chemistry in Australia

June–August 2022

Chemicals regulation: how much is too much?

chemaust.raci.org.au

raci
ROYAL AUSTRALIAN CHEMICAL INSTITUTE

- Women, the world's first chemists
- Emerging candidates for climate change remediation
- Russia's nuclear arsenal

chemistry in Australia

June–August 2022

38

erhui1979/iStockphoto

cover story

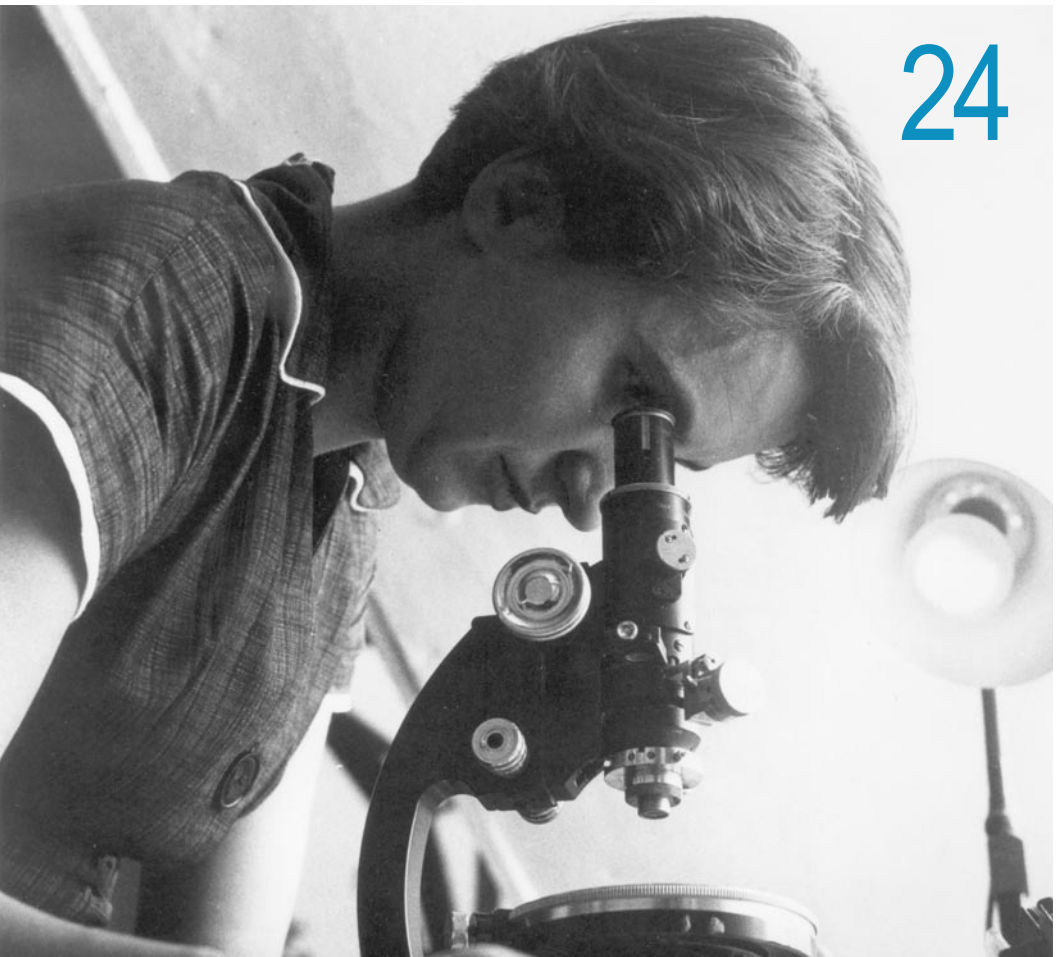
Innovation in a climate of risk and regulation

The precautionary principle has a place in regulating chemicals new to Australia, but for chemicals already used elsewhere are the burdens of time and cost unnecessarily heavy?

20

24 Women, the world's first chemists

Throughout human existence, women have made amazing contributions to chemistry. Jenny Sharwood describes some of their challenges and achievements, and shares some stories of her own.



24

5 Your say

news & research

6 News
15 On the market
16 Research

members

4 From the RACI
28 National Congress update
29 RACI news
30 New Fellows
31 Obituary

views & reviews

33 Books
34 Film
35 Travel
36 Technology & innovation
40 Grapevine
41 Letter from Melbourne

42 Cryptic chemistry
42 Events

chemaust.raci.org.au

What has chemistry ever done for us?

Like many of us on the east coast of Australia, I recently spent some time hosing out mud from inundated houses. Making conversation, one of my fellow mud-covered volunteer co-workers, an accountant, asked me what I did for a living. When I said I was a chemist, he didn't seem all that impressed and so I found myself engaged in a conversation justifying the importance of the profession. Apart from feeling as though I was in some strange version of a *Life of Brian* scene about the value of the Romans, in some ways it also felt odd that the justification was even necessary. On reflection, I realised that defining what chemistry has done for us is a useful exercise to measure our worth as a profession and the contribution chemistry has made to society. A quick Google search reveals that apart from impacts on human health, chemistry has transformed our world through the invention of means to make batteries and plastics and ammonia. Members might agree or disagree with these answers, and indeed I was less convinced by the internet's claims of the value of LCD screens. Email me your thoughts about the greatest impacts that chemistry has made on our lives, as I would love to know.

Clearly, the value of chemistry in our lives can depend on context, and there are downsides with battery chemicals and plastics, but there should be no contention as to the significance of our mastering the chemistry of ammonia manufacture and how significantly this has impacted on our world. The only way that the world can produce enough food to support current (and future) populations is because fertilisers, particularly ammonia, have been able to substantially increase crop yields. As the internet tells us, 80% of the nitrogen in our bodies comes from the industrial chemistry that converts nitrogen to ammonia. Ammonia can be directly injected into soil, or it can be converted into nitrates or urea and added in solution or solid forms. Urea is particularly important because it represents the most concentrated form of fertiliser and delivers the most nitrogen to the soil per application.

Over the last few months in Australia, we have also learned that urea is also critical to the way we transport our goods and even run our private vehicles. And we have discovered that we don't have enough of it. Almost 90% of urea is used as fertiliser; however, solutions of urea are added to diesel engines to decrease NO_x pollution, and without this additive many vehicles, particularly heavily vehicles, cannot run. The additive is generically known as DEF (diesel exhaust fluid). DEF makers import mostly from Russia and China, so due to pandemics, politics and war, supplies have recently become difficult.

Luckily, Australia still has one chemical manufacturing plant that makes urea, Incitec Pivot's facility in Brisbane. This is the only plant of its type in Australia and thankfully it has been able to step up production. Urea is manufactured by reacting natural gas with water and atmospheric nitrogen to produce ammonia and carbon dioxide, which are then recombined to form H_2NCONH_2. Local costs, including that of natural gas, as well as the potential impact on Australia's greenhouse emission targets makes economically viable local production challenging. However, even with the Brisbane plant at full production, Australia will probably not be self-sufficient in urea and a considerable quantity will need to be imported to supplement local production.

Russia is the number one exporter of fertiliser globally, and the European conflict has driven fertiliser prices to historical highs. Russia banned fertiliser exports to many countries and with Europe sourcing roughly 25% of its fertiliser needs from Russia, it could soon be a difficult time to source these valuable chemicals from anywhere in the world, let alone at a palatable price.

The Productivity Commission ... struggles to understand the nature and the worth of chemistry.

Since the pandemic, Australians have become all too aware of supply chain problems, but a report last year from the Productivity Commission claims there are few vulnerabilities in our supply chains, and these can be managed by 'stockpiling' and 'diversification' (bit.ly/3y7dy4k). Notably the report was written before Russia's invasion of Ukraine caused further disruption to supply chains. Clearly, stockpiling can only work when there is a supply to be stockpiled. While the Australian Government appears to not be overly concerned about Australia's lack of manufacturing capability, the report did mention certain 'key' chemicals and indicated that 'Australia does not have the expertise or scale to produce them well or competitively … [and] … Australia could never be truly self-reliant'.

RACI members would probably think such statements reflect a limited understanding of the true capability of the chemistry profession and Australia's chemical industry. The Productivity Commission, like my muddy accountant colleague and much of the public, struggles to understand the nature and the worth of chemistry. It is our responsibility wherever possible to try and rectify this. To attract intelligent, curious and capable people into our profession (and into the RACI!), we need to always be looking for opportunities to promote and improve chemistry's 'brand'. Wherever we can, we must also be able to convince others about matters that we, as chemists, already know – chemistry is a vital aspect of our daily lives that should not be ignored and understanding its importance in society and our economy leads to better decisions and outcomes that benefit us all.

Steven Bottle FRACI CChem (president@raci.org.au) is RACI President.

--Addison's disease, CAH and CLAN

I read with interest the article by Alf Larcher on Addison's disease in the March–May 2022 issue (p. 24). This is a topic my wife and I have some familiarity with as parents of a young man living with congenital adrenal hyperplasia (CAH), a closely related disease with similar treatment and prognosis. Similar to the situation of Alf's friend, our son was also on the brink of a medical crisis just a few weeks after he was born. Thanks to the skill and dedication of his paediatrician, a diagnosis was made just in time.

This traumatic experience in 1999 led us to truly appreciate the quality of medical care and access to medicines we enjoy in Australia. In 2004, we learned about the plight of children living with CAH in Vietnam, where families were unable to affordably access two of the key medicines described in Alf's article: glucocorticoid (hydrocortisone) and mineralocorticoid (fludrocortisone) tablets. Unlike our own son in Australia, children in Vietnam were experiencing entirely preventable mortality and morbidity. This gross inequity inspired us to found CLAN (Caring & Living As Neighbours – www.clanchildhealth.org), an Australian not-for-profit committed to equity for children living with chronic health conditions in resource-poor settings around the world.

A particular highlight of CLAN's early work was successful lobbying for the inclusion of hydrocortisone and fludrocortisone within the World Health Organization List of Essential Medicines for Children (WHO EMLc). This change has greatly enabled supply of these critical medicines into a number of developing countries and facilitated local manufacturing and availability of the medicines so they are affordably available to all.

CLAN's achievements with the CAH Community have since evolved to promote collaborative action across many other chronic conditions of childhood in more than a dozen countries. CLAN's Strategic Framework for Action focuses collaborative, rights-based action on five key pillars:

1 affordable access to medication and medical equipment
2 education, research and advocacy
3 optimisation of medical management
4 encouragement of family support networks
5 reducing financial burdens on families that result in poverty.

If any members of the wider chemistry community are interested in any aspects of CLAN's work, there is further information available on the CLAN website. There is still much to do to ensure these simple, cheap, effective medicines are affordably available to *every* child (and adult!) around the world who needs them.

Dave Hansen FRACI CChem and **Dr Kate Armstrong** AFPHM

Historical Geneva conference

I was most interested to read Ian Rae's article on Charles Bonkowski in the March–May 2022 issue (p. 41), the theme of which was nomenclature in organic chemistry, and of his absence from the follow-up conference in Geneva in 1892. Both conferences were reported in *Nature* (1889, vol. 49, pp. 369–71; 1892, vol. 46, pp. 56–9).

Ian cites two sources in support of his statement that Bonkowski was not at the Geneva event, and the second *Nature* report is a third source. This gives an official list of those attending the Geneva conference, and Bonkowski's name is not on it. The list is alphabetical, and 'Behal' is followed by 'Bouveault'. Ian informs us of a group photograph of the conference in M. Crosland's *Historical studies in the language of chemistry* (Heinemann, London, 1962). The photograph is also reproduced in a 1954 article in *Journal of Chemical Education* (vol. 31). On scrutinising it, I note that the chemists in the photograph all have European affiliations. According to the first *Nature* report, the 1889 conference did have one participant with a US affiliation. That was Ira Remsen (1846–1927) of Johns Hopkins University.

Any academic or researcher knows that it can be a struggle to raise funds to go to conferences, and that any concession can make a difference. That was true of the Geneva conference 130 years ago. We are told in the second *Nature* report that the Paris–Lyons–Marseilles Railway Company allowed those taking part in the conference to travel at half price. I can imagine that participants from England, of whom there were three, were able to take advantage of that by first taking a boat to Marseilles.

Clifford Jones FRACI CChem

chemistry in Australia
chemaust.raci.org.au

EDITOR
Sally Woollett
Ph 0406 321 312
wools@westnet.com.au

PRODUCTION EDITOR
Catherine Greenwood
catherine.greenwood@bigpond.com

ADVERTISING SALES
Mary Pappa
Ph/fax (03) 9328 2033/2670
mary.pappa@raci.org.au

PRODUCTION
Control Publishing
publishing@control.com.au
www.control.com.au

BOOK REVIEWS
Damien Blackwell
damo34@internode.on.net

RESEARCH HIGHLIGHTS
David Huang
david.huang@adelaide.edu.au

EDUCATION RESEARCH HIGHLIGHTS
Reyne Pullen
reyne.pullen@sydney.edu.au

GENERAL ENQUIRIES
Ph/fax (03) 9328 2033/2670
chemaust@raci.org.au

PRESIDENT
Steven Bottle

MANAGEMENT COMMITTEE
Antigone Christou-Rappos, Helmut Hügel, Melanie MacGregor, Nigel Simpson, Richard Thwaites

CONTRIBUTIONS
Contributors' views are not necessarily endorsed by the RACI, and no responsibility is accepted for accuracy of contributions. Visit the website's resource centre at chemaust.raci.org.au for information about submissions.

ISSN 0314-4240 e-ISSN 1839-2539

ATSE and AAS to steer international scitech collaboration

The Australian Academy of Technology and Engineering (ATSE) and the Australian Academy of Science (AAS) will deliver the Australian Government's $18.2 million 'Global Science and Technology Diplomacy Fund – Strategic Element', a key part of the new $60.2 million Global Science and Technology Diplomacy Fund.

Over the next four years, the fund will support international collaboration to enhance Australia's profile in science and technology research and application. Australian businesses, entrepreneurs and researchers can capitalise on international opportunities to commercialise their cutting-edge products and services and strengthen scientific collaborations.

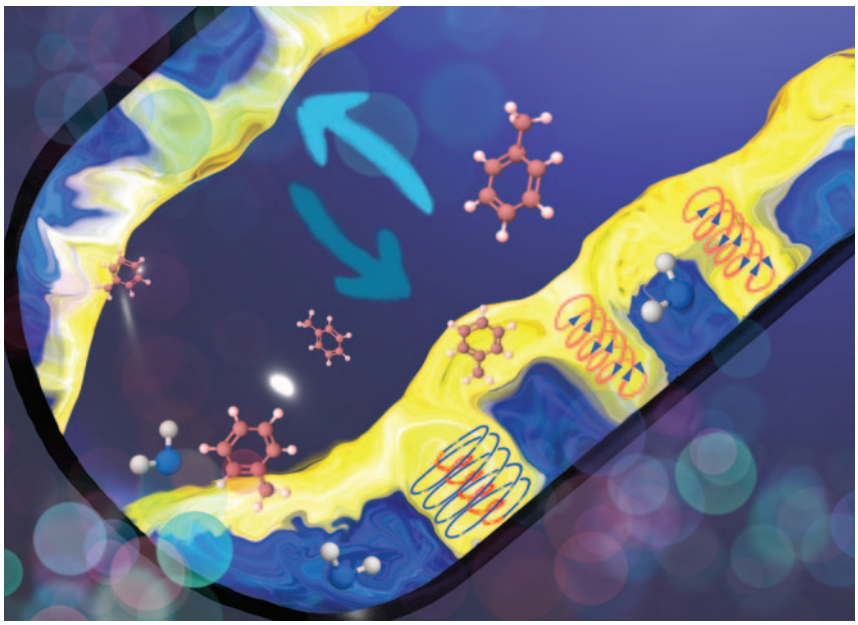
The fund will advance strategic areas such as the competitiveness of Australian advanced manufacturing; artificial intelligence and quantum computing; hydrogen production to provide a zero-emissions fuel source with strong export potential; and emerging applications of RNA (including mRNA) vaccines and therapies.

ATSE's CEO Kylie Walker said, 'By increasing links between Australia's STEM leaders and global partners, we have a unique opportunity to unlock access to international networks that can boost our sovereign capabilities, grow our economy and build our international science and technology reputation in a win, win, win'.

AAS's Foreign Secretary, Professor Elaine Sadler AO FAA said, 'The Global Science and Technology Diplomacy Fund will create a flexible and streamlined approach to supporting international collaboration at a time when we need it most. By identifying and supporting strategic international science and research collaboration with identified partners worldwide, the fund will boost Australia's science and technology research and commercialisation effort'.

Australian Academy of Technology and Engineering

Mixing the 'unmixable'



Chemical Science **(The Royal Society of Chemistry) cover artwork by PhD candidate Zoe Gardner and Dr Xuan Luo (Flinders University).**

A Flinders University device that previously 'unboiled' egg protein is now unravelling the mystery of incompatible fluids, a development that could enhance many future products, industrial processes and even the food we eat.

Using the rapid fluidic flow techniques possible in the Flinders vortex fluidic device (VFD), the research team has capped off 10 years of research to find a way to use clean chemistry to unlock the mystery of 'mixing immiscibles'.

This will have applications in a range of global industries – from food processing and nutraceuticals to cosmetics and drug delivery, said Professor Colin Raston FRACI CChem (Flinders University), senior author of a paper in *Chemical Science* (doi.org/10.1039/D1SC05829K).

'Mixing immiscible liquids is fundamentally important in process engineering and usually involves a lot of energy input and waste products', said Raston, 2020 South Australian Scientist of the Year.

'We now demonstrate how this process, using a common solvent and water, can avoid the use of other substances for controlling reactions across immiscible liquids, making it cleaner and greener.'

'Using thin-film microfluidics in combination with high shear flow chemistry and high heat and mass transfer, the rapidly evolving VFD technology is overcoming the mixing limitations of traditional batch processing', said co-author Matt Jellicoe (Flinders Institute for Nanoscale Science and Technology).

'We conducted over 100 000 experiments to establish how liquids mix and what their flow behaviours are at very small nanometre dimensions', added co-author Aghil Igder (Flinders Institute for Nanoscale Science and Technology).

The researchers have also upsized the VFD machine on experimental biodegradable polymers to start making its organic substances and clean technologies available at scale to suit a range of industries.

The VFD has been used in multiple experiments to produce quality drug elements such as peptides, better fish oil and food products and many other value-adding green chemical processes that can now be replicated in a scaled-up version of the device that has been developed.

Flinders University

Calum Drummond receives Lifetime Achievement Award

Professor Calum Drummond FRACI CChem, RMIT Deputy Vice-Chancellor Research and Innovation and Vice-President, has been awarded a Lifetime Achievement Award for Contribution to Industry–Research Collaboration by Cooperative Research Australia (CRA).

The Lifetime Achievement Award recognises Drummond's remarkable 35-year professional career advancing industry–research collaboration, and outstanding contributions to research and innovation through leadership, governance and researcher development.

Drummond is an Officer of the Order of Australia (AO) recipient, and was awarded the Victoria Prize for Science and Innovation in 2015 for his fundamental chemistry research, involving the Australian Synchrotron, that is enhancing industrial products and improving nanomedicine outcomes through drug delivery using lipid nanocarriers.

He has worked directly with more than 30 companies, adding value to their businesses. As a senior executive at CSIRO, RMIT (since 2014) and London Stock Exchange-listed CAP-XX, he has enabled thousands of Australian researchers to collaborate with companies to solve problems and capture opportunities for Australian industry.

This has included leading large-scale engagement with the Australian Government's Cooperative Research Centre's program, Boeing, General Electric, Orica and global mining houses, and overseeing initiatives to support small-to-medium-sized enterprises.

Before joining RMIT, Drummond was Group Executive for CSIRO Manufacturing, Materials and Minerals, and Chief of CSIRO Materials Science and Engineering.

He has actively managed large organisational patent portfolios to deliver value to society, and has commercialised numerous technologies as the inaugural Vice-President Research at CAP-XX, and through many collaborative projects between RMIT, CSIRO, CRCs and companies.

'Professor Drummond has made an astonishing impact in a remarkable career to date, and has been a steadfast champion of the CRC Program going back 30 years. His approach to conducting and managing research is one which is founded on

an uncompromising focus on research excellence coupled with passionate pursuit of research translation outcomes that contribute to the prosperity of Australia', CRA Chief Executive Jane O'Dwyer said.

'Cooperative Research Australia is delighted to award Professor Drummond a richly deserved Lifetime Achievement Award for Contribution to Industry–Research Collaboration.'

On receiving the CRA Lifetime Achievement Award, Drummond said:

'My research and collaboration efforts, including with CRCs, are driven by the desire to innovate and partner for impact, through understanding and solving problems faced by industry and the community. It is humbling and indeed an honour to receive recognition for our work.'

Drummond was one of two Lifetime Achievement Award recipients revealed at the CRA Innovation Awards. World-renowned hearing expert Professor Bob Cowan from the University of Melbourne is the other recipient.

Cooperative Research Australia

Support for researchers forced to flee Ukraine

Scientists are among the many people forced to flee Ukraine after Russia's invasion. Joel Carillet/iStockphoto

With a $500 000 donation, the American Chemical Society (ACS) has joined the US National Academy of Sciences (NAS) in an effort to help researchers who are being forced to flee Ukraine because of Russia's invasion. The donation will support the NAS Scientists and Engineers in Exile or Displaced (SEED) program, which is working to help scientists and engineers relocate and continue their work in Poland and other neighbouring countries.

Under agreements with the Ukrainian and Polish academies of sciences, NAS support for researchers and their families includes providing the displaced researchers with grants and placements in appropriate research institutions for up to six months. The funding from ACS will be prioritised to assist Ukrainian chemical scientists to the extent possible.

Millions of Ukrainians have fled their country since the start of the war, including an estimated 20 000 researchers. With many male family members still in Ukraine, the NAS effort is initially supporting primarily female scientists, but this may change as the situation evolves. Although Poland has been the principal destination for refugee scientists, many are also fleeing to Estonia, Lithuania and elsewhere. The NAS plans to help expand the program to include partnerships with other science academies.

In addition to providing immediate assistance to these researchers and their families, the SEED program aims to ensure that Ukrainian science will be better positioned to be restored after the war ends. Keeping the affected researchers engaged in their work and connected to the international science community allows the world to continue to benefit from their ideas and discoveries.

'As our thoughts go out to all those impacted by this war, we appreciate the need to assist the scientists being displaced so that they can continue their work and their careers', said Paul W. Jagodzinski, chair of the ACS Board of Directors. 'Through NAS, we are proud to provide support for these skilled and talented people.'

'The world very much needs the contributions of these displaced researchers, and eventually, their work will also be essential to one day help rebuild Ukraine', said NAS President Marcia McNutt, 'We are thankful that the American Chemical Society is partnering with us in this important effort to provide safety, dignity and opportunities for international research collaboration for our Ukrainian colleagues, without triggering a brain drain from Eastern Europe.'

Recognising that years of specialised training could be at risk for refugees and displaced individuals, the SEED program was established in 2021 to provide opportunities that enable scientists and engineers to remain connected to the global scientific enterprise. The program initially focused on helping Afghan scholars fleeing the Taliban, successfully placing them in academic appointments at the University of Rwanda.

American Chemical Society

Editor's note: The Communiqué on Ukraine by the InterAcademy Partnership, of which the Australian Academy of Science is a member, is at www.interacademies.org/publication/iap-ukraine.

Catalyst development becomes Historic Chemical Landmark

The American Chemical Society (ACS) honoured the development of Raney® nickel with a National Historic Chemical Landmark designation in a ceremony at the University of Tennessee at Chattanooga in April.

Murray Raney (1885–1966) invented the catalyst now known as Raney nickel in 1926 while working out of his home laboratory near Chattanooga, Tennessee. Raney didn't attend high school, but after working for a few years, he enrolled at the University of Kentucky, and graduated with a degree in mechanical engineering.

Originally, Raney nickel was used to turn liquid vegetable oils into solid shortening, but by 1950 it had become one of the most widely used catalysts in the world. Today, Raney nickel produced by W.R. Grace & Co. is used to convert building-block chemicals into pharmaceuticals, food ingredients, agrochemicals, personal care products, fibres, fragrances and many other products that are integral to modern life.

ACS established the National Historic Chemical Landmarks program in 1992 to recognise seminal events in the history of chemistry and to increase awareness of the contributions of chemistry to society. Past landmarks include the discovery and production of penicillin, the invention of synthetic plastics and the works of such notable scientific figures as educator George Washington Carver and environmentalist Rachel Carson. For more information, visit www.acs.org/landmarks.

American Chemical Society

Regulating the environmental fate of chemicals

The New Zealand Parliamentary Commissioner for the Environment, Simon Upton, is proposing changes to the way New Zealand manages chemicals to make sure their environmental impacts are not overlooked.

'On paper, there is a robust system in place to assess risks when a chemical is introduced to the country. But many chemicals that have been in use for decades have not been subject to close scrutiny. Much of the science on their environmental impact has changed', the Commissioner said in a report released in March.

'Restrictions should be based on the latest science and informed by New Zealand-specific data on use and impact.'

The report, *Knowing what's out there: regulating the environmental fate of chemicals*, found that there are gaps in the way chemicals in the environment are monitored and in how we interpret their impact on living things.

Equally, there is little feedback from the monitoring that is undertaken to the chemical management system that determines how chemicals are used.

'While not all chemicals present a high level of concern, there is a lot we don't know about chemicals reaching our environment, including how much is used, where they are used, and the effects they are having', the Commissioner said.

The Commissioner proposes that all agencies dealing with chemicals, alongside Maori, develop a common framework to better manage the environmental impacts of chemical use. This framework should prioritise action on contaminants that pose the highest risk based on how much a chemical is being used, the potential environmental harm it could cause, and how much of it is being detected in the environment.

To gauge the scale of a chemical's use in New Zealand, the Commissioner recommends collecting and reporting data throughout a chemical's lifecycle. This would require importers, manufacturers and sellers of chemicals to report on chemical quantities.

'There are over 30 000 chemicals approved for use across the country, but only around 200 chemicals are routinely tested for.

'While we cannot test every ecosystem for every chemical in New Zealand, we can do more to target those of highest potential risk to the environment.

'We also need to do a better job of setting limits for acceptable concentrations of chemicals in the environment and monitor whether these levels are being exceeded', he said

To assist these goals, the Commissioner wants greater use made of environmental exposure limits and better guidance on monitoring on a regional and national scale.

Monitoring guidance should include the scope and frequency of monitoring as well as the development and implementation of Maori cultural monitoring.

Dr Nick Kim, Senior Lecturer in Applied Environmental Chemistry, Massey University, and one of the technical reviewers of the draft report, commented, '… scientists can only ever hope to scratch the surface of characterising the many potential type of harms that may exist, let alone develop risk-based guidelines. … The best we can do, even with a sizeable budget, is monitor for a tiny target subset of the chemicals that are in use, in some places, some of the time. … That raises the very real problem that in focusing on managing the subset of things that we do know a lot about, we may miss the significance of larger events that are going on right under our noses'.

Parliamentary Commissioner for the Environment (New Zealand)

Aoteara New Zealand has more than 28 species of native bee. Pollinators can be exposed to neonicotinoids used on commercial crops, and sublethal effects include impaired foraging activity and metabolism. CreativeNature_nl/iStockphoto

CSIRO moves towards open access

CSIRO's Acting Chief Scientist, Dr Sarah Pearce.

Research aimed at solving Australia's greatest challenges will be made increasingly accessible as part of a shift towards open access models at CSIRO.

The changes represent significant and coordinated steps towards open access for a research organisation in Australia, and will see CSIRO lead the way in removing paywalls and enabling unrestricted access to its research in scientific journals, instead of readers paying journals to access CSIRO's published research.

The global shift towards open access aims to democratise science by ensuring research is available to everyone, not just those with journal subscriptions.

The 100-year-old organisation has begun the journey towards open access, expected to take a number of years, by signing transformative 'read and publish' agreements with publishers, including the American Institute of Physics, the Company of Biologists, Elsevier, the Microbiology Society, the Royal Society and the Royal Society of Chemistry to publish CSIRO science for readers to access for free – many of which are the first of their kind in Australia.

CSIRO's editorially independent publishing business, CSIRO Publishing, also offers open access arrangements, including a number of agreements with the Council of Australian University Librarians (CAUL) member institutions, as well as with CSIRO itself.

CSIRO Acting Chief Scientist Dr Sarah Pearce said CSIRO was removing barriers to access and increasing opportunities for their published research to make a difference in the world.

'At a time when people around the world are turning to science for answers, we're proud to be making more and more of our published research openly available,' Pearce said.

'In this way, everyone can read the science themselves and increase the impact of our research.

'At the same time, we must maintain the very highest standards of peer review and publishing practices, so finding a viable way to transition the model for journal publishers, like CSIRO Publishing, towards open access is exciting.

'We can expand the reach of the outputs of scientific research while ensuring scientific integrity is protected.'

CSIRO Chief Information and Data Officer Brendan Dalton encouraged other research institutions to join the movement.

'As the national science agency, sharing our research with the world is essential to supporting national and international research excellence and fostering collaboration, so we're proud to have signed a number of transformative agreements already, and look forward to increasing this number over the coming years as contracts come up for renewal', Dalton said.

'Open access ensures we can solve the greatest challenges by sharing new knowledge across borders, across industries, and across communities to stimulate innovation, deliver social benefits and drive economic prosperity.'

CSIRO Publishing

Smoke from major wildfires destroys the ozone layer

A new study shows that smoke from wildfires destroys the ozone layer. Researchers caution that if major fires become more frequent with a changing climate, more damaging ultraviolet radiation from the Sun will reach the ground.

Atmospheric chemists from the University of Waterloo (Canada) found that smoke from the Australian bushfires of 2019 and 2020 destroyed atmospheric ozone in the southern hemisphere for months. The ozone shield is a part of the stratosphere layer of Earth's atmosphere that absorbs UV rays from the Sun.

The researchers used data from the Canadian Space Agency's Atmospheric Chemistry Experiment (ACE) satellite to measure the effects of smoke particles in the stratosphere. The results appear in *Science* (doi.org/10.1126/science.abm5611).

'The Australian fires injected acidic smoke particles into the stratosphere, disrupting the chlorine, hydrogen and nitrogen chemistry that regulate ozone', said Peter Bernath, research professor in the University of Waterloo's Department of Chemistry and lead author of this study. 'This is the first large measurement of the smoke, which shows it converting these ozone-regulating compounds into more reactive compounds that destroy ozone.'

Similar to the holes over polar regions, this damage is a temporary effect, and the ozone levels returned to pre-wildfire levels once the smoke disappeared from the stratosphere. But an increase in the prevalence of wildfires would mean the destruction happens more often.

'The ACE satellite is a unique mission with over 18 continuous years of data on atmospheric composition. ACE measures a large collection of molecules to give a better, more complete picture of what is happening in our atmosphere', Bernath said. 'Models can't reproduce atmospheric smoke chemistry yet, so our measurements provide a unique look at chemistry not seen before.'

University of Waterloo

Women in STEMM combat gender bias on Wikipedia

Three women from the Centenary Institute taking part in the 2022 Wikipedia Edit-A-Thon. Cain Cooper

Women working in the health, medical and life sciences sectors took to their keyboards on World Health Day in April to increase the visibility of women in science on Wikipedia, combatting gender bias on the online encyclopaedia.

Only 19% of all profiles on Wikipedia are about women. The Wikipedia Edit-A-Thon is part of an ongoing global movement that aims to make Wikipedia more representative of diverse talent in STEMM (science, technology, engineering, mathematics and medicine) and their contributions to society. Participants will add and update pages to include the achievements of health and medical researchers who are women.

This is the second time that Franklin Women – a social enterprise that empowers women pursuing careers across the health and medical research sector – and biopharmaceutical company AbbVie Australia joined forces to host the event.

Dr Melina Georgousakis, founder of Franklin Women, said the success of their first Wikipedia Edit-A-Thon highlighted how important grassroots events like this are to increase awareness of gender bias online, but also to drive momentum towards change.

'Two and a half years have passed since our first Wikipedia Edit-A-Thon and while more than 70 000 new Wikipedia profiles have been added for women over this time, women still only account for around 19% of profiles on the global encyclopaedia', said Georgousakis.

'Addressing gender bias on Wikipedia is not just about equity, it is also about ensuring that scientific discoveries and their impact on society are accurately captured. When people search for information online, Wikipedia is usually among the first results that appear and as such it plays a big role in informing people on the history of science and the role of women and other under-represented groups in the field', said Georgousakis.

'Even though scientific discoveries made by the late Rosalind Franklin, the UK researcher after whom Franklin Women is named, were crucial for determining the double-helix structure of DNA, her contributions went largely unrecognised. Rather, it was her male colleagues who received the accolades and went on to be awarded the Nobel Prize after her death. Now Franklin's work is celebrated globally. This is the change we want to effect and the time is now', she said.

Chris Stemple, Vice President and General Manager of AbbVie Australia and New Zealand, believes it is crucial for organisations across the health and medical research sector to support impactful, grassroots initiatives like the Franklin Women Wikipedia Edit-A-Thon.

'With a second iteration of the Wikipedia Edit-A-Thon, we're thrilled to play a part in elevating the visibility of inspiring women who have made remarkable contributions to science, and who continue to pave the way for the scientific breakthroughs of tomorrow', said Stemple.

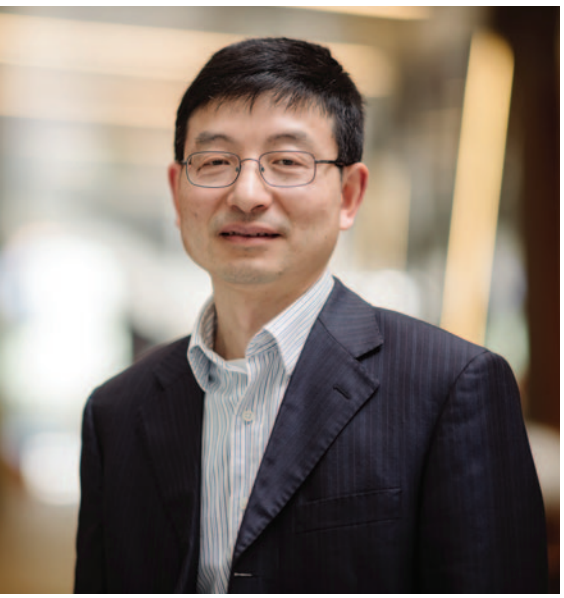
Another outcome from the Franklin Women Wikipedia Edit-A-Thon is providing an opportunity for women to learn how to contribute to the platform. Just 15% of the people who actively contribute content to Wikipedia identify as women. Encouraging women to become Wikipedia editors is key to longer-term change to make platforms more representative.

Following the successful model of the 2019 Wikipedia Edit-A-Thon, this year's event saw participants receive full training and support from experienced Wikipedia editors, so they leave feeling empowered with the skills to continue editing Wikipedia after the event.

To further build this impact, this year's event also includes a dedicated 'Article Aftercare' session. The follow-up workshop will reconnect participants with experienced Wikipedia editors to reinforce their confidence in autonomous editing of articles and ensure they are able to make longer-term contributions, if they choose.

Franklin Women

Faster, more efficient nanodevice to filter proton and alkaline metal ions



Professor Huanting Wang

Monash University researchers have developed a faster, more efficient nanodevice to filter proton and alkaline metal ions that will help design next-generation membranes for clean energy technology, conversion and storage.

The new nanodevice works with atomic-scale precision, while generating its own power through reverse electrodialysis.

In the paper published in *Science Advances* (doi.org/10.1126/sciadv.abl5070), the researchers led by Australian Laureate Fellow Professor Huanting Wang have reported that a metal–organic framework (MIL-53-COOH)-polymer nanofluidic device mimics the functions of both biological inward-rectifying potassium channels and outward-rectifying proton channels.

'It has important real-world implications, particularly for designing next-generation membranes for clean energy technology, energy conversion and storage, sustainable mining and manufacturing, with specific applications in acid and mineral recovery', said Wang, who led the project with research fellow Dr Jun Lu from Monash University's Department of Chemical and Biological Engineering.

Potassium channels are the most widely distributed type of ion channels and are found in virtually all living organisms. Directional ultrafast transport of ions with atomic-scale precision is one of the core functions of biological ion channels in cell membranes. These biological ion channels cooperatively maintain the electrolyte and pH balance across cell membranes, which are essential for the physiological activities of the cells.

For example, the electrolyte concentration disorder in cells, especially for the positively charged ions such as potassium, sodium and proton, is recognised to have a direct link with diseases such as epilepsy.

Artificial nanochannel devices constructed from porous materials have been widely studied for the experimental investigation of nanofluidic ion transport to achieve the ion-specific transport properties observed in biological ion channels. For example, carbon nanotubes, graphene, polymers and metal–organic frameworks have been used to construct nanometre-sized pores to mimic atomic-scale ionic and molecular transport of biological ion channels.

However, the discovery of bioinspired ultrafast rectifying counter-directional transport of proton and metal ions has not been reported until now.

'The unprecedented ion-specific rectifying transport behaviour found in our metal–organic framework (MIL-53-COOH)-polymer nanofluidic device is attributed to two distinct mechanisms for metal ions and proton, explained by theoretical simulations. This work furthers our knowledge of designing artificial ion channels, which is important to the fields of nanofluidics, membrane and separations science', said Wang.

Monash University

Green ammonia production a step closer

Incitec Pivot Limited (IPL) and global green energy company Fortescue Future Industries (FFI) have reached the first milestone in their quest to develop industrial-scale green ammonia production at IPL's Gibson Island facility.

From preliminary studies conducted by each party, FFI have found the project to be technically feasible and have issued IPL with a notice to proceed to the next phase. This allows the parties to negotiate an agreement to progress this project to a Front End Engineering Design study. The study will refine cost, schedule, permitting and commercial agreements, and inform a potential Final Investment Decision.

Located in Brisbane, the Gibson Island plant currently uses natural gas as a feedstock to produce ammonia. In October, IPL and FFI announced a partnership to investigate the feasibility of replacing gas with renewable hydrogen to produce industrial-scale green ammonia.

If the project proceeds, it is currently proposed that FFI would construct an on-site water electrolysis plant and develop and operate the hydrogen manufacturing facility, with IPL operating the ammonia manufacturing facility.

The new water electrolysis facility would produce up to 50 000 tonnes of renewable hydrogen per year and be a complete replacement of Gibson Island's current gas feedstock. This renewable hydrogen would then be converted into more than 300 000 tonnes of green ammonia for Australian and export markets.

The Front End Engineering Design study is expected to be completed by the end of 2022.

Incitec Pivot

UN member states endorse resolution to end plastic pollution

Heads of state, ministers of environment and other representatives from UN Member States endorsed a historic resolution at the UN Environment Assembly (UNEA-5) in Nairobi to End Plastic Pollution and forge an international legally binding agreement by 2024. The resolution addresses the full lifecycle of plastic, including its production, design and disposal.

The resolution, based on three initial draft resolutions from various nations, establishes an Intergovernmental Negotiating Committee (INC), which will begin its work in 2022, with the ambition of completing a draft global legally binding agreement by the end of 2024. It is expected to present a legally binding instrument, which would reflect diverse alternatives to address the full lifecycle of plastics, the design of reusable and recyclable products and materials, and the need for enhanced international collaboration to facilitate access to technology, capacity building and scientific and technical cooperation.


Falkue

The suburb of Dandora in Nairobi, Kenya contains a huge dumpsite that receives thousands of tonnes of plastics each day and is a hazard to human health and the environment.

The UN Environment Programme (UNEP) will convene a forum by the end of 2022 that is open to all stakeholders in conjunction with the first session of the INC, to share knowledge and best practices in different parts of the world. It will facilitate open discussions and ensure they are informed by science, reporting on progress throughout the next two years. Finally, upon completion of the INC's work, UNEP will convene a diplomatic conference to adopt its outcome and open it for signatures.

'Let it be clear that the INC's mandate does not grant any stakeholder a two-year pause. In parallel to negotiations over an international binding agreement, UNEP will work with any willing government and business across the value chain to shift away from single-use plastics, as well as to mobilise private finance and remove barriers to investments in research and in a new circular economy', said Inger Andersen, Executive Director of UNEP.

Plastic production soared from 2 million tonnes in 1950 to 348 million tonnes in 2017, becoming a global industry valued at US$522.6 billion, and it is expected to double in capacity by 2040. The impacts of plastic production and pollution on the triple planetary crisis of climate change, nature loss and pollution are a catastrophe in the making.

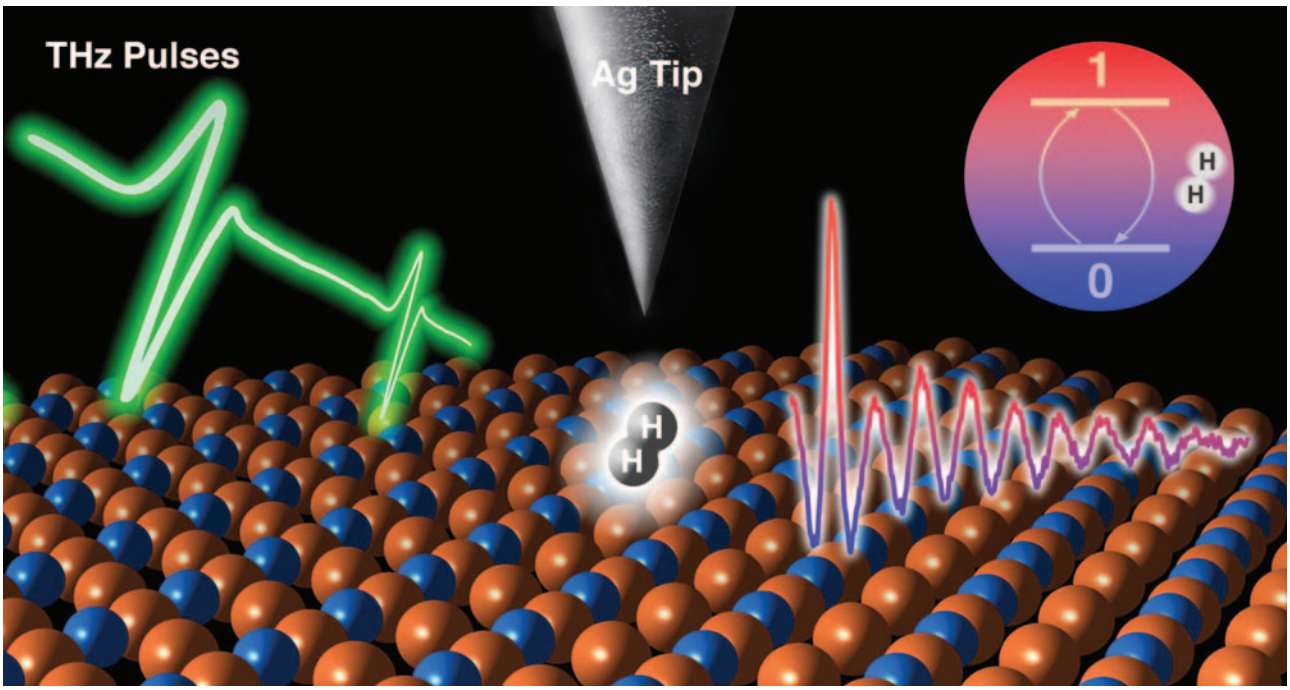
By 2050, greenhouse gas emissions associated with plastic production, use and disposal would account for 15% of allowed emissions, under the goal of limiting global warming to 1.5°C.

Some 11 million tonnes of plastic waste flow annually into oceans. This may triple by 2040. More than 800 marine and coastal species are affected by this pollution through ingestion, entanglement, and other dangers.

A shift to a circular economy can reduce the volume of plastics entering oceans by over 80% by 2040; reduce virgin plastic production by 55%; save governments US$70 billion by 2040; reduce greenhouse gas emissions by 25%; and create 700 000 additional jobs – mainly in the global south.

United Nations

Physicists turn hydrogen molecule into quantum sensor



In the ultrahigh vacuum of a scanning tunnelling microscope, a hydrogen molecule is held between the silver tip and sample. Femtosecond bursts of a terahertz laser excite the molecule, turning it into a quantum sensor. Wilson Ho Lab, UCI

Physicists at the University of California, Irvine (UCI) have demonstrated the use of a hydrogen molecule as a quantum sensor in a terahertz laser-equipped scanning tunnelling microscope (STM), a technique that can measure the chemical properties of materials at unprecedented time and spatial resolutions.

This new technique can also be applied to the analysis of two-dimensional materials that have the potential to play a role in advanced energy systems, electronics and quantum computers.

In a recent issue of *Science* (doi.org/10.1126/science.abn9220), the researchers describe how they positioned two bound atoms of hydrogen in between the silver tip of the STM and a sample composed of a flat copper surface arrayed with small islands of copper nitride. With pulses of the laser lasting trillionths of a second, the scientists were able to excite the hydrogen molecule and detect changes in its quantum states at cryogenic temperatures and in the ultrahigh vacuum environment of the instrument, rendering atomic-scale, time-lapsed images of the sample.

'This project represents an advance in both the measurement technique and the scientific question the approach allowed us to explore,' said co-author Wilson Ho, Donald Bren Professor of Physics & Astronomy and Chemistry. 'A quantum microscope that relies on probing the coherent superposition of states in a two-level system is much more sensitive than existing instruments that are not based on this quantum physics principle.'

Ho said the hydrogen molecule is an example of a two-level system because its orientation shifts between two positions, up and down and slightly horizontally tilted. Through a laser pulse, the scientists can coax the system to go from a ground state to an excited state in a cyclical fashion, resulting in a superposition of the two states. The duration of the cyclic oscillations is vanishingly brief – mere tens of picoseconds – but by measuring this 'decoherence time' and the cyclic periods, the scientists were able to see how the hydrogen molecule was interacting with its environment.

'The hydrogen molecule became part of the quantum microscope in the sense that wherever the microscope scanned, the hydrogen was there in between the tip and the sample', said Ho. 'It makes for an extremely sensitive probe, allowing us to see variations down to 0.1 angstrom. At this resolution, we could see how the charge distributions change on the sample.'

The space between the STM tip and the sample is almost unimaginably small, about six angstroms or 0.6 nanometres. The STM that Ho and his team assembled is equipped to detect minute electrical current flowing in this space and produce spectroscopic readings proving the presence of the hydrogen molecule and sample elements. Ho said this experiment represents the first demonstration of a chemically sensitive spectroscopy based on terahertz-induced rectification current through a single molecule.

The ability to characterise materials at this level of detail based on hydrogen's quantum coherence can be of great use in the science and engineering of catalysts, since their functioning often depends on surface imperfections at the scale of single atoms, according to Ho.

University of California, Irvine

Calix receives regulatory approval for BOOSTER-Mag

Calix Limited has received APVMA approval for its safe, environmentally friendly crop protection product BOOSTER-Mag.

BOOSTER-Mag can now be supplied or sold and used safely according to the label directions by farmers.

- BOOSTER-Mag aims to reduce farmer input costs and produce food more safely and sustainably.
- The initial registration has been approved without restriction on crop residue, reflecting intrinsic BOOSTER-Mag safety.
- Large-scale field trials indicate that regular foliar application of BOOSTER-Mag can allow for a material reduction in the use of conventional pesticides without compromising crop yield or yield quality.
- The initial label registration creates a bioactive materials platform, establishing product safety, and paves the way for expedited approval for use in more crops and more applications.

BOOSTER-Mag is a suspension concentrate of bioactive magnesium hydroxide, developed as a foliar treatment to supress a variety of crop insect pests and diseases. Large-scale field trials have indicated that regular foliar application of BOOSTER-Mag reduces farmer reliance on conventional pesticides without compromising crop yield or yield quality.

BOOSTER-Mag is part of several larger field trials overseas where other types of crops and applications (e.g. antifungal) are being evaluated.

For more information, visit www.calix.global.

Innovative GC and GC-MS products enable greater uptime and efficiency

The innovative gas chromatography (GC) and GC–mass spectrometry (GC-MS) portfolio from Thermo Fisher Scientific is designed to deliver enhanced customer experience, easy adoption and simplified operations.

Analytical testing laboratories across a variety of sectors, including food, environmental, industrial and pharmaceutical, can now meet their ever-increasing efficiency and productivity needs with a collection of new GC and GC-MS instruments offering innovative hardware and software updates.

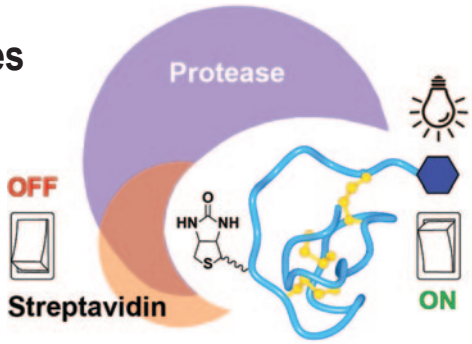
The GC and GC-MS instrument portfolio, including the Thermo Scientific™ TRACE™ 1600 Series Gas Chromatograph, Thermo Scientific™ AI/AS 1610 Liquid Autosampler, Thermo Scientific™ ISQ™ 7610 Single Quadrupole GC-MS, and Thermo Scientific™ TSQ™ 9610 Triple Quadrupole GC-MS/MS, now features:

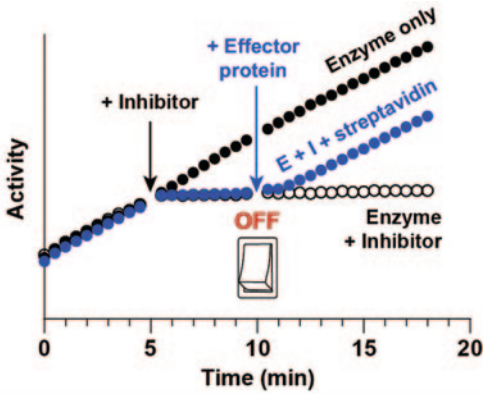
- unique GC modularity and NeverVent technologies that enable increased instrument uptime by accelerating maintenance operations through user-exchangeable injectors and detectors modules, and the ability to remove MS ion source, filaments and analytical column without breaking the vacuum
- wider high-resolution multi-function touch screen, tool-free column connection
- illuminated GC oven and autosampler syringe compartment

- support from how-to videos directly on the GC touch screen for quick familiarisation and adoption
- consistent sensitivity and extended linear dynamic range of the new MS detector that enable methods consolidation for maximised sample throughput.

Learn more at the Innovation Summit: 'Stay Ahead with new GC and GCMS Technology' (on-demand) at https://chrom-ms.info/innovation-summit-cia.

On/off switch for enzymes

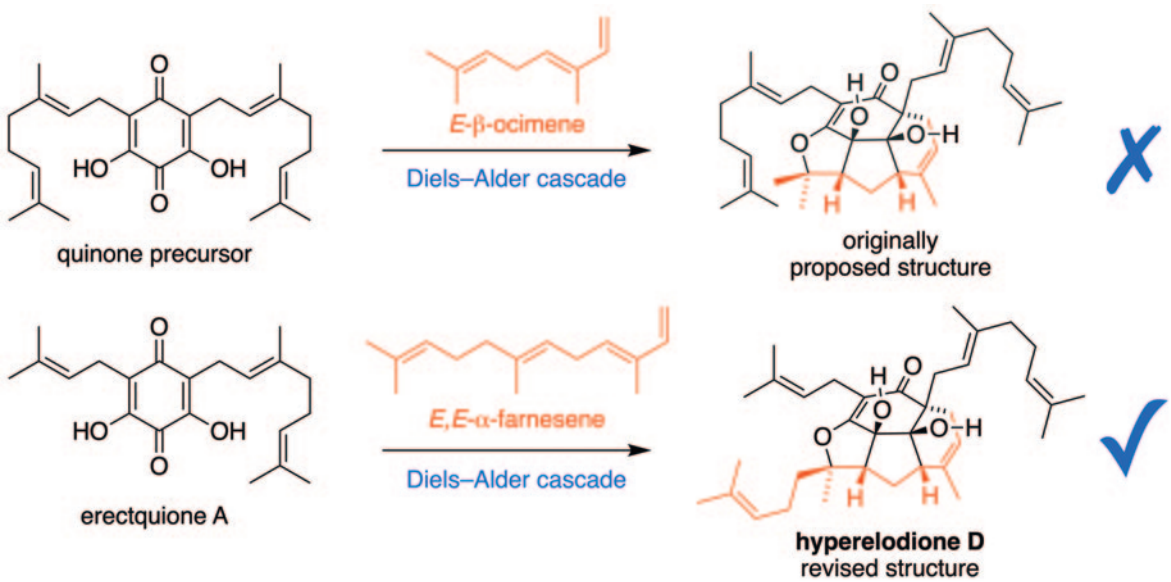




Tuneable peptides and proteins unlock new possibilities for modulating chemical or biological processes with exquisite temporal control. A team from the University of Queensland has applied this concept to topologically complex peptides called knottins to design tuneable protease inhibitors that can be controlled with light or an effector protein (Li C.Y., Rehm F.B.H., Yap K., Zdenek C.N., Harding M.D., Fry B.G., Durek T., Craik D.J., de Veer S.J. *Angew. Chem. Int. Ed.* 2022, **61**, e202200951). Knottins are ultra-stable peptides that feature a cystine knot consisting of three disulfide bonds and are valuable scaffolds for designing pharmaceutical leads or molecular tools. The team designed protease inhibitors that had light-controlled activity and could be switched ON against new targets by activating a second mode of action. Additionally, by introducing a biotin tag next to the key binding residues, labelled inhibitors were produced that could be rapidly switched OFF by adding an effector protein, streptavidin. This approach was used to start, stop, then restart an enzymatic reaction in the space of 15 minutes, and to switch OFF the anticoagulant activity of an engineered knottin in human plasma. This work expands the scope of engineered knottins for modulating protein function with deft control.

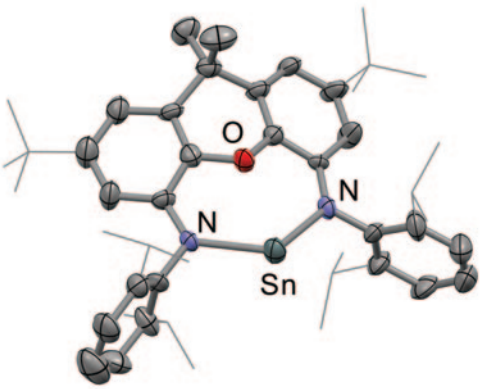
Don't believe the hype

Flowering plants of the *Hypericum* genus (such as St John's wort) are extensively used in traditional medicine because they produce a vast range of biologically active natural products. These natural products are often highly complex, with multiple stereocentres and ring systems, so their precise structural assignment can be problematic. For example, the isolation and characterisation of an elaborate meroterpenoid natural product, hyperelodione D, from *Hypericum elodeoides* was recently disclosed. Soon after this report, researchers at the University of Adelaide synthesised the fused 6-6-5-5 tetracylic core of the proposed structure of hyperelodione D, using a bioinspired Diels–Alder cascade reaction between *E*-β-ocimene and a quinone precursor (Franov L.J., Hart J.D., Pullella G.A., Sumby C.J., George J.H. *Angew. Chem. Int. Ed.* 2022, **61**, e202200420). However, spectroscopic data for the synthetic compound did not quite match the natural product. A revised structure of hyperelodione D was therefore proposed, based on a new biosynthetic hypothesis involving a Diels–Alder cascade reaction between *E*,*E*-α-farnesene and a naturally occurring quinone called erectquione A. Realisation of this biosynthetic proposal in a biomimetic chemical synthesis then allowed the structural reassignment of hyperelodione D. This work highlights the important role that biosynthetic speculation can play in the accurate characterisation of intricate natural products.

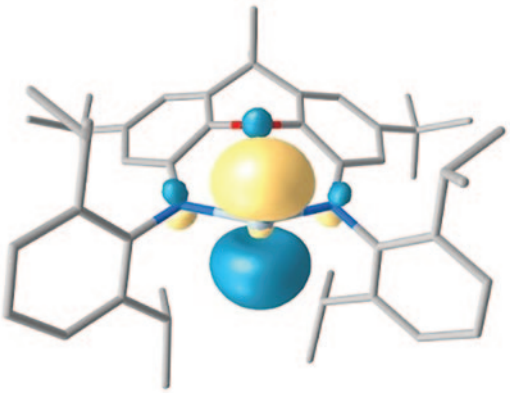


Who says main group elements aren't radical?

Open-shell electronic configurations are not typically associated with the main group elements. Main group elements with unpaired electrons are typically extremely reactive species, which rapidly disproportionate or dimerise to form more stable closed-shell compounds. That said, using a combination of sterically demanding ligands and electrostatic repulsion, an international team led by Jamie Hicks and Nick Cox at the Australian National University have reported the first isostructural series of group 14 E(I) radical anions from Ge(I) to Pb(I) (Lim L.F., Judd M., Vasko P., Gardiner M.G., Pantazis D.A., Cox N., Hicks J. *Angew. Chem. Int. Ed.* 2022, **61**, e202201248).



Solid state structure of the Sn(I) radical anion

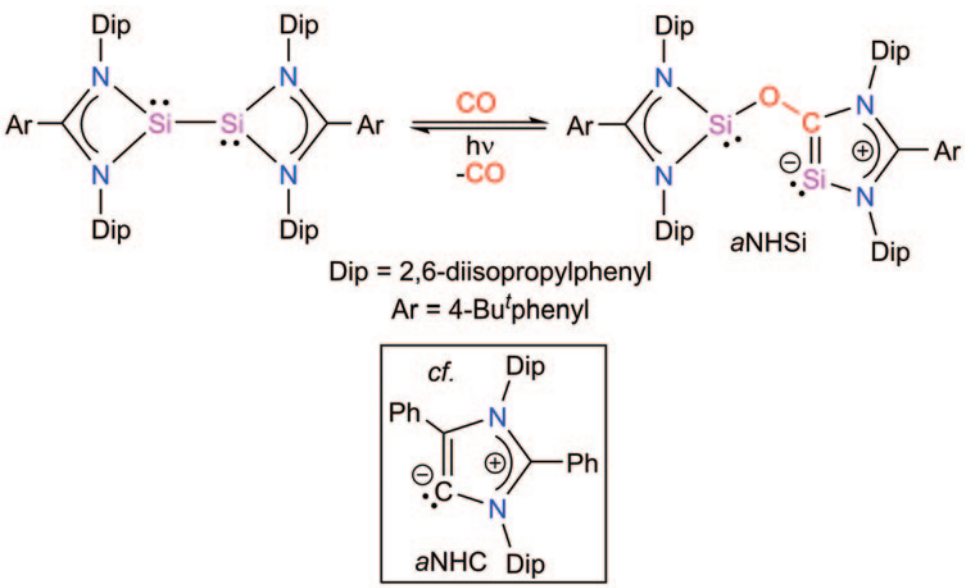


SOMO of the Sn(I) radical anion as calculated by DFT

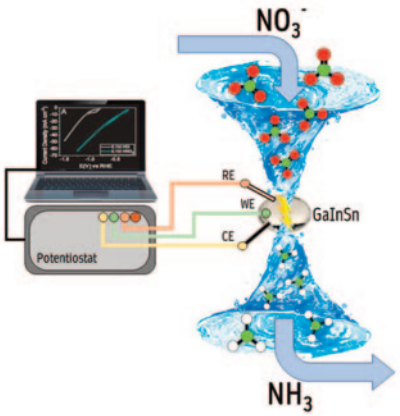
Remarkably, two of these radical anions were isolable as single crystals (albeit only at low temperatures) and therefore could be characterised in the solid state for the first time. Using a combination of X-ray diffraction, EPR spectroscopy and DFT analysis, the team found that, in all cases, the spin density of the unpaired electron almost exclusively resided in a singly occupied molecular orbital (SOMO) that was a p-orbital of π-symmetry located on the group 14 metal centre. The team are currently investigating the reactivity of these novel radical anions towards small-molecule activation.

The first 'abnormal' N-heterocyclic silylene

As is the case for 'normal' N-heterocyclic carbenes (NHCs), the coordination chemistry of 'abnormal' NHCs (*a*NHCs) has been widely explored, and their transition metal complexes are increasingly finding use as catalysts. Recently, the groups of Cameron Jones at Monash University and his theoretician collaborator Laurent Maron at the University of Toulouse (France) have shown that a reactive 1,2-disilylene can readily activate CO, leading to high yields of the first 'abnormal' N-heterocyclic silylene (*a*NHSi), which is substituted by an oxysilylene fragment (Garg P., Carpentier A., Douair I., Dange D., Jiang Y., Yuvaraj K., Maron L., Jones C. *Angew. Chem. Int. Ed.* 2022, **61**, e202201705). Remarkably, the reaction is cleanly reversible under irradiation by UV light. Moreover, the ability of the compound to act as a bidentate ligand towards transition metal fragments was demonstrated. Given the computed differences in electronic structure between *a*NHCs compared with *a*NHSis, there is significant potential to develop the chemistry of the latter as novel ligands in catalysis.



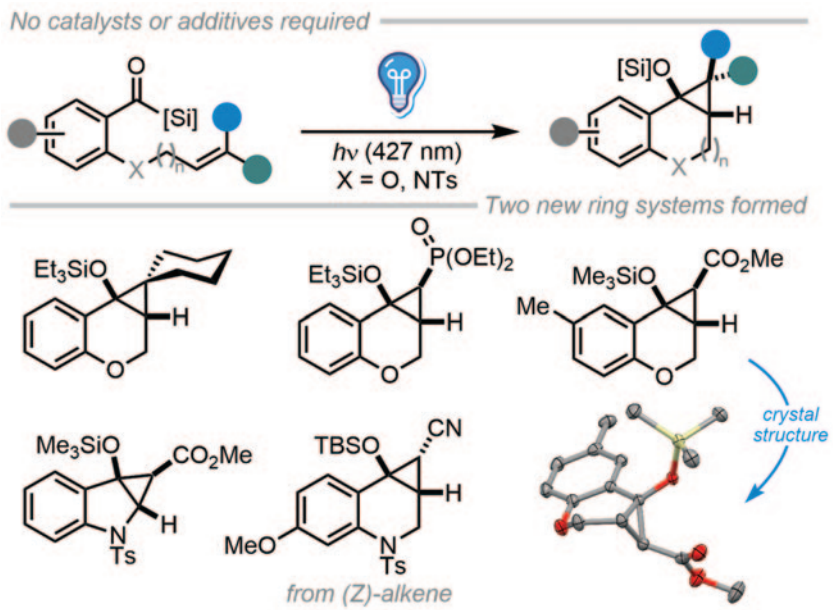
Converting nitrates to ammonia on liquid metals



Electrochemical formation of hydrogen carriers such as NH_3 is a key step in achieving a sustainable energy economy, not only in terms of subsequent hydrogen extraction and utilisation, but also as an alternative to the energy-intensive Haber–Bosch process. The electrochemical conversion of nitrates to ammonia is a rapidly emerging research area, but improvements in NH_3 production rates and electrode stability are needed. Researchers at the Queensland University of Technology have addressed these issues by using a liquid-metal electrode consisting of Ga, In and Sn that converts both nitrate and nitrite ions into NH_3 at high Faradaic efficiency (Crawford J., Yin H., Du A., O'Mullane A.P. *Angew. Chem. Int. Ed.* 2022, doi.org/10.1002/anie.202201604). The active site was determined to be In_3Sn within a Ga matrix that forms during the electrochemical reaction, and was confirmed experimentally and corroborated by density functional theory calculations. This material is not only active for the reaction but suppresses side reactions such as the hydrogen evolution reaction. This process offers a potential route for treating wastewaters with high NO_x concentrations to produce a valuable and sustainable hydrogen carrier.

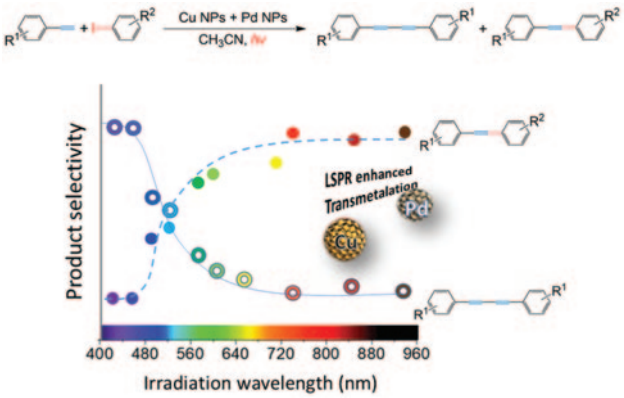
Making light work of building strained rings

Photochemical reactions offer significant potential in chemical synthesis, as light irradiation can generate high-energy, electronically excited intermediates that produce highly strained and unusual molecular frameworks. In this context, the irradiation of acyl silanes with blue light is known to promote the 1,2-Brook rearrangement that generates nucleophilic carbene intermediates. These visible-light-induced carbene intermediates have proven valuable in chemical synthesis, participating in reactions including carbon–hydrogen insertion reactions and 1,2-carbonyl addition. Researchers at the University of Melbourne have recently identified new opportunities to exploit the photochemical generation of carbene intermediates, discovering a stereospecific [2+1]-cycloaddition reaction between siloxy carbenes and tethered alkenes (Bunyamin A., Hua C., Polyzos A., Priebbenow D.L. *Chem. Sci.* 2022, **13**, 3273–80). This catalyst- and diazo-free cyclopropanation reaction showcases a significantly underexplored mode of reactivity for nucleophilic carbenes and produces cyclopropane-fused bicyclic scaffolds – attractive targets in a medicinal chemistry setting due to their unique three-dimensional structure and conformational rigidity. As a result of the inherent ring strain, these cyclopropane-fused scaffolds can also be readily engaged in subsequent ring-expansion reactions to rapidly generate molecular complexity.



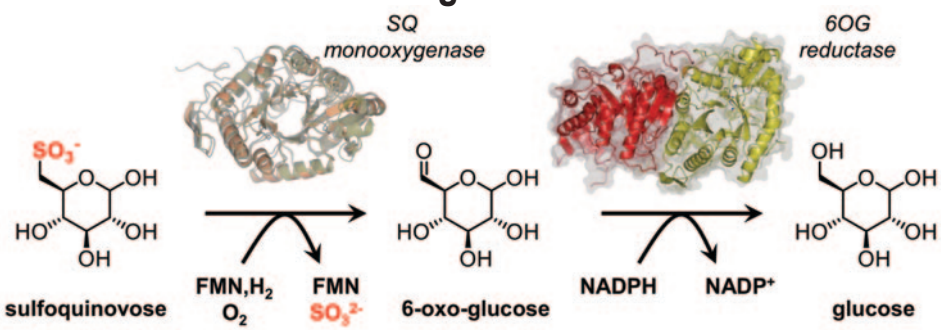
Surface-plasmon-enhanced transmetallation in coupling reactions

The widely accepted mechanism of carbon–carbon coupling reactions, such as Sonogashira and Glaser coupling, follows a multistep pathway of oxidative addition, transmetallation and reductive elimination that proceeds by two synergistic catalytic cycles. Transmetallation – the transfer of an organic group from one metal centre to another – is a rate-determining step in these metal-catalysed cross-coupling reactions. Recently, researchers at the Queensland University of Technology revealed a transfer of a phenylacetylide intermediate from a Cu to a Pd surface that is mediated by localised surface plasmon resonance (LSPR), which affords a novel mechanism for transmetallation, enabling wavelength-tuneable control of cross-coupling and homo-coupling reaction pathways (Liu X., Shi Y.J., Jin Y.C., Tana T., Peiris E., Zhang X.M., Xu F., Waclawik E.R., Bottle S.E., Zhu H.Y., Sarina S. *Angew. Chem. Int. Ed.* 2022, doi.org/10.1002/anie.202203158). The researchers found that the reaction pathway can be controlled by switching the excitation wavelength. Shorter wavelengths (400–500 nm) give the Glaser homo-coupling diyne, whereas longer wavelengths (500–940 nm) significantly increase the degree of cross-coupling Sonogashira coupling products. The ratio of activated alkyne intermediates to the iodobenzene depends on the wavelength, which thus regulates transmetallation. This wavelength-tuneable reaction pathway is a novel way to optimise the product selectivity in important organic syntheses.



New pathway cleaves sulfur–carbon bond in sulfosugars

Sulfoquinovose is a sulfosugar produced by plants and is metabolised by a wide range of bacteria. Yet some organisms can achieve its breakdown despite lacking known catabolic pathways. Researchers at the University of Melbourne, Walter and Eliza Hall Institute, and York University (UK) have discovered a new pathway for sulfoquinovose metabolism in *Agrobacterium tumefaciens* and determined the 3D structures of the enzymes in this pathway (Sharma M., Lingford J.P., Petricevic M., Snow A.J.P., Zhang Y., Järvå M.A., Mui J.W.-Y., Scott N.E., Saunders E.C., Mao R., Epa R., da Silva B.M., Pires D.E.V., Ascher D.B., McConville M.J., Davies G.J., Williams S.J., Goddard-Borger E.D. *Proc. Natl. Acad. Sci. USA* 2022, **119**, e2116022119). A key discovery of this study was a sulfoquinovose monooxygenase that cleaves the sulfur–carbon bond and forms the novel metabolite 6-oxoglucose, which is then reduced to glucose and enters glycolysis. This new sulfoquinovose monooxygenase pathway is widespread in rhizobia, an important group of bacteria that form symbiotic and pathogenic relationships with plants.



Compiled by **David Huang** MRACI CChem (david.huang@adelaide.edu.au). This section showcases the very best research carried out primarily in Australia. RACI members whose recent work has been published in high-impact journals (e.g. *Nature, J. Am. Chem. Soc., Angew. Chem. Int. Ed., Chem. Sci.*) are encouraged to contribute general summaries, of no more than 200 words, and an image to David.

Innovation *in a* climate *of* risk and regulation

Satenik_Guzhanina/iStockphoto

BY RICHARD THWAITES

The precautionary principle has a place in regulating chemicals new to Australia, but for chemicals already used elsewhere are the burdens of time and cost unnecessarily heavy?

Life is full of hazards. We take risks every day. The riskiest trip many of us take is along the birth canal – much more hazardous than white-water rafting, they say – but here we all are, mostly having arrived quite safely . . .

We understand the precautionary principle, but if we always applied it in order to know all the outcomes of every action we might take before we set out, we'd perhaps still be living in caves or in the Dark Ages, without any of the comforts of modern living or benefits of modern science. Professor K. Clive Thompson from the UK's Society of Chemical Industry spoke on the topic 'Does the over-zealous implementation of the precautionary principle inhibit innovation?' at the RACI Centenary Congress in 2017. In short, his answer was 'yes'. In early 2019, Daniel Castro and Michael McLaughlin at the Information Technology & Innovation Foundation wrote 'Ten Ways the Precautionary Principle Undermines Progress in Artificial Intelligence'. One of their key messages was that, to capture the full benefits of AI, policymakers should follow the 'innovation principle', which holds that the vast majority of new innovations are beneficial and pose little risk, so government should encourage them. Is what should be right for AI be right for the chemical industry?

Chemical engineers have spent

decades studying and refining risk profiles of chemical reactions. Usually, when something goes seriously awry in a chemical plant, it is because someone's homework hasn't been done properly, or someone hasn't evaluated all the possibilities of what might go wrong. The literature of the risk engineering fraternity is littered with examples of failures because shortcuts were taken, or insufficient account was taken of all possible eventualities.

If new chemicals with measurable benefits are to be introduced into the world, how much risk are we prepared to tolerate before their introduction is permitted? Addressing this question has challenged many an industrial research chemist over many years.

We know how important it is to ensure that the food we eat doesn't poison us, and that the medicine we take helps to cure us, not make us worse. The Food and Drugs Administration (FDA) was set up in the USA to ensure these sorts of outcome. Established in 1848, it originally focused on chemical analysis of agricultural products to ensure their safety, and then in 1906, the Pure Food and Drugs Act, 25 years in the making, laid the groundwork for the FDA's modern regulatory functions, prohibiting interstate commerce in adulterated and misbranded food and drugs etc.

Similar regulatory bodies in other jurisdictions offer similar protections to consumers. In Australia, for example, one of the key functions of Food Standards Australia New Zealand (FSANZ) is to control the introduction of new food additives to ensure that they are safe to use and safe to consume. The Australian Pesticides and Veterinary Medicines Authority (APVMA) regulates agricultural and veterinary products, and the Therapeutic Goods Administration (TGA) regulates the introduction of pharmaceuticals: no new pharmaceutical compounds can be introduced on the market unless and

If new chemicals with measurable benefits are to be introduced into the world, how much risk are we prepared to tolerate before their introduction is permitted?

until they have been rigorously tested, evaluated and pronounced safe and efficacious. Admittedly, in days gone by, before the need for rigorous evaluation under all conceivable conditions of application were appreciated, things sometimes did go wrong, sometimes with disastrous consequences. But we have learned from our mistakes.

Should new industrial chemicals be subjected to similar evaluations? Well, yes, because we know of the potential dangers to people and the environment if potentially hazardous substances are discharged in an unregulated manner without appropriate controls. But how rigorous should those regulations be if the products concerned have demonstrably beneficial properties, are going to be used in a properly regulated environment, and particularly if they are already used overseas?

An early step along the route to chemicals regulation in Australia was the establishment of the Australian Core Inventory of Chemical Substances (ACOIN). Published in 1984 by the Department of Home Affairs and Environment, it listed all chemicals that companies said were in use at the time. The idea of collating a database like this was to establish a foundation from which to build new knowledge about new chemicals. If a chemical entity was listed on the inventory, then companies could introduce (i.e. manufacture, import and/or use) it provided that the organisations concerned had registered with the department, and paid the requisite fees. Of course, some of the listed chemicals, despite having been in use for ages, weren't as safe as they might have been and over time were subject to more critical examination by the department, sometimes with subsequent restrictions on how they could be used in future. Industrial chemicals were defined by exclusion: an industrial chemical is anything that is not a foodstuff (regulated by FSANZ), a medicine (regulated by the TGA) or a veterinary product (regulated by the APVMA).

The establishment of the National Industrial Chemicals Notification and Assessment Scheme (NICNAS) the same year as ACOIN meant that new chemical entities (new to Australia, that is) not on the inventory had to be subject to rigorous examination before they could be introduced (manufactured, imported or used) in Australia in industrial applications. (Some exemptions were allowed for small-scale and research purposes.) Chemicals were identified by their CAS numbers, which generally worked well. An organisation wishing to introduce a new chemical first had to be registered, then had to produce a wide range of data on the new chemical's physical and chemical properties, toxicity to a range of plant life, river, ocean and terrestrial organisms, impact on the environment etc. All well and good in theory, but in practice the cost of carrying out the requisite tests as required under Australian conditions, often in circumstances where overseas evaluations were not readily accepted, often made the introduction of the new chemical uneconomic. The department set itself a clock by which to respond to new product submissions, but the clock stopped

Chemicals, conventions and the 'dirty dozen'

The period from 1997 to 2007 was a bumper decade for introducing controls on the chemical industry.

The Chemical Weapons Convention entered into force in 1997. The Rotterdam and Stockholm Conventions were signed in 2004. And the European Chemicals Agency (ECHA), responsible for implementing the REACH (Registration, Evaluation, Authorization and Restriction of Chemicals) program was established in 2007. So, Australia's AICIS program is not an isolated example of a government wanting to regulate the production and use of chemicals.

In 2001, the Stockholm Convention, an international agreement to minimise the emission or discharge of persistent organic pollutants (POPs), was adopted. Australia became a signatory in 2004, the year that the Convention entered into force.

Initially, 12 POPs – the 'dirty dozen' – were recognised under the Stockholm Convention as causing adverse effects on humans and ecosystems:

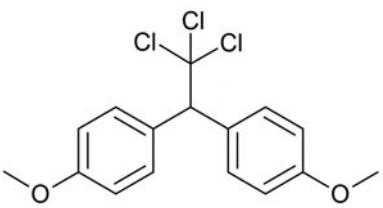
- Pesticides: aldrin, chlordane, DDT, dieldrin, endrin, heptachlor, hexachlorobenzene, mirex, toxaphene
- Industrial chemicals: hexachlorobenzene, polychlorinated biphenyls (PCBs)
- By-products: hexachlorobenzene; polychlorinated dibenzo-*p*-dioxins and polychlorinated dibenzofurans (PCDD/PCDF), and PCBs

POPs covered by the Stockholm Convention have been added to over time and now numbers around three dozen chemical entities. Chemicals currently under review include methoxychlor and chlorpyrifos.

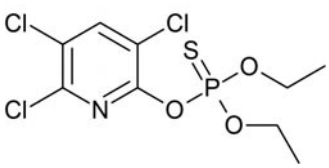
Two other international conventions, those of Basel and Rotterdam, are international agreements concerning international trade and transboundary movement of hazardous waste and pesticides/certain hazardous chemicals, respectively. The Rotterdam Convention focuses on pesticides and industrial chemicals that have already been banned in various countries, such as asbestos. The 52 chemicals covered by the Rotterdam Convention can also be very persistent in the environment. Signatories to the Convention ban the import and export of the chemicals and products listed in Annex III with the aim of including more countries where the chemicals are banned.

REACH, under the administration of the ECHA, is the mechanism that controls the production, use, introduction and sale of chemicals in the EU. The ECHA was established in Helsinki and currently has about 600 staff working for it. Its role is to implement the EU's chemicals legislation to protect people and the environment from the hazards of chemicals. It claims also to contribute to the well-functioning internal market and the innovation and competitiveness of the European chemicals industry.

The Basel, Rotterdam and Stockholm Conventions Conference of Parties is being held in Geneva in June this year. For further information, visit www.pops.int.



Methoxychlor



Chlorpyrifos

New reforms for industrial chemicals management

A national roadmap to deliver Australia's new Industrial Chemicals Environmental Management Standard (IChEMS) is now available.

Deputy Secretary of the Department of Agriculture, Water and the Environment James Tregurtha said that, when in place, IChEMS will deliver more consistent regulation of industrial chemicals and make it easier for industry to choose less harmful alternatives.

'IChEMS was developed collaboratively by the Australian, state and territory governments working together as part of broader reforms to Australia's chemicals and waste management', Tregurtha said.

'IChEMS will not only support informed choice about chemicals but will also function as a single consistent source of information on how industrial chemicals should be managed in Australia.'

Australia's states and territories are working to adopt and implement IChEMS into their own regulatory frameworks from the end of the year.

For more information, and to contribute to this national reform, go to www.awe.gov.au/environment/protection/chemicals-management/national-standard.

Department of Agriculture, Water and the Environment

every time the proponent was asked to provide more data, which often meant substantial time delays in getting approval. And I don't think the clock was ever beaten!

So what happened in practice was that Australia was quite probably deprived of new products and new technologies because, although they were already being used overseas, the cost of providing data required by Australian authorities exceeded the revenue expected from the Australian market. And this applied not just to new chemicals, but also to formulations (cosmetic, toiletry, paint, inks or glues) that contained these new chemicals.

NICNAS transitioned to the Australian Industrial Chemicals Introduction Scheme (AICIS) in 2020 in order to address some perceived deficiencies in the old scheme. The AICIS website claims that although this new scheme has the same mission as the old scheme, some of the operating principles have been modified: they now include inter alia risk-proportionate regulation, a rebalancing of pre-introduction versus post-introduction controls, with less focus on pre-introduction assessment, and more on post-introduction monitoring and evaluation, and incentivising lower risk chemical introductions.

The idea as outlined on the AICIS website is for the government to regulate chemicals, including polymers, introduced (manufactured, imported and/or used) for industrial applications such as in inks, paints, adhesives, solvents, cosmetics and personal care products, cleaning products, as well as in manufacturing, construction and mining applications. The legislation establishing the AICIS was contained in the *Industrial Chemicals Act 2019*.

The website says that the scheme helps to protect the health of Australians and our environment by finding out the risks of industrial chemicals and recommending ways to promote their safer use. It doesn't refer to the potential impact of regulation on the health of Australian industry. Although to be fair, some aspects of the new scheme have attempted to address this.

Too often, the term 'scientific interpretation' just means ticking boxes.

Would proponents of the precautionary principle say the safest thing to do is to not use new industrial chemicals and relocate the risk associated with their manufacture and use offshore? That thinking would bring about the further demise of Australian manufacturing industry and deprive Australian consumers of the most modern technology. It is very frustrating when new chemicals with advantages over existing products in terms of safety, efficacy and reduced environmental impact are *not* introduced into Australia to substitute for less efficacious existing products because the cost of testing makes their introduction uneconomic. At least AICIS is more receptive to overseas test results than NICNAS was.

What AICIS claims it does is to conduct scientific risk assessments on the introduction and intended use of industrial chemicals in Australia. It publishes its findings. Actually, the AICIS takes data developed, provided and paid for by industry and, according to the website, scientifically interprets it to determine potential risks. Too often, the term 'scientific interpretation' just means ticking boxes.

The AICIS maintains the Australian Inventory of Industrial Chemicals on which something like 40 000 entities are listed. More than 7000 companies are registered to import, manufacture or use industrial chemicals. The AICIS issues certificates and authorisations for the introduction of industrial chemicals in Australia. It makes risk management recommendations to protect human health and the environment. It sets and maintains the Industrial Chemicals Categories Guidelines and maintains the Register of Industrial Chemical Introducers. It also monitors compliance and investigates breaches of the relevant laws and collects statistics (which all 7000 companies registered with AICIS have to provide at their own cost) on the use of industrial chemicals in Australia.

The AICIS is funded by the fees and charges paid by manufacturers and importers (introducers) of industrial chemicals, so maintaining AICIS represents a direct cost on innovation. In effect, industry pays to get its products tested, pays to get the tests assessed by the AICIS, then pays to hold the relevant licence to 'introduce' the products. Surely, all these costs are a disincentive to innovation?

I wonder what would have happened if the precautionary principle had been applied to the first chemical processes that humans worked on, such as fermentation to make beer and wine. Would alcohol, with all its adverse effects, have ever been allowed? Maybe some people would have set the precautionary principle aside and taken note instead of the psalmist acknowledging God for 'wine that gladdens human hearts' (Psalm 104:15). Maybe there is a case for taking a similar innovative approach today!

Richard Thwaites FRACI CChem retired in 2008 after a 41-year career in the chemical industry. He currently chairs the RACI Victorian Branch Health, Safety and Environment Group, is a member of the HS&E Division, convenes the RACI Victoria Retirees, and is a member of the RACI Victorian Branch Food Nutrition and Analytical Chemistry Group.

Women, the world's first chemists

ilbusca/iStockphoto

Throughout human existence, women have made amazing contributions to chemistry. Jenny Sharwood describes some of their challenges and achievements, and shares some stories of her own.

Aboriginal Australians are the oldest civilisation on Earth. Traditionally, in all Aboriginal Australian groups, the women have had crucial roles. They discovered a range of medicines and how to extract them from plants, including painkillers, anticancer treatments and healing ointments. They worked out how to remove poisons from highly toxic plants to obtain a valuable food source. They were the givers of life, the suppliers of most of the food and other resources, and the healers of their societies. Accordingly, they held respected positions within their groups.

Long after Aboriginal people settled in Australia, in early civilisations – including those in India, Tibet, Egypt, Afghanistan and China – people mined and processed many of the natural resources to produce things they needed and things they desired: weapons, tools that included mortars and pestles, containers, food preservatives, jewellery, dyes for fabrics, cosmetics and perfumes. This involved a lot of experimentation.

According to the fascinating book *Hypatia's heritage*, it was mostly the women who were at the forefront of all this experimentation and processing, while the men were more occupied with hunting and building. Also, women were usually the physicians and surgeons and discovered the medicinal properties of various plants, oils, minerals and metals.

So it was the women, first and foremost, who were the world's first chemists. They invented and built equipment, and they discovered how to extract, break down, separate and purify substances. Women are also said to have had a prime role in the founding of alchemy, the earliest form of chemistry. It is likely this began when it was observed that fire could transform substances into new substances.

Unfortunately, true alchemists were often misjudged and even persecuted because their reputation was tainted by the actions of unscrupulous people who posed as alchemists. But true alchemists discovered much of our valuable chemical and medical knowledge, and developed many of our widely used laboratory techniques.

A great blow to women in chemistry in those early years was the assertion of Greek philosopher Aristotle that females are merely 'deformed' males. This was published in his very influential work on embryology, *De Generatione Animalium*, based on his conclusions after dissecting hundreds of animal species.

Aristotle firmly believed that all matter is made up of the four elements – earth, air, fire and water – and vehemently opposed the theory proposed around 500 BCE by the Greek philosopher Leucippus, and later by his student Democritus, that matter is made of atoms.

Unfortunately, when these theories of Aristotle were brought to Europe in about the 12th and 13th centuries, they were embraced by the churches as having an almost divine authority. Those who opposed them were prosecuted. This was the Dark Ages for Western chemistry.

Despite all that, at least one French alchemist, Marie Meurdrac, dedicated herself to her research work. In 1666, she published her first report on all her discoveries. She described laboratory apparatus she had invented and laboratory techniques she had developed. Her report displayed tables of atomic weights of various substances, the results of her experiments on metals and instructions on how to prepare a number of medicines and cosmetics.

Fortunately, thanks to Robert Boyle's questioning of some of Aristotle's ideas, there was an increased questioning of the assumptions behind his theories. It was realised that theories must be backed by experimental evidence. This was the start of the age of enlightenment and the adoption of the scientific method.

After oxygen was discovered in 1774 and hydrogen in 1781, quantitative experiments on the combustion of hydrogen conducted by both Antoine and Marie Lavoisier led them to conclude the four-element theory could not be correct. They also were able to explain what combustion actually involved.

Marie played an integral part in all of Antoine's research work after marrying him at the age of 14. Antoine was 28 when they were married. Fortunately for both Marie and for chemistry, Antoine realised straight away that his bride was highly gifted and, unlike many men of that time, he gave her every opportunity to make the most of her gifts. With his encouragement, she quickly proved that she was a very talented scientist, linguist and artist. She learned English and Latin so that she could translate important documents into French for Antoine, and soon was annotating these with her own comments. She collaborated with him in designing, performing and recording their experiments, translated their reports into other languages and drew their technical drawings with great accuracy and skill.

Marie turned their home into a popular scientific meeting place, taking part in all of the discussions and debates. Their learned guests were very impressed by her.

After conducting some brilliantly designed experiments, the Lavoisiers wrote the first modern chemistry textbook, *Elements of chemistry*, which was published in 1789.

Portrait of M. and Mme Lavoisier **by Jacques-Louis David, 1788.**

Metropolitan Museum of Art, Manhattan, New York City

Despite Marie Lavoisier's outstanding contribution, most men of science did not appreciate the role of many women scientists, who often worked without support and acknowledgment. Indeed, men often did their utmost to limit what women scientists could achieve, treated them poorly and even took credit for their work.

One such story is that of Lise Meitner, a young Jewish girl who lived in Vienna in the late 1800s. Fortunately, her parents valued education very highly. At that time, girls were not allowed to study beyond primary school, so Lise's parents engaged a private tutor to teach her. Then in 1901, the Austrian Government opened universities to women and Lise enrolled to study her two great passions – physics and mathematics. Soon she had to deal with male prejudices, with some male professors refusing to have a female in their class. Despite that, she persisted and received her doctorate in 1906.

At the time, the only jobs available for female physicists in Austria were teaching or tutoring, so Lise moved to Berlin to further her studies in the new exciting field of radioactivity. There she was forced to work in an old carpentry workshop in the basement because the male laboratory supervisor would not allow a female to work in the official laboratory alongside male researchers. Then, just before World War 2 broke out, she had to leave Germany secretly and in haste because she was Jewish.

Lise found refuge in Sweden, where she continued her work on nuclear radiation. As part of her research, she pioneered the use of the Geiger counter. Lise also furthered the work of

Ievgeniia Lytvynovych/iStockphoto

… a little of my own story

I still vividly remember the moment that decided the direction I would take in my academic studies in Years 11 and 12.

We were only given a choice between humanities, science and commerce. I had just told my Year 10 History teacher I was thinking of doing science. 'Girls don't do science!' he roared. My respect for my hitherto outstanding teacher was shattered in one blow. All that he achieved was to make me determined to prove him wrong. And so I was the first girl in the school to choose to study science.

Sadly, at that time many girls were forced by their parents to leave the day they turned 14, though some chose that for themselves. Many parents believed that girls did not need much education because they would 'only get married and have children'. The loss of both girls and boys continued after that. When I started high school in 1957, there were roughly 100 girls and 100 boys starting at the same time. By the time I reached Year 12, there were only 10 girls and about 30 boys left.

When I started at the University of Melbourne, there were very few women in my honours chemistry course. Unfortunately, some of the men in that course were very unkind, and even bullies. I remember my first-year partner for practical work scoffing when the lab staff told him that I was to be his partner, saying loudly to the students around us 'What, do I have to work with a girl?' So I kept quiet and worked even harder.

But it concerned me then and still does that many boys and young men have not learned to respect girls or women or to recognise and appreciate their abilities. And it concerns me greatly that so many other boys and men stand by and say nothing, which implies they approve of this behaviour, instead of telling them that it is unacceptable. It takes great courage to stand up for what is right!

The other barrier faced by so many girls and women is social and economic injustice. When I completed the third year of the four-year honours chemistry course, the highly respected female senior lecturer Dr Joan Radford encouraged me to go further with my studies. Dr Radford wrote to the state education department to ask for an exemption from my studentship conditions so that I could continue my studies.

Unfortunately, its bureaucrats, who probably were all male, refused, despite the fact I achieved very high marks. In fact I was equal first in the class in second year honours chemistry and second in the class in third year honours chemistry. They said if I decided to go on, I would have to pay back all my fees and allowances for the three years I had completed. Given my parents' situation, I had no choice but to comply.

And so it was that I completed my teacher training and began teaching, to meet the terms of the studentship. When I did, my salary was way below that of my male counterparts, even those with fewer qualifications, simply because I was female.

I am sorry to say that the situation has not changed greatly in Australia. Even today, it has been found that on average women earn about 25% less than males in the same field. And far fewer women than men go on to complete higher degrees after achieving success in their first degree. I shudder to think of all the fine minds and talent that have been lost to our society, the discoveries and inventions not made …

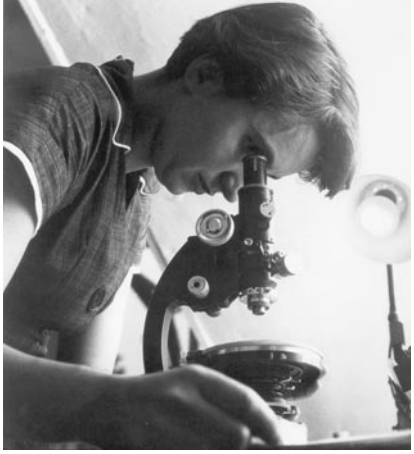
… teachers can play a crucial role in teaching young people to respect others, show kindness and compassion, behave with dignity and integrity and uphold and defend the core values of our society.

I decided I would not let these injustices limit who I was and what I could achieve. As well as my teaching I set about trying to help young women in particular learn how to be effective, just and compassionate leaders. I initiated and convened a number of student leadership events for girls at the University of Melbourne, which included overnight stays at the university, as well as a residential national conference on poverty and statewide conferences on other social justice issues, such as racism and refugees, for both girls and boys.

If our society is to mature, then teachers can play a crucial role in teaching young people to respect others, show kindness and compassion, behave with dignity and integrity and uphold and defend the core values of our society. Teachers are the ones in close day-to-day contact with our next generation – our future leaders, doctors, scientists, inventors, engineers, judges, builders, manufacturers, thinkers and writers. Teachers are the ones who plant the seeds they need to grow. We nurture our students and foster a love of learning and a belief in their own abilities and sense of worth.

Lise Meitner at the Catholic University in Washington, DC in 1946.
CA Briggs/Smithsonian Institution

Cecilia Payne.
Smithsonian Institution @ Flickr Commons



Rosalind Franklin, 1955.
MRC Laboratory of Molecular Biology

another scientist, Enrico Fermi, some of whose experiments were then repeated at her request by a former German colleague, Otto Hahn. Neither Enrico nor Otto could explain the results they obtained. It was Lise who was able to analyse and explain the results and in doing so she discovered the process of nuclear fission. She even calculated the energy released in the process. But over that war period she was not permitted to put her name on any of papers she wrote, and the 1946 Nobel Prize in Physics was awarded to Otto Hahn instead.

Eventually Lise's work was recognised. She received a number of awards and became professor of physics at the University of Berlin. In 1992, the newly discovered element 109 was named meitnerium, symbol Mt, in her honour, recognising her as one of the most important scientists of the 20th century.

Another story is that of Cecilia Payne, a British-born American astronomer and astrophysicist who proposed in her 1925 doctoral thesis that stars are composed primarily of hydrogen and helium. She also discovered what the Sun is made of.

Henry Norris Russell, a fellow astronomer, is usually given credit for discovering that the Sun's composition is different from Earth's, but he came to his conclusions four years later than Cecilia, after telling her not to publish.

After dealing with prejudices and barriers, Cecilia was the first woman to be promoted to full professor from within Harvard, and is often credited with breaking the glass ceiling for women in the Harvard science department and in astronomy and inspiring entire generations of women to take up science.

A third story is that of Rosalind Franklin, a brilliant and dedicated X-ray crystallographer. In 1953, James Watson and Francis Crick burst into a pub in Cambridge, England, and announced they had worked out the structure of DNA. Today, many people mistakenly think they were the ones who made this discovery, especially as they were awarded a Nobel Prize for it.

Several biochemists had already deduced that hereditary material consisted of nucleic acids and that there were two possible base pairs. Moreover. the chemist Linus Pauling had discovered from experiments, including using X-ray crystallography, that many protein molecules have a spiral shape.

By this time, Rosalind Franklin had pioneered the technique of using X-rays to determine the position of atoms in complex organic molecules. In 1952, Rosalind managed to obtain clear X-rays of the DNA molecule, a great achievement because DNA was very hard to isolate in a form suitable for taking X-rays. When she analysed her results, she realised that DNA is in the shape of a double helix, and its two strands consist of alternating sugar and phosphate groups.

While Rosalind was refining her results for publication, and without her permission, one of her male colleagues secretly passed her key findings and X-rays on to Watson and Crick, who used them and other evidence from scientists across the world to build their model of DNA. They had not performed any experiments themselves.

Tragically, by the time Watson and Crick were awarded the Nobel Prize in 1962, Rosalind had died from cancer at the age of 37. It is likely this was due to her exposure to all the radiation. Sadly, unlike Lise Meitner and Cecelia Payne, Rosalind Franklin was never given the credit for the pivotal role she played.

Today, there are many women researchers who have made very important discoveries in many branches of both pure and applied chemistry. There are many women who are dedicated chemistry educators. And there are many girls who are studying science and dreaming of becoming famous scientists one day. They all deserve our encouragement, support and respect. To limit them in some way is to limit all that science can achieve.

Jenny Sharwood OAM, MACE, FAIE, FRACI CChem is a chemistry education consultant and writer. This article has been adapted from a presentation she gave to a global breakfast attended by chemistry educators across India to celebrate the United Nations International Day of Women and Girls in Science on 17 February.

Congress plenaries and symposia

In July this year, the RACI – the oldest professional scientific society in Australia – will host its National Congress Meeting in Brisbane. This meeting is an opportunity for chemists around the world to meet and participate in the varied activities that the Congress has to offer. We are looking forward to sharing our research, developing new collaborations and building on existing ones, and making new friends during the social program activities once again.

The six-day congress will cover all the discipline areas of chemistry and will provide opportunity for delegates to move between parallel sessions to hear presentations across diverse topics or simply immerse themselves in a given discipline area. The social program includes a welcome reception on Sunday, Awards dinner on Monday, Congress dinner on Wednesday, and catered poster sessions on Monday, Tuesday and Thursday.

The Queensland Early Career Chemist group will be using the Congress as an opportunity to host networking and professional events throughout. They invite you to come along and get to know your fellow early career chemists from around the country. Their first event will be a meet and greet on Sunday 3 July before the Congress registration opens. Watch out for further information on the Congress website!

The following titles are from our plenary speakers:

- 'Ionic liquid electrolytes for next-generation sodium batteries' by Professor Maria Forsyth
- 'Assembly line synthesis' by Professor Varinder Aggarwal
- 'Carbon in two and three dimensions' by Professor Rodney Rouff
- 'Learning about carbohydrate recognition from functional glycomimetics' by Professor Thisbe Lindhorst
- 'Proton-coupled electron transfer in catalysis and energy conversion' by Professor Sharon Hammes-Schiffer
- 'Taking a scientific approach to science education' by Professor Carl Wiemann
- 'From simple discrete metal–ligand motifs to supramolecular assembly, nanostructures and functions' by Professor Vivian Yam

These eminent chemists will share their research and demonstrate how it is Catalysing Solutions to Global Challenges.

There are 13 RACI Divisions and four crossover subjects delivering symposia at the RACI Congress. Here are just a few overviews.

The **Inorganic Chemistry** symposium will promote dissemination of the latest research in inorganic chemistry, provide inclusive networking opportunities for researchers from a variety of sectors, particularly early- and mid-career researchers with an interest in inorganic chemistry, and provide a forum for cutting-edge research at the interface of inorganic chemistry and other disciplines, e.g. molecular electronics, advanced materials and medicinal inorganic chemistry. The meeting will cover all aspects of inorganic chemistry, including chemistry of the main group elements, transition metals and lanthanoid elements, coordination chemistry, organometallic chemistry, bio-inorganic chemistry, materials chemistry, solid-state chemistry, synthetic chemistry, catalysis, theoretical chemistry and spectroscopy.

The **Physical Chemistry** symposium aims to enable students, postdoctoral researchers, research fellows, academic staff and other chemists to engage in constructive discussions about their cutting-edge research. The symposium will cover current topics in experimental and computational/theoretical physical chemistry. We will have keynote lectures delivered by senior scientists, invited lectures by early-to-mid-career scientists and outstanding students, and contributed talks by researchers within the physical chemistry community. The symposium will offer the opportunity to engage in insightful discussions, disseminate research outcomes, and network with physical chemists within Australia and internationally in an informal environment.

The **Materials Chemistry** symposium will be dedicated to providing a platform for dialogue between students, researchers, technical support staff and industrial partners who work in materials chemistry. It will cover the synthesis, structure and property characterisation as well as applications of materials, with a special focus on the relationship between synthesis, structure, property and function of materials. We will run sessions on hard, soft and nanomaterials. Additionally, a panel discussion on 'National Facilities for Chemistry' will give you an opportunity to meet representatives from the National Computational Infrastructure, Microscopy Australia, Australian Centre for Neutron Scattering, Australian Synchrotron, Centre for Accelerator Science and Australian National Fabrication Facility; learn about these national facilities and ask questions.

Are you interested in radiochemistry? Then the **Radiochemistry** symposium is just for you. A diverse program of radiochemistry relating to the environment and health will be the focus. We look forward to hearing the latest research from Dr Brett Paterson (University of Queensland) in his keynote lecture in radiopharmaceutical science. Jennifer Harrison (ANSTO) and Dominique Scott (Queensland Health) are invited speakers showcasing and sharing developments in environmental radiochemistry and hospital-based radiochemistry respectively. These lectures will be complemented by a range of contributed presentations and networking opportunities. We welcome everyone to join the symposium to learn and understand more about the impact of radiochemistry research.

The Congress website www.raci2022.com is the place to go for all the latest information about the Congress as well as how to register to attend or present. Keep your eyes open for emails and social media posts for the latest information on the RACI Congress! We look forward to seeing you in Brisbane very soon.

RACI careers development volunteering opportunities

The RACI Career Development team is looking for volunteers for the following projects. Please email mentoring@raci.org.au if you would like to be involved in a project or in running the mentoring program itself.

Careers map project

The concept of the project is to approach RACI's 4500 paid members with a short questionnaire asking them about their current role.

Responses would be aggregated and classified to yield a searchable database (ideally with a suitable visual 'map') that could be used for participants to 'find their inspiration' and potentially then connect with professionals in their discipline of choice.

This resource could also be used as a broad networking tool that could help members find a job.

Micro-credentialling project

Over the last two years, RACI Careers has established a portfolio of more than 50 careers event videos. This portfolio will grow throughout 2022–2024 as more online/recorded events are conducted.

RACI is looking for volunteers from universities and industry to put together short courses and videos on micro-credentialling. These courses might yield small 'badges' or similar that could be placed on LinkedIn profiles (for example).

Topics could include laboratory skills for students/ECCs; grant writing; entrepreneurship, finance, commerce for STEM professionals; and management/leadership.

Alumni networking project

The RACI Mentoring Program has grown substantially over recent years, and there is now an alumni base of nearly 200 former mentees, plus additional contacts who were participants in other RACI Careers initiatives. This is a sufficient base to establish an alumni network, which would offer many advantages.

Volunteers would work with the mentoring team to establish this alumni network so we can further connect the right people for professional development.

Looking for casual mentors

We are looking for casual mentors to have a chat with some of our mentees to help them get insight in specific roles within the chemistry industry. We are looking for mentors in environmental chemistry, food and cosmetics, QA/QC chemistry, biotechnology (Queensland), drug design, analytical chemistry, food chemistry and technical writing.

Chief Executive Officer

The Royal Australian Chemical Institute (RACI)

- **Leadership role in chemical sciences sector**
- **Respected professional association**
- **Flexible working arrangements possible**

The organisation

The Royal Australian Chemical Institute (RACI) is a membership-based association acting as the key body advocating for chemical scientists in Australia. With over 4000 members across the country, the RACI's focus is on advancing their professional interests by providing services and activities that range from professional and career development across all chemical sciences sectors, through to regular and engaging networking opportunities.

The person

RACI is seeking an inspirational leader to join the organisation as the Chief Executive Officer (CEO). The successful candidate will possess the following six key attributes:

1. Experience in:
   a. associations in a senior policy, membership or corporate services role, or
   b. university, scientific or research organisation in a senior functional role
2. Business management skills to ensure the provision of appropriate services to members
3. Proven ability to strengthen the organisation's financial position and to manage risks
4. Demonstrable relationship management skills to represent the profession to government, external organisations and industry groups
5. High-level communication and staff management skills to motivate and inspire staff, members and other key stakeholders
6. Capacity to provide valuable advice, guidance and support to the Board so that governance, compliance and strategic goals can be achieved

The RACI has its head office in Melbourne; however, it is possible that the CEO could work remotely, so non-Melbourne applicants might be considered.

Individuals looking to step up into the role of CEO are welcome to apply. If you have the aspiration to play a leading role in the growth of this highly respected association, then this position will provide your next career challenge.

Contact

Please contact Professor Steven Bottle, RACI President, on (07) 3138 1356 or email your resume to s.bottle@qut.edu.au. To apply, please include a cover letter addressing how you meet each of the six key attributes outlined above as well as a current copy of your resume.

For more information on RACI, visit www.raci.org.au.

New Fellows

Christopher (Chris) Sumby is Professor of Chemistry and Deputy Director of the Centre for Advanced Nanomaterials at the University of Adelaide, where he researches porous materials to address energy, environmental and industrial challenges. Chris has been the fortunate recipient of various fellowships and awards, including an Australian Research Council (ARC) Future Fellowship, a Young Tall Poppy Award, and a JSPS International Invitational Fellowship. In collaboration, he has led multiple ARC Discovery Projects, successfully re-established and developed X-ray diffraction structure determination facilities for South Australia, and worked on industry projects with companies such as Petronas. Chris is currently Head of Chemistry at the University of Adelaide and prior to this he was Deputy Dean – Research in the Faculty of Sciences.

Chris completed his PhD in Chemistry in 2003 at the University of Canterbury (New Zealand). After a postdoctoral position at the University of Leeds, he returned as a New Zealand Science and Technology Fellow, before taking up a position at the University of Adelaide. Chris's training is as a synthetic chemist with expertise in the characterisation of porous materials, in particular metal–organic frameworks (MOFs). One example of his work is using MOFs to trap – matrix isolate – and characterise catalytically active species, with this knowledge informing the development of new catalysts and materials for separation of gases.

Chris has co-authored more than 140 peer-reviewed journal publications and published numerous papers in invited issues (e.g. *Chemical Communications* – Emerging Investigator, Pioneering Researcher), and guest-edited a special issue of *Australian Journal of Chemistry* (coordination polymer chemistry) and *CrystEngComm* (MOF catalysis).

Chris has supervised a large cohort of research students and postdoctoral researchers, with 19 students completing since 2012. Researchers he has mentored work as academics and researchers (University of Malaysia, University College Dublin, University of Adelaide), and research chemists (e.g. SAHMRI, Trajan Scientific and Medical, and Dominant Chemicals), and have completed postdoctoral positions.

Chris has been active in the South Australian Branch of RACI (over many years), associated with the Inorganic Chemistry Division, including chairing the virtual IC21 meeting, and active in the Society of Crystallographers in Australia and New Zealand.

James Chapman is currently employed at RMIT University. He is an experienced higher education program manager, who has extensively managed degree programs in Science (Chemistry and Biology) and Environmental Science. He is experienced in degree design, program architecture, change management, and degree implementation at multiple universities.

He was awarded his PhD from Dublin City University in 2011, working under the supervision of Professor Fiona Regan. He went on to win a three-year Irish Research Council Fellowship, working on the development of novel materials for antibiofilm applications, with a focus on analytical characterisation and developing assays to understand microbial contamination on surfaces.

In 2013, James took up his first tenure as Lecturer in Analytical Chemistry at CQUniversity. James was promoted to Head of Science and discipline leader for Chemistry. James worked in a vibrant Science department and supervised several PhD students to completion in this role.

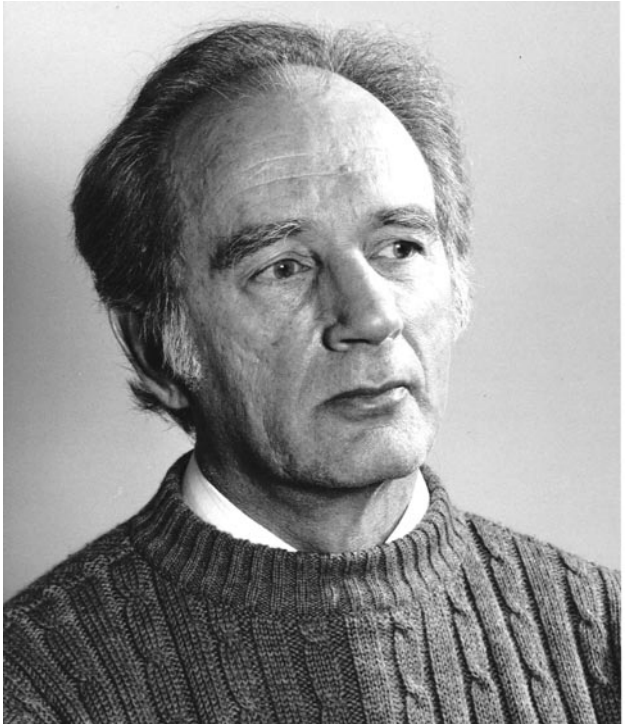
In 2018, James moved to RMIT University and became the Program Manager in the Applied Chemistry and Environmental Science discipline in the School of Science. He is an associate professor of chemistry and has published more than 120 peer-reviewed articles. James's work concentrates on developing rapid diagnostic tools to understand biochemical changes in various applications using spectroscopy, spectrometry and microscopy.

He holds a patent on new antimicrobial agents using stimuli-responsive materials. His work has been cited more than 2500 times, with an *H*-index of 30 (Google Scholar). He has won awards for his research and has a current research group of 10 PhD students and two postdoctoral fellows. James's research interests are focused on developing strategies to diagnose and detect biological and chemical markers for health and environmental applications. He has several grants and projects specialising in rapid diagnostic tools to understand chemical changes using artificial intelligence and chemometrics. This research is aimed at transforming diagnostic capabilities to develop new point-of-care devices or in-field sensor systems. He is passionate about chemical education, where he has developed augmented reality packages to teach environmental chemistry.

James has served as Secretary and is the current Chair of the Analytical and Environmental Chemistry Division. James likes to hike and run, is an avid 'foodie', and travels in his spare time.

Vale Claude Charles Culvenor

Australia's first chemistry PhD



Family, friends and former colleagues gathered at the Our Lady of Perpetual Succour Church in Surrey Hills, on 29 December 2021 to celebrate the life of an extraordinary organic chemist and scholar.

Claude Charles Culvenor* was born in Castlemaine, Victoria, on 15 May 1925 to Alexander (Pack) and Julia Culvenor. Claude was awarded a Junior Government Scholarship of £4 a year to attend Castlemaine High School where, over the period 1937–1941, he held the positions of head prefect, captain of the school cricket team, and member of the football and athletics teams. He then commenced his BSc at the age of 16, having won the State Savings Bank bursary of £150, an Education Department Scholarship and a Newman College Scholarship to undertake a course at the University of Melbourne. He completed his BSc (with First Class Honours) in 1944, his MSc in 1946 and his PhD in 1948. His PhD was supervised by Professor Bill Davies and was the first PhD in chemistry awarded by an Australian university.

In 1948, Claude was offered one of 27 scholarships from the Australian National University (ANU) to continue studies in branches of research of interest to the ANU and a fellowship from CSIRO to study at the University of Oxford. Claude accepted the CSIRO offer and went to Oxford in 1948. He completed his DPhil under the supervision of (Sir) Robert Robertson then returned to Australia and joined the Division of Industrial Chemistry at Fishermens Bend in November 1950.

His interest was the animal health issues associated with pyrrolizidine alkaloids in *Heliotropium europaeum* (heliotrope), *Crotalaria retusa* (rattleweed) and *Seneca jacobaea* (ragwort). He worked closely with the CSIRO Division of Animal Health in the application of his work in farm practice. This resulted in his 1968 reference book with Lionel Bull and Allan Dick *The pyrrolizidine alkaloids: their chemistry, pathogenicity and other biological properties*. Claude was part of the CSIRO 'Phytochemical project' and was a co-author of the 1990 book *Plants for medicine: a chemical and pharmacological survey of plants in the Australian region* with D.J. Collins, J.A. Lamberton, J.W. Loder and J.R. Price. In 1962, he also investigated the toxicity problems associated with *Phalaris* species and identified the responsible staggers-inducing tryptamine alkaloids, leading to development of cultivars low in these compounds.

In 1978, he expressed alarm at the increasing use of comfrey as a herb or green vegetable because it contained pyrrolizidine alkaloids that could cause liver damage. Despite some resistance, its sale was soon banned in Victoria and in 2001 it was banned for sale for internal use by the US FDA. Similarly, in the early 1980s, he demonstrated that honey derived from Paterson's curse had high levels of the toxic alkaloid echimidine. His international reputation led to invitations to sit on two WHO working groups to reach consensus on the carcinogenicity of pyrrolizidine alkaloids. In 1986, he chaired a WHO working group convened in Tashkent to review the hazard to humans of pyrrolizidine alkaloids present in herbal medicine, contaminated cereal crops and other foods.

Claude was made the Acting Chief of the Division of Organic Chemistry in 1966 and was promoted to chief research scientist in the Division of Applied Chemistry in 1969 (all at Fishermans Bend). In 1970, he transferred to the Division of Animal Health in Parkville and led a highly skilled multi-disciplinary research group on plant toxicity until his retirement from CSIRO in 1989. Claude continued to pursue his interests in toxic plants as an honorary professor at La Trobe University.

Claude was very active in the RACI. He was a member of the Victorian Branch Committee from 1975 to 1977 and Branch President in 1976. He won the H.G. Smith Memorial Medal in 1971 (jointly with D.H. Solomon).

Claude's post-retirement activities included extensive research on the Culvenor family, which he published in 1990. His mother's family were the Gervasonis from Bergamo in Lombardy, and their rich cultural and musical traditions are still evident in that part of Victoria. In addition to his family history, he also researched and published a history of the Yandoit area and the interactions of the Indigenous population of his childhood area with the colonising authorities.

Claude married Mary Nicholls in 1947 before he left for Oxford. He is survived by two of his three children, five grandchildren and two great-grandchildren.

Tom Spurling FRACI CChem and **Peter Cockrum** MRACI CChem

*Perceptive readers will note that this is an obituary for C.C. Culvenor, not C.C.J. Culvenor. He added his confirmation name Joseph to his name upon confirmation in the Catholic Church and was known as C.C.J. Culvenor (except on his passport) until, soon after retiring, he realised that this was not normal practice.

Hazelwood

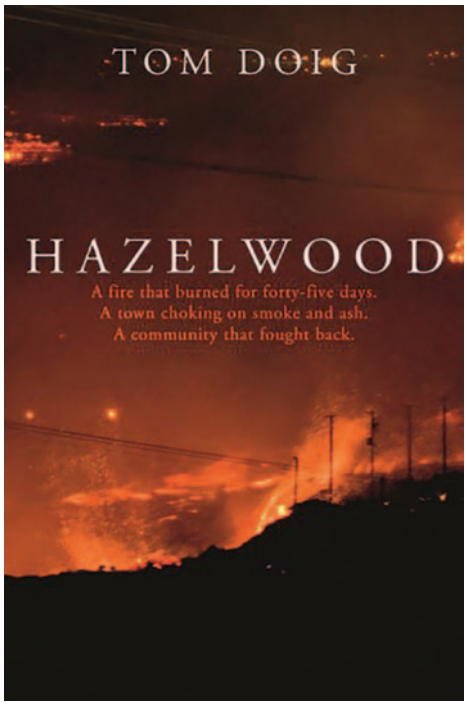
Doig T., Viking (Penguin Random House), 2019, paperback, ISBN 9780143793342, 304 pp., $34.99

Hazelwood by Tom Doig will strike particular resonance with Victorian readers who remember the now-closed giant Hazelwood brown coal power station, located in the Latrobe Valley, just a very few hundred metres from the town of Morwell (population 13 000). In February 2014, under heatwave conditions a bushfire set alight the towering embankments of the enormous open-cut mine feeding directly into the power station. That fire raged, largely uncontrolled and uncontrollable, for 45 days, blanketing its environs in a thick haze of toxic smoke and ash. Twenty-three deaths were directly attributed to the fire and much larger numbers had their lives shortened or blighted by its impact. What is possibly even worse is that for most of the 45 days, there was remarkably little attention, interest or concern shown by government, or the general population. It seemed to be very much a case of NIMBY, so not my concern and 'nothing to see here folks' for virtually everyone not directly enduring the disaster.

Doig's book explores how and why this tragedy arose and its short-term, and long-term, health, social and economic impacts on residents of the Latrobe Valley. This is all very sad, but why would this be of any more than passing interest? Why should you read this book? Because it has messages for all of us. It is an excellent case study of disastrous social impacts that can arise when technology, economics, social wellbeing and government fail to properly mesh; of how easily people slip into corporate thinking even at the expense of their own espoused principles.

The owners of the mine could see the end in sight: the power station was approaching the end of its economic life.

The owners of the mine could see the end in sight: the power station was approaching the end of its economic life. Environmental and OHS risks were not paramount. Staff decreases had resulted in only a skeleton safety staff. The sprinkler system, designed to extinguish fires, had not been maintained and considerable sections of it had been removed and sold for scrap. Access roads were poorly maintained and overgrown with bush. The exposed batters on depleted areas of the mine had not been rehabilitated to cover the exposed coal face and obviate fire risk. The boundaries of the mine were surrounded by flammable scrub.



A substantial concrete public highway was constructed between the township and the mine, squashing underground aquifers that drained into the mine. To solve this diversion of the watercourse, the adjacent mine wall was drilled with a series of horizontal holes stretching across under the highway to relieve the water pressure. Nobody ever thought this could offer a very ready path for any fire to propagate beneath the ground. It did.

For a facility nearing the end of its lifespan, planning for site remediation and official cost estimates for this were preliminary at best and viewed by some as inadequate. Subsequent plans to create a 740 billion litre recreational lake from the mine site seem of dubious validity both in terms of availability of water to fill it (estimated as 1.5 Sydney Harbour's worth!) and any recreational value it might have.

However, as Doig reports, the State of Victoria was also far from blameless. How was an enormous mine allowed to encroach within 300 metres of a township? The state government appeared to lack any apparent concern for the health of the citizens of Morwell, with the Department of Health and Human Services informing the affected citizens at the time that a bit of smoke and ash never did anyone much harm. Equally, the state police force was not mobilised to evacuate vulnerable citizens even when evidence of pulmonary distress was obvious. The state EPA was not significantly engaged in air quality monitoring in the Latrobe Valley, prior to the fire, despite the area's long involvement in dirty power generation. In short, the citizens of Morwell were spectacularly let down.

You should read this book. It is a salutary lesson on how the best (or perhaps 'least best'?) laid plans can go awry and wreak havoc.

R.J. Casey FRACI CChem

Carbon – the unauthorised biography

Feature film (89 minutes) and ABC TV documentary (56 minutes). Produced by Genepool Productions (Australia) and Handful of Films (Canada), 2022 (thecarbonmovie.com)

Carbon – the unauthorised biography, written by Daniella Ortega and co-directed by Niobe Thompson and Daniella Ortega, is a documentary film of outstanding quality. I applaud the enthusiasm of participating climate scientists, astrophysicists, forest ecologists and others, which is almost infectious.

Carbon (actor and narrator Sarah Snook) tells 'her' story in three significant parts, complemented by the animation of Bruce Alcock and Jonathan Kawchuk's attractive music score. First, the birth of carbon by nuclear fusion in the hot stars of the universe. Then, carbon 'star dust' depositing on the forming planets in good graphic illustrations. Then, carbon being incorporated into all forms of life, with scenes of the Pilbara and the 'living' stromatolites created by bacteria, to DNA synthesis in animals and humans, and photosynthesis fixing carbon in plants. Early trees provided heat energy, but many were fossilised to become 'a buried form of sunlight – coal'.

The film portrays 'coal' as providing the driving force for the 'Industrial Revolution' of 19th-century Europe and the resultant benefits to humankind, largely the result of technological change, over the past 200–300 years. But what is on the negative side of this 'coin'?

The film makers then reflect on some 'shadows' cast by our carbon world, using the spectacle and machinery of war (e.g. carbon in explosives and the race for ownership of the oil fields for fuel). Oil has unquestionably driven many positive technological and social outcomes in aviation, large-scale production of the family car, and land transport systems. Further, with the aid of modern science, oil has provided the raw material to produce new materials – polymers (plastics) – that have also changed our lives. As 'carbon' comments in the film, 'Humans have made more synthetic polymers than all the biological production of similar biopolymers known', but most of these materials are not biodegradable and cause irreparable ecological damage.

The film's final part focuses on climate change – the debate over the last five decades, where attention has turned to some of the disbenefits of 'burning' Earth's carbon resources, including the resulting 'greenhouse effect' created by emissions of CO_2 exacerbated by higher contributions of methane and nitrogen dioxide. (These gases act as a thermostatic shield around Earth to retain heat, hence raising the planet's temperature.)

The film uses current evidence for rising CO_2 levels from Tasmania's remote Cape Grim, a key source of data used in the CO_2 debate by former CSIRO scientist Graham Pearman in 1986. The spectacular ice lakes of Alaska show ever-increasing amounts of methane, bubbling up from rotting animal carcasses (and vegetation) at the lakes' floor as winters progressively warm. Dr Joelle Gergis shows us coral bleaching of the Great Barrier Reef, the estimated 50% 'loss on our watch' caused by warmer air and ocean surfaces. Our Canadian guide Gisele Martin of the *Tla-o-qui-aht* First Nation transports us to the tranquil natural forest habitats of Clayoquot Sound, to remind us that carbon (CO_2) can be sequestered by photosynthesis; and Professor Suzanne Simard (Canada), the driving force behind 'finding the mother tree', shows scenes that humankind has left only 60% of old growth forests intact. Geoengineering techniques for long-term carbon storage (carbon sequestration) are also explored. But are such plants energy efficient and can they be commercially scaled up?

Andy McCarthy, a Victorian entrepreneur and renewable energy advocate, asserts new solar systems and battery storage now provide a pragmatic solution to 'burning energy', on a level comparable with past coal-fired power stations (which the film shows being demolished).

It's unfortunate the film fails to show the social ills (environmental destruction and atmospheric pollution) brought about by carbon over the past three centuries, and as new countries become industrialised.

Carbon poses the question, 'Is carbon a builder or a destroyer?' Carbon is us and we must get along with her. Carbon is highly durable and continuous. She suggests humankind is the writer of the story from here on, with the quite moving song 'I'll be there in the end' (anyway).

Does the film provide sufficient evidence to change the mindsets of our sceptical world leaders, especially those with vested interests in traditional, carbon-based energy sources? Perhaps not quite, but it's another step in the right direction! If one aim is to educate 'influential leaders' about climate change, then the film should have a tighter run time. I also found the concluding 'birthing scene' rather redundant. Its removal would provide for more general audience classification.

Watch *Carbon – the unauthorised biography* and encourage others, especially your local politicians, to do so as well! Frankly it's about time we all took up the gauntlet to save our planet for the generations to come.

Dr Alan J. Jones FRACI CChem

Taking the waters

After the long lockdown, we escaped to London to visit family for Christmas.

In the New Year, we all drove down to Somerset, and spent a week near Wells. It wasn't any warmer in Somerset than in London! But it gave us a chance to experience the Somerset countryside, to visit Bath, en route, which we hadn't been to before, to drive through the Cheddar Gorge and on the return journey to catch a glimpse of Stonehenge from the motorway.

It was while we were walking in Bath, after visiting the Circus, designed by John Wood the Elder (1704–1754), that we came across the Royal Mineral Water Hospital (pictured), on the corner of Upper Borough Walls and what is now Union Street. The Hospital, also designed by John Wood the Elder, opened in May 1742.

The Hospital was built to take advantage of the thermal waters at Bath for treating the 'sick poor from Britain and Ireland' and the genuinely sick among the numerous beggars on the streets of Bath, at the time. Originally it was just two storeys. The top floor, designed by the then city Architect, Thomas Baldwin, was added in 1793. The royal coat of arms of Queen Victoria can be seen on the pediment of the Georgian facade.

Patients wore brass badges, which served two purposes: to admit them to the Corporation Baths for treatment and to exclude them from public houses!

Later, pipes were laid to bring mineral water from the Corporation Baths (King's Bath) to the Hospital, which enabled all treatments to be provided under supervision in the Hospital.

In Bath, more than one million litres of hot (about 45°C) mineral water emerges daily from three natural springs near the centre of the city, in the vicinity of the Roman baths and museum, both major tourist attractions of Bath. The mineral springs were discovered by Bladud, a Celtic prince, in 9 BCE. In 60–70 CE, the Romans developed the site, building a temple and baths for public bathing. Over time, the baths fell to ruins, but were redeveloped during the Middle Ages. Visitors today can tour the baths and museum but cannot enter the water because of earlier detection of the harmful microorganism *Naegleria fowleri*, an amoeba-like pathogen that thrives in hot water. In 1982, a new spa water bore hole was sunk, providing clean and organism-free mineral water for drinking in the Pump Room. Bathers can again take the waters in the newly constructed Thermae Bath Spa and the refurbished Cross Bath, both of which receive mineral water through new bore holes.

So, what is special about mineral water? It is subterranean water, which often emerges hot, as a result of geothermal heating. As it passes through underground rock formations it dissolves mineral salts and gas (CO_2). Gallois (bit.ly/3s4udlg) has published details of the formation and geology of the hot springs at Bath Spa, Somerset. The composition of the Bath (Hetling Spring) mineral water has remained constant for the past 100 years. The most abundant ions are sulfate (1015 mg/L), calcium (358 mg/L) and chloride (340 mg/L).

tirc83/iStockphoto

Drinking mineral water as an accompaniment to food is widespread. Anyone who has been to an Italian restaurant will know that soon after being seated, a chilled bottle of *acqua minerale*, bread and the menu will land on their table, in quick succession. Mineral water, with or without gas, is a pleasant and refreshing drink. The full composition of commercial mineral water is usually printed on the bottle label. The ancient Romans were perhaps the first to recognise the benefits of bathing in natural mineral water and they left behind them Roman baths in many of the countries they invaded.

In the 17th and 18th centuries, it became fashionable to 'take the waters', which included bathing in and drinking mineral water, believed to be a curative for all manner of illnesses – arthritis, skin conditions, back and neck pain, osteoarthritis, varicose veins and circulatory disorders – but also for relaxation and emotional wellbeing. The treatment of disease by bathing in mineral spring water has acquired the name 'balneotherapy'.

It continued to be a popular social activity for wealthy people in the UK, at Bath, Buxton and Harrogate, but declined in the 19th century. Germany still has about 350 active spa towns, designated by the prefix 'Bad' (bath) (e.g. Bad Kreuznach). In Australia, the best-known spa towns are Hepburn (Victoria), Moree (New South Wales) and Lightning Ridge (South Australia).

Plans to convert the Royal Mineral Water Hospital to a 167-bed hotel, after much opposition and previous rejections, have been approved (August 2021) by the Bath and East Somerset Council.

Dr Peter G. Lehman FRACI CChem

Climate solutions: thinking global, acting local

There is now a broad international consensus that climate change is a serious problem and one that requires stronger responses from many governments. The global focus now needs to move from convincing the unconvinced minority to finding practical solutions while the planet still has time. The UNDP Oxford University Peoples' Climate Poll (2021) and earlier international polls confirm that majorities in virtually all countries surveyed agree that climate change is real and is caused by human activities. Australia and New Zealand have climate majorities in the 72–80% range. So, what strategies do our countries have to adopt to achieve the aim of zero carbon by 2050? The first step is to review what new solutions are emerging internationally; then we need to evaluate which of these are feasible candidates for climate remediation in the Australasian region.

Natural climate solutions

One strategy that is gaining momentum relates to natural climate solutions. Natural climate solutions involve conservation, restoration and improved land management actions that increase carbon storage or avoid greenhouse emissions in landscapes and wetlands. Natural climate solutions are being promoted by the World Economic Forum and other organisations. A recent report in *Proceedings of the National Academy of Sciences* indicates that this strategy including mitigation pathways could contribute up to 37% of carbon dioxide reduction and hence play a significant role in enabling the planet to achieve the <2°C warming objective. This is not a new strategy, and it includes massive reforestation projects such as the iconic Great Green Wall crossing Africa along the southern margins of the Sahara. This extraordinary project led by the African Union, will deliver both climate and food benefits to impoverished populations in several African countries that depend largely on natural food sources. The Great Green Wall has had its difficulties, but now appears to be approaching a successful conclusion. If the Great Green Wall does succeed, it should inspire other similar and smaller natural climate solutions projects elsewhere in the world.

Improved solar and wind technologies

A second strategy is to further develop, refine and scale up existing solar and wind energy systems. The World Economic Forum has recently reported on some of these developments. The long-term trend of increasing efficiency in solar panels is expected to continue, given the development of hybrid panels that combine photovoltaic cells and thermoelectric cooling modules to improve system efficiency. Building-integrated photovoltaics are a new generation of solar films that are integrated into building envelopes, thereby achieving greater efficiency and improved aesthetics by avoiding the rather functional appearance of conventional panels. Floatovoltaics are another larger scale development that deploy solar panels on bodies of water. Floatovoltaics are simpler to install than on land, and the natural cooling effect of water can significantly increase efficiency and output. The world's largest floatovoltaic facility in the Sirindhorn Reservoir 660 kilometres from Bangkok involves 145 000 solar panels that harness solar energy during the day and three turbines that extract the accumulated energy by night.

A related development involves floating islands of wind turbines that are expected to alter the global energy landscape. The global wind energy market has quadrupled in size over the past 10 years. For California, in particular, floating offshore wind farms could be the key to the state achieving 100% renewable electricity by 2045. The Gansu Wind farm (pictured) in western China will be one of the largest wind farms when completed, with 7000 turbines and 20 GW output. This is enough to power a small country. The largest offshore wind farm at present is Hornsea 1 (UK) with 174 turbines that generate 1218 MW output. Significantly, Statoil – a major oil company – is now developing oceanic wind farms. This is an example of a growing trend in which large oil and gas companies are developing major projects in renewable energy.

New, safer nuclear power

A third strategy involves new, safer sources of nuclear energy technology. Nuclear energy generally does not contribute to atmospheric greenhouse gas emissions such as carbon dioxide, methane, nitrous oxide and chlorofluorocarbons. Bill Gates argues that we will not be able to achieve a sustainable climate solely by switching from fossil fuels to solar, wind, hydro, green hydrogen etc. To fill the gap, Gates advocates the increased deployment of new nuclear technologies that do not generate greenhouse gases and are safer than large nuclear power sources. An *Our World in Data* report (sources include the journals *Nature* and *Lancet*) confirms that coal, natural gas and biomass all involve many more fatalities than nuclear. Doubling of large nuclear power plants are planned for the fastest growing emissions country, China, as it seeks to replace coal by nuclear energy over the next 10 years as a step towards zero carbon by 2060.

These new nuclear technologies include preconstructed small modular reactors, which could power a small town, an airport or a hospital. Small modular reactors are being developed by NuScale, Westinghouse and Rolls Royce and seem very likely to play a role in major northern hemisphere countries (USA, Canada, UK, EU). The smaller scale of small modular reactors brings disadvantages of scale and cost compared with large conventional reactors.

Another option under development is the thorium reactor being developed in Norway by Thor Energy. A prototype thorium reactor has been developed in China and another exists in India. Thorium reactors have advantages over uranium reactors in that they can be closed down quickly, generate much less

nuclear waste and cannot be used to make weapons. The thorium mineral monazite is abundant in many countries, including India and Australia. India, with its increasing carbon emissions associated with coal deployed for economic development, has only recently set itself an extrapolated zero carbon target (2070). Thorium reactors may in the future provide India with a silver bullet to achieve zero carbon on a more realistic time frame.

Fusion reactor technology has been in development for decades. Nuclear fusion simulates the energy-generation processes in the Sun. If fusion energy can be recreated on Earth, it holds the potential of virtually unlimited supplies of low-carbon, low nuclear-radiation energy. The next-generation ITER fusion reactor in France (using heavy isotopes of hydrogen) is being developed by the EUROfusion Consortium, which involves 5000 science and engineering experts. Reports suggest that the necessary scale-up development of fusion reactors will take longer than the generic zero carbon deadline of 2050. On the other hand, the recent emergence of 25 start-up companies in fusion technology is expected to accelerate this urgent and transformational development.

In both Australia and New Zealand, there has been an understandable reluctance to embrace conventional nuclear energy. In the case of New Zealand, which already has a high proportion of its energy from sustainable sources, it is difficult to see a conventional large-scale nuclear power station playing a significant future role. Indeed, a single conventional nuclear power station would oversupply the national grid, which in turn would create contingency issues. However, the remaining New Zealand coal power station at Huntly, which is due for replacement in 2025, acts as a safety net when hydro sources are depleted by drought. Huntly might conceivably be replaced by a few small modular reactors.

Sequestration of atmospheric carbon dioxide

A fourth strategy involves the removal of existing carbon dioxide from the atmosphere. A facility in Iceland is operational and effectively is a proof of concept on a small scale. This facility recovers 4000 tonnes per year of carbon dioxide that is converted into carbonate minerals, which are then buried. The problem with this technology is that its scale is dwarfed by the massive rate of increasing global carbon emissions (52 billion tonnes per year). It would clearly be simpler, much less expensive and more sensible to simply reduce our current emissions. However, the Iceland facility does constitute a small-scale proof of concept and the decision by Exxon to establish a $100 billion carbon recapture hub will hopefully provide a more demanding and better scaled test of this technology.

Geoengineering

A final more radical strategy involves injecting sulfate particles into the upper atmosphere to reflect excess solar energy back into space. This concept was based on the natural atmospheric cooling caused by volcanic particles that was observed during the Pinatubo volcanic eruption in 1991. This natural process was quantified by Paul Crutzen, who was awarded the Nobel Prize in Chemistry in 1995, and his analysis could provide guidelines for the injection of the particles into the atmosphere. An in-depth and more recent *Nature Education* review indicates that large-scale temporal and spatial variability makes this strategy more complex than originally thought.

Conclusion: the global state of play

The global expectation of achieving zero carbon status can be summarised in the following 10 aims and probabilities. The probabilities of success reflect the author's judgement: certain, feasible or uncertain.

- The global population will plateau by 2100 at 11 billion and populations in some high-emitting countries (China and India) will decrease by 2050 and by 2100 respectively (certain).
- Natural remediation strategies will provide a maximum of 37% of remediation (feasible but not certain).
- Large-scale floating wind farms and floatovoltaics will become more widely utilised (certain).
- China will replace coal by large nuclear reactors within 10–20 years (almost certain).
- India will develop and implement thorium reactors to replace coal (uncertain).
- The USA and EU will continue to reduce emissions by adopting renewable technologies, including small nuclear energy (almost certain).
- The electric transportation revolution (cars, planes, ships etc.) already underway will continue to conclusion (certain by 2050).
- About 130 out of 198 countries have adopted zero carbon targets so far but an even greater global majority is needed (promising but not certain).
- Only 9.8% of 965 cities' climate strategies evaluated by CDP in 2021 were ranked A and a higher level of commitment is needed (uncertain).
- A fifth of the world's largest companies have committed to a net zero target (Forbes, 2021) and this number is expected to grow rapidly, driven by international consumer pressure (certain).

There are significant grounds for optimism in the above global score card. However, the increasing drive for renewables and other strategies will have to accelerate over the next few decades if we are to achieve our zero carbon targets in 2050.

Ralph Cooney ONZM, FRSNZ, FRACI CChem has had a science and innovation career bridging New Zealand and Australia. He was former University of Auckland Pro Vice Chancellor of the Tamaki Innovation Campus, Dean of Science, Head of Chemistry and Science Leader of several major national research programs.

The RS-24 (Yars) intercontinental ballistic missile, a weapon very similar to the Mod 1 Topol-M. Соколрус/Wiki

Russia's nuclear arsenal – a scientific commentary

In the appalling event that Russia uses a nuclear weapon against Ukraine, it would be the third use of a nuclear weapon in war. The first and second – Little Boy and Fat Man – were air dropped by US forces at Hiroshima and Nagasaki, Japan, respectively on 5 August 1945 and 9 August 1945. Little Boy used uranium-235 fission and Fat Man used plutonium-239 fission. While these are the only nuclear weapons used in war, there have been thousands of *tests* of nuclear weapons since then.

The explosion energy of any bomb is conventionally expressed as the 'TNT equivalence'. Non-SI units (tons not tonnes) continue to be used to express TNT equivalence. The bomb at Hiroshima was 15 kilotons and that at Nagasaki was 20 kilotons.

The term 'nuclear missile' is frequently used synonymously with 'nuclear weapon'. Missiles for nuclear warheads use conventional propellants, and a particular missile might be suitable for use with conventional or nuclear weapons. Some missiles can hold more than one warhead. I am aware of only one example of a 'nuclear missile' where the missile propulsion uses a nuclear fuel. That is the Russian 9M730 Burevestnik cruise missile, which uses a nuclear thermal rocket for propulsion.

A strategic nuclear weapon is intended to impact a location distant from its launch, for which either a long-range missile or a gravity drop is needed. A tactical nuclear weapon is for 'battlefield' use. Advances in nuclear weapons are often not in the nuclear part per se but in the missiles. Once a missile suitable for a particular application is available, it might be straightforward to select an existing nuclear warhead for use with it. A nuclear weapon is said to be deployed if it is in position and ready for use, in contrast to being stockpiled.

The current Russian nuclear arsenal includes the SS-27 Mod 1, also called the RS-12M (Topol-M), the latest in a succession of Topol intercontinental ballistic missiles (ICBM) dating from the 1980s. In one form, the RS-12M is supported in a silo for ground launching and in the other form it is supported on a transport erector launcher (the 'mobile type'). Each version of the Topol-M carries a single nuclear warhead of 800 kilotons TNT equivalence. An article in the *Bulletin of the Atomic Scientists* this year (bit.ly/3L0maNW) states that 60 of the silo type and 18 of the mobile type are in deployed status. The missile uses a solid propellant, and the range is 11 000 kilometres. The warhead was developed by the Russian Federal Nuclear Centre in Sarov, a 'closed town' about 400 kilometres from Moscow.

Also in the ICBM category is the SS-X-29, otherwise known as the RS-28 (Sarmat) nuclear missile, expected to be in deployed status by the end of 2022. It will be capable of carrying ten nuclear warheads each of TNT equivalence 500 kilotons, or a larger number of smaller ones. The warheads can be independently directed. It will be silo launched and will use a liquid propellant. The missile range is 10 000 kilometres.

The TNT equivalences of the warheads used with the RS-28 (Sarmat) nuclear missile suggest (with the information accessible it cannot be put more strongly than that) that they use boosted fission. Neutrons obtained in a fusion reaction are supplied to a fission reaction to 'boost' it. This featured in some of the US atomic tests in Nevada in the 1950s. There was no such boost in Little Boy or Fat Man.

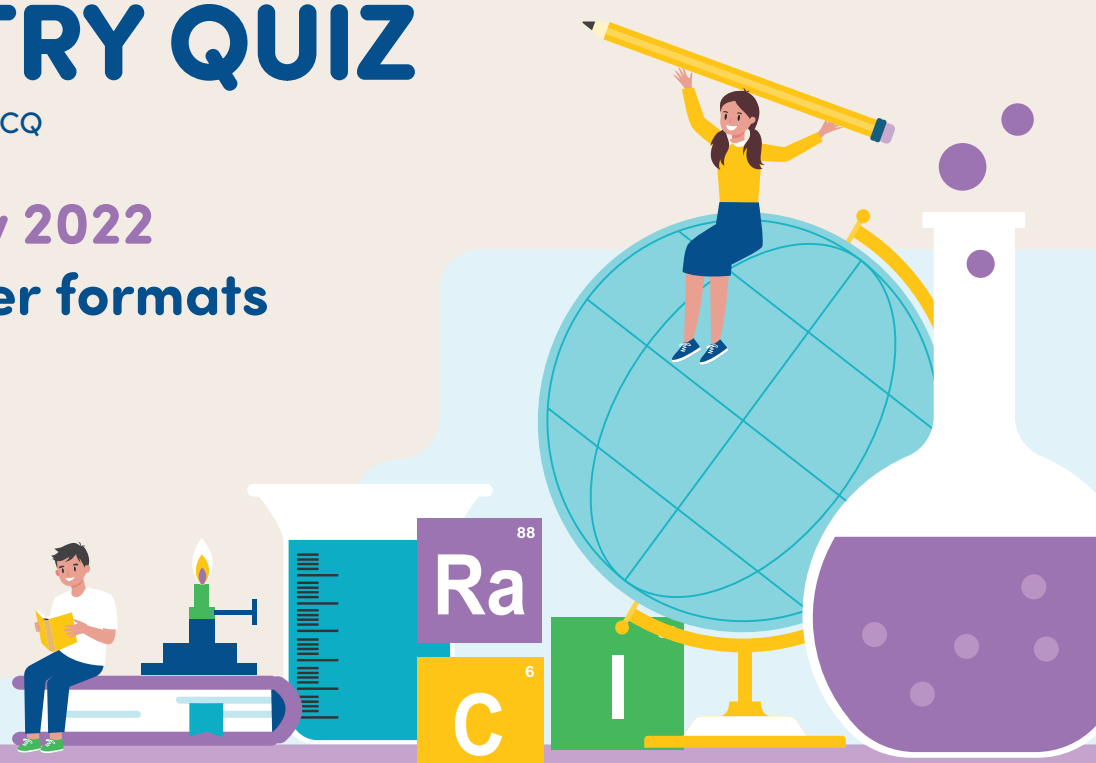
At Hiroshima in 1945, a 15-kiloton weapon was dropped on a city of population of about a quarter of a million, and there were 66 000 deaths. Ukraine has three cities with populations in excess of a million, and the RS-28 (Sarmat) carries ten 500-kiloton warheads. The facts speak for themselves.

According to the *Bulletin of the Atomic Scientists* article, Russia has air-launched cruise missiles, including the Kh-55 (aka AS-15). This has a range of 2500 kilometres and uses conventional jet fuel for propulsion. It carries a 200-kiloton nuclear warhead. The Tupolev-160 aircraft can carry up to 12 such missiles. Russia also has, in deployed status, submarine-launched ballistic missiles with nuclear warheads, including the SS-N-32 (aka R-28RMU) missile. This has a range of 8300 kilometres and can carry six 100-kiloton warheads, which one expects would be fission only. It is intended for use with the Delta IV class submarine, which itself uses nuclear power. The UK uses nuclear-powered Vanguard submarines with Trident nuclear missiles. That is the total nuclear deterrent capability of the UK at present. In September 2021, Australia undertook to acquire nuclear-powered submarines under AUKUS, the trilateral security pact between Australia, the UK and the US. Missiles carried by these submarines will carry conventional, not nuclear, weapons.

All of the Russian nuclear weapons discussed here have been in the strategic category, but Russia does have a significant complement of deployed tactical nuclear weapons. Tactical weapons are sometimes (as in the *Bulletin of the Atomic Scientists* article) described as 'non-strategic and defence weapons'. The Russian Iskander-M short-range ballistic missile, which has already proved its worth with conventional weapons, can also be used with nuclear warheads of TNT equivalence up to about 100 kilotons. It has a range of up to 480 kilometres, and a point that naturally arises in one's mind is that the distance from the Russian border with Ukraine to Kiev is shorter (about 385 kilometres).

Since President Eisenhower's 'Atoms for Peace' plans from about 70 years ago, enormous amounts of electricity have been generated by nuclear fuels, although that is in decline. Nuclear fuels have found limited application in naval vessels but not in passenger ships. Nuclear weapons have retained their importance, even though it is 77 years since one was used in warfare.

Clifford Jones FRACI CChem is the author of *The application of nuclear science to space* (2022), *An overview of nuclear weapons* (2021), *Nuclear powered ships and submarines* (2021) and *Nuclear powered generation of electricity – a world evaluation* (2020).



Ultrafiltration for wine protein stabilisation

In my column in the September–November 2020 issue (p. 40), I outlined several approaches to replace the use of bentonite to achieve protein stabilisation in white wine. In essence, the alternatives included the addition of a polysaccharide (carrageenan) or a polyphenol (grape seed powder), flash pasteurisation with aspergillopepsin enzymes and magnetic nanoparticles.

The so-called heat test is the industry standard for assessing protein stability (bit.ly/3rPpoMx). This test involves heating a small volume of wine at 80°C for two hours and then cooling for three hours before assessing haze development by eye or by turbidity measurement: <2 NTU is required for a pass result. Any replacement for bentonite must satisfy the heat test. Chemical and sensory analyses are usually employed to check that there has been minimal impact on overall wine composition.

The bentonite replacements that I described earlier need some form of separation after the treatment to clarify the wine. Ultrafiltration (UF) could simplify protein stabilisation in a single step provided the UF process can be managed with minimal impact on the chemical and sensory properties of the wine. UF functions by size exclusion and can be regarded as sitting between microfiltration and nanofiltration. The size range for particle cut-off in UF is 0.01–0.1 µm, although this depends on membrane type to some extent. Blockage of pores during filtration also influences the success of size separation, so operating the filter in the cross-flow method is normal practice.

A study in 1987 explored the feasibility of achieving protein stability in white wine. While some success was achieved, there appeared to be 'protein leakage' into the permeate, suggesting an issue with membrane selectivity. The need to characterise the protein profiles in both the permeate and the retentate was seen to be essential to ensure that the membrane has the necessary selectivity to remove the proteins responsible for heat instability.

Significant advances in membrane technology have occurred over the last decade, especially with better definition of pore size and selectivity. Polyethersulfone membranes are now commonly used because they have good mechanical strength and stability. From a commercial perspective, it is also preferable that the extent of permeation is at least 90% or higher. The interaction of wine components, other than proteins, with the membrane leading to blockage needs to be considered when designing UF treatment.

These questions formed the basis of Yihe (Eva) Sui's PhD project at the University of Adelaide with support from VAF Memstar and funding from the Australian Research Council Training Centre for Innovative Wine Production. Proof-of-concept experiments were performed with a benchtop UF unit and filtering five litres of white wine through a 10 kDa or a 20 kDa nominal molecular mass cut-off (NMMCO) filter. A permeate that satisfied the protein stability test was obtained and the wine proteins were concentrated in the retentate (Sui et al. *Aust. J. Grape Wine Res.* 2021, vol. 27(2), pp. 234–45).

One of the limitations of bentonite treatment is the loss of product due to difficulty in separating the treated wine from the bentonite residue (see September–November 2020 issue, p. 40). With UF, the retentate needs to be protein-stabilised before it can be back blended with the permeate. Scaling up the UF experiments yielded sufficient retentate for further examination. Significant protein removal could be achieved by heat treatment with added pectolytic enzyme. When the treated retentate was blended with the permeate, the resulting wine required only a small amount of bentonite to be heat stable (Sui et al. *Aust. J. Grape Wine Res.* 2021, vol. 27(2), pp. 234–45).

This initial study clearly demonstrated the ability of UF for white wine protein fractionation. The next phase of the Adelaide group's work was to apply the proposed methodology on a commercial scale. Six wines, with volumes ranging between 5400 and 71 000 litres, were filtered using 5 or 10 kDa NMMCO filters (Sui et al. *Sep. Purif. Technol.* 2022, vol. 284, 120227). Permeation rates between 90% and 97% were achieved.

The heat test showed that all six permeates were heat-stable, even though not all protein had actually been removed from the permeate. Not all classes of protein found in wine can lead to heat haze or instability, implying that UF is successful in the removal of the haze-forming proteins.

The UF procedure will also retain other wine macromolecules. Thus, the permeate was found to be markedly lower in wine phenolics and this was linked to a lower brown colour. The added bonus from a winemaking perspective is that the reduced phenolic concentration will moderate the astringency and/or bitterness of the wine, thereby removing the need for a subsequent fining step with a protein (see September–November 2021 issue, p. 41). This, together with the elimination of the requirement for bentonite fining, are two major winemaking benefits of UF.

There were measurable differences in some basic wine parameters, such as titratable acidity, but the changes did not affect the sensory properties of the wine. In a study yet to be published, the Adelaide group found that the wine sensory profiles and quality scores of UF-treated protein-stable wines were comparable with traditionally fined wine. It is reasonable to expect more developments in the use of UF for wine adjustment, especially as advances in membrane technology may lead to the targeted removal of specific wine components.

Geoffrey R. Scollary FRACI CChem (scollary45@gmail.com) has been associated with the wine industry in production, teaching and research for the last 40 years. He now continues his wine research and writing at the University of Melbourne and Charles Sturt University.

All that glitters is not gold

In September 1904, Sydney newspapers picked up a story from London's *Daily Mail* about what appeared to be gold on the teeth of a sheep's head someone had purchased from a local meat market. It was part of a shipment from Australia or New Zealand, and when tested by a local doctor it was found to be resistant to *aqua fortis* (nitric acid), causing Dr Styles to deduce that the yellow coating on the teeth was, indeed, gold. Amid general scepticism, and a suggestion that the cause was the practice of grazing of sheep in Australia on grass growing on soil rich in alluvial gold, Mr Richard Smithson, a grazier from Cobar, wrote to say that a recent drought had decimated sheep flocks, causing owners to take extra good care of their animals, including dental care by a Cobar dentist who had used gold fillings that had travelled all the way to London.

About a year later Andrew Liversidge FRS, professor of chemistry at the University of Sydney, exhibited a sheep's head with yellow, metallic-looking teeth at a meeting of the Royal Society of New South Wales. With simple tests, he had identified the presence of phosphate, and concluded that the coating on the teeth was none other than common tartar (as pictured), consisting mainly of calcium phosphate. The metallic appearance, more like brass than gold, he thought, was due to the refraction of light by the overlapping edges of the thin lamellae of the deposit.

Not everyone was satisfied by this common-place explanation, and from time to time people showed up at the Royal Mint, in Sydney, hoping to cash in on golden sheep jaws. In May 1917, however, a Mr Beeby Thompson wrote to *Nature* to say that 'golden teeth' were commonly observed in English sheep and cattle, and that the colour was due to iron sulfide, FeS_2, that he characterised as pyrite or marcasite. It had obviously formed, he wrote, from iron salts in the water the animals drank, reacting with sulfides formed by microbiological reduction of sulfate in the animals' mouths. Subsequent correspondence in that journal included some 'me too' letters; a precis of the paper that Liversidge had published in the *Proceedings of the Royal Society of New South Wales*; and a showstopper from Thomas Steel, of Sydney, who ridiculed Thomson's explanation and supported Liversidge's view. Steel had seen many cases in Sydney and doubted that the situation was any different in England.

Steel's full paper was published in *The Chemical News* in 1922. 'From the stocks of bones passing through a large bone charcoal factory in Sydney', he wrote, 'I have been able to examine the teeth of numerous sheep and also those of oxen, horses, pigs, etc.' In collaboration with a local dentist and several museums, he had examined human teeth and those of

lindarocks/iStockphoto

camel, dromedary, babirusa (a pig-like animal from islands to the north of Australia) and rhinoceros. The analytical figures were quite similar, typically showing (in mineralogical style) about 40% CaO and 30% P_2O_5, which suggested a mixture of several calcium phosphates. The teeth of carnivores (dogs, cats), rodents (mice, rats), snakes, lizards and fish were generally free of tartar. Steel also noted similar analytical results and conclusions reported in 1814 by the great Swedish chemist Jons Jakob Berzelius.

So, who was analyst Steel and what was he doing with all that bone charcoal? Thomas Steel (1858–1925) was born in Glasgow and learned his trade in the laboratories of a sugar refiner. Recruited by Colonial Sugar Refineries (CSR), he came to Sydney in 1882 and worked in a number of the company's refineries in Fiji, New Zealand and Australia. A key step in the decolourisation of sugar involved passing the solution through a bed of bone char, a process I saw at the old Yarraville refinery not far from where I live. Being vertically integrated, and very proud of its 'chemical control' of the refining process, CSR made its own charcoal. Bone char had very high surface area, consisting as it did of calcium phosphate particles coated with activated carbon. At Yarraville, the spent charcoal, when its decolourising days were done, went next door to Cuming Smith's to be converted into superphosphate, large quantities of which were sold to wheat farmers in Australia … and to sugar growers in Mauritius, who sent their raw sugar to Yarraville for refining.

Ian D. Rae FRACI CChem (idrae@unimelb.edu.au) is a veteran columnist, having begun his Letters in 1984. When he is not compiling columns, he writes on the history of chemistry and is an editor of *Historical Records of Australian Science*.

For further details, visit raci.org.au/events

RACI 2022 National Congress
3–8 July, Brisbane, Qld

13th Australasian Organometallics Meeting
11–14 July, Cairns, Qld

Hazards Australasia
25–27 September, Melbourne Convention Centre, Vic.

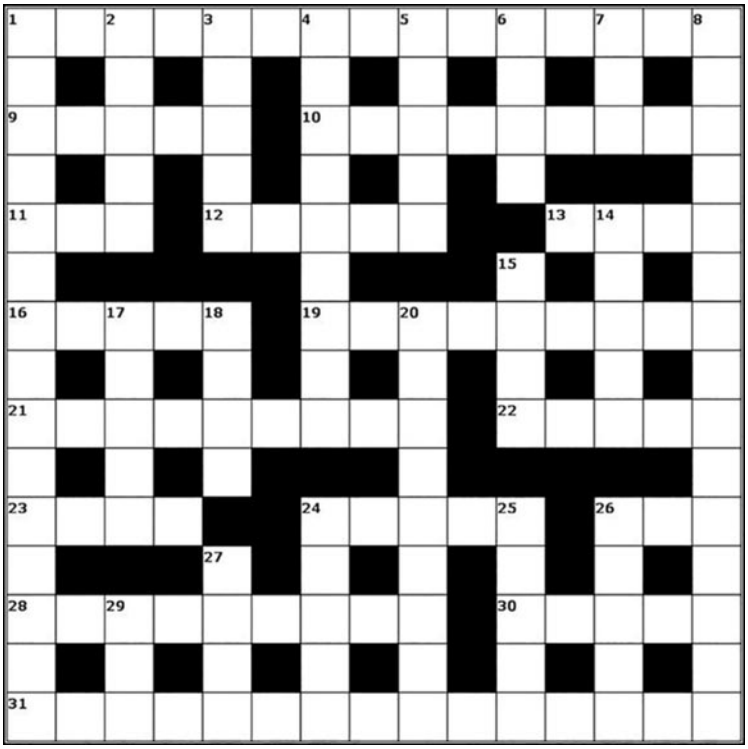
International Conference on Micro Reaction Technology
27–30 November, Melbourne, Vic

Grants for National Science Week

Thirty-five public science projects will share in more than $500 000 as part of Australia's annual celebration of science and technology. The grants include funding for the University of Melbourne's interactive travelling science and art show bringing quantum physics to regional and rural areas, the Student Robotics Club of South Australia's Robot Scrimmage competition day and the Hunter Medical Research Institute's oversized inflatable re-creation of the digestive system where children can conduct interactive food experiments and learn about digestion. Minister for Science and Technology Melissa Price said National Science Week was a great way to encourage interest and participation in science, technology, engineering and mathematics (STEM).

'National Science Week is a fantastic and fun opportunity to recognise the wonderful work of our scientists and hopefully inspire our next generation of big-thinkers', Minister Price said.

The 2022 school theme for National Science Week is 'Glass: More than meets the eye' and is based on the UN International Year of Glass. National Science Week 2022 will run 13–21 August. More details, including the full list of grant recipients, are available at scienceweek.net.au.



Across

1 Ceramists try ore (processed). It's the same mistake made again and again! (10,5)
9 In the thick of morning on first glance. (5)
10 Compounds media stir. Storm! (9)
11 Three elements charged. (3)
12 Attend to 34 over 6823. (5)
13 See 30 Across.
16 Only nitrogen can be used to make a compound composed of polyamides. (5)
19 Acetic nor by-product added part. (9)
21 Speak for about now. (9)
22 Ether reacted on the spot. (5)
23 Nucleus issue. (4)
24 Describes the left-handed propeller twist observed in a model tank. (5)
26 See 7 down.
28 Brain as an origin of polysaccharides. (9)
30 & 13 Across Puck is an example of minor neon deterioration. (5,4)
31 Cited nylon ester by mistake. How much negativity there is at that point! (8,7)

Down

1 Novel nitrate to stay as all observables are independent of time. (10,5)
2 Lead and nitrogen made clear. (5)
3 Creeps in prolonged gestation study. (5)
4 Modify two elements and get back up. (9)
5 Use iodine to extract $R_2C{=}NR$. (5)
6 The stromal stem cells last in trees. (4)
7 & 26 Across Fish finder relaxed. (6)
8 Neon's regeneracy can be obtained when the most stable contributing structure converts to the true delocalised structure. (9,6)
14 A 5 Down produced by mixing molybdenum, iodine and xenon. (5)
15 Observed and retained. (4)
17 Slip stop. (5)
18 Want to bring up in polysaccharide encapsulated considerations. (4)
20 Delays act as a way to speed things up. (9)
24 Media zoo holds on to two linked sevens at the terminal position. (5)
25 Straighten and join sides. (5)
26 Mushrooms? They're said to be a blast, man! (5)
27 Brume sense not noticed. (4)
29 Took in termination of an anion. (3)

Graham Mulroney FRACI CChem is Emeritus Professor of Industry Education at RMIT University.
Solution available online at chemaust.raci.org.au, Other resources.

RACI 2022 NATIONAL CONGRESS

Sun 3 – Fri 8 July | 2022

Brisbane Exhibition & Convention Centre

Chemistry: Catalysing solutions to global challenges

Royal Australian Chemical Institute National Congress 2022

Brisbane | Australia

Join scientists and experts from around the world for six days of inspirational speakers, exhibitions and networking opportunities.

Full program now available - visit https://www.raci2022.com/program/

Hosted by raci ROYAL AUSTRALIAN CHEMICAL INSTITUTE | WWW.RACI2022.COM