2019 Summer Research Opportunities
For Chemistry Undergraduate Students

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Table of Contents

I. Introduction ......................................................... Page 2
II. How to find a position .......................................... Page 2
III. Working conditions ........................................... Page 2
IV. Funding and typical pay ..................................... Page 2
V. Scholarship Opportunities ..................................... Pages 3 - 5
VI. Faculty Research Interests .................................. Pages 6 - 7
VII. Student Testimonials ......................................... Pages 8
VIII. Research Projects ............................................. Pages 9 - 28
This booklet describes summer research opportunities for undergraduate students in the Department of Chemistry at the University of Calgary during the period of **May to August 2019**.

I. **Summer research projects**

The following pages describe projects that are offered subject to availability of funds by various faculty members, and that are suitable for undergraduate students with the stated qualifications. Normally, these projects are part of ongoing research programs, the results of which, in principle, are publishable in scientific journals. These programs are generally funded by grants from national or provincial agencies or by contracts with government or industry. In some instances, the projects may involve exploring and/or improving undergraduate laboratory experiments, in which case they are funded by the Department. These summer positions offer unique opportunities for undergraduate students to become involved with original research in chemistry thereby providing valuable research experience and assistance in academic or career planning.

II. **How to find a position**

In order to secure a summer research position in the Department, students are urged to enquire early. Examine the descriptions in this booklet, and then speak to faculty members whose research projects you are interested in. Go directly to their offices or phone/email them to arrange a mutually convenient time. During your conversation you will want to become better informed about the project.

As there are no application forms to submit, faculty members may request a résumé and/or an academic transcript.

Not all research opportunities in the Department will be contained in the project descriptions of this booklet. Interested students should also consider speaking with other faculty members in the Department to learn about other possible research opportunities.

III. **Working conditions**

The stipend and the number of hours are, to a certain extent, left up to agreement between the faculty member and the student.

IV. **Funding and typical pay**

Funding for undergraduate summer research is most commonly provided from the individual researcher’s grants or contracts. Additional funds given directly to the student from Federal and Provincial sources are available in the form of summer studentships from the Natural Sciences and Engineering Research Council (**NSERC USRA**), **PURE Awards** from the University of Calgary, and Alberta Innovates Health Solutions (**AIHS**) if the work has medical relevance.

Funding from awards can range from $4,200 to $5,600 depending on the specified work term, usually 12-16 weeks.
V. Scholarship Opportunities

NSERC USRA

To apply for an NSERC USRA, you must complete and submit your application using NSERC’s On-line System. Applications prepared and/or submitted by any other means will not be accepted.

Eligibility
- Are Canadian citizens or permanent residents of Canada;
- Are registered full-time in a bachelor’s degree program in the natural sciences or engineering;*
- Do not hold higher degrees in the natural sciences or engineering (i.e. MSc or PhD);
- Have completed all the course requirements of at least the first year of university study (or two academic terms) of their bachelor’s degrees;
- Have achieved a minimum cumulative B average (3.0) over the entire period of undergraduate studies;
- Have been registered in at least one of the two terms immediately before holding the award*;
- Have not started a program of graduate studies;
- Have not held a previous USRA in the fiscal year (April 1 to March 31), or more than 2 previous USRA awards in total;
- Work on projects in a field of research supported by NSERC and involve R & D;
- Are supervised by faculty members who currently hold an active NSERC research grant.

*For a full list of eligibility criteria and further information, please see the University of Calgary NSERC USRA website https://www.ucalgary.ca/research/students/undergraduate-funding-opportunities/nserc-undergraduate-student-research-award-nserc-usra.

Application Procedure:
1. Login into the system or register as a new user at http://www.nserc-crsg.gc.ca/OnlineServices-ServicesEnLigne/Index_eng.asp
3. Upload a copy of your official transcript with your Part I. The students whose host institution is the University of Calgary are not required to upload a copy of the reverse side grading legend with their UCalgary transcripts. However, for students from other Universities a copy of the reverse side grading legend must be uploaded with their official transcripts.
4. Once Part I of form 202 is complete and your official transcript uploaded, let your supervisor know and he/she must complete Part II. Supervisors need to ensure the Research Subject Code is entered. The supervisor will then submit the form to the USRA Liaison Officer by selecting Submit to LO.

Note: Students or supervisors are no longer required to submit a hard copy of the application to the department.

Application Deadline: January 26, 2019
**PURE Award**

Please apply directly to the Faculty of Science using the online application. Complete instructions and eligibility criteria are on the PURE website at: [http://www.ucalgary.ca/provost/TLFC/awards/undergrad#purpose](http://www.ucalgary.ca/provost/TLFC/awards/undergrad#purpose)

**Eligibility**
- Applicants must be currently enrolled as a full-time, undergraduate student at the University of Calgary. Students who plan to graduate in June, are **NOT** eligible for a PURE Award.
- Have a minimum cumulative GPA of 3.2 in his/her current program

Application Deadline: **February 8, 2019**

**AIHS SUMMER STUDENTSHIPS (Alberta Innovates Health Solutions)**

[http://ucalgary.ca/research/students/aihs-summer-research-studentships](http://ucalgary.ca/research/students/aihs-summer-research-studentships)

**Eligibility**
Those candidates who meet **one of the** following criteria are eligible to apply:
- Registered in an Alberta-based undergraduate degree program in a medical or health-related field;
- Registered in an undergraduate degree program outside of Alberta, and desiring to engage in research during the summer at an Alberta institution;
- Registered in an M.D. program, and who may also hold an undergraduate or graduate degree;
- Exceptional high school students with records of participation in the healthcare system, and a clear interest in pursuing a health research career;
- Currently in the last term of their undergraduate degrees and who have applied either to Medical School or to a graduate program that would start in the coming Fall.

**MARKIN USRP (Undergraduate Student Research Program in Health & Wellness)**

[http://www.ucalgary.ca/usrp/about](http://www.ucalgary.ca/usrp/about)

**Eligibility**
- To be eligible, a student must be enrolled as a full-time undergraduate student at the University of Calgary. **SUMMER** USRP students may **NOT** be enrolled in any courses during the Spring or Summer sessions.
- To be eligible, a Faculty Mentor must hold a full-time academic position at the University of Calgary.
- Students may receive only ONE Markin USRP studentship for each of the two sessions (i.e. Each student may hold a Fall/Winter as well as a Summer studentship once).
- Students with a graduate degree (research) are ineligible for a Markin USRP Studentship, even if they are presently enrolled in an undergraduate program.
- Markin USRP projects must be full research projects, not literature reviews.
- Markin USRP award holders may not simultaneously hold any relevantly similar award, such as the Program for Undergraduate Research Experience (PURE) Awards, NSERC Undergraduate Student Research Awards, O’Brien Centre Awards Alberta Heritage Foundation for Medical Research (AHFMR), etc.
IRIC NEXT GENERATION AWARDS (Institute for Research in Immunology and Cancer)

http://www.iric.ca/en/students/internships/awards

Eligibility
To be eligible for the 2017 IRIC Next Generation Awards, students must:
• Be a Canadian citizen or a permanent resident of Canada;
• Demonstrate a strong interest in cancer research and in pursuing graduate studies in the field of biomedical research;
• Be enrolled full-time and have completed at least one year of an undergraduate program in a field related to life sciences or biomedical research;
• Have maintained a minimum cumulative GPA of 3.0 out of 4.3 (70 %, B, or the equivalent);
• Never have received an IRIC Next Generation Award.

Application Deadline: January 25, 2019; 5:00 pm (Eastern Standard Time)

CLS Undergraduate Summer Students


Calgary Laboratory Services offer a limited number of undergraduate summer studentships on a competitive basis to well-motivated students with records of exceptional academic performance. This is an opportunity to participate directly in medical/health research in Calgary during the summer months (May to August).
## VI. Faculty Research Interests

Below is a list of research faculty members in chemistry. Those with active summer projects for undergraduate students are hyperlinked to the project listing.

For contact info and detailed information on each researcher and their research interests, please go to our Research page at: [http://www.ucalgary.ca/chem/research/research_areas](http://www.ucalgary.ca/chem/research/research_areas).

<table>
<thead>
<tr>
<th>Name</th>
<th>Academic Area</th>
<th>Research Focus</th>
</tr>
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<tbody>
<tr>
<td>J. Adams</td>
<td>STEM Education</td>
<td>Examining the intersection of creativity and STEM in postsecondary science teaching and learning contexts.</td>
</tr>
<tr>
<td>T. G. Back</td>
<td>Organic</td>
<td>Organic synthesis: new methodology and applications to biologically interesting target compounds.</td>
</tr>
<tr>
<td>V. I. Birss</td>
<td>Analytical</td>
<td>Kinetics and mechanisms of chemical reactions on electrode surfaces.</td>
</tr>
<tr>
<td>D. Derksen</td>
<td>Organic/Medicinal</td>
<td>Synthetic organic chemistry that is applied to the preparation of biologically active compounds.</td>
</tr>
<tr>
<td>M. Dolgos</td>
<td>Materials</td>
<td>Solid state and materials chemistry with a focus on the structure-property relationships in electronic materials.</td>
</tr>
<tr>
<td>J. Gailer</td>
<td>Analytical/Environmental</td>
<td>Multi-element specific detection of metalloproteins in biological fluids by LC-ICP-AES.</td>
</tr>
<tr>
<td>B. Heyne</td>
<td>Biophysical</td>
<td>Study of the interaction of organic/inorganic nanomaterials with light for application in bacterial inactivation.</td>
</tr>
<tr>
<td>S. Kimura Hara</td>
<td>Analytical/Environmental</td>
<td>Chemical formation of disinfection byproducts in drinking water and reused waters using mass spectrometry and UV spectrometry.</td>
</tr>
<tr>
<td>P. Kusalik</td>
<td>Theoretical</td>
<td>Molecular simulations of liquids, solids and solutions; studies of structure and dynamics, crystallization and crystal growth.</td>
</tr>
<tr>
<td>C. C. Ling</td>
<td>Organic</td>
<td>Carbohydrate Chemistry: develop methodologies to synthesize carbohydrates and related glycoconjugates for biological and immunological studies; structural modification of cyclodextrins to enhance carbohydrate-protein interactions.</td>
</tr>
<tr>
<td>J. MacCallum</td>
<td>Biophysical</td>
<td>Protein structure and biomolecular recognition using a combination of computational modeling and biophysical experiments.</td>
</tr>
<tr>
<td>R. Marriott</td>
<td>Physical</td>
<td>Applied high-pressure chemistry and industrial sulfur chemistry with a focus on optimizing gas conditioning in the presence of H₂S, bulk fluid separation by ionic liquids, high-pressure water-hydrocarbon solution chemistry (including hydrates) and fundamental properties of elemental sulfur under industrial conditions.</td>
</tr>
<tr>
<td>H. Osthoff</td>
<td>Analytical/Environmental</td>
<td>Atmospheric chemistry, cavity ring-down spectroscopy, mass spectrometry, kinetics of gas-phase reactions, field measurements, nitrogen oxides and halogens in the atmosphere.</td>
</tr>
<tr>
<td>Name</td>
<td>Field</td>
<td>Research Area</td>
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<tr>
<td>W. E. Piers</td>
<td>Inorganic</td>
<td>Electrophilic organometallic compounds: synthesis, reactivity and applications.</td>
</tr>
<tr>
<td>R. Roesler</td>
<td>Inorganic</td>
<td>Investigating the compounds involving bonds between the elements of the groups 13, 14 and 15, as well as combinations of these elements with transition metals</td>
</tr>
<tr>
<td>D. Salahub</td>
<td>Theoretical</td>
<td>Multiscale modeling of complex systems using quantum mechanical, molecular mechanical and other methodologies with applications in systems biology and catalytic reaction networks.</td>
</tr>
<tr>
<td>D. Schriemer</td>
<td>Analytical</td>
<td>Chemical biology with an emphasis on the development of novel methods and instrumentation in protein bioanalysis.</td>
</tr>
<tr>
<td>Y. Shi</td>
<td>Physical</td>
<td>Investigation of the structures, energetics and dynamics of radicals and intermediates formed in the processes of Hot Wire Chemical Vapor Deposition (HW-CVD) of semiconductor thin films</td>
</tr>
<tr>
<td>G. Shimizu</td>
<td>Inorganic/Materials</td>
<td>Self-assembly of metal-organic microporous solids and studies of their ability to store/separate gases for CO₂ capture and natural gas storage.</td>
</tr>
<tr>
<td>S. Siahrostami</td>
<td>Physical/Theoretical</td>
<td>Designing and discovering novel catalysts for renewable energy technologies such as fuel cell, battery and electrolyzer, using theoretical simulation tools.</td>
</tr>
<tr>
<td>T. Sutherland</td>
<td>Organic/Physical</td>
<td>Supramolecular chemistry of photo- and redox- active assemblies at interfaces.</td>
</tr>
<tr>
<td>V. Thangadurai</td>
<td>Physical</td>
<td>Developments of novel solid electrolytes and electrodes for applications to fuel cells, sensors and batteries.</td>
</tr>
<tr>
<td>K. Thurbide</td>
<td>Analytical</td>
<td>Aspects of separation, detection and supercritical fluid applications in analytical chemistry.</td>
</tr>
<tr>
<td>S. Trudel</td>
<td>Materials/Nanoscience</td>
<td>Synthesis and physical characterization of nanostructures. A strong emphasis is put on magnetic nanostructures incorporating other useful and functional properties.</td>
</tr>
</tbody>
</table>
VII. Student Testimonials

My experience this summer was a great opportunity to learn more about what science research entails. I learned so much about creating procedures, doing research and running our own experiments. It was a great summer filled with learning and fun memories. *Hallie*

Research is a wonderful opportunity that I think more undergraduate students should experience. Within the lab you get to apply the skills from your classes as well as explore new skills and new knowledge. Doing research provides you with new experiences that you can’t find in your classes. *Shauna*

I participated in a CHEM 502 research project during summer 2018. This program was a great way to experience working in an academic research lab. I was paired with three great grad students and this way I could do my own research, while having guidance all along the way. I would highly recommend to every student that they should participate in a CHEM 502/402 project as it’s a great introduction into academic research. *Mark*

Doing undergraduate research in chemistry was one of the best decisions I made during my degree. I got the opportunity to do research that I was interested in and got real life experience working in a lab. I also got to meet a lot of new people and network with other researchers. *Marcus*

Doing a summer research project is an amazing opportunity. It's so much fun to see the real-world applications of what you learn about in the classroom, and to focus on a single experiment over a longer period than is possible during labs. Through the experience I learnt many lab and problem-solving skills that will be beneficial in the future. *Valerie*

I was in Dr. Derksen’s lab and I think the most valuable experience I got was learning how to collaborate in a team. I learned that in science, working in an individual manner is very foolish because everyone studies extensively into one of millions of topics. I realized the importance of finding a group dynamic that is similar to your own. *Wincy*

I spent this summer working with several post doctoral fellows under the supervision of Dr. Birss optimizing covalent bonding to novel nano-structured carbon surfaces for the electroreduction of CO\textsubscript{2} to synthetic fuel. Throughout this project I spent hundreds of hours in the lab, I was exposed to new cutting edge techniques, my first of many literature reviews and was able to practice and perfect many skills touched on in undergraduate classes. This experience has given me an even greater passion for science and enhanced my career focus, I have noticed a massive increase in my abilities and have a much more detailed and breadth of understanding of chemistry because of it. *Ben*
VIII. Research Projects

Dr. Thomas Back

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Phone: 403-220-6256
E-mail: tgbck@ucalgary.ca

Project Title:

ORGANIC SYNTHESIS DIRECTED TOWARD BIOLOGICALLY INTERESTING TARGET COMPOUNDS

Our research is directed towards the development of novel synthetic methodology, especially enantioselective processes, that can be employed in the synthesis of products that display medicinal or other useful biological activity. Examples of some target molecules that are of current interest are shown below. Thus, pumiliotoxin C is an alkaloid found in the toxic skin secretions of neotropical frogs that are used as an arrow poison by indigenous tribes. It, and related compounds, have potential medicinal properties and uses as biochemical tools because e.g. they possess cardiotonic activity, and act as blockers of the nicotinic acetylcholine receptor channel. Virantmycin is another alkaloid that has powerful antiviral activity. Bakkenolide A is a structurally unusual naturally-occurring spiro lactone that exhibits strong insect antifeedant properties against several species of insect pests. We also have long-standing interests in both natural and “designer” steroids. For example, finasteride is a drug that blocks the enzyme 5α-reductase, which has been implicated in benign prostatic hypertrophy. However, a second generation of analogues is needed for improved therapeutic performance and for extension to the treatment of prostatic cancers. Antibiotic A25822 B is a powerful antifungal agent, while brassinolide is a plant hormone that stimulates the growth of diverse species of commercially important plants at remarkably low concentrations.

Number of Students: 1 or 2 (subject to availability of funds)

Prerequisites:
Chem 355 or the equivalent is essential; Chem 453 is highly desirable. Students should be enrolled in a Chemistry Honours or Majors program and have attained a high GPA. Eligibility for NSERC or other Summer Studentships is a definite asset.
Project Title:

**ELECTROCHEMISTRY FOR FUEL CELL APPLICATIONS**

Several research projects are likely to be available this coming summer. These will involve the synthesis and evaluation of novel catalysts, deposited on a conducting substrate, for the oxidation of hydrogen, methanol or ethanol fuels, or for the reduction of oxygen, targeted for a variety of fuel cell applications.

For low temperature fuel cell purposes, the catalysts will consist of noble metal nanoparticles or what are known as core-shell nanoparticles, in which a thin (one atomic layer) catalytic shell surrounds a lower cost, spherical, core. Novel nano-porous carbon catalyst support materials will also be synthesized, characterized, and evaluated for their ability to disperse the metal nano-catalysts and to remain stable for long periods of time.

In our high temperature fuel cell work, we are developing catalytic materials that can operate both in the spontaneous fuel cell mode and in the reverse electrolysis direction, thus serving to store electricity generated renewably (solar, wind), while also reducing water and carbon dioxide to form useful fuels. The summer project will involve preparation of the catalyst layers, gathering electrochemical data (in both the fuel cell and electrolysis modes), and interpreting the results to provide important kinetic and mechanistic information.

**Number of Students:** Between 1 and 3

**Prerequisites:**
Chemistry 311/315. Experience with instrumentation would be an asset.
Project Title:

Synthesis and Characterization of Novel Lead-Free Piezoelectric Materials

The research interests in the Dolgos Group focus the synthesis and characterization of new, improved materials for both clean energy applications and for electronic materials such as piezoelectrics, dielectrics, and ionic conductors. The development of new advanced functional materials with both high performance and a low energy impact is one of the most important challenges in the scientific community today as the current energy economy, based on fossil fuels is at serious risk.

Piezoelectric materials convert mechanical to electrical energy and vice versa. They find practical applications in sensors (e.g., ultrasonic transducers, engine knock sensors, accelerometers, pressure sensors) and actuators (e.g., energy harvesting, micro-motors, microfluidics). Pb(Zr,Ti)O$_3$ (PZT), the industry standard piezoelectric material, shows outstanding properties such as a high piezoelectric response and good electromechanical coupling factor. Also, engineers can dope it to meet the requirements for many applications. However, PZT has several major performance disadvantages. For example, its inability to operate above ~150°C restricts its use in high-temperature automotive and aerospace applications. It also suffers from instability due to fatigue and incurs small strains, which inhibit its use in actuators. In addition, future legislation may restrict the use of PZT due to the toxicity of lead. New piezoelectric materials are clearly necessary, but no appropriate substitute currently exists.

This project involves synthesis, structural characterization, and physical properties measurements of novel lead-free piezoelectric materials. You will learn solid state synthesis techniques, ceramics processing, X-ray diffraction, and electromechanical properties measurements.

Robotic application of piezoelectrics

Perovskite structure found in most common piezoelectrics

Number of students: 1

Prerequisites: Motivation and a desire to create knowledge. Preference for those with external funding, but it isn’t necessary.
Probing the effect of selenite on the metabolism of Cd$^{2+}$ in red blood cells

The carcinogen Cd$^{2+}$ is of increasing public health concern as it may be involved in the etiology of other human diseases [1]. After its absorption from the gastrointestinal tract, the bloodstream represents one of the first sites where adverse biochemical reactions may occur. We have recently investigated the fate of Cd$^{2+}$ in red blood cell (RBC) cytosol, which revealed that this metal ion interacts with glutathione (GSH) and hemoglobin (Hb)[2]. Since selenite is absorbed by RBCs by the HCO$_3^-$ transporter and has been demonstrated to reduce the toxicity of Cd$^{2+}$ in mammals [3], we will investigate if this metalloid species interacts with Cd$^{2+}$ in RBC lysate. After preparing a RBC lysate which contains Cd$^{2+}$, we will analyze aliquots by size-exclusion chromatography (SEC) coupled on-line to a flame atomic absorption spectrometer (FAAS) which serves as a Cd-specific detector. After adding a physiologically relevant dose of selenite to the Cd$^{2+}$-containing RBC lysate, the latter will be analyzed by SEC-FAAS in 30 min intervals over a 2 h period. The obtained Cd-specific chromatograms will allow to infer if a Cd-Se species is formed in the RBC lysate. Repeating these experiments with selenate will serve as a negative control experiment. These investigations are intended to shed new light on the biomolecular mechanisms which protect humans from the adverse health effects of Cd$^{2+}$.

References

Number of Students: 1

Prerequisites:
CHEM 311, CHEM 315; it would be an asset if a student has also taken CHEM 321, CHEM 515 and/or CHEM 541.
Project Title:

UNDERSTANDING MOLECULAR SELF-ORGANIZATION USING LIGHT AS A PROBE

Self-organization of small molecules, such as lipids, or proteins plays a key role in the origin of life. However, research in self-organization is not limited to biology and it certainly generates great interest in different scientific fields. Nowadays, chemists are able to achieve, through assembly of molecules, complex systems with widespread applications from medicine to material. While research in molecular organization has undergone a number of rebirths throughout history, mechanisms responsible for the assembly of molecules remain unclear.

Through the use of photophysical and photochemical techniques, such as fluorescence spectroscopy, our research goal is to investigate how external stimuli influence molecular organization. Under this umbrella, we have two different projects. In the first project, we investigate the role played by ions on the organization of small organic molecules, such as cyanine dye, in water. Although, addition of salts to an aqueous solution is known to induce the dye aggregation, such as brine used to crash out organic compounds during synthetic purification. Our group recently proved that not all the salts are identical with regards to molecular organization and size truly matters. Our goal is to elucidate the rules of aggregation in order to predict the behavior of molecules going from solution to material applications.

Our second project exploit plamonic fields generated by metallic nanoparticles to amplify photochemical pathways, such as singlet oxygen production and emission. Singlet oxygen is the lowest excited state of molecular oxygen, which is highly reactive towards biological molecules. Our goal is to engineer novel nanomaterial with unique plasmonic properties to be applied to the field of bacterial inactivation.

Number of Students: 1 or 2 (subject to availability and funds)

Prerequisites:
Chem 355. Physical Chemistry courses are an asset. Students should be enrolled in the Chemistry Honors or Majors program and eligibility for NSERC or PURE scholarships is an advantage.
Project Title:

METAL COMPLEXES OF SMALL MOLECULES WITH BIOLOGICAL INTEREST

Metal ions are vital for our health. Some have important functions in enzymes (e.g., Zn, Cu, Mo), while others are involved in the charge transport process (e.g., K, Na). Some have multiple roles, like Fe that is responsible for oxygen transport and electron transfer. Some metal compounds have medical applications, like cis-platin, \([\text{Pt(NH}_3\text{)}_2\text{Cl}_2]\) used as anti-cancer drug.

For a few anti-cancer drugs, earlier studies have shown that their activity is enhanced when they are bonded to a transition metal ion, i.e., their metal complexes show enhanced anti-cancer activity. In this project, we will investigate the structure of these metal complexes in solid and solution state.

During this project, the student will synthesize these complexes and learn how to characterize them using different techniques, such as elemental analysis, thermal gravimetric analysis, vibrational spectroscopy (Raman and IR), and X-ray absorption spectroscopy (XAS). The student will have the opportunity to learn about the XAS technique, and related computer programs for extracting information about how the chemical bonds to the metal ions (such as metal-ligand bond distances) in these complexes can explain their properties.

Number of Students: 1

Prerequisites:
Students should have completed the major undergraduate chemistry courses, specifically CHEM 311/315 (analytical), 331/333 (inorganic), 371/373 (physical). Minimum GPA of 3.4 is required.
Project Title:

FORMATION OF TOXIC AND UNREGULATED DISINFECTION BY-PRODUCTS IN DRINKING WATER AND REUSED WATERS

Water disinfection, one of the most important human health developments of the 20th century, is used in water treatment to protect against waterborne diseases such as cholera and typhoid. However, chemical (e.g., chlorine, chloramines) and ultraviolet light disinfection processes react with natural organic matter, present in rivers and lakes, to unintentionally form disinfection by-products (DBPs) that may cause adverse health effects by long-term exposure.

Population growth, climate change, and increasing water demands by economic activities are jeopardizing the quality of water supplies leading to the use of waters with higher anthropogenic inputs in developed and undeveloped countries. The ability to continue to provide safe water under this constant change becomes challenging, because of the increased complexity of source waters and the multiple reactions and compounds that are produced from disinfection. Our research group investigates the formation mechanisms of unregulated DBPs from disinfected wastewater effluents and evaluates the removal of DBP precursors by current and new treatment technologies in a full-scale water treatment facility. We also develop and use various analytical methods that separate, identify, and quantify trace compounds in water using mass spectrometry techniques (e.g., gas chromatography mass spectrometry).

An undergraduate student will closely work with a graduate student and the PI and investigate the chemical formation of nitrogen-containing DBPs (i.e. haloacetamides, haloacetonitriles, and halonitromethanes) from disinfected wastewater effluents. The student will help develop analytical methods, conduct controlled laboratory reactions, characterize DBP speciation and sample a full-scale water treatment plant.

Number of Students: 1

Prerequisites:
Chemistry 311/315 (analytical chemistry), CHEM 515 is desirable. We are looking for highly motivated students to learn about drinking water treatment and water chemistry. Higher GPA are favored.
Our group utilizes molecular simulations to explore systems and processes within liquids, solids and their interfaces at the microscopic level. These approaches rely upon very powerful computers and state-of-the-art visualization techniques to probe molecular behaviour that would otherwise be very difficult to study experimentally. Two possible project areas are given below.

**Project Title:**

**BEHAVIOUR OF OH* RADICAL: STUDY OF REACTIONS CRUCIAL TO ATMOSPHERIC CHEMISTRY**

The hydroxyl radical (OH*) is a highly reactive and very important chemical species across a wide range of systems and contexts, from atmospheric chemistry to oxidative damage in cells. Making extensive use of *ab initio* molecular dynamics simulations and enhanced sampling approaches (e.g. metadynamics), the nature and behaviour of the OH radical in different local environments will be investigated, with a particular focus on the surfaces of ice and of water. The mobility (through H atom transfer) and reactivity with molecules important in atmospheric chemistry (e.g. NO₂) will be primary focuses of this project. The project will involve setting up and running sets simulations, which will be carried out on large computer clusters, construction of reaction free energy profiles, and analyses of key structural and electronic features. Visualization of molecular configurations during reactions will also be an important component.

**Project Title:**

**NUCLEATION OF MIXED GAS HYDRATE**

Natural gas hydrates are crystalline solids formed from natural gas (methane) and water. They consist of gas molecules trapped inside water cages and are most commonly encountered in deep water sediments, permafrost, and as agglomerates in gas pipelines. In the latter context, gas hydrate formation is a significant industrial concern, at total annual costs of many millions of dollars. Hence there is considerable interest in understanding the factors that might promote gas hydrate formation within pipelines. This project will utilize molecular dynamics (MD) simulations and novel approaches developed in the Kusalik group (e.g. isoconfigurational ensembles) to probe the importance of local environments and surfaces (for example, a water bubble in a hydrocarbon liquid) on the nucleation behaviour a gas hydrate crystal. The molecular dynamics simulations that are part of this project will utilize standard potential models and will be performed on large computer clusters. Visualization of molecular configurations, analysis on factors impacting hydrate cage formation, evaluation of important structures, and examination of the behaviour of different gas species will be key aspects of this work aimed at determining the roles of these various factors.

Students wishing further details on either of these projects are encouraged to contact Dr. Kusalik (pkusalik@ucalgary.ca).

**Number of students:** 1 (subject to availability of funds).

**Prerequisites:** A willingness to learn and a strong academic record. Eligibility for summer awards (e.g. NSERC or PURE) is a definite asset.
Carbohydrates are well known for their role as the energy source of all living organisms. They are commonly classified as simple monosaccharides (such as D-glucose, D-mannose), oligosaccharides (such as sucrose, lactose), polysaccharides (such as starch, cellulose). In nature, the majority of carbohydrates exist in various glycoconjugate forms such as glycolipids, glycoproteins and proteoglycans. Because they are largely found on the surface of all living cells, they play a crucial role in mediating all cellular communications and signal transduction. Bacteria / viruses take advantage of complex carbohydrates expressed on the host cell surface to initiate infection by synthesizing protein receptors that recognize specific carbohydrate sequences, and in the meantime, they come up with different strategies to evade host immune response. For example, bacteria produce complex polysaccharides such as lipopolysaccharides, capsular polysaccharides, techoic acids to coat themselves in order to avoid an immunological attack. The Ling group is interested in developing and applying modern synthetic organic chemistry to studying the molecular mechanisms involved in various important carbohydrate–protein interactions that affect human health and disease.

In this coming summer, several research projects are likely to be available. One of these involves the development of synthetic methodologies to obtain several oligosaccharide epitopes for immunological studies to raise carbohydrate-specific antibodies against *Campylobacter jejuni*. Another involves the development of water-soluble nylons as novel multivalent scaffolds to enhance carbohydrate-protein interactions. The third project will be focused on the chemistry of a special class of cyclic carbohydrates – the cyclodextrins; the student is expected to improve methodology that we have recently developed on cyclodextrin multi-substitutions – such intermediates could have wide-spread utilities in designing inhibitors to block bacterial colonization and removing pathogenic autoantibodies and toxins.

**Number of Students:** Between 1 and 3

**Prerequisites:**
Chemistry 351/353. Preference will be given to students with a higher GPA.
Elemental sulfur is recovered from fuels and other hydrocarbons to reduce the environmental impact of SO$_2$ release. After the recovery of elemental sulfur, liquid sulfur must pumped from liquid sulfur pits/tanks to solid forming facilities or liquid transportation vessels. Failure of sulfur pumps is quite common because liquid viscosity changes with temperature and high-shear rates lead to high-friction issues. Note that the viscosity of liquid sulfur increases substantially through the liquid sulfur lambda transition at $T = 160^\circ$C. This transition corresponds to the increase in polymer radical species within the elemental sulfur, which can, in part, be mitigated by the presence of H$_2$S or degassing amine additives. Amine mitigation of sulfur radicals in liquid sulfur to change viscosity has not been well studied; however, there is a great deal of anecdotal evidence that the effect is large and amine scavenging of radical species is expected. The change in viscosity for liquid sulfur due to H$_2$S solubility was studied by Fanelli [1946] and Rubero [1964]; however, these authors did not address the shear dependence of the viscosity (rheometry). Rheometric measurements for pure liquid sulfur have likely been completed but remain proprietary information for sulfur pump manufactures; whereas, several other potential processes could be designed if the shear properties were known for liquid sulfur with and without amine.

In this project, the shear dependence for the viscosity of pure elemental sulfur and sulfur with trace amine will be studied from the melting point (115°C) to 200°C using a cone and plate rheometer. In characterizing the fluids, the student also may be exposed to IR, Raman, HPLC and GC techniques. Pending instrument delivery, there may be the opportunity to aid in the assembly and commissioning of a new custom rheometer, aimed at liquids under high-pressure sour gas fluids (fluids containing H$_2$S and CO$_2$).

**Project Title:**

THE STABILITY OF SURFACTANTS UNDER HIGH-PRESSURE CONDITIONS

HP fracturing of shale gas reservoirs with aqueous fluids is required to increase overall production of hydrocarbon and decrease recovery time. Two primary methods are gel fracturing and slick water fracturing. In both cases, the goal is to get the aqueous fluid to carry a propant (e.g., sand) into the reservoir and hold open new reservoir fractures for gas flow back to the wellbore. This is achieved by modifying the rheometric properties of the fluid (gels) and/or the interfacial surface tension between the water and formation (slick water). Among the various additives to fracture fluids, surfactants are used as gelling agents, biocides, gel breakers and to reduce interfacial surface tension. Some speculate that even simple surfactants can degrade over time and potentially produce unwanted chemicals which can be carried back to the surface.

This project will involve studying the degradation products of some simple surfactant additives under high-pressure and temperature. Methods will include high-pressure autoclave vessels and variety of possible analytical equipment (GC/MS, GC/PFPD, GC/SCD, Ion Chromatography, and in situ Raman Spectroscopy). The primary goal will be to identify all degradation products for further detailed studies. The student will gain experience with high pressure equipment and H$_2$S chemistry.

**Number of students:** 1 or 2

**Prerequisites:** Motivated students with interest in applied industrial chemistry and/or physical chemistry are required. Background and/or interest in construction, mechanics or electronics would be an asset.
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Our group studies the atmospheric chemistry of trace gases that negatively impact regional air quality, i.e., lead to an increase in O\textsubscript{3} and/or particle number densities in the troposphere. To enable such studies at ambient concentration levels, we are relying on ultrasensitive analytical techniques, many of which developed in house.

A couple of projects will be available to undergraduate students in the summer of 2019.

**Project Title:**

**MEASUREMENTS OF HENRY'S LAW CONSTANTS OF ALKYL NITRATES**

The Henry's law constants (H) govern the partitioning of molecules between the gas and aqueous phases (1). H constants have been determined for simple alkyl nitrates (AN) (2), alkyl dinitrates (2-3), and C\textsubscript{2}-C\textsubscript{5} hydroxyalkyl nitrates (2, 4) but not for AN derived from biogenic precursors, even though their study has become feasible through the development of synthetic routes, e.g., for isoprene (4c, 5) and terpene nitrates (6). Recent field measurements (7) have demonstrated that these molecules constitute a significant fraction of atmospheric AN, warranting their study.

In this project, the student will synthesize one or more molecules for which H constants are known at room temperature (e.g., 5-nitrooxy-2-pentanol (4c)) to validate methods and determine the temperature dependence of the H constants. In a typical experiment, the AN of interest is dissolved in water to a known concentration. A gas stream of ultrapure air is equilibrated with a temperature-controlled solution by passing the air through a microporous PTFE membrane tube (e.g., (4c)), and its AN content is quantified by thermal dissociation cavity ring-down spectroscopy (8). The student will synthesize selected isoprene (4c, 5), and terpene nitrates by nitration of commercially available epoxides (6) and determine their H constants and hydrolysis rate constants (if hydrolysis is observed) and compare the results with estimates from a bond contribution model (9).


**Number of students:** 1

**Prerequisites:** Chem 315 or equivalent. Any of the following would be useful but are not essential: Chem 321, Chem 423, Chem 471, Chem 515, Chem 521, and experience in electronics, laser optics, and computer programming (e.g., Labview or Igor). Interested students are strongly encouraged to apply for NSERC USRA or PURE funding.
Project Title:

MEASUREMENTS OF ORGANIC NITRATES

Alkyl nitrates (molecular formula $\text{RONO}_2$) and peroxycarboxylic nitric anhydrides (PANs, molecular formula $\text{RC(O)O}_2\text{NO}_2$) are interesting trace gas constituents of the troposphere. They are formed as side products during the reactions of organic peroxy radicals with $\text{NO}_x$, the same reaction that are responsible for $\text{O}_3$ production in the troposphere. Organic nitrate mixing ratios are hence markers of the VOCs involved in the $\text{O}_3$ production process.

In this project, the student will use a HP 5890-II gas chromatograph equipped with a flame-ionization and an electron capture detector and an automated Tenax preconcentration trap to quantify alkyl nitrates in a similar manner as described by Ostling et al. (J. Geophys. Res. 106(D20), 24439-24449, 2001). The student will synthesize alkyl nitrate standards following the procedure described by Kames et al. (J. Atmos. Chem. 16(4), 349-359, 1993) and calibrate the GC using thermal dissociation cavity ring-down spectroscopy (Rev. Sci. Instrum. 80, 114101, 2009; Anal. Chem. 82(15), 6695-6703, 2010). Of particular interest are measurements of the mixing ratios of i- and n-propyl and i- and n-butyl nitrate, and pentyl nitrates as there have been reports of unusual ratios in air masses originating from boreal forests associated with biomass burning. A key component of this project will be to measure alkyl nitrates and PANs (using the group’s PAN-GC, see picture) in the Calgary atmosphere during biomass burning (i.e., forest fire) episodes.

Number of students: 1

Prerequisites: Chem 315 or equivalent. Good analytical skills will be essential for this position. Any of the following would be useful but are not essential: Chem 321, Chem 423, Chem 471, Chem 515, Chem 521, and experience in electronics, laser optics, and computer programming (e.g., Labview or Igor). Interested students are strongly encouraged to apply for NSERC USRA or PURE funding.

For more details on the above projects please contact Dr. Osthoff via email (hostoff@ucalgary.ca) or drop by the office or laboratory (SB 204/205).

Financial support: Interested students are strongly encouraged to visit the NSERC USRA web site (http://www.nserc-crsng.gc.ca/students-etudiants/ug-pc/usra-brpc_eng.asp) and the University’s PURE web site (http://www.ucalgary.ca/provost/TLFC/awards/undergrad) to apply for financial support or top-up awards.
Project Title:
WATER SOLUBLE CARBENE COMPLEXES FOR AQUEOUS CATALYSIS AND NOBLE METAL PHARMACEUTICALS

N-heterocyclic carbenes (NHCs) are a class of highly successful carbon-based ligands with numerous applications in coordination chemistry and catalysis. The outstanding ligating ability of carbenes is due mainly to their $\sigma$-donor ability (Lewis basicity) and hence free NHCs are generally unstable in an aqueous environment, where they spontaneously abstract a proton from water and convert into azolium ions. Although the vast majority of NHC transition metal complexes are insoluble in water, many of them are water stable and indeed selected examples of water soluble carbene complexes have been reported.\(^1\)

The first project will involve the development of water soluble gold and platinum complexes featuring NHC ligands such as those depicted below. Complexes of these metals are well-known for their pharmaceutical applications based on their citostatic or bactericidal action; however, NHC complexes have not yet been investigated in this respect. Several articles reporting on the bactericidal action of water soluble silver NHC complexes have been published.\(^1\)

The second project will investigate the catalytic ability of water soluble NHC complexes with selected transition metals in water or at the interface between water and organic solvents, aiming at diminishing the use of organic solvents in industrial applications. Several articles describing the use of palladium and ruthenium complexes for cross-coupling reactions and olefin metathesis, respectively, have been published; however, the investigations have been so far limited to these systems.\(^1\)

Both projects will involve the synthesis of novel NHC precursors (imidazolium ions) using the extensive experience with such systems available in the group and the methodology specific to inorganic and organometallic chemistry. The transition metal complexes will be synthesized by direct methods, circumventing the isolation of the free carbenes, and their properties will be investigated.


Number of Students: 2

Prerequisites:
Chemistry 331/333 and enthusiasm.
Project Title:

MULTISCALE MODELING IN BIOLOGY OR IN IN-SITU CATALYSIS

Many of today's most interesting and challenging research projects cross the traditional barriers between the disciplines. My group is associated with two interdisciplinary institutes, the IBI (Institute for Biocomplexity and Informatics) and ISEEE (Institute for Sustainable Energy, Environment and Economy).

Within the IBI we are trying to understand transcription and the enzymatic chemistry of RNA Polymerase, on the one hand, and to understand and predict electron transfer rates in the respiratory chain, on the other.

Within ISEEE we want to develop computer models that will describe the catalytic hydrotreatment of the oil sands in an in-situ environment.

All of these projects require the development and application of computer codes that embody multi-level features, spanning several orders of magnitude in space and in time. A typical problem involves the quantum chemical treatment of a chemical reaction, with an adequate treatment of the surrounding environment.

The student will have the opportunity to learn quantum chemistry (Density Functional Theory) and/or molecular mechanics and molecular dynamics and/or stochastic methods of modeling reaction networks, all within the context of front-line applications, be they the secrets of life or the route to a sustainable energy supply.

Number of Students: 1 or 2 (subject to availability of funds)

Prerequisites:
An inquiring mind and good grades. Eligibility for NSERC or other Summer Studentships is a definite asset.
EFFECT OF FILAMENT MATERIAL IN THE GAS-PHASE REACTION CHEMISTRY WITH SILACYLOBUTANE MOLECULES IN A HOT-WIRE CHEMICAL VAPOR DEPOSITION PROCESS

Hot-wire chemical vapor deposition (HWCVD) uses a heated metal filament (typically made of W and Ta) to initiate the catalytic decomposition of source gases, therefore, the metal filament plays a key role in the process of HWCVD. The W and Ta metal filaments typically used in HWCVD tend to age after long-time exposure to the source gas. This shortens the filament lifetime. Recently, a lot of effort has been made in finding new filament materials. Caburized W and Ta filaments have been shown to have longer lifetime than their pure forms. However, whether these carbides show the same catalytic behavior as the pure metal is not clear. In this project, the effect of new filament material (metal carbides) on the gas-phase reaction chemistry of cyclic silacyclobutane molecules will be investigated. Tungsten carbides will be formed by heating the pure W filaments up in the presence of 1,1,3,3-tetramethyl-1,3-disilacyclobutane [1] and tantalum carbides are from a commercial supplier. The reaction chemistry of 1-silacyclobutane and 1,1-dimethyl-1-silacyclobutane will be examined by identifying products formed in the direct hot wire decomposition and in the secondary gas-phase reactions using the diagnostic tool of SPI-TOF mass spectrometry. Comparison with our previous results using the pure W and Ta filaments [2,3] will reveal whether the longer-lived tungsten and tantalum carbides maintain or improve the reactivity of source gases.


Number of Students: 1
Prerequisites: Chem 371, 373, and motivation
Project Title:

METAL-ORGANIC FRAMEWORKS FOR GAS CAPTURE AND STORAGE

Metal organic frameworks (MOFs) are a relatively new class of porous compounds. They can be considered as replacing the $\text{O}^2-$ ion in a metal oxide with an organic linker to expand the network and generate pores. We are interested in making derivatives of these materials where different chemical functionalities line the pores to interact with CO2 for carbon capture applications. We have had very good success in making such derivatives, characterizing them in the solid state, and measuring the gas uptake properties. CO2 capture from flue gas is the ultimate target but there are stepping stone targets on the way. Ultimately, we wish to understand how to design the best CO2 capture materials from a molecular perspective. The picture below shows two molecules of carbon dioxide trapped inside one of our porous MOFs. A summer project would involve making the linker for the MOF (a bit of organic chemistry possibly) and then growing crystals of the MOF (hydrothermal synthesis, diffusion methods). Structural characterization of the networks is by X-ray diffraction, thermal analysis, and gas sorption analysis. These techniques are performed along with a senior PhD student or postdoc.

![Figure. New MOF materials for CO2 capture. The left shows the location of two CO2 molecules, oriented in a T-shape that maximizes the quadrupole interaction. The right shows several CO2 molecules in the pores of a MOF network.](image)

**Number of students:** up to 2

**Prerequisites:** Chem 331, 333, 351 and either 371 or 373
Project Title:

ORGANIC n- AND p-TYPE MATERIALS FOR PHOTOVOLTAIC APPLICATIONS

The goal of our research group is to synthesize electron poor acceptor (n-type) and electron rich donor (p-type) compounds to be utilized in photovoltaic applications, such as solar cells.

Currently, there are relatively few compounds that can function as electron acceptor (n-type) materials in organic photovoltaic cells. Therefore, their development is an exciting and important area of research. A molecule can be considered a good electron acceptor if it has a low LUMO energy level. This can be achieved by incorporating electron withdrawing functional groups into fused aromatic cores. An illustrative example is shown in Figure 1 with the pyrene and phenanthrene thiadiazole dioxide molecules, which have been shown to have good n-type character. Our research in this area involves functionalization of these and other fused aromatic cores in two ways: 1) Creation of other kinds of electron withdrawing heterocycles to afford new n-type molecules, and 2) Decoration of the peripheral parts of these molecules to induce self-assembly of these molecules into liquid crystalline phases. An interested student may choose to focus their project along one or both of these lines.

Prevalent in nature, porphyrins are being investigated as potential donors due to their large molar absorptivities and low oxidation potentials. Currently, research involves the synthesis of N2S2 core modified porphyrinoids, as shown in Figure 2, and includes functionalization at the meso-positions with either long alkyl or polyethylene glycol chains. The inclusion of long chains is required to induce different liquid crystalline self-assemblies such that efficient charge transport can occur. Other work will involve expansion of the porphyrin aromatic core by incorporating fused phenyl rings to the thiophene moieties. Upon successful synthesis of these materials, we will assemble functional solar cells using either literature or group-synthesized n-type materials.

Projects will be independent, but closely mentored by a PhD or MSc student and students should have an interest in organic synthesis and a drive to understand the physical principles responsible for charge transport. Students will be exposed to standard organic synthesis, Schlenk techniques, 2D NMR, supramolecular design and characterization, liquid crystal characterization (cross-polarized optical microscopy, differential scanning calorimetry and powder x-ray diffraction) and electrochemical techniques (cyclic voltammetry and impedance) to quantify charge transport properties.

Number of Students: 2

Prerequisites: Chem 453 is desirable. Students should be enrolled in the Chemistry Honors or Majors program and eligibility for NSERC or PURE scholarships is an advantage.
Solid electrolytes are ionic conductors and electronically insulators. A wide range of materials are known to exhibit ionic conduction, including polycrystalline and amorphous inorganic compounds, composites and organic polymer-inorganic salt mixtures. Current research on solid electrolytes has drawn much attention because their potential technological applications in solid-state ionic devices, including solid oxide fuel cells, proton exchange membrane fuel cells, gas sensors, high energy density rechargeable (secondary) batteries, electrochromic displays and catalysis.

Several research projects in solid electrolytes are available this coming summer. In particular, the research will be focused on the design, synthesis and characterization of new oxide ion, and proton conductors for application to solid oxide fuel cells, proton exchange membrane fuel cells, and gas sensors (e.g., O₂, H₂, CO₂). The student will employ conventional solid state reaction (ceramic) route, and soft-chemical method, involving precipitation and polymerization to prepare the solid electrolytes. Also, various solid state structural and electrochemical characterization techniques that include X-ray powder diffraction, infrared spectroscopy, impedance spectroscopy, and direct current methods will be used for structural and electrical characterization.

Number of Students: 2

Prerequisites:
Chemistry 315 or 331/333 or 371 or 535, and MOTIVATION.
Project Title:

SUPERCritical FLUID APPLICATIONs IN ANALYTICAL CHEMISTRY

Research concentrates on aspects of analytical chemistry pertaining to chemical separation and identification. The main objective of this work is to develop sample preparation, chromatography, and detection methods for the analysis of trace organic and organometallic compounds present in complex environmental, biological, and industrial samples.

A central theme of this research is the construction and characterization of novel chromatographic detection methods. This has primarily encompassed photometric techniques because of their selectivity and sensitivity to certain target analytes. However, other projects have produced ionization and acoustic based methods, and further developed widely used detectors. In the past, this has led to the creation of novel analytical devices that have been used in the analysis of various additives and contaminants in samples from the petroleum and polymer industries. Current interests in this area surround the development of sensitive and specific multi-channel detectors for use in gas and supercritical fluid chromatography.

Interests in sample preparation involve the development of rapid and environmentally compatible extraction methods using sub and supercritical fluids. Past projects include the removal of metal ions and organic extractives from pulp and paper samples using supercritical carbon dioxide and sub critical solvents. Current interests in this area are the characterization and application of liquid carbon dioxide and sub critical water as extraction alternatives to environmentally hazardous organic solvents.

Supercritical Fluid Extraction Apparatus

Number of students: 1

Prerequisites: Chem 315 and 515
Aromatic nitrogen-containing heterocycles are a common core structure found in organic molecules that are medically relevant: over 250 FDA-approved therapies contain such structures. New technologies that allow for C–H bonds surrounding these sub-structures to be converted into useful functional groups (e.g. C–N, C–F, C=O) will streamline the discovery and synthesis of new treatments. Our laboratory has discovered that using two catalysts simultaneously—a transition metal to bind the heterocycle, and an organic catalyst to participate in C-H bond breaking—can deliver exactly the results that we desire. In these summer projects, we are interested in expanding upon our initial results down several parallel paths. This will include both searching for new reactions, and demonstrating how the site-selective reactions we have already developed can be used to produce high-value targets in an efficient manner.

To support our experimental efforts in laboratory, we are also interested in applying modern methods of experimental design, data analysis and visualization. No prior experience is necessary, but an interest in learning some basics in “Design-of-Experiments” (DoE) analysis is essential.

Number of Students: 2

Prerequisites: CHEM 351, 353/355 required; 453 is advantageous.
Dr. Gregory Welch  
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Project Title:

DEVELOPMENT OF ORGANIC MATERIALS FOR USE IN ORGANIC SOLAR CELLS AND FIELD EFFECT TRANSISTORS

The Welch research group is a chemistry-centric research group working on the development and understanding of sustainable materials for energy conversion, storage, and efficiency. We are currently focused on the design and synthesis of organic and organic/inorganic hybrid functional materials for use in printed electronics, specifically, organic photovoltaics (PVs) and field-effect transistors (FETs), and the integration of these materials into electronic devices. We aim to understand structure-property-function relationships in an effort to improve on molecular design and device performance.

Current summer student projects will focus on the synthesis and characterization of new isoindigo (II) based organic materials for use as active components in optoelectronic devices. II is a natural occurring dye that is an isomer of the famous indigo dye. Previously our group has shown that the installation of chlorine atoms onto the conjugated backbone of II yields materials with improved charge separation properties but poorer light harvesting properties. To improve the light harvesting properties we aim to introduce both fluorine atoms and cyano groups onto the II structure.

Students will develop novel synthetic methods towards these materials, characterize them using a suite of methods (UV-Visible spectroscopy, Cyclic Voltammetry, X-ray diffraction) and incorporate them into electronic devices.

![Previously Reported](attachment:prev_reported.png)  
![Target 1](attachment:target_1.png)  
![Target 2](attachment:target_2.png)

Organic Solar Cells

Number of Students: 2

Prerequisites: CHEM 331/333, 351/353 or 355; 453 is desirable. Students with a passion for energy research and a desire to discover are favored.