by oxygen. Researchers have identified mutant algal strains that evolve hydrogen at a rate 4 times that of the wild type, and that are 3-4 times more oxygen tolerant. Photosynthetic organisms also contain light harvesting, chlorophyll-protein complexes that effectively concentrate light and funnel energy for photosynthesis. These complexes dissipate excess incident sunlight as a protective mechanism. The amount of chlorophyll antennae in each cell is directly related to the amount of ‘shading’ experienced by subsequent layers of microorganisms in a mass culture. In a recent set of experiments, researchers observed that green alga grown under high light intensities exhibit lower pigment content and a highly truncated chlorophyll antenna size. These cells showed photosynthetic productivity (per chlorophyll) that was 6-7 times greater than normally pigmented cells, a phenomenon that could lead to significant improvements in hydrogen production efficiency. These technical challenges are being addressed by scientists from Oak Ridge National Laboratory, the University of California Berkeley, HNEI, and NREL.

The Program supports NREL in the development of bacterial systems to convert CO (found in synthesis gas) to hydrogen via the water-gas shift reaction. In industrial processes, high- (450 °C) and low-temperature (230 °C) shift reactors increase the overall hydrogen production efficiency and reduce the CO content to acceptable levels. In this project, microorganisms isolated from nature are used to reduce CO levels to less than 0.1 ppm, at 25-30 °C in a single reactor.

Multijunction cell technology developed by the PV industry is being used for photoelectrochemical (PEC) light harvesting systems that generate sufficient voltage to split water and are stable in a water/electrolyte environment. The NREL PEC water splitting system has exhibited a solar-to-hydrogen efficiency of 32.4% LHV using concentrated light. HNEI is pursuing a low-cost a-silicon tandem design with appropriate stability and performance, and is developing protective coatings and effective catalysts. An outdoor test of the a-Si cells resulted in a solar-to-hydrogen efficiency of 7.8% LHV under natural sunlight.

The production of hydrogen, from fossil fuels or from renewables, is only one part of the equation. Significant changes in our fuel infrastructure are required to address the use of this clean fuel. Codes and standards for the safe use of hydrogen are under development, and must be implemented to ensure safety to the public. As with any new fuel or technology, education is essential. The DOE Hydrogen Program continues to support the development of technologies that will enable the transition to a clean and sustainable Hydrogen Economy, with emphasis on technical viability, environmental friendliness, and economic competitiveness.

Catherine E. Gregoire Padró is the Hydrogen Program Manager at the National Renewable Energy Laboratory. She holds BS and MS degrees in Chemical Engineering and is an expert in process design and simulation of energy systems.

New Mexico State University
Chemical Engineering Department
Box 30001, MSC 3805
Las Cruces, NM 88003
Phone: 505-646-7705
Fax: 505-646-7706
Email: drockstr@nmsu.edu

American Chemical Society, Spring Meeting 2000 San Francisco
Activated Carbon Separations Symposium

Sessions on activated carbon separations will include discussions of the use of novel feedstock materials, unique manufacture techniques, physical properties of resulting materials, and separation isotherms of activated carbons generated by these techniques.

Session Chairs are David A. Rockstraw, New Mexico State University and Frank Derbyshire, University of Kentucky.

One-page abstracts with descriptive titles are being accepted for this session, and should be sent to Dr. Rockstraw at the address above by September 2, 1999.
THIS HAS BEEN A SUMMER OF MOMENTOUS EVENTS according to my notes and observations. Of special distinction so far, I would list the French Open (Andre A gassi), Wimbledon (Pete Sampras), the British Open (golf), Women’s World Cup Football (soccer to those who don’t know better), the screening of Star Wars (Episode I The Phantom Menace), Notting Hill, South Park (Bigger, Longer, Uncut), and the unsurpassable, never to be repeated, thrill of a futile attempt to co-ordinate the efforts of local artisans who trooped in and out of my house at random times over a period that seemed like years in order to construct a new mega-shower in the bathroom.

Yet overshadowing even these extraordinary highlights, which clearly harbor all kinds of ominous portents for the coming millennium, was the CAER’s hosting of the Fifth Carbon Workshop in Lexington in July. To explain, we have held this meeting every two years starting in 1991, come rain or shine, but mostly shine, and sometimes with oppressive, jungle-like heat and humidity. The aims of the workshops have been simple - to hold a small and short focused meeting on selected topics in carbon science, to emphasize practical applications, and to schedule them to precede the Biennial Conference of the American Carbon Society so that we can attract world-recognized researchers who are en route to that conference. The limited size (in the region of 70 to 80 attendees) encourages free discussion and helps to create an informal atmosphere, reinforced by a higher than usual ratio of social to technical sessions. The cost has been very affordable thanks to some very supportive and constant sponsors who I’ll get back to in a moment. If I have to express our intentions in a single phrase, they are to give the attendees a good time (sailor). And if I were to speculate on what makes a successful meeting, I would more or less repeat the expression. It seems that the one ingredient that people take away and retain is whether they enjoyed themselves.

In designing the format of the workshops, each occasion has been a new experiment, and something of a gamble, in an attempt to avoid repetition and to adjust to changing technologies and priorities. The 1999 meeting marked perhaps the most radical departure where, instead of using the traditional approach of focusing on the use of one type of carbon in different applications, we considered how different forms of carbon (namely, activated carbons and carbon nanotubes) can offer complementary or even competitive solutions in given areas of application - energy and medicine. One concern was that researchers specializing in one area of carbon might not be too interested by work in another, and a second was that people in energy and medical research might not be endlessly fascinated by learning about a material that only provides a part of the solution to the problems they are considering. In fact, the experiment appeared to work very well - it seems that curiosity and a desire to examine the
Interfaces between different fields of science and technology prevail above artificial boundaries. Judging from some very positive comments, I believe that most people regarded this meeting with at least as much enthusiasm as the earlier ones. High Five!

Here, I want to make some space to express a few words of gratitude. First I would like to acknowledge and thank the sponsoring companies and the individuals who work with us - Air Products and Chemicals Inc. (Tim Golden), Anshan East Asia Carbon Fiber Co. (Sophia Hodsdlen), Calgon Corporation (Nick Pollack), Conoco Inc. (Steve Harris), Hiden Analytical (Mike Benham), and one generous sponsor who wishes to remain anonymous despite the offer of free advertising.

Second, I would like to recognize and thank our sponsors within the University of Kentucky - Dr. Fitzgerald Bramwell, Vice President for Research and Graduate Studies, Dr. James Boling, Vice Chancellor for Research and Graduate Studies, Dr. Robert Haddon, Director of the Advanced Carbon Materials Center (MRSEC), and Dr. John Connolly, Director of the Center for Computational Sciences.

Next, I want to thank and congratulate the CAER team who, once again, did such an excellent job of organizing and running the workshop with seemingly effortless efficiency: Teresa Epperson, Marit Jagtoyen, Marybeth McAlister, Gisele Rabchevsky, and Apparao Rao.

Last but by no means least, my grateful thanks to the speakers, poster presenters, chairs, and to all of the participants - both new and familiar faces - without whom none of this is possible and who determine whether or not the workshop is a success.

In a sense we have come to the end of our workshop road after five meetings and the passage of a decade. We won’t be repeating this event for some time to come - at least five years - as in 2001 we will be busy hosting the Biennial Carbon Conference, and the next such conference won’t be held again in the US until 2004, which will be the earliest possible date for the sixth workshop. So it’s rather good to feel that we have ended on a high note (please do not contact me to correct this illusion). That is why the photographs that are sprinkled around the newsletter reflect not only this year’s meeting but are also a reprise of the earlier ones.

As I write, we are still in the furnace of the 1999 heat wave. Putting together these few words has been unusually exhausting, and I think that it’s time to close and go for a long relaxing soak under my new shower (Bigger, Longer, Uncut).

Hope to see you in 2001.

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