The right chemistry

Richard Pike, Chief Executive of the Royal Society of Chemistry, sets out how chemical scientists must adapt to meet future challenges and engage with stakeholders…

On 1st December 1783, the world's first manned hydrogen balloon lifted slowly from its anchor point in the Tuileries Gardens in Paris to provide one more step in the history of aeronautics, which, just 10 days earlier, had seen the world's first hot air flight. Although it took place over 200 years ago, the later event tells us as much about some of the challenges facing the chemical sciences today as it did then.

Few realise that it was discoveries in chemistry that underpinned the venture – the finding that the reaction between sulphuric acid and iron filings generates hydrogen – and today we find the public largely unaware of the scientific methodology that lies behind modern products and services linked to energy, environmental issues, sustainability, food, health and the provision of water.

What is more, the word 'chemistry' is fast disappearing from the lexicon of university courses and research councils, in a drive for either a catchy new name or interdisciplinarity. The fundamentals of atomic and molecular behaviour, however, are more important than ever, and this needs to be continually stressed in an increasingly sophisticated and competitive educational world. Merely repeating this mantra is not enough though, and the scientific community needs to rethink how it engages more effectively with the wider public, sceptical over the pace of scientific developments.

This involves a clever combination of explaining the benefits of science while capturing the attention of both the faithful and unconverted, drawing on humour, controversy, competitions, personal interaction, challenging the status quo or received wisdom, making connections between apparently disparate issues, or having the audience see matters in a new or imaginative way. Delivering science education in schools that is both inspirational and relevant, in particular, is crucial to enhancing the scientific literacy of the wider population and also encouraging more to see science as a stepping stone to a fulfilling career.

A further common theme is that scientific progress is rarely linear or amenable to detailed planning. Priestley and Cavendish, in England, had stumbled upon the method of manufacturing hydrogen, and called it initially 'inflammable air', suggesting its role as a fuel rather than for buoyancy. It was only subsequently that the race to take man aloft for the first time became the trigger in linking the low density properties of hot air and hydrogen. There was no centralised administration for the discovery of the lightest element in the universe, or in applying it to balloon flight; serendipity was the principal actress on that stage, and she continues that role today in ever more complex ways.

The message is that investigative work is essential in supporting progress, with appropriate requirements for funding, and that the right balance has to be struck between 'blue skies' research where the outcome and applications are initially almost unpredictable, and more directed or project-oriented work where there will be fewer surprises. History shows that many advances in chemistry have been the result of careful observation providing new insight, and that the eventual use may have been in an area not originally envisaged. It is that research environment that attracts the most imaginative minds, in contrast to more mechanistic work that has characterised the goal-driven approach more prevalent in Europe recently.

So, what are the key chemistry-related challenges, which increasingly must be seen as business opportunities rather than merely problems to be solved? In energy, the holy grail is to make more effective use of light from the sun, whether in conversion to electricity and hydrogen, or the mimicking of photosynthesis to produce liquid fuels. High capacity storage and transmission for the first two of these will underpin the future carbon-free economy, covering power generation, heating and transportation. This will require advances in materials science and superconductivity. Nuclear fusion also remains a long-term goal. In the interim, chemistry associated with storage of nuclear waste from fission and the application of carbon capture and storage (CCS) to remaining fossil fuels will take high priority.

Use of biomass, from agricultural, marine or food waste sources, has the attraction of being ostensibly carbon neutral in providing energy and chemicals feedstock. In the future, integrated bio-refineries using more than one feedstock will provide power, fuels and a range of chemicals with minimal waste. But the principal hurdle is to overcome the presently low net yield per hectare – in energy terms 50-100 times less than solar devices – and improve the life-cycle benefits to the environment.

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But it is here, already, that we begin to see the complex relationship between important resources. Desalination of sea water draws on the exhaust gases from turbines used for electricity generation, which in turn pass carbon dioxide into the atmosphere. Significant quantities of water are needed for food production (which could be competing against biofuels for land-use) and a varied diet, clean water, heating, and energy demanding facilities and equipment all contribute to the healthy, comfortable lifestyle that an increasing proportion of the world's population – which, itself, continues to grow – now seek to achieve.

Agricultural productivity is key to this, and has increased significantly in some parts of the world, through selective breeding, genetic modification and pest control, but remains a major challenge globally. Research at the chemistry-biology interface, in particular, in both food crops and livestock, covering fertilisers to pesticides, and food processing to preservation, will play a significant role in the future.

In the health sector, the adage that prevention is better than cure will be more to the fore, with techniques developed for earlier diagnosis, and improved monitoring of disease. That will be supported by a revolution in drugs and therapies, which will harness the basic sciences to transform drug discovery, development and the healthcare landscape. The objective will be to have new therapies that can be delivered more efficiently and effectively throughout the world.

Making best use of minerals and their constituent elements is essential in a world of finite resources, and this will need to draw on improved processes, material substitution, and greater recyclability to support a sustainable future.

Energy, agriculture, health and the utilisation of mineral resources all compete for, or are linked to water use, and impact in different ways on the wider environment, including as organic or inorganic pollutants. Monitoring the air, water and soil, and mitigating any adverse consequences will have to be high on the agenda, particularly within a framework of global trading where differing quality assurance measures may be in place for food, drink and other critical products.

Many of the solutions and commercial outcomes reflected here will draw on an interdisciplinary approach, not only between the sciences, but between scientists and those involved in finance, engineering, and social, ethical and behavioural issues, as well as the perceptions of the general public. It is how chemical scientists engage with these stakeholders, and adapt the way they do this, that will determine our success in meeting these challenges.

Richard Pike
Chief Executive
Royal Society of Chemistry
Tel: +44 (0)20 7437 8656
www.rsc.org

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