

chemistry

January/February 2020

in Australia

Quantum value in a materials economy

chemaust.raci.org.au

- Real versus synthetic: can you spot the diamond difference?
- 2019 scientist salary survey results
- A robotic future on oil and gas platforms

www.rowe.com.au

Online 24 hours 7 days a week, by phone or face to face,
we give you the choice.

INSTRUMENTS - CONSUMABLES - CHEMICALS - SERVICE & REPAIRS



Bel-Art Products



cowie



Gilian

Kartell LABWARE

WMA-ALDRICH



MERCK

METTLER TOLEDO



SIMAX

Tarsons
TRUST DELIVERED



Techno Plas
Dedicated to Plastic Consumables & Quality Packaging

VELP
SCIENTIFICA

witeg
GERMANY

A 100% Australian owned company, supplying scientific laboratories since 1987.

South Australia & NT
Ph: (08) 8186 0523
rowesa@rowe.com.au

Queensland
Ph: (07) 3376 9411
roweqld@rowe.com.au

Victoria & Tasmania
Ph: (03) 9701 7077
rowevic@rowe.com.au

New South Wales
Ph: (02) 9603 1205
rowensw@rowe.com.au

Western Australia
Ph: (08) 9302 1911
rowewa@rowe.com.au



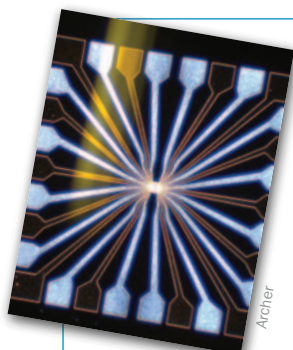
chemistry

in Australia

January/February 2020

36

12



cover story

Chemistry for a circular materials economy

Advances in the fields of materials chemistry are enabling the full lifecycle of a circular materials economy.

On the cover: First components of Archer's qubit processor chip, which is smaller than the width of a human hair.

16 Diamonds forever?

With the advent of chemical vapour deposition to synthesise diamonds, can real diamonds still make the cut?

20 Scientist employment and remuneration

Results of the 2019 salary survey by Professionals Australia, Professional Scientists Australia and Science & Technology Australia are in.

news & research

- 5 On the market
- 6 Research
- 10 Education research
- 42 Events
- 42 Cryptic chemistry

members

- 22 Top stories from the periodic table
- 24 Obituary
- 25 New Fellow
- 26 2019 National Awards winners

views & reviews

- 4 Editorial
- 5 Your say
- 32 Literature & learning
- 34 Books
- 36 Technology & innovation
- 40 Grapevine
- 41 Letter from Melbourne

chemaust.raci.org.au

16



Restoring a remarkable engineering endeavour

On a recent visit to Sale in eastern Victoria, I had some time to wander around its pleasant Victoria Park. At the main entrance sits an imposing water tower, recently restored and opened to the public earlier this year.

The water tower, built in 1888 and with a capacity of 150 000 litres, was used until the 1970s to supply around 3000 residents. Before that, European settlers arriving after the 1850s gold rush in Orbost sourced water from the Thomson River and Flooding Creek, which would have been sullied quickly by livestock. The arrival of the railway in Sale in the 1870s represented a further urgency for water of a quality suitable for both a growing population and rewatering steam engines.

Also in Victoria Park are John Brady's wood sculptures of architect and civil engineer John Grainger (father of composer and pianist Percy Grainger), who designed the tower; and John Niemann, who discovered the artesian water supply, as reported in the *SA Advertiser* in 1881:

One of his [Niemann's] last works was the sinking of an artesian well at Sale, Gippsland, for the borough Council. By means of a bore 2 inches in diameter, and at a depth of 238 feet, he struck fresh water, which rises 43 feet above the surface, and the daily outflow from which is equal to 46,000 gallon!, which is sufficient to supply the town and fill the gutters.

According to Engineering Heritage Victoria, Sale was the first Victorian municipality to trial artesian water as a reticulated public water supply: '... water supply in Sale has been at the forefront of engineering endeavour, from the use of McComas lifts to assist watermen, to the use of artesian water as a source of supply, to the application of flexible membranes for storage.'

The tower offers excellent views of the region if you're willing to climb several flights of stairs to the top. Inside, over three levels, is a museum detailing the history of the tower, including storyboards and displays of water sampling equipment.

The Sale Water Tower is open on Saturday afternoons, and a free audio guide is available at www.salewatertower.com.au. If you're in Sale, you might also like to visit the historic swing bridge at the Latrobe River, the first moveable bridge in Victoria and also designed by Grainger.



Sally Woollett (editor@raci.org.au)

chemistry
in Australia
chemaust.raci.org.au

EDITOR

Sally Woollett
Ph (03) 5623 3971
wools@westnet.com.au

PRODUCTION EDITOR

Catherine Greenwood
catherine.greenwood@bigpond.com

ADVERTISING SALES

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

PRODUCTION

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

BOOK REVIEWS

Damien Blackwell
damo34@internode.on.net

RESEARCH HIGHLIGHTS

David Huang
david.huang@adelaide.edu.au

EDUCATION RESEARCH HIGHLIGHTS

Reyne Pullen
r.pullen@unsw.edu.au

GENERAL ENQUIRIES

Robyn Taylor
Ph/fax (03) 9328 2033/2670
chemaust@raci.org.au

PRESIDENT

Vicki Gardiner FRACI CChem

MANAGEMENT COMMITTEE

Renate Griffith, Helmut Hügel, Colin Scholes, Madeleine Schultz, Richard Thwaites

CONTRIBUTIONS

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

© 2020 The Royal Australian Chemical Institute Inc. unless otherwise attributed. Content must not be reproduced wholly or in part without written permission. Further details on the website (chemaust.raci.org.au).
ISSN 0314-4240 e-ISSN 1839-2539



Orwell and the atomic bomb

In the November/December issue, P.G. Lehman refers to Orwell's essay 'You and the atomic bomb' (p. 34). At about 1450 words, the essay was published in the magazine *Tribune* on 19 October 1945. Its publication was 74 days after the dropping of the atomic bomb at Hiroshima. It was because of the inevitable association of atomic energy with death and destruction that President Dwight D. Eisenhower had an 'Atoms for Peace' policy. An early result of that was the Shippingport Atomic Power Station in Pennsylvania, which began electricity production in 1957 and is correctly described as 'the world's first atomic electricity power plant devoted exclusively to peacetime uses'. There was an atomic electricity utility at Calder Hall in England at that time but its primary function was manufacture of plutonium for weapons, and electricity generation was a bonus, so it was not 'devoted exclusively to peacetime uses'.

Eisenhower's 'Atoms for Peace' policy is usually dated from a speech of that title that he gave before the United Nations General Assembly in December 1953. That is almost four years after George Orwell died.

Clifford Jones FRACI CChem

Chemistry poems

I want to congratulate not only the winners (Daisy Herr and Sam Lang) of the poetry competition organised by the *Double Helix* magazine for school-aged students, but also all the other entrants, and especially Michelle Neil for her excellent selections, which demonstrate the importance of calcium, hydrogen, beryllium, helium, argon, fluorine, lithium and potassium to everyday life (see November/December 2019, p. 30).

It is worth reminding readers of the excellent volume *Chemical poems – one on each element*, written by Professor Mario Markus, in which he presents a choice feast of poetic works covering every element in the periodic classification (*Chemistry in Australia*, April 2014, p. 32).

Alan J. Jones FRACI CChem

Timegate Instruments Ltd joins Bio-Rad's KnowItAll program

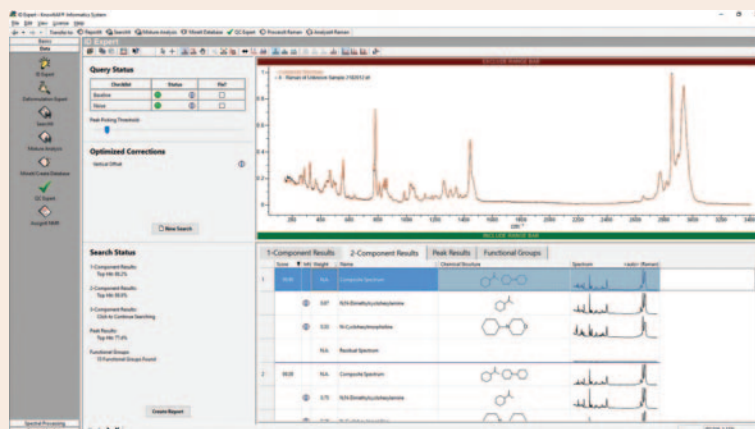
Timegate Instruments Ltd has joined Bio-Rad's KnowItAll Raman Spectral Identification partner program.

Timegate is bundling its Raman products with a one-year subscription to Bio-Rad's KnowItAll Raman Identification Pro, giving customers the ability to identify spectra with patented tools that are only available from Bio-Rad.

Partners who join Bio-Rad's Raman Spectral Identification partner program also have the option to integrate the KnowItAll technology into their software to offer a streamlined customer experience.

Researchers use spectral search/identification spectral software along with Raman spectral reference databases to identify unknown substances and verify the composition of synthesised materials in a number of applications and industries. Bio-Rad's KnowItAll solutions provide search software tools, as well as the most extensive collection of reference spectra used in this type of analysis.

Bio-Rad's award-winning KnowItAll spectroscopy software offers comprehensive solutions for spectral analysis, identification, search, data management, and reporting. It supports multiple instrument vendor file formats and techniques (infrared, Raman, near infrared, nuclear magnetic resonance, mass spectrometry, ultraviolet-visible spectroscopy and chromatography). The software, combined with the world's largest spectral library, helps chemists extract even greater knowledge from their spectral data. Learn more at www.knowitall.com.



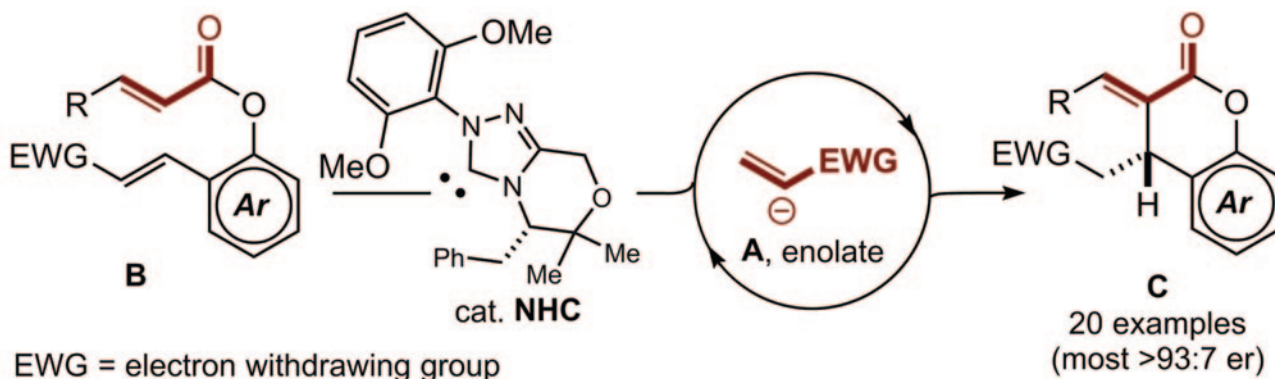
Erratum

In Alf Larcher's article 'How I discovered the periodic law of the elements' (November/December 2019, p. 21) '... the periodic table was ordered by atomic number (the number of atomic neutrons)' should have read '... the periodic table was ordered by atomic number (the number of atomic protons)'. Thank you to the RACI member who brought this error to our attention.

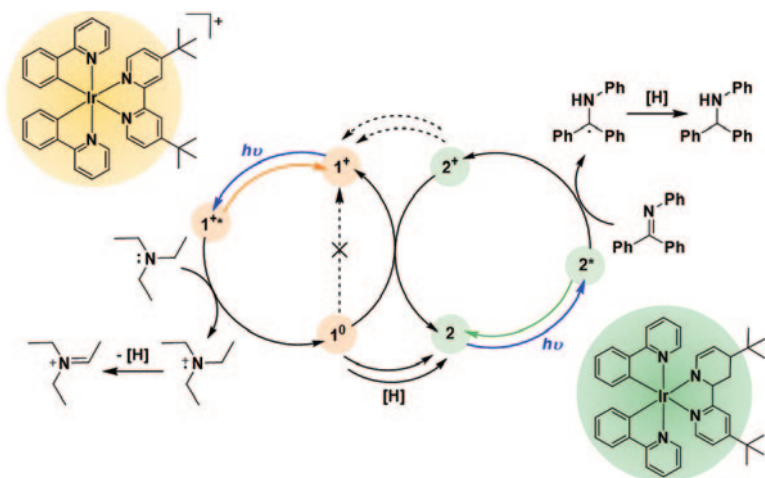
Making better use of conjugate acceptors

Catalysis with conjugate acceptors has a rich history. Some of the earliest work exploits the transient addition of nucleophilic catalysts leading to enolate intermediates (**A**). Despite the discovery of such reactions more than 60 years ago, a series of unmet challenges remains. Within a broader study focused on organocatalysis exploiting conjugate acceptors, David Lupton and his team at Monash University recently examined the reactivity of very poor conjugate acceptors in the Rauhut–Currier reaction. Traditionally such substrates cannot be used in enantioselective reaction designs. But Lupton's team postulated

that such materials can be exploited by using highly nucleophilic catalysts. Led by PhD scholar Song Bae, the team showed that it is possible to cycloisomerise *bis*-ester **B**, a very poor conjugate acceptor, into lactone **C** with high enantioselectivity (most >93:7 enantiomeric ratio) (Bae S., Zhang C., Gillard R.M., Lupton D.W. *Angew. Chem. Int. Ed.* 2019, **58**, 13 370–4). The reaction was achieved using one of the most nucleophilic N-heterocyclic carbene (**NHC**) catalysts known. This chemistry expands the way in which conjugate acceptors can be considered in synthesis design.



Unlocking new pathways in photoredox catalysis



Photoredox catalysis facilitates a wide range of organic transformations by providing ready access to reactive one-electron intermediates under mild conditions. The transition metal catalysts used in these transformations typically either donate or accept an electron, following excitation to a triplet excited

state, through an oxidative or reductive quenching cycle, respectively. While these catalysts have long been considered purely as electron shuttles between organic substrates, a team of researchers from RMIT University, Deakin University, CSIRO and the University of Melbourne has now demonstrated that

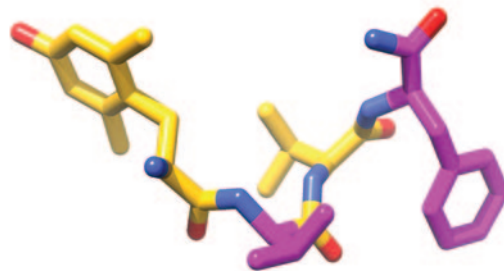
this is not always the case (Connell T.U., Fraser C.L., Czyz M.L., Smith Z.M., Hayne D.J., Doeven E.H., Aguiaro J., Wilson D.J.D., Adcock J.L., Scully A.D., Gómez D.E., Barnett N.W., Polyzos A., Francis P.S., *J. Am. Chem. Soc.* 2019, **141**, 17 646–58). Under the right experimental conditions, the common photoredox catalyst $[\text{Ir}(\text{ppy})_2(\text{dtb-bpy})]^+$ (**1**⁺) is transformed into a new highly reducing complex (**2**) distinguished by semi-saturation of its bipyridyl ligand. The team also showed that these two catalysts work cooperatively, through distinct yet interconnected cycles, in the first known example of a dual oxidative and reductive photoredox system. The work paves the way for new synthetic strategies to engage energy-demanding organic substrates using common iridium photoredox catalysts.

New analgesic based on unusual peptides

Researchers from the University of Queensland and the University of Sydney have discovered a new class of peptides with unusual alternating chirality from which a novel analgesic was derived (Dekan Z., Sianati S., Yousuf A., Sutcliffe K.J., Gillis A., Mallet C., Singh P., Jin A.H., Wang A.M., Mohammadi S.A., Stewart M., Ratnayake R., Fontaine F., Lacey E., Piggott A.M., Du Y.P., Canals M., Sessions R.B., Kelly E., Capon R.J.,

Alewood P.F., Christie M.J. *Proc. Natl Acad. Sci. USA* 2019, **116**, 22 353–8). The peptides, called bilaidis, were isolated from a *Penicillium* species. Given their resemblance to known short peptide opioid agonists, the researchers modified them, leading to the design of bilorphin, a potent and selective mu-opioid receptor agonist. In sharp contrast to all natural product opioid peptides, which efficaciously recruit β -arrestin, bilorphin is G-protein biased,

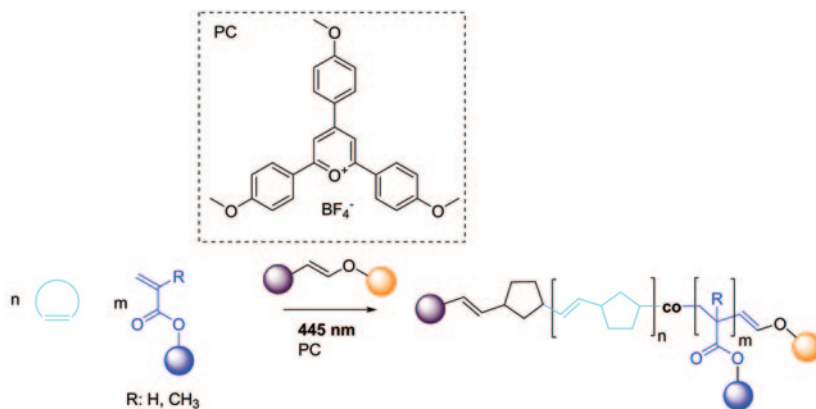
only marginally recruiting β -arrestin, with no receptor internalisation. Molecular dynamics simulations of bilorphin suggested that distinct receptor interactions may underlie its biased pharmacology. Further modifications to bilorphin led to a glycosylated analogue, bilactorphin, which is orally active with similar in vivo potency to morphine.



Hybrid copolymerisation of two monomer classes using visible light

Incorporation of ring-opening and vinyl monomers in a linear polymer chain via hybrid copolymerisation of the two monomer classes is a challenging task. Now researchers from the Soft Matter Materials Laboratory at the Queensland University of Technology collaborating with scientists from the University of Wisconsin–Madison (USA) have demonstrated a visible-light-mediated process using photoredox chemistry that achieves this goal (Krappitz T., Jovic K., Feist F., Frisch H., Rigoglioso V.P., Blinco J.P., Boydston A.J., Barner-Kowollik C. *J. Am. Chem. Soc.* 2019, **141**, 16 605–9). They excited a pyrylium salt with blue light, leading to the formation of a cationic radical on the olefinic ether moiety, which served as the initiator for the living hybrid photopolymerisation. The team proposed a possible underlying mechanism

based on in-depth kinetic studies and size-exclusion chromatography coupled on-line with electrospray ionisation mass spectrometry.

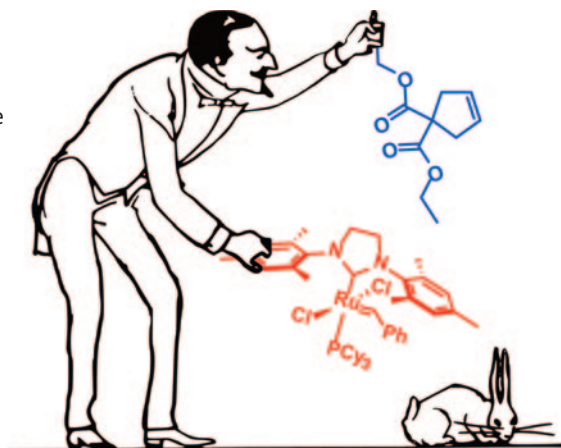


Enhanced diffusion or entranced illusion?

The hydrodynamics of nanoscale objects in solution have important consequences for molecular transport and cellular biochemistry. Recent work has led to surprising reports that enzymes and molecular catalysts are actively propelled through solution by catalysing a chemical reaction in a phenomenon termed 'enhanced diffusion'. The mechanism of this process has been unclear and studies using different analytical techniques have been inconsistent or, in some cases, have failed to find any evidence of enhanced diffusion. Until recently, a single report existed of enhanced diffusion of a small-molecule system, using Grubbs ring-closing metathesis. PhD student Thomas MacDonald and Jon

Beves at UNSW Sydney, in collaboration with Dean Astumian at the University of Maine (USA) and Bill Price at Western Sydney University, have studied this Grubbs catalysed system using time-resolved diffusion NMR techniques that they developed. Probing the reactions with high time resolution, they were able to show the underlying phenomenon to be convective flow and not microscopic diffusion as previously reported (MacDonald T.S.C., Price W.S., Astumian R.D., Beves J.E. *Angew. Chem. Int. Ed.* 2019, <https://doi.org/10.1002/anie.201910968>). These findings have sparked considerable interest, including discussion by Derek Lowe on his *In the Pipeline* blog for *Science Translational*

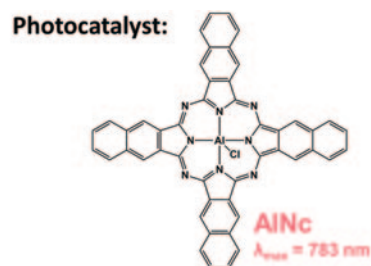
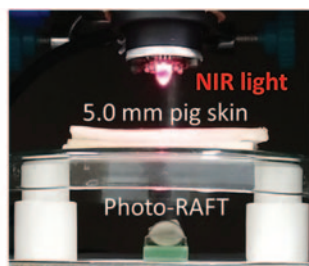
Medicine (<https://blogs.sciencemag.org/pipeline/archives/2019/11/06/enhanced-diffusion-real-or-illusion>).



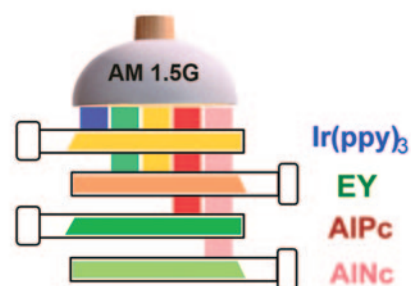
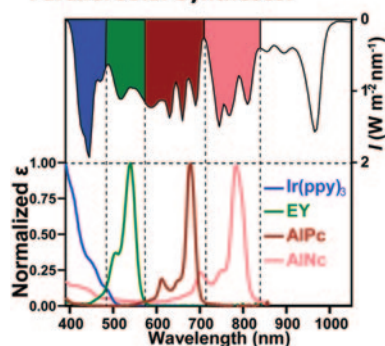
Adapted from www.goodfreephotos.com

To NIR and beyond

A wide variety of photochemical transformations mediated by visible wavelengths have been developed in recent years. Now researchers are looking towards the low-energy radiation in the near-infrared (NIR) region to extend the usable range of the electromagnetic spectrum for photochemistry. Addressing this challenge, a team led by Cyrille Boyer at UNSW Sydney has reported a highly efficient photopolymerisation technique mediated by metallophthalocyanines absorbing in the far-red and NIR regions (Wu Z., Jung J., Boyer C. *Angew. Chem. Int. Ed.* 2019, <https://doi.org/10.1002/anie.201912484>). Efficient activation of peroxides under NIR irradiation afforded fast photopolymerisations in the order of minutes even through non-transparent barriers. The team also showcased an interesting concept for performing chemical syntheses using broadband solar energy. Noting the narrow and complementary absorptions of many photocatalysts, they combined their NIR



Parallel Solar Syntheses:

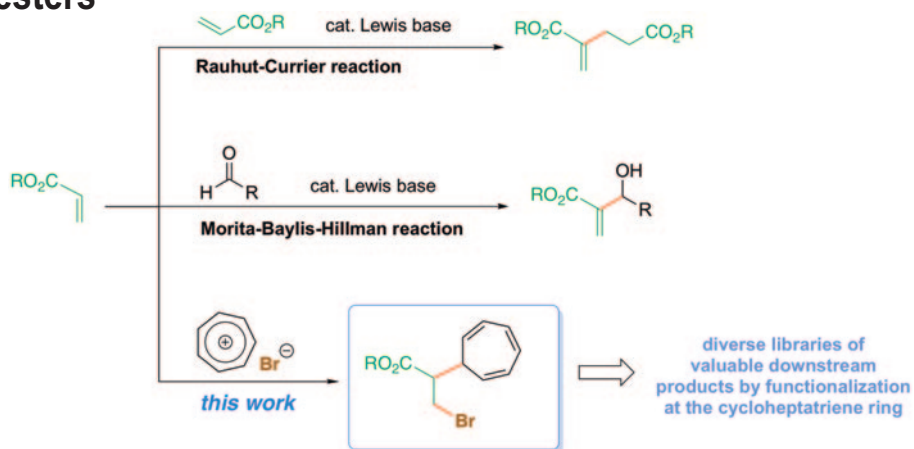


chemistry with previously reported photocatalysts and stacked the segregated reactions so that unused photons could pass through to the layer underneath. This approach facilitated concurrent, independent polymerisations

and organic transformations under simulated sunlight (AM 1.5G). This efficient use of broadband solar energy shows how far the field of photochemistry has advanced from its beginnings of placing flasks on rooftops.

New reaction for acrylate esters

Acrylate esters are versatile building blocks in organic synthesis. Apart from being good acceptors for the Michael reaction, they can also be activated by Lewis-base catalysts, such as tertiary amines and phosphines or N-heterocyclic carbenes for the Morita–Baylis–Hillman and Rauhut–Currier reactions. Vinh Nguyen's group at UNSW Sydney and collaborators have recently developed a new type of reaction with these substrates (Hussein M.A., Tran U.P.N., Huynh V.T., Ho J., Bhadbhade M., Mayr H., Nguyen T.V. *Angew. Chem. Int. Ed.* 2019, <https://doi.org/10.1002/anie.201910578>). They found that tropylium bromide could undergo non-catalysed, regioselective additions to a large variety of acrylic esters and convert them into β -bromo- α -cycloheptatrienyl-propionic esters. Quantum chemical calculations by Junming Ho at UNSW

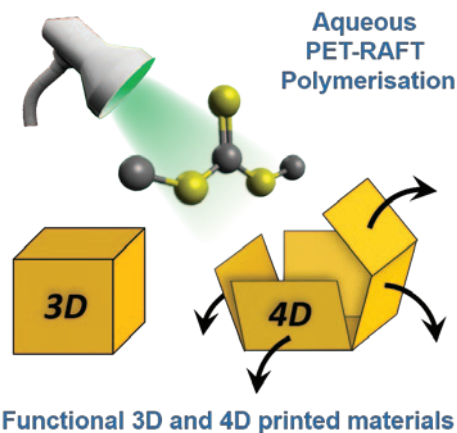


Sydney showed that the reaction mechanism involves nucleophilic attack of bromide ions at the electron-deficient olefins and the approach of the tropylium ion to the incipient carbanion. This reaction is the first example of a more general reaction principle for linking Michael acceptors with stabilised

carbocations, which was confirmed by some preliminary examples. In addition, the resulting bromo-cycloheptatrienylated adducts could easily be further manipulated to yield a diverse range of interesting complex structures, enhancing the synthetic value of this new reaction.

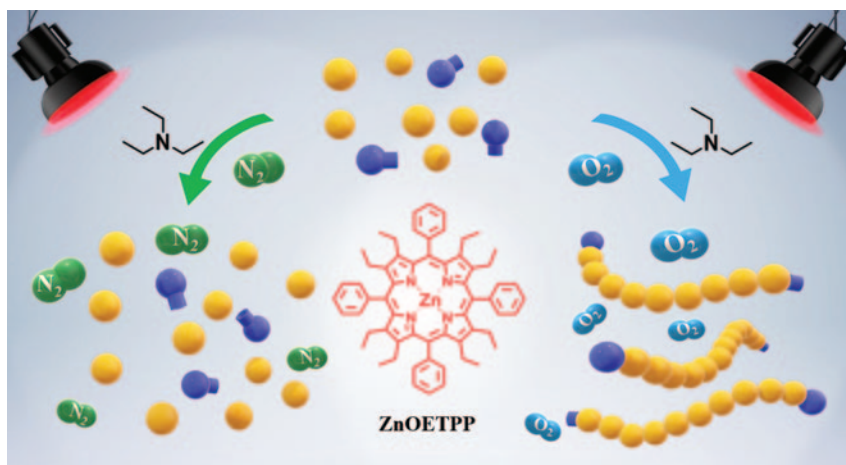
Living polymerisation for 3D and 4D printing

3D printing techniques provide simple ways to produce geometrically complex materials while reducing waste. Typically, objects made from polymeric (plastic) materials cannot be manipulated after 3D printing as the polymerisation process results in 'dead' polymer chains. Zhiheng Zhang, Nathaniel Corrigan and Cyrille Boyer from the UNSW Sydney, collaborating with researchers from the University of Auckland (New Zealand), have reported a significant breakthrough that tackles this problem by combining a 'living' polymerisation process with 3D printing (Zhang Z., Corrigan N., Bagheri A., Jin J., Boyer C. *Angew. Chem. Int. Ed.* 2019, **58**, 17954–63). The photomediated 'living' 3D printing process, based on the RAFT polymerisation process developed at the CSIRO, uses metal-free and non-toxic components in water and is activated by harmless green light irradiation. The polymeric materials can then be modified after 3D printing by performing successive polymerisations from the 'living' chains, which produces 3D printed objects with complex and tailorable chemical and physical properties. Additionally, by controlling the light irradiation, 4D printed materials (3D printed materials that respond to an external stimulus) can be formed, as



demonstrated by 3D printed objects that reversibly folded when exposed to water. This process could facilitate the development of functional and stimuli-responsive 3D-printed materials for varied applications, including nanomedicine and other bioapplications.

Radical polymerisation immune to oxygen



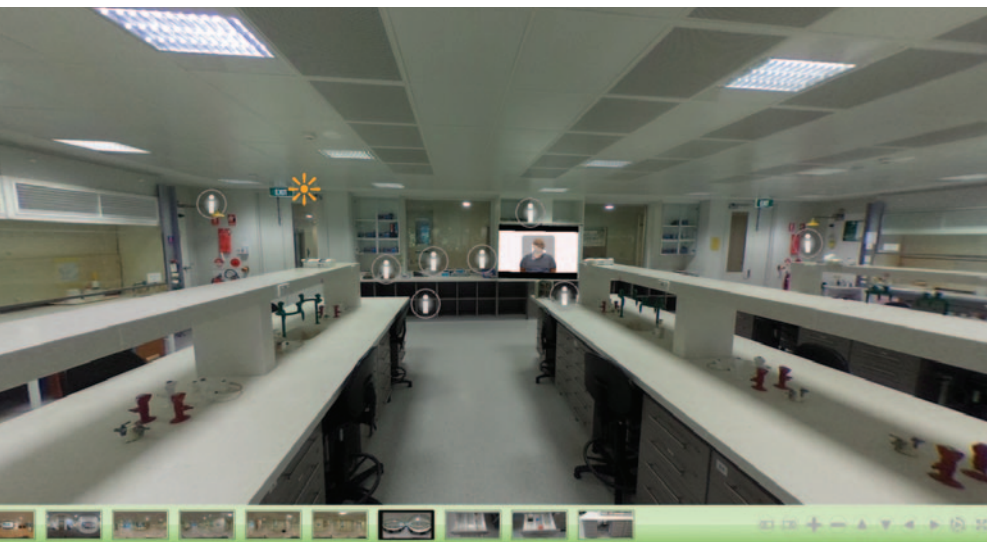
Oxygen and radical polymerisations are two things that traditionally do not go well together. As an efficient radical scavenger, oxygen retards radical polymerisations, which necessitates its removal by techniques such as freeze-pump-thaw or purging with inert gases.

A team of photochemists at UNSW Sydney led by Cyrille Boyer has discovered a peculiar photocatalyst that only induces polymerisation in the presence of oxygen (Zhang L., Wu C., Jung K., Ng Y.H., Boyer C. *Angew. Chem. Int. Ed.* 2019, **58**, 16811–4). By using

an octa-substituted metalloporphyrin absorbing light in the far-red region ($\lambda = 685 \text{ nm}$), polymerisation was found to occur only in the presence of light and oxygen: removal of either resulted in suppression of polymerisation. The researchers exploited this capability to show dual-gated temporal control over the process. As both light and oxygen were required, the polymerisation could be temporarily paused by switching off the light or by purging with an inert gas, such as nitrogen or carbon dioxide. From a combination of experimental and computational methods, it was proposed that oxygen functioned as a catalytic mediator between the various reaction components. This finding paves the way for the design of new photopolymerisation strategies immune to the presence of oxygen.

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.

Virtual tour of laboratory for first-year students



Students entering tertiary education come from diverse backgrounds. As universities encourage enrolment by students from regional and international schools and offer pathways for students already in the workforce, they cannot

guarantee that most will be familiar with a chemistry laboratory and equipment. This is a challenge for academics in first-year chemistry units. There are large numbers of students enrolled in the units; therefore, offering all students a

tour of the facilities before laboratories start is practically difficult. A team of academics at the University of Western Australia, over a two-year period, developed and evaluated the use of a 360° virtual tour of the first-year chemistry laboratories and surrounding areas (Clemons T.D., Fouché L., Rummey C., Lopez R.E., Spagnoli D. J. *Chem. Educ.* 2019, <https://dx.doi.org/10.1021/acs.jchemed.8b00861>). Students can explore the ground floor of the Bayliss Building, travel to their first-year laboratory, visit the technical staff and even look at the common chemistry equipment in the drawer. The evaluation revealed that 92% of students agreed that the 360° virtual tour helped to familiarise them with the laboratory environment while 85% agreed that it helped in their preparation.

Scaffolded online learning for self-directed and inquiry-based learning

Engaging students in the process of independent active-learning within blended learning environments requires careful integration of multiple instructional scaffolding strategies. The aim is to engage students in the process of learning without any synchronous student-teacher interactions or feedback. Hence, the focus during instructional design is on the student-content interactions. In this study, a Predict-Observe-Explain-Evaluate (POEE) framework has been developed to maximise the ways in which students interact with two learning modules addressing concepts of phase change and heat energy (Al Mamun M.A., Lawrie G., Wright T. *Comput. Educ.* 2020, **144**, 103 695, <https://doi.org/10.1016/j.compedu.2019.103695>). Representations of chemical concepts in the form of simulations provide interactivity and four types of scaffolding prompts are embedded to guide students through activities. These prompts include cognitive conflict questions, question prompts (reflective, elaborative and procedural), concept check questions, and confidence check questions. Critical elements of the scaffolding that facilitated student engagement and learning was found to be the provision of immediate feedback, which required a response by students, and question prompts. The latter were observed to play a valuable role in sustaining students' exploration of self-regulated inquiry activities. The findings of this study have enabled the conceptualisation of a multimodal scaffolding strategy for self-directed inquiry.



Student-Teacher Interaction



Student-Student Interaction



Student-Content Interaction

Engaging undergraduates to reflect on their skill development




Many chemistry and other science undergraduates complete university without engaging in meaningful reflection on their learning and skill development. Students are often unaware they are developing important transferable skills during their degree (such as initiative, adaptability, numeracy, creativity, commercial awareness, problem-solving, critical thinking, time management, independent learning and interpersonal skills) and lack confidence and the ability to articulate these skills in job interviews and their CV. To address this, a recent semester-long program at Monash University invited chemistry and other science students to record and reflect on degree-related skill development (Hill M.A., Overton T.L., Thompson C.D. *High. Educ. Res. Dev.* 2019, <https://doi.org/10.1080/07294360.2019.1690432>). The 60 participants were challenged to write a weekly reflection, supported by email prompts and group discussions. Although many students initially found it difficult, with practice they improved their ability to identify skill development experiences and reflect on them, and they identified many benefits from doing so. They gained more value from learning tasks, improved recognition of skill development, strengths and weaknesses and articulated examples they could use in job applications and interviews. Many students also gained motivation to improve their skills and employability. Recommendations are made for how to implement skills reflection in the curriculum so all students can benefit.

ASELL inquiry slider

The ASELL program was initially developed for universities and provides a multi-institutional, collaborative approach for improving undergraduate laboratories and providing professional learning for academics (www.asell.org). ASELL is the expansion of the previous APCELL (Barrie S.C., Buntine M.A., Jamie I.M., Kable S.H. *Aust. J. Educ. Chem.* 2001, **57**, 6–12) and ACELL projects (Buntine M.A., Read J.R., Barrie S.C., Bucat R.B., Crisp G.T., George A.V., Jamie I.M., Kable S.H. *Chem. Educ. Res. Pract.* 2007, **8**, 232–54). It began in 2000 when academics noticed high levels of student dissatisfaction with their undergraduate laboratory courses. In 2012, the ASELL program was extended into schools and received funding through the Australian Maths and Science Partnerships Program (AMSPP). Nodes were established in South Australia, the Northern Territory, Victoria and New South Wales and a regional node was based in Armidale, New South Wales. ASELL aims to support teachers' professional learning to improve the teaching of science at schools (years 7–10) and increase student retention in science. This is done through workshops involving teachers and students, and supporting teachers in developing and improving their current experiments. Pedagogical tools to assist teachers teaching science in schools were developed. One such tool is the ASELL Inquiry Slider (Cornish S., Yeung A., Kable S.H., Orgill M., Sharma M.D. *Teach. Sci.* 2019, **65**(1), 4–12). This tool was developed for use in school classrooms and provides a tangible way for teachers to easily modify their experiments to fit their purpose. This tool has been adapted for use in different states and is also used in university settings.



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.



Chemistry *for a* circular materials economy

Testing of lithium-ion coin cell batteries that incorporate Archer's Campoona graphite from South Australia.

Advances in the fields of materials chemistry are enabling the full lifecycle of a circular materials economy.

**BY MOHAMMAD
CHOUCAIR**

The materials economy has thrived thanks to the contribution of materials to the lives of billions of people on Earth. For a materials-related economy to continue to flourish, the materials sector must use every opportunity to develop a more circular concept to consumption (capitalism is not necessarily a solution), especially with current rapid rates of technological change and demand for new applications. Landfills are rapidly filling with discarded electronics, the oceans are littered with plastic, it is becoming harder to secure the supply of clean water, and the environmental impact of climate change is devastating. The tools, processes and discovery schemes used by chemists and materials scientists today to address these problems are faster and more powerful than ever. We can visualise matter in extreme detail down to the atom scale, run accurate computer simulations, observe

materials' behaviour in real time, and transition across billionths of a metre in length scales to understand materials properties at each level.

Discovery can lead to intellectual property (IP) that can create new revenue streams, jobs and economic growth. Leveraging IP rights for competitive advantages in a market is therefore essential. Advances in quantum computing hardware hold high commercial value, cathode and electrolyte compositions (often performance-limiting) in lithium-ion batteries are well-kept secrets, materials are at the heart of the patent landscape to desalinate and purify water, and IP remains a key issue for cleantechs to raise capital.

The qubit processor chip

Materials that enable quantum information processing could transform all industries that depend on computational power and are at the heart of some of the biggest

challenges in quantum computing. The quantum computing industry represents a rapidly growing sector in the more than US\$500 billion market of the global semiconductor industry. Using materials to process quantum information could lead to the design and synthesis of new materials (e.g. better catalysts, drugs and pollutant absorbers) that can turn the materials economy into a positive, virtuous feedback loop.

Limitations on the practical working conditions of quantum computing processors (qubit processors) are imposed by the operating temperatures required to coherently control quantum states in materials components and integrating these materials into modern devices. Currently, all qubit processors either only work at extremely low temperatures or are very difficult to integrate into modern electronics (or both). Materials' advances towards practical quantum computing represent potential multibillion-dollar economic drivers.

At Archer, we are building a qubit processor chip, dubbed 12CQ, that has the potential to operate at room temperature and be easily integrated into modern electronic devices. We are using unique carbon nanospheres to store and process quantum information using the quantum property of electron spin. I co-invented the technology that resulted from the underlying discoveries during my Fellowship at the University of Sydney in the School of Chemistry, together with colleagues at EPFL (Lausanne, Switzerland).

By coherently controlling the quantum state of the electron spin at room temperature without the need for isotopic engineering, spin dilution, cryogenic temperatures, well-defined crystal structures, photonics, or the use of metals, many of the technological barriers to realising practical quantum computing using solid-state materials are reduced.

Archer is not a 'university spin-out' – the company has been listed on the



Archer staff inside the Research and Prototype Foundry, based at the Sydney Nanoscience Hub.

Australian Securities Exchange since 2007, and now provides the public exposure to financial returns from innovative technologies, such as quantum computing, and the materials that underpin them.

In less than 12 months, Archer has begun assembling the first materials components of the 12CQ chip. Recently, we positioned a single nanoscale carbon-based qubit component on silicon with nanoscale precision. The qubit component is produced from naphthalene, which is derived from oil and gas feedstocks. Directly positioning individual qubits is a key requirement for building a scalable 12CQ chip, and scalability is a key requirement for successful commercialisation. The work to build the 12CQ chip continues at a rapid pace.

Quantum value beyond hardware development

Quantum computers employ the quantum phenomenon of entanglement that makes them useful. This allows the fields of chemistry and materials science to go beyond the limits of complexity that can be achieved through simulations on classical computers, especially in areas relying on strong electron correlations. However, current quantum computers are error prone and require error-correction routines, which in turn require more qubits.

Chemists, therefore, have value to add beyond hardware development.

This has been in devising algorithms that run in the error-prone regime to find something useful to do with today's quantum computers. They are making an immediate impact using several quantum computers to find molecular ground (Peruzzo A. et al. *Nature Commun.* 2014, vol. 5, p. 4213) and excited states (<https://arxiv.org/pdf/1910.05168.pdf>), and in exploring the properties of materials, even with only four qubits (Kandala A. et al. *Nature* 2019, vol. 567, pp. 491–5).

New ways to use and store energy

The global, multibillion-dollar Li-ion battery market is continuing to grow, with growth concentrated in the Asia-Pacific region. Li-ion battery devices service several growing market segments where high-power density and long lifetimes are required at ambient and near-ambient conditions, including electric vehicles.

The potential for widespread consumer adoption of electric vehicles depends on reducing the relatively high cost of batteries compared to oil and gas. The trade-off between cost and battery performance can be addressed fundamentally by a two-pronged approach: decreasing costs by using cheaper materials, efficient processing, and efficiencies of scale; and improving battery performance through effective materials and formulations.

Critical minerals are materials that play an integral part in battery



Archer staff inspecting a silicone wafer used in the 12CQ room-temperature quantum device project.

... printed graphene biosensors ... may have the potential to detect water-borne diseases.

compositions. The prominent technologies for automotive applications include cathode chemistries of lithium–nickel–manganese–cobalt, lithium–nickel–cobalt–aluminium, and lithium–iron–phosphate. Improvements in the anode are centred on using graphite with high structural quality and purity, and an appropriate particle size and optimal morphology for effective Li-ion intercalation chemistry.

The Australian government released its Critical Minerals Strategy (2019), presenting a multi-billion-dollar market value of Australia's critical minerals. It makes good sense economically to secure materials technology supply chains through mineral exploration. Archer has a broad-scope tenement portfolio to access critical minerals in Australia, including graphite, manganese, cobalt and nickel, and more. Archer has a mining lease for a Li-ion-battery-ready graphite resource in South Australia; however, there are no graphite mines currently operational in Australia.

Li-ion batteries could help reduce emissions from power generation; for example, by integration into renewable energy systems, including wind and solar. However, Li-ion batteries are not an all-encompassing solution to reducing emissions from direct combustion sectors. It is still expensive to use Li-ion batteries in these technologies (a prime example is the management of energy supply and

use between the grid) without government subsidies. Also, technologies in mining, manufacturing, the primary industries, and transport may not be driven by a scarcity of fossil fuels, but rather be due to consumer demand for new technologies.

A number of critical – even 'conflict' – minerals, such as cobalt, are used in Li-ion batteries. Although Li-ion batteries make mobility and sustainability advances possible, they are overshadowed by the environmental damage and human rights abuses in sourcing the raw materials from countries with highly deregulated and exploitive industries.

Biosensing water-borne disease

Safe and readily available water is important for public health. More than two billion people globally use a drinking water source contaminated with faeces, and by 2025, half of the world's population could be living in water-stressed areas (www.who.int/news-room/fact-sheets/detail/drinking-water).

There are many complex challenges (and opportunities) to achieving the UN Sustainability Development Goal of universal and equitable access to safe and affordable drinking water for all by 2030. These challenges and opportunities include finding materials that can address the large energy

requirements of purifying water and reducing the significant capital costs for deploying water purification systems. Materials must be a part of an integrated technological system producing clean drinking water.

Current materials solutions to produce clean water involve membranes and catalysts. Membranes for desalination and filtration are used to separate salt and/or contaminants from water, and catalysts, including photocatalysts, are used to deactivate biological contaminants (which may not be done by filtration) (Shannon M.A. et al. *Nature* 2008, vol. 452, pp. 301–10). Additive manufacturing of three-dimensional printed materials for clean water production is a potential digital solution to providing ad-hoc solutions to clean water; however, it is not yet at a mature stage of development.

Identifying and quantifying levels of pollutants in water is important in determining any danger in its consumption. At Archer, we are producing printed graphene biosensors that may have the potential to detect water-borne diseases. We have developed processable carborane–graphene inks that are printed into critical biosensor componentry. The digitisation process of graphene – a material that is essentially all interface – allows us to work towards developing an efficient point-of-use solution to disease detection.

High-tech devices for cleaning water, such as carbon-nanotube-based filters, membranes made from block polymers, and bioinspired membranes,

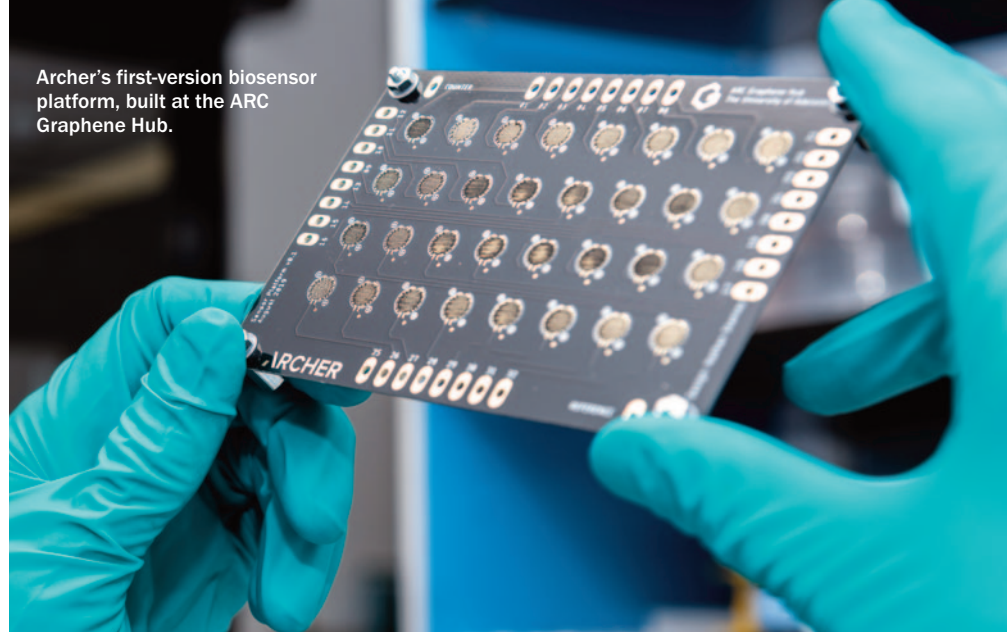
may be commercially ready in the future; however, the availability of clean water in many regions of the world is a problem today. Low-tech materials solutions manufactured at point-of-use may hold the key to widespread utility for now; for example, the use of terracotta filtration devices developed by Potters for Peace, and Kanchan arsenic and pathogen filters made from sand.

Creating new business models

The chemical and physical transformation of raw materials into functional forms is creating opportunities for value and positive financial impact in global markets. There is a need for business models that can better adapt to the growing complexity of risk presented by disruptive materials technology. Fast-paced technical progress at all stages of the materials lifecycle is facilitating the deployment of capital, which requires a careful distribution of financial risk between private and public institutes.

More than two dozen of the world's leading companies from heavy industry and chemicals sectors (i.e. aluminium, steel, concrete and chemicals manufacturing etc.) have set themselves science-based emission-reduction targets (sciencebasedtargets.org); and in Australia the total issuance of Green Bonds (debt raised specifically for environmental purposes) reached \$15.6 billion last year (www.climatebonds.net), while The New Plastics Economy Initiative, convened by the Ellen MacArthur Foundation (www.ellenmacarthurfoundation.org), has brought together more than 400 companies to help eliminate plastic pollution and waste.

Only dynamic and nimble regulatory systems can support and oversee truly disruptive and revolutionary technologies. To develop and reach effective regulation, a transparent and conscientious



Archer's first-version biosensor platform, built at the ARC Graphene Hub.

consideration of human safety and the environment is needed at every stage of the materials lifecycle. A systemic view is required in the search for new business models, while adequately addressing risks related to the negative impacts on societies by materials that underpin technological progress.

Making connections in a challenging field

Chemistry is a challenging field for advanced materials development. The inflow of talent is affected by a decline in interest, particularly in countries that have well-established capabilities in the materials field. Institutes that segment and silo the physical sciences threaten the increasingly interconnected and emerging industries serviced by materials chemistry that require a new type of talent: chemists who are capable of connecting complex concepts and operating in dynamic workplaces will propel the field.

The chemical and materials industry is a trillion-dollar industry and sectors are developing to help improve global living standards. One of the best ways the industry is contributing to making a positive financial impact is through innovation and collaboration. This is helping define new business models, and to better utilise existing business models, to leverage new materials technology developments for maximum benefit to people, communities, and societies around the



One of Archer's graphene-based ink materials.

world. The strategic injection of capital at various stages of the materials lifecycle will not only help create solutions to securing digital and legacy assets, but will also allow for greater access to energy, clean water, and sanitation, with a promising future ahead being defined by a new materials-centric economy.

Mohammad Choucair FRACI CChem has been the CEO of Archer since 2017. The Company's strategy is to build an industry-leading materials technology company, that delivers maximum value to shareholders through the commercialisation of assets at various stages of the materials lifecycle. Dr Choucair has a strong technical background in nanotechnology, and has spent the last decade implementing governance, control and key compliance requirements for the creation and commercial development of innovative technologies with global impact.



Diamonds forever?

iStockphoto/AndreyPopov

With the advent of chemical vapour deposition to synthesise diamonds, can real diamonds still make the cut?

BY **DAVE SAMMUT** AND **CHANTELLE CRAIG**

Eighty years after De Beers changed the world with its 'Diamonds are forever' ad campaign, the diamond industry is losing its sparkle. In 1940, just 10% of first-time brides in the USA received a diamond engagement ring. By 1990, that had grown to 80%, and this success was mirrored in De Beers campaigns around the world. But even then, its cartel control of the market had begun to fracture. At its peak in the 1980s, De Beers controlled 90% of the world's diamond sales. By late 2015, this had dropped to 31%.

At its eighth diamond sales event of 2019 in Botswana, De Beers was finding increasing difficulty with controlling the market. Where it had formerly held the power to hand 'sightholder' buyers a bag of diamonds and dictate the quantity and

price of the purchase, it could no longer do so. Sales in 2019 were 39% lower than the year before.

This decline may or may not be related to the growing trade in laboratory-grown diamonds. In 2016, Leonardo DiCaprio (star of the movie 'Blood Diamond') was a high-profile investor in a \$100 million capital raising for Diamond Factory, which is reported to be producing 1000 carats per month.

At that time, De Beers was one of six participants in the Diamond Producers Association (DPA), which fought a rear-guard 'Real is Rare' campaign to have lab-grown diamonds labelled as 'synthetic', and banning the term 'cultured diamond'. Regardless, in July 2018 the Federal Trade Commission revised its 'Guides for the Jewelry, Precious Metals, and

Pewter Industries', acknowledging that the lab-grown gems have the same chemical and physical attributes as the mined stones, and removing the DPA-preferred specification of 'natural origin' in the definition of a diamond.

In May 2018, De Beers did a huge about-face. Through its subsidiary, Lightbox, it began marketing its own lab-grown diamond jewellery – once again turning the industry on its head.

Of course, this development didn't come from nowhere. General Electric first announced the production of lab-grown diamonds in February 1955, a milestone in work that had commenced early in World War 2.

GE's method, termed high-pressure high-temperature (HPHT), uses pressures and temperatures in excess of 5 GPa and 1500°C. A carbon source is infused with a transition metal

solvent (alloys of Fe, Ni, Co and Mn-C), where the metal melts and dissolves the carbon under conditions somewhat analogous to natural processes deep in the Earth, with carefully controlled cooling to grow a crystal from a natural seed diamond.

Pressure reactor designs vary, with the most common being the BARS apparatus, or 'split sphere'. It can grow diamonds up to 10 carats in a cylindrical capsule as large as 25 millimetres, with six precisely aligned inner anvils of tungsten carbide forming the shape of a double pyramid. These are, in turn, placed inside a second set of anvils in the shape of two hemispheres, in an oil-filled donut-shaped housing that is heated to extreme temperatures. Thermal expansion of the oil exerts the force to produce diamond growth.

However, HPHT is more commonly used these days to modify natural diamonds, most particularly to remove nitrogen inclusions, and thereby lessen the (brown) colour and improve the clarity of the diamonds.

It is interesting to note that nanodiamonds have been found at meteorite crash sites, and one alternative method of creating diamonds is known as 'detonation synthesis'. Given that this is sometimes an unanticipated consequence of military research, much of the work is shrouded in secrecy ... but what we know seems impressive. It is reported that detonation nanodiamonds have been mass-produced in China, Russia and Belarus, the products being sold into the abrasives and coatings markets.

More practically, the other major method for growing diamonds is

At its peak in the 1980s, De Beers controlled 90% of the world's diamond sales. By late 2015, this had dropped to 31%.

chemical vapour deposition (CVD), as used by De Beers at its new \$94 million facility being constructed in Oregon, USA. In CVD, diamonds are grown layer by layer – potentially making much larger diamonds. Operating at much more benign pressures (even below atmospheric), methane or other carbon gases and hydrogen are heated to several hundred degrees Celsius.

A short history of synthetic gemstones

As early as 1880, the Royal Society published a paper by Glaswegian chemist James Ballantyne Hannay on the synthesis of diamond. Using a mixture of paraffin, bone oil and lithium in sealed wrought-iron pipes brought to red heat in a reverberatory furnace and held for 14 hours, he used the cooling of the pipes to also create pressure for diamond formation. 90% of the pipes exploded (in some cases destroying the furnace), and some pipes leaked, but some experiments produced a residue containing extremely hard particles that were confirmed as diamonds. Unfortunately, testing in 1975 showed the tiny diamond samples still stored at the British Museum were natural, not synthetic. With no accusation of fraud, this has been attributed to accidental cross-contamination from natural samples that Hannay would probably also have been studying.

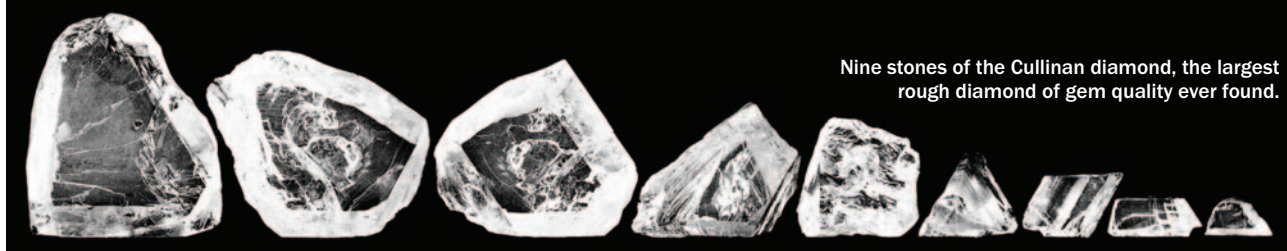
Just a few years later, Frenchman Frédéric Henri Moissan invented the electric arc furnace (now the dominant technology for iron recycling) while researching the crystallisation of carbon under pressure from molten iron. In 1893, he produced tiny artificial stones that he interpreted as diamond. In fact, he had discovered moissanite, a silicon carbide. It scores 9.25 on the Mohs scale, with a refractive index of 2.65–2.69 – higher than diamond (2.42) – which gives it heightened brilliance. Extremely rare in nature, moissanite was first found in the crater of a meteorite, but the laboratory-grown version has found some use in the gemstone market. A talented chemist, Moissan went on to win the 1906 Nobel Prize in Chemistry for his work in isolating fluorine from its compounds. He died shortly after receiving the honour.

Both Moissan's work and something quite akin to Hannay were mentioned in a detailed little scientific story by H.G. Wells: 'The Diamond Maker', which was published in 1894.

In a separate development, two German scientists experimenting in 1937 with zirconium oxide found that the melted mineral contained cube-shaped crystals, but they failed to recognise any value in their discovery. They didn't even bother to give their material a name. Then in the 1970s, Soviet scientists at the Lebedev Physical Institute (FIAN, in the Russian acronym) applied zirconium oxide to their work on lab-grown diamonds. Superheating the ZrO with stabilising oxides, they created cubic minerals that they named djevalite. In 1976, Swarovski became the first company to offer cubic zirconia gemstones, with global production now exceeding 50 million carats per year. Cubic zirconia has a lower refractive index than diamond (2.15–2.18) and lower Moh hardness (8.5), and with a much higher density (specific gravity 5.6–5.9 vs 3.52) it is easily distinguished by jewellers.



This rose-cut synthetic diamond was created using the CVD process. Wikimedia/Steve Jurvetson



Nine stones of the Cullinan diamond, the largest rough diamond of gem quality ever found.

Type I diamonds represent 98% of all natural diamonds. These contain nitrogen atoms up to ~3000 ppm as a main impurity, and absorb light in the IR and UV region, with characteristic fluorescence and visible absorption spectra. In the dominant type Ia diamonds, the nitrogen forms clusters within the carbon lattice to yield clear or pale yellow colouration via the absorption of blue wavelengths. These are then further classified as type 1aA and type 1aB depending on whether the clustered nitrogen atoms form pairs (clear colouration) or large, even-numbered aggregates (yellow to brown).

The much rarer type Ib diamonds (~0.1%) have more diffuse nitrogen, extending the absorption into the green spectra, and yielding darker yellow or brown colours. Almost all high-pressure high-temperature lab-grown diamonds are type 1b.

Type II diamonds (around 2% of natural gemstones) have no measurable nitrogen impurities. Their fluorescence characteristics differ from those of type I, and there is negligible absorption of the visible spectra. Type IIa contain virtually no impurities, yielding particularly high clarity. Some of the most famous diamonds – the Cullinan (from which nine main stones were split – see image), Koh-i-Noor and Lesedi La Rona (found in 2015) – are all type IIa, as are most CVD lab-grown diamonds. This unusual purity is one of the markers that is used to identify CVD diamonds. Type IIb are among the rarest and most valuable diamonds. They contain significant boron impurities, which absorb red, orange and yellow light to yield light blue diamonds. They show distinctive IR and red absorption spectra. Wikimedia/Plate III, The Cullinan (1908)

The dominant CVD approach uses microwave plasma activation. The seed diamond lattice is stabilised using hydrogen atoms to terminate the carbon, which prevents rearrangement to graphitic carbon, with the temperature too low for spontaneous bulk rearrangement. Under the plasma conditions, surface CH radical sites sometimes react with carbon-containing radicals from the gas phase, resulting in carbon adsorption in a very complex series of equilibrium reactions (bit.ly/33P1LFS). In many cases, the resulting CVD diamonds are then further processed by HPHT enhancement treatments.

The resulting polished product is so similar to natural stones that they are indistinguishable to the eye. (Notably, uncut natural and lab-grown diamonds are easily distinguished by their shape and morphology.) De Beers has announced that its own diamonds will be laser-inscribed with a microscopic Lightbox logo (visible under magnification) for easy identification, but as this can't be universally enforced across the many manufacturers of lab-grown diamonds, gemologists are turning to spectroscopic methods for gemstone identification.

The International Institute of Diamond Grading & Research (IIDGR) offers diamond grading services, as well as selling specialised instruments for the purpose. As a starting point, IIDGR's DiamondSure instrument (~\$12 500) is a simple-to-use FTIR

device for screening synthetics and type II and IaB natural diamonds, for referral to further testing via DiamondView (~\$50 000).

Requiring the services of a trained lab tech, DiamondView uses surface fluorescence with ultraviolet light to quickly indicate the difference between natural and lab-grown diamonds. According to IIDGR's website (bit.ly/2PpUJSa): 'The colour of the fluorescence, the fluorescence pattern and the absence or presence of phosphorescence will differ depending on the stones' natural or synthetic origin. To aid user interpretation of blue fluorescing CVD synthetics, easy to change filters are provided, which enhance synthetic-specific features.'

Depending on colour, the automated melee testing (AMS2) machine may also be applied. It uses photoluminescence to rapidly process gemstones up to 0.2 carats by photoluminescence, to determine whether they are diamonds (natural or lab grown) or other synthetic minerals such as moissanite (see box p. 17).

From there, the most expensive and accurate IIDGR instrument is the DiamonPlus, which uses photoluminescence at cryogenic temperatures. These more extreme conditions make the instrument impractical for all but specialised facilities.

As a non-destructive test, photoluminescence typically uses laser excitation at a variety of

wavelengths to distinguish between natural, treated and lab-grown diamonds. It is limited to detecting optically active defects in the diamonds, but most of the key defects are optically active. As an example, a pair of photoluminescence peaks around 736 nanometres indicates the presence of silicon impurities, which are characteristic of CVD diamonds. Other peaks occurring in natural diamond have been correlated to colour, type and geographic origin, giving power to the technique when used in combination with a library of spectra for known samples and sophisticated processing software.

Impurities in the crystal lattice commonly interrupt lattice structure, which modifies the vibration characteristics of nearby atoms. Under laser excitation, the defects show both electronic transition and vibronic variations known as 'phonon sideband'. The noise generated by the phonon sideband must therefore be eliminated by cooling in liquid nitrogen (–196°C), to separate the purely electronic transition (the 'zero-phonon line').

As noted, the technique can also then distinguish treated natural diamonds from untreated. The brown colour of type IIa natural brown diamonds is thought to be caused by clusters of atom vacancies in the carbon lattice. HPHT treatment can yield atom rearrangement to remove the brown colour, which can change the ratio of specific excitation peaks.

In CVD, diamonds are grown layer by layer – potentially making much larger diamonds.

However, much of the detail is kept secret to retard the efforts of companies conducting treatment to 'fool' the analysis. This 'arms race' of modification versus detection remains ongoing, and these days analysts recommend the application of a suite of methods and wavelengths to facilitate differentiation.

The key point is that as the differences become harder to detect, the differentiation between natural and lab-grown diamonds must surely become increasingly artificial and arbitrary.

Already, De Beers' lab-grown diamonds are significantly cheaper than their natural counterpart, at just initially \$800 per carat – and at a flat rate disunited from size. Over the nine months from their introduction in May 2018 to February 2019, De Beers CEO Bruce Cleaver was widely reported as noting a 60% decrease in the wholesale prices of lab-grown diamonds.

Cleaver went on to deny any link to a fall in the price of natural diamonds, but this remains to be verified, particularly in the light of the 2019 falls in De Beers' sales. For now, the natural diamond market dominates sales – estimated at 60 million carats of gem-quality natural stone sales from 148 million carats mined, versus 2 million carats of gem-quality lab-grown diamonds. But the numbers are shifting. De Beers' new Oregon facility will produce 500 000 carats annually from 2020

Over time, the trends must surely be in favour of the lab-grown variety. Consumer sentiment, particularly in the anticipated generation Z market, will be for ethically and environmentally

sourced products. Technological progress will continue to lessen the differences. And the inevitable price reductions will open new markets beyond the gem trade.

The physical durability, thermal stability and optical properties of diamond makes it an ideal material for all sort of applications. By 2020, China is projected to produce more than 9 million kilometres of diamond cutting wire annually, and diamond is already useful for a wide range of cutting and abrasion tools. Now, new forms of CVD diamond allow for application to less obvious tools such as thermal detectors for downhole drilling in corrosive and abrasive fluids at 150–200°C. Low-friction diamond-coated ball bearings open up possibilities for all sorts of mechanical nanodevices.

With high refractive index, diamond lenses could yield lighter and thinner lenses in eyewear. For the millennials, scratch-resistant mobile phone screens might help preserve devices all the way through to the end of a contract.

The high Young's modulus of diamond could make it a lighter and 'stiffer' alternative to aluminium in speakers. Monocrystalline diamond also has high thermal conductivity, and could potentially also substitute aluminium in microchip heat sinks, leading to the next step change in computing processor power.

The ability to produced ultra-high purity diamonds (particularly type II diamonds with low nitrogen impurity levels), together with the ability to control nitrogen, silicon and boron impurity levels and sites, have brought quantum computing one step closer. Each element sits adjacent to carbon on the periodic table, and controlled disruptions to the diamond lattice create specific optical and magnetic effects at these sites.

In recent articles in *Science* (bit.ly/2pkX5sy) and *Nature Communications*

(<https://go.nature.com/2QnCzmh>), researchers have reported breakthroughs in the controlled use of nitrogen vacancies and silicon vacancies for the storage and transfer of quantum bits (known as qubits) via the superposition of electron spin states. The science gets complicated quickly, but the headline is that the use of artificial diamonds may bring quantum computing from cryogenic temperatures to far more practical ambient applications.

For the time being, De Beers seems to be trying to have it both ways, attempting to build market dominance in lab-grown diamonds, while trying to simultaneously continue the marketing spin for natural diamonds. Hence, de Beers' \$94 million investment in Oregon is still dwarfed by its 51% investment in the new \$650 million Gahcho Kué mine in the Northwest Territories of Canada.

Cleaver stated that 'Lightbox will transform the lab-grown diamond sector by offering consumers a lab-grown product they have told us they want but aren't getting: affordable fashion jewellery that may not be forever, but is perfect for right now'.

If the lab-grown gems truly are chemically and physically the same as natural stones, then there is no reason to expect that the former won't be just as durable. And as the non-renewable natural supplies inevitably dwindle, the laboratories may be able to ensure that we truly do have diamonds forever.

Dave Sammut FRACI CChem and **Chantelle Craig** are the principals of DCS Technical, a boutique scientific consultancy providing services to the Australian and international minerals, waste recycling and general scientific industries.



iStockphoto/Model-1a



Scientist employment and remuneration: 2019 survey results

Professionals Australia, Professional Scientists Australia and Science & Technology Australia asked national solution-makers and knowledge-creators about their daily conditions of work and what they need to be primed for success.

Over the past year, remuneration for scientists has increased by 2.0%, extending beyond the cost of living increase for the year (1.6%). However, this is less than the rate of wage growth across Australian workplaces more generally with the Wage Price Index to the June quarter sitting at 2.3%. There is still work to do.

More than one-third (35.2%) of respondents reported being dissatisfied with their current level of remuneration, and 37.5% said they were considering leaving their current employer. For those who were considering leaving, a pay increase, greater professional development opportunities and better management were the most frequently cited contributing factors. 41.2% said their package did not reflect the level of responsibility they undertook in their day-to-day work.

Of particular ongoing concern is the gender pay gap. According to the survey, women in science are paid 13.8% less than their male colleagues. This is an improvement on results from last year's survey, but it is still equivalent to the national average of 14.1% and warrants urgent attention. The gap emerges at mid-career stage and becomes particularly obvious at senior levels.

When asked to reflect on their sector, respondents reported broad concern about Australia's ability to maintain its scientific capability. Almost two-thirds said cost-cutting was affecting their organisation and more than one-quarter reported a decline in service quality at their workplace. 26.9% said a decline in the number of scientists in decision-maker roles was evident in their organisation. Alarming, 72.3% of respondents said Australia was not well prepared to meet emerging challenges. 71.4% of respondents agreed that attracting, developing and retaining the next generation of scientists is one of the most important priorities for developing a sustainable STEM (science, technology, engineering and mathematics) workforce in Australia.

These findings sit alongside the latest figures showing that Australia invests 1.88% of GDP in research and development – well below the OECD average of 2.38%. OECD records also show a decline in business investment in R&D for the first time since records have been maintained.*

Wages growth

Base salaries paid to professional scientists grew by an average 2.0% over the last 12 months. 27.1% of respondents reported

* Australian Bureau of Statistics (July 2018). Research and experimental development, government and private non-profit organisations, Australia, 2016–17 (8109.0).

More training is needed for young/new medical scientists and full payment for their qualifications ...

Survey respondent

that they had not received any pay increase over the previous 12 months.

Increases paid to professional scientists across all sectors were at or above increases to the cost of living at 1.6% (to June 2018) as measured by the ABS Consumer Price Index (6401.0). Notably, however, the average increase in Research Agencies was at CPI level of 1.6% and the average increase in the State Public Service salaries was 1.7%, only marginally beyond CPI. The earnings increase across the Australian economy (to June 2018) as measured by the Wage Price Index (6345.0) sat at 2.3% to the June quarter. Average increases only in the Hospital and Government business enterprise sectors exceeded this level of growth.

Average annual base salaries and total packages were highest in the Physics, Geology and Botany fields. Annual salary movements were greatest in the Food Science/Technology, Botany, Physics and Geology fields with increases of 3.0, 2.8, 2.5 and 2.3% respectively. Movements were lowest in Marine Science and Materials/Metallurgy with increases of 0.7 and 1.0% respectively.

Average salaries

Across all sectors employing scientists, a full-time professional scientist took home an average annual base salary of \$112 151 and received a total package worth \$129 910. The average annual base salary was greatest in the Education sector at \$125 328, compared with \$114 646 in the Australian Public Service (APS) and \$105 525 in the Private sector. The highest average total package was in the Education sector at \$144 981, compared with \$132 493 in the APS and \$123 714 in the Private sector.

Satisfaction with remuneration

46.9% of scientists surveyed reported being satisfied or very satisfied with their current level of remuneration – up on last year's figure of 42.5%. 35.2% were dissatisfied or very dissatisfied – barely changed from 35.5% in 2017. The highest levels of satisfaction with remuneration were found in the Mathematics, Computer Science and Physics fields.

44.6% of respondents agreed or strongly agreed that their remuneration was falling behind market rates. 41.2% said their remuneration did not reflect the level of responsibility they undertook in their day-to-day work.

Employment intentions

12.0% of respondents had changed jobs in the previous 12 months and, of those, 40.9% had moved for a pay increase, 47.0% had moved for greater job security and 50.0% had moved for greater professional development opportunities. 21.2% had moved for promotion and 50.0% had moved to get away from an unhealthy workplace culture. 36.4% had moved to seek better management.

37.5% of respondents reported that they were considering leaving their current job – down on 39.8% in last year's survey. Respondents reported that the factors that would alter their intention were a pay increase (61.3%), greater professional development opportunities (49.8%) and better management (44.3%).



iStockphoto/Razvan

Gender pay gap

Female respondents earned on average 86.2% of male respondents' earnings – a gender pay gap of 13.8%. The survey found evidence of a gender pay gap arising from a combination of factors including concentration of female respondents in less senior roles, in roles requiring fewer years of experience and fewer females aged over 40.

Work priorities, morale and fatigue

Job security ranked highest in respondents' work priorities, followed by remuneration, positive workplace culture and work-life balance. 50.0% of respondents said that staff morale had declined in their organisation over the previous 12 months. 57.5% reported that worker fatigue had increased.

Value of postgraduate qualifications

The average base salaries by highest qualification ranged from \$125 697 for those with a PhD, through to \$114 004 for those with a Masters, \$107 893 for those with a Graduate diploma and \$96 871 for those with a Bachelor degree.

The completion of postgraduate qualifications – Graduate Diploma, Masters and PhD – delivered average earnings premiums (total package figures) of 14.4, 20.6 and 29.7% respectively over holding a Bachelor degree alone.

Working hours

Respondents worked on average 43.6 hours per week including 5.4 hours of overtime. Only 10.5% received monetary payment in recognition of their additional hours, a significant issue in view of the 11.4% of respondents reporting that they were expected to work longer hours in the past year compared to the previous one.

The average number of hours worked per week was greatest for those working in Teaching or training and Management roles, and respondents were most frequently compensated for additional hours in the Hospital sector, Local Government, and the Australian Public Service.

There should be more recognition that STEM degrees are generalist and STEM graduates should be hired across an array of industries.

Survey respondent

Skills development

42.8% of respondents said there was insufficient skills development in their workplace over the previous 12 months. Of those that had changed jobs in the previous 12 months, 50.0% had moved for further professional development opportunities.

Deprofessionalisation, professional standards and cost-cutting

Deprofessionalisation – defined as the diminution of science capability across responsibility levels, industries and/or job functions – was seen as a concern with 26.9% of respondents noting a reduction in the number of scientists in decision-maker roles over the previous 12 months.

16.8 and 26.2% of respondents respectively said reduced adherence to professional standards and reduced service quality were evident in their organisation over the last 12 months. 59.2% of respondents reported that cost-cutting was an issue in their organisation.

Science capability, STEM priorities and workforce challenges

61.8% of respondents reported that scientific capability was seen as a source of innovation in their workplace. 16.8% said that scientific capability was not seen as a source of innovation in their workplace. 72.3% of respondents said Australia was not well prepared to meet emerging challenges.

Attracting, developing and retaining the next generation of scientists was seen as one of the most important priorities for developing a sustainable STEM workforce by 71.4% of respondents.

Diversity and discrimination

38.2% of female respondents said they had experienced bias or discrimination on the basis of gender in the previous three years. 19.5% of respondents had experienced sexual harassment at least once in the course of their employment compared to 4.9% of males.

Respondents reported 3.9% of employers had formal policies in place to promote diversity and 67.2% had policies to deal with discrimination. 25.7% of respondents said their employer did not have strategies in place to actually implement policies relating to diversity and discrimination.

This is a modified excerpt of key results from the *Professional scientists employment and remuneration summary report 2019*. The summary and full reports are available at www.professionalsaustralia.org.au/scientists/employment_and_remuneration_report.

Top stories from the periodic table

Storytelling brings people closer together. Conceived by the RACI in recognition of the International Year of the Periodic Table, *Stories from the Periodic Table* collects, publishes and celebrates the personal connections we have to the periodic table and its elements.

Mercury

BY **LEN FISHER**

Mercury, the only metal that is liquid at room temperature, exerts an eternal fascination. Its symbol Hg comes from the Latin *hydragyrum*; literally, 'water-silver'. That is just how it appeared to my brothers and me as children when we chased the shining drops from a broken thermometer across the kitchen table, fruitlessly trying to pick them up with our fingers.

Mercury's fascination continued for me in high school, where my friend Dennis and I were looking for experiments to do with a bottle that we had 'borrowed' from the school's chemistry store. Guided by an ancient textbook, we floated coins on it, dissolved aluminium in it, made a rocker switch with it, and even built our own polarograph. We also found that it is the only element to have made an appearance in a Shakespearian play.

The play concerned is *Measure for measure*. It features a dissolute ne'er-do-well called Pompey and a brothel-keeper called Mistress Overdone. 'She hath eaten up all her beef', says Pompey of Mistress Overdone 'and she herself is in the tub.' The textbook's author told us primly that the tub was a bowl of heated mercury, whose vapours were thought to help cure venereal disease when the private parts of the sufferer were exposed to it.

We giggled in our prepubescent way over the picture that this evoked, but knew enough about the dangers of mercury poisoning to avoid heating our own sample. It was our English teacher who had told us about these dangers, saying that the mad hatter in *Alice in Wonderland* would most likely have had brain damage from the mercury compounds used in the making of felt hats.

Our science teacher seemed less concerned with such dangers, or he would not have had us using a blowpipe to heat red mercuric oxide in a hollow on a charcoal block until it turned into silvery droplets – an experiment that is fortunately no longer on the school curriculum. Nor would he have had us collecting up spilled mercury with a home-made gadget that consisted of a teaspoon bowl cut longitudinally in half, with each half brazed to one arm of a pair of tongs.



Steph Parkyn

I went on to a research career where my very first paper described an unusual use of mercury as a liquid piston in a pump designed to collect and concentrate gases. Sadly, Dennis could not share the excitement of my first publication. Having survived our encounters with mercury and other dangerous substances that we had accumulated in our home laboratories, he succumbed to a melanoma in his early twenties.

Melanomas are still one of the most dangerous forms of cancer, and the search for effective treatments continues. I recently came across a paper where mercury-based compounds have been shown to be effective in treating some types of cancer. It's early days, but maybe, just maybe, the eternal fascination of mercury will one day offer up yet another prize – this time a real medical one – to its devotees.

Len Fisher is a colloid scientist whose interests have covered biomedicine, food science and mining engineering. He is now primarily a writer and broadcaster on how scientists think about personal and global problems. He divides his time between Australia and the UK, where he is based at Bristol University and also works with Oxford's James Martin School on solutions to global problems.

Hydrogen: a new hope for the future

BY **KRYSTINA LAMB**

It was nearing the end of 2011, meaning the end of my Honours research program, and I still didn't know what to do next. I studied chemistry, environmental science and sustainability because I wanted to learn more about the amazing planet we live on, but more than anything I wanted to know what I could do to build an even better future for people and the environment. Three years into this journey and no closer to knowing, I had lost hope.

I don't think it was a single moment where I lost hope, but an accumulation of them. Like seeing global pollution and carbon emissions track above the worst-case scenario described by climate scientists, watching global leaders deny and attack the science and scientists, hearing every day that more forests were being cleared and burnt all over the world. It felt as though we were in a car speeding towards the cliff edge and no amount of screaming and hand-waving would deter the manic drivers. It was an unhappy time, I felt as though I was living in the shadow of inevitable crisis. And, like an overlooked piece of string clogging up the wheel of a shopping cart, hydrogen innocently lodged itself into the story of my life, changing it forever.

I already knew about hydrogen and hydrogen energy technologies. It always seemed to be 10 years away no matter how much progress there was. So when hydrogen had a bit of a renaissance in the early 2000s, I had a polite interest in the nice articles about the clean energy technologies, but didn't really think much more of it. And then between the global economic collapse in 2009 and the accountants' reports on the high cost of these technologies, the noise about hydrogen energy technologies quietened and I didn't miss what wasn't there.

But the submission of my Honours thesis meant that I had to make a move, and just in time, hydrogen found me. I was invited to one of my professor's office, and offered a PhD project working on hydrogen energy technologies. I was initially cautious, as I didn't really know that much about the topic. But I was a researcher faced with too many unknowns, so I made a hypothesis and tested it. My hypothesis was 'I will have a



Alisa Fergusson

positive impact on the future by doing this work'. And in testing this question, hydrogen gradually revealed its simple elegance, and a new hope for the future began to grow.

I decided to take on that PhD project, and have spent the past seven years working on hydrogen energy technologies. Hydrogen is not a perfect panacea, nothing is. But hydrogen planted a seed of hope that has become a sapling. And with the recent return of hydrogen to the mainstream stage, that sapling grows day by day. I now believe that, working together, we will overcome the deep challenges facing us and enter a new phase in our development as a global community; the Hydrogen Age.

Krystina Lamb is a researcher at Griffith University working in renewable energy and hydrogen technologies. She completed an undergraduate in Chemistry, Honours degree in Environmental Chemistry, and a PhD in Physical Chemistry. Her main focus is on the development of technologies for a new renewable industry based on hydrogen energy technology. She is based in Brisbane, and enjoys collaborating with her colleagues in the Queensland Micro- and Nanotechnology Centre.

New Periodic Table on Show available

In celebration of the International Year of the Periodic Table in 2019, we are pleased to launch the latest Periodic Table on Show. With new artists' impression artwork completed for elements 112–118 by printmakers Linda Abblitt (113, 115, 117) and Tina Curtis (114, 116, 118), the Periodic Table on Show is now up to date.

RACI Periodic Table on Show posters are now available to purchase online for \$15 plus postage (racichemedcentral.com.au) or discover the science and artists' descriptions at raci.org.au/IYPT.



Rowe Scientific PTY LTD
www.rowe.com.au

Suppliers of:

CERTIFIED REFERENCE MATERIALS

Reference materials from all major worldwide sources including:

NIST (USA), CANMET (Canada), SABS (South Africa), BAS (UK), Standards Australia, BGS (UK), BCR (Belgium), NWRI (Canada), NRCC (Canada), Brammer (USA), Alpha (USA), Seishin (Japan)



ADELAIDE
08 8186 0523
rowesa@rowe.com.au

BRISBANE
07 3376 9411
roweqld@rowe.com.au

HOBART
03 6272 0661
rowetas@rowe.com.au

MELBOURNE
03 9701 7077
rowevic@rowe.com.au

PERTH
08 9302 1911
rowewa@rowe.com.au

SYDNEY
02 9603 1205
rowesw@rowe.com.au

William Roy Jackson

A significant life in Australian chemistry

The death of Roy Jackson in early November 2019 brought to an end a significant life in Australian chemistry.

Born in Bacup, Lancashire, in 1935, Roy studied at the University of Manchester (BSc 1955) and took his PhD with Bernard Henbest at King's College, London. Following postdoctoral work at Oxford, he went to Queen's University Belfast in 1959, and there rose through the ranks to become Reader in 1970. Roy and Heather were married in 1960 and their three children – Tim, Martin and Catrin – were born in Belfast.

In 1972, the chair of organic chemistry at Monash became vacant when John Swan was elevated to a pro-vice-chancellor position. Roy was an applicant for the chair and he came to Monash to interview. I missed his seminar because it was time for my weekly lunchtime run (yes, those were the days), but the head of department, Professor Ron Brown, took me aside to say that I should meet this Jackson, who was likely to become my senior colleague. Jackson's chemistry was, Brown said, world leading and well in advance of anything that we Monash organic chemists were up to, and he seemed the sort of chemist who would interact with industry. How right that was.

Before accepting the Monash offer, Roy made a side trip to Canberra to consult with Arthur Birch, who must have given it a tick. The consequence was that Roy arrived a few months later and quickly established a research group in which talented students worked with him. He was very good at sharing ideas that led to collaborative research, but he was always a leader in whatever subject he touched. Among these were chromium aryl compounds with carbonyl, phosphine or arsine ligands; hydrogenolysis over supported metal catalysts; reactions of allyl palladium compounds; and palladium-catalysed additions to unsaturated systems, including control of stereochemistry. Roy worked with pharmacologists, too, and I particularly recall the work on opiates that was conducted quietly, behind closed doors!

Roy took to heart the dictum that professors should 'profess their subject', and gladly lectured to first year classes who, in turn, loved him for it.



Roy Jackson (left) and Frank Larkins in the laboratory, Monash University 1981.

As if the chemistry were not enough to fill the forty-or-so hours that Roy seemed to find in every day, at Monash he made major contributions to the life of the university, as he had in Belfast. In return, the university appointed him to an endowed chair in 1995, as the first Sir John Monash Distinguished Professor. And he was active in the profession, being a leader at RACI branch and division level, and President in 1999. He was a member of advisory committees for CSIRO and the Australian Research Council. His many contributions and awards (including his AM) were included in the appreciation written by his then colleague, Dr Patrick Perlmutter, which was published in the *Australian Journal of Chemistry* in 1999. The publishers, CSIRO, have kindly made this document open-access (www.publish.csiro.au/CH/pdf/CH99147).

Roy took to heart the dictum that professors should 'profess their subject', and gladly lectured to first year classes who, in turn, loved him for it. His 'chemical magic show', delivered on Open Day with the assistance of Doug Rash, was to some extent just a less formal version of those enthusiastic lectures.

Ron Brown's judgement about the value of appointing Roy Jackson was borne out by vigorous involvement with industry as a consultant and project leader. A major element of this was his partnership with physical chemist Dr Frank Larkins on a coal-to-oil project, following the contrived oil shortages of the 1970s and the threat of more to come. Drawing on the huge deposits of brown coal (lignite) in Victoria's Latrobe Valley, their results demonstrated the possibilities of this fuel-substitution industry, but they were never commercialised when oil supplies returned to normal.

Roy's life was rich in sporting and recreational activity. A major part of the latter was centred at the family holiday house from which family, friends and visiting colleagues set off on vigorous walks in the bush. Professor Victor Snieckus, on a short sabbatical, recalls that his common interest with Roy in palladium-catalysed reactions had to be joined by the 'nerve test' – a leap between pinnacles in the Grampians.

The Monash website carries a selection of tributes to former staff members, and the university's journalist, Kathy Evans, wrote a wonderful one for Roy (www.monash.edu/vale/home/articles/vale-william-roy-jackson-am).

Our appreciation of the life of Roy Jackson was beautifully put at the commemorative service: Roy loved life ... and he did it well.

Ian D. Rae FRACI CChem

New Fellow

Associate Professor

Mark S. Butler

studied at the University of Melbourne, where he obtained a BSc (Hons, 1st Class, Organic Chemistry) in 1988 and a PhD in natural product chemistry in 1993 (supervisor Professor Robert Capon). Since postdoctoral work at Arizona State University (1993–4) on anticancer natural products, he has led teams focusing on natural product-derived drug development at universities, research institutes and biotech company Griffith University/Astra Zeneca (1994–9), Centre for Natural Product Research/GSK (Singapore, 1999–2002) and MerLion Pharmaceuticals (Singapore, 2002–09).

From 2009 to 2017, he was at the Institute for Molecular Bioscience, University of Queensland, predominantly working on anti-infective and inflammation drug development projects. In 2016–17, he successfully studied for an MBA from the University of Queensland and from 2018 to 2019 was the Bid Manager for the Antimicrobial Resistance Cooperative Research Centre bid with Professor David Paterson (UQCCR). Since July 2019, he has worked part-time at UQCCR and undertaken work with MSBChem Consulting. His research interests include the discovery and development of drug leads to clinical candidates, natural product chemistry, antibiotics and analysis of drug development clinical pipelines.

He has published more than 110 papers and was a Clarivate Analytics Highly Cited Researcher in Pharmacology & Toxicology in 2016 and 2017. He is currently a member of the World Health Organization's antibiotic pipeline analysis team and is an editorial board member for *Planta Medica*, *Journal of Antibiotics*, *Natural Products and Bioprospecting* and *Biomolecules*. He was awarded the 2017 JA Ōmura Award and Matt Suffness (Young Investigator) Award from the American Society of Pharmacognosy in 2002. He has been actively involved with the RACI since joining in 1988 and is currently the Treasurer of the Medicinal Chemistry and Chemical Biology Division. He also wrote the section on Australian natural product chemistry for the 2017 book *The Royal Australian Chemical Institute: a centenary of bonds*.



2019 RACI National Awards winners

Applied Research Award

The Applied Research Award is given to a member of the RACI who has contributed significantly towards the development of, or innovation through, applied research, or in industrial fields.

Associate Professor

Bernard Flynn finds new treatments for disease by straddling the boundary between chemistry and biology. Using small molecules as probes, Bernard can find promising biological sites for treatment and get clues about the chemistry

needed to target the site. Together with co-workers, he has produced many promising drug leads for the treatment of cancer, liver disease, multiple sclerosis and anxiety. Some of these drugs have proceeded to clinical trials.

Currently, Bernard's team at the Monash Institute of Pharmaceutical Science is working on treating chronic kidney disease, liver disease and heart failure. They are targeting enzymes involved in the biological processes that lead to organ failure in the course of these conditions.

Bernard works at the interface of chemistry and biology. He believes that the convention of separating the disciplines into distinct silos is counterproductive for drug discovery. He sees this separation as a major hurdle for innovation. Through his work, he hopes to promote chemical biology as a creative, useful tool for creating the medicines of the future.

Bernard is the Co-Director of the Australian Translational Medicinal Chemistry Facility and Founder and CEO of Cincera Therapeutics. A member of the RACI since 1997, he has served as treasurer and committee member on the RACI Medicinal Chemistry and Chemical Biology Division.



Centenary of Federation Teaching Award in Chemistry

The Centenary of Federation Teaching Award in Chemistry rewards outstanding excellence in the teaching of chemistry in Australia at a primary or secondary school level.



Dr Andrew Eaton prepares students to become scientifically literate members of society. As Science Coordinator, he teaches secondary level science and chemistry classes at the Wollondilly Anglican College, New South Wales. But, as one of the writers for the ANCQ, his reach is global.

In operation since 1982, the ANCQ is a quiz taken annually by tens of thousands of students from more than 23 countries. Rather than testing the knowledge of students according to any syllabus, the quiz aims to promote students' understanding of chemistry and how it applies to the real world. Andrew has been writing questions for the Year 7–8 ANCQ paper for more than 10 years.

Recently, Andrew has introduced systems thinking into his Year 12 Chemistry classroom. The approach introduced students to chemical principles in the context of the United Nations Global Goals for Sustainable Development. The aim was to promote greater higher-order thinking skills but also an appreciation for the role of chemistry in the wider world.

With all his teaching activities, Andrew's aim is to leave behind a

generation of globally responsible chemists and citizens. He encourages his students to engage with the world outside the classroom through science. In 2011, his college won the World Water Monitoring Challenge for Australasia.

Citation

The RACI Citation is intended gives recognition to members who have made substantial contributions to chemistry, and especially to the progress of the profession.

Ian McMahon

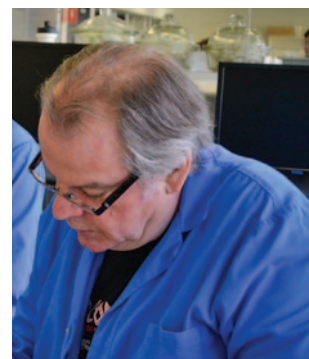
teaches chemistry at Eynesbury College in Adelaide. Ian firmly believes that chemistry education at all levels, from primary to tertiary, is equally important.

He has been a member of the RACI for more than

30 years as, and Chair of the South Australian Branch Chemical Education Group for 21 years. During this time, Ian has guided the South Australian group in providing chemistry professional development to secondary teachers through annual practical workshops, including himself as one of the teacher presenters of diverse and innovative experiments. He also served as Secretary of the Chemical Education Division in 2009–12.

Since 1995, Ian has been involved in managing the South Australian section of the Australian National Titration Competition (ANTC). Organised annually by the RACI, the ANTC tests the practical chemistry skills of senior secondary chemistry students around Australia, who are usually competing to determine the concentration of a weak acid solution. Teams of students with the most accurate results from each state qualify for the national final.

Ian's role with the ANTC has ranged from preparing local samples for both intra-school and state final competitions,



and coordinating both state final and the South Australia section of the national finals. He is proud to have facilitated the 11 national wins achieved by teams from South Australia during his time as coordinator.

Ian recently received a South Australian Science Teachers' Association medal for his contributions to science education in the state.

His current project is transitioning into retirement with dignity.



In partnership with Australian Aboriginal Elders, Associate Professor **Joanne Jamie** investigates the chemistry of bush medicines.

Based at Macquarie University, Joanne documents both traditional and contemporary bush medicines. Using her expertise in bioorganic and medicinal chemistry, she screens the medicines for biological activity. Bioactive compounds are identified and isolated through chemical manipulations.

The partnership is not limited to science: a handbook on bush medicine and an award-winning cultural immersion program for schools were created on its foundation. Results of both the scientific research and its associated programs have been reported in five peer-reviewed publications with Yaegl and Bundjalung Elders as co-authors.

Out of this collaboration, the National Indigenous Science Education Program (NISEP) was also born. NISEP empowers Indigenous youth through leadership in science activities. Through NISEP, Joanne hopes to encourage a future generation of scientists from Australian Aboriginal and Torres Strait Islander backgrounds. The program aims to improve inclusion in the sciences and is helping to 'close the gap'.

NISEP is run by the commitment, dedication and hard work of Joanne and her co-workers in universities, schools

and Indigenous communities. It is ever-growing, with more schools and university partners coming on board. NISEP was recognised in 2019 with the inaugural Australian Museum Eureka Prize for STEM Inclusion.

Joanne is a Fellow of the RACI and has been a member for over 25 years.

Cornforth Medal

The Cornforth Medal is awarded for outstanding achievement in chemistry and to promote chemical communication. The Medal, bearing the words 'For a Thesis on Chemical Research', commemorates the work of Sir John Cornforth.



Dr **Emma Watson** gains insight into human health and disease through chemistry. Proteins are responsible for all biological processes. By gaining insights into their function, chemists can better understand disease. As part of Professor Richard Payne's research group at the University of Sydney, Emma develops methods to rapidly synthesise proteins for evaluation of their biological activity. This fast generation of protein libraries enables protein-based drug discovery.

Since Emma was 12 years old, her dream has been to obtain a PhD and work as a research scientist. Through her passion, perseverance and learning to manage her own expectations, she is proud to have finally achieved this goal. She hopes her example will inspire a future generation of scientists, particularly young women, to pursue a career in chemistry.

Emma has been a member of the RACI since 2014.

Distinguished Fellowship

A Distinguished Fellowship is the recognition of highly distinguished contributions to the chemistry profession in academia, government or industry and to the RACI.

Emeritus Professor **Milton Hearn** AM is an international authority in product purification and analysis and their role in chemical manufacturing. His broad work in chemistry has promoted advances in chemical synthetic and separation methods, green chemical concepts and practices, and innovative biotechnological approaches.

Milton's areas of research innovations include (bio)separation science, chemical synthesis, production and purification of proteins, and the manufacture of chemical and biological products. Having worked closely with industry for over 40 years, he has influenced areas ranging from the manufacture of food products, pharmaceuticals, fine chemicals to diagnostic devices. He is senior author of 610 high-impact peer-reviewed scientific papers and a co-inventor on 86 issued and pending patents in 27 patent families.

Fundamental studies, the translation of this knowledge to industry and academia and helping develop public policy are all aspects of Milton's contributions. Recently, Milton has been working in partnership with industry to aid adoption of the principles and metrics of green and sustainable chemistry in manufacturing processes.

Milton has mentored more than 90 higher research degree students and 35 postdoctoral fellows. He is currently a member of the editorial boards of six major scientific journals, including *RSC Green Chemistry*. In 2015, he was appointed a Member of the Order of Australia (AM) for his significant service to science in Australia. Since he became



an RACI member in 1985, Milton has been the recipient of six RACI awards, including the Leighton Memorial Medal, and the H.G. Smith and R.K. Murphy medals and numerous international awards, including the ACS Chromatography and Alan Michaels awards.



At the intersection of chemistry, physics and engineering, Professor **Clifford Jones'** expertise is in fuels and combustion processes. Having contributed original research to the scientific literature on fuel technology and fire science, Clifford has also been a major writer of books. Since 1993, he has published 29 books.

His publication record – which expands by two or three books annually – includes *Global trends and patterns in carbon mitigation* (Bookboon, 2013), *Offshore oil and gas decommissioning* (Bookboon, 2017) and *Oil refining: the international scene* (Bookboon, 2019). Lately, Clifford has taken an interest in the intersection of science with the humanities, having for example published a book *Combustion in pre-industrial English literature* (Bookboon, 2016) as well as a number of journal articles on related topics.

Clifford's writing exploits extend to the *Oxford Dictionary of National Biography*. Among other entries, he has penned one about the lone Australian to win a Nobel Prize in Chemistry, Sir John Cornforth. Clifford now sees scientific biography as one of his formal professional activities. He is a frequent contributor to *Chemistry in Australia*, for which he also seems to have become an obituarist!

The University of Leeds (UK) recognised Clifford's scientific accomplishments in 2005 with the award of a Doctor of Science degree for his published work. He is currently an adjunct professor at Federation University Australia, a visiting professor at the University of Chester (UK) and reader emeritus at the University of Aberdeen (UK). He received an RACI Citation Award in 2016.

Fensham Medal for Outstanding Contribution to Chemical Education

The Fensham Medal for Outstanding Contribution to Chemical Education is awarded to recognise outstanding contributions to the teaching of chemistry and science in general over an extended period. This award is named after Professor Peter Fensham AM, who popularised and advocated for the notion of 'Science for all'.



Associate Professor **Siegbert 'Siggi' Schmid** is working to provide a better chemistry education experience for all.

Based on rigorous chemistry education research, Siggi strives to give students a better learning experience. He believes this will help ignite students' passion for the many STEM-related jobs that will underpin Australia's future prosperity. He is making chemistry education more inclusive. This includes improving access for students from underrepresented groups.

As a dedicated educator, Siggi sees his students' success as his greatest achievement. He believes that making a positive impact on someone's life through teaching is a great privilege. Raising the perception of chemistry education to equal that of other areas of chemistry research has for years been one of his chief goals.

Siggi is the leader of the newly established chemistry education research theme at the University of Sydney. He has served as chair for many chemistry education conferences and symposia

organised in Australia in the last 15 years, including the 25th IUPAC International Conference on Chemistry Education 2018. He has held senior offices on the RACI Chemistry Education Division and the NSW Branch Chemistry Education Group and has been a member of the RACI since 1998.

H.G. Smith Medal

The H.G. Smith Memorial Award is given to a member of RACI who, in the opinion of the RACI Board, has most contributed to the development of some branch of chemical science. The Medal depicts and commemorates Henry George Smith, who made significant contributions to organic chemistry in Australia through his work on natural products.



Professor **Richard Payne** handcrafts complex biological molecules. Using these tailored small molecules or proteins, Richard's research group at the University of Sydney aims to tackle problems in biology and medicine.

The biological activity of molecules is linked to their structure. Drug discovery often involves establishing this relationship through testing libraries of structurally similar compounds for their biological activity. To be efficient, this approach requires this library to be generated rapidly. This is commonplace for small molecules, but difficult to apply to complex biological molecules such as proteins. Employing synthetic technologies recently developed in his laboratory, Richard's research group can rapidly generate and analyse bioactive proteins. Through this process, they can also modify these proteins to improve their

activity and stability (see, for example, doi: 10.1073/pnas.1905177116).

Richard's dream is for his research to contribute to the development of a drug that is used to improve human health. However, training and mentoring the next generation of interdisciplinary chemists is equally important to him.

Richard has been a member of the RACI since 2008 and a Fellow since 2017. In 2018, he won the prestigious A.J. Birch Medal awarded by the RACI Organic Chemistry Division. He holds office as Secretary of the NSW Organic Chemistry group.

Leighton Memorial Medal

The Leighton Memorial Medal is awarded in recognition of eminent services to chemistry in Australia in the broadest sense. This includes service to the RACI, research, technology, public service and national leadership. The Medal commemorates the distinguished career of Arthur Edgar Leighton, who carried out an enormous amount of work to secure the RACI's Royal Charter, and who, as a chemical engineer, served Australia's interests in both war and peace.



By using the laws of quantum mechanics and a powerful supercomputer, Emeritus Professor **Leo Radom** aims to improve our understanding of chemistry.

Together with collaborators, Leo is currently investigating how amino acids and proteins can be damaged by radicals. Understanding this chemistry could yield improved insights into how being exposed to air pollution harms us.

Leo's greatest pride is having worked as a postdoctoral researcher in 1969–72 with Professor John Pople at Carnegie-Mellon University in Pittsburgh. Professor Pople was one of the key figures in establishing the field of computational quantum chemistry, and an eventual Nobel Laureate. Leo views this early experience as providing the foundation to his career in the field, and his attendance at the Pople Nobel Ceremony as one of the highlights of his scientific life.

The 9th Conference of the Asia-Pacific Association of Theoretical and Computational Chemists took place in October 2019 in Sydney. With Leo as chair, this conference attracted more participants than ever before. Having been involved in the field since its early days, Leo has a great passion for encouraging scientists to take the computational approach to chemistry. As computers become more and more powerful, the possibilities broaden enormously.

Leo works at the University of Sydney. He has received several RACI awards in the past, including the Rennie Memorial Medal (1977) and the H.G. Smith Medal (1988). Last year, he was made a Distinguished Fellow of the RACI.

Margaret Sheil Leadership Award

The Margaret Sheil Leadership Award was established in 2017 to honour the trail-blazing contributions of Margaret Sheil, the first Australian female professor of chemistry. The award recognises an outstanding female leader working in a chemistry-related field who has helped to inspire and mentor junior female chemists and/or helped to provide a more equitable workplace.



Emeritus Professor **Frances Separovic** studies disease-related proteins and peptides by nuclear magnetic resonance (NMR) spectroscopy. Solid-state NMR techniques allow her to understand the structure of peptides down to atomic detail, which helps reveal how they function.

With antibiotic resistance on the rise, research into the biological mechanisms that are involved in fighting bacteria is in demand. Recently, Frances has been studying antimicrobial peptides in live bacteria. Such peptides are usually studied in solution, as crystals or in model (artificial) membranes. By enhancing the NMR signal, Frances and co-workers were able to study these peptides in live cells. This method improves the researchers' understanding of their antimicrobial activity by providing important structural context.

As Margaret Sheil lecturer, Frances hopes to promote greater recognition of the many contributions made by women to chemistry. Chemistry needs more women, she believes. The only way to retain them is by encouraging a cultural

change and not just by instructing women to act more assertively, she says.

Frances was the third woman to be appointed professor of chemistry in Australia, and the first in Victoria. She was the first woman elected as Fellow to the Australian Academy of Science as a chemist.

Frances is the Deputy Director of the Bio21 Institute at the University of Melbourne. She has been a member of the RACI since 1996 and a Fellow since 2017. She has held a number of leadership positions within the Institute, including the office of Honorary General Treasurer (2008–10). She recently served on the Inclusion and Diversity Committee (2016–19).

Masson Memorial Award

Established as a memorial to the late Sir David Orme Masson, Founder of the RACI, the aim of the Award is to assist a young chemist to proceed in further studies in chemistry.



Hayden Robertson investigates smart coatings through surface chemistry. Smart coatings are designed to respond to input from the environment. They may be resistant to the growth of microorganisms (antifouling), self-cleaning or even self-healing.

Some smart coatings are based on polymers that are tethered to a surface, forming a structure called a polymer brush. Hayden has been investigating polymer brushes that respond to changes in temperature. Specifically, in his Honours

project at the University of Newcastle, he has investigated how adding mixed salt solutions alters the behaviour of such polymer brushes. He plans to continue working to enhance our understanding of smart coatings through his PhD studies commencing in 2020.

In 2017, Hayden was selected by the University of Newcastle to attend a two-week symposium in China under the New Colombo Plan. He has been a member of the RACI since 2017.

RACI Educator of the Year Award

The RACI Educator of the Year Award provides recognition to developing teachers from tutors to senior lecturers teaching in undergraduate or postgraduate university courses.



Dr Elizabeth Yuriev improves student learning in chemistry. A key feature of any science education is cultivating solid problem-solving skills. Elizabeth's research group at Monash University has developed a workflow to help chemistry students establish these skills. The tool, called 'Goldilocks Help', is designed to guide students out of dead ends and false starts. When implemented, it has increased the students' ability to use problem-solving strategies, but also their confidence in their ability to do so (doi: 10.1039/c7rp00009j).

Promoting problem-solving skills is also why Elizabeth advocates for open-note chemistry exams. Using these kinds of assessments, she believes, would allow students to move from rote memorisation to more meaningful learning.

Building a research group focused on chemistry education in a faculty otherwise intent on other research outcomes has been challenging for Elizabeth. The group requires unique support structures that they have built from the ground up. However, with publications in leading chemistry education journals, presentations at prestigious conferences and research students steadily trickling in, the group is on the right track.

Elizabeth is a member of the RACI Chemistry Education Division committee. She has been involved in organising and chairing sessions at numerous chemistry education conferences since 2016.

Rennie Memorial Medal

The Rennie Memorial Medal is awarded to a member of the RACI with less than eight years of professional experience since completing their most recent relevant qualification, who has contributed most towards the development of some branch of chemical science. The Medal commemorates the achievements of Edward Henry Rennie, the third President of the Institute.



Associate Professor **Debbie Silvester-Dean** develops electrochemical sensors to make people safer. Electrochemical sensors are widely used in areas from detecting carbon monoxide to monitoring blood sugar levels. Through understanding the chemistry that occurs on the electrode surface, Debbie is improving the design of such sensors. Her low-cost, miniaturised design could allow the sensors to be used more widely in everyday situations. Some applications of her sensors include monitoring oxygen levels in confined

spaces and detecting ammonia leaks in refrigeration systems.

These gas sensors are based on ionic liquid electrolytes. An obstacle facing this type of electrochemical sensor is interference from water in humid environments. In response, Debbie and her co-workers have recently created a hydrophobic gelled material combining ionic liquids and polymers. This new material blocks interference from the environment, but also makes the sensor design more robust. The design also improves the sensor's response speed by eliminating the common use of a membrane.

Success in her academic career is only one facet of Debbie's life. By her example, she hopes to show that maintaining a firm work-life balance allows accomplished academics to also successfully establish families.

Debbie is an ARC Future Fellow at the School of Molecular and Life Sciences at Curtin University. She is currently the Secretary of the RACI Electrochemistry Division.

Rita Cornforth Lectureship

The award was established in 2017 to give an outstanding female early-career chemist the opportunity to achieve broader recognition of their achievements. The award celebrates the pioneering contributions of Lady Rita Cornforth, the collaborator and wife of Nobel Laureate Sir John Cornforth.



Geochemist Dr **Ellen Moon** studies how heavy metals move through landscapes.

Potentially toxic heavy metals can pose a risk to the environment. Through a combination of fieldwork, laboratory studies and spectroscopy, Ellen studies how heavy metals behave in different environmental conditions. By understanding the chemistry, she can determine their potential to harm the environment. If needed, this research can form the basis of remediation strategies.

If the aim is to remove a hazard from the environment, the best solution might use materials naturally found there. Ellen is currently working on ways to remove heavy metals from contaminated water using only natural plant materials. These include leaves and bark, or fruit peel sourced from food waste. Together with a variety of collaborators, she is exploring the real-world possibilities of this research. One application they are investigating is self-manageable water treatment for remote communities.

Science has opened some surprising doors for Ellen. Like many research scientists, she has had to relocate several times to take up new positions. Building a professional network and personal relationships in a new city or country has undoubtedly been challenging. However, science has also enabled Ellen to fulfil her childhood dream of visiting Antarctica thanks to Homeward Bound.

Ellen hopes to show young people that STEM is for everyone, regardless of gender or background. She is a lecturer in Environmental Engineering and the Course Director of the Bachelor of Environmental Engineering (Honours) at Deakin University.

Weickhardt Medal for Distinguished Contribution to Economic Advancement

The Weickhardt Medal is awarded to a member of the RACI who has contributed significantly towards the economic advancement in Australia through work in a chemistry discipline. The Medal

commemorates the life and work of chemist and business executive Leonard William Weickhardt.



Dr **Grant Douglas** develops chemical technologies for environmental management and remediation. The applications of his technologies are varied: they can decontaminate wastewater from mining sites and trace contaminants exported to the Great Barrier Reef to their original sediment source.

The tricky issue of waste from nuclear power generation has one solution in a recent invention. The technology, EUREECA, traps uranium and many of the radioactive species produced by its decay.

Grant's greatest pride, however, is Phoslock™. It traps phosphorus in a lanthanum-modified clay to prevent algal blooms. This technology is now used in more than 20 countries for cleaning up aquatic environments. Its areas of application range from the Olympic Games to developing countries. Apart from its environmental benefit, the invention is also at the centre of an Australian ASX-listed company valued at more than \$800 million.

At the heart of each of these technologies is chemistry. Grant believes chemistry to be vital in addressing current and emerging environmental issues. In his 20 years as a Fellow of the RACI, Grant has been an enthusiastic advocate for chemistry. Not even his own children were safe; they have gone on to study chemistry at university.

Grant is a senior principal research scientist in the Contaminants and Biotechnology Program at CSIRO Land and Water. He is also a Fellow of the Association of Applied Geochemists.

Beyond chemistry: Ecology ‘culture shock’

Where should I start thinking about my life beyond chemistry? Much of my research has been aimed at solving problems in areas beyond the ‘central science’, so I have trouble finding one particular example to write about.

I have been a synthetic organic chemist, a biochemist, a natural products chemist and a pedagogical researcher; and I have also had a long-term hobby as a horticultural assistant, which has continued into my retirement. In all these roles I have worked in collaboration with a range of experts in fields within and beyond chemistry and learnt a variety of skills from all of them.

But wait, I do remember one particular turning point. When I returned to research after a hiatus, I needed to start understanding more about ecology and biology. I did not expect such a culture shock.

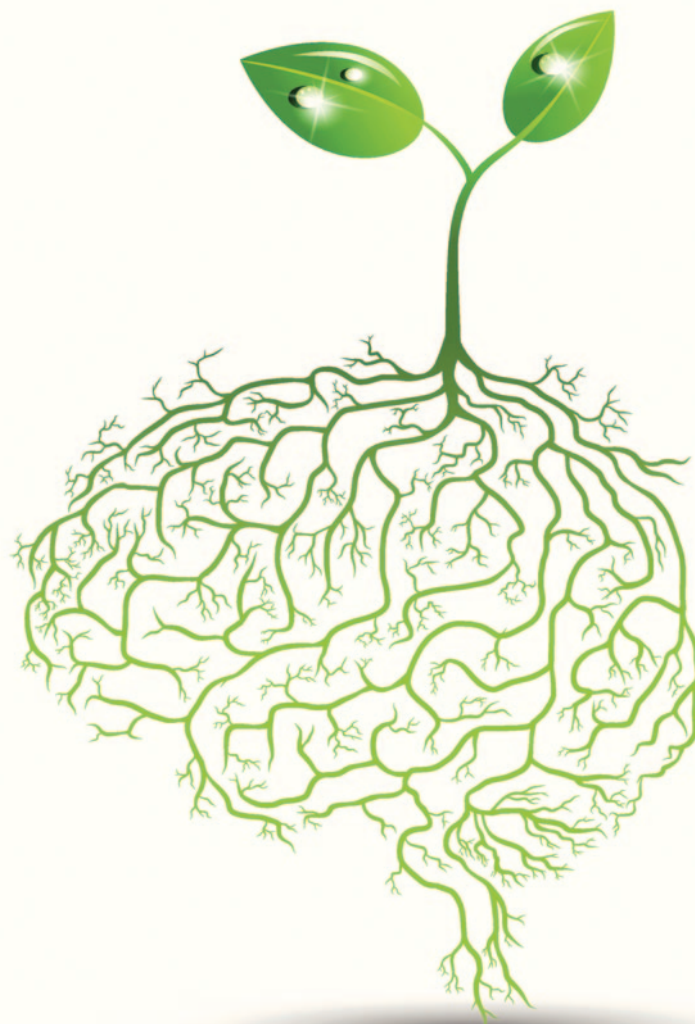
When I first read papers in ecology journals, I was gobsmacked that most of them were written in first-person singular. I had spent countless hours persuading students to write reports and papers in third-person passive, and I had once been admonished by an editor for writing ‘this diagram shows ...’, having to rewrite it as ‘in this diagram, it can be seen ...’

Because the more personal style was almost universal in these biologically focused journals, I realised there must be a sensible reason for it. And there is. Imagine if you are out there in the middle of a freezing night with an infrared camera and a very long roll of twine documenting which nocturnal marsupials pollinate what banksia flowers; or alone on windy Macquarie Island monitoring rabbits; or covered in fungicide powder roaming a steamy tropical rainforest in the wet season looking for frogs. You are the only researcher there, at that time, making personal observations, trying to understand your test organism. It is therefore legitimate that your own reactions are part of those research results and you need to report them in first person. Your subjective observations are equally as valuable to the reader as the ‘objective’ data collected.

The other aspect of research in an environment where it is difficult to control the variables is that you need to be aware of the limits of your documentation strategies. It is important to devise well-designed protocols and appropriate statistical analyses *before* you start, and to add your personal observations to that framework.

This is why my biologist colleagues emphasise the nature of ‘the research question’ to their students and teach them about how to plan sampling strategies and understand statistical significance. Conversely, in a chemistry lab, we can often put our subjects into a ‘test tube’ in a more controlled way. I have even seen chemists first play around with the chemicals and the equipment to see what they can do before planning (or changing) the aims of their research. (Guilty as charged!)

Because I was working in a multidisciplinary science department at the time I was confronting this cultural divide, I



iStockphoto/thanaphiphat

Because the more personal style was almost universal in these biologically focused journals, I realised there must be a sensible reason for it.

decided to talk about my observations at one of our informal Friday afternoon seminars, intending a humorous dig at the philosophical differences between the resident chemists, biologists and biochemists (and one physicist). Instead, my ideas were taken so seriously that people continued the discussion on the points I had raised, even after the beer and pizza ran out.

We were, at that time, buzzing with cross-disciplinary research and had several excellent research students learning each other’s techniques. An illustration from a very old but important book, *Mammalian semiochemistry – the investigation*

of chemical signals between mammals (E.S. Albone, Wiley, 1984, p. 8), nicely illustrates the problems encountered. Captioned 'Naïve optimism ... a caricature of interdisciplinarity?', it features the following exchange as a circular 'chicken and egg' conversation:

Chemist: Tell me by next week which of these hundred components are biologically active.

Biologist: I want a complete chemical analysis of this 10 μ L of secretion.

We discussed how these sentiments can be frighteningly correct. We had already learnt that we needed to be careful in choosing referees for theses and papers describing research in which several methodologies had been used. If for example you choose one referee who is a chemist, and one who is a biologist, and if neither has previously been involved in cross-disciplinary communications, then you run the risk of the chemist thinking the biology results are trivial – that not enough time and effort has been spent acquiring them or they are not sufficiently rigorous – and the biologist thinking the same thing about the chemistry.

Over the years, I have indeed learnt to think beyond chemistry. Although it is the central science, it is not the only science. Something that happens in the lab is not necessarily what happens to, or within, a living organism. To help solve real problems, it is necessary to listen to researchers in other fields, and to really understand the methods that are derived from their experiences.

And it didn't stop there. While working with plants, I also learnt to try to think like plants. Imagining life from the viewpoint of one's research subject is not new, and I hope I have learnt a tiny bit from real experts such as Einstein, Kekule, Barbara McClintock (and others). By doing this, I resolved a puzzle my results had posed, when I realised that the methodology I was using was nothing like any natural environment that the plants experienced and that I was seeing a homologous series of laboratory artefacts.

And it won't stop here. Although I am now retired, I continue a vicarious interest in the fascinating new insights about the communication between plants and their wider environment, which includes other plants, animals, insects and microorganisms. If this piques your interest, I recommend an excellent book – *What a plant knows – a field guide to the senses* (Scribe 2017) – resulting from collaboration by world-renowned chemist Daniel Chamovitz, a variety of biologists and a wonderful science communicator/editor. (Read the book's acknowledgements to see what I mean.) Chamovitz has really gone way beyond chemistry, while maintaining the importance of the central science.

Deidre Tronson FRACI CChem used to be a mad scientist, but now she is the Good Little Banksia Lady.

Deidre's learning list

In my retirement, I try to educate myself about a wide range of scientific developments with a daily dose of sciencedaily.com – from there, I can choose articles to follow up, or not. (Habits of early morning literature-browsing are hard to break.)

More specifically, relating to plant communication and the evolution of ideas, I have put together a selection of articles that illustrate various aspects of this research over the years. (The ideas about talking trees were originally poooh-pooohed in the mid-1980s. Researchers have come a long way since then.)

Bruin J., Sabelis M.W., Dicke M. 'Do plants tap SOS signals from their neighbours?' *Trends Ecol. Evol. (TREE)* 1995, vol. 10(4), pp. 167–70.

Carthew S.M. 'Foraging behaviour of marsupial pollinators in a population of *Banksia spinulosa*' *Oikos* 1994, vol. 69, pp. 133–9. (Example of first-person reporting, plus a change in paradigm about animal pollinators.)

Chadwick D.J., Goode J.A. (Eds). *Insect-plant and induced plant defence*, John Wiley & Sons, Chichester, 1999.

Chehab E.W., Yao C., Henderson Z., Kim S., Braam J. 2012. 'Arabidopsis touch-induced morphogenesis is jasmonate mediated and protects against pests' *Curr. Biol.* 2012, 24 April, vol. 22(8), pp. 701–6.

Gagliano M., Grimonprez M., Depczynski M., Renton M. 'Tuned in: plant roots use sound to locate water' *Oecologia* 2017, vol. 184(1), pp. 151–60.

Haswell E.S., Phillips R., Rees C. 'Mechanosensitive channels: what they can do and how do they do it?' *Structure* 2011, vol. 19(10), p. 1356.

Honda K., Omura H., Hayashi N. 'Identification of floral volatiles from *Ligustrum japonicum* that stimulate flower-visiting by cabbage butterfly *Pieris rapae*' *J. Chem. Ecol.* 1998, vol. 24(12), pp. 2167–80.

Runyon J.B., Mescher M.C., De Moraes C.M. 'Volatile chemical cues guide host location and host selection by parasitic plants' *Science* 2006, vol. 313(5795), pp. 1964–7.



<p>ROWE SCIENTIFIC PTY LTD. ABN 61 559 407 761 www.rowe.com.au Pledge to Chemists</p> <p>If chemists in Australia are experiencing difficulty in obtaining supply, please send me an email, peter.sommers@rowe.com.au and I promise to help you.</p> <p>This is not a 'subtle' attempt to obtain more business, but a sincere pledge to help fellow scientists source the items they need to do their work, and thereby help Australia grow. This is the raison d'être for Rowe Scientific Pty. Ltd.</p> <p>Peter Sommers (FRACI)</p> <p>Quality Systems Quality Endorsed Company ISO 9001:2008 LIC 16973 SAI Global</p>	<p>ADELAIDE 08 8186 0523 rowesa@rowe.com.au</p> <p>BRISBANE 07 3376 9411 roweqld@rowe.com.au</p> <p>HOBART 03 6272 0661 rowetwa@rowe.com.au</p> <p>MELBOURNE 03 9701 7077 rowevic@rowe.com.au</p> <p>PERTH 08 9302 1911 rowewa@rowe.com.au</p> <p>SYDNEY 02 9603 1205 rowensw@rowe.com.au</p>
--	---

The Rhubarb Connection and Other Revelations

The Everyday World of Metal Ions

Lars Öhrström and Jacques Covès
Foreword by Raychelle Banks

The rhubarb connection and other revelations: the everyday world of metal ions

Öhrström L., Covès J., Royal Society of Chemistry, 2019, paperback, 211 pp., ISBN 9781788010948, approx. \$40

What a wonderful, quirky, amusing and information-rich little book *The rhubarb connection and other revelations: the everyday world of metal ions* is. From the front cover, which features a stylised rhubarb stick figure holding a magnifying glass, to the very end, this book is a friendly, enjoyable celebration

of the role of metal ions in all sorts of areas.

Inorganic, metal-organic and other species of chemists will enjoy the book, learn much from it, and possibly gain inspiration from it.

This book will potentially greatly enhance your knowledge of metallic species and their widespread applications. For example, chelation therapy, which 'wraps' metal ions with organic ligands to facilitate their excretion from the human body, or sometimes facilitate incorporation of metallic species, is extensively discussed.

If you are interested in metal poisoning or therapeutic uses of metals, you will also find much to interest you, including the story of Lewisite (2-chloroethenylarsenious dichloride), which goes by the macabre name 'dew of death' and apparently has a quite pleasant geranium smell. There was great fear in the early days of World War 2 that the German forces would employ it as a chemical weapon. It was widely accepted at the time that Lewisite could attack vital sulfur-hydrogen bonds in some enzymes vital for the conversion of glucose to usable chemical energy in the body. That led to the development of BAL (British anti-Lewisite), $\text{HSCH}_2\text{CHSHCH}_2\text{OH}$, which preferentially bonds to the arsenic. This is nicely balanced by discussing *cis*-platin, used in the chemotherapeutic treatment of cancer. Metal-based medications, such as lithium for bipolar disorders and iron supplements for anaemia, are discussed. There is even an interesting photograph of a packet of 'Blaud's Improved Iron Pills' from the 1800s, the improvement being the addition of a tad of arsenic to the formulation. Perhaps this was to garner the custom of anaemic syphilitics, who may have derived some relief from both conditions.

You will also learn of blue-blooded crustaceans (copper-based circulation), why warships were painted pink (iron oxide paints made the ships very hard to spot at dawn and dusk), and how transition metals transform ordinary materials into colourful gemstones. The stereospecificity of some natural products is also intimately associated with the presence of metal ions.

If you have ever wondered how much gold is dissolved in the world's oceans (one heck of a lot!) and why nobody has

seriously tried to recover it, then this book will set you straight. Fritz Haber put the exact same proposition to the Kaiser as a way to pay the World War 1 reparation debt. It didn't work then and I very much doubt it would work now! Metal carbonyls and metal 'sandwiches' such as ferrocene also rate discussion in the book.

I hope with these examples you get some sense of why I am excited about this book, as well as some sense of its breadth of coverage. The book is a celebration of much of the fascination and application of inorganic chemistry.

Both authors are entirely appropriate and experienced to write this book. Lars Öhrström is a Swedish inorganic chemist and professor at Chalmers University of Technology, Gothenburg, where he researches metal-organic frameworks. Biochemist Jacques Covès is a research director at The French National Centre for Scientific Research. His research interests, pursued at the Institut de Biologie Structurale in Grenoble, are in metals in biology.

The tone of the book is quite chatty. Some readers might find that a bit annoying (and others might greatly relish it). In a few instances, the English in the text needs further editing, but the meaning is always perfectly clear. There are many structural diagrams in the book, all in grey-scale. I hope when the publishers authorise a second edition, they consider full colour because it would facilitate reading them as well as adding more pizzazz to this splendid little book.

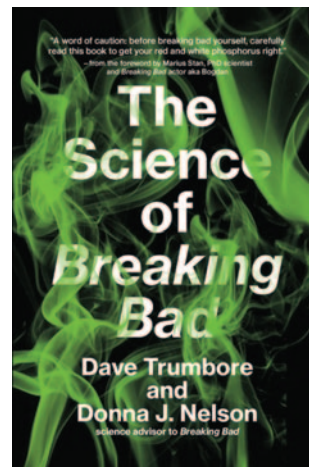
R.J. Casey FRACI CChem

The science of Breaking Bad

Nelson D.J., Trumbore D., MIT Press, 2019, paperback, 264 pp., ISBN 9780262537155, \$19.95

Early in 2008, only one person responded to the invitation to provide 'constructive comments from a chemically inclined audience' for a then-fledgling TV series. For Dr Donna J. Nelson, it was a low-key introduction to *Breaking Bad* and to a journey with what would be one of the most-watched TV series of all time. At the time, Nelson was a chemistry professor at the University of Oklahoma and a former president of the American Chemical Society.

The vision of *Breaking Bad* as a crime drama series is best described by creator Vince Gilligan: 'A story about a man who transforms himself from Mr Chips into Scarface'. The main protagonist (Walter White) is a high school chemistry teacher who is faced with a diagnosis of terminal cancer. *Breaking Bad's* five seasons follow his transformation from model citizen into a manufacturer and dealer of methamphetamines.



The science of Breaking Bad tells the story behind the physics, chemistry and biology of many of the series' memorable moments and offers insights into this 'TV' science that facilitates such character transformations. The book provides many of the details behind the science that creates this journey, equally alongside the cast of characters. As Nelson notes, 'It's not just Walt's vast knowledge of chemistry that gets him into and out of trouble over the seasons but also his general knowledge of other scientific concepts.'

The '101' and 'Inside *Breaking Bad*' sections for each topic offer the essential details if you are not looking for spoilers on the show's special effects. This holds true for the book's 19 chapters, but if you have a science background (particularly in chemistry or physics) the 'Advanced' portions of the book offer more insights into the design of specific experiments. *The science of Breaking Bad* also offers unique insight into the show's portrayal of the manufacture of illicit drugs. While this was an aspect that had initially dissuaded Nelson from involving herself with the series, the book describes modifications that were made to many experiments based on a responsibility to viewers.

The science behind some of the most significant scenes from *Breaking Bad* are described in detail throughout the book, including during the pilot episode where adding red phosphorus to water generates a cloud of incapacitating phosphine gas. Nelson discusses at length the show's achievements in many of these scenes – 'I felt that I had succeeded in my one goal. The scene demonstrates the importance of knowing chemistry, and of respecting the talented chemists who do it right. The scene is scientifically credible. It uses science to create drama.'

The science of Breaking Bad is a good read and certainly does justice to the complexity of the series' storylines. Although the episodes were shown from 2008 to 2013, I recommend watching it if you have not watched the series before. *The science of Breaking Bad* would complement watching the whole series or re-watching a few favourite episodes.

Samantha Profke MRACI



Under the stars: astrophysics for bedtime

Harvey-Smith L., Matthews M. (illustrator), Melbourne University Press, 2019, hardback, 277 pp., ISBN 9780522876086, \$39.99

Astronomer Professor Lisa Harvey-Smith has a high profile as the Australian government's first Women in STEM Ambassador, and before that she was involved in Australia's bid for the Square

Kilometre Array (SKA) telescope. In addition to her professional work as an astronomer, she's participated in television shows

The science of Breaking Bad is a good read and certainly does justice to the complexity of the series' storylines.

(including the ABC's *Stargazing Live* and documentaries) and published a popular astronomy book for adults, *When galaxies collide*.

Under the stars: astrophysics for bedtime is her newly published book for children, and it's full of information both scientifically accurate and amazing, yet simple. In 45 short chapters, mostly one to two pages long, Harvey-Smith describes Earth, our solar system, space beyond the solar system, the Milky Way and the universe. Some imaginative chapters bring the reader right into the action: seeing a black hole, taking off in a space rocket, experiencing different body weights on different planets. Many other chapters have more facts and explanation, but astrophysics facts are pretty cool, so it's a fun read.

One of the strengths of this book is the confident and joyous attitude to science. For example: 'Being an astronomer is an amazing job because sometimes you get to see something no-one has EVER seen before.' (p. 43). Of course, Harvey-Smith doesn't pretend we know all the answers. Reflecting how science really works, she discusses when scientists were first puzzled by something they saw (like the first pulsar, whose LGM-1 nickname stood for 'little green men'), what scientists are still working out (like whether the complex molecules that preceded life on Earth formed here or dropped in from space), and what we now know because of science.

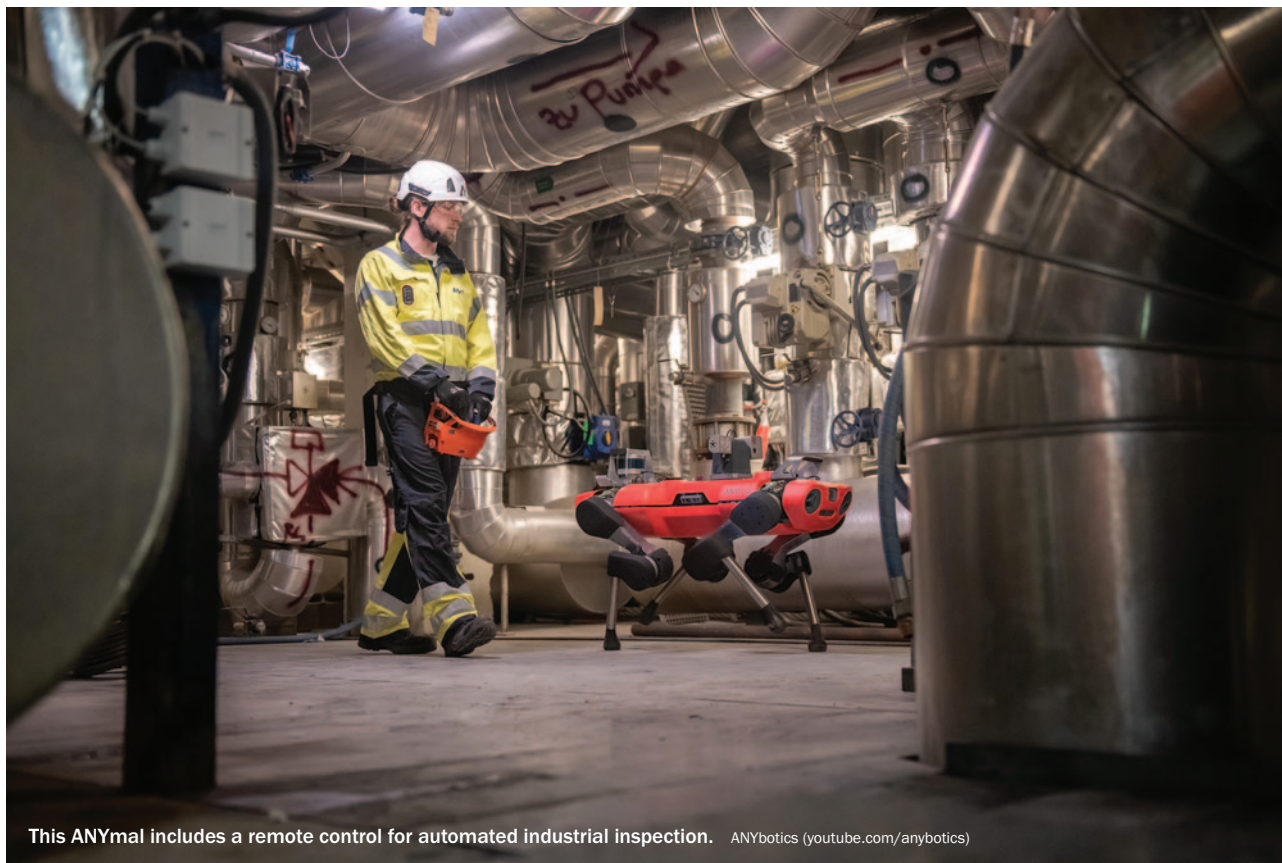
Another strength for Australian readers is the Southern Hemisphere perspective. I found it immensely refreshing to read the discussion of seasons and realise I didn't have to 'invert' it for us Down Under.

The subtitle, *Astrophysics for bedtime*, suggests the book may be designed for parents to read to their children (or is it because you can see stars at night time?). The illustrations are suitable for young children, but the style would also appeal to older kids. I imagine many children (perhaps upper primary age) would happily read the book to themselves. However, I'm not sure a child starting from no knowledge of the topic would follow the explanation in two of the early chapters (on why our sky appears blue and why there are seasons).

Perhaps because they move into ever more mind-blowing topics, the later chapters are particularly engaging, and the book finishes with an appropriate explosion. I expect the book will inspire quite a few readers (and their parents) to look up to find the International Space Station or download a stargazing app, using resources listed.

Margie Beilharz

Iron roughnecks: unmanned automation in the oil and gas industry



This ANYmal includes a remote control for automated industrial inspection. ANYbotics (youtube.com/anybotics)

When we think about our future workforce, perhaps one of the hottest topics of the moment is the rise of collaborative robots. While we prepare for the co-existence of automated and human workers, we're also placing robots in some of the world's most remote and far-flung working environments.

Located on the Norwegian North Sea, there's something different about Equinor's Oseberg H platform. With no toilets, living quarters or coffee break facilities, this oil rig was not built with human workers in mind. Remotely operated from the Oseberg field centre eight kilometres away, this is the world's first fully automated oil and gas platform.

As human workers transition from offshore oil rigs to onshore monitoring and automation managing roles, addressing the challenges that come with an automated, remote workforce is an important step towards developing more facilities like Equinor's in the future.

Many factors make offshore the perfect candidate for unmanned automation. Inherently dangerous operations, long stints at sea and remote locations make for unattractive working conditions. With an eroding human workforce, the industry is increasingly turning to robotics to carry out its operations.

When robots were first introduced to offshore environments, they were assigned rather menial tasks. While machinery

continues to carry out processes such as screwing drill pipes and connecting them into well holes, today's offshore robots are capable of much more.

For instance, Swiss robotics company ANYbotics has developed a four-legged robot fitted with a sensor head to carry out monitoring duties offshore. Named the ANYmal, its pilot installation in 2018 proved that the robot is capable of autonomously performing a range of inspection tasks, including thermal measurements and checks on water levels.

For robots to be able to achieve this level of monitoring requires them to carry a variety of sensors and cameras. Using visual sensors, robots are now able to read gauges with computer vision by training the sensors with a variety of images. Once trained, the sensors can read gauges by capturing real-time images of the system and comparing them to stored images on servers.

In the case of a patchy connection or rough conditions that impede visibility of the gauges, the images can be saved for remote interpretation. Gauges aren't the only part of machinery that can be read; in fact, systems of this sort can also be trained to read and interpret a variety of other read-outs – components such as valves and identify faults.

For example, computer vision systems could be trained to

... the ANYmal ... robot is capable of autonomously performing a range of inspection tasks, including thermal measurements and checks on water levels.

identify changes in the colour of materials to detect rust or other contaminants that could put the structural integrity of a material at risk. Conversely, the robot could simply film the inspection and send it to onshore locations for engineers and specialists to review either live or after the inspection is complete.

In the case where light is scarce, or applications are in remote areas with constant poor visibility, robots can be attached with pH probes to inspect the pH levels of a material and send the information back to onshore specialists.

Many offshore operations have been running for a long time, meaning that they precede the advent of widespread use of smart sensors. This means that thermal and vibration data is not always being collected. Widespread miniaturisation now means that robots can have these sensors easily retrofitted.

Robots can use thermal imaging to register the temperatures of applications and check whether they are in the safe limits and determine the presence of any hotspots. Acoustic sensors allow robots to listen to the vibrations of machinery, comparing it with historical acoustic data to identify if urgent action needs to be taken. This drastically reduces the cost of retrofitting entire complexes with smart sensors, especially on older rigs.

A successful unmanned platform would require continuous monitoring to keep track of its automated workforce. The technologies to facilitate this already exist, meaning unmanned facilities could be easily installed across the globe. For example, supervisory control and data acquisition (SCADA) software can continuously monitor and detect machinery faults and raise the alarm to alert maintenance engineers.

This approach can be taken further by retrofitting equipment such as sensors and programmable logic controllers (PLCs) to build a digital interface that helps onshore engineers retain insight into their offshore facility. By measuring factors such as energy consumption, leak detection and equipment failure, implementing small changes to a platform's operations could massively boost its autonomy and facilitate efficient remote management.

Developing an automated offshore structure isn't as easy as ripping out restrooms and sending workers ashore. For robot roughnecks to elevate production, offsite engineers must take a number of factors into consideration.

The terrain of an offshore platform can be pretty treacherous if you aren't equipped with hands and feet. Facilities host a



range of complex installations, including networks of pipes and steep stairs that connect multiple levels. While such an environment is no challenge for a human worker, the platform's layout may require refurbishment to make it accessible to our automated counterparts. In parallel to this, robots themselves will need to be programmed with a high degree of autonomy so that they can manoeuvre any obstacles.

Another hurdle is risk management. If a piece of equipment malfunctions or risks breakdown, a lack of on-site human workers may delay vital maintenance. Establishing relationships with parts suppliers, such as EU Automation, will be crucial in minimising downtime at an unmanned site by ensuring that replacement parts arrive with speed.

The Asia-Pacific region is a huge, growing market for the oil and gas industry – predicted to account for 70% of global oil demand by 2020. As demand for this incredibly challenging industry shows no sign of ceasing, unmanned automation could well be the key to maintaining productivity.

We may not be handing the reigns over to four-legged robots any time soon, but achieving autonomous offshore operations is certainly in our reach.

John Young is APAC director at global industrial parts supplier EU Automation.

New metric for measuring research impact

Recently, Nicola Maxwell and I published a paper entitled ‘A quantitative metric for research impact using patent citation analytics’ (bit.ly/2K8wUwg). The paper proposes a new metric for measuring the research impact of academic research. Rather than counting academic citations accruing against a journal article, or counting the number of patent filings made by an academic (both approaches have their deficiencies), the new metric focuses on academic publications that become an obstacle for any third-party attempting to obtain a patent right.

Every now and again, an academic paper is raised by a patent examiner as an obstacle to patentability during the patent examination process. The patent examiner will cite the academic paper, arguing that it contains a prior disclosure of the invention. When that academic paper is from, for example, a researcher at the Faculty of Engineering and IT (FEIT) at the University Technology Sydney (UTS), it says something about the technology merits of that research. It says that the research was commercial; it says that the research contained original and inventive content; it says, therefore, that the research had ‘research impact’ in a technology sense.

To test this newly proposed metric, we took about 22 000 FEIT UTS publications from the last 10 years and looked to see if they had been raised during patent examination – anywhere, ever. We found more than 1200 instances where a UTS published paper was cited during a patent examination process. However, we decided to go further. We wanted to find those cited by patent examiners against a patent family where there was a US patent family member (because US patent rights are arguably the most commercially valuable). We also wanted to focus on those citations that had been raised by patent examiners as novelty destroying (named ‘X’-type) or obviousness destroying (named ‘Y’-type) – not those raised simply as ‘relevant background art’ (A), or added to the body of the patent as references by the drafting patent attorneys. Both X- and Y-type citations effectively restrict the scope of what can be claimed by a patent applicant, or in some cases completely prevent a patent from being obtained.

Surprisingly, by restricting the type of citations considered, we found that the number of citation instances reduced from more than 1200 to only 100 (from the more than 22 000 publications). The 93 academic papers that had 100 ‘eligible citations’ were worth focusing on. For example, we noticed a particular author who kept posing an obstacle despite not seeming to patent his own work: a possible lost opportunity for the university.

For comparison, we also took FEIT UTS patent rights and performed a similar analysis to see how many of them appeared as obstacles to other parties seeking patent rights. Of the 84 inventions published in the same 10-year period, we found 67 eligible citations using the same methodology. Note well: 84 patent rights generated 67 eligible citations whereas more than 22 000 publications generated only 100.

That is, we found that there is 180 times greater likelihood of a patent being cited by a patent examiner than a journal article. To explain this, we argue that patent examiners substantially restrict their searching to the readily available and familiar (to them) patent databases, because of the ease of parsing the resultant documents found from the search strings, secure in the knowledge that, relatively speaking, there is far greater inventive prior art to be found in the patent databases (fuelled in part by the proliferation of spurious publication in academia over the last few years). The data of this research is of such a large quantity that it is possible that we have identified proof of an inherent flaw in some patent examination processes.

Overall, the combination of the two publication types (academic papers and patent rights) allowed for the calculation of a PC-index (a patent citation index) using the traditional H-index-type approach. FEIT at UTS had a PC-index of 4. We plan to perform the same analysis on other academic institutions (and even academic journals) to see how this PC-index fares as a relative measure of research impact. Currently, the most-used measurement of research impact is based on technology case-studies; this qualitative approach doesn’t necessarily allow unbiased comparison of the performance of different cohorts of academics.

One key feature of our new metric is that it’s very difficult to game because one cannot influence whether a patent examiner will cite a research article as significant prior art. It is a matter of fact whether a paper contains significant prior art that inhibits or blocks a party later trying to seek similar patent rights. In the academic literature, gaming occurs; for example, when groups of authors informally agree to cite each other in their publications, independent of the merits of such citing, thus increasing their individual metrics based on citation counts.

From the perspective of my co-author, as a patent analyst and patent attorney, she was deeply surprised at how difficult this research was to undertake, with much of it having to be undertaken manually. Manually processing more than 22 000 items is no mean feat. She was also surprised at the poor quality of available patent citation counting, with many patent citation counts actually being ‘references’ in the patent file wrapper (i.e. not documents actually raised by the patent examiner as substantive prior art). When we took a citation count provided automatically from existing software tools and then manually de-duplicated across patent family members, the citation count was reduced by 30%. When we manually de-duplicated to meet our X/Y citation-only requirements, the citation count dropped by 86%. This is a mind-boggling result; according to our data, most reported patent citation counts contain up to 86% noise. Any conclusions (typically called patent citation analysis) drawn from such data must be inherently flawed.

Ian A. Maxwell (maxwell.comms@gmail.com) is a CEO and entrepreneur, and a former venture capitalist. He is a Visiting Professor in Engineering and IT at UTS, who started out his career as a physical polymer chemist.

Prospecting for PhDs?

Reach out to an
RACI chartered chemist
by advertising with us.

To present your product or
service to this specialist market,
contact Mary Pappa at RACI:
(03) 9328 2033
mary.pappa@raci.org.au

chemistry
in Australia

Modelling molecular assembly in wine

From time to time in these columns I have referred to molecular assembly processes in red wine. The assembly process is proposed to result from interactions between protein and polyphenolic compounds, or tannins, as polyphenolics are commonly called. The role of polysaccharides in influencing this tannin–protein interaction is still the subject of conjecture.

It is clear that there is an interaction between tannins and proteins: think what happens when milk is added to tea. In red wine production, protein is sometimes added in the final preparation of a wine prior to bottling to ‘soften the astringency’. The general argument is that, as the amount of tannin would be in far excess of the amount of protein added, then no protein should remain. If there is residual protein bound to tannin in the wine, then this could become an issue for allergen labelling.

The issue of residual protein in wine after fining has been investigated by various researchers. The research group at the University of Porto proposed in a series of articles from 2004 to 2006 that an assembly of soluble complexes resulted from the interaction of wine tannins and proteins, with additional interactions involving polysaccharides potentially giving a three-component soluble complex; that is, residual protein in the wine is possible. Rolland et al. (*J. Agric. Food Chem.* 2008, vol. 56, pp. 349–54) expressed a contrary view when no protein residue could be detected by ELISA assay in wines that had been previously fined with casein, ovalbumin or peanut, the last being used for research purposes only.

An alternative perspective was described by the oenology research group in Montpellier. After fining with gelatin or plant proteins and applying a sodium dodecyl sulfate treatment followed by a specific analysis for the polyphenolic content, a higher amount of these compounds was detected than the amount found without sodium dodecyl sulfate treatment (*Am. J. Enol. Vitic.* 2001, vol. 52, pp. 140–5; 2003, vol. 54, pp. 105–11). The increase was interpreted as the sodium dodecyl sulfate treatment releasing the protein from the bound tannin–protein complex, thereby releasing more tannin. It was also suggested that the ELISA technique used by Rolland et al. may not have been able to detect tannin–bound protein.

Until recently, evidence for soluble tannin–protein complexes was qualitative, perhaps even speculative. Seeking more rigorous evidence, the Montpellier group used a model system consisting of a polyphenolic powder extracted from Syrah and dissolved in aqueous ethanol. This solution was then fined with two hydrolysed wheat glutens and gelatin (*Food Chem.* 2019, vol. 279, pp. 272–8). After fining and centrifugation, the viscosity of the supernatant was measured. A small, but measurable, increase in viscosity was observed for the fined samples compared to the model wine. As any unbound fining agent did not affect the viscosity, it was argued that the increase was due to the presence of soluble tannin–protein aggregates.

Not content with the viscosity result alone, the authors used a labelled protein in the fining experiments. Residual radioactivity was found in the supernatant after fining, clearly indicating the presence of residual protein in the supernatant. This, in combination with the increased viscosity and a higher proportion of amino acids specific to the fining agent in the supernatant after fining, was clear evidence for the presence of tannin–protein aggregates.

Nanoparticle tracking analysis (NTA) is finding more applications in wine research. Recently researchers from the University of Adelaide and the Australian Wine Research Institute used NTA as well as dynamic light scattering (DLS) to examine what they called ‘the characterisation of the polydispersity of aggregates resulting from tannin–polysaccharide interactions’ (*Molecules* 2019, vol. 24(11), p. 2100). Using a wine-like solution, the authors tracked the interaction between grape seed tannin with either mannoprotein or arabinogalactan. The observed shift in particle size seen by NTA was consistent with aggregation, with further confirmation of this aggregation being obtained by DLS.

The two polysaccharides behaved differently in their interaction with the seed tannin. Mannoprotein formed ‘large, highly scattering aggregates’ while only a weak interaction was found with arabinogalactan. The authors suggest that their results support the proposal that polysaccharides bind with tannin and thus limit access to the tannin by protein (see *Anal. Chim. Acta* 2004, vol. 513, pp. 135–40 for a detailed description of the optional binding models). My issue is whether it is the protein component of the mannoprotein that is the basis for the observed aggregation. I do agree with the authors that more competitive experiments with different proteins and other wine polysaccharides need to be performed to refine our understanding of the aggregation process.

The Adelaide researchers found that a 3% variation in the ethanol concentration of the model resulted in a marked change in aggregation: higher aggregation occurred at the lower ethanol concentration. This, as the authors point out, may be significant in sensory terms as the extent of aggregation versus ethanol concentration may impact on the taster’s perception of astringency and bitterness.

The outcomes of the NTA experiments open the way for additional experimentation to enhance our knowledge of sensory perception. It is essential that experiments are performed on wines of known chemical composition. Perhaps in place of fining proteins, experiments using human saliva could be performed and the aggregation results correlated with descriptive sensory analysis.



Geoffrey R. Scollary FRACI CChem (scollary@unimelb.edu.au) 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.

My chemistry set

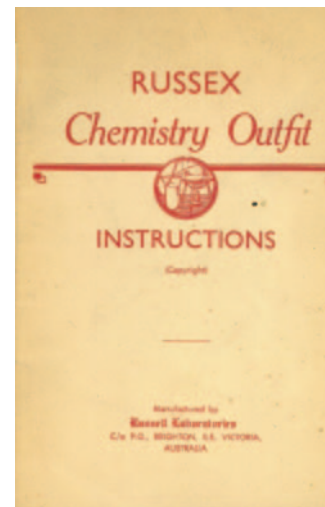
My paternal grandmother gave me a chemistry set as a Christmas present. It was a Russex Chemistry Outfit, and my research has revealed that it was assembled by Edward Russell Rotherham, the proprietor of Russell Laboratories in the southeastern suburbs of Melbourne. I was still in primary school, and since I have found an advertisement for the set in the Melbourne *Argus* for November 1947, I reckon that must have been the year. I was just ten years old.

According to the advertisement, the set contained six 'testing' tubes, a cleaning brush, six sample jars of chemicals and a book of instructions. Maybe my set was an improved version because I think it had more than six chemicals. I remember copper sulfate, nickel sulfate, ferric ammonium sulfate, cobalt chloride, sulfur, sodium bisulfate (a stand-in for sulfuric acid), ammonium chloride and sodium silicate solution. There was litmus paper, too. To refresh my memory I consulted the copy of the Russex instruction book in the State Library of Victoria and saw that it recommended augmenting the array of chemical substances with ones that were found around the home. These included lime, Condy's crystals (potassium permanganate) and Epsom salts (magnesium sulfate). There were instructions for making a burner from a glass jar: I used a Vegemite jar, one of the old white ones with a metal lid. I cut a hole in the lid, as instructed, inserted a piece of rope to act as a wick, and half-filled the jar with methylated spirits. It worked well for heating liquids in the test tubes, which I held with a strip of light cardboard, as recommended.

The prescribed experiments were a lot of fun, and much simpler than the ones described in a chemistry textbook that I had inherited from a relative. I observed the loss of 'water of crystallisation', made lime-sulfur solution and used it to stain a silver coin, prepared iron sulfide by heating sulfur and iron filings (home-made!) in an old spoon, and used that to generate rotten egg gas. I detected carbon dioxide in my breath by blowing into lime water, and I sublimed ammonium chloride.

There was nothing really dangerous in the kit, but there were instructions to make sodium hydroxide from sodium carbonate and lime. Buying quicklime (calcium oxide) may have been more difficult than buying caustic soda that was (and is) commonly available as a drain cleaner. However, generating small quantities makes a lot of sense for young chemists, and from my sodium hydroxide I was able to make the jelly-like hydroxides of nickel, magnesium and iron. Calcium oxide was also used to generate ammonia from ammonium chloride; nitric acid was made from sodium bisulfate and potassium nitrate. Finally, there was a chemical garden with sodium silicate and three of my metal salts.

There were instructions for making a burner from a glass jar: I used a Vegemite jar, one of the old white ones with a metal lid.



Russell Laboratories didn't make much of an impact on Melbourne's commercial scene, but I found quite a bit of information about Rotherham – always known as Ted – who was a skilled amateur photographer who won prizes for his work. He was President of the Melbourne Camera Club in 1958, and one of his nature photographs was published in the history of the club, written by Alan Elliott. The club has an E.R. Rotherham Trophy for Nature as part of its annual competition.

Rotherham (1923–2009) was registered as a secondary teacher in 1948 and served as a teacher in northern Victoria (I wonder if he may have been a chemistry teacher) before making a career out of his hobby, teaching photography at RMIT. He retired in 1983. Rotherham was known as an illustrator, in which capacity he was co-author of a number of books about plants and gardens (with a sideline in pictures of snakes). He was a member of the Field Naturalists Club and the Society for Growing Australian Plants. He was also interested in the local history of Warrandyte, where he lived, and this was recognised by an award from the Royal Historical Society of Victoria in 1998.

When I began writing this Letter, I headed it 'my first chemistry set', but as the writing went along, I realised that it had been my only chemistry set. Even as I worked with the Russex chemicals, I was getting supplies from a local pharmacy, and then from chemical suppliers Selby and Keogh in the city. I was also gifted the chemicals and glassware from another home chemistry enthusiast when he found enough to keep him busy at work, as an industrial chemist.



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 provides advice on chemical hazards and pollution.

Abstracts for Herbicide Discovery & Development 2020 (HDD2020)

In conjunction with the RACI Synthetic and Organic Group WA
15–17 January 2020, Crawley campus, University of
Western Australia, Perth, WA
HDD2020.org

20th Australasian Polymer Summer School

11–13 February 2020, Kioloa Campus (NSW South Coast),
Australian National University, NSW
polymersummerschool.wixsite.com/apss

**International Coalition for Energy Storage and Innovation
Conference**

1–4 March 2020, Dockside Function Centre, Sydney, NSW
icesi2020.com

Conference of Metrology Society of Australasia

3–5 March 2020, Melbourne, Vic.
metrology.asn.au/msaconnected/events-menu/msa2020-melbourne

**Joint meeting of RACI Organic Chemistry and Medicinal
Chemistry and Chemical Biology divisions**

5–8 July 2020, University of Wollongong, NSW
Further details TBA

**International Symposium on Macrocyclic and
Supramolecular Chemistry**

12–16 July 2020, Sydney, NSW
ismsc2020.org

International Conference of Microreaction Technology

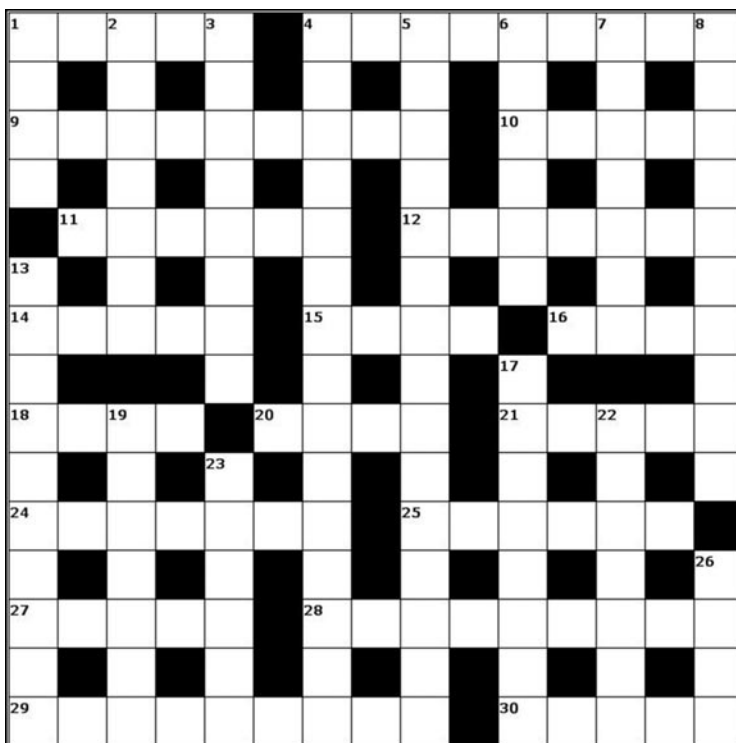
8–11 December 2020, Melbourne, Vic.
imret2020.com

RACI events are shown in blue.



Join the conference crowd

To promote your forthcoming conference or event here,
email details to the Editor at wools@westnet.com.au.



Across

- 1 Channel bonding study to hold over description of a group of gases. (5)
- 4 Smelly carpet man laid. (9)
- 9 Plant compound and angle in on reaction. (9)
- 10 Charged four elements. (5)
- 11 Generates four elements. (6)
- 12 SbH_3 bites in mutation. (7)
- 14 Indicates adjacent positioning. Hold that! Food for thought! (5)
- 15 Two or three elements of a hexahedron. (4)
- 16 Turn three elements into one. (4)
- 18 Selenium follows refractive index increase . . . (4)
- 20 . . . which makes hyaluronic acid in double time. (4)
- 21 Compounds having the $=\text{N}^+=\text{N}^-$ group mentioned in digital media zone. (5)
- 24 Like Spooner's foolish parent. (7)
- 25 Beet-rave lately included movement. (6)
- 27 OOO Australia 1. (5)
- 28 See 30 Across.
- 29 Fake press in expired spread. (9)
- 30 & 28 Across Bogus tests proceeded with radar. (5,9)

Down

- 1 No neon! Neon released. (4)
- 2 Bad buy not a positive. (7)
- 3 Discharge electron charge. (8)
- 4 Academic honours made by replacing uranium with sulfur sugars. (15)
- 5 Sturdiest tubing broke leading to changed arene. (4-11)
- 6 Ca and ZnI_2 involved in production of acid derived from $\text{H}_2\text{N}^+(\text{O}^-)\text{OH}$. (6)
- 7 Five or six elements of stress. (7)
- 8 First ever continual reaction forming crystals. (10)
- 13 Agree and put it in writing. (10)
- 17 Canvased new breakthroughs. (8)
- 19 Blossomy garden emitting oxygen characters. (7)
- 22 Excellent pitch solvent. (7)
- 23 Everyone points to $\text{R}_2\text{C}=\text{C}=\text{CR}_2$. (6)
- 26 Operated hand-me-down. (4)

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

Herbicide Discovery & Development

HDD 2020 PERTH

University of Western Australia
Jan 15-17, 2020

KEYNOTES

Stephen Duke, USDA
Laura Barter, Imperial College
Belinda Abbott, La Trobe
David Ascher, U. Melb.
Ruth Campe, BASF
Hugh Beckie, UWA
Luke Guddat, UQ

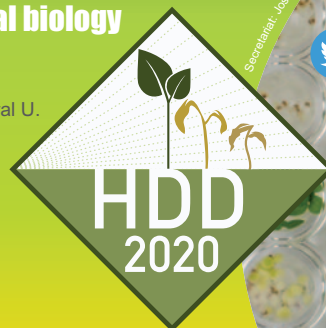


Organic chemistry
Chemical biology
Structural biology

SPEAKERS INCLUDE

Guang-Fu Yang, China Central U.
Ruibing Wang, U. Macau
Sabine Kahlau, Targenomix
Joel Haywood, UWA
Jian-Guo Wang, Nankai University
Tatiana Soares da Costa, La Trobe
Leslie Weston, Charles Sturt University
Joshua Mylne, UWA
Wen-Chao Yang, China Central U.
Amit Vasavada, Marrone Bio Innovations

hdd2020.org



Secretariat: Josh Mylne, Keith Stubbs, Joel Haywood, Grishma Vadlamani

@HerbicideDisco1



GRDCTM

GRAINS RESEARCH &
DEVELOPMENT CORPORATION

Proudly sponsored by:

Department of
Primary Industries and
Regional Development

targenomix
the target identification company



Download a flyer



Advanced Molecular Technologies



Contract Research

FTE & other models available



Custom Organic Synthesis

Multi-step and complex synthesis



Co-Development Options

Drug Discovery & Product Development



Spin-Out Company Support

Proudly supporting emerging Australian start-ups

*You may be eligible for the **R&D Tax Incentive**, if core or supporting R&D activities are conducted in Australia!*

Advanced Molecular Technologies Pty Ltd

✉ enquiries@amtechpl.com

🌐 www.amtechpl.com

☎ +61 3 9764 9220

📍 Scoresby, VIC, Aus.



Chemical Catalogue

Over 2500 high-purity products supplied globally



Analytical Services

NMR, HPLC, GC, FT-IR, UV-Vis, DSC & more



Established in collaboration with Tri-Tech



Product Development



Gram to Kilogram Quantities



Manufacturing Optimisation

🌐 www.scaledorganics.com



Reasons to join

- * access to chemistry experts
- * annual chemistry lectures to inspire
- * quizzes and competitions including the ANCC
- * access to education resources and tools
- * industry outreach
- * subscription to the RACI Magazine Chemistry in Australia
- * professional recognition for teachers
- * student and teacher days at RACI conferences
- * careers and further education advice

TO FIND OUT MORE ABOUT THE RACI'S
SCHOOL AFFILIATE MEMBERSHIP VISIT...

www.raci.org.au/schools

