SLATT UNDERGRADUATE RESEARCH FELLOWSHIP
FINAL REPORT

SCHOLAR NAME:	Matthew Riss
FACULTY ADVISOR:	Dr. Amy Hixon
PROJECT PERIOD:	August 2019 – November 2019
PROJECT TITLE:	Synthesis, Characterization, and Thermodynamic Properties of a Suite of Thorium Nitrate Salts // Encapsulation of a Uranyl Peroxide Nanocluster into a Zirconium-Based Metal–Organic Framework
CONNECTION TO ONE OR MORE ENERGY-RELATED RESEARCH AREAS (CHECK ALL THAT APPLY):	**( ) Energy Conversion and Efficiency** **(x) Sustainable and Secure Nuclear** **( ) Smart Storage and Distribution** **( ) Transformation Solar** **( ) Sustainable Bio/Fossil Fuels** **( ) Transformative Wind**

MAJOR GOALS AND ACCOMPLISHMENTS

Summarize your research goals and provide a brief statement of your accomplishments (no more than 1-2 sentences). Indicate whether you were able to accomplish your goals by estimating the percentage completed for each one. Use the next page for your written report.

RESEARCH GOALS	ACTUAL PERFORMANCE AND ACCOMPLISHMENTS	% OF GOAL COMPLETED
Periodic characterization of thorium salts	The suite of salts was characterized using RAMAN Spectroscopy	30
Encapsulate U_{24} cluster into a metal organic framework	U_{24} has been synthesized and an experimental design completed for the project; however, the MOF has yet to be received	50

RESEARCH OUTPUT

Please provide any output that may have resulted from your research project. You may leave any and all categories blank or check with your faculty advisor if you are unsure how to respond.

CATEGORY	INFORMATION
EXTERNAL PROPOSALS SUBMITTED	(Sponsor, Project Title, PIs, Submission Date, Proposal Amount)
EXTERNAL AWARDS RECEIVED	(Sponsor, Project Title, PIs, Award Date, Award Amount)
JOURNAL ARTICLES IN PROCESS OR PUBLISHED	(Journal Name, Title, Authors, Submission Date, Publication Date, Volume #, Page #s)
BOOKS AND CHAPTERS RELATED TO YOUR RESEARCH	(Book Title, Chapter Title, Authors, Submission Date, Publication Date, Volume #, Page #s)
PUBLIC PRESENTATIONS YOU MADE ABOUT YOUR RESEARCH	(Event, Presentation Title, Presentation Date, Location)
AWARDS OR RECOGNITIONS YOU RECEIVED FOR YOUR RESEARCH PROJECT	(Purpose, Title, Date Received)
INTERNAL COLLABORATIONS FOSTERED	(Name, Organization, Purpose of Affiliation, and Frequency of Interactions)
EXTERNAL COLLABORATIONS FOSTERED	(Name, Organization, Purpose of Affiliation, and Frequency of Interactions) Megan C. Wasson, Northwestern University, metal organic framework synthesis, apprx once a month
WEBSITE(S) FEATURING RESEARCH PROJECT	(URL)
OTHER PRODUCTS AND SERVICES (e.g., media reports, databases, software, models, curricula, instruments, education programs, outreach for ND Energy and other groups)	(Please describe each item in detail) A detailed research proposal has been created, which will likely translate into a journal article in the future

RESEARCH EXPERIENCE

Please let us know what you thought of your research experience: Did this experience meet your expectations? Were lab personnel helpful and responsive to your needs? What else could have been done to improve your experience or achieve additional results?

The research experience was quite novel, to say the least. Nobody was expecting this year to go the way it has, and therefore there were many oddities associated with this research experience. All things considered, though, this experience exceeded my expectations. Social distancing measures and limits to personnel allowed in the labs at the same time did not hamper the experience much. Therefore, I was still able to engage in lab work just about as much as I wanted to. Lab personnel were very accommodating and helpful throughout the semester as well.
Obviously, a lack of COVID-19 would have improved my experience. We probably could have achieved additional results if the projects had begun in the summer as originally slated. Other than that, though, I do not think anything could have improved the experience.

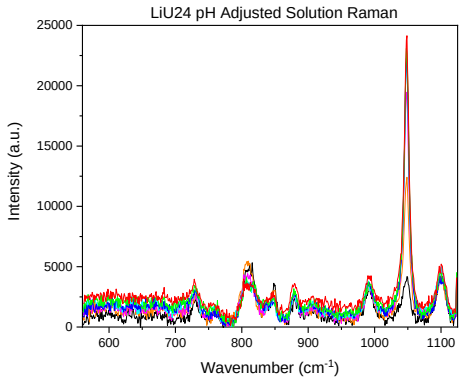
FINAL WRITTEN REPORT

(Please use the space below to describe your research project and objectives, any findings and results you can share, and graphs, charts, and other visuals to help us understand what you achieved as a result of this research experience.)

At the start of the fellowship, the research project focused on a suite of thorium salts. This project was titled: "Synthesis, Characterization, and Thermodynamic Properties of a Suite of Thorium Nitrate Salts". I worked with Dr. Hixon's graduate student Ashley Hastings on this project. As a graduate student she had access to the lab before I did; therefore, she independently synthesized the salts that we intended to characterize. Once I was able to enter the lab, we ran RAMAN spectroscopy on all the salt samples. This project was based on a published journal article that had described RAMAN characterization of only a sample of the salt suite. Therefore, our goal was to compare RAMAN results to the already published curves and to investigate those salts that had yet to be measured. Our RAMAN curves were similar to those already published, a promising sign.

However, after our RAMAN work on the salts this project ended up on the back burner. Ashley felt that, given time constraints in the lab due to COVID-19, our time would be better spent focusing on a different project: "Encapsulation of a Uranyl Peroxide Nanocluster into a Zirconium-Based Metal–Organic Framework". Whereas the former project had implications for thorium-salt reactors (i.e. the front end of the nuclear fuel cycle), this project was focused more so on the back end of the nuclear fuel cycle. Previously, different kinds of materials have been encapsulated into metal-organic frameworks, or MOFs. However, as far as we could tell, uranyl-peroxide nanoclusters had not been encapsulated into MOFs previously. If such encapsulation could be achieved, this could possibly become a remediation technique for spent nuclear fuels that contain such uranyl-peroxide nanoclusters.

Much of this semester focused on the experimental design of this project. Whereas the former project was easy enough to design for (i.e. just running instrumentation on each salt), this project took time and research to create. Eventually we decided on the U_{24} nanocluster and the zirconium-based NU-1000 for the project. While Ashley and I focused on synthesizing U_{24}, we began communicating with an individual from Northwestern University who agreed to synthesize NU-1000 for us. We spent a significant amount of time attempting different synthetization techniques for the U_{24}. We attempted catalyzing the reaction, adjusting the pH of the cluster solution, and more. Below is an example of RAMAN peaks from pH adjusted solutions of the U_{24}. The different colors represent different pH levels (i.e. 12, 11, 10, etc.).



Eventually, we had settled on using U_{24} already in solution to encapsulate into the MOF as opposed to solid crystals. Due to concerns about different pHs affecting the U_{24}, we pH adjusted solutions of the U_{24} and ran RAMAN to see whether the clusters remained intact. U_{24} has a characteristic peak around 800 cm^{-1}, which is still somewhat visible on the above graph. However, the obvious peak is around 1050 cm^{-1}; we believe that this peak is from the diluted acid that was added to the U_{24} solutions to adjust the pH. Although the U_{24} peak is significantly less intense than the acid's peak, we believe that the presence of the peak still indicates that there is uranium in solution.

At this point, we are still awaiting the (delayed) NU-1000 MOF. Once that is received, we should be able to attempt encapsulation as outlined in our experimental design. Following the experiment, a journal article will likely be drafted.