SUMMER 2026 RESEARCH PROGRAM
CARLETON CHEMISTRY DEPARTMENT

This summer several faculty in the Chemistry Department plan to participate in our continuing summer research program for Carleton students. We expect to offer research positions to approximately 15-20 new students. Most of the student researchers will come from the sophomore and junior classes. Professors Calderone, Chihade, Gross, Kohen, Skubi, and Whited will offer new students opportunities to work on projects that are described at the end of this document.
The summer research recruiting seminar will be held on **Friday, January 9th at 3:30 pm in Anderson 329**. General information on summer research in the department will be presented along with more details regarding the application process.

Dates of the Program: Monday, June 15th, through Friday, August 21st, for a total of 10 weeks. There is some flexibility in these dates that may be negotiated with your research supervisor
Expected Stipend: At least $5,800 for 10 weeks of full-time work (or $580 per week). Students are paid hourly and will fill out time cards online, so the amount earned per week may vary.

Expectations of Students by the Chemistry Department
A research position in our summer research program is a full-time position. You should not plan on taking a second job during the same period.
At the beginning and end of the summer, you will be expected to participate in a research conference with all of our summer researchers. Each student will give an oral presentation on their project at each of these meetings. Following the summer of research, you will prepare a written report and give a poster on your research at the fall Research Celebration at Carleton. You may also have the opportunity to give a presentation on your research at a local or national conference during the summer or the following academic year.

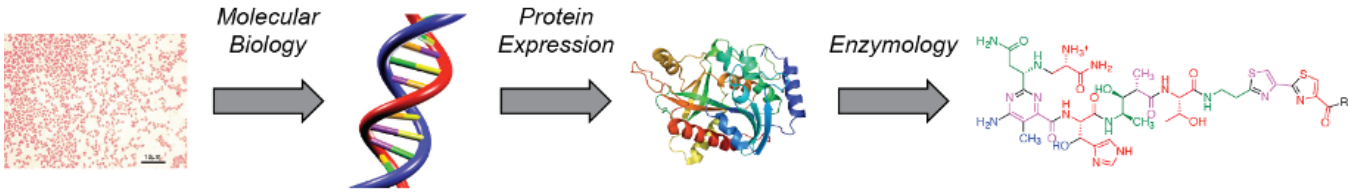
Deadlines and How to Apply
The link to the application is available on the Chemistry Department webpage at the Research Opportunities link. Follow the directions on the electronic application form to rank order your preferences for the various research projects. Also tell us how strong your preferences are and how flexible you are in accepting a position in the other research groups you list. Before submitting your application, you should talk to individual professors in order to explore your interest in their research project. Keep in mind that some professors will not take a student into their group unless the student has taken the time to meet them and discuss the research. Others may also want additional topics addressed in your application, such as relevant courses and experiences you've had outside of the department.
Applications are due at **5:00 pm on Monday, February 16**. Offers will go out by **Wednesday, February 25**. We will ask for your decision on our offer by **Wednesday, March 11** (the last day of classes).

Reasons for Participating in the Summer Research Program at Carleton

Research requires a demanding combination of intellect, creativity, endurance, and curiosity. Many valuable skills are developed in the research laboratory. Some examples include the ability to work as a member of a team, to operate sophisticated instrumentation, and to use available resources to become a life-long learner. Research is also excellent preparation for graduate school, a career in the medical sciences, or a career in other scientific or quantitative fields. Choosing to do research at Carleton offers a number of advantages. First of all, you will get to know your professors much better. In addition, you start preparing for your summer research experience during spring term. This additional preparation will improve the quality of the research you can perform during the short summer. Furthermore, your research project can be continued as appropriate through independent study during the following academic year. Some students at Carleton who have had the most positive research experiences have worked on their research projects over the course of two or more years. Unlike the experience at a larger institution, colleges like Carleton offer research opportunities exclusively for undergraduate students. At a larger institution, you would probably work most directly with a graduate student or post-doc, which is a good, yet different kind of experience. At Carleton you are guaranteed to work closely with a professor and to have your peers as research colleagues.

Life at Carleton and in Northfield is different during the summer than during the academic year. You may be surprised by the pace, and you will be pleased to know that you will not need your down jacket and warm hat (you may want to buy a fan). Normally, many of the facilities (such as the gym, pools, weekly movies, etc.) at Carleton are open for summer programs. We also hope to have a few departmental get-togethers, as well as an outing to a local beach or river during the summer.

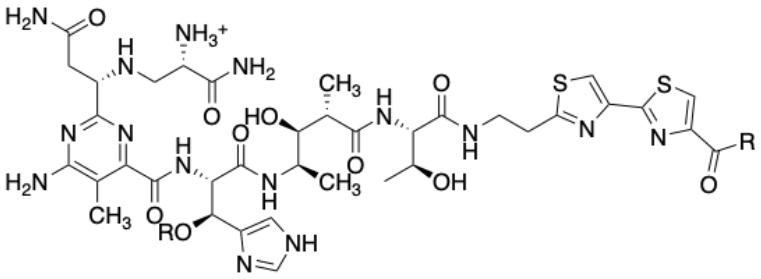
Professor Chris Calderone: Enzymology of Natural Product Biosynthesis *(Two students)*



The Calderone lab is interested in deciphering the logic of *natural product biosynthesis*. Natural products are molecules that are produced by bacteria, fungi, and plants with a wide range of biochemical functions, and many natural products have found value in the clinic as antibiotics, anticancer drugs, or other therapeutics. These molecules are produced by the conversion relatively simple molecules into highly complex natural products by sequences of highly choreographed and specific enzymatic reactions. The focus of the Calderone lab is the exploration of the functions and catalytic mechanisms of these enzymes. Ultimately, this work can have several impacts: (1) Understanding how natural products are

biosynthesized may allow us to produce clinically valuable secondary metabolites more easily using enzymatic, as opposed to often highly inefficient synthetic, strategies. (2) In many cases, the natural product biosynthesis involves biochemical reactions that have not previously been observed; thus, there is great opportunity to discover completely new enzymatic reactions and biochemistry by exploring these pathways. (3) As our knowledge of natural product biosynthetic enzymes increases, we can actually use this information to probe genome sequences for genes encoding related enzymes, and thereby potentially discover new secondary metabolites.

Our currect focus is on the natural product bleomycin, a chemotherapeutic produced by the soil bacterium *Streptomyces verticillus*. Specifically, genomic evidence suggests that two hydroxylations occur during the production of bleomycin, catalyzed by a fascinating class of iron-containing enzymes. This, summer, we will be using a combination of experimental techniques, including molecular biology (PCR, gene cloning) to generate a DNA *plasmid* that encodes these enzymes; protein expression and purification techniques to isolate the enzymes; and finally, a variety of biochemical assays to measure and characterize their (proposed) hydroxylation activity. Thus, you will be exposed to several techniques over the course of your project and see how multiple experimental strategies are brought to bear on a single scientific question.

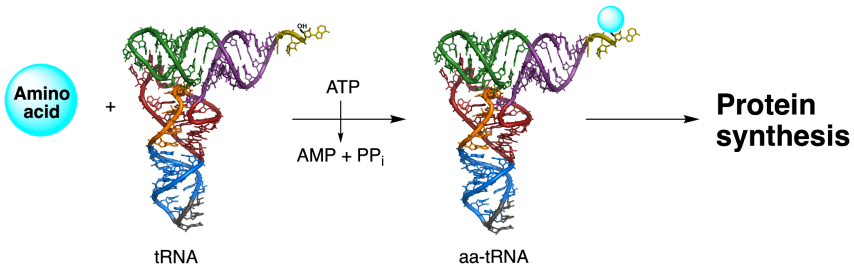


Bleomycin

How to apply. Note that summer research in the Calderone lab will be over a seven-week period, beginning July 6. I will be holding a series of open meetings (times TBA) with more information about the lab's work. You should attend one of these meetings prior to applying so that we can discuss your interest in the lab. You should also be prepared to register for one credit of CHEM394 Independent Study this Spring term.

Professor Joe Chihade – Biochemistry of aminoacyl-tRNA synthetases
Positions for 2-4 students

The general area of research in my lab are a set of enzymes, the aminoacyl-tRNA synthetases (ARSs), that catalyze the formation of ester linkages between amino acids and the particular transfer RNAs (tRNAs) with corresponding anticodon sequences, so that each of the twenty amino acids is only linked to the tRNAs that pair with the corresponding codons defined by the genetic code.



This year, we will be working on two related projects:

• Because they are crucial components of the protein synthesis machinery, ARS enzymes are drug targets in the treatment of infectious diseases caused by parasitic organisms. A large number of diseases are caused by helminths, or parasitic worms, which infect more than one billion people worldwide. In past years, students in my group identified the genes for ARS proteins in these organisms. The next step in evaluating those that are most likely to be good potential drug targets is to produce and characterize these proteins in the lab. We will continue work on that this summer.

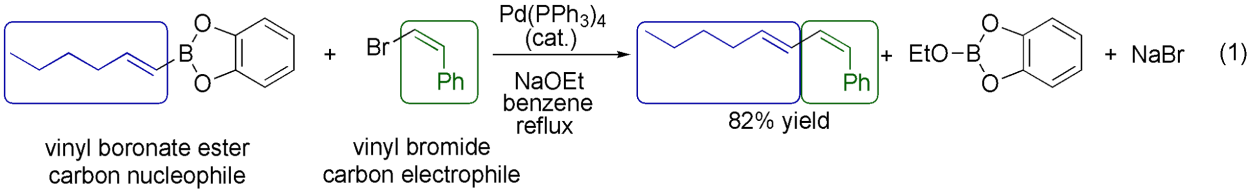
• The standard assay for measuring the action of ARS involves the use of a radioactively labeled amino acid, so it is expensive and limited in other ways. We are working to develop a new set of assays that will allow us to follow the aminoacylation reaction without using radioactivity. These assays depend on finding a way to recycle the aa-tRNA ester product by specifically hydrolyzing the ester bond. Several enzymes that might catalyze this reaction exist. Our plan for the summer is to test these enzymes in order to find one that will work best in the context of the aminoacylation assay.

All of the work in my lab involves protein purification, *in vitro* transcription of tRNAs, creation of new RNA and protein mutants using site-directed mutagenesis and other molecular biology techniques, enzymatic assays to measure charging ability, and probing of tRNA structures to determine regions of protein-RNA interactions.

Professor Gretchen Hofmeister
The students working on this project will gain expertise in organic synthesis and NMR spectroscopy, which would be broadly useful for any future work in synthetic chemistry. Interested students should contact Prof. Hofmeister right away (ghofmeis@carleton.edu) and plan to attend one of her open meetings (which will be published on the department webpage).

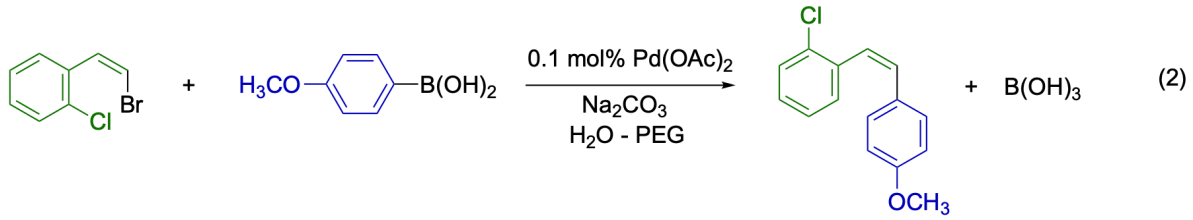
Greener Suzuki Reactions
Positions for 2 – 4 new students

The Suzuki-Miyaura cross-coupling reaction is one of the most important carbon-carbon bond-forming reactions; for example, it is ubiquitous in the pharmaceutical industry. The reaction creates a carbon-carbon bond between a boronic acid or boronate ester and an sp^2 carbon bearing a halogen or pseudohalide leaving group (eq 1). When the boronate ester and the aryl iodide are combined in solution, they do not react with one another. **The palladium metal is critical for catalyzing this reaction, by reacting with the starting materials to form bonds with both carbon species**. In the final step of the reaction, the two carbon species combine to form the product and regenerate the palladium(0) catalyst.



Based on the Twelve Principles of Green Chemistry, this reaction has many advantages—it uses catalytic amounts of palladium and the reagents and waste products are relatively benign. Importantly, however, it also requires the use of organic solvent (benzene in eq 1, or tetrahydrofuran [THF] more commonly) and triphenylphosphine ligands on palladium. These both end up as hazardous waste products from the reaction. Chemists have addressed these deficits by substituting water-ethanol or water-PEG (Polyethylene glycol) solvents for benzene or THF and by using "ligand-free" palladium sources.[1-3] While these conditions are effective in preparing biaryl compounds, in our hands, they have not been applicable to the synthesis of alkenes, such as shown in eq 1.

We hypothesize that oxidative addition in the first step of the catalytic cycle is more challenging under ligand-free conditions. Therefore, we will introduce a chelating group on the vinyl bromide, in order to coordinate the metal and promote this step. Preliminary results have shown modest levels of conversion in the reaction shown in eq 2, which incorporates an *ortho*-chloro substituent on the vinyl halide partner.



We are also using NMR to study the relative ease of oxidative addition of different substrates to palladium, in order to better understand the factors that limit the application of greener methods to a broader array of substrates.[4] Students who work on this project will design and carry out experiments to optimize the reaction in eq 2 and evaluate its scope, as well as engage in mechanistic studies to better understand their results.

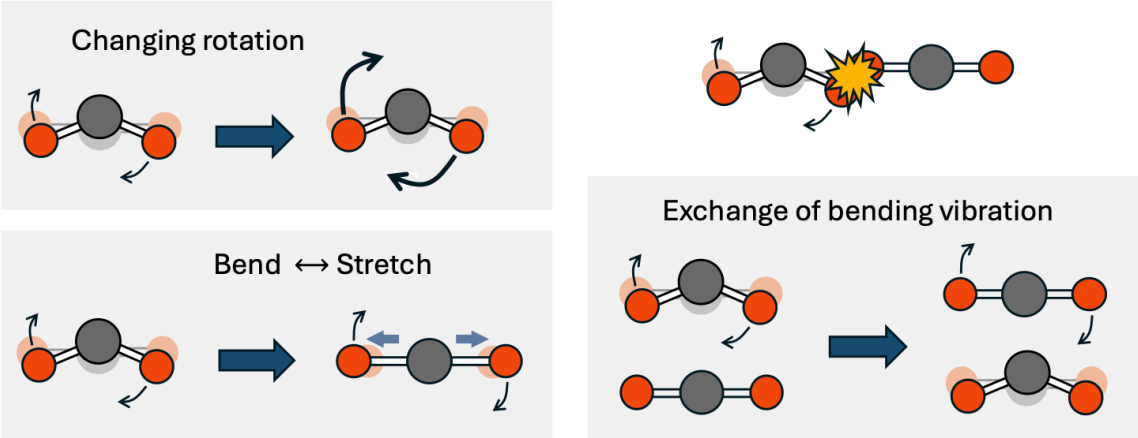
1. Liu, L.; Zhang, Y.; Wang, Y. *J. Org. Chem.* **2005**, *70*, 6122 – 6125.
2. Yin, L.; Zhang, Z.; Wang, Y. *Tetrahedron* **2006**, *62*, 9359 – 9364.
3. Hill, N. J.; Bowman, M. D.; Esselman, B. J.; Byron, S. D.; Kreitinger, J.; Leadbeater, N. E. *J. Chem. Educ.* **2014**, *91*, 1054 – 1057.
4. Lu, J.; Celuszak, H.; Paci, I.; Leitch, D. C. *Chem. Eur. J.* **2024**, *30*, e202402282.

Professor Jun Jiang – Using lasers to detect and study molecules

Positions for 2–3 new students

Physical chemistry aims to address some of the most fundamental questions in chemistry: How do molecules store and move energy? How do the motions of nuclei and electrons shape the world around us, from Earth's atmosphere to distant planets and stars? My research group explores these questions using laser spectroscopy, a powerful set of tools that lets us understand molecules by measuring how they absorb and release light.

Our goal is to use lasers not only to detect molecules, but also to uncover the fundamental chemistry behind their behavior. When a molecule absorbs mid-infrared light, its vibrational and rotational motions become excited, and that energy can flow and redistribute within the molecule or be exchanged through collisions with other molecules. Understanding these processes requires thinking deeply about quantum mechanics, molecular structure, and energy transfer — the heart of physical chemistry.



The current direction of our work focuses on methane, an important greenhouse gas whose "clumped" isotopologues ($^{13}CH_3D$ and $^{12}CH_2D_2$) occur in vanishingly small amounts but carry valuable clues about where methane in the atmosphere comes from. Developing a laser-based way to detect these rare molecules pushes spectroscopy to its limits — requiring creativity, new instrumentation, and a detailed understanding of how energy moves within methane at the quantum level.

The program also aims to extend these ideas beyond Earth. The James Webb Space Telescope is now observing molecules in space that are vibrationally excited and emit rich mid-infrared spectra. By applying the same mid-IR laser techniques we develop for methane, we can help interpret these signals and learn more about the chemistry of star-forming regions, planetary atmospheres, and the origins of complex molecules in the universe.

My group is building a new laser spectroscopy laboratory from the ground up — an exciting opportunity for students to help design experiments, assemble instruments, and shape the research environment. Students gain hands-on experience with lasers and optics as well as scientific programming in Python for data analysis, modeling, and experimental control, while learning fundamental physical chemistry concepts. If you are interested in joining my lab, please get in touch with me (jjiang@carleton.edu).

Behavior within porous materials (funded by DOE) - Professor Daniela Kohen

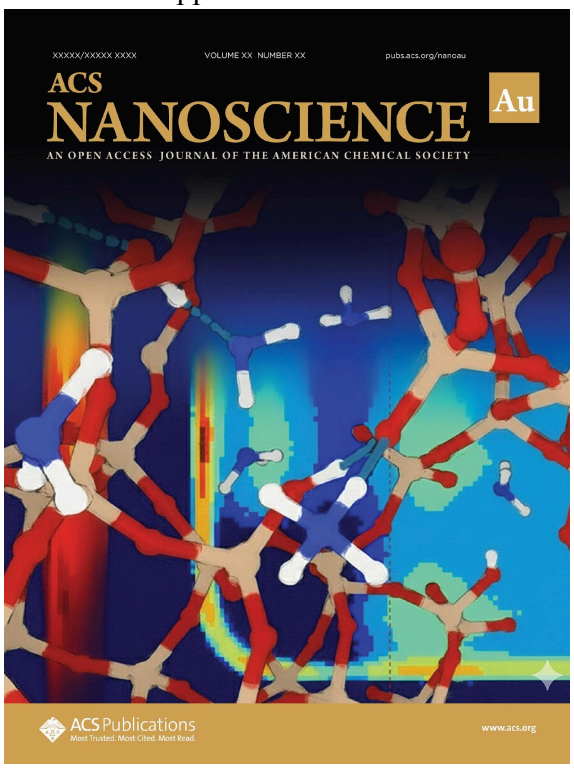
I am a theoretical and computational physical chemist. I am interested in the general area of dynamics in condensed phase, how atoms and molecules move and interact when they're not by themselves.

My group uses computer simulations to understand and characterize, at the molecular level, how molecules behave within materials with very small pores. The goal of these studies is to provide a basic understanding of these systems across a variety of applications, including energy-efficient

separations and the capture of harmful chemical compounds from air and water.

Computational Chemistry research provides scientific insights that cannot be obtained from experimental research alone. The way my research group works is that we use computer programs to investigate the chemical processes that occur in the systems we study. If you are interested in joining us, please get in touch with me (dkohen@). In addition, Lizzy Arnell (arnelld@) or Kiran Mynen (mynenik@) can provide you with a student's perspective on what being part of my group entails.

You can see an example of our work at https://pubs.acs.org/doi/10.1021/acsnanoscienceau.5c00151, where we describe what we learned about ammonia reacting within a defective zeolite (a type of nanoporous material). This figure is the article's supplemental cover art.

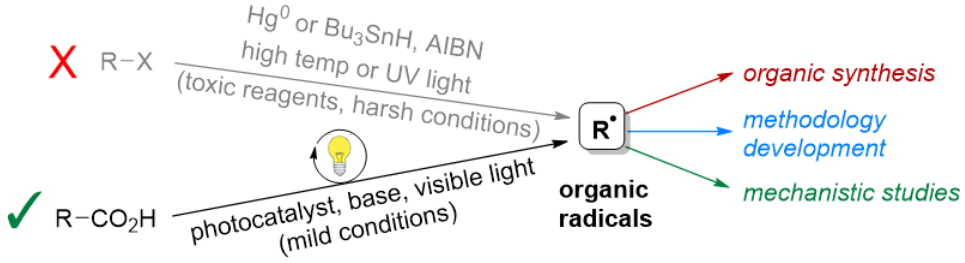


Professor Kaz Skubi – Synthetic Organic Chemistry of Radicals

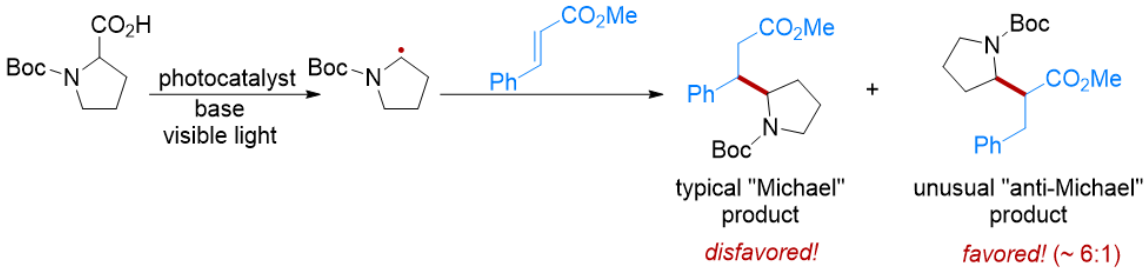
Positions for ~5 students

Research in my lab focuses on free radicals, which are molecules containing unpaired electrons. In particular, we will explore the organic chemistry of carbon-centered radicals, develop new methods for their generation, and investigate their reactivity towards conjugated π systems. The main application of this technology is for the synthesis of pharmaceuticals, natural products, and

other structurally-rich organic molecules. While historical approaches towards radical chemistry have relied on toxic reagents and/or high-intensity UV light, our goal is to employ visible light (or even just sunlight) in combination with non-toxic photocatalysts to access these reactive intermediates and explore their behavior.



This summer, we will investigate an intriguing system in which organic radicals exhibit unusual regioselectivity. The addition of nucleophiles to α,β-unsaturated carbonyl compounds is generally selective for addition at the β-position, and this is a well-studied reaction (e.g. conjugate addition and the Michael reaction from Chem 234). But recent literature has shown that radicals can preferentially add to the "anti-Michael" position.[1] This is synthetically powerful, as it allows construction of a new C–C bond with complementary selectivity to existing methods. It is also mechanistically intriguing, and the factors that dictate this atypical regioselectivity are not yet understood. That's part of what we aim to discover!



Here are some of the areas that we will be focusing on:

- Developing and optimizing new reactions
- Isolating and characterizing new organic molecules
- Performing mechanistic experiments to investigate the selectivity of these reactions
- Applying our methods to synthesize more complex organic molecules
- Reviewing the literature and using recent papers to design new experiments

This research will also improve your proficiency with experimental techniques and skills such as:

- NMR spectroscopy, including 2D methods
- Schlenk line and inert-atmosphere technique
- Isolation from complex mixtures, various purification techniques
- Organic methodology and reaction development

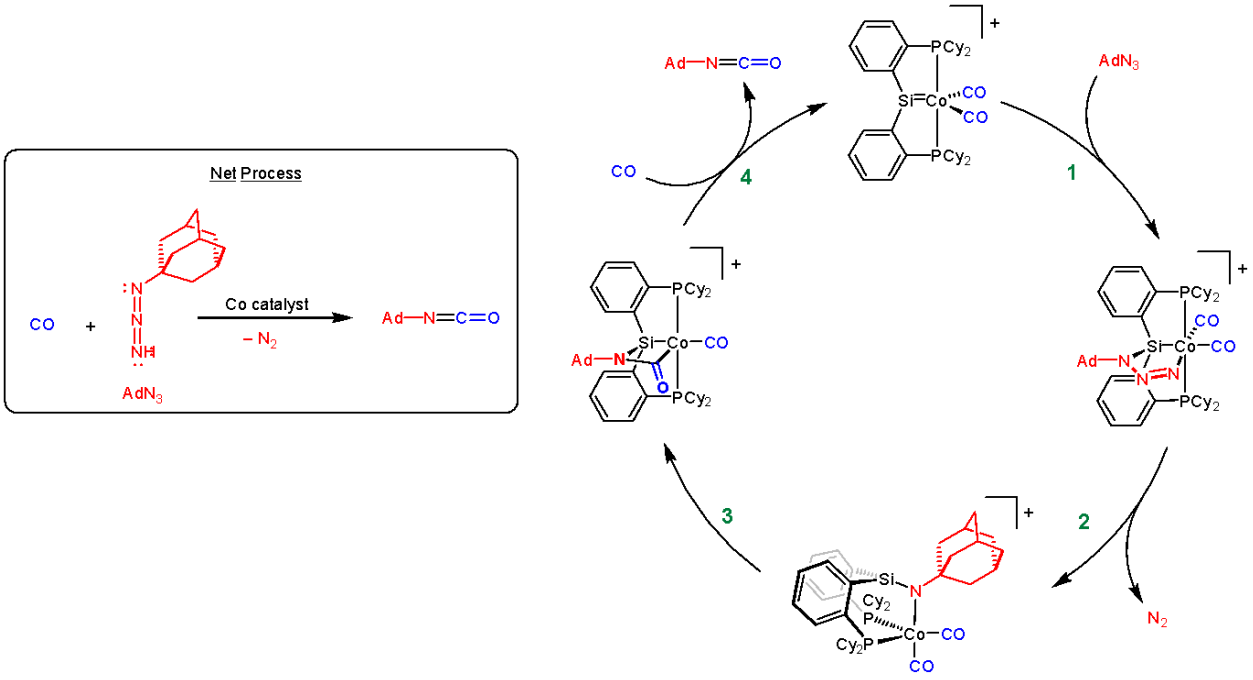
This research is ideal for someone who has enjoyed Chem 233/234, as it will directly reinforce concepts and techniques from those courses. Furthermore, it provides excellent training for those who are interested in continuing in chemistry, and has good overlap with the topics found in upper-level electives such as Chem 306 and Chem 353.

[1] (a) Lovett, G. H.; Sparling, B. A. *Org. Lett.* **2016**, *18*, 3494–3497. (b) Larionova, N. A.; Ondozabal, J. M.; Smith, E. G.; Cambeiro, X. C. *Org. Lett.* **2021**, *23*, 5383–5388.

Professors Matt Whited and Dani Kohen: Computational Studies of Metal/Silicon Bonds

Positions for 1–2 new students (supported by NSF and ACS-PRF)

In the Whited laboratory, our experimental work aims to develop new chemical transformations of small molecules that are notoriously unreactive, like carbon dioxide, carbon monoxide, and nitrogen gas. Our specific strategy involves promoting catalytic chemical reactions at metal–silicon bonds, allowing us to access new mechanisms by *cooperation* of the two dissimilar elements. One recent exciting finding is the catalytic oxidation of carbon monoxide to organoisocyanates by cobalt/silicon cooperation (ref. [1]):



Note that the proposed catalytic mechanism (right) relies on both silicon and cobalt to activate the substrates (ref. [2]). Several characteristics of the catalyst complex make this transformation possible, including the (very unusual) Si=Co double bond.

Students in the "wet lab" of the Whited Group design and prepare new metal complexes like the ones shown above in order to improve catalytic reactions already discovered and find new ones. This work is informed and supplemented by a fruitful and longstanding collaboration with Prof.

Kohen's group to use computational approach that help us better understand mechanisms of reactions, energetics of the systems we prepare, and the nature of the unusual chemical bonds we have made.

This summer, we are looking for 1–2 new research students who will focus on the computational side of our project, helping us to better understand things like how switching silicon to germanium or tin would affect the reaction, or how we can change the groups bonded to silicon to change reaction pathways. We will use density functional theory (DFT) to address these sorts of questions, and the computational findings will inspire the next steps on our synthesis and catalysis projects.

What Will You Do?

This project requires a good knowledge of organic chemistry (through CHEM 234) and a passion for identifying interesting problems and devising promising approaches using the methods available to you. While you will have individual responsibilities within the group (and your own specific project), the work is highly collaborative. No prior experience with inorganic chemistry, air-sensitive synthesis, or chemical computations is required (you will learn all that as you go). Students who do well on these projects are highly organized, enjoy solving puzzles, and like collaborating and learning about new kinds of chemistry from their peers.

If you are interested, please do the following:

- **Email Dani to set up an appointment to meet with us.**
- **Talk with recent student researchers from our lab: Claire Lee-Zacheis and Marie Schumacher**