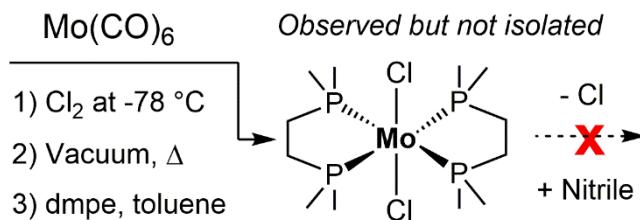


- 1) UNI-58382
- 2) Exploration of Nitrile Oxidation Reactions: Towards Synthesis of Metal-Nitrene Complexes and Nitrene Transfer to Substrates.
- 3) Christopher R. Turlington, Hope College, Holland, MI
- 4) No Co-PI

### **Preparation of Molybdenum Compounds for Nitrile Oxidation**

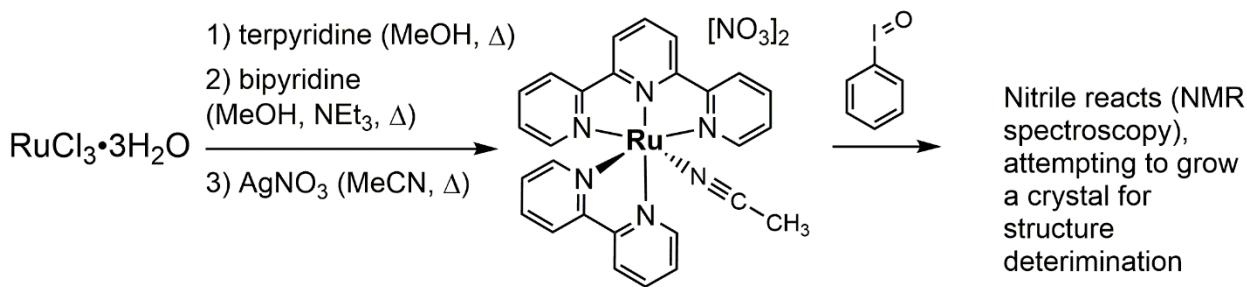
During the spring and summer of 2019, we have attempted the literature synthesis of molybdenum(II) dichloride complexes with bis-dimethyl(phosphino)ethane (dmpe) ligands (Scheme 1). The first step requires stirring molybdenum hexacarbonyl in liquid chlorine, and the air sensitive product was reacted with dmpe ligand in the second step. Although the NMR spectrum of the crude reaction mixture showed that the desired  $\text{Mo}(\text{dmpe})_2\text{Cl}_2$  was the major product, we were unable to isolate this air-sensitive metal complex. Due to the air sensitivity of the product and the presumed air sensitivity of targeted nitrile complexes later in the synthetic scheme, we abandoned this synthetic route. The hazards associated with chlorine gas and pyrophoric dmpe provided additional motivation to seek other metal/ligand combinations for the study of nitrile oxidation.



**Scheme 1. Preparation of molybdenum compounds.**

### **Preparation of Ruthenium Compounds for Nitrile Oxidation**

Ruthenium complexes are less oxaphilic than molybdenum and tend to be more stable, so we have had more success developing ruthenium complexes with nitrile ligands. During the 2018-2019 summers we successfully synthesized ruthenium complexes with terpyridine, bipyridine, and acetonitrile using literature procedures (Scheme 2). After synthesizing  $[\text{Ru}^{\text{II}}(\text{terpyridine})(\text{bipyridine})(\text{NCCH}_3)][\text{NO}_3]_2$ , we found that iodosylbenzene reacts cleanly with the  $[\text{Ru}^{\text{II}}(\text{terpyridine})(\text{bipyridine})(\text{NCCH}_3)]^{2+}$  compound to form a *diamagnetic* product. ( $\text{Ru}^{\text{IV}}$  oxo complexes are paramagnetic.) Although we do not yet know the identity of this diamagnetic product, NMR spectroscopy reveals that the resonance for the coordinated nitrile ligand at 2.1 ppm in the starting material shifts to a new resonance at 1.7 ppm as the reaction occurs. Free acetonitrile resonates at 1.9 ppm, indicating a reaction at the nitrile ligand. We are attempting to grow crystals for single crystal X-ray diffraction studies, which will provide definitive evidence if a nitrile oxidation reaction has occurred. We are hopeful we have made a significant step towards our goal.



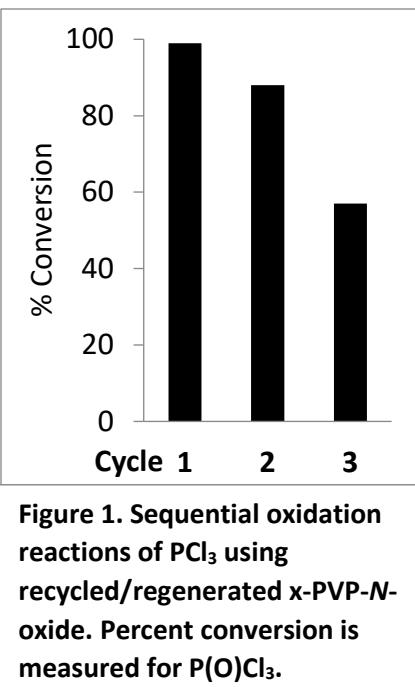
**Scheme 2. Preparation of ruthenium compounds and oxidation reactions.**

### **Preparation of Polymer-Supported Oxygen Atom Transfer (OAT) Reagents for Nitrile Oxidation**

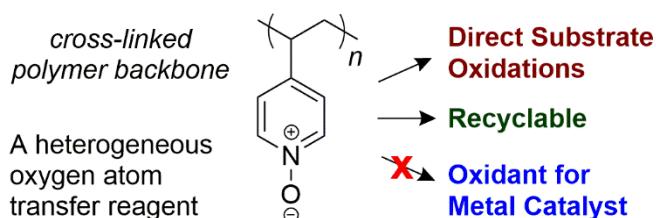
In conjunction to the synthesis of metal complexes with coordinated nitrile ligands (see above), we have also begun the development of a new class of OAT reagents for these nitrile oxidation studies. We have interest in developing polymer-supported OAT reagents because they would ease product isolation (polymer-supported reagents are easily removed by filtration), and we believe these polymers will have applications beyond organometallic oxidation

reactions. To this end, we synthesized a known compound, poly(4-vinylpyridine-*N*-oxide) that had been cross-linked with 2% divinylbenzene (called x-PVP-*N*-oxide), and tested it in organic OAT reactions for the first time.

Synthesis of x-PVP-*N*-oxide was facile using literature procedures and the x-PVP-*N*-oxide was insoluble in all solvents. The oxidation chemistry of this heterogeneous OAT reagent was tested and compared to its molecular counterpart, pyridine-*N*-oxide. The insoluble oxidant x-PVP-*N*-oxide demonstrated comparable reactivity to pyridine-*N*-oxide in direct oxidation reactions of phosphines and phosphites in acetonitrile, but x-PVP-*N*-oxide did not react in other solvents. The polymer backbone of x-PVP-*N*-oxide, however, allowed for easy filtering and separation from the reaction mixture. Recycling the x-PVP-*N*-oxide was accomplished after filtering and used for sequential oxidation reactions of phosphorus trichloride (Figure 1). It was found that x-PVP-*N*-oxide remained active over multiple oxidation reactions if the polymer was re-oxidized to x-PVP-*N*-oxide with 3-chloroperoxybenzoic acid after each phosphorus trichloride reaction. In addition, x-PVP-*N*-oxide was tested as the stoichiometric oxidant in a copper-catalyzed OAT reaction to  $\alpha$ -diazo-benzeneacetic acid methyl ester. The heterogeneous oxidant was much less reactive than pyridine-*N*-oxide,



**Figure 1. Sequential oxidation reactions of  $\text{PCl}_3$  using recycled/regenerated x-PVP-*N*-oxide. Percent conversion is measured for  $\text{P}(\text{O})\text{Cl}_3$ .**



**Scheme 3. Summary of x-PVP-*N*-oxide reactivity.**

indicating that interaction with the metal catalyst was challenging (Scheme 3). These results demonstrated a proof-of-concept that recyclable, polymer-supported OAT reagents could be a viable OAT reagents in direct oxidation reactions without metal catalysts. These results have been submitted for review to the journal *Tetrahedron Letters* and is currently under review.

### Impact on Career and on Students who Participated

This UNI grant has catalyzed the start of my independent career. Receiving this grant in the fall of my first academic year (2017) allowed me to hire more students in my first summer (2018) and second summer (2019) of undergraduate research. I used the first budget year of the grant to one extra student in the summer of 2018 and to hire two extra students in the summer of 2019. With three extra students over my first two summers, I was able to hire approximately 50% more students than I could hire with start-up funds provided by my institution (7 students). This head start has yielded much fruit on my research projects, culminating in submission of a manuscript to the peer-reviewed journal *Tetrahedron Letters* in August 2019. Undoubtedly I would not have been able to submit this manuscript after my second summer of research unless I had the support of the PRF to hire additional students. I also expect that the extra productivity that the PRF has made possible in my research lab will strengthen applications for funding in the coming summer of 2020, when I will make submissions to the Cottrell Science Scholars award and NSF CAREER award.

So far, three students have been funded by this grant, and two of them are co-authors on the submitted manuscript (one is first author and another is third author). All three students want to go to graduate school in chemistry, and having a publication as an undergraduate will improve their applications dramatically. One student travelled to and presented at the spring 2019 national meeting of the American Chemical Society in Orlando, and her travel was made possible by the travel funds supplied by this PRF grant. Finally, all three students have learned critical problem-solving skills and have had to work as a group, which will be an invaluable skill set in whatever careers they choose to pursue. Three additional students not funded by the PRF also contributed to the manuscript submitted to *Tetrahedron Letters* and are included on the author list.