NSF CAREER Proposal: Advice & Perspectives

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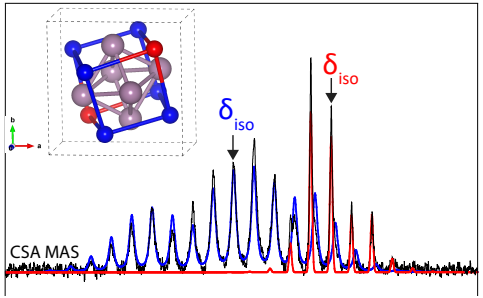

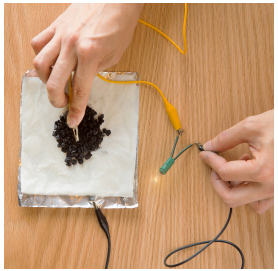

The City College of New York

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Grove School of Engineering

Messinger Group @ The City College of New York

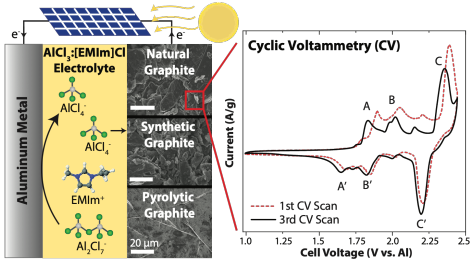
- **Electrochemical materials & multi-phase fluids for energy applications**
- **Emphasis:** understanding & controlling **molecular-level properties & processes**

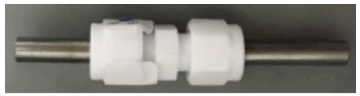
Novel Batteries:
Electrochemical Energy Storage

Multi-phase Fluids:
Thermal Energy Storage; Oil & Gas

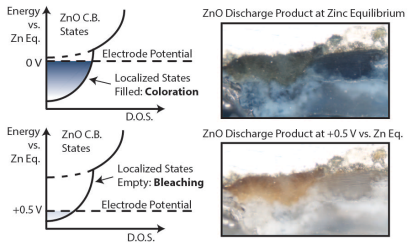
NMR Spectroscopy:
Energy materials

Metal-ionic liquid batteries Aluminum (also: Li & Zn)

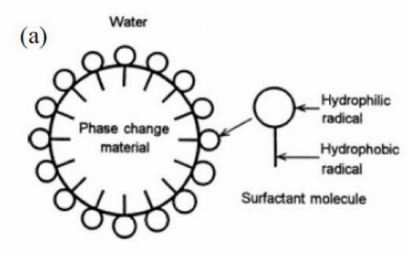


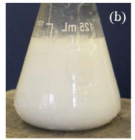


Zinc Alkaline Batteries

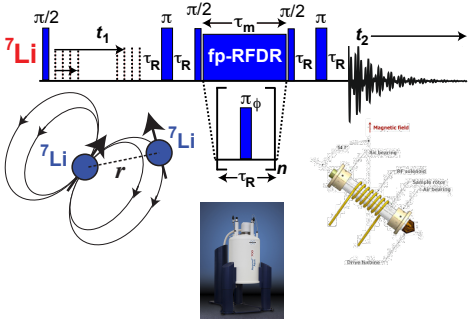


Phase-change Nano-emulsions





Dipolar recoupling & multiple-quantum methods

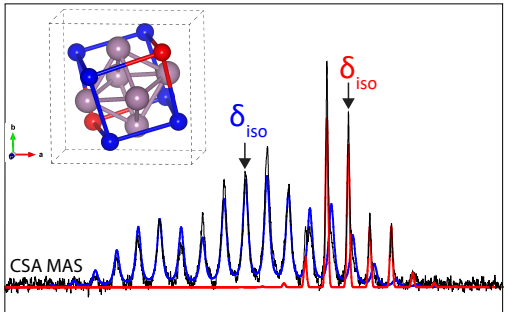


Overview of NSF CAREER Proposal

CAREER: Design and Understanding up from the Atomic Scale of Multivalent Intercalation Electrodes for High-Energy-Density Rechargeable Batteries

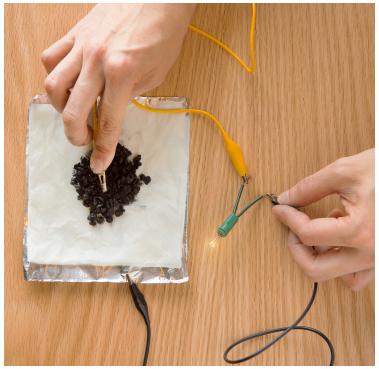
Research

Electrochemical Engineering



Physical chemistry

Education



- Submitted at the ***end of the third year*** of assistant professorship; awarded 1st attempt
- Had been through NSF grant proposal process and was fortunate to win NSF award
- Had previously participated in NSF review panel

Outline

- **Uniqueness, Passion, & Vision**
- **Most single important component** of compelling proposal
- **Project Overview**
- **Research:** tasks, subtasks, preliminary data, & tables
- **Education:** integration with research + sustainability
- **Other Advice & Thoughts**

Uniqueness, Passion, & Vision

- Think deeply about what aspects makes your research truly **unique**
- Think deeply about what **drives you** to perform fundamental scientific research and makes you **passionate** about education
  - *Research:* molecular-level understanding + energy technologies
  - *Education:* people + transformative impact on students' life trajectories
- *Concisely articulate this **vision** in 2-4 sentences*
- Build a proposal using this **vision** as a foundation
  - Not just career development as teacher-scholar; remember: stand-alone 5-year proposal
- Propose something **new** that **<u>requires</u> fundamental science** & has **impact**

The Most Important Aspect of Any Proposal

- **1st page of project description (project overview)** is most crucial
- Reviewers will begin making judgements as soon as they begin reading

GENERATE EXCITEMENT!!!

- The reviewers should know the challenges, motivation, overarching objectives, underlying hypothesis, & expected outcomes
- **Sync** with proposed taks; feedback loop b/w project overview & tasks
- You need a champion on the panel. Get them excited!

Project Overview

1. Project Overview [First paragraph]: CHALLENGE

One of the great challenges facing modern society is *to develop new technologies that transform how we sustainably store energy. In particular, ...*

Global warming & pollution

Non-renewable fossil fuels

Electrify transportation

Store renewable energy

Project Overview

Forest → ***Grove*** → ***Tree***

Project Overview

1. Project Overview [First paragraph]: CHALLENGE

One of the great challenges facing modern society is *to develop new technologies that transform how we sustainably store energy. In particular, ...*

Overarching → specific challenge in one paragraph

Lithium-ion batteries have revolutionized portable electronics, ***but…*** *[motivate]*

…When multivalent cathodes are paired with their corresponding metal anodes, potentially transformative gains in energy density are possible. ***However,*** *widespread use of multivalent battery chemistries has remained elusive, in large part due to* ***limited molecular-level understanding & control*** *of the complex electronic, chemical, and structural changes that the electrodes and their interfaces undergo upon intercalation of multivalent ions.*

Project Overview

[Second Paragraph]: Research objectives

*The **overarching research objectives** are to **gain new fundamental knowledge**, up from the atomic scale, of the electrochemical intercalation of multivalent cations in crystalline transition metal compounds and **to use this understanding to** discover and optimize novel intercalation electrodes with significantly enhanced energy storage properties.*

Aluminum metal

Zinc metal

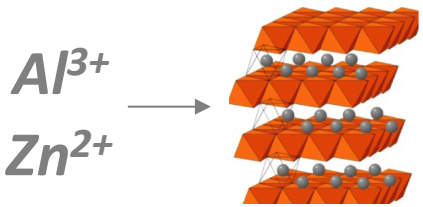
*[**Connect to specific system/problem**] The seldomly-explored aluminum-ion (Al^{3+}) and zinc-ion (Zn^{2+}) chemistries will be investigated as model multivalent battery systems. Both aluminum and zinc metal are earth abundant, non-toxic, non-flammable, low-cost, and exhibit exceptional volumetric energy storage capacities that far exceed that of lithium metal; aluminum electrochemistry offers the remarkable thermodynamic capacity associated with trivalent redox chemistry, while zinc electrochemistry is compatible with mild, aqueous electrolytes."*

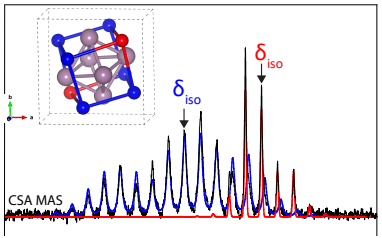
Project Overview

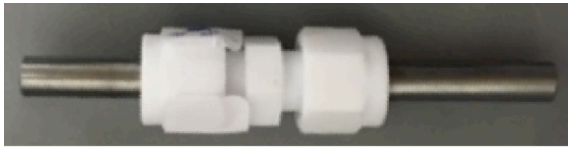
[Third paragraph]: Hypothesis & Outcomes

*The **overarching scientific hypothesis** is that **understanding** material properties and electrochemical phenomena central to their charge storage mechanisms, and strategies for their **control**, will **open pathways** for the innovative design and optimization of new multivalent intercalation electrodes with transformative macroscopic energy storage properties.*

*The **expected scientific outcome** is ….*







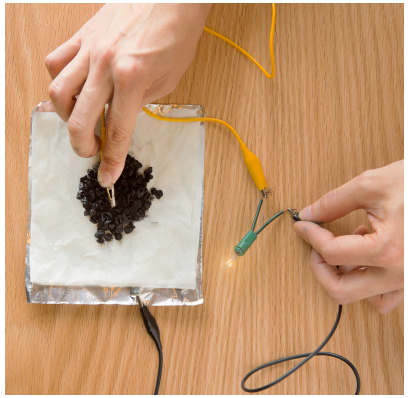
*The **expected technological outcome** is…*

Project Overview

[Fourth Paragraph]: Educational objectives

*The **overarching educational objective** is to facilitate and energize learning at the high school, undergraduate, and graduate levels in the scientific fundamentals of electrochemical engineering and physical chemistry.*

First, *the PI will host an annual summer "Battery Bootcamp" for New York high school chemistry teachers, which will teach …*



Second, *the PI will …*
Third, *the PI will…*
Lastly, *the PI will….*

(My overview was 1 page + 6 lines; 1 page is best…)

Research Plan: How to Organize

2. Research Plan

2A. Motivation & Challenges of Multivalent Intercalation Electrodes: "Beyond Li-ion"

2B. Background: Rechargeable Aluminum-Ion & Zinc-Ion Batteries

2C. Research Overview

Task 1, Task 2, Task 3. [Each task should have an objective: make it "skimmable"]

TASK 1: Intercalation of Multivalent Cations into Chevrel Phase as a Model System

Subtask 1.1. Variation of Ion Valence

Subtask 1.2. Variation of electronic structure

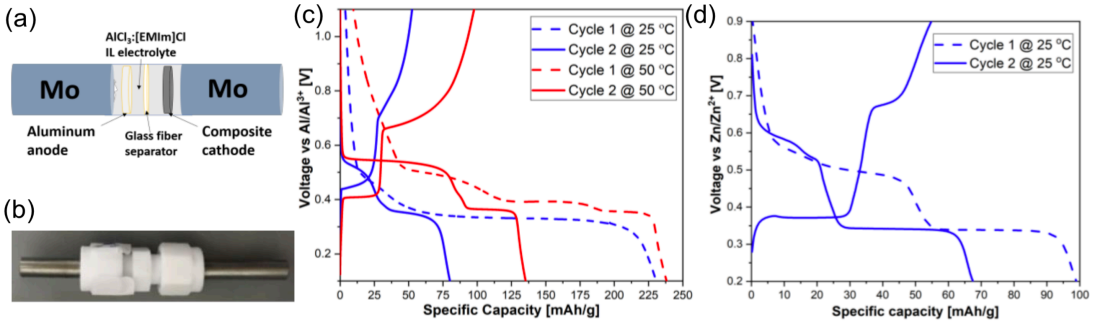
TASK 2: Intercalation of Multivalent Ions into Transition Metal Sulfides & Oxides

TASK 3: Novel Electrode Compositions & Structures for Multivalent-Ion Batteries

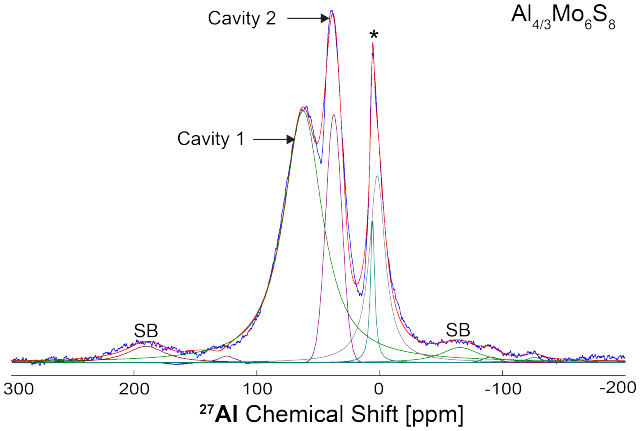
Research: Preliminary Data

- Use 1-2 figures of preliminary data to ***dispel doubt***

Electrochemical Engineering



Physical chemistry



- Explicitly state it

Initial experiments of aluminum-ion and zinc-ion intercalation into the Chevrel Mo_6S_8 have been conducted (Figure 4), establishing the PI's capabilities in solid-state synthesis, battery fabrication, and electrochemical characterization.

Research: Tables

- Use a table to summarize complex info & highlight objectives

Electrochemical Techniques	Objective
Galvanostaic Cycling (GC)	Capacity & ion (de)intercalation potential, rate-dependent capacity
Cyclic voltammetry (CV)	Electrochemical redox processes, rate-dependence of redox processes
Electrochemical Impedance Spectroscpy (EIS)	Charge transfer resistance, diffusion coefficient of intercalated ion
Galvanostatic Intermittent Titration Technique	Diffusion coefficient of intercalated ion
Direct Current (DC) 4-Point Probe Method	Electrical conductivity of pristine material
Diffraction Methods	
X-ray Diffraction (XRD)	Crystal structure
Microscopy/Imaging	
High-Res. Transmission Electron Microscopy	Atomic & nano-scale electrode structures, interfacial imaging
Scanning Electrom Microscpoy with EDS	Micron-scale electrode structures & surface elemental composition
Solid-state MAS NMR Spectroscopy	
Variable-temperature single-pulse ^{95}Mo NMR	Mo environments, electronic structure of Mo_6 (by NMR Knight shifts)
1D single-pulse ^{27}Al NMR	Al environments (intercalated & surface), quantiative populations
^{27}Al NMR relaxometry	Rotational correlation times & dynamics of intercalated Al ions
2D ^{27}Al EXSY NMR	Chemical exchange between Al species
Low-Temp. 2D ^{27}Al Dipolar Correlation NMR	Sub-nanometer proximities between intercalated Al ions
1D single-pulse ^{67}Zn NMR	Zn environments, quantitative populations
^{67}Zn NMR relaxometry	(^{67}Zn-enriched samples) Rotational correlation times of intercalated Zn ions

Education: Integrate with Research

3. Education Plan

- ***Key concept:*** activities that are do so are ***sustainable***

Electrochem. Eng	*Phys. Chem.*	*Electrochem Eng. + Phys. Chem.*	*Electrochem. Eng.*
High School Battery Bootcamp	**CUNY School of NMR**	**Undergraduate Research**	**New Course at CCNY**

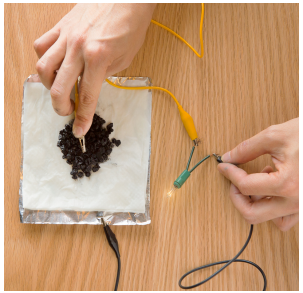
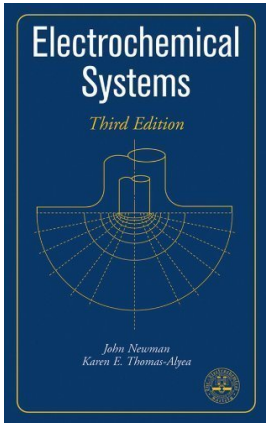


Figure 6. Al-air battery composed of Al foil, salt water, a paper towel, & activated charcoal.

Figure 7. Messinger group picture, June 2018, including five CCNY undergraduates.



Education: Integrate with Research

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Electrochem. Eng

High School Battery Bootcamp

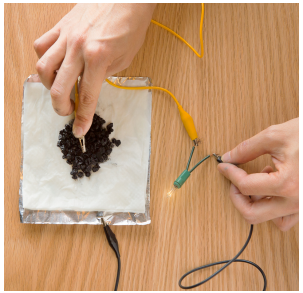


Figure 6. Al-air battery composed of Al foil, salt water, a paper towel, & activated charcoal.

Organization:

Recruitment:

Logistics:

Outcomes:

Assessment:

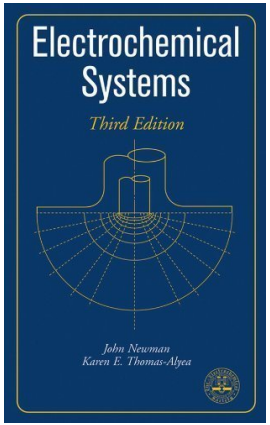
Electrochem Eng. + Phys. Chem.

Undergraduate Research

Figure 7. Messinger group picture, June 2018, including five CCNY undergraduates.

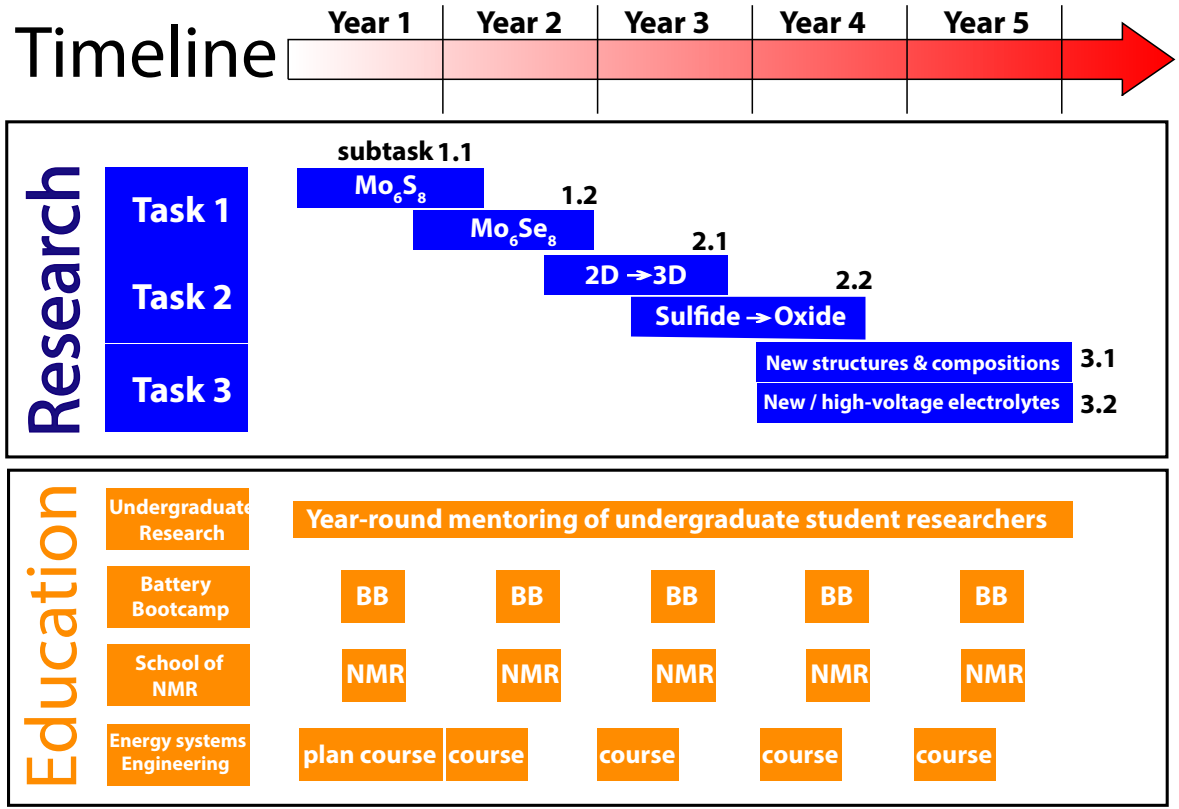
Electrochem. Eng.

New Course at CCNY



Timeline

4. PROJECT EXECUTION & TIMELINE

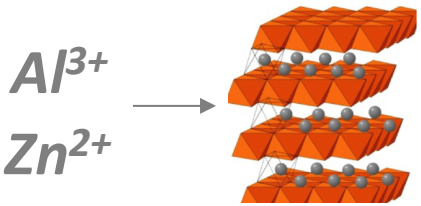


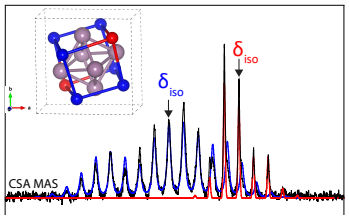
Intellectual Merit & Broader Impacts

5. Intellectual Merit

Broaden scope

First, make briefly connections to scientific outcomes discussed previously





Then, emphasize interdisciplinary connections that may not be obvious to the reviewers

6. Broader Impacts

Education

Technology

Other Advice & Thoughts

- **START EARLY**, develop deadlines, & stick to them
- You must believe in what you propose (passion, drive, & risk)
- Make the proposal “skimmable” with strong topic sentence
- Use figures to convey information and “give them room to breathe”
- Polished supporting documents; make clear budget justification
- Consider waiting 2-3 years to gain experience with grant writing

Acknowledgements

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