c&en

CHEMICAL & ENGINEERING NEWS

APRIL 25, 2022

Japan's quest to make ammonia a fuel
P.14

Periodic Graphics: Chemical leavening agents
P.18

Automotive glass

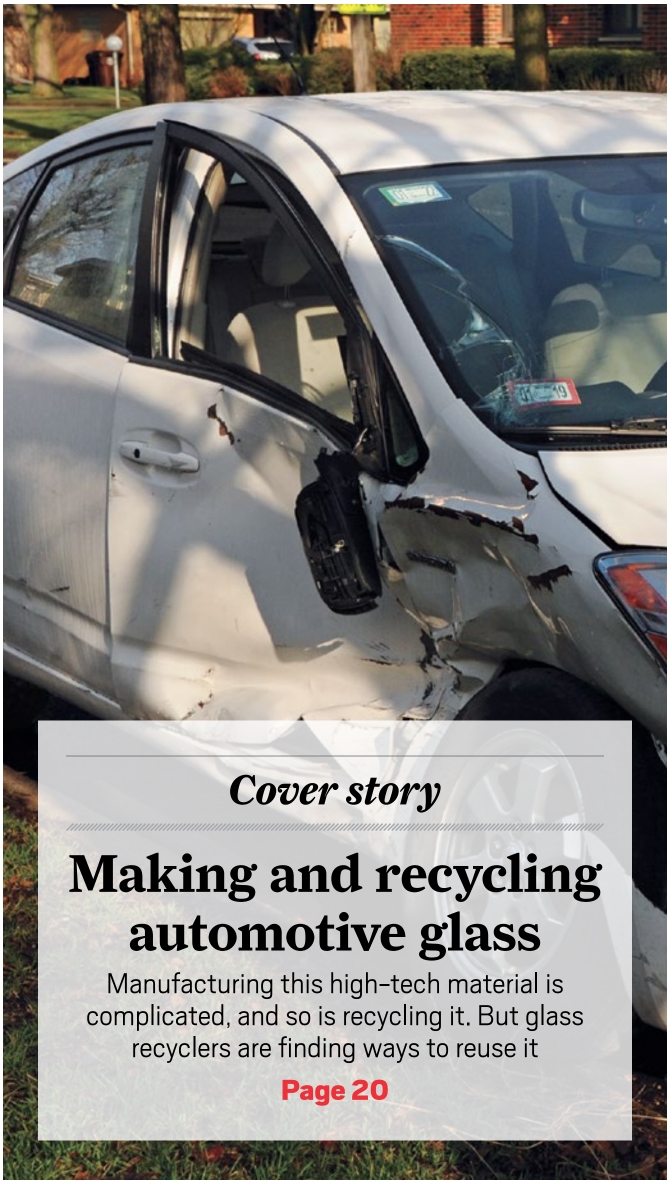
What makes this high-tech material strong and safe also presents recycling challenges
P.20

ACS
Chemistry for Life®


ACS
Chemistry for Life®
American Chemical Society
TAKE THE
NEXT STEP IN
YOUR CAREER
Prepare for your next move with resume reviews, interview strategies, and more with help from the ACS Career Consultants.
Visit www.acs.org/nextstep to get started.

Contents

VOLUME 100, NUMBER 14
April 25, 2022



Cover story

Making and recycling automotive glass

Manufacturing this high-tech material is complicated, and so is recycling it. But glass recyclers are finding ways to reuse it

Features

Departments

ACS News

Photograph by Shutterstock

Quote of the week

"Is it ethical to cite papers in which human rights abuses are clearly documented? . . . Moreover, how should a journal respond to ethically distressing content when it is discovered?"

—David W. Christianson, chair, Department of Chemistry, University of Pennsylvania

Page 19

Reactions

Letters to the editor

Proving metal-free reactions

I am writing to express my displeasure regarding the letter to the editor by Julian Tyson (C&EN, March 14/21, 2022, page 5) about "metal-free" reactions (Feb. 14, 2022, page 20). Specifically, my concern is about the suggestion that manuscripts submitted for publication that indicate a metal-free reaction must be subjected to special review to ensure that the reactions did not make use of metal. My position is that organic synthesis is perhaps the most tedious process of all the five disciplines of chemistry (inorganic, organic, physical, analytical, and biochemistry). Synthetic organic and organometallic chemistry must go through reaction workup and characterization, using infrared spectroscopy, nuclear magnetic resonance spectroscopy, gas chromatography/mass spectrometry, high-performance liquid chromatography, and single-crystal X-ray chromatography. In addition, new products require additional data in the form of high-resolution mass spectrometry or low-resolution carbon, hydrogen, and nitrogen analysis. That being said, it would be unfair to require synthetic chemists to do inductively coupled plasma analysis for metal detection. One would expect that researchers in academia and industry, including state, federal, and private research laboratories, are familiar with ethical conduct associated with research and dissemination. If an author publishes a reaction that they said is metal-free but later found to contain metal, such article should be flagged for retraction.

Cosmas Okoro
Nashville, Tennessee

Join the conversation.

facebook.com/CENews

@cenmag

@cenmag

Corrections

▶ **March 28, 2022, page 10**: A news article on Arkema's foam-blowing agents incorrectly describes the initial North American shipments of Arkema's Forane 1233zd hydrofluoroolefin. They are to companies making polyurethane spray foam, not polystyrene foam.

▶ **April 4/11, 2022, page 17**: The story about US president Joe Biden's 2023 budget proposal incorrectly states the proposed budget for the US National Institutes of Health. It is \$54.5 billion, not \$62.5 billion. In addition, the chart title has the incorrect year. The percent changes are increases from 2022 spending, not from 2021 spending.

▶ **April 18, 2022, page 27**: The Career Ladder feature about Dontarie Stallings incorrectly identifies his PhD adviser. It is John B. Vincent, not John Benson.

How to reach us

Chemical & Engineering News Letters to the Editor

▶ Our email address is edit.cen@acs.org.

▶ Letters should generally be 400 words or fewer and should include the writer's full name, address, and home telephone; letters and online comments may be edited for purposes of clarity and space. Because of the heavy volume of mail received at C&EN, writers are limited to one letter in a 3-month period.

Subscriptions

Send all new and renewal subscriptions and requests for subscription rates to ACS, Dept. L-0011, Columbus, OH 43268-0011.

▶ Changes of address, claims for missing issues, subscription orders, status of records, and accounts should be directed to Manager, Member & Subscriber Services, ACS, P.O. Box 3337, Columbus, OH 43210; telephone 800-333-9511 or 614-447-3776; or send an email to service@acs.org.

Advertising

▶ For advertising information and opportunities, go to cen.acs.org/advertise. For advertising rates, contact Stephanie Holland at s_holland@acs.org. For the editorial calendar, please visit acsmediakit.org/editorial-cal.

c&en

1155 16th St. NW, Washington, DC 20036
202-872-4600 or 800-227-5558

Published by the **AMERICAN CHEMICAL SOCIETY**
Thomas M. Connelly Jr., CEO
Susan R. Morrissey, Vice President, Communications, and Publisher, C&EN

Canadian GST Reg. No. R127571347
Volume 100, Number 14

ACS Chemistry for Life®

COVER: C&EN/DARIA KIRPACH

Concentrates

Chemistry news from the week

Highlights

SYNTHESIS

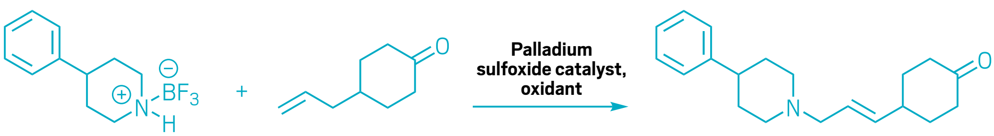
A quicker way to make amines for drug compounds

General method to make tertiary amines is straightforward and broadly applicable

Tertiary amines, made of a nitrogen bound to three carbons, occur frequently in drug structures but are complicated to make. Synthesis often requires multiple steps under different reaction conditions dictated by what functional groups are on the molecule. To cut through this synthetic red tape, M. Christina White and coworkers at the University of Illinois Urbana-Champaign have developed a fast approach to making tertiary amines that works on many types of molecules.

The team combined readily available terminal olefins, secondary amines, an oxidant, and a palladium sulfoxide catalyst to make over 80 tertiary amines, including drugs and drug derivatives (*Science* 2022, DOI: 10.1126/science.abn8382). The group doesn't have to tailor the reaction conditions according to starting materials but can use the same reagents and metal catalyst to synthesize tertiary amines containing a wide variety of functional groups. The reaction is also highly selective, producing only the linear version of the allylic tertiary amine and exclusively forming a single configuration of the double bond.

Besides being applicable to many different functional groups, White says, the reaction is straightforward to run: "Open to air, open to moisture, just applying a little heat." These uncomplicated conditions could allow chemists to automate the reaction, she says. In total, the team combined 48 secondary amines and 34 terminal olefins to form compounds that include several drugs currently on the market, such as the antipsychotics Abilify and Semap and the antihistamines flunarizine and cinnarizine. In addition, many existing drugs are complex secondary amines, White says. The group converted several examples of these compounds, including Paxil and Prozac, into tertiary amines. This opens up an easy route to making new drugs out of old ones, she says.



The simplicity of the approach could speed up the drug discovery process by allowing drug discovery chemists to quickly make a variety of molecules, White says.

> "With very small amounts of the secondary amine, the Pd would still be able to effectively interact with the C–H bond."
>
> **—M. Christina White,** William H. and Janet G. Lycan Professor of Chemistry, University of Illinois Urbana-Champaign

A key part of the research was finding an answer to an old problem. Many N-containing compounds can't be combined with the metal catalysts that chemists often use to break C–H bonds. Amines with a lot of electron density on the N, called basic amines, tend to bind to the metal and kill the catalyst. White and coworkers had developed a work-around for this problem when using primary amines as reagents, but the approach did not work with secondary amines. In the new research, the group sought a way to slowly release the amine into the reaction to minimize reaction with the catalyst. "With very small amounts of the secondary amine, the Pd would still be able to effectively interact with the C–H bond," White says.

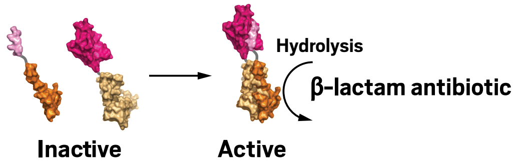
To achieve this slow amine trickle, the researchers needed to stop the lone pair of electrons on the amine N from binding to the catalyst. Converting the starting amine to an ammonium salt blocks the lone pair, so it can no longer attack the catalyst, White says. The Pd is then free to insert into the olefin's C–H bond, while the ammonium salt reacts very slowly to re-form the secondary amine. As it appears in the reaction mixture, the secondary amine couples with the olefin, ultimately forming the tertiary amine (example shown).

Combining electron-hungry metals such as Pd with basic groups like secondary amines has always been challenging, says Tobias Ritter, an organic chemist at the Max Planck Institute for Kohlenforschung. Finding a way to deliver just the right amount of the reactive amine without poisoning the catalyst is a practical way to make valuable molecules directly with olefins, he says.—LEIGH KRIETSCH BOERNER

SYNTHETIC BIOLOGY

Protecting the gut microbiome from antibiotics

Engineered microbes make an enzyme that breaks down antibiotics in the guts of mice



An engineered microbe produces two fragments that reassemble to form an enzyme that degrades β-lactam antibiotics.

When broad-spectrum antibiotics attack nonpathogenic microbes, the result can be an imbalance that affects gut health. Researchers have now engineered microbes to produce an enzyme that degrades β-lactam antibiotics in the guts of mice. This approach protects native microbes without interfering with the antibiotic's levels in blood and without promoting antibiotic resistance.

James J. Collins of the Massachusetts Institute of Technology and coworkers engineered *Lactococcus lactis* to express an enzyme called a β-lactamase, which breaks down a key type of antibiotics that includes penicillin and amoxicillin (*Nat. Biomed. Eng.* 2022, DOI: 10.1038/s41551-022-00871-9).

β-Lactamases are usually made by a class of bacteria with an outer membrane, and the enzyme stays in the space between the bacteria's inner and outer membranes. *L. lactis* does not have an outer membrane to trap the enzyme, so the protein is able to contact and degrade antibiotics in the gut.

The researchers split the gene for the enzyme into two inactive pieces and encoded them on separate genetic constructs. They linked each enzyme piece to protein domains that form covalent bonds with each other. After the proteins are secreted, the bond-forming domains bring the pieces of the enzyme together so the protein can reassemble in the active conformation. In mice injected with the antibiotic ampicillin, ingestion of the engineered microbes protected the mice's gut microbiome.

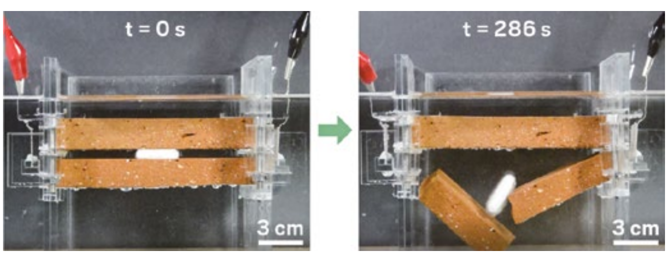
"By splitting an antibiotic resistance gene into two parts, so that they only form an intact enzyme outside of the cell, the authors cleverly kill multiple birds with one stone," says Nathan Crook, a metabolic engineer and synthetic biologist at North Carolina State University who studies the gut microbiome. "They reduce the concentration of antibiotics in the gut, and they do so using an engineered bacterium that itself is not resistant to the antibiotic nor is likely to transfer both gene fragments to another microbe."—CELIA ARNAUD

MATERIALS

Swelling hydrogel breaks bricks

Researchers harness the power of osmotic pressure in a new, plant-inspired actuator

Scientists who want to build robots from soft materials have long favored hydrogels to serve as artificial muscles in the machines. But these materials usually can't muster the strength of real muscles. Researchers at Seoul National University have now designed a hydrogel-based device powerful enough to break a brick (*Science* 2022, DOI: 10.1126/science.abm7862).



A new soft actuator (white) can swell with enough force to break a brick in minutes.

The team took its inspiration for this hydrogel design from plants. Although some plant roots can be tender and soft, even a garden weed can crack concrete as it grows. That's because plant tissues harness osmotic pressure by holding water within their cell walls like a tire pumped full of air.

Study authors Hyeonuk Na, Yong-Woo Kang, and Chang Seo Park tried to mimic plants' cell walls by wrapping a dry hydrogel cube in a stiff, semipermeable membrane, creating an actuator about 3 cm long. On its own, the fully hydrated hydrogel is brittle. But the membrane casing limits how much the hydrogel can swell as it soaks up water. The resulting tension transforms the crumbly jelly into a rock-hard balloon, the authors write in an email.

Na and his colleagues used a hydrogel network containing charged polymers and soaked it in an electrolyte solution. When an electric current was passed through the solution, the movement of electrolytes into the hydrogel dragged enough water to build upward of two times the pressure of that in a standard car tire. In less than 10 min, the turgor pressure of this charged actuator generated enough force to snap a brick in two.

The new actuator is a "groundbreaking" development in hydrogel technology, polymer scientists Pingan Song and Zhen Jiang of the University of Southern Queensland say in an email. "The key innovation of this work is that such design enables an actuation force several orders of magnitude greater than existing hydrogels," they write.—ARIANA REMMEL

CREDIT: ADAPTED FROM *NAT. BIOMED. ENG.* (MICROBE); HYEONUK NA (BRICKS)

CATALYSIS

Buckyballs boost ethylene glycol synthesis

C_{60} acts as electron reservoir for copper catalyst, improving production of ethylene glycol from CO

Adding a dash of the fullerene C_{60}—that iconic ball of carbon atoms—to a copper catalyst boosts yields of ethylene glycol under mild conditions, potentially opening a route to manufacture this commodity chemical from sustainable feedstocks such as biomass (*Science* 2022, DOI: 10.1126/science.abm9257).

"This is a breakthrough in the synthesis of ethylene glycol," says Eric Doris, who studies carbon nanomaterials and catalysis at CEA Paris-Saclay, a part of the French Alternative Energies and Atomic Energy Commission (CEA) and was not involved in the work.

Ethylene glycol is used as an antifreeze and to make polymers. Most ethylene glycol is made from ethylene derived from crude oil or natural gas, and global production is about 42 million metric tons per year.

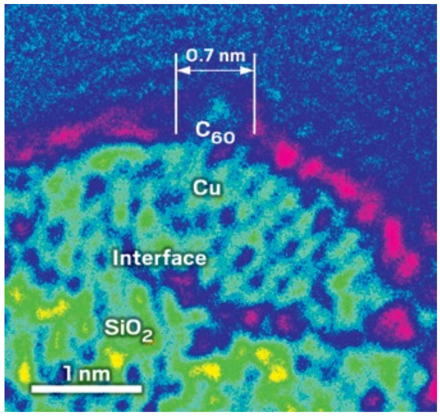
But a decade ago, companies in China commercialized an alternative route starting from syngas, a mixture of carbon monoxide and hydrogen produced by gasifying coal. Their process uses a palladium catalyst to turn CO into dimethyl oxalate, which then reacts with hydrogen over a copper-silica catalyst to make ethylene glycol. But this reaction requires expensive infrastructure to supply hydrogen at high pressure. The conditions can also deactivate the catalyst and produce a lot of unwanted by-products.

A team led by Youzhu Yuan and Su-Yuan Xie at Xiamen University has now found that loading the copper-silica catalyst with 10% C_{60} by weight dramatically improves its performance, boosting yields 10-fold to about 98% at ambient pressure. The reaction forms only 2 by-products, far fewer than the 20 or so generated under conventional conditions, and the catalyst can be reused with no loss of activity.

In principle, the syngas that feeds the process could come from the gasification of biomass, rather than coal, making it a more sustainable route to ethylene glycol, Yuan says.

The researchers used a battery of experimental techniques and theoretical modeling to understand C_{60}'s role. They found that C_{60} molecules offer a reservoir of electrons to maintain the right balance of copper oxidation states.

Two different forms of copper are active during the reaction. Elemental Cu(0) is involved in dissociating H_2 into hydrogen atoms, while Cu(I) helps add these atoms to dimethyl oxalate. Cu(I) is unstable to oxidation and reduction, so C_{60} protects it by acting as an electron buffer— it can accept electrons from Cu(0) or donate electrons to Cu(II) to achieve the ideal mix of catalytic copper states.



This false-color electron micrograph reveals a C_{60} molecule anchored to the surface of a copper catalyst nanoparticle sitting on a silica support.

CREDIT: *SCIENCE*

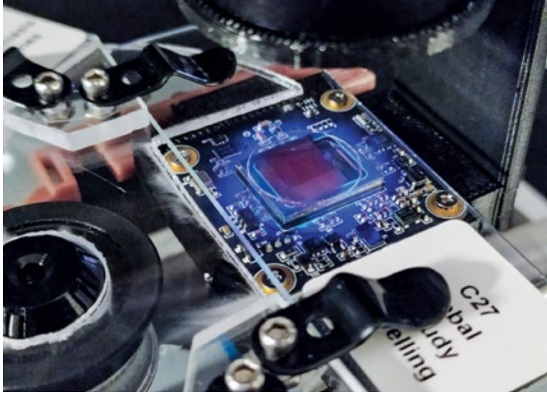
C_{60} is widely used as an electron buffer in organic solar cells but rarely in conventional catalysis, Doris says. The Xiamen researchers found that C_{60} also enhanced the copper-catalyzed hydrogenation of other molecules, and Doris thinks it could have a similar benefit for other metal catalysts.

Using C_{60} in an industrial process would once have been considered prohibitively expensive, but several Chinese firms now produce it on a large scale, which has lowered its cost considerably, Doris says. Yuan's team is now working with a company to scale up the reaction.—MARK PEPLOW, special to C&EN

IMAGING

Blu-ray device creates high-res images

Blood cells focus light in low-cost computational imaging system on par with a microscope



A laser inside a Blu-ray player is shined through a biological sample that rotates on the player's spindle (left). The sensor under the sample collects light data and sends them to a computer to create a high-resolution image.

CREDIT: GUOAN ZHENG

By hacking a Blu-ray drive and smearing blood on a sensor they installed inside it, researchers have created an inexpensive imaging system for analyzing samples at the microscale, including measuring bacterial growth and doing urinalysis (*ACS Sens.* 2022, DOI: 10.1021/acssensors.1c02704).

Getting sharp images of a whole slide using a conventional optical microscope can require manually refocusing the microscope repeatedly over different parts of the sample, a time-consuming process. And scanners that can automatically image a whole sample at high resolution are expensive—$50,000 to $300,000. So Guoan Zheng, who runs the Smart Imaging Lab at the University of Connecticut, and his colleagues were looking for a way to perform such imaging quickly and cheaply.

They turned to computational imaging, which overcomes the limits of an optical system using techniques such as collecting phase information from reflected light. A computer can then use that information to refocus a picture after it has been taken or to construct a 3D image of a sample.

To make an inexpensive system, Zheng's team repurposed a Blu-ray disc player: the lasers inside provide a light source, and the slowly rotating disc drive allows images to be taken at multiple angles.

The researchers installed a sensor under the light source but then needed a way to scatter the light into a pattern the computer could process. Looking for a material that was cheap and available, Zheng hit on the idea of pricking his finger and smearing his own blood on the sensor. The blood cells naturally spread out in a thin layer and are the right size to scatter the incoming light in a random pattern, which the computer uses to reconstruct an image of whatever sample the user puts on top of the blood-coated sensor.

Their device has resolution comparable to an objective lens with 20×–46× magnification over a theoretically unlimited area and can capture 200–400 images in under 15 s. The group's computer takes about 10 min to process the data into usable images, but Zheng hopes he can reduce that to under 1 min by using a computer with a more powerful graphics processing chip.

The team used its device to see microscopic uric acid and calcium oxalate crystals in urine samples as well as blood cells and blood parasites in a sample; the ability to see all these could be useful in diagnostics. The researchers also imaged bacterial colonies in a dish sitting above the blood-coated sensor without having to worry about manually refocusing.

Aydogan Ozcan, a bioengineer at the University of California, Los Angeles, says the research is interesting, and "it would be even more interesting to perhaps switch to microparticles to create similar computational imaging systems, which could be more sterile, durable, and last longer."

Zheng says engineering a surface with nanoscopic light-scattering features could yield similar results but would add to the cost of the system. The system wouldn't necessarily require human blood: his team also tried using fish blood purchased from a local market and found that it worked.—NEIL SAVAGE, special to C&EN

GREENHOUSE GASES

Cash rushes in for CO_2 removal

Credit purchases and investment dollars boost direct-air-capture and other CO_2-drawdown technology

Climeworks's Orca direct-air-capture plant in Iceland

CREDIT: CLIMEWORKS

A recent report by the Intergovernmental Panel on Climate Change (IPCC), a United Nations program, says the world needs carbon dioxide removal at a large scale to reach net-zero greenhouse gas emissions. As many as 15 gigatons per year must be removed alongside aggressive emission reductions to keep global warming to 1.5 °C, the report says. A new round of purchasing and investment dollars is flowing to companies trying to make that happen.

On April 5, a day after the IPCC report came out, the direct-air-capture company Climeworks announced that it had raised $650 million in private financing. Climeworks operates a plant in Iceland that captures and sequesters 4,000 metric tons of CO_2 per year. The firm says it will use the funds to build a second plant 10 times as big and double its staff to 400 people.

Venture investor Chris Sacca says that the market for carbon-removal credits like those offered by Climeworks is in the billions of dollars and that there is not nearly enough supply. To get in on the action, Sacca has launched a $350 million venture capital fund focused on early-stage carbon-removal start-ups. "There has never been a better time to start a carbon removal company," he wrote April 14 on his company's blog.

Customers are prepared to pay for carbon-removal credits. The digital payment company Stripe has recruited the tech giants Alphabet, Meta, and Shopify and the consulting firm McKinsey & Co. to purchase a combined $950 million in removal credits by 2030 through Stripe subsidiary Frontier Climate.

Carbon-removal firms will be eligible to win some of that business if their methods store carbon for over 1,000 years and have a clear path to remove at least 0.5 gigatons per year at $100 per metric ton or less, a standard that favors technological approaches over nature-based ones.—CRAIG BETTENHAUSEN

ONCOLOGY

IL-2 program falls flat for Nektar, BMS

Next-generation IL-2 contenders may still harness the protein's anticancer potential

Nektar Therapeutics and Bristol Myers Squibb have halted development of bempegaldesleukin, ending a multibillion-dollar bet on interleukin-2 (IL-2) as an immuno-oncology drug. But a broad pipeline of next-generation IL-2 candidates is keeping hopes for the therapeutic approach alive.

Bempegaldesleukin "was a flawed molecule, and we should not give up on IL-2 because of its rather unsurprising failure," says Stanford University structural biologist K. Christopher Garcia, whose work helped renew interest in the protein.

Oncologists have had their eye on IL-2 for decades, ever since the discovery that this cytokine can stimulate the growth of the cancer-killing immune cells called T cells. But despite the US Food and Drug Administration's approval in 1992 of an IL-2-based drug called aldesleukin for renal cell carcinoma, IL-2's therapeutic effect has been hard to harness. It has severe side effects at the high doses needed to kill cancer cells; at lower doses, it dampens the immune system.

Over the years, researchers have found that various subsets of immune cells express different versions of the IL-2 receptor. In 2012, Garcia and colleagues showed that it is possible to engineer IL-2 to have biased activity—activating only the immune cells with the right type of receptor—and drug developers have been working ever since to recapture IL-2's cancer potential.

Researchers at Nektar hoped that pegylation would help do the trick. They stuck six protective polyethylene glycol (PEG) groups to aldesleukin to create a reservoir of the cytokine that only becomes active as the PEGs are cleaved. These bulky PEG groups also shifted the drug candidate's activity profile toward a dimeric form of the IL-2 receptor that is expressed by naive T cells and natural killer cells, immune cells with cancer-destroying potential.

After early clinical data hinted at activity, BMS placed its bet. In 2018, it paid $1.85 billion up front and committed up to $1.8 billion in milestone payments to codevelop bempegaldesleukin. BMS would have received 35% of any profits.

The wager did not pay off. The partners disclosed in March that two Phase 3 trials for melanoma had failed. Nektar's bempegaldesleukin plus BMS's PD-1 blocker nivolumab did not outperform nivolumab alone. More recently, the firms announced that late-stage trials for renal cell carcinoma and bladder cancer had also failed.

They have discontinued further development of the drug combination.

$1.8 billion

Amount Bristol Myers Squibb paid Nektar Therapeutics to codevelop bempegaldesleukin

For analysts at the investment bank SVB Leerink, bempegaldesleukin's collapse is a reminder of the dangers of racing into Phase 3 trials. But Garcia does not see broad implications for the IL-2 pipeline. Bempegaldesleukin's PEG groups are cleaved haphazardly, he says, and the resulting mixture of drug species muddies its biological effects. Bempegaldesleukin also stimulates immune cells with dimeric receptors throughout the body rather than just in the tumor. The overall result, Garcia says, is a nonspecific agent with toxicity limitations.

Next-generation contenders address these shortcomings, he argues. Synthekine, which Garcia founded, is developing a candidate called STK-012. It aims to selectively stimulate a trimeric form of the IL-2 receptor only on antigen-activated T cells—immune cells that have been alerted to the presence of cancer markers. "These are the relevant T cells one wishes to expand," Garcia says.

Other approaches are also in development. Bispecific candidates that activate the IL-2 receptor with one arm and bind a protein on T cells with the other might improve specificity. Conditionally active IL-2 drugs—masked cytokines that are laid bare by protein-cutting proteases in the tumor microenvironment—are in the works too.

"I believe someone will figure out how to best drug it," Garcia says of IL-2.—ASHER MULLARD, special to C&EN

POLYMERS

DSM fiber unit is going to Avient

DSM has agreed to sell its protective materials business, maker of Dyneema ultra-high-molecular-weight polyethylene fiber, to the US plastics compounder Avient for nearly $1.5 billion.

DSM calls Dyneema the world's strongest fiber and claims that it is 15 times as strong as steel. The fiber, which DSM developed in the 1960s, is found in bulletproof vests, fishing gear, rope, and other demanding applications. The company expects the business to generate earnings before taxes of $130 million this year on sales of $415 million.

DSM offered the unit for sale in September, along with its much larger engineering polymer unit, which has a solid position in specialty nylon resins. The businesses had combined sales of about $2.1 billion in 2021. DSM, which has yet to find a buyer for engineering polymers, wants to focus on health, nutrition, and biosciences. It sold its coatings resin business to Covestro last year.

Jefferies Group stock analyst Chris Counihan says DSM should be in the financial position to conduct over $7 billion in acquisitions in the nutrition sector after it sells engineering polymers.

In addition to buying the DSM unit, Avient—formerly known as PolyOne—is putting its polymer distribution business up for sale. The unit has annual sales of about $1.6 billion, over a third of Avient's total. In 2020, Avient purchased Clariant's plastics colorant business for $1.4 billion.

Avient aims to to create a composites and engineered fibers franchise with $680 million in annual sales.—ALEX TULLO

Chemical companies start 2022 strong

Sales jump in the first quarter, but firms struggle with higher costs

First-quarter financial results are starting to come in from chemical makers, with Dow announcing its earnings and a few major German firms releasing preliminary figures. The companies are posting large increases in sales from a year earlier, but all have been laboring to maintain profitability in the wake of escalating energy and feedstock costs.

Dow posted a 28% sales increase in the quarter versus the quarter a year earlier. Selling prices also increased 28%, while volumes climbed a more modest 3%. Net income, excluding unusual items, rose 70%.

But profits at Dow's largest business, packaging and specialty plastics, remained flat versus the year-earlier quarter, and the business's before-tax profit margin fell from 20% to 16% as a consequence of rising energy costs. Profitability expanded in Dow's intermediates and coating materials segments because of strong demand and higher selling prices.

"We capitalized on end-market demand strength across the breadth of our diverse portfolio and mitigated the impacts of rising raw material and energy costs," Dow CEO Jim Fitterling said during an April 21 conference call with analysts.

Fitterling said Dow's operations in Europe are running well and still eking out profits despite higher energy costs resulting from Russia's invasion of Ukraine. "What's happened with Russia entering Ukraine and what that's caused has created more concerns on Europe's ability to decouple from Russia and compete long term," he said. The need for energy independence from Russia is a major reason the company decided recently to host a liquefied natural gas import terminal at its Stade, Germany, complex, he added.

BASF reported a 19% increase in first-quarter sales but a 29% decline in net income due to a write-off of loans its affiliate Wintershall Dea made to Nord Stream 2, the shelved natural gas pipeline from Russia to Germany.

Evonik Industries' earnings before taxes rose 25%, and its sales increased 34%. "Across all divisions, we were able to adjust selling prices successfully and therefore offset the increase in variable costs," Chairman Christian Kullmann said in the firm's report of preliminary figures.

Crediting strong demand, Lanxess said sales rose 44% in the quarter, while earnings before taxes and unusual items increased 32%.—ALEX TULLO

28%
Dow's increase in sales in the first quarter

19%
BASF's increase in sales in the first quarter

PETROCHEMICALS

▶ Sumitomo will exit caprolactam business

Sumitomo Chemical plans to shutter its caprolactam plant in Ehime, Japan, by October and exit the business. The company has been making the nylon raw material there since 1965. Sumitomo says it has been difficult to remain competitive given an onslaught of new output from China. It will continue to make the raw material cyclohexanone, however. Sumitomo says it has been upgrading the Ehime complex by building semiconductor chemicals and liquid crystal polymer facilities and installing a plant to chemically recycle acrylic resins.—ALEX TULLO

GREENHOUSE GASES

Baker Hughes buys MOF firm Mosaic Materials

The oil field services and equipment firm Baker Hughes has purchased Mosaic Materials, which makes carbon dioxide–capturing materials based on metal-organic frameworks (MOFs). Mosaic's MOFs are best suited to pulling CO_2 out of ambient air, executives at the firm told C&EN earlier this year, and Mosaic has been transitioning its R&D focus from MOF chemistry to the design and optimization of a direct-air-CO_2-capture system based on its materials. Joining Baker Hughes will give Mosaic access to a deep bench of gas-engineering expertise, Mosaic CEO Nathan Gilliland says in a statement. Mosaic is also working with NASA and the US Navy on CO_2 scrubbers for submarines and spacecraft, work that will continue with the merger. The firms did not disclose the financial terms of the deal. Baker Hughes has been assembling a range of CO_2 capture, transportation, and storage assets in recent years—part of a trend of pipeline and oil field engineering firms pivoting toward carbon management.—CRAIG BETTENHAUSEN

BIOBASED CHEMICALS

▶ Goodyear to make dandelion rubber

Goodyear Tire & Rubber is partnering with Farmed Materials on a project, funded by the US Department of Defense, to make rubber from dandelions. Farmed Materials says it analyzed 2,500 plants to find a suitable replacement for rubber trees, which are mostly grown in tropical locations outside the US. Ohio-based Goodyear says it's trying to create a local source of natural rubber to avoid future supply chain problems. The rubber will initially be used to make tires for military planes and could eventually be used in consumer tires.—MATT BLOIS

Farmed Materials found the dandelion species *Taraxacum kok-saghyz* to be a viable alternative to natural rubber trees.

SPECIALTY CHEMICALS

▶ Residents seek to stop Exfluor facility

Residents in Williamson County, Texas, are trying to stop Exfluor Research's project to build a facility near the San Gabriel River. Exfluor, which currently operates in Round Rock, Texas, produces fluorocarbons through what it calls a unique direct reaction of fluorine gas with hydrocarbons. A petition says the facility should not be built near a residential area. Exfluor told a local TV station that the facility would have zero water discharge.—MICHAEL MCCOY

SYNTHESIS

▶ Cinthesis advances mechanochemistry

Cinthesis, which launched in 2020 to commercialize mechanochemistry, says it has signed its first contract and is lining up more customers. The firm is based on the research of University of Cincinnati chemistry professor James Mack, who will soon become CEO. Mechanochemistry aims to reduce or eliminate the need for solvents in chemistry by combining reactants mechanically. Cinthesis works with partners to determine if a reaction is suited for mechanochemistry and then helps them scale up.—MICHAEL MCCOY

Mack (left) with Cinthesis chief technology officer Joel Anderson and CEO Edward Sawicki

MERGERS & ACQUISITIONS

▶ Lygos to go public via merger with FSI

The privately held biobased chemical maker Lygos plans to merge with Flexible Solutions International (FSI), a public company that makes biodegradable polyaspartates. Lygos executives will lead the new company if shareholders approve the deal. FSI already uses Lygos's biobased aspartic acid. The companies say Lygos will continue to make sustainable feedstocks; FSI will turn them into final products, focusing on fertilizer additives, detergents, and, eventually, superabsorbent materials.—MATT BLOIS

RECYCLING

▶ Carbios mulls North American plant

The French plastics recycling firm Carbios says it is scoping out sites for its first North American plant. The company is

CREDIT: FARMED MATERIALS (FIELD); CINTHESIS (GROUP PHOTO) developing an enzymatic process to break down polyethylene terephthalate (PET) into its raw materials, terephthalic acid and ethylene glycol. Carbios is building its first plant, set to open in 2025 with capacity of 50,000 metric tons per year, at Indorama's PET plant in Longlaville, France. CEO Emmanuel Ladent says the North American facility would also likely be colocated with a PET plant. He expects a decision next year.—ALEX TULLO

CONSUMER PRODUCTS

▶ Tire recycling links Bridgestone, LanzaTech

The tire maker Bridgestone is working with the green chemical company LanzaTech to turn old tires into new ones. LanzaTech says it can already use gas fermentation to convert tires into ethanol, which can be turned into plastic packaging or surfactants. LanzaTech now hopes to use ethanol to make butadiene, a key ingredient for tires. Bridgestone has pledged to go carbon neutral and use only renewable materials by 2050.—MATT BLOIS

PESTICIDES

▶ Vestaron searches for pesticidal peptides

The biotech company Berkeley Lights is working with the crop protection firm Vestaron to find naturally occurring pesticidal peptides. Berkeley Lights' technology can rapidly screen pesticide candidates by testing their effects on cells stored in thousands of wells on a chip. The company says that because its wells are 100,000 times smaller than typical ones, it can conduct more assays more quickly. Vestaron's goal is to find safe, sustainable pesticides that work on pesticide-resistant organisms. The company already sells peptide insecticides based on spider venom that kill caterpillars, thrips, whiteflies, aphids, and spider mites.—MATT BLOIS

BIOMATERIALS

▶ Symrise launches biobased caprylyl glycol

The food and personal care ingredient maker Symrise has launched plant-derived caprylyl glycol, also known as 1,2-octanediol, a moisturizing and antimicrobial ingredient used in lotions and other personal care products. Most caprylyl glycol is made by a petrochemical process. Biobased routes include the oxidation of caprylic acid, a component of coconut and palm oil, and the use of ethanol-derived ethylene in the conventional synthesis. Symrise will only say it is using proprietary technology.—CRAIG BETTENHAUSEN

Caprylyl glycol

DRUG DISCOVERY

▶ Sionna emerges for cystic fibrosis drugs

Sionna Therapeutics has officially launched with the closing of a $111 million series B funding. The Boston-based firm was founded in 2019 to develop small molecules that treat cystic fibrosis (CF). Its goal is to restore the function of the CF transmembrane conductance regulator protein, which is defective in CF, by stabilizing the protein's first nucleotide-binding domain. Among the firm's leaders are former executives of Biogen, Sanofi, and Vertex Pharmaceuticals, a top player in CF drugs.—MICHAEL MCCOY

ONCOLOGY

▶ Regeneron will buy cancer drug firm

Regeneron Pharmaceuticals has agreed to acquire Checkmate Pharmaceuticals in a deal that values the Massachusetts-based firm at about $250 million. Checkmate's lead drug candidate is vidutolimod, a biologic immune activator that stimulates T cells to attack tumors. It is delivered as a viruslike particle. In an announcement, Regeneron CEO Leonard S. Schleifer says he sees an opportunity to combine vidutolimod and other Checkmate compounds with Regeneron's antibody-based oncology agents.—MICHAEL MCCOY

Business Roundup

▶ **Viva Energy** will buy LyondellBasell Industries' polypropylene plant in Geelong, Australia. The plant, Australia's only facility that makes polypropylene, is located within Viva's Geelong refinery.

▶ **Nova Chemicals** and the recycling firm Enerkem are advancing to the pilot stage their collaboration to gasify municipal waste. The companies hope to eventually produce ethylene, which Nova will use to make polyethylene.

▶ **Fujitsu** is using artificial intelligence to help the Icelandic start-up Atmonia develop catalysts used to make ammonia. Atmonia says its process, which uses renewable energy, would emit less carbon than the existing Haber-Bosch ammonia production process.

▶ **Cemvita Factory** is working with the engineering firm Fluor on biomining. Cemvita's technology uses engineered microbes and enzymes to carry out industrial reactions—in this case the extraction of metals from low-grade ore and waste.

▶ **Sumitomo Chemical** will test a recycling method for lithium-ion battery cathodes that avoids some energy-intensive oxidation and reduction steps. The project, funded by the Japanese government, will also explore an improved method for separating battery components.

▶ **Satellite Bio** has emerged with more than $110 million in financing to advance its technology for programming cells and assembling them into implantable therapies. Satellite's technology is from the Massachusetts Institute of Technology and Boston University.

▶ **Asahi Kasei** will acquire Bionova Scientific, a US bioprocess services firm that helps companies developing antibody-based drugs. Asahi Kasei already sells filters and testing services to the bioprocess industry.

▶ **BenevolentAI**, an artificial intelligence–based drug discovery firm, will work with the Drugs for Neglected Diseases Initiative on dengue. The goal is to repurpose existing therapies to fight the infectious disease.

PERSISTENT POLLUTANTS

Maine bans sludge application

Move aims to prevent spread of PFAS

To prevent additional contamination by per- and polyfluoroalkyl substances (PFAS), Maine is set to become the first US state to prohibit the use of municipal and industrial sludge as fertilizer.

Application of PFAS-tainted sludge to agricultural fields in the state has caused contamination that polluted drinking-water wells and led some farmers to euthanize dairy cows and shut down organic vegetable production. Maine governor Janet T. Mills (D) is expected to sign legislation (LD 1911) in late April that would ban application of the material as fertilizer.

PFAS are a family of environmentally persistent synthetic compounds widely used in products such as firefighting foams and grease- and water-resistant coatings for paper. Some of these substances are toxic, including those found in tainted soils and wells in Maine.

The chemicals are carried in industrial and municipal wastewater to sewage treatment plants. They are not broken down by wastewater treatment, which primarily filters out organic solids before discharging water into rivers or lakes.

Biosolids transferred from wastewater treatment plants to farm fields as fertilizer may contain per- and polyfluoroalkyl substances.

PFAS persist in those solids, even if the material is composted before it is spread on land. Crops can take up the substances from the soil, and water percolating through the soil can move PFAS into groundwater.

"We must do all that we can to stop further contamination and limit exposure to these toxic chemicals," Maine state senator Rick Bennett (R), a lead cosponsor of the legislation, says in a statement.

While Maine is the first state to halt use of biosolids as fertilizer, other states could have unrecognized PFAS pollution resulting from this practice, according to the Environmental Working Group (EWG), an advocacy organization. It estimates that sewage sludge is applied to 5% of all US crop fields. The EWG points out that there are no national requirements to test biosolids for PFAS or to warn farmers that biosolids they use as fertilizer could be tainted with these chemicals.

The EWG used data that states reported to the US Environmental Protection Agency as the basis of its estimate.—CHERYL HOGUE

Formaldehyde is commonly used in resins and adhesives found in composite wood products.

CHEMICAL REGULATION

Formaldehyde causes leukemia, draft EPA review concludes

Long-delayed assessment prompts industry calls to revamp chemical risk program

Formaldehyde is carcinogenic to humans, a draft risk assessment from the US Environmental Protection Agency concludes. The review, conducted by the agency's Integrated Risk Information System (IRIS) program and released April 14, cites evidence that inhalation of formaldehyde causes nasopharyngeal cancer, sinonasal cancer, and myeloid leukemia in humans.

Formaldehyde is used in making plywood, composite wood items, adhesives, and many other products. Consumers can be exposed to the chemical in tobacco smoke, construction materials, furniture, carpets, and other household products, the assessment says.

The EPA was poised to release the draft formaldehyde review in early 2018, but it abruptly put the assessment on hold under the Donald J. Trump administration. The agency now plans to use the IRIS assessment to inform its upcoming formaldehyde risk evaluation under the Toxic Substances Control Act.

The American Chemistry Council, which represents chemical manufacturers, has been pressuring the EPA to halt the IRIS program—and its formaldehyde review—for many years. In an April 5 statement, the group claims that the process IRIS uses does not meet the agency's standards for "transparency, scientific integrity, and a robust, independent peer review process."

"The IRIS program is not fulfilling its mission. The program has long had deficiencies, especially as it relates to formaldehyde," Chris Jahn, the ACC's president and CEO, says in the statement. "ACC has consistently called upon EPA to improve the design and conduct of its chemical assessments."

Environmental groups welcome the draft formaldehyde review after years of delay. "Release of the assessment is a win for scientific integrity that follows years of pressure from industry groups and efforts during the previous administration to suppress the assessment," Maria Doa, senior director of chemicals policy at the Environmental Defense Fund, says in an April 13 blog post.

The draft IRIS assessment will be reviewed by the National Academies of Sciences, Engineering, and Medicine. The EPA is also accepting public comments on the document until June 13.—BRITT ERICKSON

CREDIT: DANA KOLPIN/US GEOLOGICAL SURVEY (TRUCKS); SHUTTERSTOCK (COMPOSITE)

Scientists' work impacted by NIH probe

US researchers with China collaborations saw fewer publications and citations

US scientists who collaborated with colleagues in China published fewer papers overall and saw them cited less often after the US government's investigations into China's influence on academia, according to a working paper published by the National Bureau of Economic Research (2022, DOI: 10.3386/w29941) that has not been peer-reviewed.

Social scientists at the University of California San Diego assessed papers published from 2010 to 2020 cataloged by PubMed. They analyzed work from 32,056 US-based scientists who collaborated with Chinese scientists and from a control of 70,746 who worked with scientists in other countries.

In particular, they looked at publications before and after 2018, which was the first year of the US Department of Justice's China Initiative and the year the National Institutes of Health began sending letters to universities asking them to investigate hundreds of grant recipients, primarily those with Chinese collaborations.

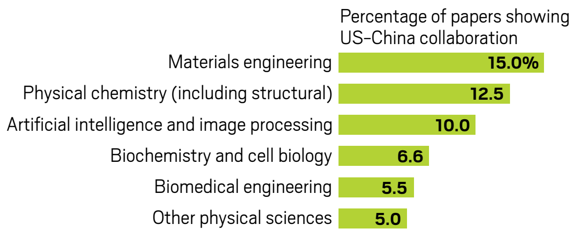
China has been US scientists' top international collaborator on PubMed publications since 2013, but its lead began to decrease in 2019, the analysis shows. Scientists with Chinese collaborations published 1.9% fewer papers and were cited 7.2% less in 2019–20 than in 2010–18. The control group saw no such declines.

The number of papers from scientists who had collaborated with colleagues in China declined across US institutions, which suggests "a broad phenomenon," the researchers write in the paper. Scientists with Asian names and those with NIH funding were most affected.

An analysis of the data by field found that those with the most NIH funding and the highest number of US-China collaborations were most affected. They include materials engineering, physical chemistry, and several other chemistry-related fields. The authors say those fields also "experienced slower growth in scientific output than fields that are less affected."—ANDREA WIDENER

Collaboration by field

Chemistry papers are among those most likely to show US-China collaboration, according to an analysis of 2010–20 publications cataloged in PubMed. Shown are selected chemistry-related fields, not all fields.



Source: National Bureau of Economic Research, "The Impact of U.S.-China Tensions on U.S. Science," April 2022.

ENERGY

Will Japan run on ammonia?

Major chemical firms want to build the infrastructure for using the chemical as a fuel

KATSUMORI MATSUOKA, SPECIAL TO C&EN

Sabic shipped so-called blue ammonia from Saudi Arabia to Japan in 2020.

In Japan, Mitsui Chemicals and three other firms are about to demonstrate the feasibility of switching from methane to ammonia as the main fuel for cracking naphtha into petrochemicals. They are not alone. All over Japan, major companies seem to have rediscovered ammonia.

Japan aims to reduce its greenhouse gas emissions to 46% of 2013 levels by 2030. Unlike many sources of energy, ammonia emits no carbon dioxide when burned. The Japanese government sees ammonia as a possible energy solution for a country that is wary of nuclear power and has few local options for renewable power.

The new policy could lead Japan to triple its annual ammonia consumption to 4 million metric tons (t) by 2030 Japan's Ministry of Economy, Trade, and Industry says. By 2050, when Japan wants to convert all coal-fired power plants to ammonia, consumption could be 30 million t.

"Ammonia could be Japan's savior when it comes to thermal power generation," says Nobuyuki Suzuki, general manager of the Basic Chemicals Division at Mitsubishi Gas Chemical (MGC).

Until recently, ammonia did not seem to be a chemical with a bright future. It is a flammable and toxic gas, and in Japan it is regulated by several safety laws.

Still, it's a staple fertilizer and raw material for chemicals, meaning companies in the chemical and shipping industries know how to handle it safely. Enticed by generous Japanese government funding, a few chemical companies have started technical development and demonstration projects, each one worth several hundred million dollars.

Ammonia's appeal is that it is rich in hydrogen while being easier to transport than hydrogen. But to be a clean energy source, not just any ammonia will do.

Ammonia is made by reacting nitrogen and hydrogen. The nitrogen is drawn from the air, and the hydrogen is typically made by reforming methane, a process that creates CO_2. So-called clean ammonia comes in two main varieties: green, produced with hydrogen that is created by splitting water with renewable electricity; and blue, made with traditional hydrogen from which the by-product CO_2 is captured and stored underground.

Clean ammonia projects are starting to get off the ground. In 2020, the Saudi firm Sabic worked with Japan's Institute of Energy Economics to ship 40 t of blue ammonia from Saudi Arabia to Japan as a test of the concept of importing ammonia for power generation. In December 2021, MGC, Ube Industries, Sumitomo Chemical, and Mitsui announced plans to study a comprehensive network in Japan to secure clean ammonia.

Mitsui and Ube currently produce conventional ammonia in Japan. MGC ceased domestic ammonia production in 2015, when it closed its plant in Niigata, but it continues to make ammonia derivatives at the site. MGC invested in the Indonesian ammonia producer Panca Amara Utama (PAU) in 2016 and started importing ammonia from PAU's plant when it opened in 2018. Last year, PAU embarked on a study of turning its ammonia blue by capturing CO_2 from the plant.

Regardless of their production status, all four members of the study group have over many years accumulated much expertise on the safe production, transport, and use of ammonia. "We have engaged in operation and maintenance of freezing and high-pressure tanks and have sufficient knowledge on operation of specialized ships and buried piping," Suzuki says.

The group members are joining hands, Suzuki explains, to "pursue economies of scale" in importing, producing, and distributing ammonia in Japan. They also have their sights set on projects overseas, where production of clean ammonia can be cheaper.

"We would like to ensure steady supply of competitive ammonia by 2030," Suzuki

> "Ammonia could be Japan's savior when it comes to thermal power generation."
>
> **—Nobuyuki Suzuki,** general manager for Basic Chemicals at Mitsubishi

CREDIT: SABIC

says. To do that, the companies need to build more infrastructure to handle the fuel. "When importing 500,000 t per year of ammonia, for example, we need two terminals at least," he says. Construction of just the storage tanks for those terminals will cost more than $80 million.

In addition to importing more ammonia, Japanese chemical companies are exploring local production from green hydrogen. Asahi Kasei, for example, wants to make hydrogen by using surplus renewable energy to split water via the alkaline electrolysis process.

In August, Asahi Kasei and the engineering firm JGC Holdings launched a project to demonstrate the use of 10 MW water electrolysis units to make hydrogen for ammonia production. The goal is to duplicate the setup in modular fashion to achieve commercial-scale production, either in Japan or overseas.

The right control system is key to the project. "Since renewable energy is employed, our primary target is to establish a robust system designed to be hardly affected by fluctuations of power generation," says Mototaka Kai, a sustainability program manager at JGC.

Asahi Kasei has a track record in alkaline water electrolysis technology. The company has been running a 10 MW unit at the Fukushima Hydrogen Energy Research Field, a public-private project in Namie, Japan. It has also taken part in Germany's Align carbon-capture project and the subsequent Take-Off project, which is aimed at producing aviation fuel from CO_2 and hydrogen.

"We have not only electrolytic cells but also all elemental technologies involved in membranes and electrode equipment," says Nobuko Uetake, manager of Asahi Kasei's Green Solution Project. She adds that Asahi Kasei intends to use digital technology from Recherche 2000, a Canadian company it acquired in 2020.

In addition to replacing coal in power plants, ammonia could be used instead of methane in furnaces that crack naphtha and other hydrocarbons into petrochemicals. Mitsui's project to test the feasibility of the approach launched in February with Maruzen Petrochemical, Toyo Engineering, and Sojitz Machinery.

"The technology has a cost advantage when taking into account carbon pricing and the estimated market price for clean ammonia in 2030," a Mitsui public relations official says.

Ammonia is not a drop-in replacement for methane, however. For example, as a furnace fuel, it burns more slowly than methane, a phenomenon that Sojitz, a designer of burners used in cracking furnaces, will have to take into account. "The four companies can contribute their specialties in R&D," the Mitsui official says.

The consortium aims to build a 10,000 t per year naphtha-cracking furnace at Mitsui's complex in Osaka, Japan, and conduct a verification test there. It will later build a larger verification furnace at Maruzen's facility in Chiba, Japan.

Ultimately, Mitsui would like to see the technology used by ethylene producers across the country. "When fuel for domestic ethylene producers is switched to ammonia, CO_2 emissions will be cut by 10.4 million t compared with the present time," the Mitsui official says.

It is not only well-established Japanese companies that are attracted by ammonia's potential. Tsubame BHB, a spin-off from Tokyo Institute of Technology, has developed a process to synthesize ammonia at a much lower temperature and pressure than with the traditional Haber-Bosch process. Employing a catalyst devised by Professor Emeritus Hideo Hosono of Tokyo Tech, the process lowers temperature by about 25% and pressure by more than 75%, the company says (*Nature* 2012, DOI: 10.1038/nchem.1476).

The Haber-Bosch process breaks the triple bond of nitrogen using a catalyst consisting of iron, potassium hydroxide, and alumina. In contrast, the Tsubame process uses an electride, or electronized, catalyst made by placing ruthenium particles on the surface of a cement-like material. The process "increases fluctuations of nitrogen and undoes the triple bonding," says Toshiharu Yokoyama, Tsubame's chief technology officer.

The firm plans to test the process in a 20 t per year plant at the Kawasaki factory of Ajinomoto, an amino acid producer and shareholder in the start-up. Tsubame envisions building numerous small ammonia units at plants that make amino acids, fertilizers, and other chemicals. Units could also be set up at semiconductor plants to provide ammonia for depositing nitride films.

"Such equipment will take the place of traditional methods in sectors where local production of ammonia for local consumption has an advantage," says Tsubame CEO Masahiro Watanabe. The necessary hydrogen can be made from water and local renewable energy.

Tsubame also aims for large-volume production of fuel ammonia through a venture launched in January by the Japanese government and firms including Tokyo Electric Power and the engineering company Chiyoda. The venture seeks to pioneer a new ammonia catalyst that works at milder conditions than the Haber-Bosch catalyst but doesn't require ruthenium, a precious metal.

Tsubame BHB operates this 20-metric-ton-per-year pilot plant at Ajinomoto's site in Kawasaki, Japan.

CREDIT: TSUBAME BHB

The road to turning ammonia into a fuel that runs Japan will be long and difficult. But MGC's Suzuki is encouraged that multiple companies and the government are joining to try to make it happen. "No one knows the whole picture of ammonia," he says. "It is time to discuss and act on the Japanese ammonia industry from a larger perspective."

Katsumori Matsuoka is a freelance writer based in Japan.

CLIMATE CHANGE

C&EN talks with Holly Jean Buck, climate change policy and sustainability analyst

Net-zero emission goals are not enough, this contributing author to IPCC report says

CHERYL HOGUE, C&EN STAFF

Companies across multiple industries, including the chemical sector, are pledging to reduce their greenhouse gas emissions to net zero. To meet that goal, they will offset carbon through various actions. One option is planting trees. Another is capturing carbon dioxide from fossil fuel use to store it or use it as a raw material.

But achieving net-zero emissions won't ensure that the planet is buffered from the environmental and health impacts of fossil fuel extraction and use, says Holly Jean Buck, author of *Ending Fossil Fuels: Why Net Zero Is Not Enough*. She argues that a net-zero goal could allow fossil fuel extraction and use to continue, drawing resources away from efforts to capture CO_2 from the atmosphere.

Climate change isn't the only reason for phasing out fossil fuels, according to Buck, an interdisciplinary researcher and professor at the University at Buffalo. She notes that fossil fuels are connected to negative impacts, including financial support of corrupt and oppressive governments, air pollution and its health effects, and environmental injustice.

Buck is one of the hundreds of contributing authors to a recent report by the United Nations' Intergovernmental Panel on Climate Change (IPCC) working group that assesses ways to remove greenhouse gases from the atmosphere. The working group released its report April 4.

Buck also served on a US National Academies of Sciences, Engineering, and Medicine committee that wrote the report, *A Research Strategy for Ocean Carbon Dioxide Removal and Sequestration, released in December 2021*.

Buck was previously a science fellow at the University of California, Los Angeles, Institute of the Environment and Sustainability and a climate engineering fellow at the UCLA School of Law, where her research focused on the governance of climate engineering. She also received funding from the US National Science Foundation's Food Systems and Poverty Reduction Integrative Graduate Education and Research Traineeship.

CREDIT: NIKKI AVIEL/UCLA

Holly Jean Buck argues that net-zero goals put the focus entirely on greenhouse gas emissions and draw attention from fossil fuel production.

Cheryl Hogue spoke with Buck about her book, net zero, the chemical enterprise, and the call to end fossil fuels. This interview was edited for length and clarity.

What are the pluses and minuses of net-zero policies and goals?

The advantage of net zero as a goal is it affords some flexibility, both in time and in space. Maybe your country produces a lot of livestock. New Zealand and Uruguay are in this situation. A lot of their emissions are from livestock, and that's hard to decarbonize.

Also, some things may be plausible to decarbonize fully in a few decades, but the technology isn't there quite yet. There are plausible routes for sustainable aviation fuel or green hydrogen to power factories. They're not quite mature.

But there are also definitely problems. The biggest one is the danger that net zero is used as kind of a loophole or a way to put off more expensive transitions, kicking the can down the road. It could delay emission cuts. That's what a lot of climate advocates are worried about when they see these targets.

The movement to address climate change is opening up economic opportunities for products that wouldn't be competitive with petrochemicals now.

Your book argues that a shift away from fossil fuels is essential to address human-caused climate change. Would you discuss this, especially in relation to net zero?

We know that we have to wind down the production of fossil fuels, not just increase renewables. We have to do both. If we want to limit warming to 1.5 °C, which the world has agreed to try to do, countries would need to be decreasing fossil fuel production by 6% a year over this decade. And yet they're planning to increase production 2% or so. We're really not on the right track.

You say that decarbonizing the petrochemical sector is especially hard. Why?

Right now, about 80% of a barrel of oil goes to fuels, and the rest goes into petrochemical products. There are emissions linked to various parts of that production. Both the extraction of oil and gas and the cracking of molecules have a greenhouse gas footprint. Plastic is not well recycled, so it's kind of a climate problem in its own right.

What are the challenges and opportunities that the chemical industry faces for ending fossil fuels rather than striving for net zero?

It's a tough industry to transition because a lot of the facilities are hugely expensive. There's a lot of capital tied up with them.

But I think there are opportunities in terms of new industries. For example, carbon capture, use, and storage. There are a lot of interesting opportunities in the utilization of CO_2 in terms of fuels and chemicals like methane, methanol, polymers, and also building materials. CO_2 can be used in all these different applications. Petrochemicals could be made with recycled carbon.

These opportunities might be new companies that are competing with legacy petrochemical businesses.

What's your message for chemists or researchers who come up with new materials in relation to net zero?

It's such an interesting and exciting time to be truly innovating in this industry. The movement to address climate change is opening up economic opportunities for products that wouldn't be competitive with petrochemicals now.

This could be a kind of new chemistry revolution, both in terms of biomaterials and CO_2 utilization. ■

Vitals

- **Hometown:** Columbia, Maryland
- **Current position:** Professor of environment and sustainability, University at Buffalo
- **Education:** MSc, human ecology, Lund University, 2011; PhD, development sociology, Cornell University, 2017
- **Quote from her latest book:** "Removing carbon from the atmosphere at a climate-significant scale means the creation of a significant new industry."
- **Previous book:** *After Geoengineering: Climate Tragedy, Repair, and Restoration*, 2019

Periodic Graphics

A collaboration between C&EN and Andy Brunning, author of the popular graphics blog ***Compound Interest***

More online

To see more of Brunning's work, go to **compoundchem.com.** To see all of C&EN's Periodic Graphics, visit **cenm.ag/periodicgraphics.**

BAKING SODA VERSUS BAKING POWDER

Baking soda and baking powder are two common ingredients in baked goods. Here we take a look at what these leavening agents are made of and how they help your cookies, muffins, and cakes rise.

WHAT ARE RAISING AGENTS?

Carbon dioxide makes doughs and batters rise during baking. The gas can be produced by yeast, other microorganisms, and chemical raising agents.

BAKING SODA

Sodium bicarbonate

$NaHCO_3$

Heat or acidity breaks down sodium bicarbonate to release carbon dioxide. If a dough or batter is acidic enough, no acid needs to be added with the baking soda.

$$NaHCO_3 \xrightarrow[\text{or heat}]{\text{Acid}} CO_2 + Na_2CO_3 + H_2O$$

Baking soda is alkaline—too much causes bitter flavors in baked products.

Potassium bicarbonate — Used to reduce sodium content of baked goods.

Ammonium bicarbonate — Produces carbon dioxide and ammonia gases. Used in crisp cookies and crackers.

BAKING POWDER

Sodium bicarbonate

Acid or acidic salt

Most baking powders are double acting, releasing gas during both mixing and baking.

During mixing

A soluble acid reacts with the baking soda.

During baking

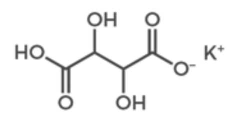
A less soluble acid reacts with the baking soda.

Different acid ingredients affect gas production differently.

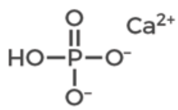
BAKING POWDER ACIDS

Cream of tartar (potassium bitartrate) is a soluble acid and reacts during mixing.

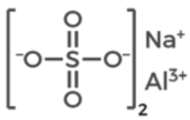
Potassium bitartrate



Double-acting baking powders often combine monocalcium phosphate, which reacts with baking soda during mixing, with sodium aluminum sulfate, which reacts during baking. Some other baking powders use pyrophosphate salts, whose different granulations can vary their reaction times.



Monocalcium phosphate



Sodium aluminum sulfate

PERIODIC GRAPHICS

Confronting human rights abuses in the scientific literature

Scientific journals must be accountable for ethically distressing content regardless of when it was published

DAVID W. CHRISTIANSON, SPECIAL TO C&EN

I find myself wondering at times how ethically distressing content could appear in a highly respected scientific journal. For example, an incendiary essay criticizing efforts to increase diversity in organic synthesis was published in 2020 by *Angewandte Chemie* but quickly withdrawn after public outcry. The journal issued this statement: "It is not only our responsibility to spread trusted knowledge, but to also stand against discrimination, injustices and inequity" (DOI: 10.1002/anie.202006717). Unfortunately, injustices abound in the scientific literature, and these include abhorrent human rights abuses. Scientific journals must be accountable for such ethically distressing content regardless of whether it is discovered days or decades after publication. Its repercussions continue long after publication, as I have witnessed firsthand.

In 1962, a paper in *Science* described radiation experiments performed on children as young as 12 months labeled "mentally defective" by doctors at Harvard Medical School, Massachusetts General Hospital, and Boston University School of Medicine (DOI: 10.1126/science.138.3538.430). These children were patients at the Wrentham State School in Massachusetts, a residential facility for children with developmental disabilities. They were fed radioactive ^{131}I to explore ways to mitigate ^{131}I uptake from nuclear fallout.

In 2015, I moved to Cambridge, Massachusetts, as a Radcliffe Fellow and visiting professor at Harvard University. While exploring my family history, I made the sickening discovery that my late twin sister, Karen, might have been one of the test subjects in these experiments. Karen suffered complications at birth that resulted in severe brain damage, and she was admitted to the Wrentham State School in 1961. Was she one of the 20 infants and children 1–3 years old mentioned in the *Science* paper? Due to poor record keeping, I'll never know. Karen died 2 months after the paper was published.

A 1994 article in the *Harvard Crimson* exposed this study, and another by scientists from Harvard Medical School and the Massachusetts Institute of Technology at the Fernald State School, where radioactive ^{45}Ca was fed to intellectually disabled boys (*J. Nutr.* 1954, DOI: 10.1093/jn/54.4.523). A 9-year-old boy diagnosed with "terminal gargoylism" was also used as a test subject (*J. Clin. Invest.* 1958, DOI: 10.1172/JCI103591). He died on day 16 of the experiment, and his remains were subject to postmortem analysis to assess ^{45}Ca uptake in various bones and tissues.

A Massachusetts task force concluded that this research "was conducted in violation of the fundamental human rights of the subjects involved." The US Advisory Committee on Human Radiation Experiments affirmed that there were no records of parental authorization for these experiments, concluding, "It might have been common for researchers to take advantage of the convenience of experimenting on institutionalized children, but the Committee does not believe that convenience offsets the moral problems associated with employing these vulnerable children as research subjects—now or decades ago."

> Is it ethical to cite papers in which human rights abuses are clearly documented? . . . Moreover, how should a journal respond to ethically distressing content when it is discovered?

What about the scientific journals that published these shameful studies?

In a valiant step toward accountability, chemist and *Science* editor in chief Holden Thorp confronted the complicity of his journal in this "regretful past" in a recent editorial (*Science* 2022, DOI: 10.1126/science.abn8856). He had been unaware until last year, and he was rightfully horrified. However, other scientists have been aware—but perhaps not similarly horrified. The Wrentham State School study has been cited 60 times, most recently in 2018; the Fernald State School study has been cited 50 times, most recently in 2020.

Is it ethical to cite papers in which human rights abuses are clearly documented? This question should be debated by the scientific community. Moreover, how should a journal respond to ethically distressing content when it is discovered?

Angewandte Chemie exemplified one approach: complete and decisive withdrawal of the offending content. However, this approach might make it easier for future generations to forget that abuses ever occurred. An alternative approach is that exemplified by *Science*—the Wrentham State School paper now prominently displays a link to the Thorp editorial. Anyone who consults this paper in the future can learn of the study's utter inhumanity.

I propose that scientific journals establish procedures for evaluating and addressing ethically distressing content, regardless of when it is discovered. What calls for retraction, and what calls for editorial annotation? Journals, editorial boards, and publishers must grapple with these difficult questions. While *Science* contemplates its own path forward, the editorial annotation of a paper documenting human rights abuses seems like a good start. Although this approach preserves ethically distressing journal content, it also ensures that future generations will see how we learned from the past as we aimed to do better.

CREDIT: COURTESY OF DAVID W. CHRISTIANSON

David W. Christianson is the Roy and Diana Vagelos Professor in Chemistry and Chemical Biology and chair of the Department of Chemistry at the University of Pennsylvania.

Do you have a story you want to share with the chemistry community? Send a submission of about 800 words to **cenopinion@acs.org.**

Designed for safety during powerful collisions, tempered window glass breaks apart into tiny, rounded pieces, while laminated windshield glass cracks but remains in the frame.

CREDIT: MITCH JACOBY/C&EN

Making and recycling automotive glass

Manufacturing this high-tech material is complicated, and so is recycling it. But glass recyclers are finding ways to reuse it

MITCH JACOBY, C&EN STAFF

Earlier this year, Riley Leon made headlines when he survived a tornado that flung his pickup truck across a highway. His story highlights the safety engineering that goes into automotive glass.

On March 21, Leon was driving along US Route 290 in Elgin, Texas, when tornado winds topping 210 km/h knocked over his pickup truck, spun it round and round, and eventually uprighted it. Despite the violent thrashing that heavily damaged the truck and blew out some windows, Leon received little more than minor scratches. That was in part because the windshield and rear window remained intact, preventing him from being ejected from the vehicle or injured by a collapsing cabin frame. Those protective features are engineered into the truck's safety glass.

Safety is one of several design needs of glass for automobiles. The glass has to be optically clear to provide drivers and passengers with an undistorted view of their surroundings, but it also needs to selectively transmit light to help drivers see clearly without squinting and to keep the interior cool on hot, sunny days. It needs to be strong to resist high-speed winds and impacts from small stones during highway driving. Windshields and sunroofs, in particular, must be structurally rugged to support the cabin frame and prevent the roof from buckling and harming passengers during rollovers. And if the glass does break, the pieces should remain in the window frame or break into small, rounded chunks, not large, jagged shards that can cut, maim, or kill the occupants. The glass also must be as light as possible to maximize fuel efficiency, must control the acoustics for cabin comfort, and should provide various tints and colors for aesthetics and privacy.

Tailoring glass to affordably provide all these functionalities requires striking the right balance among glass properties, says Thibaut Heitz, director of R&D at Paris-based Saint-Gobain Sekurit, a multinational glass company. To achieve this custom combination of properties, glass scientists and engineers fine-tune the material's composition and further tailor its properties through tempering, chemical strengthening, laminating, coating, and other procedures.

As a result, automotive glass manufacturing is complicated. It's also growing. Worldwide, manufacturers produced an average of roughly 90 million passenger

In brief

Automotive glass is designed to withstand the wind forces of high-speed driving, resist impacts from kicked-up road debris, and support the cabin structure during collisions. If the glass breaks, it is engineered to not break into dangerous, sharp shards. By tuning the composition and structure of automobile glass, manufacturers produce a rugged safety material that provides drivers and passengers with a clear view of their surroundings while controlling the cabin temperature and acoustics as well as the vehicle's weight and energy efficiency. But this complex engineering makes the material challenging to recycle compared with other types of glass. Companies are finding ways to overcome these challenges and reduce the environmental impact of this multibillion-dollar industry.

cars and commercial vehicles per year in the past 10 years, according to the International Organization of Motor Vehicle Manufacturers. Industry watchers predict that number will grow steadily in the next decade. As it does, the global automotive glass market will also grow, almost doubling from approximately $15.5 billion in 2021 to $31.1 billion in 2028, according to Fortune Business Insights, a market analysis firm. The size of the market is driving recyclers to create innovative ways to reclaim waste auto glass and turn it into valuable products, thereby reducing this industry's environmental footprint. The various manufacturing steps that tailor automotive glass and provide it with a unique combination of properties present special recycling challenges, but ones that the industry is working to overcome.

Glass composition

Like glass used for making bottles, jars, and ordinary building windows, the glass found in cars, trucks, and buses is known as soda-lime glass. It's the most common type and accounts for roughly 90% of all manufactured glass. The material's main ingredients include sand as an abundant source of silica, sodium carbonate (soda ash), and calcium carbonate (limestone). To form glass, manufacturers blend the raw ingredients and feed them to a furnace that heats the mixture above 1,500 °C, forming a molten material that is shaped into bottles or other products as it cools.

Not all soda-lime glass looks alike. Glassmakers generally customize the formulation to control the color, which varies by application. Beer, for example, often comes in brown bottles to prevent unwanted photooxidation. For some homes and art displays, designers may choose brilliant colorless glass made from highly purified starting materials.

For automotive applications, the soda-lime glass ingredients may also include iron oxide, a tinting agent that imparts a greenish color to the glass. The tint reduces light transmission into the cabin, Heitz explains. This reduction makes it easier for the driver to see the road clearly in strong sunlight. The tint also helps keep the interior cool by blocking infrared (IR) wavelengths, he says. A cooler cabin leads to less demand for air conditioning, which reduces fuel consumption and lowers emissions of carbon dioxide in gas- and diesel-powered cars and extends driving range in electric vehicles.

Other inorganic compounds play a similar role in controlling light transmission, but they impart other tint colors. Cobalt, for example, provides a neutral blue-gray tint. And glassmakers often use a combination of compounds containing iron, manganese, and selenium to produce what the industry calls privacy glass. In addition to cutting light and heat penetration and looking elegant, this dark glass, which is commonly found in rear windows of sport utility vehicles (SUVs) and many luxury cars, offers back-seat occupants some privacy and deters theft by keeping the car's contents out of sight.

Coating windshields and sunroofs with metal films is a highly effective but more complex way to control light and heat in the cabin, says Eric Rogers of AGC (formerly Asahi Glass), a technical expert on the company's intellectual property. In this procedure, glassmakers often sputter deposit one or more nanometer-thin layers of silver separated by layers of metal oxides such as tin oxide or titanium dioxide. The thinness of the stacks allows this optically engineered structure to strongly reflect IR wavelengths, thereby minimizing cabin heating without coloring the glass silver, which would sacrifice visibility, Rogers says.

Tempered glass for safety

Broken glass can be fatal, especially during high-speed collisions, when the glass can fly into the cabin or people can be thrown against a broken window. For that reason, carmakers build automobiles with two types of safety glass. Side and rear windows are generally made from specially heat-treated, or tempered, glass. Windshields are universally made from laminated glass, which has a glass-polymer sandwich structure.

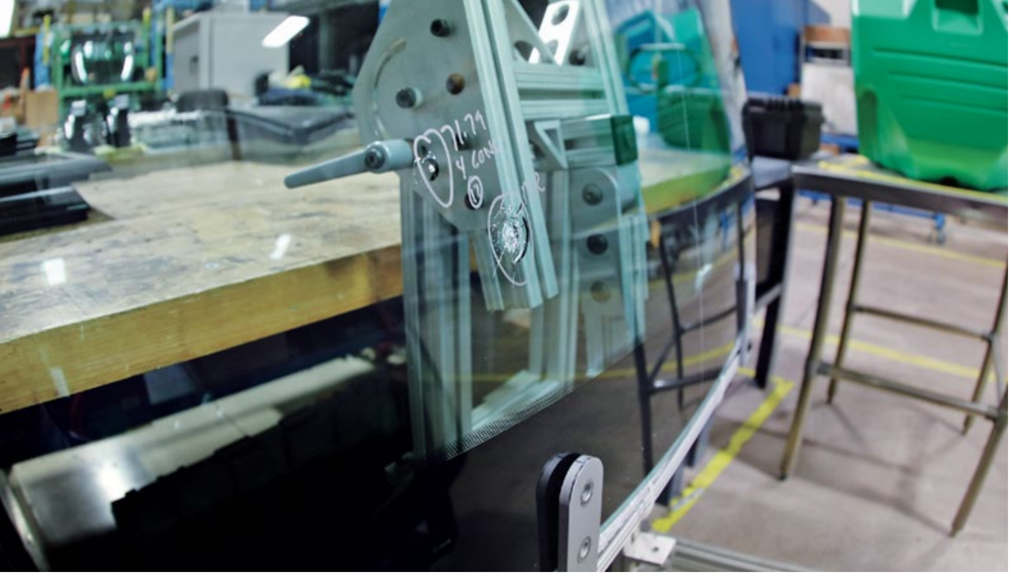
Manufacturers prepare tempered glass, which has been widely used in automobiles since the 1950s, by heating the glass to more than 600 °C, then quenching it quickly by blasting it for just a few seconds with high-pressure cold air, says Michael Richardson, a technical specialist in automotive glass at General Motors.

Corning tests the strength of Gorilla Glass windshields (left) by firing high-speed ice balls at them (right) to simulate hailstorms.

CREDIT: CORNING (BOTH)

The treatment makes the glass about four times as strong as ordinary annealed (slow-cooled) window glass. If it does break, tempering leaves the glass prone to shattering into many small, rounded pieces with relatively few sharp edges. These fragments are less likely to cut occupants than the large, jagged shards that typically form when common window glass breaks.

The cold air rapidly cools molecules at the surface, locking them in place in a state of high compression, which strengthens the surface, says Thomas Cleary, an automobile glass expert at Corning. At the same time, the molecules in the hot core are slower to cool and continue to vibrate freely until they do. "That leads to a density difference that sets up a tug-of-war between molecules in the core and at the surface," Cleary says. As a result of



By examining broken regions of a windshield (left, circled), AGC scientists can assess the damage mechanism.

that internal tension, when tempered glass breaks, it rapidly explodes into tiny pieces, releasing that pent-up energy.

Laminated windshields

Car safety has evolved a lot over the years. The earliest cars didn't have windshields. Those began appearing around 1904, but they didn't become standard equipment until more than a decade later.

The story of laminated glass for windshields dates back to 1903, when Edouard Benedictus, a French artist and chemist, made an unexpected observation while working in his lab. When Benedictus accidentally knocked a glass beaker to the floor, he was surprised to see that the beaker broke but the pieces of glass remained together, retaining the shape of the glassware. Benedictus had been working with a solution of nitrocellulose and the solution evaporated, coating the glassware with a tough film that held the glass fragments in place.

At that time, automobiles were growing in popularity, and injuries caused by broken glass during car collisions were on the rise. Benedictus saw a way to protect motorists by making windshields from toughened, polymer-coated glass that resisted shattering and stayed in the windshield frame if it did break. After a few years of development, he patented a safety-glass laminate composed of two layers of plate glass that sandwiched a film of cellulose.

By 1920, a number of companies made laminated glass for windshields and other applications, but early versions of this safety glass often discolored as the plastic interlayer film aged. Glass companies and carmakers found that polyvinyl butyral (PVB) resisted discoloring, and within a decade, several companies began using this material to laminate windshields. As a result of worldwide safety regulations implemented since the 1960s, laminated windshields are now standard everywhere, and although various materials have been used as interlayers, PVB remains the most common one.

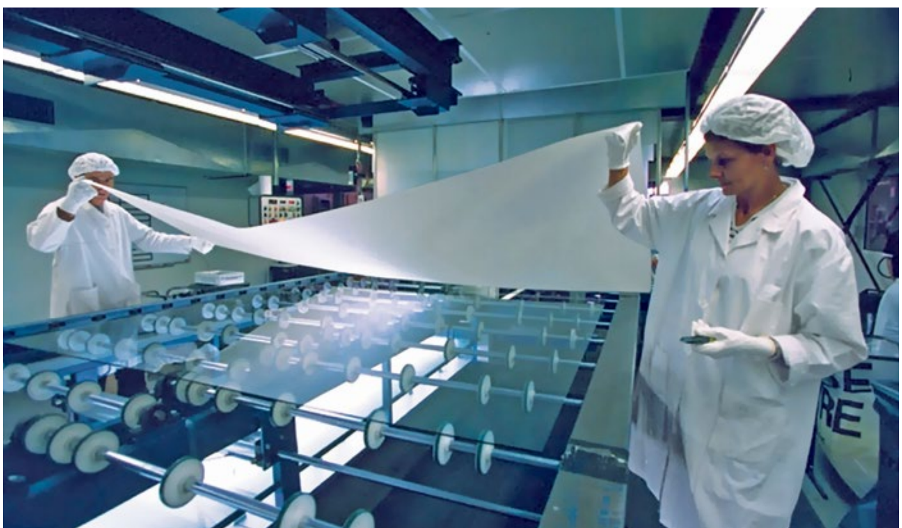
The basics of PVB chemistry were identified 100 years ago, according to Travis Smith, president of Eastman Chemical's films division, a major supplier of PVB for laminated glass. PVB remains the top choice for windshield interlayers because of its safety characteristics and optical clarity, Smith says. In addition, PVB can be tailored to control acoustics, block solar heating, and integrate displays and other electronic devices. And importantly, it can be produced economically at an industrial scale, he says.

To make laminated windshields, manufacturers cut sheets of soda-lime glass, roughly 2.5 mm thick, and shape them in a furnace to fit a car's curved windshield frame. Then they bond the glass and PVB film in a hot, pressurized vessel known as an autoclave. The procedure causes the PVB to thoroughly wet the glass surface, which leads to intimate mechanical contact between the layers, says Alan K. Phillips, Eastman's R&D director for films. It also drives hydrogen bonding between the layers, further strengthening the laminate, he says. The result is a tightly bonded, tough, transparent material that resists shattering by flexing on impact.

Chemical strengthening also plays a role in making windshields tough. In 2017, Ford debuted a windshield made from a laminated hybrid of ordinary soda-lime glass on the car's exterior and a thin piece of Corning's Gorilla Glass, a chemically strengthened aluminosilicate material, on the interior. Corning's Cleary explains that the strengthening in Gorilla Glass comes from ion-exchange chemistry that causes potassium ions to replace some of the sodium ions in a thin surface layer. Potassium's large size relative to sodium leads to compressive forces that toughen the glass surface by raising roadblocks that prevent cracks from propagating.

Before introducing the hybrid windshields, Ford and Corning ran various tests simulating impact with blunt and sharp stones on the glass. It took more than twice as much impact energy to form star cracks in the hybrids as it did in conventional windshields. And because the Gorilla Glass ply in 2017 was much thinner

Laminated safety glass features a tough polyvinyl butyral film sandwiched between sheets of glass.



CREDIT: AGC (BROKEN WINDSHIELD; SCIENTIST); EASTMAN CHEMICAL (FILM)

At Strategic Materials in Moraine, Ohio, crushed automobile glass moves along conveyors (top) to various sorting machines (middle), which generate mounds of clean cullet (bottom) used for making new glass.

and lighter than other types of glass, the windshield's weight was cut by about 30%, nearly 7 kg for some SUVs, Cleary says. Since then, the glass has become even thinner and lighter, which reduces fuel consumption and emissions of greenhouse gases, and extends driving range in electric vehicles.

Recycling challenges

Glass can be recycled repeatedly with no loss in the quality of containers, windows, and other products made from it. Most glass is recycled by crushing it to form cullet, removing impurities and sorting by color, and then blending the cullet with sand and other raw ingredients, which are melted in the furnace to make new glass. Using cullet in this way reduces glass manufacturers' need for raw materials. It also reduces the energy required to keep the furnace at temperatures high enough to generate molten glass, which lowers greenhouse gas emissions and operating costs and keeps glass prices in check. Glass recyclers process tempered window glass in much the same way as container glass—crush, clean, sort, and ship the furnace-ready cullet to manufacturers, says Mark Nelson, a vice president at Strategic Materials, the largest cullet supplier in the US.

But the same features that make windshields tough and safe also make them difficult to recycle. By design, the glass is tightly bonded to the rubbery sheet of PVB and adheres strongly even after the glass breaks, Nelson says. So even though glass recyclers process many millions of metric tons of container glass annually, they have traditionally recycled very few windshields. This is especially true in the US, which lags far behind many countries when it comes to recycling container glass. Broken windshields often ended up in landfills.

Andela Products is a company that has developed one way to pry the materials apart. Cynthia Andela, president and CEO of the company, describes the method as based on a hammer-and-chisel-like approach. Equipment beats the windshield from both sides simultaneously—repeatedly and at high speed, fracturing the glass and mechanically peeling it from the PVB. The stripping process yields millimeter-sized cullet and larger pieces of PVB.

Nearly all glassmakers use cullet to manufacture new products, so the reclaimed windshield glass is readily recycled. What about the PVB? Shark Solutions, based in Denmark, is one of a handful of companies that processes broken windshields and recycles the film. The company, which also operates in the US and Belgium, purifies the PVB and converts it to pellets and water-based dispersions. Manufacturers use those materials to make carpet backing, binders for paints, adhesives, fabric coatings, and other industrial products.

"Interest in recycling windshields has really grown in the past few years," Andela says. People are focused on sustainability and reducing the volume of material sent to landfills. They see opportunities to recycle windshields into useful materials, she says.

Recyclers process broken windshields (top) by stripping the glass from the polyvinyl butyral (PVB) film (bottom) and turning the PVB into carpet backing, paints, and other products.

Worldwide, some 75 million broken windshields are replaced annually, according to industry estimates. Recycling the PVB reduces the number that goes to landfills and lowers carbon emissions by sidestepping the need to make new polymer, says Shark Solutions vice president Rob Crivello. "It gives us a measure of fulfillment to know that this waste is no longer considered waste. It's recycled because it's valuable." ■

CREDIT: MITCH JACOBY/C&EN (SMI RECYCLING IMAGES); SHARK SOLUTIONS (PILE OF WINDSHIELDS); ANDELA PRODUCTS (PVB FILM)

COMMENT

Creating a culture of inclusion

KATHERINE L. LEE, DIRECTOR, DISTRICT I

I remember what it felt like on the first day of junior high. I was nervous and had sweaty palms and a funny feeling in my stomach. Where was my homeroom? Would I like my teachers? Who would I sit with on the bus on the way home?

Now, decades later (ahem), I have gained more life experience and confidence, and I have found ways to overcome my shyness, having grown to become a successful leader at work and in my volunteer endeavors at the American Chemical Society. I strive to be impactful and to conduct myself in a way that demonstrates integrity and respect for people, informed by how I felt on that first day of junior high school. Given that most of what I do involves working in a team environment, I believe that success is not only about the technical aspects of what we do; the "how" and culture of the team are crucial. In this Comment, I share my reflections on creating a culture of inclusion.

I believe that success is not only about the technical aspects of what we do; the "how" and culture of the team are crucial.

Why should we do this? The ACS core value of diversity, equity, inclusion, and respect (DEIR) states: "We embrace and promote diversity in all its forms, not only to create a more inclusive environment for the practice of chemistry, but also to provide fair and just outcomes for all to achieve their full potential. Inclusion of and respect for people of all backgrounds, perspectives, experiences, and ideas will lead to superior solutions to world challenges and advance chemistry as a global, multidisciplinary science."

In addition to the rationale captured above, I would like to make the case in a more personal way. Put yourself in the shoes of a first-time attendee of a conference, a new member of an ACS local section, or a scientist joining an established project team. How would you feel if someone said "Hi" and welcomed you? And if you were invited to share your thoughts? Might an organization or team be more productive and creative, and less prone to being narrow minded, if people with different experiences and perspectives contributed their insights?

Recently I had the honor of serving as a member of the organizing committee for an ACS Pharma Leaders meeting. As the members of the committee and I discussed potential topics for a breakout session, Guoxin Zhu, another committee member, suggested that we ask participants to brainstorm how to create a culture of inclusion. Here are some ideas that I took from the meeting, mingled with ideas of my own.

Set the tone from the outset. We are often asked to introduce ourselves, and we might say: "I am [name], [title] at [institution], where I have worked for X years in [discipline]." Leading with one's title and years of experience might overemphasize one's status or organizational hierarchy. A more inclusive introduction might be: "I am [name]. At [institution], I focus on [function], and my interests include X and Y."

Words matter. Imagine standing at a podium welcoming people to an event. "Ladies and gentlemen . . . " may be a common way to start. Or chatting with a group of people at lunch, one might say, "Hey guys, what do you think about the new Batman movie?" Try a gender-neutral approach instead: the ACS Inclusivity Style Guide is designed to help ACS members and staff consider diversity and inclusion in communication and includes examples of words to avoid and ones to use.

Help people feel valued. Several years ago, I was given the opportunity to join a leadership team, and was expected to contribute to projects beyond my own, receive and reflect on potentially sensitive information, and share my opinions. This was an empowering experience. At times you may be in a position to advocate for someone to literally be in the room. What will you do?

The art of managing meetings and the underlying culture of a team also play a role. Meeting moderators, how do you encourage people to actively participate and speak up? What do you do if someone interrupts another person? Leaders, do you intentionally wait until others have shared their thoughts before weighing in?

Rethink mentorship. The ACS Pharma Leaders discussion included people at different stages in their careers, and we agreed that building a culture of inclusivity has a higher probability of success if it includes both top-down and grassroots efforts. On a personal level, we might think of mentorship as a one-way relationship, in which someone with more experience imparts wisdom to someone with less. Encouraging and being truly receptive to mentorship as a two-way relationship can help us grow and perhaps address our unconscious biases and areas of unawareness. To learn about reverse mentoring, see Patrice Gordon's video, "How Reverse Mentorship Can Help Create Better Leaders."

Walk the talk. Goal 5 of the ACS Strategic Plan is a lofty, aspirational goal for DEIR. Across ACS, we are working toward this goal. As individuals, what actions will we commit to as we build a culture of inclusion?

Views expressed are those of the author and not necessarily those of C&EN or ACS.

CREDIT: PROFESSIONAL EVENT IMAGES

Obituaries

Brian K. Bennett

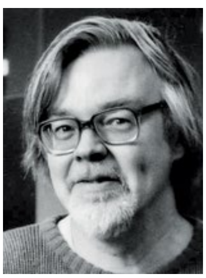
Brian K. Bennett, 55, died Jan. 6, 2021, in Stansbury Park, Utah.

"Brian passed away suddenly due to pancreatic cancer. His son inherited his musical talent, and his daughter inherited his eloquent charm. His wife of 23 years, Angela, was his best friend and the love of his life. Brian was a chemist at heart and an accomplished jazz pianist by night! Fun fact: Brian's laugh was not subject to simple physics and is still traveling the boundaries of space and time to this day. All who had the privilege of meeting him will miss him and remain devoted to making the world a better place in his honor."—Angela Bennett, wife

Most recent title: US Army combat capabilities development command chief, Dugway Proving Ground Biological Testing Division
Education: BS, chemistry, California State University, Fullerton, 1991; PhD, inorganic chemistry, University of Utah, 1997
Survivors: Wife, Angela; daughter, Hannah; son, David

Jan Bergman

Jan Bergman, 80, died Dec. 13, 2021, in Stockholm, Sweden.



"Jan was indisputably an expert on the chemistry of indole. He had an unrestrained love affair with the indole molecule and all of its lineages, with early syntheses of ellipticine, indolocarbazoles, biindoles, and numerous other biologically active indoles and other nitrogen heterocycles. He was the first to demonstrate an indolocarbazole as the putative natural ligand for dioxin. He invented a reagent for the thionation of carbonyl compounds and was a pioneer in developing organoselenium and organotellurium chemistry. He traveled widely and was a strong supporter of heterocyclic chemistry, serving on several boards, such as the International Society of Heterocyclic Chemistry."—Gordon W. Gribble, friend

Most recent title: Emeritus professor of chemistry, Karolinska Institute
Education: BSc, chemistry, 1964, and PhD, organic chemistry, 1971, KTH Royal Institute of Technology
Survivors: Spouse, Solveig; sons, Leif, Hans, and Bengt

Stephen R. Daniel

Stephen R. Daniel, 78, died April 15, 2021, in Lakewood, Colorado.

"In the course of his service to the Colorado School of Mines, Steve taught almost every chemistry class offered, never reusing lecture notes but composing new ones each time. He received numerous teaching awards and published in the fields of environmental chemistry, fuels and petrochemistry, and chemical education. Additionally, Daniel taught in the McBride Honors Program, serving as interim principal tutor in 2001. He was the faculty adviser for Mines Little Theatre for more than 40 years and was known on campus for his frequent acting roles. He sang in the Mines Chorus and participated in campus governance."—Linda H. Daniel, wife

Most recent title: Head, Colorado School of Mines Department of Chemistry and Geochemistry
Education: BS, mineral engineering chemistry, 1965, MS, chemistry and chemical engineering, 1966, and PhD, chemical and petroleum refining engineering, 1971, Colorado School of Mines
Survivors: Wife, Linda H. Daniel; daughters, Ingrid and Kirstin; sons, Erik and Kurt; five grandchildren

Hans G. Elias

Hans G. Elias, 93, died Jan. 19 in Richardson, Texas.

"We thank Hans for everything that he did for our family!"—Peter C. Elias, son

Most recent title: Consultant
Education: MS, chemistry, Technical University of Hanover, 1953; PhD, chemistry and chemical engineering, Technical University of Munich, 1957
Survivors: Sons, Peter and Rainer

Lori M. Friedman

Lori M. Friedman, 69, died Feb. 20 in Philomath, Oregon.

"Lori chose alternative careers in chemistry. She was in the forefront of computerized chemical information at PPG Industries and Sherwin-Williams as director of information services. She then switched careers, and after being admitted to the Federal Patent Bar became a patent manager at Uniroyal Chemical and director of intellectual property at Kreativ. She then struck out on her own as the owner of LMF Patents. Lori joined ACS in 1979 and was a member for 44 years. Lori succumbed to the effects of multiple sclerosis after a 30-year battle."—Howard S. Friedman, husband

Most recent title: Owner, LMF Patents
Education: BA, chemistry, New York University, 1970; EMBA, University of New Haven, 1973
Survivors: Husband, Howard

Mariano Guiducci

Mariano Guiducci, 91, died in December 2021 in Skillman, New Jersey.

"Mario's career took many twists and turns. His family fondly remembers his bumper sticker that read, 'Honk if you love

CREDIT: HANNAH BENNETT (BENNETT); COURTESY OF GORDON W. GRIBBLE (BERGMAN); COURTESY OF LINDA H. DANIEL (DANIEL); COURTESY OF PETER C. ELIAS (ELIAS); HOWARD S. FRIEDMAN (FRIEDMAN):

P-Chem.’ Didn’t get many responses, but he loved it.”—Laura Felker, daughter

Most recent title: Manager of process research, Givaudan
Education: BS, chemistry, Albright College, 1952; MS, chemistry, Lehigh University, 1954; PhD, organic chemistry, Columbia University, 1965
Survivors: Two daughters; four grandchildren

Lawrence (Larry) H. Keith

Lawrence (Larry) H. Keith, 83, died Feb. 16 in Monroe, Georgia.

“Larry was an internationally known environmental chemist. He was an ACS Fellow with more than 200 publications, served on several advisory boards, and earned numerous honors, awards, and recognitions for his work. Larry had been an environmental consultant, expert witness, teacher, editor, writer, reviewer, and publisher and developed expert systems for antiterrorism. In addition, Larry played the drums, sailed, skied, loved to travel, and was known for his calm, laid-back demeanor and for his dedication to his family and friends.”—Douglas B. Walters, friend

Most recent title: President and CEO, Instant Reference Sources
Education: BS, Stetson University, 1960; MS, Clemson University, 1963; PhD, University of Georgia, 1966
Survivors: Wife, Virginia; daughter, Emily; son, Jack; 3 grandchildren

Alvin P. Kennedy

Alvin P. Kennedy, 67, died Feb. 7 in São Paulo.

“Alvin P. Kennedy was an outstanding scientist, teacher, educator, and mentor. We will miss his infectious smile, boundless energy, and direct advice. Our thoughts and prayers go out to Sharon Kennedy and all of their family. Read more about Alvin and his remarkable life at www.nobcche.org/alvin-kennedy.”—Tim O’Neill, friend

Most recent title: Professor and chair, Morgan State University Department of Chemistry
Education: BS, Grambling State University, 1978; PhD, physical chemistry, University of California, Berkeley, 1985
Survivors: Wife, Sharon; mother, Helen; three children

Einar P. Kropp

Einar P. Kropp, 107, died Feb. 24 in Mantua, Ohio.

“Einar (‘Oscar’) spent his long, productive life eagerly learning about the natural world, finding ingenious ways to improve efficiencies and solve problems, whether minor and domestic or major and industry changing. He began at Sohio in the Chemical and Physical Research Department in 1937. Work in process development took him around the world managing start-ups for acrylonitrile plants. On retirement, he joined McKee Engineering and Construction. His thirst for knowledge and constructive pursuit of solutions to problems made for his children a rich and expansive upbringing. His warm, loving presence in our lives will be sorely missed.”—Elin Poneman, daughter

Most recent title: Manager, McKee Engineering and Construction Petroleum and Chemical Process Division
Education: BSc, chemical engineering, Michigan State University, 1937
Survivors: Children, Mary Ann Zane, Peter, Elin Poneman, Jeanne, and John; 13 grandchildren; 19 great grandchildren

John A. Maguire II

John A. Maguire II, 85, died Jan. 26 in Allen, Texas.

“In addition to being a dedicated teacher, mentor, and scholar, John was an avid reader, student of history, and lover of opera, classical music, and jazz. He appreciated a good glass of wine or a jigger of scotch.”—Katheryn Maguire, daughter

Most recent title: Professor emeritus, Southern Methodist University
Education: BS, chemistry, Birmingham-Southern College, 1958; PhD, chemistry, Northwestern University, 1963
Survivors: Son, John; daughters, Christine and Katheryn

Charles W. McGary

Charles W. McGary, 91, died Feb. 26, 2021, in Williamsburg, Virginia.

“We shared 76 years of marriage!”—Deloris McGary, wife

Most recent title: Vice president of polymers, Warner Lambert
Education: BS, science, Westminster College, 1951; PhD, chemistry, Purdue University, 1954
Survivors: Wife, Deloris; daughters, Susan, Diane Avjean, and Lynn Foley; sons, Chris and Jeff

James R. McKee

James R. McKee, 75, died Nov. 1, 2021, in Havertown, Pennsylvania.

“James McKee was a professor of chemistry at the University of the Sciences in Philadelphia for 44 years; for 20 of them, he served as the director of graduate programs in the chemical sciences. Together with his wife Trudy, he published a textbook, *Biochemistry: The Molecular Basis of Life*, that had seven editions and was translated into six languages, among a number of research papers dedicated to sulfone and sulfonanilide antibiotics. Jim will be remembered by his colleges and students for his lifelong passion for chemistry and wonderful sense of humor.”—University of the Sciences Department of Chemistry and Biochemistry

Most recent title: Professor of chemistry, University of the Sciences
Education: BS, chemistry, 1970, and

CREDIT: COURTESY OF NOBCCHE (KENNEDY); COURTESY OF JOHN KROPP (KROPP); COURTESY OF KATHERYN MAGUIRE (MAGUIRE); COURTESY OF DELORIS MCGARY (MCGARY)

PhD, organic chemistry, 1974, University of Maryland, College Park
Survivors: Spouse, Trudy; son, James

Omar Mukbaniani

Omar Mukbaniani, 73, died Jan. 18 in Tbilisi, Georgia.

"Omar Mukbaniani was a professor at Ivane Javakhishvili Tbilisi State University, chair of macromolecular chemistry, and head of the Department of Chemistry. Mukbaniani was a member of the Academy of Natural Sciences of Georgia. For several years, he served as a member of the advisory board and the editorial board of the journal *Proceedings of Ivane Javakhishvili Tbilisi State University, Chemical Series*, and was a contributing editor of the journals *Polymer News*, *Polymers Research Journal*, and *Chemistry & Chemical Technology*. He served as chair of the ACS Georgia International Chapter in 2021."—Tamara Tatrishvili, assistant

Most recent title: Director, Institute of Macromolecular Chemistry and Polymeric Materials
Education: BS, chemistry, Tbilisi State University, 1971; MS, chemistry, A. N. Nesmeyanov Institute of Organoelement Compounds of Russian Academy of Sciences, 1976; PhD, chemistry, Ivane Javakhishvili Tbilisi State University, 1977

Paul Angelo Odorisio

Paul Angelo Odorisio, 66, died Jan. 14 in Leonia, New Jersey.

"Paul was a prolific synthetic chemist at our R&D site and a key contributor for an impressive number of product development teams during his 43-year career. He specialized in antioxidants, stabilizers, and radical scavengers for plastics and lubricants. He was author or coauthor of more than 55 granted US patents and 16 journal publications. Everyone enjoyed working with Paul, especially the early-career folks, whom Paul was happy to mentor during this phase of their development. Paul was sharp, insightful, kind, honest, cooperative, generous, thoughtful, and always making an extra effort. He will be dearly missed."—Rick King and Sai Shum, colleagues and friends

Most recent title: Principal scientist, BASF
Education: BA, chemistry, 1977, MS, chemistry, 1982, and PhD, chemistry, 1985, Rutgers University
Survivors: Wife, Gina; daughter, Christina Rembon; son, Dominik; three grandchildren

Thomas A. Orofino

Thomas A. Orofino, 91, died Dec. 21, 2021, in Cleveland, Ohio.

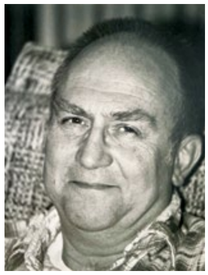
"Tom traveled the world and visited every state in the US. He was kind to all and was known to guide youngsters in math in downtown Chattanooga, Tennessee. Tom was a very learned man as demonstrated by his work in physics and mathematics and his understanding of Einstein's theory of relativity. He was a proud member of ACS for 71 years."—Chris Previte, nephew

Most recent title: Adjunct professor, University of Tennessee at Chattanooga
Education: BS, chemistry, Kent State University, 1952; PhD, physical chemistry, Cornell University, 1956
Survivors: Sisters, Jacqueline Chambers and Mary Previte

Wilbert J. Robertson Jr.

Wilbert J. Robertson Jr., 93, died Feb. 8 in Oklahoma City, Oklahoma.

"Wil loved his family, dogs (especially Irish setters), limericks, and Neil Diamond's "Sweet Caroline." He had a dry sense of humor that hid a generous heart and ferocious intelligence. "Think!" was one of his favorite exhortations, and he did not suffer fools, gladly or otherwise. He was an avid photographer and could fix anything. Wil loved figuring out what made things work, and he loved saving money by keeping them working. He will be deeply missed by his family, friends, and colleagues. Chemistry was good to him; he met his wife-to-be in the chemistry lab he taught at the University of Wisconsin–Madison."—Helen Robertson, daughter

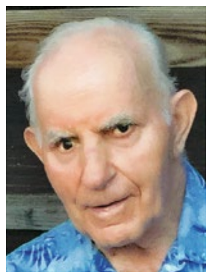


Most recent title: Research chemist, Kerr-McGee
Education: BS, inorganic chemistry, George Washington University; PhD, inorganic chemistry, University of Wisconsin–Madison, 1955
Survivors: Wife, Caroline; children, Charles, Helen, Paul, and Susan; six grandchildren; two great-grandchildren

Francis "Fritz" Schmitz

Francis "Fritz" Schmitz , 90, died March 7 in Norman, Oklahoma.

"Schmitz worked on determining the structures of many important natural products of medicinal value, and he loved teaching those skills to others. His research generated over 160 publications. Schmitz was widely and internationally recognized as a leader in the field of marine natural product chemistry. Those skills and accomplishments played an important role in Fritz being named the first marine associate editor for the American Chemical Society's *Journal of Natural Products*, a position he held from 1999 to 2002. Given that the oceans were his research home, it is notable that he was not at all fond of sharks."—Robert Cichewicz, colleague



Most recent title: Professor, University of Oklahoma
Education: BS, Maryknoll College, 1954; PhD, organic chemistry, University of California, Berkeley, 1961
Survivors: Wife, Phoebe; daughter, Kathy Ong; sons, Michael and Steven

CREDIT: COURTESY OF TAMARA TATRISHVILI (MUKBANIANI); BASF (ODORISIO); COURTESY OF CHRIS PREVITE (OROFINO); COURTESY OF HELEN ROBERTSON (ROBERTSON); COURTESY OF ROBERT CICHEWICZ (SCHMITZ)

ACS NEWS

Robert W. Summitt

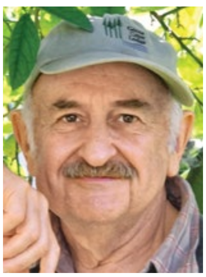
Robert W. Summitt, 86, died Jan. 9 in Portage, Michigan.

“Robert (Bob) started his career at Corning Glass Works in the R&D department in 1962. Always wanting to teach, he left Corning for a teaching job at Michigan State University in the Metallurgy, Mechanics, and Materials Science Department. He taught for 28 years, 5 of those years as department chairman. Bob’s main area of interest was corrosion. He received a grant from the US Air Force to study corrosion problems on US aircraft. Bob traveled to many countries over the years and was a guest speaker at North Atlantic Treaty Organization conventions. He loved his family, woodworking, ham radio, and music.”—Elizabeth Sandy, daughter

Most recent title: Professor emeritus, Michigan State University
Education: BS, chemistry, University of Michigan, 1955; PhD, physical chemistry, Purdue University, 1961
Survivors: Wife, Nancy; daughter, Elizabeth Sandy; son, David

Norman Sutin

Norman Sutin, 93, died Jan. 31 in South Setauket, New York.



“Norman was known for his warm and modest nature and his ability to mesmerize children with magic tricks. He helped establish many of the fundamental ideas about electron-transfer reactions, in particular elucidating the factors that control the rates of these reactions. He was one of the first to show that many biological reactions are also controlled by the same factors and can be studied using his methods. Norman later went on to develop schemes for artificial photosynthesis and showed how it was possible to sensitize semiconductors with simple inorganic metal ions for use in solar energy devices.”—Bruce Brunschwig, colleague

Most recent title: Senior chemist, Brookhaven National Laboratory
Education: BSc, chemistry and physics, 1948, and MSc, chemistry, 1950, University of Cape Town; PhD, chemistry, University of Cambridge, 1953

Guy A. Thompson Jr.

Guy A. Thompson Jr., 90, died Feb. 23 in Austin, Texas.

“Guy’s biochemical work was generally done in his laboratories, but he always envied his more botanical colleagues who spent time outdoors on field trips or other research activities. At last the urge to see more of nature led him to gradually reduce his research and teaching and become professor emeritus in 2000, at the age of 70. He plunged into new volunteer activities, such as gardening at the Lady Bird Johnson Wildflower Center, trail making at a nature conservancy preserve, and wildfire-danger monitoring for the city of Austin. He even took a paying job as landscaper at the local library that kept him busy for 12 years.”—Jeremy Thompson, son

Most recent title: Professor emeritus, University of Texas at Austin
Education: BS, chemistry, Mississippi State University, 1953; PhD, biochemistry, California Institute of Technology, 1959
Survivors: Wife, Ellen; children, Sally Macklin, Gillian Verga, and Jeremy Thompson

Charlotte Berkley Reed Ward

Charlotte Berkley Reed Ward, 93, died Jan. 30 in Auburn, Alabama.

“Charlotte was truly a Renaissance woman and a pioneer. She earned her bachelor’s degree, her Phi Beta Kappa key, and a master’s degree in chemistry at the University of Kentucky, where she also met the love of her life. Charlotte married Curtis Ward, a fellow chemist, in 1951. She earned her PhD in physical chemistry at Purdue University in 1956. Charlotte taught science for grade school students on Alabama’s first educational television network (1958–1967), long before her own family owned a television. She was on the faculty and taught in the Physics Department at Auburn University for nearly 30 years, and was a founding faculty member of the Ascent of Man curriculum, which brought together faculty and students from across the liberal arts and sciences for a truly integrated and novel curriculum.”—Ward family

Most recent title: Professor, Auburn University
Education: BS, chemistry, 1949, and MS, chemistry, 1951, University of Kentucky; PhD, physical chemistry, Purdue University, 1956
Survivors: Children, Emma Ward Morris, Bess, Mark, and Matthew; three grandchildren; two great-grandchildren

Alvin H. Weiss

Alvin H. Weiss, 93, died March 6 in Shrewsbury, Massachusetts.

“Alvin did all he wanted in his life, loved everything he did, and had a good, long life. He woke up every morning looking forward to going to work. His students were a testament to his achievements, and he was very proud of them. Because of his cultivating scientific collaborations with scientists abroad and the association with the United Nations Industrial Development Organization as a petrochemical specialist, we traveled all over the world. Add to this his friendly, full-of-life personality, quirky sense of humor, and intelligence: this was Alvin. He left this world with a head full of white hair and a beautiful smile.”—Devorah Weiss, wife

Most recent title: Professor of chemical engineering, Worcester Polytechnic Institute
Education: BS, chemical engineering, University of Pennsylvania, 1949; MS, chemical engineering, Newark College of Engineering; PhD, physical chemistry, University of Pennsylvania, 1965
Survivors: Wife, Devorah; daughter, Linda

To recognize your late loved one or colleague, submit obituary information at **cenm.ag/obits**.

CREDIT: COURTESY OF THE SUMMITT FAMILY (SUMMITT); BRUCE BRUNSCHWIG (SUTIN); JEREMY THOMPSON (THOMPSON); COURTESY OF THE WARD FAMILY (WARD)

c&en JOBS

To advertise in the C&ENjobs section, please contact Heather McNeill via email at **classifieds@acs.org** or telephone at (202) 452-8918. Please see below for current advertising options and how to get started.

Classified Line Ads (best for posting a job): Want to appear within a section with headers that are classified according to your industry? Our Classified Line Ad section gives you that opportunity. Your ad can appear with text only, or you may opt to include your logo in color or black and white. Header position classifications include: Academic, Government, Pharmaceutical, and Industry. Pricing starts at $75 gross per line ($750 minimum). If your ad is also posted online at chemistryjobs.acs.org, please ask about our print discount opportunities.

Display Ads (best for branding): Looking for a way to stand out from competitors and win the attention of potential candidates? Display ads provide an excellent opportunity to elevate your brand, highlight multiple open positions, or both.

Classified Directory Ads (best for announcements): Have something to sell? Announce? Want to promote your graduate program? Consider our directory. Header classifications include: General Directory (Announcements, Chemical Exchange, Equipment Mart, Technical Services) and Graduate Programs.

How To Get Started
To place your ad in C&ENjobs, please send your job description in Word format to **classifieds@acs.org.** Once your job description is received, you will receive a prompt response with a quote for your consideration.

Visit **acsmediakit.org/cen-classifieds/** and download the editorial calendar to find the right issue for your message.

To connect with our Global Sales Team, please visit **acsmediakit.org/contact/**

ACADEMIC POSITIONS

National Sun Yat-Sen University

FACULTY POSITION— DEPARTMENT OF CHEMISTRY, NATIONAL SUN YAT-SEN UNIVERSITY

The Department of Chemistry invites applications for several faculty positions in Analytical Chemistry, Organic Chemistry, and related fields. Postdoctoral experience is mandatory. A complete package, including (1) curriculum vitae with a publication list, (2) a research plan with start-up and instrument needs, (3) a brief statement of teaching interests, and (4) three letters of recommendation (including one from Ph.D. advisor), should be received by **June 30th**, 2022. Please send the application to Search Committee, Department of Chemistry, National Sun Yat-sen University, 70 Lien-Hai Road, Kaohsiung 80424, Taiwan or via e-mail: **jtlee@faculty.nsysu.edu.tw**.

University of Nevada, Reno

DIRECTOR OF LABORATORIES, the University of Nevada, Reno Chemistry Department is seeking candidates for a full-time administrative faculty position. Duties include overall management of the department facilities and laboratory operations. For further information, the complete position description and qualifications, and online application instructions, please use below link. Applications should be received by **April 25, 2022** for full consideration. For more information, and to apply, please visit: **https://bit.ly/nshe_dirlabchem**

EEO/AA. Women, under-represented groups, individuals with disabilities, and veterans are encouraged to apply.

The National Academies of SCIENCES ENGINEERING MEDICINE

ARL DISTINGUISHED POSTDOCTORAL FELLOWSHIPS

The Army Research Laboratory (ARL) Distinguished Postdoctoral Fellowships provide opportunities to pursue independent research in ARL laboratories. Fellows benefit by working alongside some of the nation's best scientists and engineers, while enhancing the mission and capabilities of the U.S. Army and the warfighter in times of both peace and war.

Fellows must display extraordinary abilities in scientific research and show clear promise of becoming future leaders. Candidates are expected to have already successfully tackled a major scientific or engineering problem or to have provided a new approach or insight, evidenced by a recognized impact in their field.

Fellowships are one-year appointments, renewable for up to three based on performance. The award includes a $115,000 annual stipend, health insurance, paid relocation, and a professional travel allowance. Applicants must have completed all requirements for a Ph.D. or Sc.D. degree by October 1, 2022 and may not be more than five years beyond their doctoral degree as of the application deadline. For more information and to apply visit **www.nas.edu/arl**.

Online applications must be submitted by June 15, 2022 at 5 PM Eastern Time.

U.S. ARMY

DEVCOM ARMY RESEARCH LABORATORY

INDEX TO ADVERTISERS IN THIS ISSUE

This index and additional company information are provided as a service to the advertisers. We are not responsible for errors or omissions.

Subscription & Member Record Service 2022: Send all new and renewal subscriptions with payment to: ACS, P.O. Box 182426, Columbus, OH 43218-2426. Changes of address, claims for missing issues, subscription orders, status of records and accounts should be directed to: Manager, Member & Subscriber Services, ACS, P.O. Box 3337, Columbus, OH 43210; 800-333-9511 or 614-447-3776.

Subscription Rates 2022: For 1 year of printed editions. ACS Premium package member: Included in ACS membership dues (North America); add $85 (outside North America). Nonmember: $325 (North America); $410 (outside North America). Institution: $793 (North America); $973 (outside North America). The price is higher for people living outside North America to cover shipping and handling.

Single copies: Current $25. Rates for back issues and volumes are available from Office of Society Services, ACS, 1155 16th St. NW, Washington, DC 20036, or email help@acs.org, or call 800-227-5558 or 202-872-4600.

Chemical & Engineering News (ISSN 0009-2347) is published weekly except for the last week in December by the American Chemical Society at 1155 16th St. NW, Washington, DC 20036. Periodicals postage is paid at Washington, DC, and additional mailing offices.

POSTMASTER: Send address changes to: Chemical & Engineering News, Member & Subscriber Services, P.O. Box 3337, Columbus, OH 43210.

Canada Post Mail Agreement Number: 40612608

ACS Advertising Sales Group
(See list of offices to the right)

c&en MEDIA GROUP

ACSMediaKit.org
1155 16TH ST. NW, WASHINGTON, DC 20036

STEPHANIE HOLLAND
Director of Global Advertising Sales & Marketing
202-872-4536
s_holland@acs.org

ADVERTISING OPERATIONS & TRAFFICKING
Joyleen Longfellow
202-452-2110
DisplayAds@acs.org

Sales Representatives

Recruitment & Professional Development
Heather McNeill
Tel: 202-452-8918
Email: classifieds@acs.org

IN, OH, PA, WV, KY, TN, VA, NC, SC
Michael Runkle
Office: 312-348-1210
Cell: 312-375-6065
Email: m.runkle@jgeco.com

ME, VT, NH, NY, MA, CT, RI, MS, AL, GA, FL, NE, ON, QC & PE
John Day
Tel: 917-421-9042
Email: j.day@jamesgelliott.com

WA, OR, CA, MT, ID, NV, WY, UT, AZ, ND, SD, CO, NM, TX, MN, NE, KS, OK, IA, MO, AR, LA, AK, HI, NJ, DE, MD, AB, BC, NZ & AU
Christopher C. Nolan
Tel: 312-348-1209
Email: c.nolan@jamesgelliott.com

Central Europe, Germany & Switzerland
Uwe Riemeyer, IMP InterMediaPartners GmbH
Tel: +49-202-271-690
Email: riemeyer@intermediapartners.de

United Kingdom, Belgium, France, Ireland, Italy, Portugal, Scandinavia & Spain
Paul Barrett, Hartswood Media
Tel: +44-1268-711-560
Email: paulbarrett@hartswoodmedia.com

China
eChinaChem, Inc.
Sammi Wang
Tel: +86-189-6499-9689
Email: sammi@echinachem.com

India
Faredoon Kuka, RMA Media
Tel: +91-22-6570-3081
Email: info@rmamedia.com

Korea
DOOBEE Inc.
Tel: 822-3702-1700
Email: dbi@doobee.com

Singapore & Thailand
Heather McNeill
Tel: 202-452-8918
Email: h_mcneill@acs.org

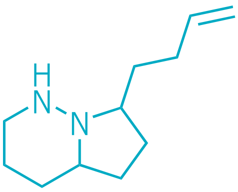
Newscripts

Curating quirky science since 1943

Musical molecules

A quick glance through past instances of this column will tell the reader that Newscripts can often take a musical turn. But at the University of Michigan, Timothy Cernak has added a new riff by incorporating effects such as pedals and synths to his lab kit. Instruments they certainly are, but chemical instrumentation? Maybe, if you want to use melody to design molecules, Cernak says.

Cernak is an expert in designing drugs using artificial intelligence. That requires computational ways to describe compounds, such as string notations or matrices of molecular data. He says computers can read these descriptors, but they're less immediately recognizable to human chemists. Wondering if these representations could be constraining how he and other chemists think about molecules, Cernak started thinking about the problem of how to encode all the structural information. If the medium chemists use to describe a molecule influences how they perceive it, why not mix up the medium?



Melodic molecule: Otherwise known as "Twinkle twinkle little star" in the key of D-flat

Last year, 18 months into the pandemic and looking for a lighter project for the lab, Cernak decided to explore musical interactions with molecules. The result: take molecular information in a computationally readable form called Self-referencing Embedded Strings (also known as SELFIES), and encode it into a phrase of music. Change the molecule; change the melody. The idea works in reverse too: play a tune to the algorithm, and you can see what compound results.

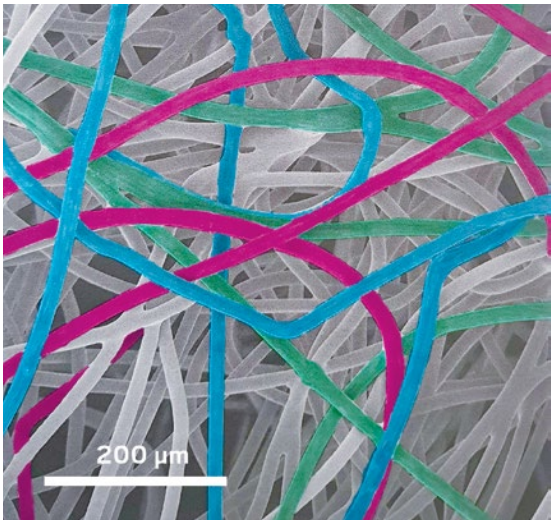
"We went in as chemists," Cernak tells Newscripts, "but it's also exciting as art." Chemists can use musical similarities to recognize harmonies between compounds or combine different motifs into new chemical compositions. Musicians might be able to use chemical riffs to inspire new tunes, he says.

Cernak and his lab have published a description of the project so far as a preprint (ChemRxiv 2022, DOI: 10.26434/chemrxiv-2022-g7xkl). The manuscript is currently undergoing peer review, but curious chemists can already listen to the tunes produced by their favorite molecules. Meanwhile, the lab keeps acquiring more musical instruments. This Newscriptster wonders if one day we'll have concerts alongside scientific meetings.

Micro-mindfulness

When Wageningen University chemist Vittorio Saggiomo started learning scanning electron microscopy (SEM) last year, he was quickly struck by the beauty of the images the method produced. So much so that he started digitally coloring them in. After users on the social network Twitter liked his images, Saggiomo wondered if they could be printed and shared in the form of a coloring book. The last few years have seen an explosion in coloring books for adults to help people relax and unwind. These days you can find coloring books on almost any theme, even science, and Saggiomo has some himself. But most coloring books share a common characteristic—they use black lines to outline the shapes on white paper. SEM images, meanwhile, come out gray scale. Would that work with coloring pencils?

Saggiomo drafted nephews, nieces, and even his mother to test the idea. Reassured by their success, Saggiomo returned from the December holiday break with a mission: find 10 items that could go under the microscope and be turned into images for coloring in. *The Electron Microscopy Coloring Book* is filled with magnified images of objects at different resolutions. Inside the pages, you can color in the details of materials like chalk, seashells, yeast, and the now-familiar respirator masks. The images all "show something you know, but in a way you've never seen them," Saggiomo says.



Artful science: Newscripts got to work coloring in this magnified image of a mask.

CREDIT: LAURA HOWES/C&EN

So is this book a one-off foray into a different sort of scientific publication? Perhaps not, Saggiomo admits to Newscripts. He's already thinking about how other microscopy images might translate to the format of a coloring book.

But for now, pass the pencils!

Laura Howes wrote this week's column. Please send comments and suggestions to newscripts@acs.org.

ACS
Chemistry for Life®
American Chemical Society

NEED TO NEGOTIATE FOR MORE?

Use the ACS Salary Calculator™ to guide the compensation discussion with an employer. Visit ***www.acs.org/negotiate*** to get started.