doi:10.2533/chimia.2021.895 Chimia 75 (2021) 895-896

A Perspective on Chemistry and Society

A Column on the Occasion of the 75th Anniversary of CHIMIA

EPFL

Society and Chemistry They Are a-Changin'

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Need for Change

As we write this article over the summer the extreme weather events around the globe are difficult to ignore. In several parts of the world record temperatures have been witnessed for prolonged periods, resulting in massive wildfires as well as countless premature deaths. Closer to home unprecedented flooding has also resulted in extensive damage and loss to life. These events have been linked to anthropogenic climate change, a phenomenon known for decades,[1] and yet where politics and economics largely overrule scientific recommendations. The latest scientific report from the Intergovernmental Panel on Climate Change (IPCC) underscores the urgency of strong, sustained cuts in greenhouse gas emissions.

Graffiti by Banksy, a street artist and political activist. Photo by Matt Brown, https://www.flickr.com/photos/londonmatt/4203327856/in/photostream/. License: CC_BY 2.0.

The Past and the Present

Chemistry has no doubt transformed the world we live in for the better. The Haber-Bosch process coupled with other agrochemicals feed the burgeoning population of the planet, pharmaceuticals and other chemical products contribute significantly to increased life-expectancies and quality of life, and chemical fuels largely power the planet. However, nearly all these molecular products we take for granted are derived from petrochemicals, and it is the uncontrolled use of petrochemicals that is the greatest contributor to the anthropogenic increase in the global temperature. Over the last century modern chemistry has been developed around transforming relatively simple petrochemical feedstocks into a wealth of complex and valuable molecules. Switzerland has been particularly successful at discovering ingenious routes to agrochemicals, food supplements, pharmaceuticals and performance polymers, which correspond to a major part of the economy.[2] This chemistry has taken many decades to develop and specific advances are far too many to mention. However, catalysis, combined with developments in modern analytical techniques, may be attributed as being principal drivers.

The Future

To avert further global warming, we must rapidly transition to a carbon neutral or even a carbon negative society. Such a transition is highly challenging, and requires efforts from many sectors, with energy and chemistry having a major role to play. A considerable increase in energy demand is required beyond merely switching fossil-based energy sources to renewable sources. Chemistry has a key role to play here, *e.g.* with the development of the next generation of photovoltaics, efficient (solar driven) green hydrogen production, *etc*.[3] Moreover, the broad introduction of smaller footprint mobility will not be feasible without basic research in chemistry. Key topics in this respect include the development of inexpensive high capacity batteries, fuel cells based on non-precious metal catalysts for hydrogen-based mobility and synthetic renewable based hydro-carbon fuels.[4] On another axis, the use of petrochemical feedstocks by the fine/specialty chemical industries must be phased out and all our chemical products must be derived from renewable feedstocks such as biomass and carbon dioxide, *etc*.[5] Non-organic feedstocks are also diminishing and landfill sites are increasingly overflowing – this waste also represents a valuable future resource and at some point the word waste should be confined to the history books. All waste must be considered a resource/feedstock for a sustainable, circular and carbon neutral economy.

The transition to a circular economy is pressing and we do not have the luxury of another century to invent the chemistry required for this major undertaking. To achieve this goal, *i.e.* transforming renewable feedstocks and waste streams into useful products, catalysis remains the key to success, potentially with an even greater role compared to today as synthetic fuels will have to replace fossil fuels. Although continued improvements in instrumentation may be expected, in order to achieve the development of new catalysts that transform these alternative feedstocks, which relies on selectively decreasing complexity, at least in the first instance, it will be necessary for chemists to increasingly embrace robotic high-throughput experimentation with the generation of large data sets. Armed with this data,

machine learning methods and artificial intelligence will likely become accelerators for the game-changing discoveries in new sustainable catalytic transformations. Eventually, quantum computing will start to play a significant role for more accurately predicting the properties of molecules and materials, and consequently facilitating the search for the optimal catalysts needed drive the transition to a circular economy.

Swiss academia has taken up this challenge. At the EPFL, one of our core tasks is to anticipate such megatrends and chairs with a focus on renewable energy, solar fuels, biomass conversion, and most recently in digital chemistry, have been strategically created over the years. Of equal importance is the training of the next generation of chemists – beginning with Bachelor studies and progressing all the way to our doctoral program. New courses covering these topics are constantly implemented and hands-on expertise in cutting-edge research topics is fostered. The scientific challenges are manifold and call for synergistic collaborative approaches. In this respect, EPFL together with ETHZ created a National Center of Competence in Research (NCCR) in Catalysis headed by Javier Perez-Ramirez and Jerome Waser, and primarily funded by the Swiss National Science Foundation.[6] Its core mission is to establish Switzerland as international leading center for sustainable chemistry research, education and innovation.

The Catalysis Hub CAT+ initiated by Christophe Copéret and Nicolai Cramer is a cutting-edge technology platform for catalyst discovery and optimization embracing automated experimentation and artificial intelligence and machine learning tools.[7] While localized at EPFL and ETHZ, it aims to be an open-access facility serving the entire Swiss scientific community. Moreover, the Swiss Chemical Society also launched SusChem Switzerland that bridges academia and industry and is a testament to the interests and efforts of Swiss industry in transitioning to carbon neutrality.[8]

Concluding Remarks

This is without doubt an exciting time to be a research chemist and we should feel confident about solving the challenges facing society. Chemistry has transformed the world for the better, and in recent years chemistry has come to the rescue at short notice, showing the power of the theories and tools available to us today. We expect that robotic-based high throughput experimentation, machine learning, artificial intelligence and quantum computing will gain rapidly further significance for chemists and become key tools to tackle the challenges we face. Despite these advances, the need for creative and imaginative chemists with a firm foundation in the chemical sciences will remain important.

Received: August 16, 2021

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