PEROVSKITE SOLAR CELLS
Mines and NREL researchers developed a perovskite solar cell that retains its efficiency after 1,000 hours of continuous use.

LI WINS RATH AWARD
Presented to the graduate dissertation demonstrating the greatest potential for societal impact.
Colorado School of Mines is a public university focused on science and engineering, dedicated to pioneering research that addresses the great challenges society faces today—particularly as they relate to the Earth, energy and the environment—and committed to educating students who will do the same.
Welcome from Dr. Tom Gennett

Exponential learning

As promised, here is our second newsletter within a year. Over the last six months, I have been on an exponential learning curve since joining the Department of Chemistry at Mines last fall (I know you all know what that is). I can honestly say, while things have been quite busy, I have been having a blast! It was fun when we had to break the candle in half because one candle burning from both ends just doesn’t get it done fast enough. The department has continued its excellence in both teaching and research. We also added another new faculty member starting this fall, Dr. Judith Klein, Associate Professor.

Other news, currently three faculty members are on sabbatical this year: Professor David Wu is at the National Taiwan University in Taipei; Professor Tina Voelker spent time at the Swiss Federal Institute of Aquatic Science and Technology and the Environmental Chemistry group at the Swiss Federal Institute of Technology in Zurich; and Professor Kim Williams has spent time at the Institute for Polymer Research in Dresden, Germany and at Mote Marine Lab and Aquarium in Sarasota, Florida.

This past fall, Xuemin Li, PhD ’17, won the Rath Award for her thesis Development of Advanced Materials for Next Generation of Rechargeable Batteries. The Rath Award is given for the best PhD thesis with the potential for the greatest domestic societal impact.

The National Renewable Energy Laboratory and Mines now have a memorandum of understanding where our undergraduates may conduct their research at NREL. This has greatly expanded opportunities for both pre- and post-baccalaureate degree endeavors of our students. In response to this success, we are currently trying to expand this program to include Los Alamos National Laboratory in New Mexico and Pacific Northwest National Laboratory in Washington.

For this summer, we re-designed Field Session to impart synergy between different segments of the course. Students will synthesize inorganic metal-ligand complexes and nanoparticles, will characterize their properties using computations, will study the environmental toxicity of these complexes and nanoparticles in organisms and will eventually utilize their uptake mechanisms in bacterial systems. We expect the theme to improve the program significantly.

Overall, it has been a great first year. As always, it is you, our alumni and students, whose consistent high-level accomplishments, vocational successes, entrepreneurship and achievement are our department’s greatest legacy.

Go Orediggers!

Dr. Tom Gennett
Department Head
Advancing polymer materials by integrating chemistry and chemical engineering

The polymer-themed NSF-sponsored REU program at Mines offers a unique 10-week interdisciplinary research experience combining polymer science and polymer engineering. These research experiences are designed to drive the plastic and polymer industry toward more sophisticated technology, innovative products and efficient processes by introducing undergraduate students to cutting-edge polymer research and technology. The REU program targets highly qualified chemistry and chemical engineering students with diverse backgrounds from across the country, with a particular emphasis placed on recruiting students from underrepresented groups.

The Polymer REU has run over the past six years and is currently the only REU program at Mines. During this time, 66 undergraduate students from across the country have participated in the program, over 900 applications were submitted. The program participants come from diverse backgrounds and included 58 percent female students, 28 percent of students from underrepresented ethnic groups and 25 percent of students from universities that do not have PhD programs. In addition, because of the research conducted by the REU students during the program, 18 manuscripts have been published or submitted for peer review that include at least one REU student as a co-author. Also, 19 of the students who participated in the REU program presented their research as a poster at a conference. One of the students, Curtis Martin, won an award for best undergraduate poster at the 2013 AIChE Annual Meeting. Another student, Amanda Rightler, was a co-author on a poster that won an award for outstanding poster in the polymer division at a National ACS meeting. Finally, of the students who participated in our REU program and have graduated from their home undergraduate institution, 64 percent have been accepted into PhD programs, 26 percent have gone into industry and 10 percent have been accepted into medical or pharmaceutical schools.

For more information about the Polymer REU program, contact Stephen Boyes at 303-273-3633, sboyes@mines.edu or visit polymerreu.mines.edu/index.html.
Mines and NREL researchers improve perovskite solar cells

Researchers from the Mines Department of Chemistry and the National Renewable Energy Laboratory have developed a perovskite solar cell that retains its efficiency after 1,000 hours of continuous use, with their findings published in *Nature Energy*.

Associate Professor Alan Sellinger, graduate student Tracy Schloemer and former Mines postdoc Jonathan Tinkham are co-authors of the paper, titled “Tailored interfaces of unencapsulated perovskite solar cells for >1,000 hour operational stability.” The project was led by NREL’s Joseph Luther and Joseph Berry and also included Jeffrey Christians, Philip Schulz, Steven Harvey and Bertrand Tremolet de Villers.

Over the past decade, perovskites have rapidly evolved into a promising technology, now with the ability to convert about 23 percent of sunlight into electricity. But work is still needed to make the devices durable enough for long-term use.

According to the researchers, their new cell was able to generate power even after 1,000 straight hours of testing. While more testing is needed to prove the cells could survive for 20 years or more in the field—the typical lifetime of solar panels—the study represented an important benchmark for determining that perovskite solar cells are more stable than previously thought.

A new molecule developed by Sellinger, nicknamed EH44, was used to replace an organic molecule called spiro-OMeTAD that is typically used in perovskite solar cells. Solar cells that use spiro-OMeTAD experience an almost immediate 20 percent drop in efficiency, which continues to steadily decline as it becomes more unstable.

The researchers theorized that replacing the layer of spiro-OMeTAD could stop the initial drop in efficiency in the cell. The lithium ions within the spiro-OMeTAD film move uncontrollably throughout the device and absorb water. The free movement of the ions and the presence of water causes the cells to degrade. EH44 was incorporated as a replacement because it repels water and doesn’t contain lithium.

The use of EH44 as the top layer resolved the later more gradual degradation but did not solve the initial fast decreases that were seen in the cell’s efficiency. The researchers tried another approach, this time swapping the cell’s bottom layer of titanium dioxide (TiO₂) for one with tin oxide (SnO₂). With both EH44 and SnO₂ in place, as well as stable replacements to the perovskite material and metal electrodes, the solar cell efficiency remained steady. The experiment found that the new SnO₂ layer resolved the chemical makeup issues seen in the perovskite layer when deposited onto the original TiO₂ film.

“This study reveals how to make the devices far more stable,” Luther said. “It shows us that each of the layers in the cell can play an important role in degradation, not just the active perovskite layer.”

Funding for the research came from the U.S. Department of Energy Solar Energy Technologies Office.
Shafer elected 2019 ACS NUCL division chair

Assistant Professor Jenifer Shafer will be the chair of the American Chemical Society’s (ACS) Division of Nuclear Chemistry and Technology (NUCL) in 2019. At over 1,000 members, the ACS NUCL division is the premier organization for nuclear and radiochemists. Nuclear and radiochemistry is a broad technical field that encompasses everything from super heavy element synthesis, to radiopharmaceutical development, to Professor Shafer’s specialties in nuclear fuel cycle and forensic chemistry. The NUCL Division supports many endeavors relevant to nuclear and radiochemists, including:

- Organization and sponsorship of NUCL programming at each ACS National Meeting and Exposition, including special symposia, award symposia and poster sessions. On average, each national meeting organizes nearly 150 abstracts into various symposia and poster sessions.

Xuemin Li wins Rath Research Award

I defended my PhD thesis in May 2017 and received my diploma in Aug. 2017 from the Department of Chemistry. My research focused on materials synthesis and surface modification for lithium ion batteries (LIBs), including alkali sulfide (M2S, M = Li and Na) cathodes, ALD coated high-voltage LCO cathode and lithiated silicon (lithium silicide, LixSi) anodes. Lithium ion batteries represent the subject of rapidly increasing research efforts and have been widely used in portable electronic devices in recent years.

In July 2017, I began a postdoctoral researcher position at the National Renewable Energy Laboratory in Golden, Colo., working on commercial lithium ion battery degradation mechanisms focusing on electrochemical and material characterizations. New and advanced electrode materials developed and shown to be promising at the research level have been more frequently applied and scaled up to industrial levels. However, often when the production of commercial batteries is scaled up to have higher energy densities, the failure mechanism is more complicated and requires comprehensive investigating. I use the skills and knowledge base I obtained from my thesis work in Dr. Yongan Yang’s laboratory to contribute to understanding the battery degradation process and improving the life of lithium ion batteries.

From left to right: Yongan Yang, Xuemin Li, Yangzhi Zhao
This past academic year, Professor Trewyn appointed the first Mines Chemistry Department Graduate Student-Invited Seminar Committee, of which I am a member. Our goal: bring inspirational scientific leaders from academia, government and industry to connect with Mines students. This past academic year, we had the privilege to host two excellent chemists: in October, Professor Jillian Buriak, of the University of Alberta; and in February, Sir Fraser Stoddart, a Nobel Laureate currently at Northwestern University.

Professor Buriak broadly conducts research in surface chemistry and nanomaterials synthesis for a myriad of applications such as solar photovoltaics and energy storage. On top of that, she is the editor-in-chief of the ACS Journal Chemistry of Materials. Highlights of her visit included thoughtful feedback to student research presentations, and a question-and-answer session for students about research dissemination from her keen editorial perspective. She led us into the world of publishing: both how it functions currently and her future dreams for increasing scientific accessibility for all researchers. She is passionate about high quality, open-access science and is taking great strides to make science accessible to all.

We also had the pleasure of hosting Sir Stoddart, the most humble Nobel Laureate I could ever imagine spending the day with. Like Professor Buriak, he was adamant about spending his time with students—to get to know them, to hear their research and then to tweet every experience.

Sir Stoddart’s question-and-answer session highlighted each and every life experience that has contributed to where he is today: from growing up on a farm to his undergraduate career to the highs and lows of finding supportive colleagues over his illustrious career. He has made cross-cutting connections among multiple fields to co-create a new field that led to a Nobel Prize, yet is keen to point out that this was only possible with the support of his family and an army of graduate students, post-doctoral researchers and collaborators.

His seminar, for a standing-room only lecture hall, actually had nothing to do with his Nobel Research, but highlighted work that led to a start-up company that is dramatically reducing the negative environmental and health impacts in gold mining.

Sir Fraser Stoddart
Nobel Laureate
Northwestern University

All in all, serving on the seminar committee has been amazing. I was inspired by the candid stories our invitees chose to share about pursuing their careers—their struggles, their highlights and their persistence. They were once in our shoes as students. They worked hard—slowly but steadily—with the support of many along the way. It was crystal clear how genuinely they wanted to give back and how they would not be in the same position without the mentorship and support of many others. We are grateful for the department support of the opportunity to interact with visiting scholars in such a unique setting.

Tracy Schloemer, Class of 2019

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  Alexander Mahmoud
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EVENTS & ACCOMPLISHMENTS

Mines Chemistry: A place for support

As the former president of the ACS student chapter, I’ve had a lot of interface with the department faculty—they’ve been nothing less than amazing. This spring, the department made it possible for me and another student in the ACS chapter to visit the ACS National Conference in New Orleans. I am eternally grateful because that conference is one of the highlights of my college career. I learned so much in such a cool place, and without the department and the student ACS chapter, I would have never been able to do something like that.

The ACS student chapter will always hold a special place in my heart. I have met so many good people in this major (which is a small one), and getting to know Dr. Caster, our chapter advisor, has been a blast. It is just great to have a nerdy group of people to talk about chemistry with. The chapter has also given me significant experience. For example, during our visit to NREL this fall, Department Head Dr. Gennett gave us a private tour around one of the most state-of-the-art government facilities in the country. It was the coolest thing to visit a national lab while meeting the head of our department all in one day. He was very interested in what we had to say about the department and was open to all of our suggestions. It was also clear that he was passionate about improving the department in any way possible.

I am grateful for the Department of Chemistry because its faculty, staff and students have made my time at Mines the best it could possibly be. I can’t imagine being part of any other department.

Dakota Isaak, Class of 2019

Selfie Science: An infrared adventure

The Denver Museum of Nature and Science (DMNS) and CBS4, along with co-sponsor Colorado School of Mines, hosted the fourth annual Girls & Science event at DMNS on March 3. Students and their families meet with women career mentors and experienced the many opportunities a career in science, technology, engineering, art and math can bring.

Students from numerous academic departments and programs at Mines participated in the event. Amy Settle, chemistry PhD student, used infrared cameras to teach the girls about heat transfer in different materials and energy conservation in regard to lightbulb selection.
New chemistry course offerings

Chemical Biology • Assistant Professor Dylan Domaille

Dr. Domaille developed a new course in Fall 2017 that introduced upper-division undergraduate and graduate students to the fundamentals of chemical biology, a field of study dedicated to developing new chemical tools to study biological systems. Using principles from organic and physical organic chemistry, the class looked at how structure imparts the behavior/reactivity of biomolecules. Because chemical biology is fundamentally rooted in chemistry, the class also learned about representative enzymatic mechanisms; ways to synthesize biomolecules in the laboratory; the chemistry behind DNA and protein sequencing; and the chemical differences in subcellular locales and how these distinctive chemical profiles can be exploited to selectively deliver drugs/fluorescent molecules. The final weeks of the semester were dedicated to reviewing some of the most notable achievements in the field by examining the associated primary literature.

Biochemistry Laboratory • Teaching Professor Angela Sower and Assistant Professor Brian Trewyn

During the 2018 Spring Semester, the Chemistry Department launched its first Biochemistry Lab. The overarching goal is to enrich the “Bio” package our department has to offer students. This lab is designed to provide opportunities for students to learn and experience the techniques described in the Biochemistry and Microbiology lecture courses offered at Mines through the Chemistry Department. Labs have been selected and designed with the intention of providing exposure to a broad range of both conventional/traditional and cutting-edge practices. These range from column chromatography to gel electrophoresis to ELISA and real-time PCR. Exposure to techniques and tools encountered within the Biochemistry lab will strengthen our students’ scientific background and proficiency as they advance to their next step in industry or graduate school.

Chemistry and Biochemistry of Pharmaceuticals • Assistant Professor Brian Trewyn

This course covers the synthesis, mechanisms of action, sites of binding, and metabolism of many of the chemical therapeutics used in healthcare today. Relying on the knowledge base and skills picked up in biochemistry and organic chemistry students enrolled in this course participate in discussions of pharmaceutical treatments for many of the diseases that surround us today. Topics covered in this class include opioid pharmacology, cancer drugs, drugs for treating infectious disease, cardiovascular and respiratory medications, performance enhancing drugs, and medications for mental health treatment. Coverage includes new areas of pharmacology including drug delivery, controlled release, and drug-drug interactions.

Introduction to Nanoscience and Nanotechnology • Professor Ryan Richards

The course is intended as an elective for students of all majors at Mines and requires only Chem 1 as a prerequisite. The primary objective of this course is to provide all students a suitable background to understand the role nanotechnology will play in broad range of future technologies and the underpinning principals involved. After a general introduction to the field that involves a discussion of density of states and quantum confinement, we cover the phenomena associated with working on nanoscale with materials of all classes. We will then focus on the synthesis and characterization of various nanoscale materials, including metals, metal oxides, graphene, fullerenes and carbon nanotubes. Aspects of their structure, properties and selected applications (toxicity, drug delivery, bio-detection, electronics, optics) are also covered. A focus of the applications related to energy and particularly renewable energy (solar, biomass, fuel cells, etc.) and energy storage (batteries) round out the semester.
**Investigating algae’s relationship with coral**

Dear Mines Chemistry Community,

After finishing up my PhD at Mines in early 2014, I headed out to Stanford, Calif. to begin my postdoc at the Carnegie Institution. There, I continued research on algae, using robots to do high-throughput functional genomics screens.

In July 2017, I started a faculty position at the University of California at Riverside in the Department of Chemical and Environmental Engineering. I just finished teaching my first class on analytical instrumentation and methods. Looking back, I am extremely grateful to have taken Prof. Patrick MacCarthy’s advanced analytical class at Mines. It not only prepared me for teaching the course material, but also served as a model for how to present these topics in an interesting way.

Since starting my own lab, I have been able to work on several new topics. We recently started a project investigating the algae that form symbiotic relationships with coral. These algae live inside of coral and give them color. When faced with environmental stress, such as warm temperatures, coral have bleaching events where the coral-algal symbiosis breaks-down and the algae are lost from the coral. This can lead to coral death and devastation to coral reef ecosystems. We are investigating this process to learn more about the molecular mechanisms that underpin this symbiotic breakdown and if it is possible to engineer algae that are more resistant to bleaching. And as a perk, when you study coral reefs you get to travel to nice tropical islands, like Guam!

Robert Jinkerson, PhD ’14

**Sharing chemistry in a new corner of the world**

The unofficial Peace Corps motto is: “It’s the toughest job you’ll ever love.” When I stepped onto the plane to begin my Peace Corps service in Aug. 2016, those words echoed in my ears, but I had yet to learn what exactly they meant. I’m now 18 months into my service, saying with certainty that no truer words about Peace Corps have ever been spoken.

I teach 9th and 10th grade chemistry in rural Mozambique at a school with six small classrooms, often crammed with up to 70 students at once. Goats roam in and out of class occasionally and the heat can sometimes be too unbearable to teach in. During rainy season, I am often interrupted by deafening sheets of rain on a tin roof. Some of my students walk up to 10 miles each way to school and some of my students are older than me with children and families of their own. Too many have lost one or both parents to illnesses such as malaria, cholera and HIV/AIDS, and some are illiterate or innumerate. Girls and young women face sharp gender inequalities in the classroom and at home. There is no running water or electricity here either. It’s without question the most difficult challenge I’ve ever faced, but I’ve loved every minute of it.

As an educator myself now, I am deeply grateful for the education I received at Mines. The knowledge and strong chemistry background I gained have been vital in developing my teaching philosophy and helping me become a more effective teacher. I enjoy making difficult subject matter accessible and easily conceptualized and working with limited resources to help my students visualize what they learn (our molecular model kits consist of matches and sticky putty here). I make sure I understand concepts front to back in order to explain them in many different ways, many different times. I’m always finding new ways to keep a classroom of rowdy teenagers engaged in hydrocarbons for an entire hour. And, I do it all in Portuguese (the official language of Mozambique) with a piece of chalk and a chalkboard.

In nine months, my Peace Corps service will come to an end. I am uncertain what is next, but I am certain that moving to Mozambique was the best decision I ever made. I thank Mines for an education that has allowed me to share the joys of science with a new corner of the world, for always challenging me to think bigger, for encouraging me to be a global citizen and for the support before, during and after my walk across the graduation stage.

Leah Froehle, BS ’16
COMMUNITY NEWS

Babies

NEW ADDITION
Dr. Domaille and his wife, Monica, welcomed the arrival of their first child, Florence Jeanne Domaille, in April 2017. Flora has since discovered the joys of gardening, dancing, and scavenging dropped food.

A GROWING FAMILY
Henry Liu welcomed his baby sister Isabella in September 2017. Dr. Yuan Yang and family are enjoying the busy household.

Congratulations, chemistry graduates!

BACHELOR’S GRADUATES
James Everett Baumann
Paige Elise Bowling
Alisha Grace Eskew
Grace Gamba
Jaime Hagen

David Knittel
Armando Lopez, Jr.
Angela Rachel Moser
Juliet Elizabeth Mullen
Maleigh Pagenkopf

Casey Taylor Reeves
Cassidy Rae Steen
Abbi Lynn Zeiger

MASTER’S GRADUATES
Devon William Fish
ME, Nuclear Engineering
Jarrod Gogolski
MS, Nuclear Engineering

Jordan Goss
MS, Chemistry
Luke Williams
MS, Materials Science

Shuo Liu
MS, Chemistry
Tyler Pitcher
Professional Masters, Environmental Geochemistry

PHD GRADUATES
Malcolm Russell Davidson
PhD, Materials Science
Thesis Advisor: Dr. Trewyn

Samuel Harrison Gage
PhD, Applied Chemistry
Thesis Advisors: Dr. Richards, Dr. Pylypenko

Kevin McCann
PhD, Applied Chemistry
Thesis Advisor: Dr. Shafer

Brett McNichols
PhD, Applied Chemistry
Thesis Advisor: Dr. Sellinger

Nicholas Saichek
PhD, Applied Chemistry
Thesis Advisor: Dr. Voorhees

Michael Servis
PhD, Nuclear Engineering
Thesis Advisors: Dr. Shafer, Dr. Wu

Sarah Shulda
PhD, Applied Chemistry
Thesis Advisors: Dr. Pylypenko, Dr. Richards

Derek Strasser
PhD, Applied Chemistry
Thesis Advisor: Dr. Knauss

Mengze Xu
PhD, Applied Chemistry
Thesis Advisor: Dr. Richards
THANK YOU FOR YOUR SUPPORT!

This year’s 24-hour #idigmines Giving Day was a great success raising $224,300 for 31 campus causes in just 24 hours!

Thanks to our generous supporters, the Department of Chemistry sent two undergraduates to join thousands of chemists from around the world at the American Chemical Society National Meeting in New Orleans (read more on p. 9). We are grateful for the opportunity to share this experience with students.

After last year’s campaign, we announced a new initiative inviting industry representatives to campus in hopes of providing our students and faculty with insight into private-sector jobs and employment. Stay tuned for our fall newsletter to read more about this initiative.

To learn more about supporting the Department, contact the Mines Foundation at giving.mines.edu or 303.273.3275.

#idigmines
GIVING DAY