

chemistry

May 2016

in Australia

Indigenous people and chemistry: addressing the participation gap

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- Launching the Decadal Plan for Chemistry
- New creations in the periodic table
- Carbon sinks beneath the desert

National Awards

2016

The RACI National Awards recognise and promote the contributions and achievements of our members.

The awards cover a broad range of areas and are aimed at the full membership demographics.

They are open to all members of the RACI. Some can be applied for by the candidate; others have to be nominated by third parties.

- Academia:** Applied Research Award
Cornforth Award
CS Piper Award
HG Smith Memorial Award
Rennie Memorial Award
- Distinction:** Citation
Distinguished Contribution to Economic Advancement (Weickhardt) Award
Distinguished Fellowship Award
Leighton Memorial Award
- Education:** Fensham Award for Outstanding Contribution to Chemical Education
RACI Chemistry Educator of the Year Award
- Young Chemists:** Masson Memorial Award

MRACI Post Graduate Student Travel Bursary

An amount of \$2000 to assist Post Graduate Student members of the RACI to travel professionally from their home institution, to collaborate with a research group, at another Australian university or overseas, or to make use of specialised research facilities (e.g. an advanced light source), or to deliver a paper at a meeting overseas.

Full details of the awards and the requirement criteria can be found on the RACI website at:
www.raci.org.au/events-awards/national-awards-2016



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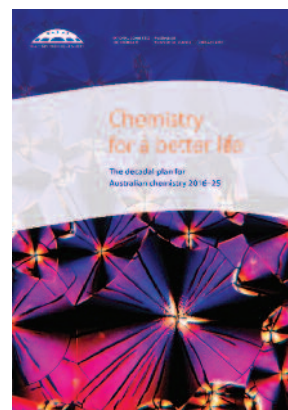
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cover story

Increasing Indigenous presence in chemistry

A lack of Indigenous people in chemical science is not unique to Australia. We can learn much from progress made in the US.

Angkerle (Standley Chasm), part of the Iwupataka Land Trust in the Northern Territory. At the 2011 national census, Aboriginal and Torres Strait Islander Australians constituted 30% of the population of the Northern Territory, the highest proportion of any state or territory. Two-thirds of Aboriginal and Torres Strait Islander Australians were living in regional or remote areas of Australia. (Source: Australian Bureau of Statistics).

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24 Completium! Race to the end of period 7

Four more superheavy elements have made it to the periodic table, but what evidence did their creators need to get them there?

28 Chemistry: the next 10 years

The 2016–2025 Decadal Plan for Chemistry supports growth in chemical manufacturing and research, explains the working group chair.

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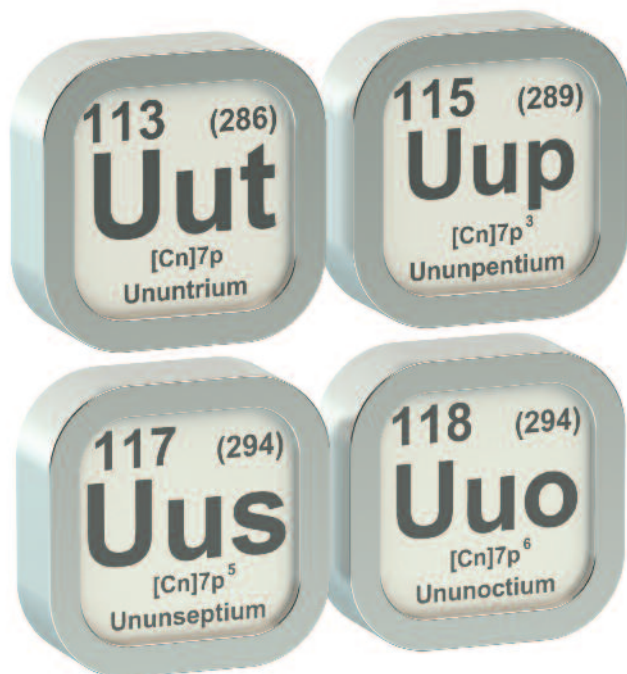
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Cover-to-cover chemistry

Since the publication of the March edition, a few readers have contacted me to find out more about the table of esters and their smells on the back cover. This table, and a similar one on the back cover of this month's issue, are the brainchild of James Kennedy, a VCE chemistry teacher at Haileybury in Melbourne. James very kindly gave me permission to use some of the excellent graphics on his website (jameskennedymonash.wordpress.com).

The magazine would be a bunch of blank pages without the gratis contributions of feature writers and columnists, and others like James. Each month, I search for good stories about chemistry and of interest to chemists. I have some more ideas for infographics, so keep a lookout. Better still, please send me your infographic suggestions.

After I come up with some story possibilities, I must find writers and tailor articles to the *Chemistry in Australia* audience. It's so stimulating to be able to collaborate with many people in this process, and to be able to offer the end results to readers each month.

The editorial, production and advertising team of *Chemistry in Australia* is a small and efficient group that is great at long-distance professional relationships. Their home offices range from Melbourne to Gippsland to Tasmania, with a printer in Singapore. Thanks to ICT, the magazine can be produced very well with this arrangement, but occasional face-to-face meetings are nice to have nonetheless.

After a short stint as a research chemist, I started with the magazine nearly 20 years ago and have been involved in-house or freelance for most of the time since then. Catherine Greenwood has been involved with *Chemistry in Australia*, off and on, for 20 years. Her current role is production editor – she subedits and works out the layout of each issue – how features, news, reviews and columns will all fit in with any advertising material that needs to be included.

Catherine and I choose suitable images and she designs the feature articles. Catherine and I edit the text and then send it, along with sample layouts, to Guy Nolch, who has been typesetting the magazine for more than a decade. Guy combines the text, images and advertisements to transform our combined editing and design efforts into the vibrant pages you turn in each edition of the printed magazine. After several rounds of proof checking, including authors' corrections, the magazine's final layout is uploaded to the printer.

Marc Wilson of Gypsy Media services is the appointed media representative for all RACI media, including *Chemistry in Australia*, the RACI website and all RACI e-newsletters. His role is to prospect, attract and convert third-party companies to advertise their products and services to the members in the various RACI media.

Marc has been representing the RACI now for five years, and he is a part of the team that has guided *Chemistry in Australia* into the high-quality publication that it is today.

The dedicated website, launched in 2014 (chemaust.raci.org.au), provides access to the content of the print magazine, plus a news feed, indexes and a magazine archive, and more.

Gratis contributions are not limited to writing. Two committees assist the running of the magazine: a management group, which discusses finances, advertising and general editorial matters; and a subcommittee, which meets to talk in more detail about the content that is published. The magazine is supported in many ways by these generous volunteers.



Sally Woollett (editor@raci.org.au)

Thanks to Guy, Catherine and Marc for providing some information for this editorial.

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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.

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CSIRO's future

Recently there have been several articles in the press about the cuts to staff and changes in climate positions in the CSIRO.

Even the previous Chief Scientist has expressed concern on ABC Radio about what is planned for the CSIRO. About 2900 researchers from nearly 60 nations have expressed concern about plans to halve the number of researchers working on climate monitoring and modelling.

In the September 2015 issue of *Chemistry in Australia*, Larry Marshall was described as a serial entrepreneur, venture capitalist and private investor. He has gone to the US to try and secure deals for the CSIRO to be engaged in big projects (*Sydney Morning Herald* 13–14 February 2016).

A proposed cut of 100 full-time positions out of about 140 staff alarmed the global research community.

There are ethical, scientific and economic reasons for having a strong climate change unit at CSIRO. Ethically, climate change and the world's ability to survive must be a major concern for CSIRO and Australia given our place in the Pacific. Scientifically, the impact and flow-on from these cuts could be large. Already CSIRO has developed exceptional data, monitoring techniques and sustainability projects in urban and rural societies short of water or food resulting from climate change.

A change in direction for the CSIRO will come at a loss for the basic issue for this world, which is the nature, causes and remedies for climate change. Spin-off from climate change research has already created industry for the future.

Christopher Michael Owens FRACI CChem

High-tech nonsense

What a refreshing change from the stuff in the hack media to read the article by Ian Maxwell (March issue, p. 36). In addition to the frequent press nonsense about 'high-tech, innovation etc., etc.' we also are frequently assailed by motherhood statements from politicians and press hacks about the huge shortage of STEM-qualified young scientists and engineers and the consequences for the future of Australia.

Given that the Australian workplace is a 'free market', in so far as supply and demand regulate salaries and working conditions, one would expect sky-high salaries for people in such 'high demand and importance'. This appears not to be so (with the possible exception of financial mathematics specialists) and it does make me wonder as to the motivation of the spruikers of this material.

B.F. Gray FRACI CChem

Thoughts from the February issue

The February 2016 edition of *Chemistry in Australia* again provided many points for further thought and discussion.

Firstly, congratulations to Clarrie Ng of ABG and Richard Thwaites of A&W, who I remember from my years spent at BBA – the biggest flavour house in Australia in the 1970s, when ABG

was a customer and A&W a sister company. Clarrie and Richard are the only two RACI 2015 National Award winners who spent their professional careers in industry; the other 10 recipients are all from academia or teaching.

From some demographic data prepared by RACI (May 2015), 58% of RACI members were classified as 'Commercial' and yet anecdotally industry is under-represented in the annual awards, while many of the major articles in *Chemistry in Australia* have a practical approach.

The main time we appreciate the chemistry input from industry-based members is in the Obituary column. In my opinion, industry members should have their stories told before the final word is written of their lives.


Secondly, the article by Kieran Lim, 'Improving laboratory learning' (p. 36), makes some great points, particularly about the 'decline in STEM' enrolments, which is reflected in numbers and quality of graduates available for industry.

However, the two photos accompanying the article show students conducting laboratory experiments *without* safety glasses, even if in the breaking strain experiment it appears unlikely that safety glasses are required. The metal corrosion experiment offers no excuse, although one student is wearing glasses (optical or safety?) and both are wearing gloves and proper aprons as an option to laboratory coats.

This same error occurred several years ago in an earlier education article, which showed a group of overseas women in a titration situation wearing reasonable safety equipment but again no safety glasses.

Thirdly, on a lighter note, on receipt of the February edition, my immediate and habitual attention to Ian Rae's Letter from Melbourne was diverted by the back page, which is usually reserved for advertisements. This particular back page may be also an ad but I could not immediately or on further inspection detect the 'message'. This particular page was innovative in the visual and practical manner of showing the chemistry of esters that are part of the organoleptic spectrum of foods and particularly flavours. There are many lists, tables and descriptive pages providing the same information but none as dramatic or educational yet simple and illustrative as this back page.

Tony Zipper FRACI CChem

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<p>Quality System Quality Endorsed Company ISO 9001:2008 LIC 10872 SAS Group</p>	<p>If chemists in Australia are experiencing difficulty in obtaining supply, please send me an email: peter.sommers@rowe.com.au and I promise to help you. This is not a 'subtle' attempt to obtain more business, but a sincere pledge to help fellow scientists source the items they need to do their work, and thereby help Australia grow. This is the raison d'être for Rowe Scientific Pty. Ltd. Peter Sommers (FRACI)</p>	

Denying science

I am unhappy with the philosophy that I perceive to underlie John Cook's essay on countering 'science denial' (March issue, p. 28). Science is a process, not an inerrant collection of facts. 'Science denial' does not consist of advancing a hypothesis contrary to a consensus position, but of – for example – refusing to consider alternative hypotheses when the predictions of a hypothesis are not confirmed by observation; ruling alternative explanations for observations out of bounds for discussion on grounds other than scientific ones; and applying pejorative labels to people who disagree with you rather than addressing their substantive criticisms.

As a science communicator, I think the greatest disservice to science I can do is push a simplified emotive version of some *ex cathedra* truth. My duty is to impart a true sense of the complexity of the universe, how science allows us to begin to understand that complexity, and the contingent nature of the understanding we achieve.

Chris Fellows FRACI CChem

Congratulations for the March issue, which included several informative contributions appropriate for teaching chemistry (e.g. your editorial plus articles from Jeff Hughes, John Cook, Duncan Seddon, Ian Maxwell and Ian Rae).

A difficulty for teaching often comes up when science involves society. When I was teaching, one topic involved misrepresentation within a subject 'Science and Society'. This was intended to alert students to some of the tricks used in politics, prospectuses, shareholder reports, and even equipment brochures to sugar-coat objectives. We covered things such as 'gee whiz' graphs, distorted bar graphs, cherry-picking, buzz words and inappropriate use of percentages to exaggerate facts. Not only did this approach allow students to see through the fog of misinformation, but a possible side effect was teaching them how to create 'spin' if they were ever asked to do so in a workplace.

In the important contribution 'Busting myths', the author advocates giving facts first, then uses an analogy of a courtroom plus refers to a challenge

given to Rutherford to keep explanations simple. These are important for allowing an untrained jury to reach a verdict. When applying the proposed method in the author's example of climate change myths, key facts supplied involve *percentages of opinions*. Without debating the complexities of climate science, this practical example appears self-defeating. To say 99.9% of the petition of 31 000 dissenting *scientists* were not peer-reviewed 'climate' scientists contradicts the article's intent. Simple facts do convince other scientists. Phrases used in the past such as 'the science is settled' or advocating a 'no regrets' policy and percentages do not convince. Most of the 31 000 so-called 'deniers' would not argue with facts such as [CO₂] has doubled to 0.04% since industrialisation or that we are in a current warm period, but differ on the cause. Reversing [CO₂] is costly to achieve; better options would be to reverse other humankind degradations to our planet.

Ray Hodges FRACI CChem

Two letters critical of my article on countering science denial unfortunately display a lack of awareness of the scholarly research into science denial.

First, Chris Fellows objects to the term 'denial' in reference to the rejection of climate science. However, a large body of psychological research examines what drives rejection of scientific evidence and how scientists might respond. This is necessary to understand why people might reject humans' role in causing global warming when many independent lines of empirical evidence find human fingerprints in climate change. These fingerprints include satellite measurements of outgoing heat, the changing structure of the atmosphere and the shrinking annual cycle with winters warming faster than summers. These fingerprints also rule out other natural causes – and yet climate science deniers persist in attributing climate change to natural causes. The consilience of evidence has resulted in a consensus among climate scientists, with 97% of publishing climate scientists agreeing that humans are causing global warming.

Psychological research finds that the strongest predictor of climate science denial is political ideology. Political conservatives are more likely to reject humans' role in climate change because of the policy implications: regulation of polluting industries. Psychological experiments have also found that presenting scientific evidence has little effect on those

who reject climate science, and can be counter-productive. The implications of this research are that climate science denial is expected to persist despite the strengthening evidence (and, indeed, this has been observed). Consequently, scientists need to develop evidence-based responses to misinformation.

Second, Ray Hodges argues that 'percentages do not convince', referring to my mention of the 97% consensus and refutation of the 31 000 dissenting scientists argument. Psychological research says otherwise. Public perception of the scientific consensus is a 'gateway belief', meaning people use expert opinion as a mental shortcut, or heuristic, to guide their views on complicated scientific matters. Communicating the 97% consensus has been observed to significantly increase acceptance of climate change, particularly among conservatives. Conversely, the 31 000 dissenting scientists argument is one of the most potent climate myths in lowering acceptance of climate change. My own research, using randomised psychological experiments, found that explaining the 'fake expert' fallacy in the 31 000 dissenters argument completely removes the influence of this particular myth. My results have been replicated by researchers at Yale University, who also found that explaining the techniques of science denial is a potent strategy in neutralising misinformation.

John Cook

High-resolution views of lightweight atoms

Researchers at the US Department of Energy's Lawrence Berkeley National Laboratory (Berkeley Lab) have developed a new imaging technique, tested on samples of nanoscale gold and carbon, that greatly improves images of light elements using fewer electrons.

MIDI-STEM (matched illumination and detector interferometry scanning transmission electron microscopy (STEM)), combines STEM with an optical device called a phase plate that modifies the alternating peak-to-trough, wave-like properties (the phase) of the electron beam. This phase plate modifies the electron beam in a way that allows subtle changes in a material to be measured, even revealing materials that would be invisible in traditional STEM imaging.

The highly focused beam of electrons used in traditional STEM can easily destroy delicate samples, so a low-electron dose is needed to image biological or other organic compounds, such as chemical mixes that include lithium. Cryo-EM, an electron-based technique used to determine the detailed structure of delicate, frozen biological samples, is generally not useful for studying samples with a mixture of heavy and light elements.

'The MIDI-STEM method provides hope for seeing structures with a mixture of heavy and light elements, even when they are bunched closely together,' said Colin Ophus, a project scientist at Berkeley Lab's Molecular Foundry and lead author of a study, published in *Nature Communications* (doi: 10.1038/ncomms10719), that details this method.

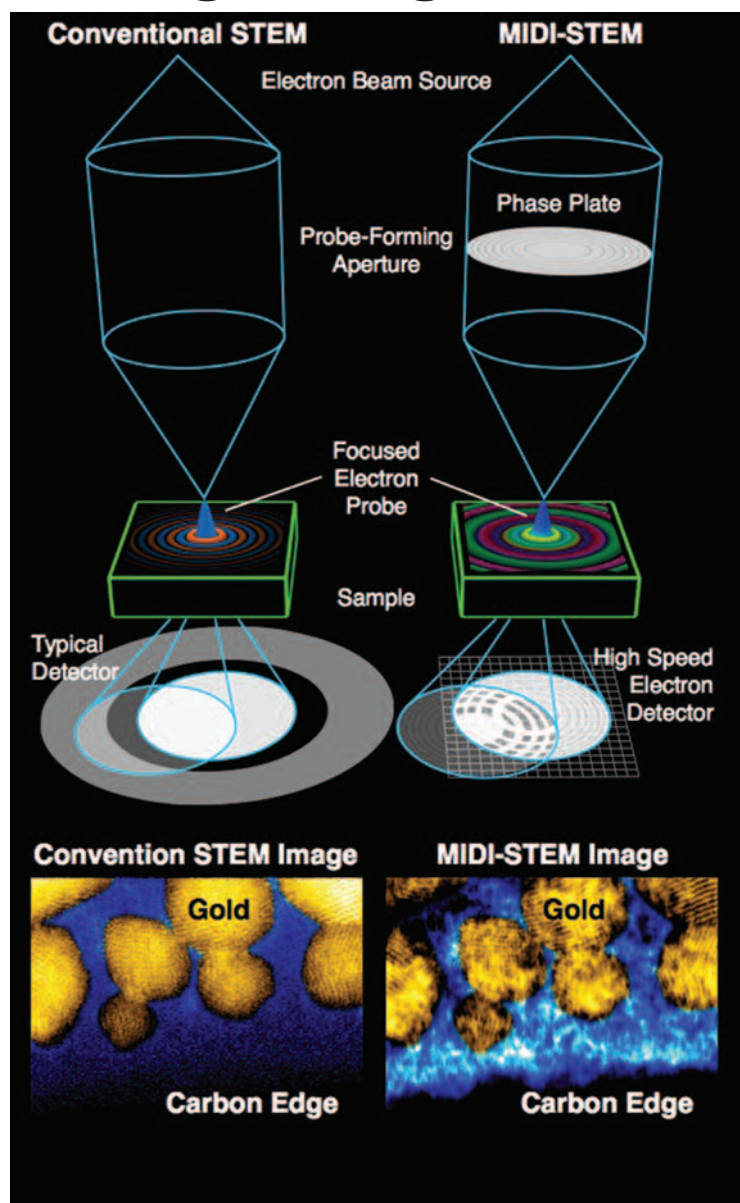
If you take a heavy-element nanoparticle and add molecules to give it a specific function, conventional techniques don't provide an easy, clear way to see the areas where the nanoparticle and added molecules meet.

'How are they aligned? How are they oriented?' Ophus asked. 'There are so many questions about these systems, and because there wasn't a way to see them, we couldn't directly answer them.'

While traditional STEM is effective for 'hard' samples that can stand up to intense electron beams, and cryo-EM can image biological samples, 'We can do both at once' with the MIDI-STEM technique, said co-author Peter Ercius, a Berkeley Lab staff scientist at the Molecular Foundry.

The MIDI-STEM technique could prove particularly useful for directly viewing nanoscale objects with a mixture of heavy and light materials, such as some battery and energy-harvesting materials, that are otherwise difficult to view together at atomic resolution. It also might be useful in revealing new details about important two-dimensional proteins, called S-layer proteins, that could serve as foundations for engineered nanostructures but are challenging to study in atomic detail using other techniques.

'If you can lower the electron dose, you can tilt beam-sensitive samples into many orientations and reconstruct the



In MIDI-STEM (right), developed at Berkeley Lab, an electron beam travels through a ringed 'phase plate', producing a high-resolution image (bottom right) that provides details about a sample containing a heavy element (gold) and light element (carbon). Details about the carbon are missing in an image (bottom left) of the sample using a conventional electron imaging technique (ADF-STEM). Colin Ophus/Berkeley; *Nature Communications*: 10.1038/ncomms10719

sample in 3D, like a medical CT scan. There are also data issues that need to be addressed,' Ercius said, as faster detectors will generate huge amounts of data. Another goal is to make the technique more 'plug-and-play', so it is broadly accessible to other scientists.

Lawrence Berkeley National Laboratory

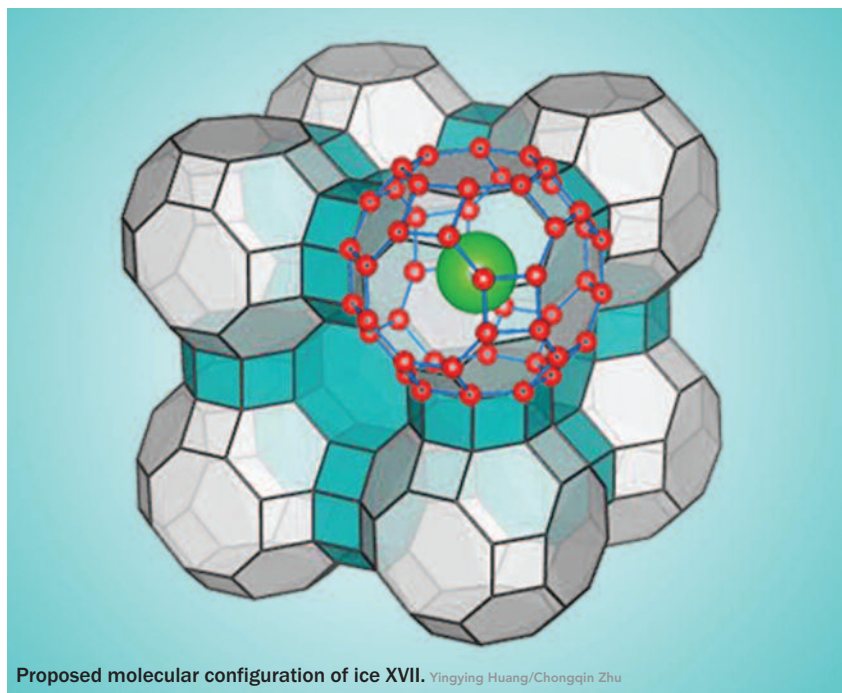
Prediction of ice XVII

A group of chemists, led by Xiao Cheng Zeng from the University of Nebraska-Lincoln and Jijun Zhao from the Dalian University of Technology, have predicted a new molecular form of ice: ice XVII.

If the proposed ice XVII can be synthesised, it would become the 18th known crystalline form of water, according to Zeng, Zhao and their colleagues. It would be about 25% less dense than a record-low form, ice XVI, synthesised by Werner Kuhs from the University of Göttingen and co-authors in 2014.

'We performed a lot of calculations whether this is not just a low-density ice, but perhaps the lowest-density ice to date. A lot of people are interested in predicting a new ice structure beyond the state of the art,' said Zeng, senior author of a paper in *Science Advances* (doi: 10.1126/sciadv.1501010).

Zeng, Zhao and their colleagues used a computational algorithm and molecular simulation to determine the ranges of extreme pressure and temperature under which water would freeze into the predicted configuration. That configuration takes the form of a clathrate – a series of water molecules that form an interlocking cage-like structure.



Proposed molecular configuration of ice XVII. Yingying Huang/Chongqin Zhu

It was long believed that these cages could maintain their structural integrity only when housing 'guest molecules' such as methane, which fills an abundance of natural clathrates found on the ocean floor and in permafrost. Like Kuhs' team before them, however, the chemists have calculated that their clathrate would retain its stability even after its guest molecules have been evicted.

Synthesising the clathrate will take some effort. Based on the team's

calculations, the new ice will form only when water molecules are placed inside an enclosed space that is subjected to ultra-high, outwardly expanding pressure.

According to the *Science Advances* article, ice XVII is the most stable ice polymorph in the pressure region below –5834 bar at 0 K (–273°C) and below –3411 bar at 300 K (29°C).

Sci-news.com

Twelve teachers from schools around New Zealand are heading back into the classroom as confident leaders of science within their school community. In December, they completed phase one of the Science Teaching Leadership Programme, where they worked alongside scientists to gain a deeper understanding of New Zealand's overarching science curriculum strand, called the Nature of Science, as well as undertaking leadership training.

Now these teachers are returning to school to commence phase two of the program that involves working with students, staff and their local community to enhance the quality of science teaching and learning.

An integral part of being selected on to the Science Teaching Leadership Programme is that schools or science departments and their nominated teacher commit to science being a major professional learning focus where the quality of science teaching and learning is significantly enhanced.

Minister of Science and Innovation, Hon Steven Joyce launched the program early last year, which supports the government's strategic direction for science in society, as outlined in the document *A Nation of Curious Minds – He Whenua Hihiri i te Mahara*. The program is administered by the Royal Society of New Zealand.

Royal Society of New Zealand

BASF now has 145 ingredients for personal and home-care products certified to the international halal standard HAS 23000. Along the entire value chain, strict guidelines for raw material purchasing, manufacturing, filling, warehousing and transport are followed to ensure product purity in compliance with Islamic law.

BASF's portfolio of halal ingredients ranges from sugar-based surfactants, pearlisers, emollients and protein derivatives for personal care applications – such as facial cleansers or baby

In search of Earth's oldest ice

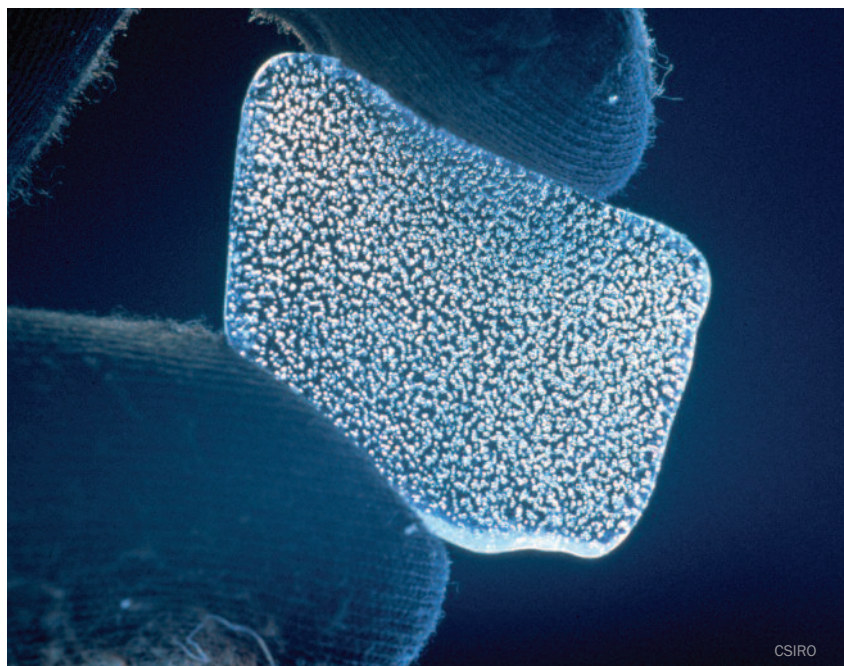
The search for the world's oldest ice core – likely to be a million years or older – was among the key topics for a major meeting of climate scientists in Hobart in March.

The International Partnerships in Ice Core Sciences (IPICS) Second Open Science Conference brought more than 200 scientists and drilling experts from 22 countries to Tasmania for a week of scientific presentations and planning discussions. The conference was co-hosted by the Australian Antarctic Division and the Antarctic Climate and Ecosystems Cooperative Research Centre.

Conference Chair, Tas van Ommen, said: 'Ice cores are immensely important to climate science but the logistical and technical challenges of drilling ice cores are enormous, and require extraordinary levels of cooperation between nations.'

Van Ommen said one of the major priorities for the conference was progress toward finding and drilling the world's oldest ice.

'The oldest ice core retrieved from Antarctica to date is about 800 000 years old, which falls just short of a major shift in global ice age cycles that occurred



about a million years ago. We think that million year-old ice exists deep within the Antarctic icecap, and if we can recover it, then we can start to piece together exactly what caused this fundamental change in climate cycles.'

Van Ommen said there was considerable optimism about the potential for new and emerging technologies to improve the efficiency of ice core drilling projects: 'Antarctic ice


cores can be well over three kilometres deep and hundreds of kilometres away from any permanent base, which tends to make ice core drilling costly and time consuming,' he said. 'There is quite a bit of excitement at the conference about the potential for new rapid access drilling technology, which can penetrate several kilometres of ice in just days or weeks.'

University of Tasmania

bubble baths – to detergent and cleaning agents, and raw materials for the pharmaceutical industry. These ingredients have been approved by Halal Control, Russelsheim, or the Halal Food Council of Europe, Brussels, which are both recognised by the Indonesian Council of Ulama (Majelis Ulama Indonesia) – a major umbrella association of Islamic quality management organisations.

BASF

Safe Work Australia has completed an update of the Hazardous Substances Information System (HSIS) database and the GHS Hazardous Chemical Information List (HCIL) to incorporate assessments made by the National Industrial Chemicals Notification and Assessment Scheme (NICNAS). These changes represent human health assessments made as part of tranches 1–7 of the Inventory Multi-tiered Assessment and Prioritisation (IMAP) framework.



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This update includes approximately 300 new entries and approximately 130 amendments to existing entries for both datasets. A full list of the changes to HSIS and HCIL can be downloaded at safeworkaustralia.gov.au.

Safe Work Australia

Methamphetamine residue increase in wastewater

Methamphetamine residue found in the wastewater of a Queensland city has increased by a factor of almost five since 2009. University of Queensland scientists from The National Research Centre for Environmental Toxicology (Entox) worked with Wayne Hall of the Centre for Youth Substance Abuse Research to obtain the results.

‘More than 1000 samples were taken from a coastal metropolitan city and a major inland regional city between 2009 and 2015,’ Hall said. ‘Methamphetamine consumption increased 4.8 times in the metropolitan area over the time frame, and 3.4 times in the regional area. This coincides with a recent study that showed an upsurge of more than 170 000 regular meth users across Australia between 2009 and 2015, to a total of 270 000 users nationwide.’

Jochen Mueller of Entox and colleagues Phong Thai, Foon Yin Lai and

Jake O’Brien collaborated to build on previous insightful studies featuring waste testing. Armed with knowledge about the ways that specific drugs are excreted, they used census populations for both the metropolitan and regional catchments to ascertain their results.

In 2009, the mean for the coastal metropolitan area was 234 mg/day/1000 people, which increased to 1126 mg/day/1000 people in 2015. The study began a year later in the inland regional city, marked by a mean of 115 mg/day/1000 people in 2010, which increased to 398 mg/day/1000 people in 2015.

Hall said the wastewater analysis alone did not determine whether consumption had increased because there were more users or because existing users were consuming more. ‘However, when you view this together with other timely research, it is consistent with there being

exponential growth in the number of users,’ Hall said.

A report on national estimates, led by Louisa Degenhardt from the National Drug and Alcohol Research Centre at the University of New South Wales, was released in March. Hall was a contributor to the report, which gave the total number of regular users in Australia as 270 000 – greater than the 2014 total population figures for Hobart (219 243) or Townsville (178 649).

Both the wastewater study (doi: 10.5694/mja15.01054) and the study on Australian usage estimates (doi: 10.5694/mja15.00671) have been published in the *Medical Journal of Australia*.

University of Queensland



Fir0002/Flagstaffphotos

Copper at the right time more beneficial for wine



Andrew Clark in the laboratories at Charles Sturt University. Charles Sturt University

Charles Sturt University (CSU) research is giving winemakers new insight into how timing the use of copper can work more effectively to remove an unpleasant smell that's sometimes created during fermentation.

CSU senior lecturer in wine chemistry Andrew Clark said, 'During the fermentation process, sometimes a tiny amount of hydrogen sulfide can be produced. The unpleasant smell can be removed by winemakers adding very small amounts of copper to bind with the hydrogen sulfide and remove the smell. The new compound, copper sulfide, is then removed from the wine.'

The research at the National Wine and Grape Industry Centre at CSU in Wagga, funded by Wine Australia, found:

- copper added early in the production process, when protein from the grapes is still present, is more easily removed
- copper added late in the production process doesn't bind as effectively and it is harder to remove
- if significant copper sulfide is left in the wine, the copper and hydrogen sulfide are not inert and copper can still be active in catalysing less desirable reactions
- adding copper just before bottling 'just in case' is counter-productive.

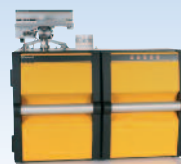
Clark said the research is providing winemakers with valuable information about the most effective time to add copper if it is needed.

The researchers, Clark, PhD student Paris Grant-Preece from CSU, Natalie Cleghorn, a former CSU student who works for Yalumba, and Geoff Scollary FRACI CChem from the University of Melbourne have been recognised for their work (see February issue, p. 30). Their research paper, 'Copper(II) addition to white wines containing hydrogen sulfide: residual copper concentration and activity' (doi: 10.1111/ajgw.12114), was named the Australian Society for Viticulture and Oenology's Oenology Research Paper of the Year for 2015. Further research about metals in wine is being conducted at CSU, in collaboration with the Australian Wine Research Institute.

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Evidence for curium at solar system formation

University of Chicago scientists have discovered evidence in a meteorite that the rare element curium was present during the formation of the solar system. This finding ends a 35-year-old debate on the possible presence of curium in the early solar system, and plays a crucial role in reassessing models of stellar evolution and synthesis of elements in stars. Details of the discovery appear in *Science Advances* (doi: 10.1126/sciadv.1501400).

‘Curium is an elusive element. It is one of the heaviest-known elements, yet it does not occur naturally because all of its isotopes are radioactive and decay rapidly on a geological time scale,’ said the study’s lead author, François Tissot, from the Massachusetts Institute of Technology.

And yet Tissot and his co-authors Nicolas Dauphas and Lawrence Grossman have found evidence of curium in an unusual ceramic inclusion they called ‘Curious Marie’, taken from a carbonaceous meteorite. Curium became incorporated into the inclusion when it condensed from the gaseous cloud that formed the sun early in the history of the solar system.

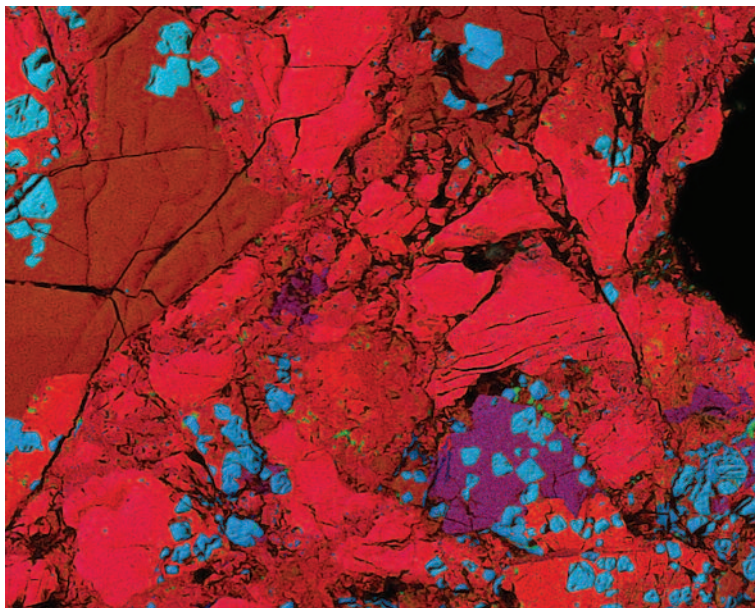
On Earth today, curium exists only when manufactured in laboratories or as a by-product of nuclear explosions. However, curium could have been present early in the history of the solar system, as a product of massive star explosions that happened before the solar system was born.

The longest-lived isotope of curium (^{247}Cm) decays over time into an isotope of uranium (^{235}U). Therefore, a mineral or a rock formed early in the solar system, when ^{247}Cm existed, would have incorporated more ^{247}Cm than a similar mineral or rock that formed later, after ^{247}Cm had decayed. If scientists were to analyse these two hypothetical minerals today, they would find that the older mineral contains more ^{235}U than the younger mineral.

Early studies in the 1980s found large excesses of ^{235}U in any meteoritic inclusions they analysed, and concluded that curium was very abundant when the solar system formed. More refined experiments showed that these early results were spurious, and that if curium was present in the early solar system, its abundance was so low that state-of-the-art instrumentation would be unable to detect it.

Scientists had to wait until a new, higher-performance mass spectrometer was developed to successfully identify, in 2010, tiny excesses of ^{235}U that could be the smoking gun for the presence of ^{247}Cm in the early solar system.

Models predict that curium, if present, was in low abundance in the early solar system. Therefore, the excess ^{235}U produced by the decay of ^{247}Cm cannot be seen in minerals or inclusions that contain large or even average amounts of natural uranium. One of the challenges was thus to find a mineral or inclusion likely



The Allende carbonaceous meteorite is peppered with inclusions that have a ceramic-like chemistry (red for calcium, blue for aluminium, green for magnesium in the false colour image shown; field of view is 0.5 mm). When they formed, these inclusions incorporated the short-lived nuclide curium-247 (with a half-life of 15 million years), traces of which have been detected as a significant excess in uranium-235, its decay product. François L.H. Tissot

to have incorporated a lot of curium but containing little uranium.

With the help of study co-author Lawrence Grossman, the team was able to identify and target a specific kind of meteoritic inclusion rich in calcium and aluminium. These CAIs (calcium, aluminium-rich inclusions) are known to have a low abundance of uranium and likely to have high curium abundance. One of these inclusions – Curious Marie – contained an extremely low amount of uranium.

‘It is in this very sample that we were able to resolve an unprecedented excess of ^{235}U ,’ Tissot said. ‘All natural samples have a similar isotopic composition of uranium, but the uranium in Curious Marie has 6% more ^{235}U , a finding that can only be explained by live ^{247}Cm in the early solar system.’

Thanks to this sample, the research team was able to calculate the amount of curium present in the early solar system and to compare it to the amount of other heavy radioactive elements such as iodine-129 and plutonium-244. They found that all these isotopes could have been produced together by a single process in stars.

‘This is particularly important because it indicates that as successive generations of stars die and eject the elements they produced into the galaxy, the heaviest elements are produced together, while previous work had suggested that this was not the case,’ Dauphas explained.

University of Chicago

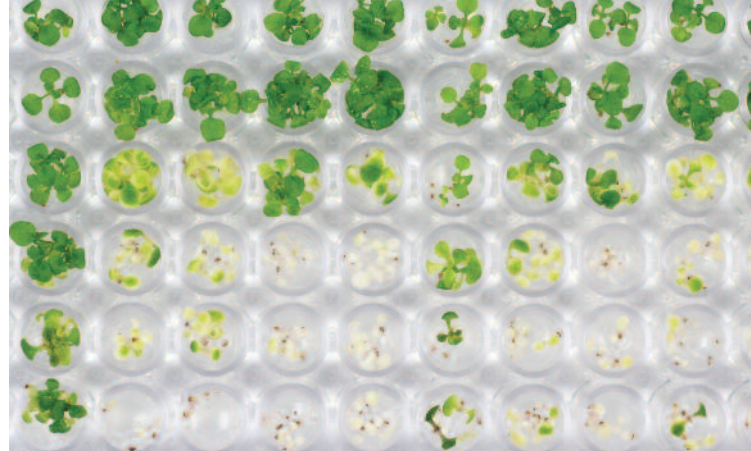
Common antibiotic inspires hunt for new herbicide

Plant biologists at the University of Western Australia (UWA) have discovered that the commonly used antibiotic ciprofloxacin, which kills bacteria, also kills plants by blocking the DNA copying machinery of the plants.

The research, published in the *Journal of Biological Chemistry* (doi: 10.1074/jbc.M115.689554), was a collaboration between UWA researchers and Tony Maxwell from the John Innes Centre in the UK. The work at UWA was carried out by graduate research assistant Julie Leroux and Joshua Mylne, a Future Fellow in UWA's School of Chemistry & Biochemistry and affiliated to the ARC Centre of Excellence in Plant Energy Biology.

Mylne said the researchers found a plant that could grow on ciprofloxacin and by working out which gene mutation enabled this, could prove how the antibiotic killed plants. 'The machinery that ciprofloxacin affects is not currently targeted by known herbicides, making this an untried mode of action to focus on.'

This work built on prior knowledge from Maxwell's lab that the enzyme DNA gyrase (part of the DNA copying machinery) is made in plants and is essential in plant growth and development.



Ciprofloxacin-resistant (columns 1, 6), wild-type (column 5) and resensitised (other columns) *Arabidopsis thaliana* on a graded range of ciprofloxacin concentrations. J. Leroux

By generating mutations in the model plant *Arabidopsis thaliana* and finding one plant that is resistant to the antibiotic ciprofloxacin and analysing its genome, the team confirmed that DNA gyrase in plants can be targeted effectively by this antibiotic.

University of Western Australia

Gene regulation boosts ammonia production

Nitrogen fixation in cyanobacteria metabolic processes may provide an important means for producing ammonia, a crucial ingredient in the chemical industry. Regulating the cellular processes involved to optimise microbial ammonia production has been a challenge. Researchers at Tokyo Institute of Technology have successfully demonstrated a gene regulation strategy for enhancing ammonia production in the cyanobacterium *Anabaena* strain PCC 7120 (A. 7120).

The researchers first investigated the gene expression system in *Anabaena* using *tetR* (tetracycline resistance regulatory gene) promoter, which is regulated by anhydrotetracycline. Anhydrotetracycline is an antibiotic known to have a strong affinity to the Tet repressor protein, TetR. When a nitrogen-dependent *tetR* promoter was used, they observed a nitrogen-dependence in the amount of anhydrotetracycline needed to express the desired gene.

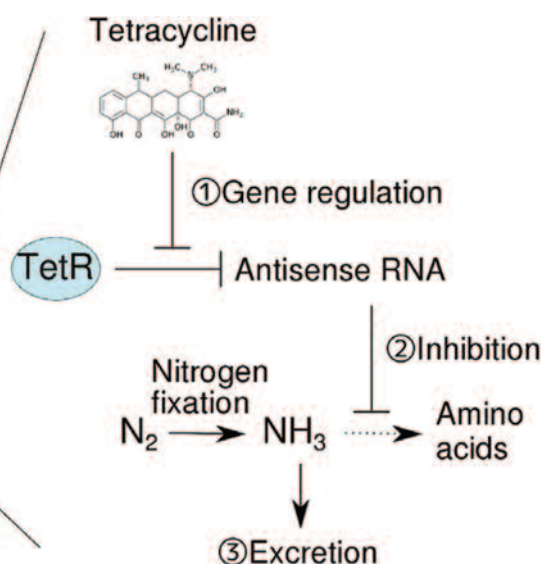
For the production of ammonia, the researchers repressed expression of *glnA* with an antisense small RNA. The gene *glnA* encodes an essential enzyme,



V Heterocysts

The metabolic engineering system for ammonia excretion developed in the study. During nitrogen starvation, some cyanobacteria form specialised nitrogen-fixing cells called heterocysts.

glutamine synthase, for nitrogen assimilation in cyanobacteria. The antisense RNA – which represses it – was expressed under the control of the promoter previously used in this study, and *tetR* was expressed under the control of the nitrogen-dependent promoter. They successfully observed increased excretion of ammonia when the expression of antisense RNA was induced.



They conclude: 'These results demonstrated that the antisense repressors, used as the regulators of endogenous gene expression, may become useful tools for the production of desired substances in A. 7120.'

The study was published in *Plant and Cell Physiology* (doi: 10.1093/pcp/pcv202outer).

Tokyo Institute of Technology

Concerns over long-term use of chromium diet pills

Concerns have been raised over the long-term use of nutritional supplements containing chromium, after an Australian research team found the supplement is partially converted into a carcinogenic form when it enters human cells.

Chromium is a trace mineral found primarily in two forms: a range of chromium(III) forms are sold as nutritional supplements, while hexavalent chromium(VI) is its 'carcinogenic cousin', gaining notoriety from the book and 2000 movie *Erin Brockovich*, which linked a cluster of illnesses to its presence in drinking water. Controversy remains over whether the dietary form of chromium is essential, with an increasing body of evidence indicating it is not safe.



The coordination compound tris(picolinate)chromium(III) is marketed and sold as a nutritional supplement. Hydrogen atoms are omitted in the model shown. Wiki

In the study, researchers from the Universities of Sydney and New South Wales treated cells with chromium(III) before creating a map of every chemical element contained inside the cell, using an intense synchrotron X-ray beam at the Advanced Photon Source (APS) in Chicago. The team accessed the APS through the Federal Government's Australian Synchrotron Research Program, which provided researchers with synchrotron access prior to the Australian Synchrotron opening in 2007.

Research lead Dr Lindsay Wu, from the University of NSW's School of Medical Sciences, said the high-energy synchrotron beam allowed the team to identify and classify chromium spots

throughout the cell.

'The powerful X-ray enabled us to determine whether the spots were chromium(III) or a combination of chromium(III), chromium(V) and chromium(VI).

'The health hazards associated with exposure to chromium are dependent on its oxidation state – we were able to show oxidation of chromium inside the cell does occur, meaning it loses electrons and transforms into carcinogenic forms, which no one had been able to do in a biological sample before.'

Supplements containing chromium are consumed for the purported treatment of metabolic disorders, such as insulin resistance and type 2 diabetes, but chromium's mechanism of action in the body is not well understood.

These supplements are also commonly used for weight loss and body building with some containing up to 500 micrograms per tablet, above the 200 micrograms estimated as a safe and adequate daily dietary intake for adults by the US National Academy of Sciences. Australia's current National Health and Medical Research Council Nutrient Reference Values, which are currently under review, recommend 25–35 micrograms of chromium daily as an adequate intake for adults.

Professor Peter Lay from the University of Sydney's School of Chemistry said with the latency period for chromium(VI)-related cancers often greater than 20 years, the finding raises concerns over the possible cancer-causing qualities of chromium compounds and the risks of taking chromium nutritional supplements long term or in high doses.

'With questionable evidence over the effectiveness of chromium as a dietary supplement, these findings should make people think twice about taking supplements containing large doses of chromium.

'However, additional epidemiological research is needed to ascertain whether chromium supplements significantly alter cancer risk, since long-term laboratory experiments have not been conducted

under the conditions of high oxidative stress (which promotes chromium(III) oxidation) associated with diabetes.'

The researchers said the findings are very unlikely to apply to trace amounts of chromium(III) found in food.

Experiments were also conducted at the former Australian National Beamline Facility at the Photon Factory in Japan, operated by the Australian Synchrotron, which helped clarify the nature of the chromium(V) and chromium(VI) species formed in the cells, both of which can cause cancer.

The research, published in *Angewandte Chemie* (doi: 10.1002/anie.201509065), was also supported by the Australian Research Council.

Australian Synchrotron. Original story published by UNSW Media.



Streaming answers: SurPASS™ 3

Anton Paar launches SurPASS™ 3 – another milestone in surface charge analysis.

SurPASS™ 3 determines the zeta potential at the surface of a macroscopic solid in contact with an aqueous solution. The compact instrument design with plug-in sample holders gives easy access to material surface charge to everyone – from scientists in academia to technicians in industrial labs.

The laboratory space occupied by SurPASS™ 3 is significantly reduced compared to previous models of streaming potential analysers. The compact instrument design does not contain any moving parts, unnecessary tubing or cables, which may be subject to measuring artifacts. SurPASS™ 3 keeps the promise of a real plug-and-measure instrument: simply plug in the measuring cell and hit the START button.

The enhanced SurPASS™ 3 principle gives access to zeta potential data in less than three minutes. The high time resolution for data acquisition and the extremely sensitive measurement of streaming potential improve the reliability and reproducibility of zeta potential even in the range below 3 mV.

The operating software of SurPASS™ 3 offers the selection of single zeta potential data, the analysis of the surface isoelectric point, or a full pH scan. The operation modes are complemented by the investigation of solute effects on the solid surface to characterise adsorption and desorption processes.

Independent of sample geometry, size and origin, SurPASS™ 3 determines reliable and reproducible zeta potential values. Elaborate measuring cells for individual sample materials give you the utmost flexibility for your quality control and investigations. Mounting sample holders was never that easy. The measuring cell in use is automatically detected by the SurPASS™ 3 software.

The lean structure of the SurPASS™ 3 operating software helps you to focus on the important task: the analysis of the surface zeta potential of your sample. The software still remains intuitive even if you do not care much about the physical background of the surface zeta potential. Together with the enhanced measuring principle of SurPASS™ 3, the software facilitates the fastest route to the zeta potential of macroscopic solids.

The full range of Anton Paar instruments and solutions is available at MEP Instruments – a Metrohm and Anton Paar Company. For further information, contact MEP Instruments, ph. (02) 8899 5200, email info@mep.net.au or visit www.mep.net.au.

Measure surface-molecule interactions and detect structural changes

The launch of Q-Sense Initiator enables surface scientists to gain access to the well-established Q-Sense technology at an entry level. Q-Sense Initiator maintains the core Q-Sense functions and quality while focusing on new customer segments who have a need for an introductory Q-Sense system capable of fundamental analysis. The new Q-Sense Dfind software dramatically simplifies data handling and reporting through an intuitive interface and powerful tools for complex analysis.

Traditional Quartz Crystal Microbalance (QCM) has been used for more than 50 years to analyse mass changes on rigid surfaces. However, this technique starts to break down when the added mass is not rigidly coupled to the sensor surface.

Quartz Crystal Microbalance with Dissipation monitoring (QCM-D, patented by Q-Sense) enables real-time measurements of both mass/thickness (frequency) and structural properties (dissipation) of molecular layers. By measuring the dissipation parameter (D) the QCM-D allows for the accurate analysis of soft films that do not obey the linear relation between change in frequency and change in mass. In this way, the dissipation parameter provides novel insights regarding structural (viscoelastic) properties of adsorbed layers. Combined with the new Q-Sense Dfind, the next generation analysis software, the user can access information such as mass, thickness, viscoelastic properties, adsorption rates etc. and quantify, compile and compare data, from start to end.

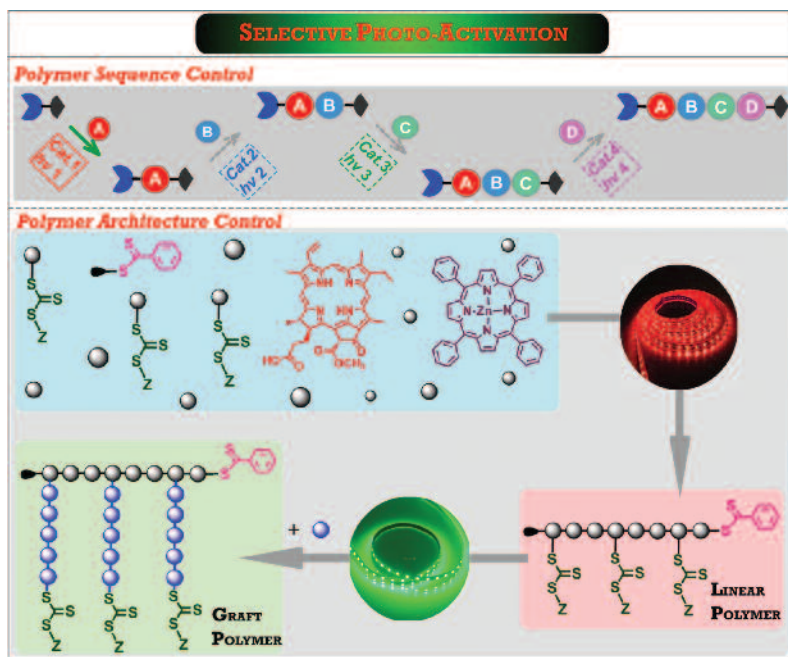


Defining qualities:

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- Wide range of sensor surfaces

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Mimicking nature with light-controlled polymerisation



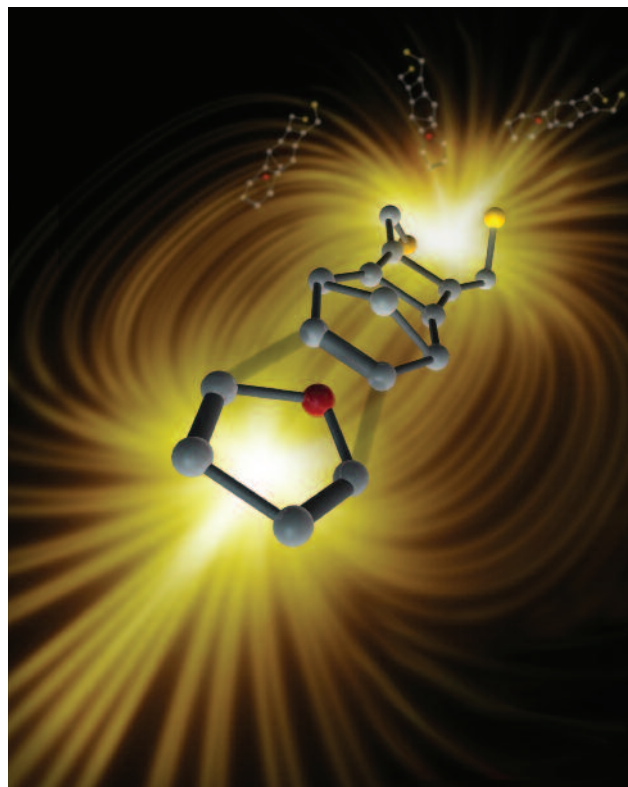
Living organisms are intricate machines that can perform specific chemical reactions in succession in a highly regulated manner in a complex molecular environment. For example, protein

synthesis can be activated or deactivated in response to external stimuli in order to control and regulate a specific function. The ability to mimic the precise control of biology over molecular structure would

have far-reaching consequences for polymer synthesis. The research team of Associate Professor Cyrille Boyer at the University of New South Wales has taken significant steps towards this goal. They have taken advantage of selective photoactivation of thiocarbonylthio compounds to implement single-unit monomer insertion reactions and selective controlled radical polymerisation via visible light-mediated photo-induced electron transfer-reversible addition-fragmentation chain transfer (PET-RAFT) (Xu J., Shanmugam S., Fu C., Aguey-Zinsou K.-F., Boyer C. J. *Am. Chem. Soc.* 2016, **138**, 3094–106). Precise single-unit monomer insertion into dithiobenzoate was achieved with high yield (>97%) using an organic photoredox catalyst, pheophorbide *a* (PheoA), under red light irradiation. Furthermore, the exceptional selectivity of PheoA towards dithiobenzoate was used in combination with another catalyst, zinc tetraphenylporphyrin (ZnTPP), to prepare a complex macromolecular architecture.

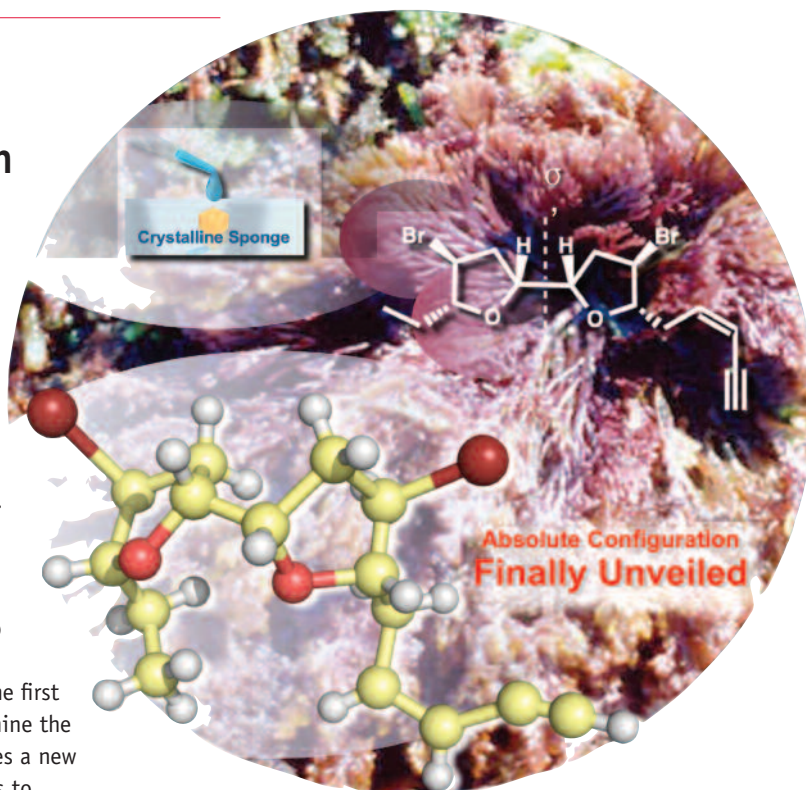
Chemical-free catalysts

It is often thought that the ability to control reaction rates with an applied electrical potential gradient is unique to redox systems. However, researchers from the Australian National University, the University of Wollongong and the University of Barcelona have recently demonstrated that a simple Diels–Alder reaction can be catalysed with an oriented electric field (Aragonès A.C., Haworth N.L., Darwish N., Ciampi S., Bloomfield N.J., Wallace G.G., Diez-Perez I., Coote M.L. *Nature* 2016, **531**, 88–91). In principle, such electrostatic catalysis should be possible because most transition structures can be stabilised via minor charge-separated resonance states that can be further stabilised by an appropriately aligned electric field. However, in practice, orienting molecules in an applied field poses a significant challenge. To overcome this problem, the researchers designed a surface model system to probe unfavourable Diels–Alder chemical reactions and coupled this to the break-junction technique in scanning tunnelling microscopy. They showed that the reaction rate increased with field strength when the field was negatively biased and remained constant for positive bias, in agreement with quantum-chemical calculations on the same system. The work opens up a new way of studying chemical reactivity and heralds a new ‘chemical-free’ approach to chemical catalysis.



Revolution in microgram-scale absolute structure determination

The determination of the absolute structure of natural products presents a major challenge, particularly for oily compounds that preclude analysis via X-ray crystallography. The research teams of Dr Sylvia Urban at RMIT University and Professor Makoto Fujita at the University of Tokyo have unveiled the absolute structure of elatenyne, an oily dibrominated marine natural product first isolated 30 years ago (Urban S., Brkljača R., Hoshino M., Lee S., Fujita M. *Angew. Chem. Int. Ed.* 2016, **55**, 2678–82). This was achieved on the microgram scale using the crystalline sponge method, in which a porous coordination network (a crystalline sponge) capable of absorbing organic guests is used to order the absorbed guests and thereby render them crystallographically observable. The study represents the first application of the crystalline sponge method to determine the absolute configuration of a natural product and provides a new avenue for both natural product and synthetic chemists to obtain complete crystal structures for compounds that would otherwise not be amenable to X-ray crystallographic analysis. The ability to establish the absolute configuration of highly



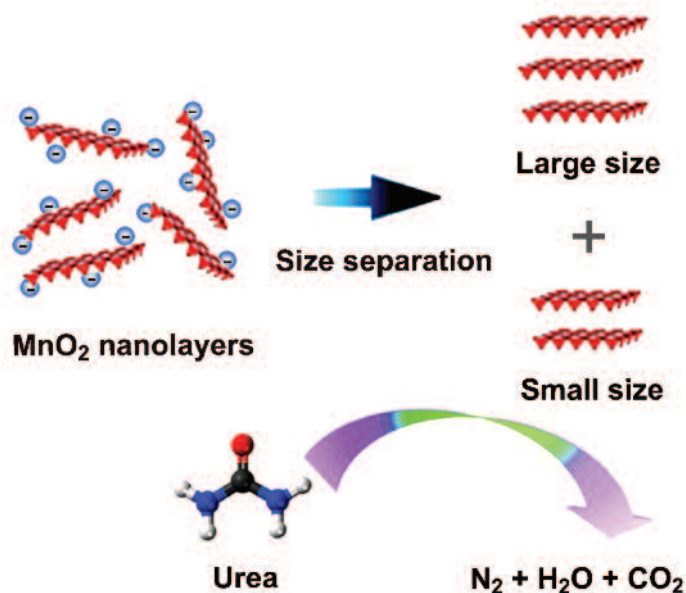
complex bioactive natural products by this method will be groundbreaking, particularly for drug discovery.

Size fractionation of 2D nanomaterials

Two-dimensional (2D) crystals such as transition metal oxides and dichalcogenides are leading successors to graphene with diverse properties and applications. As with graphene, the properties of 2D nanocrystals are sensitive to structural features, including thickness, lateral size, crystal planes and defects. Lateral size is particularly important and is correlated with advanced properties. For example, small 2D manganese oxide (MnO_2) crystals with more exposed edge sites are better for electrocatalysis than large ones. In general, small 2D nanocrystals are useful for applications such as catalysis, biosensing and drug delivery, while large nanocrystals (>500 nm) can stack to form three-dimensional networks for energy storage. Thus, lateral size control of 2D crystals is critical for specific applications. Professor Shi Zhang Qiao and coworkers at the University of Adelaide have reported a universal technique for sorting subnanometre-thick

2D crystals according to their lateral dimensions (Chen S., Duan J., Vasileff A., Qiao S.Z., *Angew. Chem. Int. Ed.* 2016, **55**, 3804–8). The technique is based on tuning the zeta potential of aqueous dispersions of 2D crystals, which induces

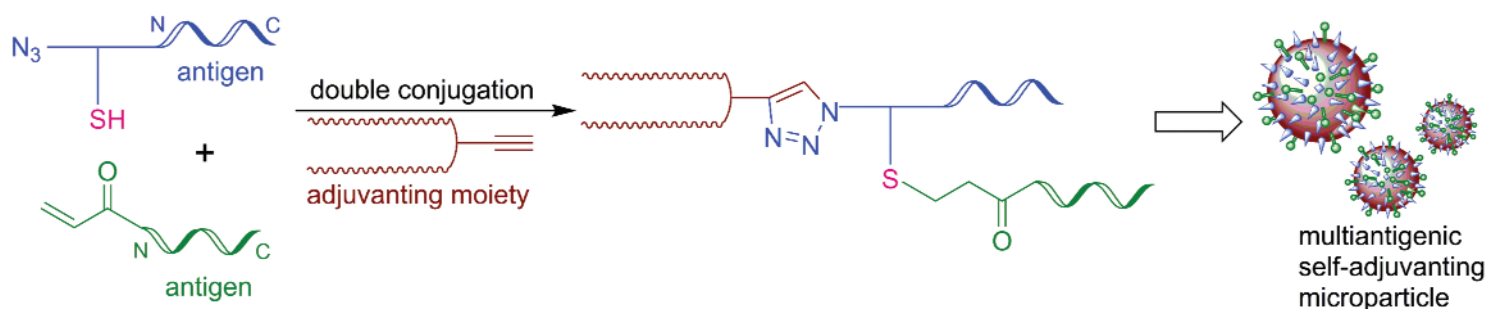
selective sedimentation of large crystals and leaves smaller crystals in suspension. Small MnO_2 nanocrystals that were selected in this way demonstrated outstanding performance as electrocatalysts for urea oxidation.



Double conjugation strategy for self-adjuvanting peptide vaccines

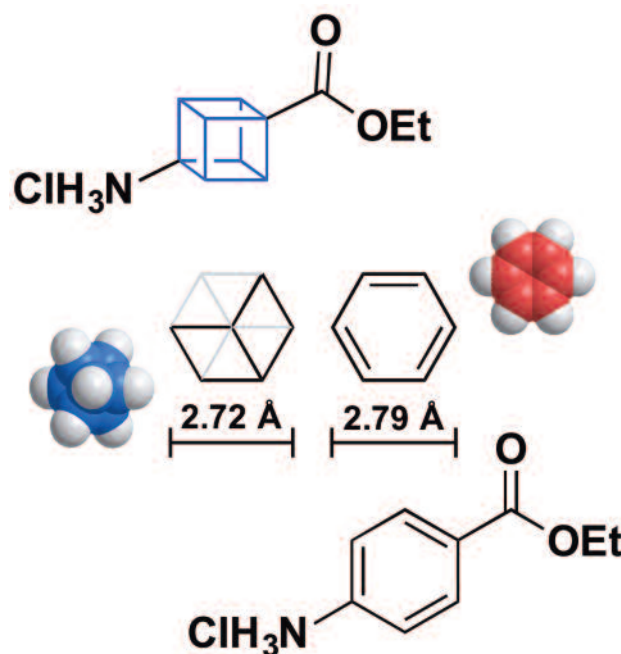
The conjugation of multiple components into a single antigenic construct is a promising strategy for vaccine development. A team from the University of Queensland School of Chemistry and Molecular Biosciences, School of Pharmacy, and Diamantina Institute, has established a synthetic pathway to conjugate peptide antigens and adjuvant moieties into a single fully-defined multicomponent system (Hussein W.M., Liu T.-Y., Maruthayanar P., Mukaida S., Moyle P.M., Wells J.W., Toth I., Skwarczynski M. *Chem. Sci.* 2016, **7**, 2308–21). The synthetic strategy combined a Michael addition mercapto-acrylate conjugation and a copper-catalysed alkyne-azide 1,3-dipolar cycloaddition (CuAAC) reaction to produce constructs bearing

N-termini conjugated peptide antigens and newly designed self-adjuvanting lipids. The efficiency of this novel technology was highlighted through the production of a library of therapeutic vaccine candidates against human papillomavirus type-16 (HPV-16) infection, which causes most cervical cancers. These vaccine candidates targeted the HPV-16 E6 and E7 proteins. However, because of their oncogenic properties, only small fragments of these proteins were selected as antigens. The lead vaccine candidate produced using this double conjugation strategy self-assembled into microparticles, induced cellular immunity, and was able to eradicate a model tumour in 46% of immunised mice.



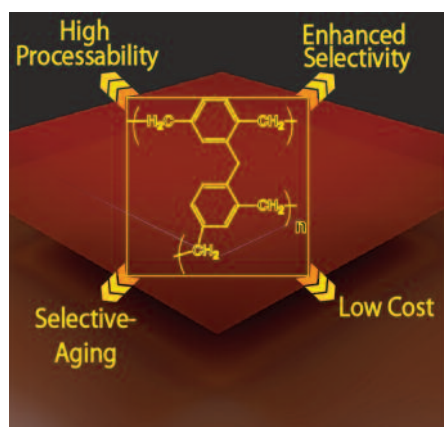
Synthetic hydrocarbon breathes new life into drug discovery

New medicines and food security measures are critical for coping with an ever-increasing world population confronted with problems such as drug and insect resistance. Associate Professor Craig Williams at the University of Queensland and Dr John Tsanaktsidis and Dr Paul Savage of CSIRO Manufacturing have taken an innovative step towards tackling this problem. In a recent study involving an extensive collaborative team, they showed that the hydrocarbon cubane, which consists of eight carbon atoms bonded in the shape of a cube, behaves as a surrogate for benzene, a commonly occurring structural motif in many pharmaceuticals and agrochemicals (Chalmers B.A., Xing H., Houston S., Clark C., Ghassabian S., Kuo A., Cao B., Reitsma A., Murray C.P., Stok J.E., Boyle G.M., Pierce C.J., Littler S.W., Winkler D.A., Bernhardt P.V., Pasay C., De Voss J.J., McCarthy J., Parsons P.G., Walter G.H., Smith M.T., Cooper H.M., Nilsson S.K., Tsanaktsidis J., Savage G.P., Williams C.M. *Angew. Chem. Int. Ed.* 2016, **55**, 3580–5). Organic chemists at the University of Queensland synthesised analogues of a variety of different drugs, replacing the benzene ring motif with cubane. Extensive biological assessment showed that some analogues had similar bioactivity to their benzene counterpart, while others were superior. The precedent set by this study has the potential to reduce the time and cost of drug discovery and to rejuvenate pharmaceuticals and agrochemicals currently on the market.



Affordable additives for ageless gas-separation membranes

The key to commercialising polymer membranes that do not age is to use a highly dispersible and scalable additive. Following up from their previous work on selectively ageing polymer membranes containing porous aromatic frameworks produced via onerous chemical reaction conditions, CSIRO researchers led by Dr Cher Hon (Sam) Lau, Dr Matthew Hill and Dr Colin Wood have made significant steps towards commercialisable ageless polymer membranes for carbon capture from flue gases and natural gas (Lau C.H., Mulet X., Konstas K., Doherty C.M., Sani M.-A., Separovic F., Hill M.R., Wood C.D. *Angew. Chem. Int. Ed.* 2016, **55**, 1998–2001). By using affordable dichloroxylene-based hypercrosslinked polymers as additives, they effectively halted ageing in polyacetylenes without sacrificing gas permeability. Membrane fabrication time was also drastically reduced compared with that for porous aromatic frameworks. The superior processability of these hypercrosslinked polymers is due to their inherent particle size. The study advances membrane use for alternative energy production. The CSIRO team is expanding this study to solvent separations and pharmaceutical purification.



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.*) are encouraged to contribute general summaries, of no more than 200 words, and an image to David.



Tribute to Brice Bosnich

The May issue of the *Australian Journal of Chemistry* contains a significant number of papers that pay tribute to the memory of a great Australian chemist, Brice Bosnich (or Bos, as he was known to all and sundry). This issue of the journal is guest edited by Bos's last PhD student, James Crowley, who is now at Otago University, and also contains a paper by, from what I understand, his first PhD student, Michael Fryzuk, University of British Columbia, and many other coworkers.

By no means do I want to supplant the excellent Foreword to the issue written by James, but I thought I'd reflect on what I knew of Bos. I'd like to say that I knew him well, but that's not quite the truth. The profound effect he had upon his co-workers and their delight in passing on their stories about his idiosyncratic ways is really why I feel as if I knew him. Thus, the many stories I know about Bos came from my colleague and friend Jack Harrowfield, who was one of a number of Australians who joined Bos in Canada as postdoctoral fellows.

Others with similar tales of Bos's delight in upsetting the equilibrium of his co-workers were S. Bruce Wild and Greg Jackson, and if you ever catch up with Bruce you should ask him about the tale of the Meker burner. The following quote from the online guestbook of *The Canberra Times* might also help set the scene.

I am one of few women who trained with Brice Bosnich as a PhD chemist. Many consider it a badge of courage. But I also consider myself lucky. Elegant, thoughtful project design, concentration, focus, attention to detail, and respect for the materials, methods and tools of the trade were high standards set and demanded by Professor Bosnich. They were rare then. They are almost unheard of now. We snapped to attention when we heard Bos coming, his distinctive gait down the hallway from his office to the lab in Searle. Nicknames, Aussie-isms, debatable politics, bonsai trees and white lab benches so clean that we used them for afternoon tea are other memories that I won't soon forget. There is no question, our education was unique.

Cassandra Fraser, University of Virginia

While Bos's unique personality was well known, his chemistry was world class, and perhaps better known, as evinced by the many awards to Bos. His work in developing rational approaches to the design of chiral diphosphine ligands, the best known perhaps being chiraphos, is a case in point. While we, of course, take time for contemplation of a life lived, it should be said that these issues of the journal are also a celebration of an individual's chemistry and more importantly the impact of that individual on others.

I'll leave you with the dedication from Jack Harrowfield's contribution to the issue: 'Vale Bos, we miss his cheerful and memorable hypercynical and irreverent aphorisms, e.g. "In the land of the one-eyed, the two-faced man is king"'

George Koutsantonis FRSC, FRACI CChem (george.koutsantonis@uwa.edu.au)

Increasing Indigenous presence in chemistry

BY **COLIN A. SCHOLLES**

A lack of Indigenous people in chemical science is not unique to Australia. We can learn much from progress made in the US.

Chemistry is connected with the wider community through ways other than the products of chemical industry or the promise of chemical research. Careers in science are well recognised for being personally rewarding as well as having positive impacts on society. Unfortunately, Indigenous Australians are under-represented in the chemistry community in Australia. This significant issue is an example of a lack of cultural diversity within Australian science.

Generational discrimination and disenfranchisement are the most

obvious causes of low representation of Indigenous Australians in the sciences (*Indigenous engagement with science: towards deeper understandings*, 2013, www.innovation.gov.au).

Compounding this are strong perceptions that I have observed in the broader Indigenous community that the sciences are 'whitefeller business' and science education alienates Indigenous students from their traditional culture, as well as a stereotype in the education system that Indigenous students perform poorly in maths and science.

Science in Australia has benefited from and should continue to seek Indigenous engagement and knowledge. Ngarrindjeri man David Unaipon (1872–1967), for example, made significant contributions to Australian science and engineering, including in mechanical engineering and ballistics. Indigenous knowledge is very relevant to medicinal and food chemistry. It includes a deep knowledge of the ecology of the Australian natural environment; similarly, there is a detailed body of work associated with animal tracking and footprints, comparable to fingerprinting in forensic science, and a unique understanding of local meteorology. However, this knowledge is often passed down in an oral tradition and so until relatively recently has been overlooked by ‘mainstream’ science.

Recently, I was fortunate to undertake a study tour of US institutions that have a range of programs focused on engaging Native Americans in the sciences. The tour was supported by the Australian Government through an Endeavour Fellowship. Native Americans have been subject to many of the same exclusion pressures as Indigenous Australians, but progress in the US is better, partly because the Native Americans are very well organised at promoting wider career choices to their youth and importantly at the same time keeping links with their heritage. They have achieved this through strong networks between Native American scientists, promoting and demanding Native American inclusion into scientific professions, as well as developing strong mentoring schemes.

Lack of networks and mentoring schemes is a core barrier to cultural diversity in science in Australia. There are very few Indigenous chemists, which makes it extremely difficult to provide Indigenous students with role models to emulate and be inspired by. Most Indigenous school students

cannot identify with any type of science career. This is exacerbated by a critical lack of support for scientific careers within Indigenous families and communities. For many secondary school students, the primary motivation in terms of subject choice, career direction and support is from parents and other family members. In the broader community, children generally follow their parents into similar professions, or are motivated by their parents to pursue alternative professions that offer better financial prospects. This motivation within the Indigenous community appears to be strongly directed to the medical, legal and business professions. This can be partially understood because Indigenous involvement in the medical and legal professions has been promoted for a number of years.

I and others have been developing programs in Australia to overcome these barriers to the sciences for Indigenous people at both secondary and tertiary levels. They are being developed by universities, research organisations and NGOs, such as Scientifiques Sans Frontières Australia. All of the programs aim to increase

Lack of networks and mentoring schemes is a core barrier to cultural diversity in science in Australia.

Indigenous students’ knowledge about chemistry and science in general, in an effort to retain their interest in science throughout their secondary education. These programs are getting scientists into schools and augmenting Indigenous students’ science education through access to additional resources. Mentoring networks are being established to encourage and support Indigenous students to remain within sciences, and provide guidance for their career development.

Another barrier for Indigenous students is their predominant residency in regional or remote areas. Geographical isolation prevents access to role models, educators, resources and exposure to scientific



Some aspects of the deep knowledge of Indigenous Australian culture are comparable to those of the Indigenous peoples of North America, and many have much relevance to science. This illustration is based on part of a model developed by the Lower Kuskokwim School District, Alaska.



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infrastructure, taken for granted by those living in capital cities. The CSIRO's Aboriginal Summer School for Excellence in Technology and Sciences (ASSETS) is currently addressing geographical challenges by taking high-achieving Indigenous secondary students and getting them involved in hands-on programs involving academics and educators from institutions such as James Cook University and the University of Adelaide. The purpose is to overcome geographical distance in terms of resources, access to science mentors and exposure to the university experience. Similarly, the Murrup Barak Institute for Indigenous Development at the University of Melbourne runs an annual experience camp that brings Indigenous students outside of Victoria in their final years of secondary school to the University of Melbourne for five days. The purpose is to introduce students to university and city life, as well as build networks among themselves and with educators that will overcome issues of isolation when they start their tertiary education.

A lot more work is needed in this area, and one of the best examples to emulate are those run by sporting codes. The Korin Gamadji Institute, coordinated in part by the Richmond Football club and AFL, is an excellent example of tying together education, Indigenous culture and sporting achievement to assist Indigenous students to achieve in all aspects of life. Incorporating a strong science component into this model is easily achievable, and transferring this model from a sporting to science foundation is possible.

For primary school students, the Australian Academy of Sciences undertook a pilot study in 2007 (*Small study – big success story: primary connection incorporating Indigenous perspectives pilot study report*, 2008) exposing students to science through a coordinated interactive program in rural Western Australia. The study found no difference between Indigenous and non-Indigenous students' interest in participating in the program and no difference in understanding the science being presented. Essentially, the most important aspect was providing an interesting and active forum for students to engage with science, which is sadly lacking in rural environments. It is hoped that aspects of this study will be trialled in other rural locations and on a larger scale in the near future.

For all of the excitement these programs are causing, we need to be honest about the task in front of us. Improving Indigenous Australians' presence in Australian scientific community will be a multi-decade effort. The initial work has already been undertaken, and we now know what works and where we can make improvements. Importantly, continuing commitment will be needed from a range of governments, schools, universities, scientific institutions and the active engagement of individual scientists, focused on making a difference.

Colin A. Scholes FRACI CChem is a lecturer in the Department of Chemical and Biomolecular Engineering at the University of Melbourne.

Shaping an Indigenous future in engineering

In 2013, a group of like-minded Australians got together to discuss why there were so few Indigenous Australians in the field of engineering.

In 2015, the first National Indigenous Engineering Summit brought together the engineering industry, professional bodies, educational providers and policy leaders to exchange ideas and develop strategies to create and support pathways into the engineering profession for Indigenous Australians.

A head count showed there are practising Indigenous engineers in Australia, but in low numbers.

Summit organisers gave an undertaking to identify the key obstacles to Indigenous Australians joining the profession and to formulate a strategy for achieving demographic parity by 2030.

Stakeholders have been aware of the reasons for low levels of interest in the field, and while this is not confined to Indigenous students, it is reflective of a general societal ignorance of what engineers actually do. Arguably this situation also needs attention.

One way to focus on change was through The Partners for Pathways, a nationwide initiative being led by the University of Melbourne through a Commonwealth grant of \$700 000. The project aims to create scholarships and devise strategies to promote pathways into engineering and remove barriers to entry for Indigenous and other students who do not have the STEM prerequisites.

Most of the major Australian university engineering schools were represented at the summit.

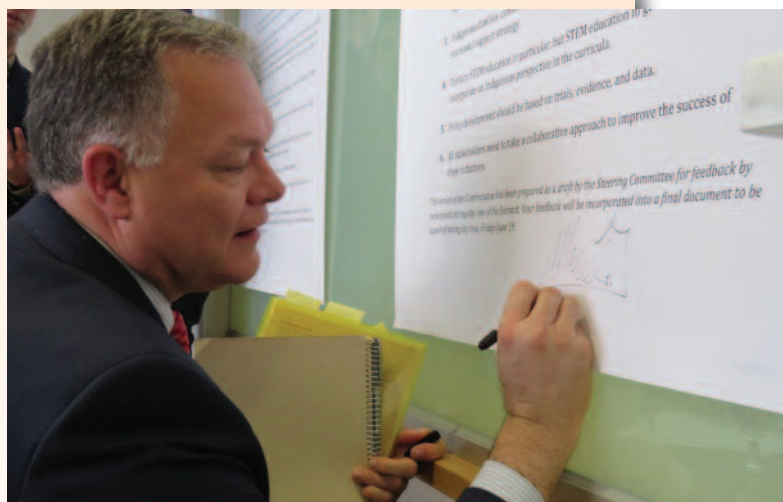
The stakeholders examined the blockages preventing Indigenous students from pursuing studies in engineering, with a view to devising ways of working around these barriers.

One of the key barriers was a lack of take-up of maths and science subjects among Indigenous school students. There are low levels of attainment in maths by the end of year 12. Studying engineering at university without good results in advanced maths at secondary school is not ideal, and is arguably a set-up for failure.

Professor Ian Anderson, Pro-Vice Chancellor (Engagement), says the University of Melbourne has a commitment to population parity as a key feature of the 2015 Reconciliation Action Plan (RAP).

‘Building on that commitment and taking greater steps towards setting hard targets to achieve population parity, the university will look towards the recruitment and retention of Aboriginal and Torres Strait Islander students,’ Anderson said. ‘This will certainly assist with young Aboriginal children seeing real-life role models of Indigenous engineers and how that it is possible.’

Understanding the high level of connectedness between



Professor Iven Mareels, Dean of the Melbourne School of Engineering, signing the declaration of the event: the National Indigenous Engineering Summit Communique (bit.ly/1TgLiCx).

the First Australians and the land itself is perhaps a key to better representation in engineering pathways.

The impact of decisions made by engineers in both the design and specification processes is profound and often irreversible, especially when these decisions become contractual requirements.

The collective Indigenous cultural ignorance of non-Indigenous engineers needs consideration. But Indigenous engineers can have a real influence over what is being planned and is a worthwhile aspiration.

There are many projects, especially in the resources sector in remote locations that are of significant cultural importance to the traditional owners. These projects often hold real, local employment opportunities for traditional owners but such roles are usually taken Fly-in Fly-out staff at the higher technical levels.

Several major resource companies are showing the way in providing employment opportunities to locals, especially at lower skill and knowledge levels, with some outstanding examples of Indigenous engineers in key roles.

Until recently, there was little or no consideration of the environmental impact of what we were designing and specifying in terms of engineering the land. Environmental awareness arose and changed that forever and no engineer now does anything without a comprehensive evaluation of environmental impact and any remediation required.

Perhaps in a decade or two, the community will benefit from having a similarly deeper understanding of, and commitment to, the impact of our actions on our First Australians and our shared land. For that to happen we need to get more Indigenous students into engineering studies.

Adapted with permission from *The Voice* 2015, vol. 11, no. 7, University of Melbourne.

Complete-ium!

Race to the end of period 7

BY **DAVE SAMMUT**

Four more superheavy elements have made it to the periodic table, but what evidence did their creators need to get them there?

Science is celebrating the creation of four new elements. On the cusp of New Year's Eve 2015, IUPAC's Joint Working Party announced its decision on the discovery and priority of elements 113, 115, 117 and 118, and global joy erupted in fireworks the very next day.

Chemists are, of course, delighted to hear that period 7 of the periodic table is now complete – a delight somewhat tempered by the knowledge that we're going to have to buy a new edition of *SI chemical data* now, and again when the elements are actually named.

My first response was, of course, 'how?' How were these new elements created? How can we even tell? How do these new elements behave?

Creation and competition

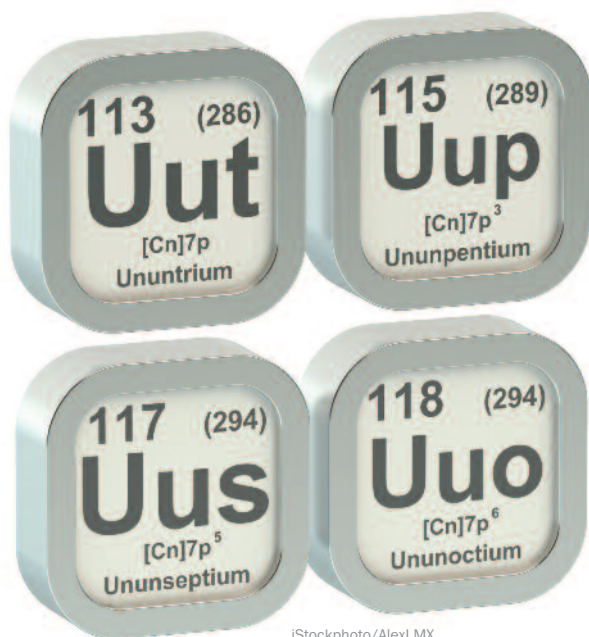
My high school chemistry teacher once likened subatomic particle physics to 'crashing two cars into each other at really high speed, then trying to work out what they're made of by looking at what falls off'. In simple terms, the science of creating these synthetic new superheavy elements is pretty similar. We crash two atomic cars into each other at some fraction of the speed of light, and hope that if they stick together for just long enough they'll fuse into a new atomic truck ... *then* we look at the bits that start falling off.

The creation of ununtrium (Uut, atomic number 113) is a perfect case in point. It was claimed in 2003 from the Joint Institute for Nuclear Research (JINR) in Dubna, Russia (via a collaborative project with the Lawrence Livermore National



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Laboratory (LLNL) in California USA), based on the production of element 115 by bombarding an americium target with high-energy calcium particles, where the new atoms then quickly decayed to element 113.



iStockphoto/AlexLMX

The problem was that this element 113 atom then fissioned directly (rather than decaying to already known isotopes), and therefore did not meet the criteria set down by IUPAC that the new atom must demonstrate 'firm connections to known nuclides'. Falling back on the analogy, the truck fell apart again into a couple of wrecked cars before someone could read the license plate.

The JINR/LLNL team then claims that over the subsequent years, it has produced element 113 'about 100' times across five different isotopes, and that this is sufficient evidence for their joint discovery with the Americans. IUPAC disagreed.

A group at the RIKEN facility in Japan claimed the discovery of element 113 in 2004 via the bombardment of a bismuth target with zinc. Their atom had the advantage of decaying via a series of alpha emissions to an 'anchor' element (a known isotope), which comes closer to

satisfying IUPAC's criteria for the 'discovery' of a new element. However, the RIKEN facility produced only two atoms, then spent another seven years trying fruitlessly to repeat their results. They only succeeded in 2012; hence the fact that the element has only now been ratified, 13 years since it was first claimed by either side.

Press comments from the groups in response to the IUPAC announcement pretty strongly indicate competitive feelings. The RIKEN team expressed pride in discovering element 113; so too the Livermore group, in being credited with the collaborative discovery of 115, 117 and 118 (oh, and also finding 113 first). The JINR team was more blunt – what I read between the lines was 'not only did we find 113 first, but we produced much more of it, ours lasted longer and we taught the Japanese team leader everything he knows. So there [tongue poke].'

Detecting the new elements

The next obvious question is how they even detect just one atom of a new element. The high-energy particles are bombarded onto static metal targets. These targets are extremely thin, so the new particles are basically 'knocked free' following the collision. Remember, those particles are coming at a decent fraction of the speed of light. Coming off as charged particles, the target atoms are separated in gas-filled separators based on the average charge state and momentum via dipole/quadrupole controls and magnetic fields – the same principles as mass spectroscopy.

Two main types of silicon radiation detectors are used in superheavy element research: those working on the principle of charge separation (resistive strip passivated implanted planar silicon (PIPS) detectors) and positional detectors termed double-side silicon strip detectors (DSDD).

Advanced calculations are used to separate/suppress the decay of background products from the rare decays of the anticipated elements.

If that sounds vague, that's because it is. As Arthur C. Clarke noted in his third law, 'any sufficiently advanced technology is indistinguishable from magic'. Even having read a couple of JINR papers on the topic, as far as this author is concerned that's how the new atoms are detected – magic.

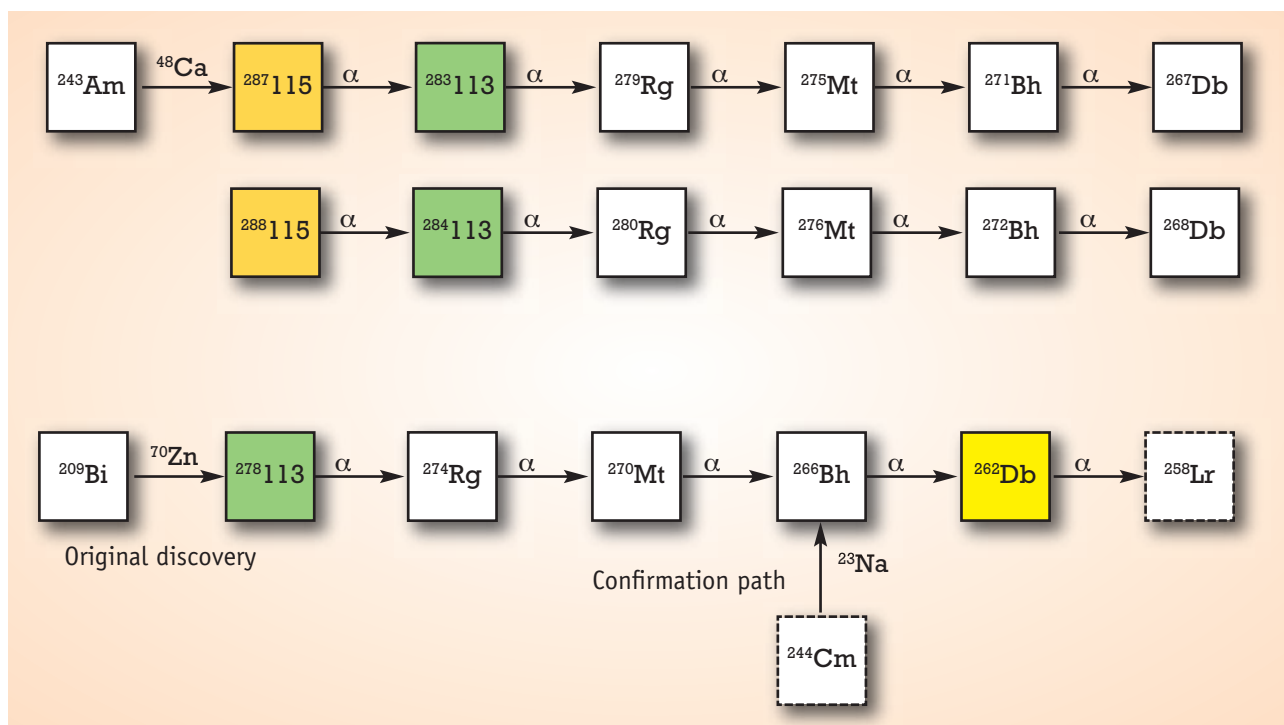
Superheavy elements and the 'island of stability'

Elements with more than 82 protons are unstable. Up to this point in the periodic table, theoretical physical chemists have pretty accurate models to predict the behaviour of the elements, balancing the strong nuclear force (holding nuclei together) against the repulsive force of the protons (seeking to tear the nuclei apart). Even neutrons are slightly repulsive towards each other.

These theories predict 'magic numbers' of protons and neutrons to fill 'shells' of quantum energy levels within the nuclei and confer stability, in much the same way that electron shell theories work. One 'magic number' combination is 82 protons and 126 neutrons, and ^{207}Pb is the heaviest naturally occurring stable element.

According to these theories, an 'island of stability' is suggested to exist somewhere up in the region of about 114, 120 or 126 protons, and (across multiple models) 184 neutrons. At this combination, the atoms should be resistant to alpha decay, and half-lives have been predicted anywhere from minutes to millions of years.

The problem is that the models don't work well for superheavy elements because of relativistic effects, so the estimates are still rubbery. Relativistic effects can be used to explain anomalous properties of the known elements, such as why mercury is a liquid to -39°C . The $6s^2$ orbital is contracted and the bonding of the Hg–Hg pair is dominated by van der Waals



The JINR/LLNL collaboration bombarded an americium target with calcium, producing multiple isotopes of element 115 depending on the energy of the collision. It was claimed that these isotopes showed an alpha decay to element 113, then via four alpha decays to dubnium, which then fissioned. (Main data source: bit.ly/1THCANj)

The RIKEN team bombarded a bismuth target with zinc to directly produce element 113 as an extremely rare event. The element 113 atoms underwent four alpha decays to dubnium-262. In a subsequent experiment, RIKEN confirmed this path by bombarding a curium target with sodium to produce bohrium, which showed an alpha decay to the same dubnium-262 isotope, then to lawrencium-258, which was a known isotope. (Main data source: bit.ly/1THCANj)

The isotopes being produced for the most recent four elements are still well short of the 'magic number' in their neutron count. But various commentators have noted that we are now 'lapping the shores' of the island of stability.

forces; hence, the weak bonding and low melting point.

The exact nature of the strong force is still subject to extensive research, and the global study of SHEs contributes to this developing understanding.

The isotopes being produced for the most recent four elements are still well short of the 'magic number' in their neutron count. But various commentators have noted that we are now 'lapping the shores' of the island of stability.

One fact should be emphasized from the outset: while the various theoretical predictions about the superheavy nuclei differ as to the expected half-lives and regions of stability, all theoretical predictions are in agreement: superheavy nuclei can exist. Thus, the search for superheavy nuclei remains as a unique, rigorous test of the predictive power of modern theories of the structure of nuclei.

Seaborg G.T., Loveland W. *Contemporary Physics*, 1987, vol. 28, p. 33

Properties of the new elements

Given their extremely short half-lives (just milliseconds for some isotopes), the new elements have been subject to relatively little physical experimentation.

Element 113 sits in group 13, under gallium, indium and thallium. It is predicted to have a much higher density than thallium (potentially 16–18 g/cm³, as compared to 11.9 g/cm³), with a counter-trend atomic radius smaller than thallium. However, the few experiments conducted on Uut isotopes conducted by JINR have been inconclusive, given the tiny number of elements produced.

A more thoroughly studied element is flerovium-289 (element 114). It has a 'magic number' of protons, but too few neutrons for stability, giving it a half-life of 2.6 seconds. This slightly longer half-life has allowed some limited experimental chemistry, but this is

What's in a name?

IUPAC's decision on priority is not without controversy and deep division, just as it was during the 30 years of discovery and naming of elements 104–109, which were only resolved in 1997.

The Transfermium Wars, as they came to be known, were a period of acrimonious debate, where both the priority of discovery and the naming of those synthetic elements were hotly contested between laboratories in the US, Russia and Germany. The debate only ended when IUPAC awarded elements 104 (rutherfordium) and 106 (seaborgium) to the US, 105 (dubnium) and 107 (bohrium) to Russia, and 108 (hassium) and 109 (meitnerium) to Germany.

Since 1992, IUPAC's rules have stated that new elements can be named after a mythological concept, a mineral, a place or country, or a property or scientist. The name should sound similar across multiple languages, and it should have an ending that reflects and maintains historical and chemical consistency. This would be in general '-ium' for elements belonging to groups 1–16, '-ine' for elements of group 17 and '-on' for elements of group 18 (noting that this aspect is under review).

The successful laboratories now have the right to propose names. However, fans of author Terry Pratchett (who died in 2015) are actively campaigning for element 117 to be named octarine after the magical element in Pratchett's novels (chn.ge/1paf92G).

again limited by the rarity of the synthesis reactions – generally only one or two atoms at a time.

A 2008 report from JINR initially suggested that flerovium has chemical properties closer to noble gases than to lead (its nearest group 14 element) (bit.ly/1LgULqx). This was an unexpected result, and differed from the models, but experiments suffered from the decay of the flerovium to dubnium during transport through the gas separator (1–2 seconds). Follow-up tests by the same collaborative teams in 2010 cast further doubt on the initial interpretation.

The GSI Helmholtzzentrum für Schwerionenforschung weighed in with a 2012 paper stating 'Relativistically stabilized sub-shell closures give rise to a new category of elements in the Periodic Table: volatile metals (bit.ly/1oLgwF1). The prototype for this property is element 114 which, due to the relativistic stabilization of its electron configuration, is volatile in its elementary state ...'. In simple terms, just as relativistic effects are cited as the reason that mercury is unexpectedly a liquid at room

temperature (a break from the expected metallic bond trend), the GSI paper predicts that the enhanced relativistic effects for the heavier flerovium might actually make it a gas at the same temperature.

GSI's paper is one of the more accessible works found by the author on the predicted theoretical physical and chemical properties of the super-heavy elements. Even so, it was still heavy going.

Forging ahead

Every scientist working on this endeavour is to be congratulated for further extending the limits of human knowledge, and for the way that their work has captured the public's imagination. Like a modern-day Haphaestus, science is forging fantastical new materials for the world, the ultimate act of creation. Who knows what more might lie just beyond the edge of our current capabilities?

Dave Sammut FRACI CChem is principal of DCS Technical, a boutique scientific consultancy, providing services to the Australian and international minerals, waste recycling and general scientific industries.

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Chemistry

The next 10 years

BY **PAUL MULVANEY**

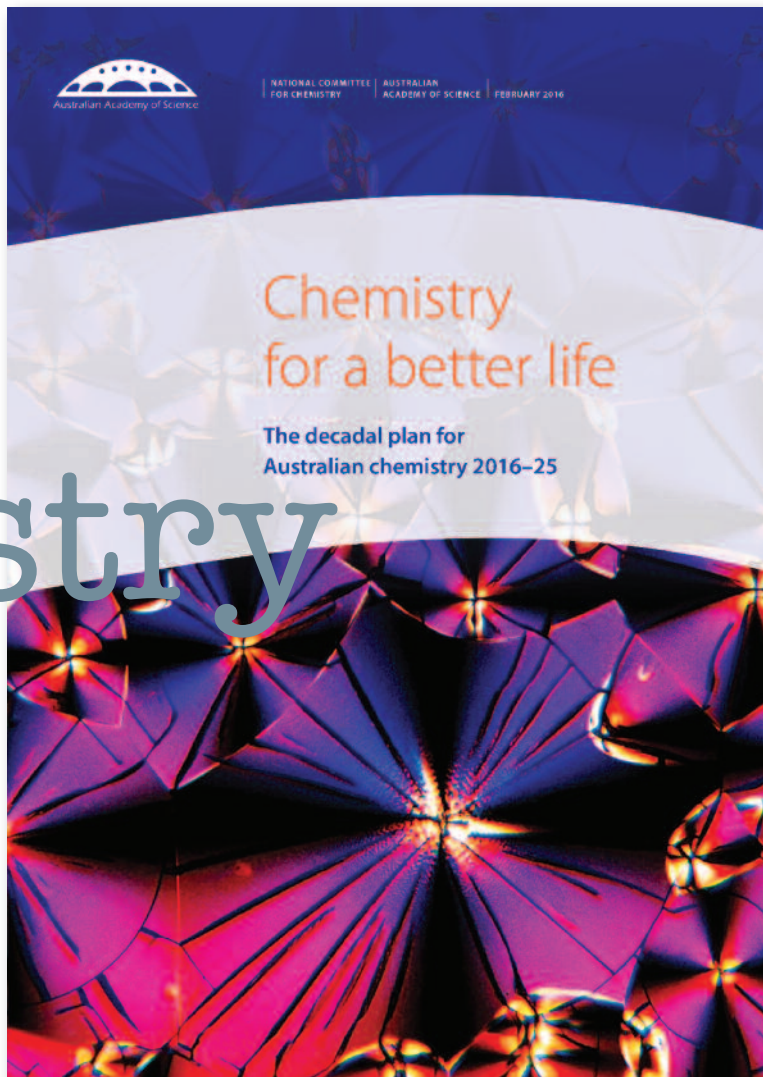
The 2016–2025 Decadal Plan for Chemistry supports growth in chemical manufacturing and research, explains the working group chair.

On 19 February, the first Australian Decadal Plan for Chemistry was launched. As Chair of the National Committee for Chemistry, I had the honour of doing this, along with Professor Andrew Holmes (President of the Australian Academy of Science) and Professor Aiden Byrne (Chair of the Australian Research Council). This important event was attended by more than 80 people from all areas of chemistry, including industry, RACI, CSIRO, secondary education, government and academia.

The preparation of a decadal plan is another step forward along the path to re-building Australia's chemical manufacturing base and growing the quality and relevance of its strong chemistry research base. The decadal plan is a grass roots document, put together by a working group under

the auspices of the National Committee for Chemistry (NCC). The key goals of such a bottom-up approach are to ensure that it is the chemistry community itself that establishes the directions of the field and identifies the opportunities and challenges ahead.

The decadal plan is the first overall review of the chemistry discipline in Australia since the publication of *Chemistry: a vision for Australia* by Paul Savage and colleagues in 1993. In 2005, a review of chemistry (*Future of chemistry study – the supply and demand of chemists*) was carried out by the RACI, but this focused tightly on education and training aspects. A further, smaller report, commissioned and managed by CSIRO in 2006 (G. Upstill et al., 'Innovation strategies for the Australian chemical industry', *J. Bus. Chem.* 2006, vol. 3, p. 9),



explored the state of the chemical industry.

Chemistry is the largest scientific discipline, and is often termed the 'central science'. In 2014, the global chemicals industry contributed 4.9% of global GDP and the sector had gross revenues of US\$5.2 trillion. That corresponds to US\$800 for every person on the planet. We anticipate that, during the 21st century, chemistry will continue to define the directions of technological change. For example, chemical research and development will contribute to energy-efficient LEDs, solar cells, electric vehicle batteries, water desalination technology, biodiagnostics, advanced materials for durable clothing, aerospace, defence, agriculture and health and medicine.

Without doubt, chemistry in Australia is in a comparatively healthy state. Currently around 35 000 secondary school students do year 12 chemistry, although there has been a consistent decline in participation over recent decades. At present, at least 27 of Australia's universities have dedicated, RACI-accredited, chemistry departments (bit.ly/20WlBGa).

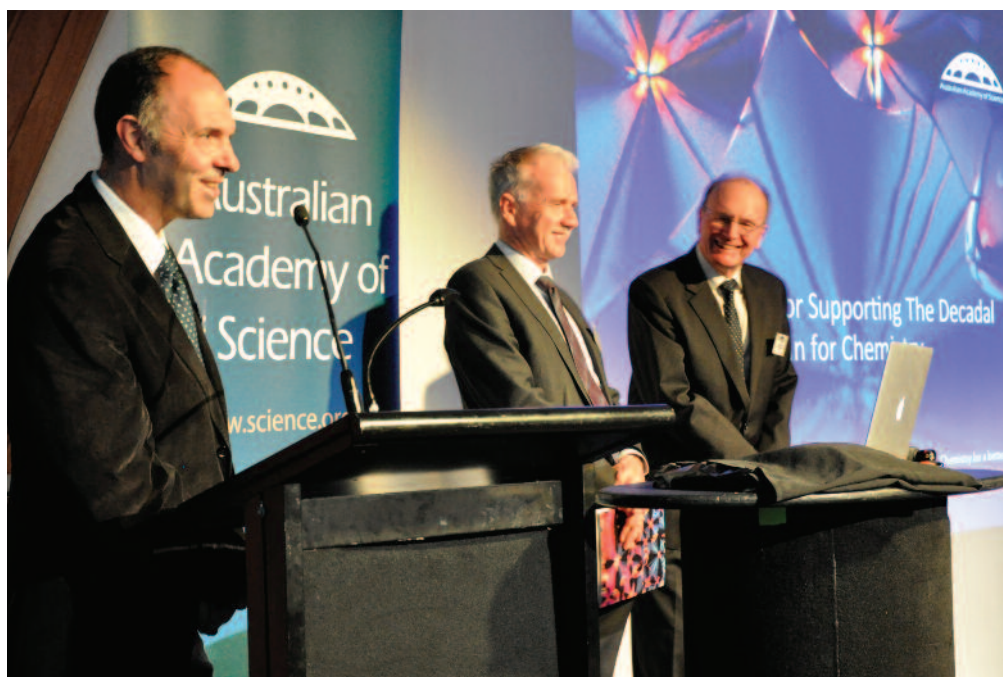
Contrary to popular belief, there is close to gender balance, with just 55.7% of all graduates in chemistry being male. According to Graduate Careers Australia, mean salaries are \$50 000 p.a. with a mean graduation age of 22. Currently, around 50% of chemists work in industry, 25% work in universities or teaching and most of the remaining 24% are employed in government laboratories. The peak academic body for chemistry, the RACI, currently has some 5000 members and has a rising membership, while the Plastics and Chemicals Industry Association (PACIA) remains the largest industry group. Chemicals and plastics supply 109 of Australia's 111 industries. More than 60 000 people are employed in the chemical industry and it is our second largest manufacturing sector. According to PACIA's 2011 Strategic

Roadmap, the sector contributes \$11.6 billion annually to Australia's GDP.

Because of the enormous impact of chemistry across so many parts of the economy, it is difficult to formulate a simple and linear plan for the future. Instead, the goal of the NCC was to first create a decadal plan, which is basically a bottom-up survey of all the stakeholders in chemistry, and to understand the current landscape. There are large-scale global forces shaping the future of chemistry, such as climate change, demographic and economic market-driven shifts, as well as technology-driven shifts. These can have enormous ramifications for investment in Australia's chemistry future. For example, the fluctuating global oil and gas prices will determine whether long-term investment in natural gas production in Australia is viable. Natural gas is a vital feedstock for fertiliser (ammonia) production, which currently consumes 3–5% of the world's energy and is essential for production of grain for almost 40% of the planetary population.

The implementation of the core goals of the decadal plan will require the chemistry community to coordinate the development of policies across the chemistry industry, R&D and education sectors.

The Decadal Plan Working Group began collecting information from across Australia in September 2014 and carried out 26 public meetings at various universities in every state, at CSIRO in Victoria, at the Australian Nuclear Science and Technology Organisation in New South Wales and at CONASTA, the annual National Science Education Conference of the



Left to right: Paul Mulvaney, Aiden Byrne and Andrew Holmes at the launch of the 2016–2025 Decadal Plan for Chemistry in February in Melbourne. Australian Academy of Science

The biggest challenge identified by the Decadal Plan Working Group is poor communication across the sector.

Australian Science Teachers Association, in Adelaide. Organisations such as BioMelbourne Network helped to run workshops or other forums. They also conducted two industry-focused meetings and held discussions at a Women in Chemistry meeting in Melbourne, sponsored by Phillips Ormonde Fitzpatrick. Telephone and internet surveys, as well as web-based data collection, were used to survey the chemistry community until March 2015.

The working group compiled a white paper that was open to the public for feedback via the Academy of Science website during September–October 2015. Final editing was carried out in late 2015 and the decadal plan was sent to press in early February.

From the findings of the decadal plan process and the statistics outlined above, it is evident that chemistry in Australia remains a healthy but underperforming science. On the positive side, chemistry graduates continue to find jobs across a broad spectrum of employment fields and research quality is undoubtedly high. Chemistry is an attractive career choice, with a wide range of smaller companies and large multinationals employing graduates. Chemistry remains vital to many Australian

industries, including construction, mining and agriculture. Despite this, there are declining numbers of students studying chemistry as a proportion of students entering tertiary education.

The biggest challenge identified by the Decadal Plan Working Group is poor communication across the sector. While scientific publication quality and patenting rates are comparable to other leading countries, the efficiency of translation into new jobs, companies and value-adding products is alarmingly low. For example, while 40% of companies in many European countries have direct interactions with universities and research institutions, only 4% of Australian companies report such links. These numbers, while likely to be somewhat subjective, correlate strongly with recent reports from the Office of the Chief Scientist on the STEM disciplines and with OECD numbers on innovation. Australia can do much better in exploiting its genuinely strong chemistry know-how and its multidisciplinary research base. A major conclusion is that the chemistry community must work together more effectively to create a genuine 'value-adding chain'. A healthy chemistry industry in Australia will create high-quality chemistry jobs, and this will in turn attract students to

stay in science. Better linkages between universities and industry will ensure Australia can generate the products needed to maintain high living standards. Governments need to support this value-adding chain by developing long-lasting, bipartisan policies that foster risk-taking and greater investment in manufacturing. We may have heard a lot of this before but now it is being said with one voice.

The second, more ambitious, part of the program will be designing and creating an implementation plan, beginning in 2016. The implementation of the core goals of the decadal plan will require the chemistry community to coordinate the development of policies across the chemistry industry, R&D and education sectors. A key goal from working together will be to drive the creation of government policies that increase the value of the entire chemistry chain – from primary school programs that attract children into doing science, through to incentives for companies to invest in R&D and which can enable start-up companies to sell into Asia. While it has been a rewarding experience interacting with so many of the chemistry community during this process, the real work is only just beginning. We know what the chemistry community aspires to, we now have to work hard to get there.

The 2016–2025 Decadal Plan for Chemistry is available at www.science.org.au/node/2216.

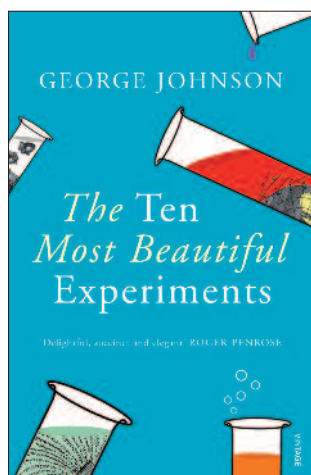
Paul Mulvaney FRACI CChem is Chair of the Decadal Plan Working Group, National Committee for Chemistry.



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The ten most beautiful experiments

Johnson G., Alfred A. Knoff, 2008, hardback, ISBN 9781400041015, 190 pp. approx.

The ten most beautiful experiments, 16 years after publication, may be on the precipitous brink of becoming an *oldie*, but be very assured it is a *goodie*. It is readily available for a modest price, new or used, hardback, paperback and e-book. On the front cover of the paperback, celebrated

English mathematician and physicist Sir Roger Penrose is cited describing the book as, 'delightful, succinct and elegant'. I couldn't put it better myself. It really is a lovely little book of ten chapters (can you guess why?) about ten of the great leaps in the history of science that were associated with splendid and elegant thought and experimentation. Each chapter stands alone, so it is ideal to read on the train on the way to work, in bed before you fall asleep, or in the doctor's surgery instead of fuming about the delay, and so forth. And it is really interesting stuff, carefully and competently explained so it is readily intelligible to scientist and non-scientist alike.

Author George Johnson, a widely respected American science writer, has obviously had to make some hard, and perhaps eclectic, choices. Why only ten experiments? Well, I guess it is a nice round number, makes for a reasonably sized book and provides an obvious enough title! What about the selection? The history of science is resplendent with beautiful experiments, some of which led to wildly spurious conclusions and theories. I guess they got left by the wayside and the choice is from what is left. In an Afterword, Johnson acknowledges that none of his beautiful experimenters (or, if you prefer, doers of beautiful experiments!) were women. He excludes Marie Curie, claiming her work was more hard slog than inspirational, but acknowledges that Rita Levi-Montalcini's discovery of nerve-growth factor or Barbara McClintock's work on genetic regulation and jumping genes would be worthy of an 11th chapter. The closest we really get to the female of the species is to Marie Anne Lavoisier, who assisted her husband Antoine and made elegant drawings of his experimental apparatus, reproduced in the book. She and Antoine were married when she was 13 and he was in his mid-20s (Australian law takes a jaundiced view of this sort of thing these days, but it did get her out of marrying a 50-year-old, so she possibly wasn't too stressed). After Antoine lost his mind (and the rest of his head) courtesy of the guillotine, she married renowned scoundrel Count Rumford (Benjamin Thompson), he of the work-heat nexus, but he denied entry to her friends. So she tossed him out, albeit with a couple of hundred thousand francs to encourage him not to return.

The people selected for inclusion in Johnson's top ten are Galileo (motion on inclined planes), William Harvey (blood circulation), Isaac Newton (light and colour), Lavoisier (chemical experiments), Galvani (animal electricity), Faraday (associating electricity and magnetism), Joule (energy), Michelson (speed of light), Pavlov (conditioning) and Robert Millikan (electronic charge). These are all worthy of inclusion, and I'm sure you can think of plenty more worthies. It is particularly interesting to read about the people as well as the science and why the insights were important. Johnson has melded these elements splendidly. These are some of the giants on whose shoulders we stand. I can't guarantee you'll see further from reading this book, but you'll certainly know a lot more about some of your scientific forebears and the reading is an altogether pleasant experience.

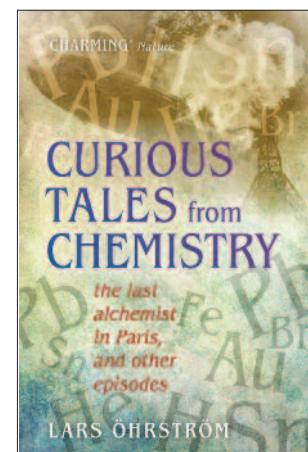
R. John Casey FRACI CChem

Curious tales from chemistry

Öhrström L., OUP, 2015, paperback, ISBN 9780198743927, 257 pp., US\$20 approx.

Curious tales from chemistry is a very easy book to review, because the front cover highlights *Nature* magazine's description of 'charming', while the back cover provides further glowing testimonials to its worth. One of these, from *Chemistry World*, sums it up pretty well: 'This excellent book will provide an entertaining read to all chemists and is also just the kind of text to place in the hands of school students.' I couldn't have said it better myself! It really is a great little book, darting down different pathways, full of interesting juxtapositions and conjectures, brim-full of fascinating facts and information, great bedtime reading for nerds (not so big and heavy that it will break your nose when you fall asleep reading it, and, in any case, you'll find it too engaging to nod off!), awash with good chemistry, and utterly good fun. For instance, did you know that all of the world's lapis lazuli comes from one mine in Afghanistan? Or that Agatha Christie studied pharmacy (and knew a bit about the Marsh test)? Or that Astrid Lindgren (of Pippi Longstocking fame) was at one time secretary to Harry Soderman, a founder of modern forensic science and of Interpol? Or that Chaim Weizmann, the first president of Israel, used to be a chemistry lecturer at the University of Manchester?

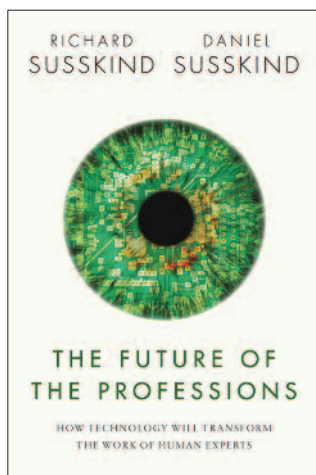
Author Lars Öhrström is a Swedish chemist and chemical engineer, currently professor of inorganic chemistry at Chalmers University of Technology in Gothenburg. His teaching interests lie in curriculum development and teaching first year chemistry, while his research interests are in metal-organic frameworks with applications in green and sustainable chemical engineering.



Students are interested in the people and the context of chemistry. They are interested to see what Fritz Haber looked like (a remarkably mild-looking chap, despite his invention of chemical warfare), or that Marie Curie was a fairly ordinary-looking, plumpish (dare I say motherly looking?) woman in middle age, despite her Nobel Prize. It is always interesting and instructive to see the characters behind the facts. As a personal aside, many years ago I followed with great interest the publications of inorganic chemist (Harry) Irving from the University of Leeds. When I subsequently visited that university, Irving's photograph was displayed in the Chemistry foyer. Beneath the picture of this bespectacled figure were listed his achievements, together with his hobby – *tap dancing*. That just made him so much more 'real' for me than his dour 'professorial' picture.

Chemistry is about people, what they were (and are) like, what 'floated their boats', and the context and motivation for their discoveries, as well as being a vehicle providing a way of making sense of our physical world. There is a risk in ignoring the first aspect and concentrating all our teaching on the last bit. This may sometimes lead to a sterile student experience, or at the very least to one that could be so much richer. *Curious tales from chemistry* is a significant contribution to the context of chemistry and helps allay concerns that it is overlooked. Every chemistry teacher in Australia ought to buy this book, read it and apply its message. The rest of you ought to read it too. It's great fun.

R. John Casey FRACI CChem



The future of the professions: how technology will transform the work of human experts

Susskind R., Susskind D., OUP, 2016, hardback, ISBN 9780198713395, 256 pp., \$29.95

One thing you can say about the future is it is likely to be different from the past. *The future of the professions: how technology will transform the work of human experts* is

a groundbreaking work, challenging the relevance of professionals in the 21st century, predicting a decline in the professions as we currently know them and postulating new paradigms for knowledge interchange and what we now think of as professional work in the future. Bold stuff, indeed! Richard Susskind, a lawyer, has a prominent career advising international business and governments at the highest level (including as IT advisor to the Lord Chief Justice of England and Wales), while his son and co-author Daniel lectures in Economics at Balliol College, Oxford.

The authors write of 'the grand bargain', the arrangements under which many professionals currently work and which grant them a monopoly over the services they render. For example, you cannot simply decide to nail up a shingle proclaiming yourself a doctor, lawyer, pharmacist, accountant and so on. There are laws and gatekeepers to exclude outsiders and to de facto grant a monopoly on provision of services to the elect. The Susskinds' thesis is that in an information age, we neither want nor need doctors, teachers, accountants, architects, the clergy, consultants, lawyers and sundry others performing their roles in the traditional ways. Interestingly, neither engineers nor scientists get any particular mention. Contemporary professions are painted as antiquated and hidebound, no longer affordable and, generally speaking, rarely providing any genuine best practice service to clients.

The Susskinds suggest six new models to produce and distribute expertise to society. Machines can out-perform human beings in their capacity to generate and analyse vast amounts of information, even pointing out correlations and observations beyond your dreams. At a trivial level, you only have to consider the mountain of information that must be available from the use of loyalty cards and credit cards. For example, the book remarks that the British Taxation Office has access to more documents in its records than the British Library (which has everything ever published in English!). So who should own all this information? Who should control it? What is the role of people in the scheme of things where computers can not only store knowledge, but, more importantly, generate it? There are serious moral and ethical issues at stake here.

In teaching, for example, the authors see a change from 'the sage on the stage' to 'the guide beside' occurring in practice, but not being reflected in the architecture and curriculum of schooling. There is not too much doubt things are changing. In *The tombs of Atuan* (Ursula Le Guin), Ged Sparrowhawk (the wizard) describes what a wizard does. There are spells and incantations to learn and various practices to be mastered, but ultimately he concludes the paramount skill a wizard needs is 'knowing how to know'. But is that all we need? Yes, it is tremendously important to know how to find out things. The internet is crammed to the gunwales with information. Hard copies of chemistry (and other) journals seem doomed to imminent demise because neither institutions nor individuals can afford them, so it is becoming doubly important that any undergraduate course in chemistry ought to incorporate familiarity with and exploration of the literature. But you also need some knowledge or you are like the minister and Sir Humphrey Appleby (But minister, you have only to ask! But, I don't *know* what to ask!). So, claims of the death of traditional education may be, as Mark Twain remarked, premature. And, of course, the internet is largely unfiltered. And, boy-oh-boy is there some guff on it!

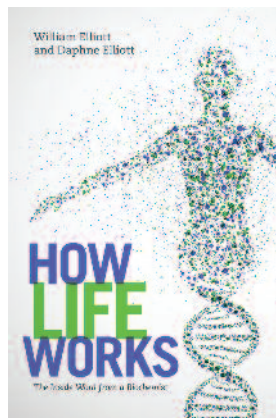
The authors have not considered the ownership aspects of professional work. If an academic, say, develops an online course (when Harvard put its first course online, it instantly

recorded more enrollees than it had graduated in its entire history), ownership will, of course, be claimed by their employer, who may well adopt the short-term financial expedient of sacking the person and using computer-generated and -marked assessment. Does a professional have any proprietorial interests in the new scheme proposed?

And what about privacy and confidentiality? With huge, all-encompassing data banks, the possibilities of fraud, hacking and the like become more worrying. Given hackers seem to have been able to penetrate the Pentagon, the slackness inherent in professionals' keeping their own decentralised records might not be all bad.

Overall, this is a very well written and cogently argued book. There is much wisdom in its observations and food for thought in its prognoses. In some ways, it paints a picture of a brave new world, with a certain inevitability to its progression, and in others of a dawning of an age of mass human empowerment. There are messages for chemists, for the future of chemistry and chemical education, and for the future of professional societies. It is an engaging, thoughtful and fascinating work and a valuable contribution to futurology. All professionals (even retired ones like me) ought to read it.

R. John Casey FRACI CChem



How life works: the inside word from a biochemist

Elliott W., Elliott D., CSIRO Publishing, 2015, paperback, ISBN 9781486300471, 176 pp., \$29.95

How life works: the inside word from a biochemist is the distillation of a life's work in biochemistry by William (Bill) Elliott, who spent many years researching and teaching at the University of Adelaide. This short book is written for readers without scientific

training, and Elliott's desire to impart the 'big picture' of life as he knows it is evident. After Bill Elliott died in 2012, his wife and colleague, Daphne Elliott, prepared the book for publication. Science writer Sarah Keenihan contributed additional material.

Starting from the Big Bang and the formation of the Universe, the book takes you from subatomic particles to cells.

Along the way, Elliott introduces the challenges to the existence of life posed by the nature of the universe; both its constituents (atoms, subatomic particles and elements) and its physical laws (such as thermodynamics and quantum mechanics). Then, in straightforward prose that's easy to follow, he describes how life solves these challenges.

Readers may come to this book with background knowledge that makes some of the content familiar. But the strength of *How life works* is its systematic progression through increasing levels of complexity. For people without a biochemistry background, this introduction to the intricate working of atoms and molecules to create life is fascinating.

The book answers questions such as: How do we harness the energy in our food so that we can grow? How does growing a sophisticated organism not contravene the second law of thermodynamics (that entropy, or disorder, must always increase)? How do enzymes speed up a chemical reaction? Why are vitamins and minerals so important? How can protein molecules have so many different structures and roles in the body?

If William Elliott had a favourite chemical bond, it may well be the hydrogen bonds between the base pairs of DNA. If adenine didn't always bond with thymine, and guanine always with cytosine, then the DNA molecule that is the basis of all life would not replicate consistently, and life would be vastly different or perhaps impossible. We learn how gene sequences are 'read' to create the proteins that build up our bodies, another subject I knew something of, but not the details.

How life works touches on modern areas of research, such as epigenetics, stem cells and genetic engineering, too briefly to really inform decisions on such issues. But it provides a clear and engaging explanation of the underlying processes of life that may encourage some non-scientists to give due credence to modern life sciences.

Margie Beilharz

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The plastics project that went to waste

Presently there is renewed interest in banning or taxing plastic bags used in supermarkets. The aim is to reduce perceived problems with plastic bag litter. Supermarket chains import these bags by the billion and I am not aware of any production in Australia.

When I first came to Australia in the early 1980s, supermarkets used paper bags. There was a bagger (usually a spotty youth) employed on each payment aisle to assist the customer and speed up throughput. Plastic bags are considerably cheaper than paper bags and, along with the metal holding rack, allow the cashier to do the bagging, hence eliminating the bagger.

Plastic bags first came to be an item of use in the 1950s when low-density polyethylene (LDPE) became available. Bags made from LDPE are very strong and useful for carrying heavy material such as fertiliser. They are often reused by builders' merchants selling sand.

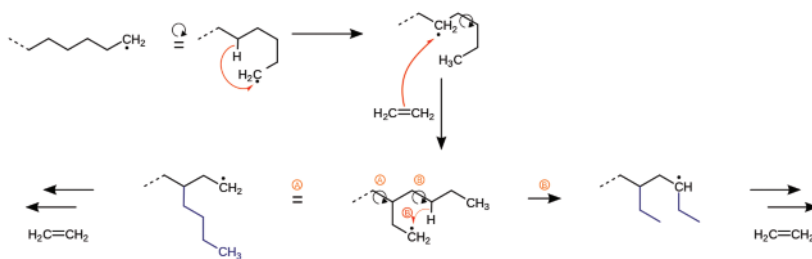
LDPE is the original form of polyethylene, accidentally discovered in the 1930s in attempt to convert ethylene into lubricating oil at high pressure (2000 atmospheres). In the present day technology, ethylene and free radical initiators polymerise ethylene at 200 atmospheres.

LDPE chains have a high level of branching. Many of the branches are C2 and C4 units caused by a primary radical back-biting the growing chain. There are also longer branches, with pendent C2/C4 groups, and some long-range cross-linking.

In the early 1950s, organometallic catalysts for ethylene polymerisation at low pressure were discovered and developed by Ziegler and by workers at Phillips Petroleum. The product they developed, called high-density polyethylene (HDPE), had little if any branching and the chains could be closely packed, resulting in higher density. HDPE is cheaper to produce but bags produced from it are generally weak and used for such things as groceries.

In the 1960s, the idea was developed that copolymers of ethylene, butene and hexene made by the low-pressure route could have similar properties to LDPE. Copolymers were produced in which butene/hexene was incorporated randomly into a growing ethylene chain and thus had randomly distributed pendant C2/C4 groups. The density was intermediate between LDPE and HDPE and the copolymer was named linear low-density polyethylene (LLDPE). Bags made in this way were durable (sometimes better than LDPE) and relatively cheap to produce.

My first industrial R&D job (40 years ago) was subsequent to a project to develop a new and cheaper way to make LLDPE. Organometallic chemistry was all the rage in the late 1960s and early 1970s and the company was researching novel organometallic catalysts for polymerisation. A new system was invented that appeared to deliver LLDPE cheaper than the routes in use at the time. A large research program was launched that involved three separate divisions of the company – central



B: Formation of butyl side chain

A: Formation of ethyl side chains (adjacent)

Minihaa (Own work) [CC0], via Wikimedia Commons





iStockphoto/Suljo

research, the monomer division and the polymer division.

It was thought that if the catalyst could randomly copolymerise monomers, then copolymerisation of ethylene, propylene and a diene could lead to EPDM elastomer (rubber). This could lead to greater profits for the company through a new rubber division. And so more resources were allocated to the project. This was a time of general downturn in the chemical industry and researchers not involved looked on jealously as more resources were poured into the effort.

One chemist on the project, realising that resources were unlimited, took the opportunity to research the best solvent for cleaning old paintbrushes. He found the best to be ethanolamine.

Because of the complexity of the project and the need for good communications, it was decided to have a monthly conference at a central location with easy access for the various research groups. A suitable conference facility was identified that also just happened to have a fine dining restaurant, wine cellar and overnight accommodation.

At an early coordination meeting, the audience was enrapt by a physicist who described testing procedures for the films being produced. This involved dropping a dart on the film and measuring, in exacting detail, the shape of the deformation, which was duly mathematically modelled, proving the high quality of the LLDPE produced. A chemist working in an analytical laboratory related how he had examined the products by infrared spectrometry. He said he thought there were some problems with the LLDPE (long runs of homo-polymer in the chains) and the EPDM did not look much like rubber. Denialists of this ilk were not welcome and he was not invited to further meetings. After a lavish dinner of duck à l'orange with fine Burgundy, and as the port was served with Stilton, the benefits of ethanolamine solvent were discussed.

The project got bigger, with a large technical plant producing the LLDPE and a bagging line to produce bags. A product demonstration was organised and the company directors were invited to witness the beauty of the new bags.

Back then it was common for fertiliser bags to be unloaded from trucks by manually throwing them off. LDPE was durable enough for this treatment. One Friday, at the demonstration, fertiliser bagged in the new LLDPE was placed on the back of a truck along with two likely lads to do the unloading.

The assembled crowd with the directors in front, all in fine suits, gathered around the truck tailgate and the first bag was off-loaded. On striking the ground, the bag split and sprayed fertiliser over the witnesses. The directors dusted themselves off and took a step back. Perhaps the first was just a one-off, so a second was off-loaded with the same result and again with a third.

The directors dusted themselves off again and left. The silent crowd slowly dispersed. Only the two likely lads seemed to be amused by the event.

In private enterprise things can happen quite quickly. By 9 a.m. on Monday the project was canned. All the reports were re-classified as ultra secret only to be accessed with written permission of a director. Scientists were re-assigned to managers not involved with the project, who now with larger groups were promoted. The inventor was sent back to the lab (he later had a career as an academic), the analyst was sent back and was never promoted. No one knows what happened to the physicist. The chemist went on to discover other uses for ethanolamine.

And so this was my first experience of the cycle for major projects: unquestioning enthusiasm, disillusionment, panic and hysteria, the hunt for the guilty, punishment of the innocent and reward for the uninvolved. It was not the last.



Duncan Seddon FRACI CChem is a consultant to coal, oil, gas and chemicals industries specialising in adding value to natural resources.

‘Carbon sink’ detected underneath world’s deserts

The world’s deserts may be storing some of the climate-changing carbon dioxide emitted by human activities, a recent study suggests. Massive aquifers underneath deserts could hold more carbon than all the plants on land, according to the new research.

Humans add carbon dioxide to the atmosphere through fossil fuel combustion and deforestation. About 40% of this carbon stays in the atmosphere and roughly 30% enters the ocean, according to the University Corporation for Atmospheric Research. Scientists thought the remaining carbon was taken up by plants on land, but measurements show plants don’t absorb all of the leftover carbon. Scientists have been searching for a place on land where the additional carbon is being stored – the so-called ‘missing carbon sink’.

The study suggests some of this carbon may be disappearing underneath the world’s deserts – a process exacerbated by irrigation. Scientists examining the flow of water through a Chinese desert found that carbon from the atmosphere is being absorbed by crops, released into the soil and transported underground in groundwater – a process that picked up when farming entered the region 2000 years ago.



Researchers gathered groundwater flowing under the desert sands. The amount of carbon carried by this underground flow increased quickly when the Silk Road, which opened the region to farming, began 2000 years ago. Yan Li

Underground aquifers store the dissolved carbon deep below the desert where it can’t escape back to the atmosphere, according to the new study.

The study estimates that because of agriculture roughly 14 times more carbon than previously thought could be entering these underground desert aquifers every year. These underground pools that taken together cover an area the size of North America may account for at least a portion of the ‘missing carbon sink’ for which scientists have been searching.

‘The carbon is stored in these geological structures covered by thick layers of sand, and it may never return to the atmosphere,’ said Yan Li, a desert biogeochemist with the Chinese Academy of Sciences in Urumqi, Xinjiang, and lead author of the study accepted for publication in *Geophysical Research Letters* (doi: 10.1002/2015GL064222), a journal of the American Geophysical Union. ‘It is basically a one-way trip.’

Knowing the locations of carbon sinks could improve models used to predict future climate change and enhance calculations of the Earth’s carbon budget, or the amount of fossil fuels humans can burn without causing major changes in the Earth’s temperature, according to the study’s authors.

Although there are most likely many missing carbon sinks around the world, desert aquifers could be important ones, said Michael Allen, a soil ecologist from the Center for Conservation Biology at the University of California-Riverside who was not an author on the new study.

If farmers and water managers understand the role heavily irrigated inland deserts play in storing the world’s carbon, they may be able to alter how much carbon enters these underground reserves, he said.

‘This means [managers] can take practical steps that could play a role in addressing carbon budgets,’ said Allen.

Examining desert water

To find out where deserts tucked away the extra carbon, Li and his colleagues analysed water samples from the Tarim Basin, a Venezuela-sized valley in China’s Xinjiang region. Water draining from rivers in the surrounding mountains supports farms that edge the desert in the centre of the basin.

The researchers measured the amount of carbon in each water sample and calculated the age of the carbon to figure out

Knowing the locations of carbon sinks could improve models used to predict future climate change and enhance calculations of the Earth’s carbon budget ...

Scientists followed the journey of water through the Tarim Basin from the rivers at the edge of the valley to the desert aquifers under the basin. They found that as water moved through irrigated fields, the water gathered dissolved carbon and moved it deep underground. Yan Li

how long the water had been in the ground.

The study shows the amount of carbon dioxide dissolved in the water doubles as it filters through irrigated fields. The scientists suggest carbon dioxide in the air is taken up by the desert crops. Some of this carbon is released into the soil through the plant's roots. At the same time, microbes also add carbon dioxide to the soil when they break down sugars in the dirt. In a dry desert, this gas would work its way out of the soil into the air. But on arid farms, the carbon dioxide emitted by the roots and microbes is picked up by irrigation water, according to the new study.

In these dry regions, where water is scarce, farmers over-irrigate their land to protect their crops from salts that are left behind when water used for farming evaporates. Over-irrigating washes these salts, along with carbon dioxide that is dissolved in the water, deeper into the earth, according to the new study.

Although this process of carbon burial occurs naturally, the scientists estimate that the amount of carbon disappearing under the Tarim Desert each year is almost 12 times higher because of agriculture. They found that the amount of carbon entering the desert aquifer in the Tarim Desert jumped around the time the Silk Road, which opened the region to farming, began to flourish.

After the carbon-rich water flows down into the aquifer near the farms and rivers, it moves sideways towards the middle of the desert, a process that takes roughly 10 000 years.

Any carbon dissolved in the water stays underground as it makes its way through the aquifer to the centre of the desert,



where it remains for thousands of years, according to the new study.

Estimating carbon storage

Based on the various rates that carbon entered the desert throughout history, the study's authors estimate 20 billion metric tonnes of carbon is stored underneath the Tarim Basin desert, dissolved in an aquifer that contains roughly 10 times the amount of water held in the North American Great Lakes.

The study's authors approximate the world's desert aquifers contain roughly 1 trillion metric tonnes of carbon – about a quarter more than the amount stored in living plants on land.

Li said more information about water movement patterns and carbon measurements from other desert basins is needed to improve the estimate of carbon stored underneath deserts around the globe.

Allen said the new study is 'an early foray' into this research area. 'It is as much a call for further research as a definitive final answer,' he said.

American Geophysical Union



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Are you an NSW-based scientist interested in becoming a mentor to a student member?

See April issue, p. 28 for details of the mentoring program.

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Grape and wine acidity

Acidity management is one of the most important wine quality issues, especially in terms of wine stability. Some of the significant stability issues related to pH include the inhibition of spoilage organisms at low pH, reflecting how a lower pH favours 'molecular sulfur dioxide', the antimicrobial form. Oxidation rates decrease as pH decreases and there is a higher red colour at low pH, with the wine going to 'blue' as the pH increases.

Winemakers assess acidity in grapes and wine using two parameters: pH and titratable acidity (TA). The pH is measured in the usual way while TA is determined by titration with sodium hydroxide to a pH 8.2 endpoint. The volume of hydroxide is then converted to a mass of tartaric acid equivalents, as tartaric tends to be the dominant acid in wine. In some parts of the wine world, a pH 7 endpoint is chosen and the results quoted as an equivalent mass of sulfuric acid. This reflects the old (now not permitted) practice of adding sulfuric acid to increase the acidity if the natural acidity was regarded as too low. Several countries have regulations that include total acidity (the same as titratable acidity), volatile acidity (steam-distillable acids such as acetic) and fixed acidity (non-distillable acids).

There is a mixture of organic acids found in wine, some originating from the grape and others from the fermentation. The two major acids that originate from the grape are tartaric acid and malic acid. *Vitis vinifera* would appear to be the only cultivated European plant that accumulates L(+)-tartaric acid in significant quantities and it is produced as a secondary product from sugar metabolism, actually being formed from ascorbic acid in the grape berry. Of the major organic acids in wine, tartaric acid is the strongest. It is relatively stable towards degradation during the berry ripening process. Some losses may occur late in ripening as the pH of the berry pulp increases, thus increasing the proportion of the hydrogen tartrate anion. If the concentration of potassium is high, precipitation of KHT (in wine jargon) may occur.

Malic acid is common in many plants (green apples, for one). In grapes, its formation proceeds by well-characterised pathways including links to the phosphoenolpyruvate, glycolytic and TCA cycles. Malic acid respire after véraison (the transition from berry growth to ripening), but the mechanism is not fully understood. The extent of respiration and malic acid loss depends on the temperature of the growing region. Thus, in Australia's warm climate grape-growing conditions, malic acid degradation is significant, leading to lower acidity in the grapes at harvest and often higher than optimal pH values. This is the opposite of what happens in the cool-to-cold growing regions where the malic acid concentration at harvest may equal or exceed that of tartaric acid.

Succinic acid and citric acid are both formed during yeast fermentation. Citric acid addition to a wine post-fermentation may be used for young wines to add an 'acid zest' taste. The

contribution of succinic acid to a wine's structure is now receiving more attention. Some active dried yeasts can produce succinic acid at a concentration where it can contribute to the wine's taste. This is rather unfortunate, as the taste is far from pleasant, being described as 'sour', 'salty' and 'bitter'.

Lactic acid is produced from malic acid in wine through bacterial-mediated decarboxylation, commonly known as malolactic fermentation (MLF). Lactic acid is milder than malic acid, so MLF results in a decrease in acidity and a softening of the acid taste. Some acetic acid is formed during fermentation, although the amount is small, unless there are problems with the fermentation. The major source of acetic acid is a consequence of the aerobic oxidation of ethanol by *Acetobacter*. Acetic acid is readily volatile and gives an unpleasant 'vinegar' aroma to oxidised wine.

With all these different acids in wine, it is often asked if external factors such as climate change may be affecting the various amounts formed. A recent 2015 article by Peter Gooden, Eric Wilkes and Dan Johnson of the AWRI entitled 'Trends in the composition of Australian wine 1984–2014' (*Aust. J. Grape Wine Res.* 2015, vol. 21, pp. 741–53) includes data for TA and pH over this time frame. There is good evidence for a decrease in TA and an increase in pH, especially since 2008 for red wines. While it may be easy to relate this to climate/prolonged drought issues, the authors note that 'It is difficult ... to attribute any of the compositional trends discussed here to either any change in climate or compressed vintages.' Marketing issues may also be contributing to these changes as higher pH wines are perceived as softer in mouthfeel and more consumer friendly.

The need for adjustment to the natural acidity, that is the acidity that is grape derived, is an issue that has always been somewhat contentious. While it is common practice in Australia to add some form of acid during the winemaking practice, I have worked in one winery where the winemaker absolutely refused to allow acid addition. In this case, the argument was that acid addition brings the wine out of balance with all the other natural features derived from the grape. Many who follow biodynamic principles do not add acid for the same 'balance' reason and acid addition is contrary to the so-called natural winemaking practice. In my next column, I will outline some of the processes used for acid addition.



Geoffrey R. Scollary FRACI CChem (scollary@unimelb.edu.au) was the foundation professor of oenology at Charles Sturt University and foundation director of the National Wine and Grape Industry Centre. He continues his wine research at the University of Melbourne and Charles Sturt University.

A persistent pesticide problem

Australia's appetite for new residential land means that market gardens and orchards on the urban fringe are being taken over by houses. It is also revealing a legacy of decades of horticultural pesticide and fertiliser use.

In my contaminated land work, my first port of call for background information on potential contaminants, insecticides in particular, was Ben Selinger's classic, *Chemistry in the marketplace*. My 1975 edition was an aid to understanding old-style horticultural practices. While I had an inkling that inorganic pesticides were predominant before the introduction of the synthetic organic pesticides, I was surprised to learn that fluorides (such as sodium fluoride and cryolite, Na_3AlF_6) were used. My knowledge had been limited to a few lead- and copper-based compounds. Some natural Australian soils, such as silurian clays, are naturally high in fluoride, so determining what is background and what is introduced (i.e. contamination) requires a bit of extra effort.

Inorganic compounds don't degrade, and so persist in soil unless leached away (thus causing a water contamination problem). The organochlorine pesticides (OCPs) were introduced to address this, as well as the problem of metal toxicity to humans and other vertebrates. However, there was probably not a lot of work done on understanding the persistence of these compounds before they were introduced, nor on the unintended consequences of their use. They were subsequently banned in the 1980s.

The environmental data we collect now tell us that the OCPs are only marginally less persistent than the inorganics they replaced, at least on an intergenerational time scale. The toxicology literature also records that the human health impacts are not trivial. In the National Environment Protection Measure (NEPM) for contaminated sites, the Health Investigation Level (HIL) for lead, on a standard residential site, is 300 mg/kg. For chlordane it is 50 mg/kg and for aldrin plus dieldrin it is 6 mg/kg. So, what were once promoted as

safer, alternative insecticides turn out not to be so safe in all cases, after all, and they can still be found in the environment, decades after their last use.

For some of the OCPs, the HIL values are for total concentrations of the compound that was applied plus decomposition products. This is the case for DDT, and its breakdown products DDE and DDD, and for aldrin plus dieldrin as mentioned above. This is so because when the parent compound slowly degrades in the environment, the product(s) are also slow to degrade, and often have appreciable toxicity. Some pesticides are not the active compound with lethal effect on the target species. Rather, the insect metabolises it to a toxic form in vivo (to dieldrin, in the case of aldrin).

It is also important to understand how OCPs were used in practice, as well as understanding their chemistry and toxicology. If insecticides are sprayed throughout an orchard or market garden, with a boom or mist sprayer pulled behind a tractor, it creates a fairly uniform distribution across the site, meaning a regular sampling pattern is likely to identify an average concentration. Hot spots of higher concentrations are usually associated with storage areas, or areas where concentrated bulk chemicals were diluted and loaded into the sprayer. However, on one site I know, to prevent termite attack on the roots of trees, aldrin was applied to the soil directly, into the hole into which seedlings were to be planted. The outcome was that there were small hot spots in a regular pattern across the site. A conventional grid-based sampling pattern won't necessarily detect all of the hot spots and, when the trees were removed, there was some degree of mixing of the soil. Some of the hot spots become bigger and some were diluted with uncontaminated soil. The result was a complex pattern of contamination, which taxes the routine sampling processes of the environmental assessor.

Earlier on, I mentioned the use of lead as an insecticide, which was often applied as lead arsenate, and discussed its NEPM HIL value. In 2015, the NHMRC revised its guidance on the allowable blood lead level in children, halving it from 10 $\mu\text{g}/\text{dL}$ to 5 $\mu\text{g}/\text{dL}$. The NEPM HIL value is based on the allowable blood lead level, so this reduction will eventually result in a reduction of the NEPM HIL for lead. With the risk assessment methodology used to derive the HIL, there is not a linear relationship between blood lead level and the HIL value, so a revised HIL may be less than half the current value. If the same were to happen to the HILs for OCPs, a new set of standards will apply to all those orchards and market gardens out there still to be assessed for urban use. What that might mean for sites already converted to urban use is an interesting question.



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Jack's magazine and his brother

The Ammunition Factory in Gordon Street, Footscray, had a long history of service to the Victorian and then the Australian economy. Bullet cases were fashioned from brass and stuffed with gunpowder, originally imported but later manufactured at the Explosives Factory a few kilometres away. All part of the Arsenal of the West, that also included the Ordnance Factory where the big guns were made.

By the 1990s the Ammunition factory had outlived its usefulness. The business was transferred to a new Australian Defence Industries (ADI) factory at Benalla in central Victoria, while the Footscray land was sold off for housing. All except one part of the factory, that is – the magazine that dated back to the 1870s. It had not been used in recent decades, but in 1987 it was classified by the National Trust and thus afforded a measure of heritage protection. It had always been known as Jack's Magazine but nobody at ADI could remember who Jack was. 'Jack who?' was the question that management asked as they combed through company records and consulted present and (where possible) past employees as they prepared to vacate the site.

They never found the answer, but it turned up a few years later when the magazine was the subject of heritage interest and the National Trust of Australia (Victoria) organised an open day at the site for which they prepared some explanatory material. Again the question was raised, 'Jack who?', but the answer came from a volunteer worker at the Trust, Nancy Jack. It was her uncle, Mr Jack, who was manager of the magazine and she remembered that, as a small girl, she had stayed with the Jack family in the manager's house, adjacent to the magazine.

Wally (Walter Annandale) Jack (1876–1969) was the keeper from World War I days until 1943. He was awarded an MBE in 1960 for his social welfare work with young people but other than that I don't know much about him. His younger brother, Keith Andrew Jack (1885–1966) was an Associate and Original ACI Member (1917) and FRACI (1944), having graduated MSc in physical chemistry from the University of Melbourne in 1914. He was a member of Shackleton's disastrous Antarctic expedition in 1914. Jack was in the Ross Sea party stranded in Antarctica for several years. From 1916 he worked at the Explosives Factory, dealing with small ammunition, detonators and fuses. He spent war years attached to Australia House, London, as an explosives expert and returned to be Secretary of Operational Safety in the Commonwealth Department of Supply until he retired in 1950.

When ADI moved out, the plan was for Jack's Magazine to be sold but nobody wanted to purchase two vaulted buildings with one-metre thick walls and tiny ventilation slits (protected by copper gauze) that was tucked away behind massive earth walls (www.jacksmagazine.org.au). The only interest seems to have come from metal thieves, who made off with the copper, including the lightning protection structures. Victoria's government has accepted that the magazine will remain in public hands and it has joined a list of facilities for which an advisory committee is trying to find uses. I reckon Jack's Gym and Jack's Disco (no noise



problems for the neighbours!) would be good. To have your say, visit www.workingheritage.com.au.

Opened in 1878, the magazine was constructed of local bluestone (basalt) for the Victorian Government, on a site above the flood plain of the Maribyrnong (then known as the Saltwater) River. Two buildings were protected by high earthen blast walls and accessed through short tunnels. Imported gunpowder arriving in Port Phillip was trans-shipped into barges for transport up the shallow river. They entered a canal leading to the magazine, where loads were winched up, then trundled along a tramway through the tunnels to secure storage. In 1888, the Colonial Ammunition Company, an offshoot of the New Zealand company led by Captain John Whitney, built a factory next door to the magazine. The Commonwealth Government leased the factory from 1921 and purchased it in 1927.



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Fire Australia & Hazmat 2016

4 and 5 May 2016, Melbourne Convention and Exhibition Centre, Melbourne, Vic.
www.fpaa.com.au/events/fire-australia.aspx

7th Heron Island Conference on Reactive Intermediates and Unusual Molecules

9–15 July 2016, Heron Island, Qld
www.Heron7.org

27th International Conference on Organometallic Chemistry
 (incorporating the RACI Inorganic Chemistry Division Conference)

17–22 July 2016, Melbourne Convention and Exhibition Centre, Melbourne, Vic.
<http://icomc2016.com>

International Conference and Exhibition on Marine Drugs and Natural Products

25 July 2016, Rydges, Melbourne, Vic.
<http://naturalproducts.pharmaceuticalconferences.com>

2nd Energy Future Conference and Exhibition

4–6 July, University of NSW, Sydney, NSW
<http://energystoragealliance.com.au/event/energy-future-conference-exhibition>

NZIC-16

21–24 August 2016, Millennium Hotel, Queenstown, New Zealand
www.nzic16.org

European Symposium of Biochemical Engineering Sciences (ESBES)

11–14 September 2016, Dublin, Ireland
www.esbes2016.org

Chemeca 2016

25–28 September 2016, Adelaide Convention Centre, Adelaide, SA
www.chemeca2016.org

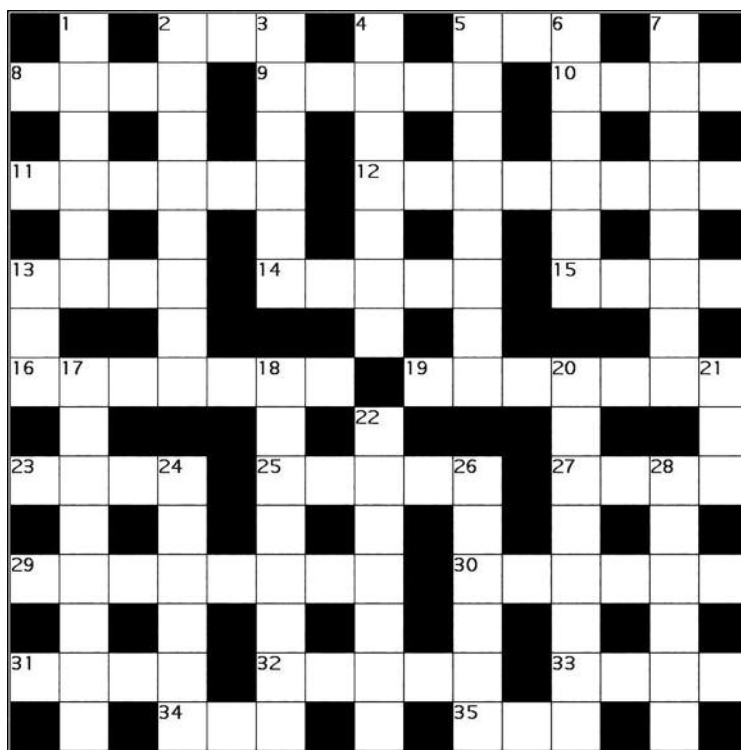
6th International Conference and Exhibition on Pharmaceutical Regulatory Affairs and IPR

29 September – 1 October 2016, Orlando, Florida, US
<http://regulatoryaffairs.pharmaceuticalconferences.com>

AusBiotech 2016

24–26 October 2016, Melbourne Convention Centre, Vic.
www.ausbiotechnc.org

RACI events are shown in blue.

**Across**

- 2** Particular Vice-Chancellor begins to make polymer. (1.1.1.)
5 Hard water drug. (3)
8 Third prime boron. (4)
9 Decides standards. (5)
10 A couple of unknowns about radium used for medical imaging. (1-3)
11 Shapes out solid and liquid, perhaps. (6)
12 Procedure for each guy on his bike. (8)
13 Rocks or transuranic element. (4)
14 See 27 Across.
15 Scrutinise sulfur and tin. (4)
16 Light researcher oddly forced lens back. (7)
19 Meant to take away the music?! (7)
23 We object to transuranic element applications. (4)
25 The 8th Greek or the 73rd. (5)
27 & 14 Across Remain calm, remain free. (4,5)
29 Made and put on. (8)
30 The simplest carboxylic acid for Metal-induced crystallisation. (6)
31 Guys with uranium list. (4)
32 Fashion icons held with charges. (5)
33 Get out! Way out! (4)
34 Alternate music to a higher degree. (1.2.)
35 Impugn sailor. (3)

Down

- 1** One or the other organic compound holds iodine. (6)
2 P.S. Sister is out and carries on. (8)
3 Moving closer to methylphenol. (6)
4 Metal chill over hydrogen compound. (7)
5 Opener is over $\text{CH}_2=\text{C}(\text{CH}_3)\text{CH}=\text{CH}_2$. (8)
6 Additional charges included in next rascal's ruse. (6)
7 Little truck with a meeting about VO_4^{3-} , perhaps. (8)
13 & 21 Down Not performing well when not scheduled to work. (3,3)
17 Again waited, distant. (8)
18 The lowest and sharpest melting point of a solid mixture of Te/Ti/Cu/Ce. (8)
20 Obstetrics computer can't fully participate. (8)
21 See 13 Down.
22 Interpretation of Spooner's expensive circle. (7)
24 Eleventh sulfur disgrace. (6)
26 F_2 etc. a new influence. (6)
28 A group of investigators in charge of low pH. (6)

Graham Mulroney FRACI CChem is Emeritus Professor of Industry Education at RMIT University. Solution available online at Other resources.



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Organic compounds and their smells

Courtesy James Kennedy (jameskennedy@monash.worpress.com)

	ALKANES	ALKENES	ALCOHOLS	ALDEHYDES	KETONES	CARBOXYLIC ACIDS	HALOALKANES	THIOLS	AMINES	NITRILES	LACTONES								
	-ane	cyclo- -ane	-ene	-anol	-an-2-ol	-anal	2-methyl -anal	-enal	-an-2-one	methyl -an-2-one	-anoic acid	chloro -ane	bromo -ane	iodo -ane	-anethiol	-anamine	diamino -ane	-anenitrile	LACTONES
meth- 1 carbon	none	doesn't exist	carbons is too unstable to smell	ABSOLUT VODKA	doesn't exist	doesn't exist	doesn't exist	doesn't exist	doesn't exist	doesn't exist	! PUNGENT & PENETRATING	! TOXIC & MILDLY SWEET	! LIKE CHLOROFORM	! SWEET, ACID	! SKUNK	?	?	!	-anolidine
eth- 2 carbons	none	doesn't exist		ABSOLUT VODKA	doesn't exist	doesn't exist	doesn't exist	doesn't exist	doesn't exist	doesn't exist	VINEGAR	MILDLY SWEET	! SWEET, ACID	! SKUNK	!	?	?	!	doesn't exist
prop- 3 carbons	none			ABSOLUT VODKA	RUBBING ALCOHOL	ATTRACTS SPERM	WET CEREAL	ATTRACTS SPERM	NAIL VARNISH REMOVER	doesn't exist	SLIGHTLY RANCID	MILDLY SWEET	! SWEET	! SHARP, UNIQUE	!	?	?	!	none
but- 4 carbons	none				WINE	LILY	FRUITY, ETHREAL	ATTRACTS SPERM	BUTTERSCOTCH	doesn't exist	! RANCID BUTTER	! SHARP	! SWEET, ACID	! SHARP, UNIQUE	!	!	!	!	none
pent- 5 carbons	STARTING FLUID			STRONG SWEET	WINE	?	FRESHLY CUT GRASS	?	ATTRACTS NICE	! LIKE NAIL VARNISH REMOVER	! DISGUSTING	! MILD	! PLEASANT, SWEET	! ?	! ROASTED GARLIC	!	!	!	HERBAL
hex- 6 carbons	STARTING FLUID			FRESHLY CUT GRASS	?	?	FRESHLY CUT GRASS	?	ATTRACTS NICE	! LIKE NAIL VARNISH REMOVER	! DISGUSTING	! AROMATIC	! SLIGHTLY SWEET	! ?	!	!	!	!	&
benzene	n/a			SICKENINGLY SWEET AND ETHREAL (Fruity)	doesn't exist	?	?	?	doesn't exist	doesn't exist	BALSAMIC	! AROMATIC	! AROMATIC	! ?	!	!	!	!	doesn't exist
hept- 7 carbons				FRESHLY CUT GRASS	STRONG, FRUITY COGNAC	?	STRONG, FRUITY COGNAC	?	ALMOND BUTTER	! BAD (6-methyl-)	! RANCID	! none	! SLIGHTLY SWEET	! none	!	!	!	!	CARAMEL &
oct- 8 carbons	PETRO			PENETRATING, SWEET	STRONG CITRUS-LIKE	?	?	?	?	?	! RANCID	! none	! none	! SEAWeed	!	!	!	!	?
non- 9 carbons	DIESEL			CITRUS	ATTRACTS MOSQUITOES	?	ATTRACTS MOSQUITOES	?	MILK	?	! RANCID	! none	! none	! none	!	!	!	!	?
dec- 10 carbons	JET FUEL			CITRUS FLOWERS	BUCKWHEAT	?	BUCKWHEAT	?	ATORA	?	! RANCID	! none	! none	! none	!	!	!	!	?
undec- 11 carbons	NEW JET FUEL	?		CITRUS FLOWERS	MAKES SPERM UNABLE TO FIND THE EGG	?	MAKES SPERM UNABLE TO FIND THE EGG	?	ALGERIAN OIL OF RUE	?	! WAXY	! PUNGENT & PENETRATING	! none	! none	!	!	!	!	?
dodec- 12 carbons		MUSTY		FLOWERS		?	?	?	?	?	! BAY OIL	! UNIQUE & UNPLEASANT	! none	! none	!	!	!	!	?
tridec- 13 carbons	SKUNK PHENOLINE	UNIQUE; FOUND IN ROSES		PLEASANT	GRAPEFRUIT PEEL	?	ROASTED	?	WAXY	?	?	! UNIQUE & UNPLEASANT	! none	! none	!	!	!	!	?
tetradec- 14 carbons	KAPOK BUSH FLOWERS	none				?	?	?	?	?	?	! UNIQUE & UNPLEASANT	! none	! none	!	!	!	!	?
pentadec- 15 carbons	LAMARINO	?		ABSOLUT VODKA	FRESH	?	?	?	CELERY	?	?	! UNIQUE & UNPLEASANT	! none	! none	!	!	!	!	?