European Association for Chemical and Molecular Sciences

CHEMISTRY

Finding solutions in a changing world

Initial input on the future of the EU's Research Framework Programme, FP8

Global change is creating enormous challenges relating to energy, food and climate change, action is both necessary and urgent. The European Association for Chemical and Molecular Sciences (EuCheMS) is fully committed to meeting these challenges head on. Working with a wide range of experts we have identified six key areas where advances in chemistry will be needed in providing solutions. In each area we are in the process of identifying the critical gaps in knowledge which are limiting technological progress and where the chemical sciences have a role to play.

The EU's renewed commitment to innovation, resulting in growth and jobs, will take research from the lab in to the economy. Chemistry is the most industrially relevant science, chemists and chemistry research will play a pivotal role in ensuring the European Union is able to realise its vision of becoming an 'Innovation Union'. In a multi-disciplinary world chemistry is the most pervasive science, it is central to progress in many scientific fields from molecular biology, to the creation of advanced materials, to nanotechnology.

We have identified the following areas that should be priorities in the future framework programme. There is a strong overlap with the 'Grand Challenges' identified in the Lund Declaration[1] :

About the **European Association for Chemical and Molecular Sciences** : the European Association of Chemistry and Molecular Sciences, is a non-profit-making organisation and has 47 member societies which represent chemists in academia, industry and government in 34 countries across Europe, including Turkey and Israel. EuCheMS has several Divisions and Working Groups which cover all areas of chemistry and bring together world class expertise in the underpinning science and development needed for innovation.

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1 http://www.se2009.eu/polopoly_fs/1.8460!menu/standard/file/lund_declaration_final_version_9_july.pdf

BREAKTHROUGH SCIENCE

Scientific breakthroughs require advances in fundamental knowledge and support for curiosity driven research.

"**A significant part of the new goods and services that will be available in the market in 2020 are as yet unknown, but the main driving force behind their development will be the deployment of key enabling technologies (KETs). Those nations and regions mastering these technologies will be at the forefront of managing the shift to a low carbon, knowledge-based economy, which is a precondition for ensuring welfare, prosperity and security of its citizens**" – European Commission Communication, 'Preparing for our future : Developing a common strategy for key enabling technologies in the EU', September, 2009.

Underpinning scientific knowledge is critical to ensuring future innovation. The areas outlined below are not an exhaustive list, but provide an indication of the critical areas where the chemical sciences will need to advance science, in order to ensure that Europe maintains a cutting edge in research enabling the EU to compete in a global market.

Analytical science

This encompasses both the fundamental understanding of how to measure properties and amounts of chemicals, and the practical understanding of how to implement such measurements, including designing the necessary instruments. The need for analytical measurements arises in all research disciplines, industrial sectors and human activities that entail the need to know not only the identities and amounts of chemical components in a mixture, but also how they are distributed in space and time. Recent developments in this area have underpinned huge advances in the biosciences such as genome mapping and diagnostics. Further developments are allowing real time and remote analysis. Miniaturisation will also allow in-situ and in-vivo analysis.

Catalysis

Catalysis is a common denominator underpinning most of the chemical manufacturing sectors. Catalysts are involved in more around 90 per cent of chemical manufacturing, and catalysis is a key component in manufacturing pharmaceuticals, speciality and performance chemicals, plastics and polymers, petroleum and petrochemicals, fertilisers, and agrochemicals. Its importance can only grow as the need for sustainability is recognised and with it the requirement for processes that are energy efficient and produce fewer by-products and lower emissions. Key new areas for catalysis are arising in clean energy generation via fuel cells and photovoltaic devices. Biocatalysis is the main factor in white biotechnology and becoming increasingly important for a wide variety of processes. Increasing could also be made of catalysts that make use of more commonly available metals, such as, iron, replacing more rare and expensive noble metals.

Chemical biology

This area focuses on a quantitative molecular approach to understanding the behaviour of complex biological systems and this has led both to chemical approaches to intervening in disease states and synthesising pared-down chemical analogues of cellular systems. Particular advances include understanding and manipulating processes such as enzyme-catalysed reactions, the folding of proteins and nucleic acids, the micromechanics of biological molecules and assemblies, and using biological molecules as functional elements in nano-scale devices. This can be used, by way of example, for rapid diagnosis and treatment.

Computational chemistry
Computational chemistry plays a major role in providing new understanding and development of computational procedures for simulating, designing and operating systems ranging from atoms and molecules to interactions of molecules in complex systems such as cells and living organisms. Collaboration between theoreticians and experimentalists covers the entire spectrum of chemistry and this area has applications in almost all industry sectors where chemistry plays a part.

Materials chemistry
Materials chemistry involves the rational synthesis of novel functional materials using a large array of existing and new synthetic tools. The focus is on designing materials with specific useful properties, synthesising these materials and understanding how the composition and structure of the new materials influence or determine their physical properties to optimise the desired properties. The availability of materials with tailor made properties is a crucial component for innovations improving sustainable development.

Supramolecular chemistry and nanoscience
This involves devising a framework to understand and manipulate non-covalent interactions, and the physico-chemical engineering of nanoscale materials and systems. Notable advances have been made in self-assembled molecular and biomolecular systems, synthetic molecular motors, biologically inspired nano-systems, nano-structured surfaces, hierarchically-functionalised systems and measurement at the nanoscale. It is imperative to protect health and the environment in the use of any new material, there are particular sensitivities linked to the physical properties of nanomaterials, therefore decisions on use should be based not only on a substances physical properties and on the actual use and exposure presented in its use.

Synthesis
Synthesis, is the art of creating new substances, synthesis is achieved by performing chemical transformations, some of which are already known and some of which must be invented. One of the goals of the underpinning science of synthesis is to invent new types of transformations because novel transformations are the tools that make it possible to create interesting and useful new substances, a renewed importance should be given to the application of 'green chemistry' in synthesis, for example, creating fewer by-products, making less use of energy and using environmentally benign solvents. Chemists also create new substances with the aim that their properties will be scientifically important or useful for practical purposes.

Electrochemistry
Electrochemistry is concerned with inter-converting electrical and chemical energy. Electorchemistry is an area of science that is critical to a variety of challenges, including : the storage o intermittent renewable energy sources, batteries for the next generation of electric cars, the clean production of hydrogen, solar cells with greater efficiency and sensors for use in research of biological systems and healthcare.

Formulation
Formulation is about creating multi-component, often multi-phase products. The combined global market for these products exceeds is over €1200 billion/year. Formulation is used in many fields, from personal care and pharmaceutical applications to agrochemicals. Formulation requires multidisciplinary and cross-sector teams, bringing together expertise in particles, surfactants, polymers, crystallisation, modelling and process engineering.

FOOD

Creating and securing a safe, environmentally friendly, diverse and affordable food supply.

By 2030, the world's population will have increased by more than 20% to over eight billion. A rapidly expanding world population, increasing affluence in the developing world and limited land and water availability mean that we have no alternative but to significantly and sustainably increase agricultural productivity to provide food, animal feed and fuel. In the Commission's strategic document on the Common Agricultural Policy towards 2010, 'meeting the food, natural resources and territorial challenges of the future'[2] the Commission underlines the importance of technological development and the uptake of research.

The EU wishes to preserve current levels of food production on a sustainable basis throughout the EU, guaranteeing long-term food security for European citizens and enabling Europe to contribute to growing world food demand. Increased market instability and climate change have added to the pressure felt. However, increased production needs to be achieved sustainably, in line with the EU's high environmental, water, animal health, plant health and public health requirements. EuCheMS will be identifying some of the areas where Chemistry can help Europe find 'Smart' and 'Sustainable' solutions.

How can the chemical sciences help?

Chemistry is key to developing more targeted pesticides in order to deliver the maximum potency against pests with minimum effects on the environment.

Further understanding of plant nutrition, together with the intricacies of soil chemistry and microbiology, will aid in the optimisation of fertilisers, irrigation and crop protection.

To cope with extremes of water quality and availability simple accurate water monitoring devices and targeted water delivery systems are needed.

Developments in genetic modification offer many improvements for agriculture, such as creating better disease resistance and crops that are designed to grow in nutrient poor soil.

Scientists need to develop new vaccines, medicines and high protein/high calorie feeds for livestock. They also need to improve our understanding of the role of genetics in selective breeding and the engineering of new hybrids.

By working together, chemical, environmental and agricultural scientists can help us to understand and predict the future impact of climate change on farming practices.

Sensors and processing tools need to be developed to minimise any loss of quality and value to products that may occur through crop handling storage.

[2] COM(2010)672 final

ENERGY

Creating and securing environmentally sustainable energy supplies, and improving efficiency of power generation, transmission and use

"The energy challenge is one of the greatest tests for us all. Putting our energy system onto a new, more sustainable and secure path may take time, but ambitious decisions need to be taken now." - Günther Oettinger, Energy Commissioner.

In the Europe 2020 strategy for 'smart, sustainable and inclusive growth', the EU sets the ambitious target of achieving a reduction of greenhouse gas emissions by at least 20% compared to 1990 levels or by 30%, if the conditions are right; increasing the share of renewable energy sources in our final energy consumption to 20%; and a 20% increase in energy efficiency.

In 2008 EuCheMS produced a paper entitled, 'Chemistry and Energy' in which EuCheMS identified some of the critical areas where Chemistry can help Europe find 'Smart' and 'Sustainable' solutions, current work will renew and update this document.

In particular, three main areas have been identified where the chemical sciences play a central role : energy conversion and storage; solar power; and, bio-refineries. Chemistry not only plays a major role in the production and storage of energy, but also in energy conservation (insulating materials, for example), and improved energy efficiency.

How can the chemical sciences help?

Energy conversion and storage

For technologies such as, fuel cells and batteries, the life span, recyclability and durability of components must be improved. By producing better batteries and new energy storage devices, and encouraging the move to recyclable materials their adverse impact on the environment will be greatly reduced.

A full understanding of the chemical processes that occur within storage devices will be key to designing new components that optimise performance.

The amount of material used in manufacturing new storage devices must be reduced and optimised through the development of nanotechnology and smart materials that do not rely on the use of rare chemical elements such as lithium.

Fuel cell technology, could be greatly improved by further chemistry research, in to both materials and chemical processes - this will be particularly relevant in finding sustainable transport solutions.

Solar energy

Manufacturing solar cells is expensive and requires a lot of energy. The expertise of chemists is needed to improve and optimise the manufacturing processes to make these more commercially viable and more environmentally friendly to produce.

There are exciting opportunities for a more versatile 'second generation' of solar cells, which chemists are currently helping to develop. Thin-films of semiconducting materials can coat surfaces offering a more adaptable way to convert the sun's energy into electricity. Further developments in the materials used are needed and the production processes must be improved.

'Third generation' solar cells promise to deliver even more versatile thin-film technology; using materials such as novel plastics and organic photovoltaics, this could transform the opportunities and applications available to convert the sun's energy into electricity.

There is also potential for chemists to further explore how we can take advantage of biological methods to harvest and store the sun's energy, by mimicking photosynthesis.

Biorefineries

The chemical sciences have a significant role to play in improving bio-refinery processes through: advancing modelling and analytical methods; improving ways of hydrolysing diversified biomass and lignocellulose; improving the extraction of high value chemicals before energy extraction; developing thermochemical processes including developing better catalysts, microbes and enzymes. Breakthroughs also need to be made in developing better pre-treatment technologies and ways of managing bio-refinery waste streams so as to minimise environmental impact.

Other fields include **hydrogen, wind** and **water** technologies.

HEALTH

Improving and maintaining accessible health, including disease prevention

Europe faces many health challenges. Europe's population growth is falling and its citizens are ageing. By 2050, the number of people over 65 in the EU will increase by 70 %, and the number of people over 80 will grow by 170 %. Promoting healthy and active ageing will become increasingly important. There are also a number of chronic illnesses that present challenges to the EU's healthcare system, in the EU-27 alone there are now over 31 million people living with diabetes.

Priority health areas for the chemical sciences include cancer, cardiovascular disease, stroke, mental health and well-being, infectious disease, respiratory disease, obesity and diabetes. Many areas of chemistry will be critical to finding solutions, from the analysis and identification of illnesses, through to the synthesis and development of new chemicals suitable for therapeutic use.

EuCheMS has identified some of the critical areas where Chemistry can help Europe find 'Smart' and 'Sustainable' solutions. In particular, six main areas have been identified where the chemical sciences play a central role: ageing; diagnostics; hygiene and infection; materials and prosthetics; drugs and therapies; and personalised medicine.

How can the chemical sciences help?

Drugs and Therapies

The chemical sciences have a vital role in harnessing and enhancing basic sciences to help transform the entire drug discovery, development and healthcare landscape so that new therapies can be delivered more efficiently and effectively to the world.

Improving knowledge of analytical chemistry, of how cells interact within the body and how drugs are absorbed at a cellular level, allows the creation of tailor made therapies. The chemical sciences will also be key to developing non-invasive monitoring of the effect of therapies.

Diagnostics

Earlier diagnosis and improved monitoring are vital for effective treatment, several common forms of cancer, for example, are treatable if detected on time. The chemical sciences can work closely with the biological sciences to measure subtle changes before symptoms are displayed.

Materials and Prosthetics

Polymer and bio-compatible material chemistry will improve the functioning of orthopaedic implants and traditional prosthetics, but also high functional prosthetics, including, artificial organs.

WATER

Ensuring the sustainable management of water and addressing societal impact on water resources (quality and availability)

Globally more than 1.2 billion people do not have safe drinking water, 2.4 billion lack sanitation facilities, and 1,000 children die every day as a consequence of waterborne diseases. Current population forecasts suggest that by 2015 an additional 784 million people worldwide will need to gain access to improved water sources, to meet the Millennium Development Goal target to halve the proportion of people without sustainable access to safe drinking water. As part of the International Year of Chemistry, EuCheMS will host an exhibition in the European Parliament, called 'Our Children and Water'.

International co-operation is essential to maximise the impact of future developments, and innovative monitoring, treatment and water management systems must be appropriate for local needs. In 2008 EuCheMS produced a paper entitled, 'Sustainable Water, the role of the Chemical Sciences', current work will renew and update this document.

How can the chemical sciences help?

Water quality issues in developing nations are often different to those in the developed world. Pollution from arsenic, agricultural and industrial waste, and pharmaceuticals are widespread problems. Chemists can develop simple, energy efficient ways to purify water at the point where it is being used. This might involve new disinfection processes and the use of novel membranes to filter drinking water.

Portable 'fit for purpose' technologies are vital. Scientists need to develop new instruments, sensors and analytical approaches to ensure consistent real-time measurement of water quality and to allow local populations to monitor quality and pre-empt, or effectively respond to, contamination disasters.

Energy efficient methods of producing usable water from salt water, such as sea water, are urgently needed to increase the availability of water in times of shortage.

Through collaboration with social scientists to understand water quality in the context of political, economic and social conditions, chemists will be able to develop innovative low-cost technologies appropriate for local needs, especially in areas of the developing world.

RESOURCE EFFICIENCY

Creating and sustaining a supply of sustainable materials, by designing processes and products that preserve resources.

'What is resource efficiency? ... It means using less of what we have to achieve the same, or even more. It means managing our resources sustainably, throughout their life cycle, so as to reduce the environmental impact of their use. It means living, producing and consuming within the physical and biological limits of this Planet' Commissioner for the Environment, Janez Potočnik[3].

The Europe 2020 Strategy has identified the need for a "Resource Efficient Europe", as one of its seven flagship initiatives. The flagship initiative aims to help decouple economic growth from the use of resources.

EuCheMS has identified some of the critical areas where Chemistry can help Europe find 'Smart' and 'Sustainable' solutions. In particular, three main areas have been identified where the chemical sciences play a central role in resource efficiency : sustainable product design, the conservation of scarce natural resources, conversion of biomass and recovering feedstocks into useful chemicals and fuels.

EuCheMS has taken a lead in this area by launching the **European Sustainable Chemistry Award**. The award raises the profile of sustainable chemistry acts as a spur to innovation and competitiveness. The European Sustainable Chemistry Award recognises outstanding contributions to sustainable development by applying green and sustainable chemistry.

Thinking sustainably when looking at all production has become increasingly important. Sustainable thinking should not be limited to the 'end of life' of a substance, instead each stage in the life cycle should be considered, including : resource consumption, energy use or waste disposal. This presents an opportunity to apply new chemistry methods and technology to improved overall sustainability. A renewed emphasis on the principles of Green Chemistry is needed.

The principles of Green Chemistry:

The prevention of waste;

the design of design safer chemicals and products;

the creation of less hazardous chemical syntheses;

the use of renewable feedstocks;

the use catalysts, not stoichiometric reagents;

the avoidance of chemical derivatives;

the maximisation of atom economy;

the use of safer solvents and reaction conditions;

the increase in energy efficiency;

the design of chemicals and products to degrade after use;

the analysis in real time to prevent pollution;

the minimisation of the potential for accidents.

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[3] http://europa.eu/rapid/pressReleasesAction.do?reference=SPEECH/10/118

How can the chemical sciences help?

Sustainable Product Design

The '4Rs' of product design (reduction, remanufacture, reuse and recycle) must be integrated into every design process. Chemistry will be central to the development of biodegradable products and materials that are easier to recycle. The chemical sciences are also needed to develop new ways to recover useful components from waste.

Existing manufacturing processes need to be redesigned and optimised using new tools. Through green chemistry and chemical engineering, methods can be improved for every chemical product, from creation to end of life.

Conservation of Scarce Natural Resources

The amount of material used in current and new technological devices must be reduced and optimised. This will be achievable through the development of nanotechnology and smart materials. Continued and enhanced research on the substitution of critical raw materials with more common materials, for example, the replacement of rare and by extension expensive metals, such as, platinum with the much more common and less expensive iron. Where materials cannot be replaced they should be reclaimed at the end of the product life.

Conversion of Biomass and Recovering Feedstocks

Chemists and engineers can develop biomass derived chemicals so that industries can become more sustainable. In the future, chemicals will be based increasingly on biomass, which will also be used to help meet our energy needs. Robust and transparent methods for assessing the life-cycle impact of renewable and comparing alternative routes is a priority. Life cycle assessments performed so far indicate that using renewable chemicals has good potential for energy and greenhouse gas savings. For bio-based renewable chemicals to compete with fossil-fuel based feedstocks there are several key areas of technology that must be developed and this offers huge potential for the chemical sciences.