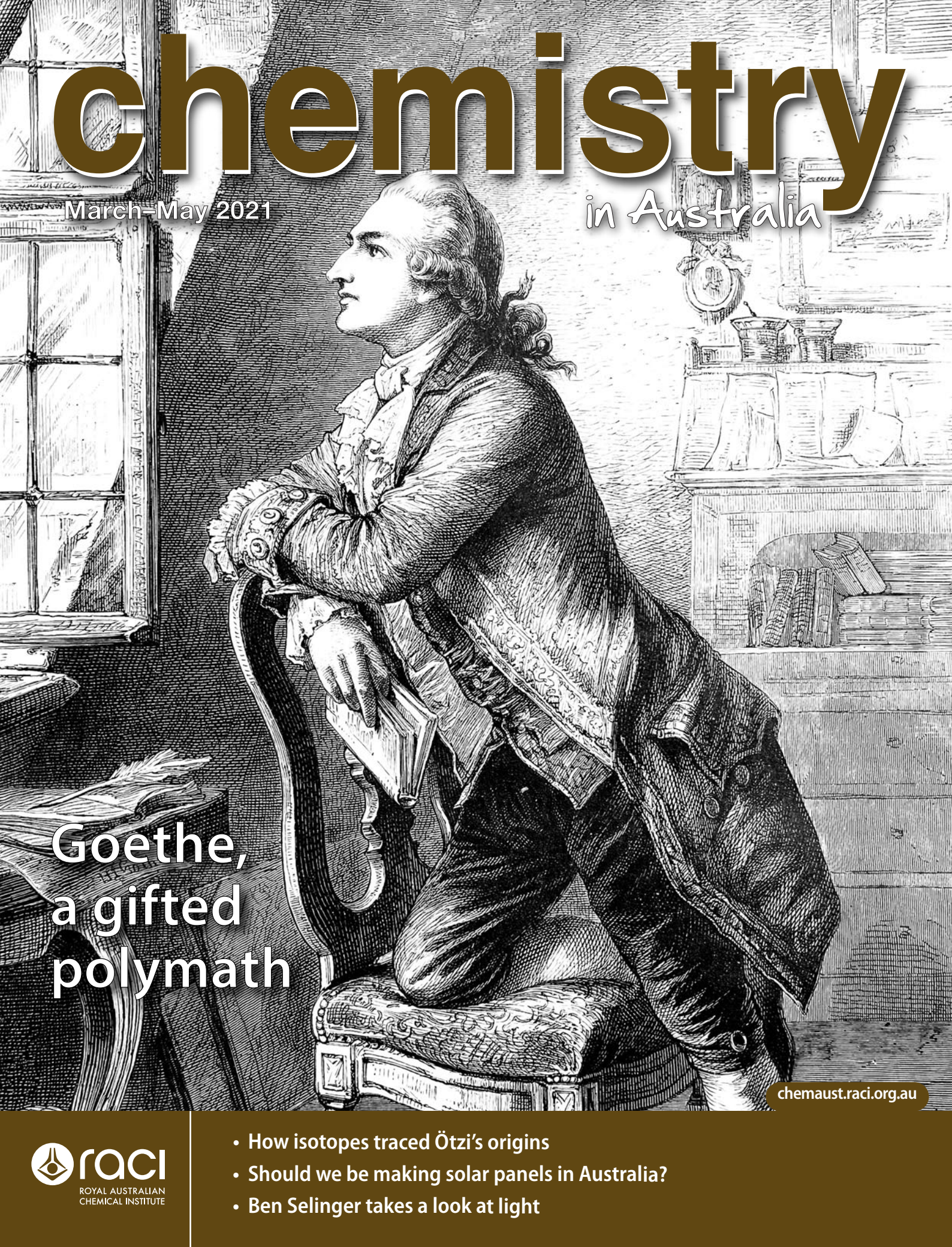


chemistry

in Australia

March–May 2021



Goethe,
a gifted
polymath

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- How isotopes traced Ötzi's origins
- Should we be making solar panels in Australia?
- Ben Selinger takes a look at light

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cover story

Alchemy and chemistry – lifelong fascinations of a literary great

Although Goethe is best known for his literary achievements, he wanted to be remembered as a philosopher and scientist – but this was not to be.

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Some stunning analytical chemistry has revealed the story of Ötzi, a Neolithic man whose frozen remains were hacked free from a glacier on the Austro-Italian border after 5300 years.



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An appetite for science

Peter Lehman's story in this issue (p. 22) about Goethe and his wide-ranging talents and interests across science and the arts reminded me of my recent reading about Jean Anthelme Brillat-Savarin (1755–1826) – French politician, lawyer and gastronome, and Goethe's junior by six years.

Brillat-Savarin's famous work *Physiologie du goût* (*The physiology of taste*), first published shortly before his death, is still in print. Perhaps reflecting his earlier studies in medicine and chemistry, Brillat-Savarin wrote:

Gastronomy is a chapter of natural history, for the fact that it makes a classification of alimentary substances.

Of physics, for it examines their properties and qualities.

Of chemistry, from the various analysis and decomposition to which it subjects them.

Brillat-Savarin studied these sciences during his time studying law in Dijon. Alexandre Balthazar Laurent Grimod de la Reynière, also a French lawyer and a person of influence to Brillat-Savarin, was well known for his gastronomic lifestyle. For him, as he explained in *L'Almanach des gourmands*, fine cuisine was the pinnacle of art and science:

Chemistry, painting, sculpture, architecture, geometry, physics, pyrotechnics, all are more or less closely allied with the great art of fine dining; and the artist who, in addition to a profound knowledge of culinary art, possesses a fair smattering of all these sciences, should reap great benefits indeed.

Goethe had a keen interest in the natural sciences, and he studied and wrote on such subjects as colour theory, homology, botany and meteorology. It is no ordinary person whose work in one field inspires a symphony from Wagner and that in another is used by Charles Darwin as evidence of common descent.

His renown as a literary figure was not something that Goethe wished for. In his work *Theory of colours*, he remarked:

As to what I have done as a poet ... I take no pride in it ... But that in my century I am the only person who knows the truth in the difficult science of colours – of that, I say, I am not a little proud, and here I have a consciousness of a superiority to many.

Brillat-Savarin had a gâteau and a cheese named in his honour; in Goethe's name are the mineral goethite and tropical plant *Goethea cauliflora*. Grimod had a hotel in the family name, although it was built under his father's direction. Hôtel Grimod de la Reynière was a venue for his many grand and sometimes outlandish dinner parties. In the same style, he hosted a number of mock-funeral dinners – including his own (to see who would attend). Although seemingly frivolous, these events are said to have been a theatrical and pointed rejection of the aristocratic lifestyle of his parents by someone with a genuine love of and respect for food – Grimod is widely known as the father of food critique.

The French Revolution was an event common to the lives of all three men. Goethe ridiculed what it symbolised in his satirical play *Der Bürgergeneral* (*The citizen general*). Brillat-Savarin, at that time mayor of his home town of Belley, fled to Switzerland. The Grimod family fortunes were partly lost during the revolution, but during this time Grimod reconciled with his mother. Together with French chef Antonin Carême, Brillat-Savarin and Grimod are considered pivotal in the development of modern French cuisine.



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A sense of Le Fèvre

Chemistry in Australia is so full of human interest. On receiving the most recent issue, I find mention of Madame Curie and of Dorothy Hodgkin (December 2020 – February 2021, p. 14). A little further into the issue, we are informed of the award of the Le Fèvre Prize to Dr I. Kassal.

Raymond James Wood Le Fèvre (1905–86), who was originally from London, was professor of physical chemistry at the University of Sydney from 1946 to 1970. In the April 2014 issue (p. 27), I wrote of people, including chemistry Nobel laureate Sir John Cornforth, who had overcome major disabilities (in Cornforth's case total deafness) and risen to the top of their respective fields of endeavour. Le Fèvre was minus a sense of taste and a sense of smell. He was elected Fellow of the Royal Society (FRS) in 1959, and his Royal Society biographical memoir has an account of how he lost these senses, as does his entry in the *Australian Dictionary of Biography*. When World War II broke out, Le Fèvre was a reader in chemistry at University College London. Early in the war, he became an 'advisor on chemical weapons', and was made an Honorary Wing Commander in the RAF. The role eventually took him to Australia where he was seconded to the RAAF. In January 1943, the vessel *Idomeneus* arrived at Glebe in Sydney with a cargo of mustard gas. There was leakage of the gas, resulting in two deaths and many non-fatal injuries, and Le Fèvre himself was exposed to the gas while investigating the leak. He was taken to Concord Repatriation Hospital in Concord, from which he departed with permanent loss of the senses of taste and smell.

Le Fèvre returned to England in December 1943 and was demobilised from the RAF shortly afterwards. He returned to Australia in 1946 to a chair at the University of Sydney as noted, and discharged the post with distinction.

Clifford Jones FRACI CChem

'Your say' guidelines

We will consider letters of up to 400 words in response to material published in *Chemistry in Australia* or about novel or topical issues relevant to chemistry. Letters accepted for publication will be edited (no proof supplied) for clarity, space or legal reasons and published in print and online. Full name and RACI membership type will be published. Please supply a daytime contact telephone number (not for publication).

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Send letters to wools@westnet.com.au.

Mind your manners!

This socialising message rang throughout our childhood. It aimed to condition us for civil society. Of course, different cultures vary significantly and interestingly in what is deemed acceptable. Where these cultures interact in a multicultural society can create serious flash points. For example, the French tradition of ultra-free speech based on the alleged Voltaire dictum 'I disapprove of what you say, but I will defend to the death your right to say it' resulted in tragedy for Charlie Hebdo cartoonists (and others) when deadly serious offence was taken, literally. With further killings to follow.

The banning of Trump tweets to avoid potential greater tragedy, was arguably in contradiction to the US's constitution's first amendment on free speech. Which makes me wonder, what 'cultural'-activated changes will occur in the Chinese (and Korean) versions of *Chemistry in the marketplace*, currently underway.

So, what is the culture of science? The major strength of science is that it is self-correcting. Conflicting theories fight it out and those surviving are those where the evidence in support slowly and sometimes chaotically overwhelms the counter arguments. Human-induced climate change is an example. But I recall my physical chemistry lecturer warning to be careful about situations akin to trying to measure the weight of the captain of a Manly ferry by weighing the boat with and without the captain. Having a wider appreciation of our rich history of famous influential scientific debates could help inform how such debates could be better managed today. A conversation in *The Conversation* (9 September 2020) on the silencing of Australia's environmental scientists sits in direct contrast to the sacking of Dr Peter Ridd at James Cook University for criticising colleagues' pro-environment-focused research on the Great Barrier Reef; an appeal has been approved to be heard by the High Court. The recent codes of conduct issued and updated by the Australian universities (e.g. ANU) require that 'lecturers ... will not openly critique and attack each other'.

The Conversation (21 January 2021) discusses the media's free speech dilemmas in a world of division, violence and extremism. That dilemma leads back to the controversial judgement against media personality Andrew Bolt, where the judge made the important distinction that Bolt's failing was not the issues that he raised, but the unacceptable manner in which he raised them, when he unreasonably attacked those whom he accused of falsely claiming indigenous origins for personal advantage. So 'how' needs to be considered as well as 'what'. I am left with a deep memory of an aphorism from my primary school teachers, all male, all fresh home from the war. In a lesson on the defence of free speech one summarised: 'Your right to swing your fist, ends where my nose begins'.

Ben Selinger FRACI CChem

More RACI news?

Several recent letters have questioned the decision to reduce publication frequency to four issues per year. The response of our CEO suggested this was a cost issue and possibly related to decreased income, inter alia, from membership fees.

As a member of the Institute for more than 50 years, I regard *Chemistry in Australia* as an interesting read each issue. The problem with it is not what is in it, but what is not in it. I refer to the absence of news about the Institute as an organisation. It is surely a reasonable expectation of members that they should receive reports from time to time of how the organisation is travelling, particularly in times of change.

What does the Board consider at its meetings? Members would not know from reading *Chemistry in Australia*. Years ago, there were some 6000 members and summaries of the financial situation were published. There were various national committees dealing with accreditation, employment etc., which regularly summarised their activities so that members were informed. Surveys were regularly published on the numbers of students in tertiary institutions majoring in chemistry.

In recent years, there have been vast changes that affect provision of education in chemistry at universities. Since graduates of these courses are the ones who will become members of the Institute, the organisation and its members should have a keen interest in what is happening. An obvious question – how many universities still offer major studies in chemistry, as opposed to bits and pieces? There has been much talk in recent years of the importance of STEM studies in schools but what is happening in the university sector in these areas?

Can we please have some information on these issues from our Board?

Mal Nolan FRACI CChem

Catalyst mimics natural processes to break down plastics

While plastics recycling is not new science, current processes don't make it economically worthwhile – waste plastics get 'down-cycled' into lower grade, less useful material. It is a challenge that continues to be an obstacle in tackling a growing global pollution crisis in single-use plastics.

A multi-institutional team of scientists led by the US Department of Energy's Ames Laboratory has developed a first-of-its-kind catalyst that can process polyolefin plastics such as polyethylene and polypropylene, types of polymers widely used in plastic grocery bags, milk jugs, shampoo bottles, toys and food containers (doi.org/10.1038/s41929-020-00519-4). The process results in uniform, high-quality components that can be used to produce fuels, solvents and lubricating oils, products that have high value, and could potentially turn these and other used plastics into an untapped resource.

'We've made a big step forward with this work', said Aaron Sadow, a scientist at Ames Laboratory and the Director of the Institute for Cooperative Upcycling of Plastics. 'We hypothesised that we could borrow from nature, and mimic the processes by which enzymes precisely break apart macromolecules like proteins and cellulose. We succeeded in doing that, and we're excited to pursue optimising

and developing this process further.'

The unique process relies on nanoparticle technology. Ames Lab scientist Wenyu Huang designed a mesoporous silica nanoparticle consisting of a core of platinum with catalytic active sites, surrounded by long silica pores, or channels, through which the long polymer chains thread through to the catalyst. With this design, the catalyst can hold on to and cleave the longer polymer chains into consistent, uniform shorter pieces that have the most potential to be upcycled into new, more useful end products.

'This type of controlled catalysis process has never before been designed based on inorganic materials', said Huang, who specialises in the design of structurally well-defined nanocatalysts. 'We were able to show that the catalytic process is capable of performing multiple identical deconstruction steps on the same molecule before releasing it.'

Ames Laboratory's solid state NMR expert Fred Perras' measurements allowed the team to scrutinise the catalyst's activity at the atomic scale, and confirmed that the long polymer chains moved readily through the catalyst pores in the manner resembling the enzymatic processes that the scientists were aiming to emulate.

DOE/Ames Laboratory

The process results in uniform, high-quality components that can be used to produce fuels, solvents and lubricating oils ...

‘Digital chemistry’ turns words into molecules

A new system capable of automatically turning words into molecules on demand will open up the digitisation of chemistry, scientists say.

Researchers from the University of Glasgow’s School of Chemistry, who developed the system, claim it will lead to the creation of a ‘Spotify for chemistry’ – a vast online repository of downloadable recipes for important molecules, including drugs.

The creation of such a system could help developing countries more easily access medications, enable more efficient international scientific collaboration, and even support the human exploration of space.



The ChemPU/Chemputer robot system in a fumehood. Cronin Group

The Glasgow team, led by Professor Lee Cronin, has laid the groundwork for digital chemistry with the development of what they call a ‘chemical processing unit’ – an affordable desktop-sized robot chemist that is capable of doing the repetitive and time-consuming work of creating chemicals. Other robot chemists, built with different operating systems, have also been developed elsewhere.

Up until now, those robot chemists have required a massive amount of programming from their human counterparts, with detailed instructions. The problem is there is currently no standard programming language for chemistry, meaning that programs made for one robot do not work on any other type.

In a new paper published in *Science* (doi.org/10.1126/science.abc2986), the Glasgow researchers describe a universal approach to digitising chemistry, including a programming system that could remove the vast majority of the effort required to program the robots.

They have found a way to create new sets of instructions for robot chemists by harnessing the power of natural language processing. They developed a computer program called SynthReader to scan through scientific papers and recognise sections that outline procedures for organic and inorganic chemical synthesis. Synthreader automatically breaks down those procedures to simple instructions and stores them in a format the team call Chemical Description Language, or XDL, which is a new open-source language for describing chemical and material synthesis.

Those XDL files are chemical instructions that can in principle be read by any chemical robot. The team built an easy-to-use interface called ChemIDE to integrate with any

robotic chemist system and allow the XDL instructions to be turned into chemicals. The only human input required is ensuring that the equipment the robot needs to make the molecules is set up correctly.

The paper describes how the team used their system to scan scientific papers and produce 12 different molecules using their chemical processing unit, including the analgesic lidocaine, the Dess-Martin periodinane oxidation reagent, and the fluorinating agent AlkylFluor.

Cronin said: ‘What we’ve managed to do with the development of our ‘Chemical Spotify’ is something similar to ripping a compact disc into an MP3. We take information stored in a physical format, in this case a scientific paper, and pull out all the data we need to create a digital file which can be played on any system, in this case any robot chemist, including our robotic system which is an order of magnitude lower cost than any other similar robot.

‘We’re hoping that the system we’ve built will massively expand the capabilities of robot chemists and allow the creation of a huge database of molecules drawn from hundreds of years’ worth of scientific papers.

‘Our system, which we’re calling Chemify, can read and run XDL files which have been shared among users. Putting that kind of knowledge directly in the hands of people with access to robot chemists could help doctors make drugs on demand in the future. It could even mean that future manned missions to Mars could take raw chemical materials with them and make whatever they need right there on the red planet.’

For more information on Chemify, visit www.chemify.org.

University of Glasgow



Australia lifts performance on global maths and science test

New results from the world's longest running large-scale international assessment of mathematics and science show that Australia has significantly improved in Year 8 mathematics and science, and Year 4 science – but not mathematics.

Conducted every four years since 1995, the Trends in International Mathematics and Science Study (TIMSS) shows that Australia was outperformed by just six countries in Year 8 mathematics and science, and eight countries in Year 4 science in the latest assessment cycle. More than 580 000 students from 64 countries and eight benchmarking systems participated in the 2019 study, including 14 950 Australian students from 571 Australian schools.

Between 68 and 78% of Australian students achieved the TIMSS Intermediate international benchmark – the nationally agreed proficient standard – compared to more than 90% of students in the highest achieving country, Singapore. The proportion of Australian students achieving this standard improved since 2015 in Year 8 science only.

TIMSS results also provide a measure of Australia's progress towards the United Nations 2030 Sustainable Development Goal for universal quality education, as the UNESCO Institute for Statistics has named the TIMSS Low international benchmark a reliable global indicator of minimum proficiency in mathematics at the end of lower secondary schooling. Ninety per cent of Australian Year 8 students achieved the Low international benchmark, compared to the international median of 87%.

In terms of student equity, TIMSS 2019 shows:

- boys outperformed girls in Year 4 mathematics in 27 of the 58 participating countries, including Australia. There was no significant difference between the average performance of Australian girls and boys in Year 8 mathematics, Year 4 science or Year 8 science
- the achievement gap between First Nations Australian students and other Australian students has narrowed slightly in Year 4 science and Year 8 science since 1995, but has not changed significantly since 2015. The gaps in Year 4 mathematics and Year 8

mathematics have not changed significantly in the short or long term

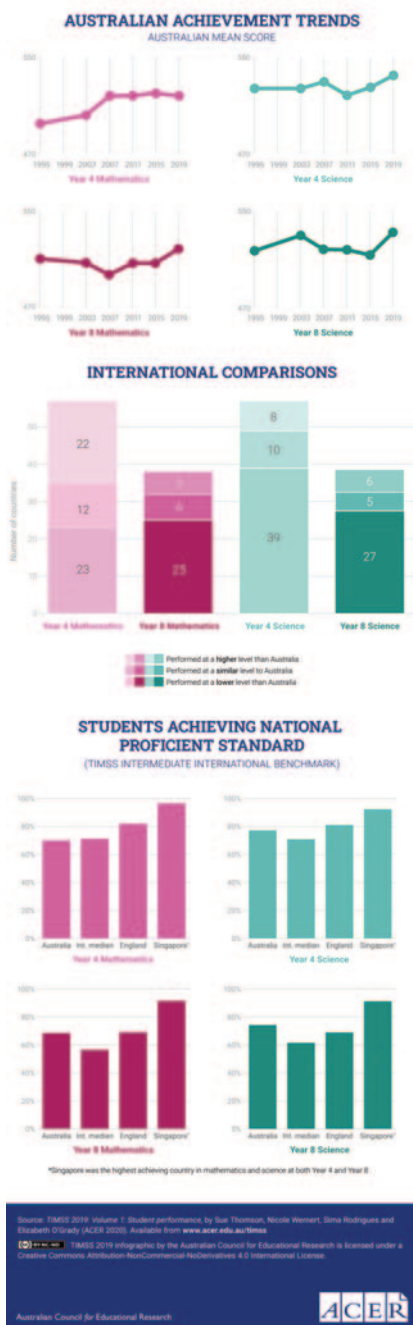
- there was no difference in achievement between Australian students by language background in Year 4 mathematics or Year 8 science. In Year 8 mathematics, students who spoke a language other than English at home outperformed students who spoke English at home. In Year 4 science, students who spoke English at home performed at a higher level than students who spoke a language other than English at home
- at both year levels and across both mathematics and science, students from metropolitan schools performed at a higher level than students in regional and remote schools.

TIMSS National Research Coordinator and ACER Deputy CEO Dr Sue Thomson said, 'These are welcome results for many Australian schools, students and teachers. Strong results in mathematics and science are vital for our long-term economy, and these findings show that some progress has been made in achieving our national goals. However, as always, we need to note that these results are not uniform, and that there is still a solid tail of underachievement that needs to be addressed. Acknowledging that the primary underlying factor behind poor achievement is socioeconomic background, and finding ways of redressing the imbalance in opportunities and resources available to these students, will help lift achievement for all Australian students.'

TIMSS explores how well Year 4 and Year 8 students have mastered the factual and procedural knowledge taught in school mathematics and science classes. For comparability across countries and across assessments, data collection was conducted at the end of the school year: in late 2018 in southern hemisphere countries and in early-mid-2019 in northern hemisphere countries.

TIMSS is a project of the International Association for the Evaluation of Educational Achievement and is directed by the TIMSS International Study Center at Boston College. ACER manages the implementation and reporting of TIMSS within Australia.

ACER





ANU PhD scholar Xingshuo Huang holds the diamond anvil that the team used to make the diamonds in the lab. Jamie Kidston, ANU

Scientists defy nature to make insta-bling at room temperature

An international team of scientists has defied nature to make diamonds in minutes in a laboratory at room temperature – a process that normally requires billions of years, huge amounts of pressure and super-high temperatures.

The team, led by the Australian National University (ANU) and RMIT University, made two types of diamonds: the kind found on engagement rings and lonsdaleite, which is found in nature at the site of meteorite impacts such as Canyon Diablo in the US.

One of the lead researchers, ANU Professor Jodie Bradby, said their breakthrough shows that Superman may have had a similar trick up his sleeve when he crushed coal into diamond, without using his heat ray.

‘Natural diamonds are usually formed over billions of years, about 150 kilometres deep in the Earth where there are high pressures and temperatures above 1000°C,’ said Bradby.

The team previously produced lonsdaleite in the lab only at high temperatures.

This new unexpected discovery shows both lonsdaleite and regular diamond can also form at normal room temperatures by just applying high pressures – equivalent to 640 African elephants on the tip of a ballet shoe.

‘The twist in the story is how we apply the pressure. As well as very high pressures, we allow the carbon to also experience something called “shear” – which is like a twisting or sliding force. We think this allows the carbon atoms to move into place and form lonsdaleite and regular diamond,’ Bradby said.

Co-lead researcher Professor Dougal McCulloch and his

team at RMIT used advanced electron microscopy techniques to capture solid and intact slices from the experimental samples to create snapshots of how the two types of diamonds formed.

‘Our pictures showed that the regular diamonds only form in the middle of these lonsdaleite veins under this new method developed by our cross-institutional team,’ McCulloch said.

‘Seeing these little “rivers” of lonsdaleite and regular diamond for the first time was just amazing and really helps us understand how they might form.’

Lonsdaleite, named after the crystallographer Dame Kathleen Lonsdale, the first woman elected as a Fellow to the Royal Society, has a different crystal structure to regular diamond. It is predicted to be 58% harder.

‘Lonsdaleite has the potential to be used for cutting through ultra-solid materials on mining sites,’ Bradby said.

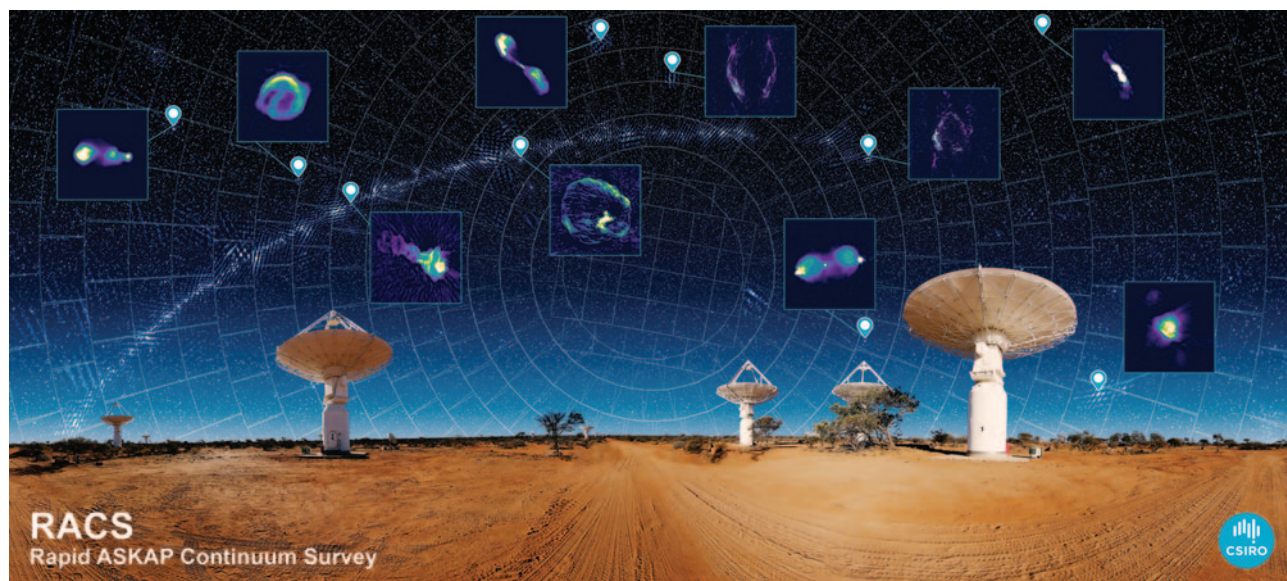
‘Creating more of this rare but super useful diamond is the long-term aim of this work.’

Xingshuo Huang is an ANU PhD scholar working in Bradby’s lab.

‘Being able to make two types of diamonds at room temperature was exciting to achieve for the first time in our lab,’ Huang said.

The team, which involved University of Sydney and Oak Ridge National Laboratory in the US, have published the research findings in the journal *Small* (doi.org/10.1002/sml.202004695).

Australian National University



Australian telescope creates a new atlas of the universe

A world-leading CSIRO radio telescope has conducted its first survey of the entire southern sky in record speed and detail, creating a new atlas of the universe. The Australian Square Kilometre Array Pathfinder (ASKAP) mapped approximately three million galaxies in just 300 hours.

The Rapid ASKAP Continuum Survey is like a Google map of the universe where most of the millions of star-like points on the map are distant galaxies – about a million of which have never been seen before.

The telescope's key feature is its wide field of view, generated by new CSIRO-designed receivers, that enable ASKAP to take panoramic pictures of the sky in amazing detail.

Using ASKAP at CSIRO's Murchison Radio-astronomy Observatory in outback Western Australia, the survey team observed 83% of the entire sky. The initial results are published in the *Publications of the Astronomical Society of Australia*.

This result proves that an all-sky survey can be done in weeks rather than years, opening new opportunities for discovery.

The new data will enable astronomers to undertake statistical analyses of large populations of galaxies, in the same way social researchers use information from a national census.

'This census of the universe will be used by astronomers around the world to explore the unknown and study everything from star formation to how galaxies and their super-massive black holes evolve and interact,' lead author and CSIRO astronomer Dr David McConnell said.

With ASKAP's advanced receivers, the Rapid ASKAP Continuum Survey team only needed to combine 903 images to form the full map of the sky, significantly fewer than the tens of thousands of images needed for earlier all-sky radio surveys conducted by major world telescopes.

'For the first time ASKAP has flexed its full muscles, building a map of the universe in greater detail than ever before, and at record speed. We expect to find tens of millions of new galaxies in future surveys,' McConnell said.

The 13.5 exabytes of raw data generated by ASKAP were processed using hardware and software custom-built by CSIRO.

The Pawsey Supercomputing Centre's 'Galaxy' supercomputer converted the data into 2D radio images containing a total of 70 billion pixels. The final 903 images and supporting information amount to 26 terabytes of data.

The images and catalogues from the survey will be made publicly available through the CSIRO Data Access Portal and hosted at Pawsey.

ASKAP's advanced technologies are providing insights for the development of the Square Kilometre Array (SKA), an international mega-science project to build the world's largest radio telescopes. CSIRO will host the low-frequency SKA telescope at the Murchison Radio-astronomy Observatory.

CSIRO



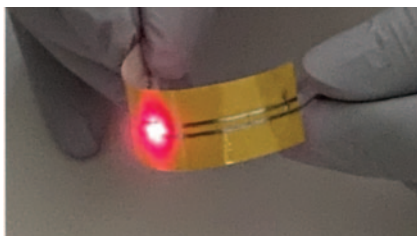
Si wafer



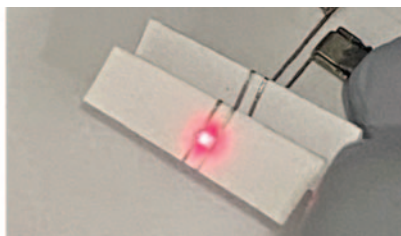
Plastic



Paper



Bending (Kapton tape)



Folding (writing paper)

Written traces with the sticky liquid metal ink.

Nature-inspired glue for writing liquid-metal ink onto any surface

Room-temperature liquid metals, such as gallium and its alloys, are fascinating materials because of their unique combination of metallic and fluidic properties. Liquid metals have been at the forefront of developing next-generation flexible electronics, actuators, sensors and robotics. For many of these applications, writing/patterning of liquid metals is a key processing step, of which the efficiency and ease of operation are of critical importance. However, patterning of liquid metals onto different surfaces is not easy. The current liquid-metal inks suffer from undesired inconsistency of writing, operational complexity and, most importantly, regardless of the applied strategy, extremely limited choice of surface for consistent patterning.

According to a study published in *Advanced Functional Materials* (doi.org/10.1002/adfm.202007336), scientists from University of New South Wales Sydney and RMIT have now addressed the writing problems by combining a natural compound with liquid metals to make sticky liquid-metal inks that can be written or patterned on virtually any surfaces.

‘Surface specificity during writing with liquid metal ink is a serious challenge that

stems from the high surface tension of these liquid metals. Solving this problem with inexpensive adhesives and a simple methodology can be a game-changer’, said Professor Kourosh Kalantar-Zadeh (UNSW Sydney), one of the corresponding authors of the paper.

The inspiration for this study came from the various marine invertebrates (e.g. mussels) that survive in strong tidal environments, by secreting gluey substances that stick them to any solid surfaces. The catechol functional group in the glue is responsible for such adhesion. Interestingly, this group is also prevalent in plants, in the form of polyphenols – regularly found in tea, chocolate and wine. The research team used tannic acid, a polyphenol, as the molecular glue for the liquid-metal ink preparation.

The writing method is simple: put the ink into a regular ballpoint pen and write words or design patterns as you wish. And the choice of surface is unlimited, as the sticky inks can be applied onto a wide range of substrates with varying surface chemistries and physical properties. The team further explored the potential applications of the sticky inks, for stretchable electronics, touch and toxic metal sensors.

University of New South Wales

ANSTO scientist wins competition for beamline research

ANSTO scientist Jessica Hamilton has been named the winner of the Falling Walls Lab Australia Competition – bringing down walls using science and innovative breakthroughs.

The competition had scientists, academics and innovators from across Australia presenting their ideas, research and initiatives focusing on the theme ‘Which are the next walls to fall?’

Hamilton gained first prize after using beamline technology for solutions to mining, finding a way to produce valuable products and offset CO₂ emissions by recycling mining wastes.

Hamilton’s method reuses mineral waste, by combining it with waste acid to accelerate a natural weathering process leading to the capture of CO₂. Valuable products are produced such as calcium and magnesium carbonates that can then be re-used.

The competition was hosted by the Australian Academy of Science, with participants presenting solutions to the challenges of our time in a three-minute presentation.

Hamilton said, ‘The approach I developed during my PhD at Monash University is currently being tested in diamond mines in Africa and Canada in a collaborative effort led by my PhD supervisor Dr Sasha Wilson and colleagues at the Universities of Alberta and British Columbia, with industry, and the Canadian Government, and hopefully one day it will be used to offset emissions at mines around the world.’

ANSTO

One of the strongest magnets in the universe makes its presence known

Astronomers from the ARC Centre of Excellence for Gravitational Wave Discovery (OzGrav) and CSIRO have just observed bizarre, never-seen-before behaviour from a 'radio-loud' magnetar – a rare type of neutron star and one of the strongest magnets in the universe.

Their new findings, published in the *Monthly Notices of the Royal Astronomical Society* (MNRAS), suggest magnetars have more complex magnetic fields than previously thought, which may challenge theories of how they are born and evolve over time.

Magnetars are a rare type of rotating neutron star with some of the most powerful magnetic fields in the universe. Astronomers have detected only 30 of these objects in and around the Milky Way – most of them detected by X-ray telescopes following a high-energy outburst.

However, a handful of these magnetars have also been seen to emit radio pulses in a similar way to pulsars – the less magnetic cousins of magnetars that produce beams of radio waves from their magnetic poles. Tracking how the pulses from these radio-loud magnetars change over time offers a unique window into their evolution and geometry.

In March 2020, a new magnetar named Swift J1818.0-1607 ('J1818' for short) was discovered after it emitted a bright X-ray burst. Rapid follow-up observations detected radio pulses originating from the magnetar. Curiously, the appearance of the radio pulses from J1818 were quite different from those seen from other radio-loud magnetars.

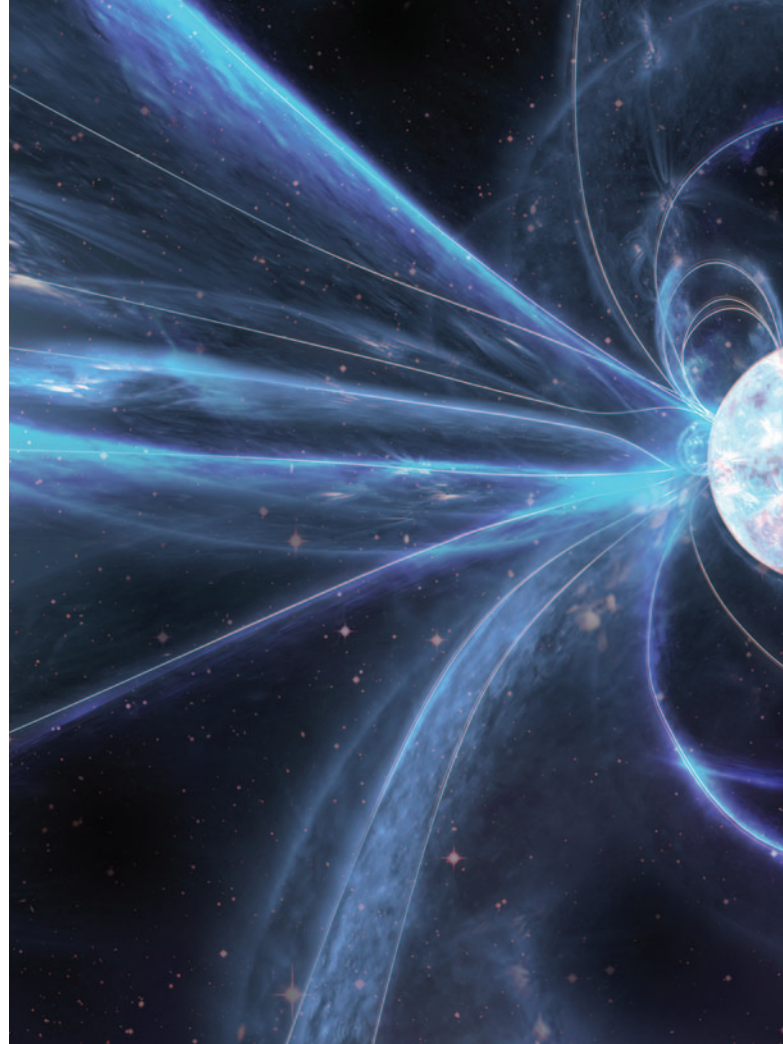
Most radio pulses from magnetars maintain a consistent brightness across a wide range of observing frequencies. However, the pulses from J1818 were much brighter at low frequencies than at high frequencies – similar to what is seen in pulsars, another more common type of radio-emitting neutron star.

To better understand how J1818 would evolve over time, a team led by OzGrav scientists using the CSIRO Parkes radio telescope (also known as Murriyang) observed it eight times between May and October 2020.

During this time, they found that the magnetar underwent a brief identity crisis: in May it was still emitting the unusual pulsar-like pulses that had been detected previously; however, by June it had started flickering between a bright and a weak state. This flickering behaviour reached a peak in July where the astronomers saw it flicking back and forth between emitting pulsar-like and magnetar-like radio pulses.

'This bizarre behaviour has never been seen before in any other radio-loud magnetar', said study lead author and Swinburne University/CSIRO PhD student Marcus Lower. 'It appears to have only been a short-lived phenomenon as by our next observation it had settled permanently into this new magnetar-like state.'

The scientists also looked for pulse shape and brightness



changes at different radio frequencies and compared their observations to a 50-year-old theoretical model. This model predicts the expected geometry of a pulsar, based on the twisting direction of its polarised light.

'From our observations, we found that the magnetic axis of J1818 isn't aligned with its rotation axis', said Lower.

'Instead, the radio-emitting magnetic pole appears to be in its southern hemisphere, located just below the equator. Most other magnetars have magnetic fields that are aligned with their spin axes or are a little ambiguous.

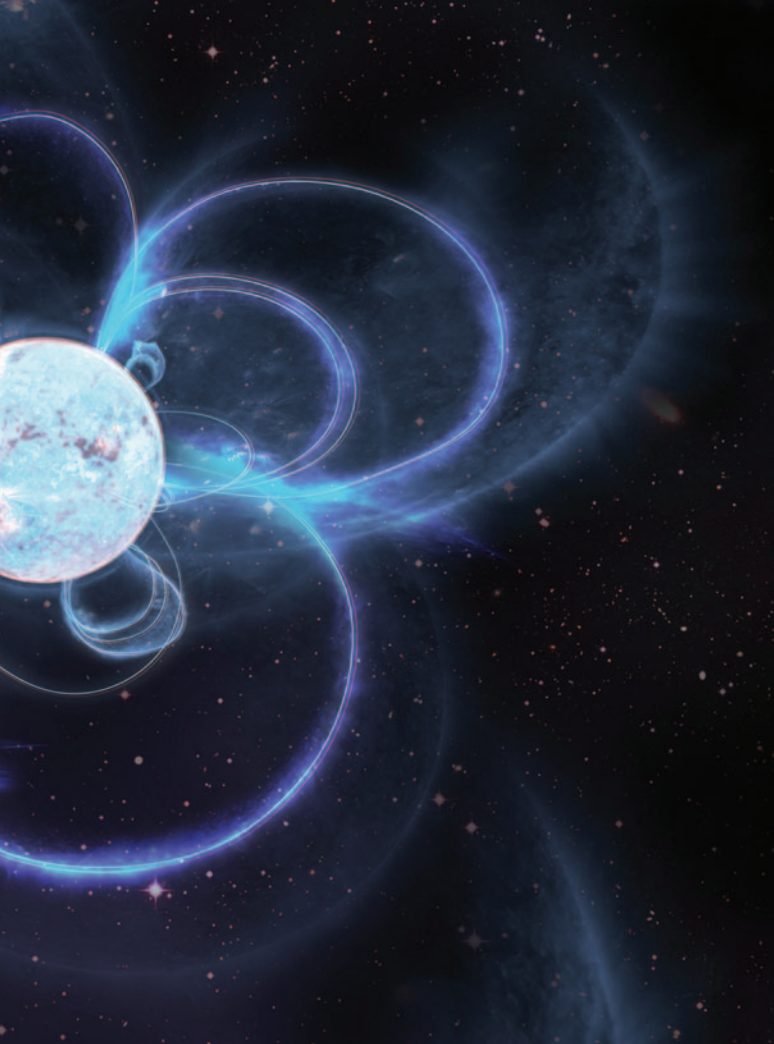
'This is the first time we have definitively seen a magnetar with a misaligned magnetic pole.'

Remarkably, this magnetic geometry appears to be stable over most observations. This suggests any changes in the pulse profile are simply due to variations in the height the radio pulses are emitted above the neutron star surface. However, the 1 August 2020 observation stands out as a curious exception.

'Our best geometric model for this date suggests that the radio beam briefly flipped over to a completely different magnetic pole located in the northern hemisphere of the magnetar', said Lower.

A distinct lack of any changes in the magnetar's pulse profile shape indicate the same magnetic field lines that trigger the 'normal' radio pulses must also be responsible for the pulses seen from the other magnetic pole.

The study suggests this is evidence that the radio pulses from J1818 originate from loops of magnetic field lines



Artist's impression of the active magnetar Swift J1818.0-1607.

Image by Carl Knox, OzGrav

connecting two closely spaced poles, like those seen connecting the two poles of a horseshoe magnet or sunspots on the Sun. This is unlike most ordinary neutron stars, which are expected to have north and south poles on opposite sides of the star that are connected by a doughnut-shaped magnetic field.

This peculiar magnetic field configuration is also supported by an independent study of the X-rays pulses from J1818 that were detected by the NICER telescope on board the International Space Station. The X-rays appear to come from either a single distorted region of magnetic field lines that emerge from the magnetar surface or two smaller, but closely spaced, regions.

These discoveries have potential implications for computer simulations of how magnetars are born and evolve over long periods of time, as more complex magnetic field geometries will change how quickly their magnetic fields are expected to decay over time. Additionally, theories that suggest fast radio bursts can originate from magnetars will have to account for radio pulses potentially originating from multiple active sites within their magnetic fields.

Catching a flip between magnetic poles in action could also afford the first opportunity to map the magnetic field of a magnetar.

ARC Centre of Excellence for Gravitational Wave Discovery (OzGrav)

Patent filed for COVID-19 detection tool

Scientists at the Australian National Phenome Centre (ANPC) at Murdoch University in Western Australia (WA) have filed a patent that represents a major advance in the detection of COVID-19 infection. The patent involves the use of advanced magnetic resonance technologies to detect the pathological signature of the disease that does not rely on direct detection of the virus, but on the biological fingerprint the disease has on the patient. The patent is jointly filed with Bruker Biospin GmbH, which develops advanced analytical technologies.

Director of the ANPC Professor Jeremy Nicholson said this paved the way to the development of new regulatory approved tests that can be rolled out in multiple countries.

'The new testing paradigm also allows long-term effects of the disease (long COVID) to be monitored in a way that will help enable personalised healthcare for long-term COVID-19 sufferers', Nicholson said.

Nicholson said the method identifies new molecular biomarkers linked to abnormal fat biochemistry and the way in which those fats bind to circulating proteins. The novel signatures proved to be highly effective (95% or higher) at distinguishing SARS Cov-2 positive patients from patients with mild-to-moderate non-COVID-19 respiratory disease.

'The importance of this patent is that it paves the way to developing a regulatory approved test that would be used to help distinguish COVID-19 from other respiratory diseases based on changes in metabolism, not the presence of the virus itself.

'An important possible use of this would be to augment existing PCR methods that are a mainstay of border biosecurity protection measures.'

Nicholson said the methods will be developed further over coming months with international partners and regulators to create an internationally recognised testing procedure that can be uniformly applied across the world.

'Although WA has been spared the most serious effects of the COVID-19 pandemic so far, there are still many challenges ahead until the population is protected adequately by vaccines or other therapies and biosecurity vigilance, which has worked well in WA so far and must be upheld in the presence of new more aggressive virus variants.'

Nicholson said new physical and chemical methods for detection such as the one proposed will assist in improving screening procedures in the future but are subject to further regulatory refinement and approval, which is now ongoing at the ANPC and partner laboratories.

'The test currently works on a small blood plasma sample that requires no pre-treatment and takes about 3–4 minutes per test', Nicholson said.

'We are further optimising the test procedure for speed and sample size and we expect performance improvements during regulatory development – even though this is still a work in progress, we regard it as a significant translational development.'

Murdoch University

Ellume COVID-19 home tests to be produced in US

Australian-based digital diagnostics company Ellume has announced a \$231.8 million agreement with the US Department of Defense, in coordination with the Department of Health and Human Services, to accelerate domestic US production of its COVID-19 home tests.

The Ellume COVID-19 Home Test is the first rapid self-test for COVID-19 detection authorised by the US FDA for both asymptomatic and symptomatic use without a prescription. With the CDC reporting that at least 50% of COVID-19 cases are transmitted asymptotically, Ellume's test will play a crucial role as the only diagnostic tool authorised for non-prescription use as a screening tool in the US.

Ellume has developed a proprietary diagnostic technology, specifically designed for at-home testing for respiratory diseases such as COVID-19. At the core of the product is a highly sensitive but inexpensive single-use test cartridge that measures and analyses a near-infrared light signature generated by the immunoassay reagents and transmits it wirelessly to the user's own smartphone via bluetooth low energy. The immunoassay detects the nucleocapsid protein of the SARS-CoV-2 virus and consists of two parts: (i) a biologically activated immunochromatographic strip that is assembled within the test cartridge; and (ii) antibody-labelled quantum dot nanoparticles that are contained with the sample collection device. Proprietary light guides funnel UV excitation light from a light-emitting diode on the printed circuit board assembly to the assay and then collect and filter near-infrared light emitted from the assay onto a photosensor also located on the printed circuit board assembly.

The user self-collects a mid-turbinate specimen using the custom swab device. The swab specimen is then processed with an extraction fluid that contains the nanoparticles. This homogeneous fluorescent sample fluid is dispensed into the port of the cartridge, which automatically detects the sample and continues to collect test and reference measurements every second until the 15-minute endpoint. In the presence of SARS-CoV-2 in the sample, the immunoassay reagents form a sandwich complex that produces the characteristic light signature at the test zone, with the amount of signal generated



proportional to the amount of virus in the sample. In the absence of virus, the test zone produces no signal. At the end of the measurement window, the test and reference data are analysed by an algorithm programmed within the firmware of the cartridge.

The agreement includes funding to support the establishment of Ellume's US-based manufacturing facility and the delivery of 8.5 million COVID-19 home tests that will be distributed across the US in accordance with the National Strategy for the COVID-19 Response and Pandemic Preparedness plan.

This US-based manufacturing capacity builds upon Ellume's existing Australian production capacity, which is on track to procure approximately 200 000 tests a day this quarter. Under the agreement, Ellume will be delivering 100 000 tests a month from the Australian manufacturing facility until the US facility is built. At full capacity, the US facility will be able to produce up to 19 million tests a month.

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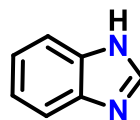


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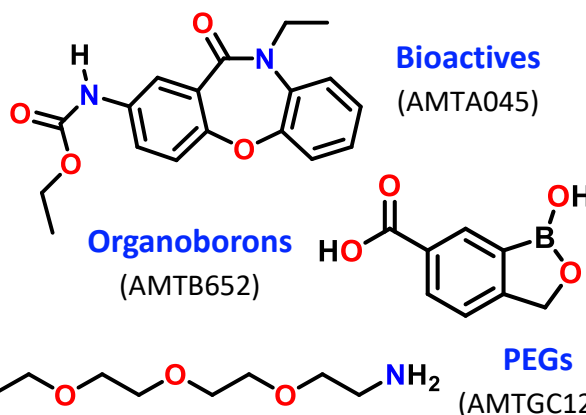
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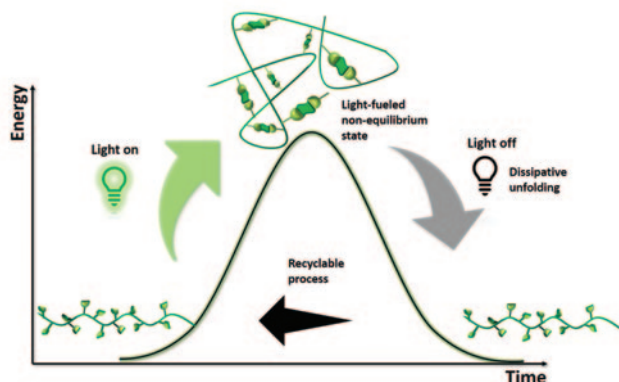
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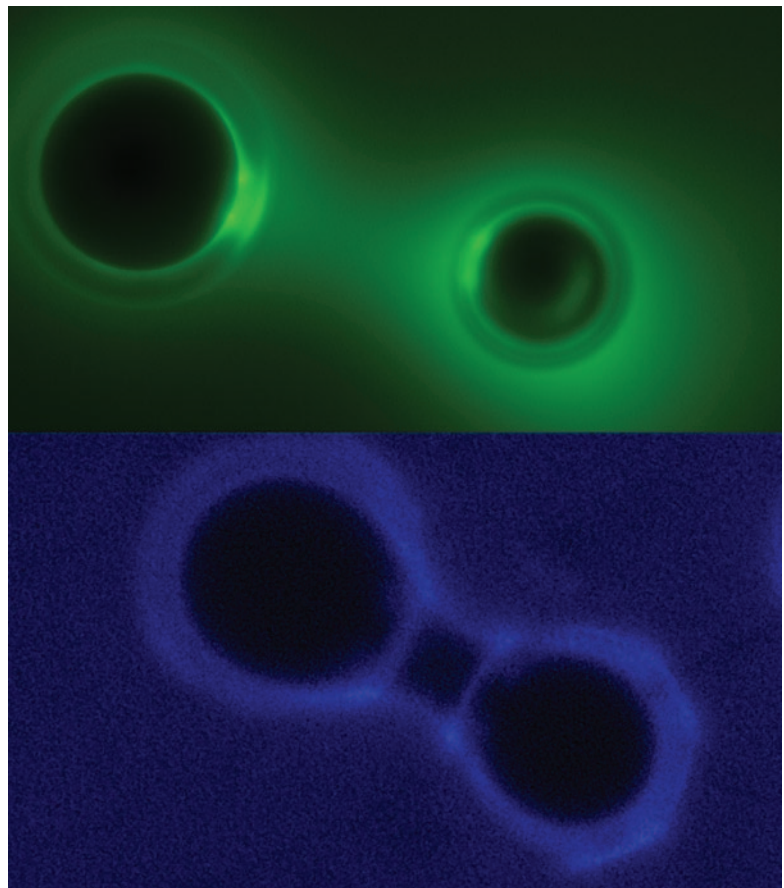
Controlling polymer conformation out-of-equilibrium with light



Whereas chemical synthesis proceeds predominantly towards thermodynamic equilibrium, living systems operate on the reverse principle – consuming fuel to maintain a non-equilibrium state. Inspired by life, QUT's Soft Matter Materials Laboratory in collaboration with the University of Ghent (Belgium) has developed the first synthetic polymers that undergo intramolecular cross-linking in the presence of green light to yield single-chain nanoparticles (Kodura D., Houck H.A., Bloesser F.R., Goldmann A.S., Du Prez F.E., Frisch H., Barner-Kowollik C. *Chem. Sci.* 2021, **12**, 1302–10). If the fuel supply (light) is turned off, however, the cross-linked polymer dissipates into a linear polymer chain. These morphological transitions are highly reversible through cycles of light and darkness, enabling unprecedented light-gated folding and unfolding of the nanoparticles. The folded conformation of the polymer chain can be kinetically trapped, made thermodynamically favoured by a chemical modification, or preserved through a constant supply of fuel. The fuel-driven stabilisation over longer periods is an inherent feature of the confined macromolecular environment within the nanoparticles, whereas small-molecule equivalents of the chemical cross-links were largely degraded after 3 days, even in the presence of fuel.

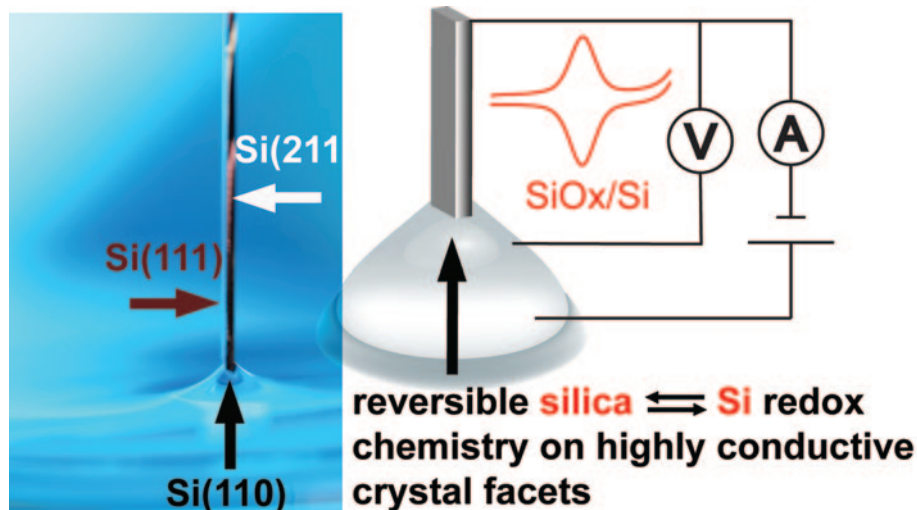
Electrified bubbles

The formation of bubbles at electrodes is a ubiquitous problem in technologies from batteries to industrial smelting. An adhering gas bubble will mask a portion of the electrode, preventing fresh solution from reaching it. Consequently, electrochemists and engineers unanimously regard surface bubbles as redox-inactive passivating entities. But now a team of researchers from Curtin University, the Australian National University, the University of New South Wales and the University of Western Australia has demonstrated that this is not case: bubbles adhering to an electrode surface initiate the oxidation of water-soluble species under conditions for which such reactions would normally be considered impossible (Vogel Y.B., Evans C.W., Belotti M., Xu L., Russell I.C., Yu L.-J., Fung A.K.K., Hill N.S., Darwish N., Gonçalves V.R., Coote M.L., Iyer K.S. Ciampi S. *Nat. Commun.* 2020, **11**, 6323). By coupling fluorescence microscopy, electrochemistry and multi-scale modelling, the researchers revealed that the corona of a surface bubble accumulates an unbalanced excess of hydroxide anions, reaching pH 14 even in ultra-pure water. This excess causes the oxidation of hydroxide to hydroxyl radicals to occur at potentials more than 0.7 V below tabulated values. The downhill oxidation shift in a bubble's corona is likely to be a general mechanism involved in the initiation of heterogeneous electrochemical oxidations in water and could be harnessed in chemical synthesis.



Explaining background signals in cyclic voltammetry with silicon electrodes

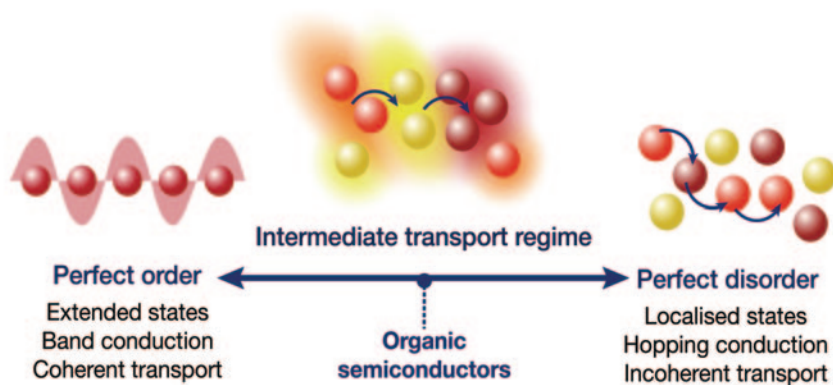
Due to the simplicity of recording electrical currents versus time, chemists and surface scientists routinely turn to electrical-charge values extracted from cyclic voltammograms to monitor the progress and estimate yields of surface reactions. The chemisorption of only a fractional monolayer of molecules ($<0.1 \text{ ng cm}^{-2}$) generally leads to currents well above the noise for a basic commercial potentiostat, making voltammetry one of the best techniques for studying the reactivity of surfaces. However, while all common adventitious electrochemical signals have been explained and assigned for platinum, gold and carbon electrodes, recurrent parasitic signals observed for semiconducting silicon electrodes have remain unexplained until now. Recently, researchers at Curtin University demonstrated reversible electrochemical silica-to-silicon conversion at room temperature for the first time by coupling



electrical measurements in atomic force microscopy and electrochemistry; furthermore they identified this silica-silicon redox chemistry as the source of parasitic voltammetry signals (Zhang S., Ferrie S., Peiris C.R., Lyu X., Vogel Y.B., Darwish N., Ciampi S. *J. Am. Chem. Soc.*

2021, **143**, 1267–72). This discovery redefines the electrical-potential window for silicon that is free from redox parasitic signals and therefore suitable for studying surface reactions by electroanalytical methods.

A little delocalisation goes a long way



Organic electronics is a rapidly expanding field: organic light-emitting diodes are found in the latest smartphone displays and organic photovoltaics are beginning to be deployed commercially in certain applications. All of these devices are

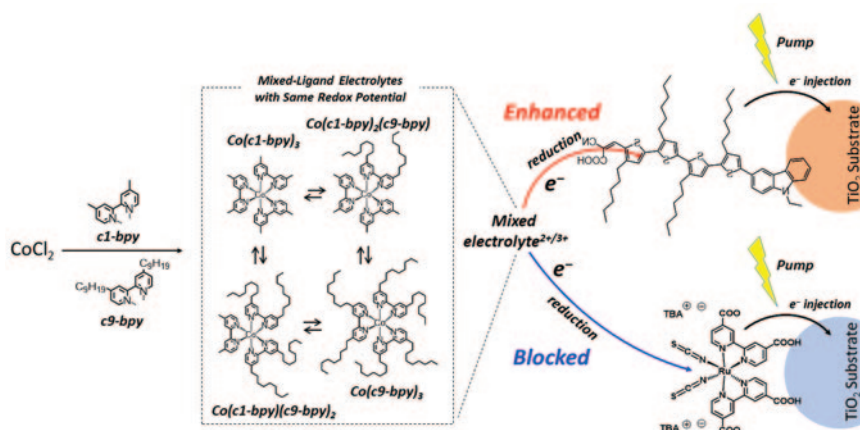
made of organic molecules that can conduct electricity, but despite the technological progress, the fundamental mechanisms of electrical conduction in organic semiconductors have been incompletely understood. The most

common approach has been to assume that charges hop from one molecule to another, but this assumption can underestimate charge mobilities by an order of magnitude or more. The Kassal group at the University of Sydney has recently uncovered that even small amounts of intermolecular delocalisation can dramatically enhance carrier mobilities (Balzer D., Smolders T.J.A.M., Blyth D., Hood S.N., Kassal I. *Chem. Sci.* 2021, doi.org/10.1039/D0SC04116E). Even if the charges are smeared out over fewer than two molecules on average, the predicted mobility can increase by a factor of ten. This finding explains the failure of classical hopping models and underscores the promise of engineering subtle quantum-mechanical effects to improve the performance of molecular devices.

Tuning electron transfer with mixed-ligand electrolytes

To meet various requirements of electron transfer (ET) using redox electrolytes, using a mixture of redox couples could offer increased design flexibility. The ET behaviour of multi-redox electrolytes is explained by the redox potential difference within a reaction cascade. While several beneficial applications have been demonstrated in energy conversion, their fundamental limitation is the loss of electrochemical energy as electrons are transferred within the cascade.

Researchers at the University of Wollongong and Shinshu University (Japan) have demonstrated a new concept of a multi-redox system termed a 'multi-ligand electrolyte', in which the redox species have the same redox potential, but different ET rates due to their molecular substituents (Cho I., Wagner P., Innis P.C., Mori S., Mozer A.J. *J. Am. Chem. Soc.* 2021, **143**, 488–95). The team synthesised asymmetrically substituted $\text{Co}(\text{bpy})_3^{2+/3+}$ complexes



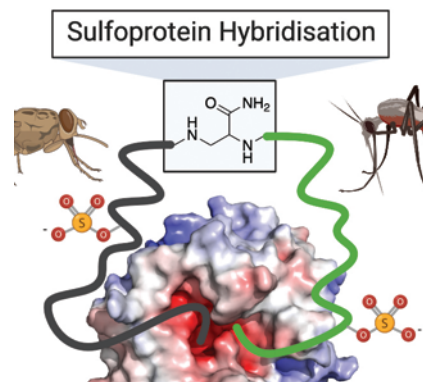
(bpy = bipyridyl) containing various ratios of dinonyl- and dimethyl-substituted ligands. Due to fast ligand exchange, four complexes were formed with the same redox potentials. The ET rates of the mixed-ligand electrolytes were enhanced when paired with substrates on which molecules with alkyl chains were adsorbed and blocked when the adsorbed molecules lacked alkyl

chains. The substrate-dependent behaviour was explained by selective intermolecular interactions, which opens up novel ways to tune ET rates simultaneously in applications containing multiple ET interfaces, such as in redox-mediated photocatalytic and energy-conversion systems.

Anticoagulants inspired by nature's bloodsuckers

Blood-feeding organisms such as ticks, leeches, flies and mosquitoes have evolved a variety of exquisitely potent protein-based anticoagulants to facilitate acquisition of their blood meals. These molecules typically act by binding to both the active site of thrombin (a key protease involved in blood coagulation) and one of its two positively charged exosites (exosites I and II). This binding is assisted by native sulfation of one or more tyrosine residues. An international team led by Richard Payne at the University of Sydney has recently used these insect-derived anticoagulants as inspiration to rationally design a series of

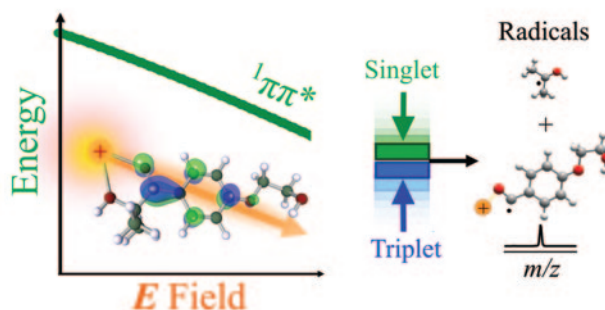
novel thrombin inhibitors through hybridisation of exosite I and exosite II binding inhibitors (Agten S.M., Watson E.E., Ripoll-Rozada J., Dowman L.J., Wu M.C.L., Alwis I., Jackson S.P., Pereira P.J.B., Payne R.J. *Angew. Chem. Int. Ed.* 2021, doi.org/10.1002/anie.202015127). The target hybrid inhibitors were assembled by bidirectional solid-phase synthesis, together with two different peptide-ligation techniques. The engineered sulfoproteins spanned both exosites as well as the active site of thrombin and exhibited femtomolar inhibitory activity against human thrombin and potent



anticoagulant activity in vitro. A lead hybrid was also shown to possess potent in vivo activity in a murine model of thrombosis.

Charge up your photoinitiators

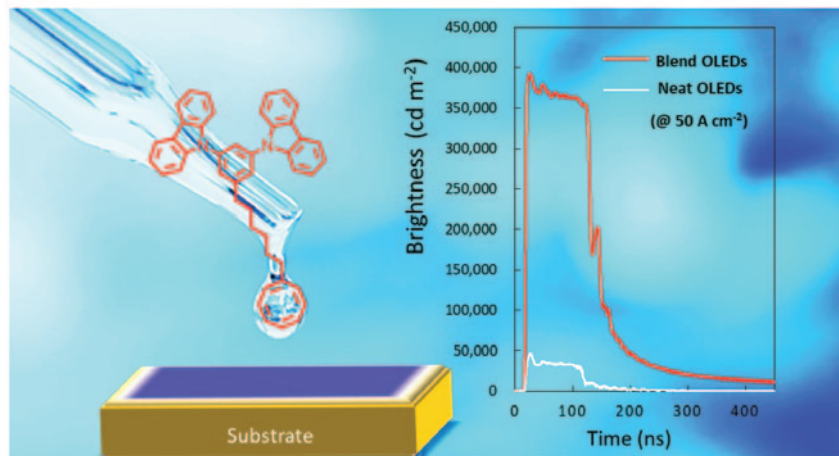
Oriented electric fields can influence chemical reactivity and recent research is applying this idea to enhance the performance of photoinitiators. Importantly for photoinitiators, shifts in the absorption transition must be considered along with shifts of other excited states that mediate activation (e.g. α -cleavage bond homolysis). Researchers at the University of Wollongong and Australian National University have shown how oriented electric fields, arising from single monatomic cations, can be used to tune the photodissociation of a common photoinitiator, Irgacure 2959 (Marlton S.J.P., McKinnon B.I., Hill N.S., Coote M.L., Trevitt A.J. *J. Am. Chem. Soc.* 2021, **143**, 2331–9). Mass-selected cation–Irgacure complexes were selectively confined within an ion trap and irradiated with tuneable laser photons. Photodissociation events were then detected by mass spectrometry. Analysis of shifts in the photodissociation action spectra with quantum-chemical calculations showed that the electric field arising from the cation perturbs the key electronic states. In some cases, the



cation caused a >1 eV red shift in the action spectra along with variations in the α -cleavage yield of up to four orders of magnitude. The study shows how oriented electric fields can shift electronic quantum states to tune photoinitiators by affecting both absorption profiles and photodissociation pathways.

Efficient triplet quencher for organic lasers

Since their invention, lasers have been applied in a wide range of areas, from fundamental science, photolithography and industrial laser cutting to surgery, imaging and biosensing. Organic lasers offer various advantages over inorganic lasers, including compact size, high mechanical flexibility, transparency and wavelength tunability. However, to achieve organic laser diodes, extremely high current densities or optical brightness are generally required, adversely resulting in high levels of triplet-exciton accumulation. These non-emissive triplets are detrimental to lasing because they lead to significant losses under continuous-wave (CW) operation and/or electrical excitation through processes such as triplet absorption, singlet–triplet annihilation and triplet–polaron annihilation. Now, researchers at the University of Queensland, collaborating with teams at Flinders



University and Kyushu University (Japan) have developed an efficient solid-state triplet quencher that effectively suppresses singlet–triplet annihilation under both optical and electrical excitation (Mai V.T.N., Ahmad V., Mamada M., Fukunaga T., Shukla A., Sobus J., Krishnan G., Moore E.G.,

Andersson G.G., Adachi C., Namdas E.B., Lo S.-C. *Nat. Commun.* 2020, **11**, 5623). The quencher also shows negligible effects on laser-dye photophysical properties but results in a 20-fold increase in photostability under CW excitation – a significant step towards organic laser diodes.

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.

Home practical activities during campus closures

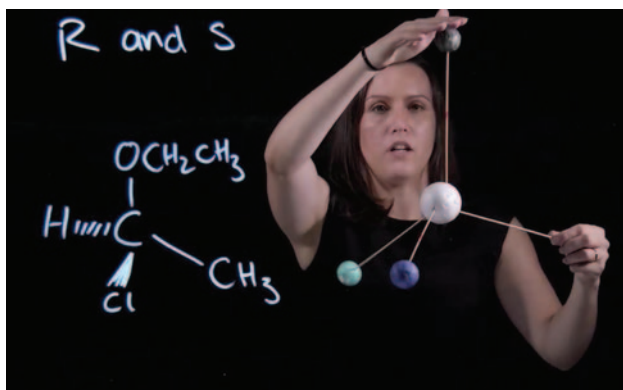
During first semester 2020, along with most institutions, the authors were unable to run their usual practical activities for a large foundational chemistry unit. They did not want to use only online learning activities because they wanted to give their students the opportunity to use all their senses and engage with their hands. Instead, the authors developed two sets of simple, safe activities that students could complete at home using common household items. Each activity included worksheets requiring students to record their observations and apply theory taught in class, and perform some calculations. Although not a laboratory experience, this was nonetheless a practical experience, focused on observation skills, measurement and significant figures. The proportion of students who submitted online chemistry practicals was the same as typically attends face-to-face practicals (90%), and the feedback was largely positive from students and staff. Since publication of this report, a significant number of enquiries have been received (mostly from developing countries) so it seems that others are likely to adapt and adopt these activities (Schultz M., Callahan D.L., Miltiadous A. *J. Chem. Educ.* 2020, **97**(9), 2678–84).



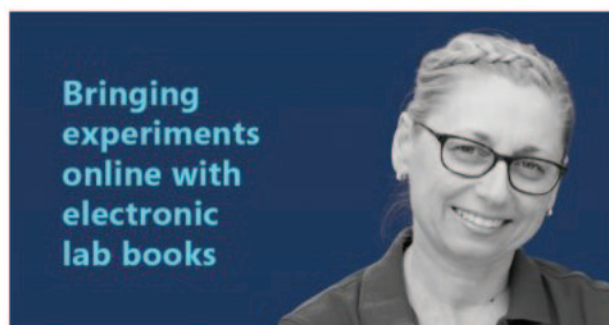
Bringing experiments online

In 2018, at Edith Cowan University, electronic laboratory books were introduced into chemistry laboratory classes to increase student engagement, utilise video and photo capabilities, provide students with feedback on their reports in laboratory class, and share student data. In 2020, chemistry classes moved to a new science building and more than 300 OneNote Notebooks were launched in two first-year chemistry units. On 23 March 2020, alongside many equivalent institutions, Edith Cowan University had to transition to fully online teaching. In a webinar, Magda Wajrak (pictured right) describes how this transition was made seamless by the use of these digital notebooks and Microsoft Teams meetings. The goal was to make the transition to online learning as stressless as possible for students. Wajrak was concerned that students would find it challenging to learn chemistry without doing laboratory work,

Lightboard videos



With higher education now being delivered in either multi-modal or online formats, there is a need to focus more on engaging students outside of their class times. One such resource that has proven engaging for students is lightboard videos. Lightboard videos provide the audience with a clear view of the educator and allow the educator to write out a message (such as a chemical mechanism or chemical equation) on a transparent board that is illuminated to enhance the focus on the presenter and their written message. Stephanie Schweiker (pictured) and Stephan Levonis have evaluated student engagement over the past few years and have found that using short and snappy lightboard videos between classes has increased their engagement. The videos are on-point with minimal details and extended examples. This means they are quick to watch for students practising questions relating to the videos. The authors have found that their students' average test scores have increased, and the students have a strong appetite for this type of resource (Schweiker S., Levonis S. *J. Chem. Educ.* 2020, **97**(10), 3867–71).



an integral part of studying chemistry. To suddenly remove the laboratory component of this unit would make this learning a lot more challenging. She wanted to maintain a rich learning environment online and discusses how she did that by using Teams and OneNote programs. Watch the webinar (bit.ly/3jjJl8L) for more.

Comparing success of online and face-to-face learning

In this study, the authors compared the standard offering of a large foundational chemistry unit in 2019 with an online version in 2020. They were interested to examine the relationship between student engagement with learning activities and assessment tasks, and student success in the unit. The authors examined the completion and scores on two weekly online assessment tasks, as well as the uptake of learning activities, including lectures with in-class polling and tutorials, which moved from face-to-face in 2019 to online in 2020. The drop in level of engagement in the low-stakes assessment tasks and learning activities over the course of the semester was similar for both years. Each form of engagement was associated with increased likelihood of success in the unit, whether face-to-face or online. Of the multiple forms of engagement measured, only tutorial participation had a significantly lower impact on student success in the online than the face-to-face environment. Participating in in-class polling, goal setting and reflection activities had the same impact on success in both years (Miltiadous A., Callahan D.L., Schultz M. *J. Chem. Educ.* 2020, **97**(9), 2494–501).

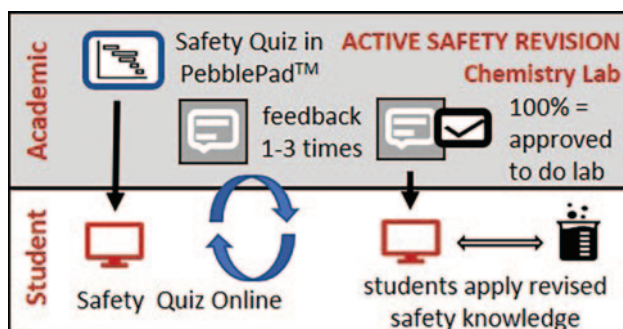


New paradigm for teaching and learning

The COVID-19 pandemic triggered a transformation in teaching and learning as we knew it across schools and universities. On reflection, that whole experience can be considered to be a threshold

teaching event! It is unlikely that everything will return to 'normal' once the pandemic retreats; instead, we will be operating a new paradigm for teaching and learning practice. It is important that we acknowledge that the prior learning experiences of students have also shifted in parallel – their ways of thinking and engaging in their study have also been transformed. There is now an opportunity to work collaboratively towards identifying best pedagogies and practices for hybrid and online teaching. In the editorial of the first issue of *Chemistry Education Research and Practice* this year, Professor Gwen Lawrie as new Editor in Chief (pictured) reflects on how the chemistry education community responded to teaching in response to COVID-19. She also calls for examples of evidenced teaching innovation that have demonstrated positive student learning outcomes embracing the opportunities presented by this new learning landscape (Lawrie G. *Chem. Educ. Res. Prac.* 2021, **22**, 7–11).

Online safety quiz



A flexible strategy to improve students' general knowledge of safety for a second-year inorganic chemistry laboratory was implemented at Griffith University. The strategy used an online interactive revision Safety Quiz Template, that was device agnostic and thus flexible for students and academics. Details of the design process, technical aspects of the implementation of the Safety Quiz Template using PebblePad™ and analysis of submissions for 2018–19 are compared (Loughlin W.A., Cresswell S.L. *J. Chem. Educ.* 2021, **98**, 218–23). Results showed that low numbers of students (18%) achieved 100% correct completion of the Safety Quiz Template with their first submission. However, most students (98%) could achieve 100% correct completion by their third submission and implementation appeared to contribute to improved student knowledge and safe behaviour in the laboratory sessions. The most noticeable aspect of the implementation of a Safety Quiz Template was the identified need for upper-undergraduate chemistry students to revise their safety knowledge regularly and actively for chemistry laboratory environments, beyond any safety training received in first year. Analysis of the student responses revealed the areas for improvement of laboratory safety in second-year undergraduate chemistry included basic chemical knowledge of solvents, maintenance of proper PPE and correct identification of safety equipment.

Compiled by **Reyne Pullen** MRACI CChem (reyne.pullen@sydney.edu.au). This section showcases exciting chemistry education research carried out primarily in Australia. RACI members whose recent work has been published in prominent chemistry education journals (e.g. *Chem. Educ. Res. Pract.*, *J. Chem. Educ.*, *J. Res. Sci. Teach.*) are encouraged to contribute general summaries, of no more than 200 words, and an image to Reyne.



Alchemy *and* chemistry

Lifelong fascinations of a literary great

iStockphoto/Astrid860

BY **PETER G. LEHMAN**

Although Goethe is best known for his literary achievements, he wanted to be remembered as a philosopher and scientist – but this was not to be.

I have been interested in Johann Wolfgang von Goethe's works for more than 50 years. It may have been in my blood even longer. After reading Goethe's book *Elective affinities*,* I began an exploration of Goethe's scientific work, beginning with alchemy.

Johann Wolfgang Goethe was born in Frankfurt am Main in 1749. His father was a wealthy lawyer, who was able to live a life of leisure with his family, travelling and collecting books and paintings. His mother, Katharina Elisabeth née Textor, was the daughter of J.W. Textor, several times Bürgermeister (mayor) of Frankfurt. Young Goethe was home schooled until age 16 and was expected to

follow his father into the law, which he did reluctantly.

As is often the case, his university experience at Leipzig, which had been the centre of Germany's literary revival, presented him with many distractions. It was there that Goethe developed an interest in alchemy, and where the first of his many romantic attachments failed. Following two bouts of serious illness, he began a more detailed study of alchemy while recuperating, before moving to Strasbourg to continue his law studies. All the while he had been writing poetry, prose and a play – the last said to be revenge for his spurned love. His doctoral dissertation, on a subject from ecclesiastical law, which questioned

* The terms *elective affinities* and *chemical affinities*, suggesting attraction, were used by chemists from the 18th century to explain how substances interacted with each other. The concept gave rise to numerous affinity tables, the best known of which is due to E.F. Geoffroy (1718). *Affinity* has since been displaced by the term *free energy*.



J.H.W. Tischbein's *Goethe in the Roman Campagna* (1787). Städel Museum, Frankfurt

the status of the Ten Commandments, was judged to be scandalous and was rejected. He then successfully took the oral examination for the licentiate in law, which allowed him to practise and use the prenominal *Doktor*.

C.A. Burland asserts in *The arts of the alchemists* (Macmillan, 1967) that Goethe's attitude to scientific work was to seek a unity in all of nature. Three types of alchemy are identified by R.D. Gray in *Goethe the alchemist: a study of alchemical symbolism in Goethe's literary and scientific works* (Cambridge University Press, 1952): transmutation (changing base metals into gold); a symbolical representation of mystical doctrines; and a projection of the unconscious mind, leading to an integration of the

personality, as proposed by C.G. Jung. Gray concludes that Goethe was principally concerned with mysticism, but later in life logic eclipsed mysticism for him.

We learn that, following his recuperation, Goethe established a laboratory in the Frankfurt house and carried out experiments such as heating white flints (quartz) from the river Main with sodium hydroxide to produce sodium silicate (*Liquor Silicium*), a result that had been achieved by others more than 100 years earlier.

While in Strasbourg, Goethe made the acquaintance of Johann Gottfried Herder, a young literary intellectual, who encouraged his literary talent and introduced him to the works of

Goethe is revered by Germans to this day. He is recognised as the greatest of the German poets, and an influential novelist and playwright. Tischbein's painting is said to be immediately recognisable to most German people.

In recognition of his high offices and exemplary service, the prince raised Goethe to the nobility and in 1782 he became von Goethe.

management of the Weimar court theatre, more his forte.

From about 1800, Goethe began a collaboration with J.W. Döbereiner, who later became professor of chemistry and pharmacy at the University of Jena. Together, they investigated a wide sweep of technological chemistry, but made no attempts at commercialisation. Aspects of alchemy and chemistry are mentioned in Goethe's literary works: *Faust*, *Wilhelm Meister* and *Dictung und Wahrheit*. Goethe is honoured in the name of a crystalline form of hydrated ferric oxide, goethite and the plant *Goethea cauliflora*.

In 1809, Goethe published his third novel, *Die Wahlverwandtschaften* (*Elective affinities*), which had been written during Napoleon's occupation of the region following the Battle of Jena, a short distance from Weimar. It took its title from Swedish chemist Torbern Bergman's 1775 textbook, *A dissertation on elective attractions*. Ever since, Goethe's book has been studied, analysed, discussed, dissected and interpreted in many different ways. The prevailing view is that it was a metaphor for human relationships.

The book observes the behaviour of a young married couple, Charlotte and Eduard, Eduard's friend the Captain and Charlotte's orphaned and beautiful niece, Otilie, brought together in a big house surrounded by idyllic gardens, describing their interactions in terms of the alchemic laws of chemical affinity.

The house and gardens are likened to a chemical retort, in which the



Temperamentenrose ('rose of temperaments') is a 1798–9 study by Goethe and Schiller, matching 12 colours to human occupations or their character traits (tyrants, heroes, adventurers, hedonists, lovers, poets, public speakers, historians, teachers, philosophers, pedants, rulers), grouped in the four temperaments. Goethe had a great interest in how colour is perceived. Although physicists largely rejected his work *Theory of colours*, it was somewhat influential in the arts world.

Wikicommons/Biedermeier: Die Erfindung der Einfachheit. Hatje Cantz Verlag, 2006

human elements are brought together, allowing the reader to observe the resulting reactions, including the critical double displacement reaction.

In 1817, Goethe saw his son August married, while continuing to write in Weimar. To secure the family finances, he commissioned a final edition of his collected works (then having grown to 40 volumes), including additions to his autobiography and a second volume of *Faust*.

Goethe died at home in Weimar in 1832, aged 83.

Belgian artist René Magritte painted his interpretation of *Elective affinities* in 1933, and in Günter Grass' first novel, *The tin drum* (1959), the central character Oskar refers to Goethe's book for guidance.

Goethe is revered by Germans to this day. He is recognised as the greatest of the German poets, and an influential novelist and playwright. Tischbein's painting is said to be immediately recognisable to most German people. Others have described him as the German equivalent of Shakespeare, while many

saw him as a gifted polymath. His literary contemporary Friedrich Schiller called him a genius. That the German language became widely read and spoken among educated Europeans is attributed to Goethe. Today, the worldwide Goethe Institute continues to promote German language and culture. His literary output was prodigious.

At times, Goethe gave the impression that he wanted to be remembered primarily as a scientist. But his studies in alchemy, chemistry, physics, botany, geology and anatomy were not taken seriously and he was never able to achieve the recognition as a scientist he craved. Goethe is credited with discovering the premaxillary bone in the human skull. But it is his literary works, rather than his scientific excursions, that are today still held in high esteem.

Peter G. Lehman FRACI CChem (pglconsulting@bigpond.com) joined the RACI as a student member in 1963. He pursued a career in industry in Australia and the US, with interludes in academia. He served as editor of *Chemistry in Australia* (1981–4) and in retirement he has written articles for the magazine. A reference list is available upon request to the author.

How isotopes traced Ötzi's origins



BY **ALF LARCHER**

Some stunning analytical chemistry has revealed the story of Ötzi, a Neolithic man whose frozen remains were hacked free from a glacier on the Austro-Italian border after 5300 years.

While hiking in the southern Austrian mountains very close to northern Italy in September 1991, Erika and Helmut Simon stumbled across the top half of a human corpse protruding from glacial ice. Once notified, local authorities thought it was a hiker missing in the area from some years back and they 'hacked' the corpse out of the ice, initially with a jackhammer, resulting in it sustaining some damage. Along with some then-unidentified materials that were collected and bagged, the corpse was taken for closer inspection to the University of Innsbruck. It became quickly evident that the corpse was not a recent victim of the mountains but rather, it was many thousands of years old, having been dehydrated, preserved and

mummified by the ice that encapsulated it. It was another case where post-mortem decomposition processes were slowed by the environment surrounding the corpse (see May 2018 issue, p. 18). The materials collected at the site were found to be personal artefacts of the mummy, comprising clothing, shoes, hunting equipment and a variety of other implements that a mountain-dwelling Neolithic *Homo sapiens* would evidently have.

It became apparent that the mummy was one of the most significant archaeological finds of the century. As this information came to light, the world's attention heightened. What was to become of this man in the ice? His future firstly depended on one fundamental question – was he found in Austria or in Italy? This was

important as the mummy was clearly of great scientific and monetary value.

The mummy, dubbed 'The Iceman' by the press, was found on the very edge of the Ötztal Valley of Austria, and christened with the descriptor of an inhabitant of that valley – Ötzi (pronounced *Ertzi*). The border in this region has been disputed for centuries, with the current agreement signed in 1919 after World War I depending on the line between the highest rock ridges in the area – literally the watershed where rainwater flow is split between the two adjacent valleys.

While the initial discovery was thought to be on the Austria side of this border, subsequent excavation of the site revealed that the glacial ice in the area had retreated to unprecedented levels that summer, and the underlying rock ridges had taken a slightly different course than expected. This meant that the mummy was actually inside the Italian border by 93 metres, in the Schnalstal Valley. The glacial mummy should therefore have been renamed Schnalzi, but it was too late as the original name had stuck.

The survey also revealed that Ötzi's preservation was a stroke of luck. He had been pinned under a rocky ledge and was protected from the inexorable glacial flow, which would have otherwise crushed him.

The border dispute settled, Ötzi was transported from Innsbruck University in an ambulance under police and helicopter escort across the alpine watershed to the new, purpose-built South Tyrol Museum of Archaeology in Bolzano, Italy (see www.iceman.it). I have been reliably informed that Austrian scientists who had looked after Ötzi shed tears during this episode, while others were not happy about the deliberations that had resulted in this terrible loss.

A high-tech refrigerated showcase was constructed for the new Italian, but the first problem encountered was that Ötzi was dehydrating and losing weight at an alarming rate. Museum

scientists were very concerned about their prized specimen, even more so the Museum's management after spending so much money on their new facility. Refrigerated storage of mummies had to be re-invented so that Ötzi would be preserved for posterity at a glacial -6°C and 98% humidity to prevent his desiccation. The observation facility is in a quiet corner of the Museum where visitors can pay due respect to the mummified remains.

The life and death of Ötzi

So why is Ötzi, a 5300-year-old mummified Neolithic European found in a rocky gully 3200 metres in the Alps, so special? Apart from the altitude at which he was found, which was believed to be impossible for Neolithic humans to travail, the technology of his extensive clothing and implements has caused a virtual bonfire of the textbooks to that time.

The Neolithic was a period of tremendous human development, commencing with the beginning of farming about 10 000 BCE and ending with the smelting of ores to obtain metal for tools between 4500 and 2000 BCE. Ötzi was a Copper Age Neolith, possessing both tools made from stone and the first metal humans learned to smelt – copper.

He was not a young man for a Neolith, being about 46, but he must have been fit, strong and very experienced in the skills needed to travel alone in mountainous terrain at altitude. For example, he carried birch bark containers in which he stored glowing charcoal embers that enabled him to start a fire quickly to cook and keep warm. He was very well clothed, having different layers, including leggings, a hefty woven grass cape and intricately woven shoes stuffed with straw for insulation.

He was also very well armed, carrying a small, sharp flint-bladed dagger, a hefty axe with a beautifully



Ötzi's reconstruction by Alfons and Adrie Kennis. © South Tyrol Museum of Archaeology/Ochsenreiter

finished copper blade, and a longbow with a quiver of arrows.

A large variety of Ötzi's personal possessions were also found with him, comprising an incredible array of implements and materials to ensure his survival. These included medicinal plants, highly nutritious berries, an

... when the young Ötzi was thirsty, he would have drunk from mountain streams and springs and incorporated strontium into his system. As his new teeth set, the isotopic fingerprint of the strontium he had ingested was preserved.

antler sewing needle and string among many other items of equipment that he packed into a belt pouch and a rucksack.

Closer inspection of Ötzi's body found that it was covered with about 60 tattoos made by rubbing charcoal into tiny skin cuts.

However, all his technology and endurance did not stop someone shooting an arrow into his back – sensationally found by X-ray imaging 10 years after the original discovery – resulting in his death at his alpine resting place.

The isotope chemists

Ötzi's glacially mummified body has been the subject of intense scientific investigation using a vast array of instrumentation and techniques, including the analysis of a number of isotopes. For the non-scientist, isotopes are forms of an element with

slight differences in atomic structure in the central nucleus; they are the same element and occupy the same position in the periodic table, but all have slightly different chemical and physical properties.

A prime example of the usefulness of this quirk of nature is ^{14}C radiogenic dating, which was used to determine Ötzi's time of death. The technique was developed by Willard Libby in the late 1940s at the University of Chicago, for which he received the 1960 Nobel Prize in Chemistry. It is based upon the continuous production of a radioactive isotope of carbon (^{14}C) in the atmosphere by the interaction of cosmic rays with atmospheric nitrogen. Subsequent reaction with atmospheric oxygen results in the formation of radioactive carbon dioxide. This becomes incorporated into plants via photosynthesis and into the animals that consume them. These



© South Tyrol Museum of Archaeology/Ochsenreiter

processes result in an equilibrium mixture in living plants and animals of ^{14}C with other stable isotopes of carbon (mainly consisting of ^{12}C), and is essentially constant over time. When an animal or plant dies, it stops exchanging carbon in its environment and the amount of ^{14}C in the organism decreases by radioactive decay.

With a half-life of 5700 years, ^{14}C techniques can date preserved animal and plant samples to ten half-lives, or approximately 60 000 years. Because this period covers a tremendous change in human development, it has been referred to as a 'gift of nature' to archaeology.

The downside is that ^{14}C 's low concentration makes its analysis a challenge – its relative amount in the carbon pool is in the order of one part per thousand billion (10^{12}). Historically this has required high sample weights, but modern mass spectrometry techniques using ion acceleration have reduced sample requirements to milligrams.

The samples used to date Ötzi came from his damaged left hip (following the jackhammer episode) as well as grass from his straw cape and left shoe. The finding that about half of the ^{14}C in his body had radioactively decayed revealed that Ötzi died and was cocooned in glacial ice 5300 years ago. This would place Ötzi's age at around 3300 BCE, well before the construction of the Great Pyramid at Giza (about 2570 BCE) and at about the time when Stonehenge construction began (about 3000 BCE).

Another treasure trove for isotope chemists is the teeth and bones of any subject, which encapsulate an isotopic trail about where they grew up, travelled, and where they are now. Ötzi's teeth have been extensively analysed, in particular the enamel, which is an outer layer of mainly calcium phosphate that formed in early childhood. As calcium is deposited, so too is its 'group 2 chemical cousin' strontium, which comes from rocks, and is a common constituent in soil via

weathering and thus the food grown from it, as well as water that has been in contact with the rocks.

Once it is incorporated in tooth enamel during early childhood, the strontium becomes sealed and does not exchange with any further ingestion of the element. This makes things interesting, since strontium exists as a mixture of isotopes that are particular to the rock from which it was derived. Therefore, when the young Ötzi was thirsty, he would have drunk from mountain streams and springs and incorporated strontium into his system. As his new teeth set, the isotopic fingerprint of the strontium he had ingested was preserved.

The archaeological isotopic ratio of interest is $^{87}\text{Sr}/^{86}\text{Sr}$, the latter being stable while ^{87}Sr is formed from rubidium-87 by radioactive decay. This ratio varies significantly with rock age and chemical composition, and for the most part is different for different rock bodies. Analysis showed that the ratio of strontium isotopes in Ötzi's tooth enamel most closely matched rocks south of the alpine watershed. (Archaeologists in the future will hopefully be aware that many of us drink bottled water from exotic places and won't place our childhoods in the French Alps!)

To further determine more precisely where Ötzi spent his early childhood, another favoured suite of the isotope chemist was also analysed. Lead exists as four stable isotopes with mass numbers 204, 206, 207 and 208. The twist in this quartet is that all but the first come from the radioactive decay of uranium and thorium, both of which have different half-lives.

Lead is a common constituent of rocks, and their different ages and compositions provide a characteristic lead isotope fingerprint for each rock type. Once again, ingestion of food and water in contact with these rocks incorporates a lead isotope fingerprint in the tooth enamel during early childhood.

The diverse rocks and water

streams around Ötzi's discovery site have been extensively sampled, and their strontium and lead isotopic composition determined and compared with Ötzi's tooth enamel. The isotopic fingerprints of the tooth enamel match rocks in the vicinity of the discovery site, most closely in the Eisack Valley in Italy approximately 60 km south-east of the discovery site. Some archaeological relics from Ötzi's time have also been found there.

Isotope fractionation

The bane of isotope chemists is that when isotopic mixtures are stored, chemically treated, transferred from one container to another or manipulated in some way, one isotope may be enriched or depleted (or so-called fractionated). However, this has been used as a positive by archaeological isotope chemists, especially in the case of heavy-oxygen water. Oxygen exists as a number of isotopes, three of which are stable: ^{16}O (99.76%), ^{17}O (0.04%) and ^{18}O (0.20%). This results in a significant amount of 'heavy' water (H_2^{18}O) with slightly different physical properties from those of normal water (mainly H_2^{16}O).

In a rain event, the heavier isotope (being less volatile) is enriched in the rainwater while the remaining water vapour is depleted of this isotope. This fractionation is more pronounced as the distance from the source of the rainwater and the actual rainwater increases, as successive rain events during the water vapour's movement results in successive depletions of the heavier H_2^{18}O .

Fractionation is amplified at altitude, such as where Ötzi was found. This is especially the case in the area around the alpine watershed between the Ötztal and Schnalstal valleys, as areas north of the watershed mainly capture precipitation from the more distant Atlantic Ocean, while areas south of the watershed capture precipitation from the closer Mediterranean Ocean. The resulting rainwater in areas south of the watershed has an $^{18}\text{O}/^{16}\text{O}$ ratio



(a) Ötzi's hand axe is the oldest axe found complete with a copper blade, hide strips, birch tar and handle made of yew wood. (b) Casting defects and deformation in the talon of the copper blade. *PLoS One*

slightly higher than in areas north, since it has experienced less rainwater fractionation events.

Just like lead and strontium isotopes, the oxygen from the water consumed during early childhood is also incorporated and sealed in the dental enamel. Analysis of Ötzi's tooth enamel showed that as a child he drank water from south of the alpine watershed, in line with the findings from the strontium and lead isotopes.

However, analysis of Ötzi's bone samples, which are remineralised with ingested substances every 10–20 years, showed oxygen isotope values that were closer to the more northerly discovery site. This indicates that he may have spent time in a more northerly location after childhood.

Getting down to the nitty gritty

I hope that Ötzi wasn't a private person because, apart from knowing where he grew up and travelled, the whole world now knows about his final meal. His stomach contents have been analysed by a variety of techniques, such as DNA fingerprinting, which show that his hearty last meal comprised mainly ibex, red deer and einkorn wheat.

I have hiked the mountains near the discovery site and have seen ibex perched precariously on high rock ledges. They are impressive, big, hairy, goat-like animals with huge horns; I'm

not sure how I'd go hunting one of them with a bow and arrow!

Ötzi's intestinal contents have also been examined in detail and revealed 12 small (100–400 μm) fragments of mica, a rock used commonly to make cereal grinding equipment. Ötzi would have incorporated these mica fragments while enjoying his cereal meals and/or from gritty drinks from the local water sources.

A common constituent of mica is potassium (K), which exists as a number of isotopes in nature. Two of these are stable: ^{39}K (93.3%) and ^{41}K (6.7%). One is radioactive, ^{40}K (0.012%) having a half-life of 1.25 billion years. One of the radioactive decay products of ^{40}K is argon-40 (^{40}Ar), which is the most common isotope of argon (99.6%). Because of the long half-life of this K–Ar system, it is characteristic of many rocks and can be used to date them.

Mass spectrometric techniques have evolved to such an extent that this analysis could be performed on the tiny mica fragments found in Ötzi's intestine. This showed that the micas were from the Italian Vinschgau area approximately 20 km south of the discovery area.

The isotopic data indicates that Ötzi grew up south of the Austrian–Italian watershed in the Eisack Valley, and as an adult spent time in mountains of the Vinschgau before setting off for his

final journey in the Ötztal Alps (doi.org/10.1126/science.302.5646.759b and doi.org/10.1126/science.1089837).

The copper for Ötzi's axe

Hatchets, axes and the like have been found in many archaeological sites, but Ötzi's is still one of the most spectacular of the artefacts found with him. It is in 'as new' condition, complete with wooden handle, rope attachments and pitch tar to hold the 99.7% copper blade in place. It is the oldest implement of this type ever found in its complete form.

Non-destructive analyses showed that the axe was cast from a bivalve mould. The metal was not hardened, even though the technology was available at the time, presumably because Ötzi favoured malleability over hardness.

The provenance of the copper was a question that could not be answered by non-destructive techniques. Historical copper and copper ores from all over Europe have been extensively fingerprinted in terms of composition and trace elements present, so all that was required was an actual sample of the precious axe's copper. After extensive consultation, this was allowed in 2016, and three microsamples of total weight 6.7 mg were removed from the blade and analysed to determine the lead isotope signature and trace element profile.

The composition of the axe blade was similar to a number of copper ores known to be used in Ötzi's time, but what clinched its origin was that the axe's copper contained low amounts of antimony (doi.org/10.1371/pone.0179263).

All the information pointed to copper ore deposits in southern Tuscany. This example of the drive to travel and trade so early in human technological development was a surprise to many anthropologists.

Alf Larcher FRACI CChem is a petroleum, environmental and industrial chemist with an occasional urge to write science articles. Reproduced with permission from *Australasian Science* (www.australasianscience.com.au).

New Fellow



Associate Professor **Debbie Silvester-Dean** is an electrochemist and ARC Future Fellow in the School of Molecular and Life Sciences at Curtin University, Perth. She completed her DPhil (PhD) at the University of Oxford, UK, then spent a short time as an intern for Schumberger Cambridge Research, UK, before arriving at Curtin University in 2009 as a Curtin Research Fellow. In 2012, she was awarded an ARC Discovery Early Career Research Award, and in 2017, an ARC Future Fellowship.

She has published more than 80 papers, two book chapters and two patents. Her work has been cited more than 3600 times, with an *H*-index of 30 (Google Scholar).

She has won various awards for her research: she was named on the 2020 Analytical Scientist Power List, and received the 2019 Rennie Medal (RACI), a 2019 WA Young Tall Poppy award, the 2017 Peter W. Alexander Medal (RACI Analytical and Environmental Division), the 2013 A.M. Bond Medal (RACI Electrochemistry Division), the 2012 Pro-Vice Chancellor's Researcher of the Year Award (Early Career) (Faculty of Science and Engineering, Curtin University) and the 2011 *Electrochimica Acta* Travel Award for Young Electrochemists. Silvester was also a 2013 finalist for the Woodside Early Career Researcher of the Year (WA Science Awards).

Currently, Silvester is Secretary of the RACI Electrochemistry Division, the Australia/New Zealand representative for the International Society of Electrochemistry, and a member of the editorial board for two international journals: *Scientific Reports* and *Frontiers in Chemistry*.

Silvester's research interests lie in understanding electrochemical processes in ionic liquids, from understanding fundamental physical parameters such as reaction mechanisms, solubilities, partitioning, double layer structure, through to analytical applications for the sensing of toxic gases and explosives. She is passionate about promoting the visibility of women in STEM and has appeared as a panel member and a chair for several women-in-research events.

In her personal life, she is a wife and a mum to two daughters, aged 6 and 8. She spends most of her weekends at swimming lessons, at birthday parties, at the beach, hiking in the Perth hills or cycling around her neighbourhood. She loves to travel and is a keen (amateur) photographer.

2020 RACI Distinguished Fellowship

Professor **Mary Fletcher** received a 2020 Distinguished Fellowship. Fletcher is an applied organic chemist with a passion for the application of chemistry in agriculture. She graduated from the University of Queensland (UQ) with BSc (Hons I) and then a PhD in Chemistry with Dr Ray Carman in 1986. Fletcher was then drawn to applied chemistry research, undertaking insect pheromone research with Professor Bill Kitching (UQ) and subsequently with the Queensland



Department of Primary Industries (QDPI). She was awarded a UQ Re-entry Postdoctoral Research Fellowship (1994–6) before once again making the move to QDPI in 2003 to commence a new research direction in natural toxins affecting livestock production. Fletcher has since developed a specialist knowledge of the toxins in poisonous plants and fungi and their impacts on livestock and human health, food safety and food regulations, and is recognised as a national and international expert in this field.

In 2010, Fletcher completed the circle and transitioned back to UQ with the formation of the Queensland Alliance for Agriculture and Food Innovation (QAAFI). For the past 10 years she has led the Natural Toxins Research Group within the QAAFI Centre for Animal Science, with her research influencing agricultural and food industries to improve practices and better manage risks that effect both agricultural production and food safety.

Fletcher has been an active member of the Analytical and Environmental Chemistry Group of RACI's Queensland Branch for many years, as Secretary 2007–11 and Group Chair 2012–14. In 2014, she became President Elect RACI Queensland Branch, and then Queensland Branch President 2016–18. Since 2018, Fletcher has been a member of the RACI Membership and Accreditation Committee, the national committee that assesses all RACI fellowship applications.

Vale Michael Gallagher

Strong supporter of RACI

Associate Professor Michael John Gallagher, who died on 3 October 2020, was an admired and well-respected member of the School of Chemistry at the University of New South Wales (UNSW) and a very active member of the RACI. He was almost 85.

Mike was a Queenslander and did his undergraduate degree at the University of Queensland, followed by an MSc, on natural products, under Maurice Sutherland. He then went to England where he completed a PhD under F.G. Mann in the field of organophosphorus chemistry at Cambridge University in 1962. He was a member of Trinity College and attended Cambridge University at the same time as David Black and Graham Johnston. Then followed two years at the Milstead Laboratory of Chemical Enzymology with Nobel Laureate Sir John Cornforth.

Mike was appointed to the UNSW in 1964 as a lecturer in the Department of Organic Chemistry. He was promoted to senior lecturer in 1969 and associate professor in 1978. He retired at the end of 1996. His field of research was organophosphorus chemistry. He was the only academic in Australia carrying out research in this area at the time. His research interests, as listed in the School of Chemistry Research Activities, include an interest 'Predominantly in the fields of heterocyclic derivatives of main group elements (P, As) and in methods for generating reactive intermediates involved in the chemistry of these organometallic compounds'. He also had interests in the stereochemistry of phosphorus compounds,³¹P, ¹H and ¹³C NMR, phosphorus isosteres and the synthesis of heterocycles containing more than one phosphorus atom.

Mike's organisational activities included being on the editorial board of the journal *Heteroatom Chemistry*, being the Presiding Member of the Faculty of Science in the three years before his retirement. Mike co-authored the School history book celebrating the 50th anniversary of the School in 1999. Together with David Black and Roger Read, in 1990, Mike initiated the annual series of Southern Highlands Conferences on Heterocyclic Chemistry, now into their 30th year.

Away from the bench, Mike was a committee member of the Oriental Rug Society, his interest in oriental rugs being sparked by the chemical components in the dyes. He was also a superb cook and host, and a connoisseur of fine wines. As well, he was in his younger days a very good competition squash player.

Mike's contribution to the RACI was over a long period of time and very significant at both NSW Branch and national levels. Michael joined the RACI in May 1966 and became a Fellow in November 1980. He joined the NSW Branch as Secretary in 1984 and continued in this role to 1991. He became Branch Vice-President for 1992–3 and President 1994–5. He remained on the NSW Branch until 1999, having retired from his UNSW posting in 1996. Throughout his membership of the NSW Branch, he was on the Membership Committee, which subsequently evolved to Membership Development Committee and then Membership Development and Public Relations in 1998.

On the National platform, he was Secretary of the RACI from 1996 to 1999. The RACI incorporated in 2000 with a governing Board replacing its previous administrative structure. As a Board member, Michael was National Representative from 2001 to 2004.

He was awarded a Citation in 1999.

Mike will be sadly missed by his many friends, who at least will retain a legacy of even more wonderful memories.

Together with tributes from many RACI colleagues and friends, a more detailed obituary can be found on the NSW Branch website at bit.ly/3a3D2DA, as well as the UNSW obituary at bit.ly/3q4LIPL.

David Edmonds FRACI CChem

My thanks to UNSW School of Chemistry for the (edited) use of its obituary, and to the contributions by Michael's university and RACI colleagues. My thanks also to RACI National and NSW Branch offices in the provision of RACI records.

OAM awarded posthumously to Graeme Paul

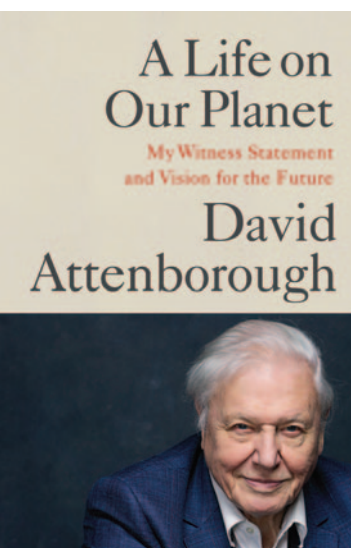
The late Mr Graeme Allan Paul (FRACI 1991) (National RACI President 1995, Chairman of the Industrial Chemistry Division) was awarded the Medal of the Order of Australia on 25 January 2021 for service to the community of the New South Wales Northern Beaches, and to chemical engineering. Graeme was passionate about chemistry helping the community in many aspects both in Australia and in Papua New Guinea (see September–November 2020, p. 30).

Graeme was educated at The Scots College, Sydney, the University of Technology, Sydney, and the University of New South Wales (UNSW School of Chemical Engineering and Industrial Chemistry) (BSc 1970).

Graeme's professional involvement included Selleys Chemical Company, House of Fonteyn, Dermacos, Catoleum, W.R. Grace, F.T. Wimble Inks, SICPA, Hardman Chemicals and K.K. Kingston (Lae, PNG). Graeme was a consultant and legal expert, also working with the late Professor David Trimm and CSIRO on high-temperature/pressure reactors for catalytic conversion of LPG into liquid petroleum fuel.

In the Australian honours system, appointments to the Order of Australia confer the highest recognition for outstanding achievement and service. The Medal of the Order of Australia is awarded for service worthy of particular recognition.

R.F. Ryan FRACI CChem



A life on our planet: my witness statement and vision for the future

Attenborough D., Witness Books (Penguin Random House Group), 2020, hardback, 270 pp., ISBN 9781529108279, \$39.99 (also available as audiobook and ebook)

A life on our planet is both a thoughtful and thought-provoking memoir and offers a road map towards a more secure, sustainable and better future for humans on Earth. In many ways, it is also a deeply troubling book as, in effect, Attenborough holds a mirror up to humankind and says, this is what we have done to our planet, these are the

consequences and if we do not remediate the situation pretty quickly, we are going to suffer enormous consequences.

Author Sir David Attenborough, aged 94, needs little introduction. He has devoted most of his life to keen observation of the natural world and to making the wild world accessible to millions of people through the obvious enthusiasm brought to his career as a commentator. His message is not unique, nor perhaps particularly original. For example, Rachel Carson sounded alarm bells in 1962 with *Silent spring*. Sir James Lovelock (aged 101), possibly best known for proposing the (controversial) Gaia hypothesis, which postulates that Earth functions as a self-regulating system (1960s), was saying much the same. Incidentally, Lovelock, a very interesting person, greatly advanced knowledge about CFCs in the atmosphere with his invention of the electron capture detector (ECD). You should read about this truly remarkable man. Attenborough's unique contribution is that he has been able to intelligently observe and study, at first hand, as it has been occurring, the major decline in the variety of species, the clearing of rainforests for agriculture, the upsurge in the application of monocultures, the acidification of the oceans, the fouling of the environment and the rise in global temperatures. And he offers sound advice on how we might re-wild Earth, restore some balance to our voracious and relentless suborning of our planet, ameliorate a lot of our self-imposed travails and generally improve the future for every creature on the planet.

You might care to ponder why you don't see bees or butterflies as often as you used to. Don't you feel just a little sadness when you view the 1930s photograph of the last thylacine in Tasmania? Of course, not all creatures are nice and cuddly: I dislike a lot of species ranging from spiders to snakes to blowflies! However, by Attenborough's reckoning, if you accept that every creature exists for some role in nature, then it surely follows that wiping out species by 'accidentally' destroying their habitat, eliminating their food supply, shooting them to oblivion, or poisoning them out of existence must have its consequences (like, for example, increased probability of

COVID-19-type events). If you don't believe me, you might like to read of the ship worms in Julian Barnes *A history of the world in 10½ chapters* (1989). It is all a matter of balance.

Attenborough's book all made perfect sense to me. It is well written, logical and minimally judgemental. To say it is pleasant reading is not quite true (bits of it made me feel a tad guilty ... on *your* behalf, of course!), but it is very engaging, quite insightful and somewhat optimistic about our possible future, provided we wake up and act pretty expeditiously. Everybody ought to read Attenborough's reflections and sage words.

Finally, in an act of gross hypocrisy, let me assure you I will in future avoid snakes, but let every spider or blowfly take care lest I 'hit 'em with the old Pea-Beu'. As Dame Mary Gilmour so eloquently put it, 'All men at God's round table sit, And all men must be fed, But this loaf in my hand, This loaf is my son's bread'. Isn't self-interest a terrible thing?

R.J. Casey FRACI CChem

Science fictions: exposing fraud, bias, negligence and hype in science

Ritchie S., Bodley Head (Penguin), 2020, hardback, 368 pp., ISBN 9781847925657, \$39.99 (also available as paperback, audiobook and ebook)

Science fictions: exposing fraud, bias, negligence and hype in science is a most interesting and intriguing book. When I recently reviewed Naomi Oreskes' *Why trust science* (September–November 2020 issue, p. 32) the conclusion was that one could basically trust science because of its rigorous social vetting processes. Ritchie's book may well convince you to trust science about 'as far as you can throw it'!

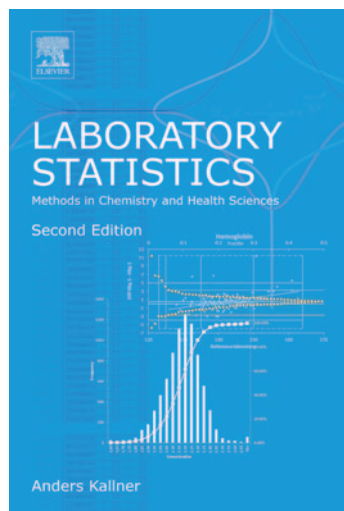
Author Stuart Ritchie lectures in the Institute of Psychiatry, Psychology and Neuroscience at King's College London. Accordingly, most of his case studies are drawn from the realms of the social rather than physical sciences. This is not to say the physical sciences are free from fraud, bias, negligence and hype. Let me give you a simple example from my own experience of observing university students performing titrimetric analysis. (In triplicate, of course! Why? Because it substantially narrows the confidence interval.) Almost invariably, the first titration sees the eyes focused firmly on the flask. In the subsequent two, the emphasis tends to shift to the burette reading. That is how one gets concordant but possibly biased results. Interestingly, Ritchie cites *Organic Syntheses* where an editorial board member tries to replicate the results of every submission as having a 7.5% failure rate because the result cannot be replicated.



We have all seen the results of poorly designed experiments. You only have to look in the daily papers and on television at the plethora of bilge on fad diets, over-hyped claims of medical breakthroughs, and brilliant discoveries promulgated shortly before the research grants 'season' gets underway. Academic career advancement is closely related to securing funding grants, research output and publication. There are games to be played with publication, including a sort of 'never mind the quality, just feel the width' strategy, which Ritchie refers to as 'salami slicing'. There are well-known games to be played with statistics, particularly with small data sets but also by careful selection and de-selection with large sets. Remember all the codswallop of Daltonism, of white people being inherently brighter than black people, of all the endless to-and-fro arguments about how to teach reading or whether co-education is better or worse than gender-segregated education. If you start off with a dodgy premise or belief and you are a half-way-smart statistician, you can probably fool a lot of people a lot of the time.

So, Ritchie unveils all the tricks, chicanery and outright lies pervading science in an accessible and entertaining manner. This is a very interesting, well-written and informative book, certainly well worth reading. And if you fancy having a go at gaming the system, this book just might give you ideas, which is quite, quite the opposite of Stuart Ritchie's intentions.

R.J. Casey FRACI CChem



Laboratory statistics: methods in chemistry and health sciences

Kallner A., Elsevier, 2019, 2nd edition, paperback, 174 pp., ISBN 9780128143483, \$118

There are, supposedly, three kinds of lies: lies, damned lies and statistics. If you hunt around for the origin of this bon mot, you may find yourself (on average, if you see what I mean) more confused than enlightened. One contribution I came across suggested a Google search revealed 42.9% of respondents believed it originated

with Benjamin Disraeli, 27.4% with Mark Twain, 27.3% with Winston Churchill, and 21.7% believed it to be anonymous. Recently, in an otherwise quite erudite book, I came across an analytical result quoted as (something like) $12.21 \pm 0.000\,024\,689$ ppm. One can but gape in awe of the wonders of Microsoft Excel and the god-like omniscience of computers and calculators. If I had a dollar for every laboratory report on which I have written 'Sig. Figs!' I would, indeed, be

wealthy. Every day in newspapers and on television screens, we are bombarded with numerical data and graphs, frequently skewed, plotted less than honestly to advance some dubious point, even with totally inappropriate coordinates or values, and presenting a biased perspective or a version of 'alternative truth'. The current COVID-19 pandemic provides an excellent source of shonky statistics. So, any book trying to sort out the statistical chaff from the wheat must be valuable and worthwhile.

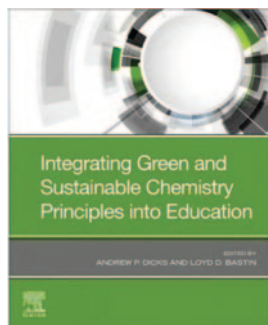
Laboratory statistics: methods in chemistry and health sciences (2nd edition) certainly addresses those statistical procedures appropriate for treatment of chemical data. That it does this in about 160 pages is both its strength and a weakness. The strength is that pretty much everything you might need to help you analyse your data is presented in the book. The weakness is in the brevity; there is very little discussion of the background to tests or what their validity, meaning or best applicability might be. The book is difficult to read, prescriptive and very much a statistical 'cookbook'. My overall impression is its ideal reader is somebody who says, 'Blow all this understanding claptrap! Just tell me what to do!' While this is probably better than nothing, it encourages a black-box syndrome and an unholy reliance on computer-generated numbers.

Many of the treatments covered are amenable to calculation using Excel and the book outlines these. This is good. At the very least, it saves you time reinventing the wheel. Excel is certainly one of the most inventive and useful computer programs ever developed. One can but marvel at its ability to produce all sorts of statistical outputs (and to 15 decimal places) at a few strokes of the keyboard. Unfortunately, the propensity to cite meaningless statistics, simply because they are calculable, can sometimes obscure rather than clarify. Again, let me stress the need for understanding, lest we fall into the garbage-in-garbage-out trap. There are, indeed three sorts of lies!

Author Anders Kallner is from the Karolinska University Hospital, at the Karolinska Institutet in Stockholm, Sweden. His background ranges across chemistry, biochemistry, clinical chemistry and medicine, which provides an excellent pedigree for writing about statistical methods for chemists and health sciences.

So, overall, this book is reasonably good as a quick abbreviated compendium of statistical methods for chemists and health scientists. My real quibble is a feeling that if you want to quote statistics, then you ought to understand exactly what they mean. I did not feel this book covers this understanding as much as I would like. I am all for making the third edition twice as long!

R.J. Casey FRACI CChem



Integrating green and sustainable chemistry principles into education

Dicks A.P., Bastin L.D. (eds), Elsevier, 2019, paperback, 255 pp., ISBN 9780128174180, \$118 (also available as ebook)

As Kermit put it, 'It's not easy being green'. Accordingly, *Integrating green and sustainable chemistry principles into education*

suggests a step in the right direction for chemical educators. Green chemistry rests on 12 broad principles developed in 1991 by Paul Anastas and John Warner at the US Environmental Protection Agency. There is nothing terribly radical about the principles. They all make extremely good sense and group naturally into two sets centred on risk reduction and minimising environmental footprint. It is essentially about walking safely and gently on Earth. If you wish to re-familiarise yourself with these principles, the USEPA website has some nifty downloadable (free) green chemistry bookmarks.

However, even more fundamental than these principles is the engendering of attitudes and practices, which is where education comes into play. In 1984, Donald Schön wrote a seminal book, *The reflective practitioner: how professionals think in action*, which ably advocated the positive role of reflection on practice. This is entirely consistent with a role for green chemistry in chemical education: to produce reflective practitioners. In some aspects, this has been successful. Most undergraduate students would have some understanding of material safety data sheets and be required to submit checklists outlining potential hazards before commencing a laboratory exercise. Hopefully, they will carry an appreciation of safety matters into their future careers. My guess is that a lot fewer neophytes would be required to reflect on less hazardous means to the same end, or ways for minimising waste, maximising yields or increasing energy efficiency. However, as one-time Victorian governor Dr Davis McCaughey put it, 'students need time to waste and places to waste it in, if they are to become reflective men and women'. It takes time to reflect and science courses often have little to spare. Is less laboratory work and more reflection the answer?

Sustainable chemistry is a broad church, concentrated on measurement of an environmental impact as a tool for

enhancing consideration or sensitivity to environmental issues. Like green chemistry, the aim is to get students to reflect on practice and hopefully move towards more sustainable practices.

Accordingly, I was a little disappointed with this book. It is a series of nine discrete chapters written by 12 authors. Editing multi-author works could be compared to herding cats, a complex operation almost inevitably of limited success. Here, the chapters do not relate to each other in any obvious way, as one might expect. Each chapter is, however, well referenced, meaning if you do find a chapter of interest to you there is plenty of opportunity for follow-up. The first chapter ('Green chemistry as the inspiration for impactful and inclusive teaching strategies') summarises a lot of useful material. Chapter 2 ('Incorporating elements of green and sustainable chemistry in general chemistry via systems thinking') also provides useful insights. Mostly, the book seems to be about environmental chemistry, which I suppose can be viewed as a subset of sustainability. One notable exception is a chapter advocating the use of microwave ovens in the organic laboratory as an example of application of the green chemistry maxim of energy reduction. That may be true or not: you would really need to do some life-cycle analysis on laboratory microwave ovens as well as considering capital costs before you leapt in.

My suggestion is that if you are looking for a good book about the interaction between green and sustainable chemistry and education, this book is probably not the one. Obviously, if particular chapters interest you (and you can find them listed on the Elsevier website), then go for it!

R.J. Casey FRACI CChem

Sustainable chemistry is a broad church, concentrated on measurement of an environmental impact as a tool for enhancing consideration or sensitivity to environmental issues.



An atomic absorption spectrometer. iStockphoto/sergeyryzhov

Looking at light

We can see the colour spectrum, but we do not sense much beyond this tiny region. Beyond visible light, we feel the warming effect of heat, see the chemical changes wrought by ultraviolet light, and experience the damage caused by excess infrared, X-rays and gamma rays. However, our senses cannot interrogate these types of electromagnetic radiation directly. To do that, we have made use of electromechanical intermediaries that allow us to sense, interpret and exploit this extended electromagnetic radiation range in both directions.

So just how far has this widened our personal and scientific worlds?

Think big – think the cosmos

Thirteen billion years of cosmic history would be guesswork without the ability to study the chemistry of distant objects from their spectra; their distances and speeds and directions (including their Doppler shifts), all by exclusively using spectroscopy.

The weak anisotropic universal long wavelength microwave radiation turned out to be a mighty Doppler shift from the time

of the ultra-short emissions of the Big Bang at the birth of the universe. This discovery buried the Steady State model, in which the constantly expanding universe is said to maintain its density due to creation of matter. Dark matter, as postulated to explain gravitational anomalies, cannot currently be detected directly 'precisely' because it does not interact with electromagnetic radiation.

Agriculture and mining

Back on Earth, Alan Walsh at CSIRO brilliantly realised in the 1950s that combining absorption with emission could solve myriad analytical problems in industry.

Particularly in Australia, trace elements in soils are crucial to the success of agriculture. Walsh's development of atomic absorption spectrometry revolutionised the efficient quantitative determination of metals critical to agriculture and mining.

Mining boomed in Australia in the 1960s: iron in the Pilbara, bauxite in Western Australia, Cape York and the Gove Peninsula, nickel ores at Kambalda, manganese on Groote Eylandt as well

DIY spectrometer

With an empty cereal box and a discarded CD or DVD, you can build a simple functioning spectrograph, a device that splits light into its components. CDs/DVDs have finely spaced spiral grooves that can act as a diffraction grating. (You can find a great set of instructions at www.scienceinschool.org/2007/issue4/spectrometer.)

From this exercise you will learn all about line spectra, both emission and absorption, from the Sun and on Earth, how salt colours a candle flame and the source of the emission lines in fluorescent tubes.

Why does adding solid NaCl result in the light emission of an atomic (neutral) sodium atom? Crystalline salt dissolves in water because the water molecules stabilise the ions. In the heat of the flame, this stabilising effect is removed and some ionic electrons convert to their respective atoms. The colour of many fireworks is a result of the same chemistry.



Ubern00b CC BY-SA 3.0

as the discovery of new phosphate, coal and oil deposits. This quickly created a demand for millions of analyses of exploration samples.

Unlike traditional methods, it is possible for a relatively unskilled person, performing hundreds of determinations per hour, to operate an atomic absorption spectrometer.

Health diagnostics and therapeutic medicine

In medicine, we use X-ray machines, thermal imaging, MRI, PET, radiation treatment and, more recently, the infrared thermometer. CT scans and mammograms use X-rays. MRI uses radio and microwave frequencies. Radiation treatment uses mainly gamma rays. Thermal imaging and infrared thermometers use infrared light.

Airport security



Detection instruments are variously based on X-ray and mini mass spectrometry. These detect explosives, medicines, illicit drugs and metal objects. A relatively new entry is nuclear quadrupole resonance (NQR). The Cinderella sibling to the chemist's all-powerful nuclear magnetic resonance (NMR), NQR doesn't require a (large expensive) magnet. It is particularly useful because of its sensitivity to the nitrogen atom, a component of most explosives.

Ben Selinger FRACI CChem (benselinger39@gmail.com) is Emeritus Professor of Chemistry at ANU. A list of useful references for teachers is available from the author.



If you're admitted to hospital, an oximeter is immediately placed on your finger. It has a very cunning double-beam mini-spectrometer that compares oxygenated with non-oxygenated haemoglobin.

Wikicommons/rama

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Solar panel manufacturing in Australia?



iStockphoto/zstockphotos

During last year's state election campaign here in Queensland, I noticed a large billboard posted by the Greens party proclaiming that, if they win the election, they will be investing taxpayers' money into 'government-owned' solar panel manufacturing in Queensland. They proposed 250 MW of annual solar panel manufacturing capacity, which is between 600 000 and 1 000 000 solar panels (subject to the average power output per panel).

This policy is very clever, managing to kill a few birds with the one stone. These are that solar panels are green and therefore 'good'; local 'manufacturing', as a political slogan, seems to be making a comeback in these COVID times; no other party seems to have this policy, or anything like it; there are more solar panels per person in Queensland than just about anywhere else in the world, resulting in a high awareness factor of the benefits of solar power; and just about everyone knows that solar panels are mostly imported from China, whose political leaders are seemingly trying to bully Australia by instructing various industries to not buy Australian goods and services.

So here is the proposition that I want to explore: would it be possible or sensible to make solar panels in Australia?

First, one must distinguish between the production of solar panels and the production of solar cells. The actual assembly (manufacturing) of solar panels (or solar modules as they are called within the industry) is the very last step in a very long manufacturing supply chain. It is also the 'lowest capex' step in

that, say, the cost of a 250 MW factory (a solar factory output is measured by the annual power produced by the products that are made in the factory) for solar module assembly is a small fraction of that required to make solar cells or solar wafers. At the start of the supply chain, the processing plants that make purified silicon are many, many times more expensive to build and at least three times more expensive per watt than a solar module assembly plant.

For example, one might be able to build a 250 MW solar module assembly plant for about \$US25 million, but that would require assembly equipment purchased from low-cost Chinese companies, which may be directed by their government not to sell to Australian companies. But say, for argument's sake, one could get the manufacturing capital equipment at the same cost as the Chinese companies that do solar module assembly; could an Australian company be price competitive? To cut a long story short, the answer is no.

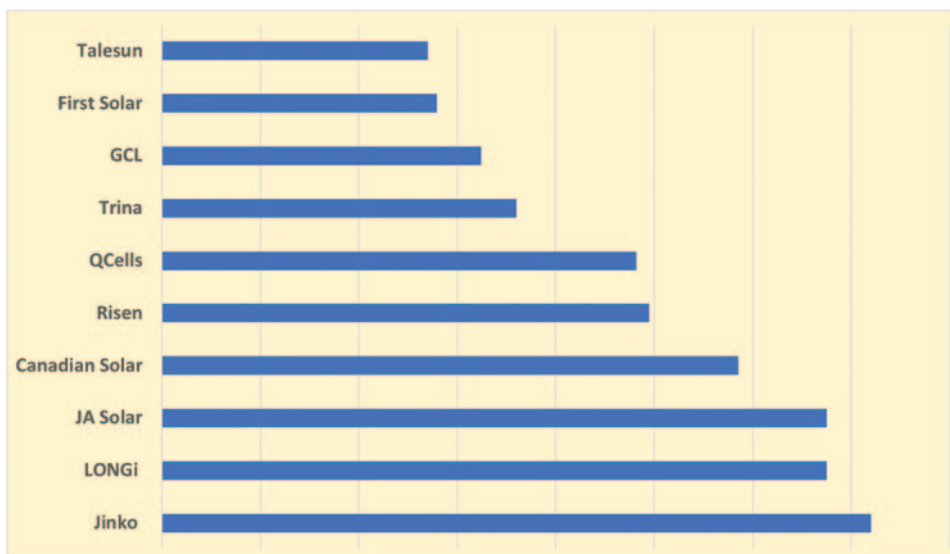
China would out-compete us on price every time because of a number of factors: they would have cheaper access to the key raw material, high-performance solar cells, which are often made by the same companies that do the solar module assembly; they do not always have to pay income tax; they can access much cheaper business finance than is possible in Australia; they have substantially less business red tape in China (i.e. government rules and legislation that adds substantial costs to business); and – most importantly – culturally, the Chinese are in my opinion the best manufacturers

in the world. This is a result of a work ethic that we simply do not have, an unparalleled entrepreneurial spirit by Chinese business owners, and a philosophy of manufacturing that solves problems at their source and through their key suppliers, rather than by adding complexity as we often do in the West. (This observation is worthy of an essay in itself, but think of it as the KISS principle – ‘keep it simple, stupid’.)

Could we in Australia make solar cells, and before that silicon solar wafers, and before that purified silicon? That is, could we attempt to build a whole manufacturing supply chain using raw materials sourced in Australia (being sand, coke and cheap electricity)? No, we could not – not in our wildest dreams. For the reasons why not, just re-read the previous paragraph.

If we did attempt to build a solar module manufacturing capability here, for all the reasons previously stated, the solar module products would be substantially more expensive than Chinese imports. So, does government then start placing import tariffs on Chinese imports so as to create a market for their own more expensive, locally produced solar modules? I am not sure consumers here would think that a good outcome, and imagine the knock-on effect to our already troubled relationship with China. We might also be signatories to a few trade treaties that make this a difficult path to follow.

A final point to note is that, in China today, solar manufacturers are racing to remove labour from their factories through the implementation of ever-more sophisticated automation. This has two key goals: to remove costs and to improve quality (since humans in factories are one of the main sources of yield and quality issues). If we wanted to kickstart



Top 10 photovoltaic module manufacturers, 2020.

Based on information at <https://review.solar/latest-tier-1-solar-panels-list-2020>

If we did attempt to build a solar module manufacturing capability here, for all the reasons previously stated, the solar module products would be substantially more expensive than Chinese imports.

solar manufacturing here in Australia, we must be clear that it wouldn't create many jobs. 'Manufacturing equal jobs' is an obsolete concept that died with the last century.

Looking more broadly than the solar industry, the key points here pretty much hold true for all industries. Currently, Australia is an exporter of 'high-tech' commodities (i.e. low-cost mining and agricultural products) and services (education, tourism and the like). It is perfectly sensible to focus on these sectors as long as we admit to ourselves that we are then dependent upon the mutual goodwill of partner countries that convert our raw materials into products (that are then imported to us), and that also use their collective profits to buy our services. Antagonism to said partners can only be understood in the context of the fool's belief in an alternative future where Australia competes as a manufacturer.

Ian A. Maxwell (maxwell.comms@gmail.com) is a CEO and entrepreneur, and a

Expressing terroir from soil to wine

My thoughts on this topic have come about following a question posed during a Zoom wine tasting late in 2020. The winemaker was commenting on wine characters and alluding to different soil types in the various vineyards from which the grapes had been sourced. This led to the immediate question of ‘just what is the link between soil and wine?’

There are some obvious examples of direct influence of soil on wine composition. In Australia, we have an increasing problem with soil salinity as well as higher salt concentration in irrigation water. The uptake of chloride and sodium from the salt can affect the vine’s physiology as well as giving a ‘salty’ character to the wine’s taste. A long-term study on Shiraz led by Dr Rob Walker of the CSIRO has found that the choice of rootstock to which the Shiraz has been grafted can provide a benefit in terms of reduced salt effects on wine sensory attributes (*Aust. J. Grape Wine Res.* 2019, vol. 25, pp. 414–29). Some years ago, I visited the Hungarian wine region of Somló. This region is situated on the side of an extinct volcano and the high magnesium content of the soil is reflected in the taste of the wine – think Epsom salts! The centuries’ old claims of the health benefits of this wine are still to be justified.

The relationship between vineyard soil and wine composition is more subtle than the direct effects described above. It is clearly a multi-faceted issue, best described as terroir, that involves the soil, the climate, the terrain or topography and the planting material (grape cultivar and rootstock). Human intervention in vineyard management and wine production can reduce or even eliminate the terroir effect if extensive manipulation occurs. If the commercial priority is to produce a wine that is the same or similar in character year after year, akin to beer perhaps, then control of the grape to wine process is important and, when coupled with blending across regions, the terroir influence on the finished product is not relevant.

Terroir has always been seen as a major marketing tool in European wine production, especially in France, Italy and Spain, the regions I know best. It is becoming increasingly important in Australia, especially for smaller wineries that are trying to secure a well-defined market position. Soil plays a critical role in defining terroir. It is the substrate on which the vine grows. Water availability, supply of nitrogen and other nutrients and the capacity to build a stable microflora population (see my July/August 2020 column) are significant aspects of the soil’s contribution to terroir.

The soil, nitrogen, water availability question is something that we studied over a three-year period when I was at the

National Wine and Grape Industry Centre. Using a 1.2-hectare experimental vineyard in the Riverina region, we could manipulate the timing of irrigation and nitrogen addition at three critical periods from bud-burst to harvest. Two important outcomes were the variation in the total amino acid amount as well as changes in the individual amino acid profile. Arginine, an important yeast food, could be enhanced or suppressed depending on the management practice. The role of specific amino acids in the production of wine aromatic compounds has been examined in some detail recently (*Front. Microbiol.*, doi: 10.3389/fmicb.2017.02554), opening up a new aspect of the soil/wine composition link.

In a recent article, Professor Robert White from the University of Melbourne addressed ‘The value of soil knowledge in understanding wine terroir’ (*Front. Environ. Sci.*, doi: 10.3389/fenvs.2020.00012). This comprehensive article expresses succinctly the main issues in the soil/terroir relationship, summarising the present state of knowledge and posing questions that need to be answered to enhance our understanding, particularly the provision of methodologies to map terroirs and to monitor changes over time.

Bordeaux has long argued that the terroirs of its regions play a critical role in determining each region’s wine characters. Professor Cornelis van Leeuwen and his team from the Bordeaux Institute of Agricultural Sciences have been at the forefront in providing a strong scientific basis to the terroir concept. The scientific basis is a major step forward for, as the comedian Stephen Colbert once quipped ‘What’s the use of science if it cannot justify marketing claims!’ The Bordeaux group has reviewed soil-related terroir factors (*OENO One* 2018, vol. 52, pp. 173–88) and extended a part of this review to summarise the measurement and management of the soil effect in terroir expression (*IVES Tech. Rev.*, doi.org/10.20870/IVES-TR.2020.4484). Spatial distribution of soil resistivity (as a surrogate for soil temperature), vine water status and vine nitrogen status can be mapped across a vineyard using 8–10 sampling points per hectare. Enhanced terroir expression can then be achieved by matching planting material and management techniques that are specific to the site. Expect more on this strategy as technology evolves.



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

Chemistry and the pandemic

Australians spending long periods at home during last year's on-again, off-again restrictions on public and private life found many ways to fill in their time and stave off boredom. Vegetable gardens flourished, sales of dogs and bicycles boomed, home cooking was encouraged, and the mysteries of sourdough were explored in many a house. There was a lot of DIY chemistry, but the words 'chemistry' and 'chemical' were not often used by advocates of wellness or sustainability. There was a re-emergence of traditional formulations from grandma's day that included stain removers, cosmetics and garden sprays, and a few new angles on well-being.

Among the 'natural' remedies for almost everything are plant oils, and one that caught my eye (but not my credit card) was bay leaf oil. It's probably the oil of the common bay laurel that we use in cooking, *Laurus nobilis*, but some products use the oil of the West Indian bay, *Pimenta racemose*. The oils are similar: 40–50% eucalyptol (cineole) accompanied by a range of other terpenes. It's the West Indian oil that was used in Bay Rum aftershave, something I haven't seen on the shelves for a long time. It really did contain rum, which functioned to extract the oil from the bay leaves during preparation of the mixture. The rum can be replaced by aqueous alcohol or even another spirituous liquor such as vodka, but the real thing always used West Indian rum. Thinking of aftershaves and male deodorants, I wondered whether there had been a dramatic drop in sales last year when working from home replaced the daily commute, hours of the mingling in the office, and stopping off for a few drinks on the way home.

The shelves of alternative medicines (although they are never called that) in the pharmacy feature a range of magic minerals, too. Looking for a historical example, I dug into my files and retrieved information about a product from the 1930s called 'Bathoids'. Bathoid tablets added to the bathwater were said to 'open the pores of the skin, and dissolve and extract the surplus fat which accumulates in the epidermis' or, to put it another way, 'promotes free and active perspiration whilst you are actually in your bath, which has the three-fold benefit of reducing your weight, generally toning the system, and cleansing the skin of all impurities and making it smooth and velvety'. 'The days of dieting, tiring exercise and internal drugs are passed', read another advertisement. Satisfied customers gave testimony that a pound, or even two or three pounds, of unsightly fat could be lost in a single bath. One actress wrote to say that during eight baths she lost nine pounds, and as you can guess from this the customers being targeted were women. Surely there were markets among jockeys and boxers who were striving to meet weight limits?

The magic ingredient in Bathoids was magnesium sulfate (Epsom salts). Critics, possibly competitors who feared their



livelihood being stolen, claimed benefits had nothing to do with the solute but could instead be ascribed to sweating in a hot bath. If only it were that easy! Looking through the press of the day, I didn't find any warnings that the bather would need to be careful not to ingest any of the bathwater lest there be an unexpected loss of weight caused by this well-known laxative.

Coming closer to the present, the vulgar emphasis on weight reduction seems to have given way to the more subtly expressed benefit of feeling well and getting 'the best sleep I ever had'. Some advocates claim relief from arthritis, allergies and eczema, as well as the lowering of blood pressure. All this can happen in a 'halotherapy' suite – a room lined with blocks of salt, sometimes having a salt bed where the wellness-seeker can recline. To get the customer closer to the salt, a 'halogenerator' in the suite grinds common salt into a dry aerosol and disperses it 'to mimic the atmosphere of a salt cave'. This is a reference to the supposed benefits gained by Europeans who descended into historic salt caves. I have been in such a salt cave, albeit an artificial one in Cheshire where the British alkali industry began. I won't go into the chemistry but just remind readers that the Na of NaCl winds up in NaOH. As a boots-on-the-ground (in this case, under-the-ground) historian of chemistry, I felt pretty good after my visit but I don't think the salt dust in the air was the reason. I did bring back the sample of the salt pictured here and I can make some of it available to anyone with a halogenerator who'd like to try it out.



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



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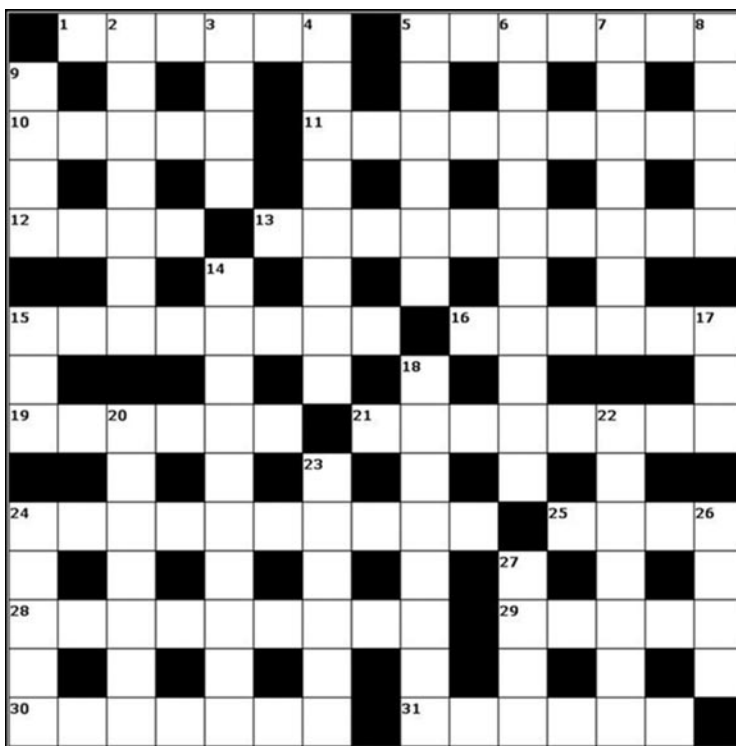
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Across

- 1 Saturated two metals with an electron. (6)
- 5 Degrade mixture of sodium, cerium, helium and phosphorus. (7)
- 10 Double and triple audit E9. (5)
- 11 Perhaps 1 Across and 15 Across break up condoms. (9)
- 12 Questionnaire structure. (4)
- 13 Treat Al/Ag pyrite like a snake. (10)
- 15 See 21 Across.
- 16 There's a mixture of anisole and oxirane for example. (6)
- 19 Electron is one said to be jumped over. (6)
- 21 & 15 Across Academy hired a lot to synthesize vanillin as one example. (8,8)
- 24 & 25 Across Aid cyclic change, adding borax and another compound. (10,4)
- 25 See 24 Across.
- 28 My richest result. It's what we're all about. (9)
- 29 Compound Secret Service came back to including. (5)
- 30 Flame meter damaged - more so than 27 Down. (7)
- 31 Sly try to make $C_6H_5CH=CH-$. (6)

Down

- 2 Relayed new laminate. (7)
- 3 Notice holder for gas is dismissed. (4)
- 4 Fling spade ace away. (8)
- 5 Carbon resin displays convexity. (6)
- 6 See my costs for connecting organisms with each other and their environment. (10)
- 7 Confine two elements and C_5H_8 , some would say. (7)
- 8 Three nose elements. (5)
- 9 Thin metal foil found on 23 Down. (4)
- 14 Cool! Her mix produces $RC(Cl)=NOH$. (10)
- 15 A 50-50 or the whole ball of wax? (3)
- 17 Three elements. As written. (3)
- 18 Lays ring structure for $(NH_2)_2CNHCH_2CH(NH_2)CO-$ residues. (8)
- 20 Forewarning a lousy shelter has been picked up. (7)
- 22 Without explaining, blend titanium with tantalum and yttrium in the presence of chlorine. (7)
- 23 Evergreen: try elm hybrid. (6)
- 24 Krebs discovered one was held by the bankruptcy clerk. (5)
- 26 See 27 Down.
- 27 & 26 Down Pitch 23 and rake dry mixture. (4,4)

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

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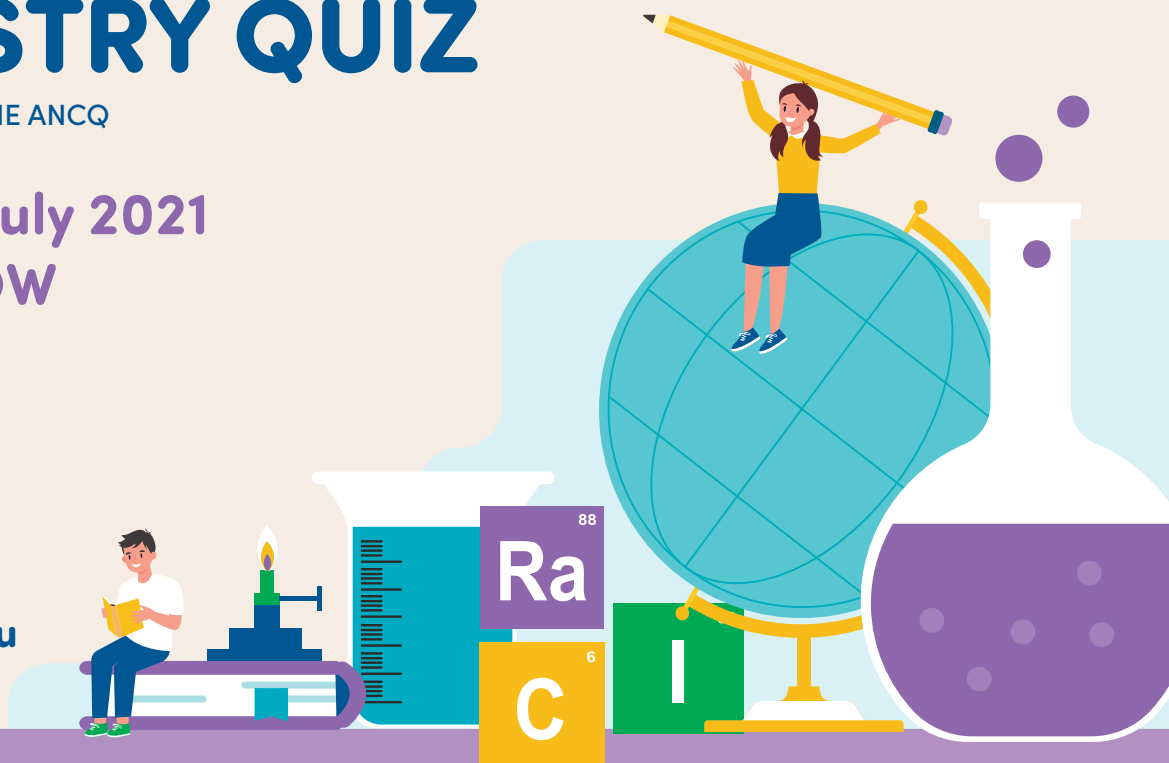
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