Thank you to:

Breaking the Crystal Lattice

Improving Salt Conductivity

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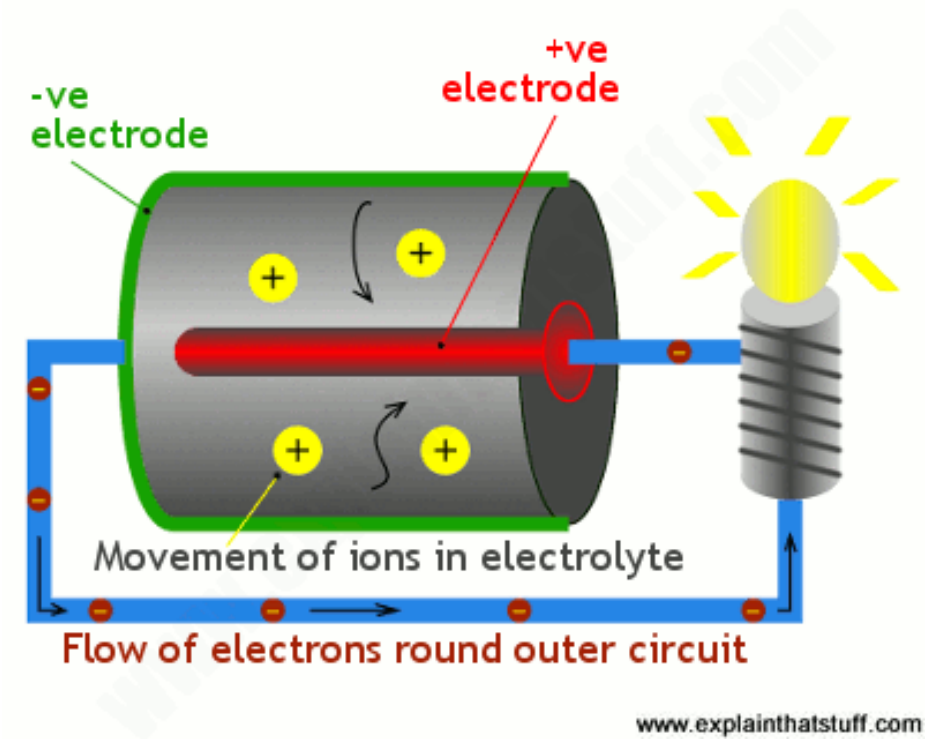
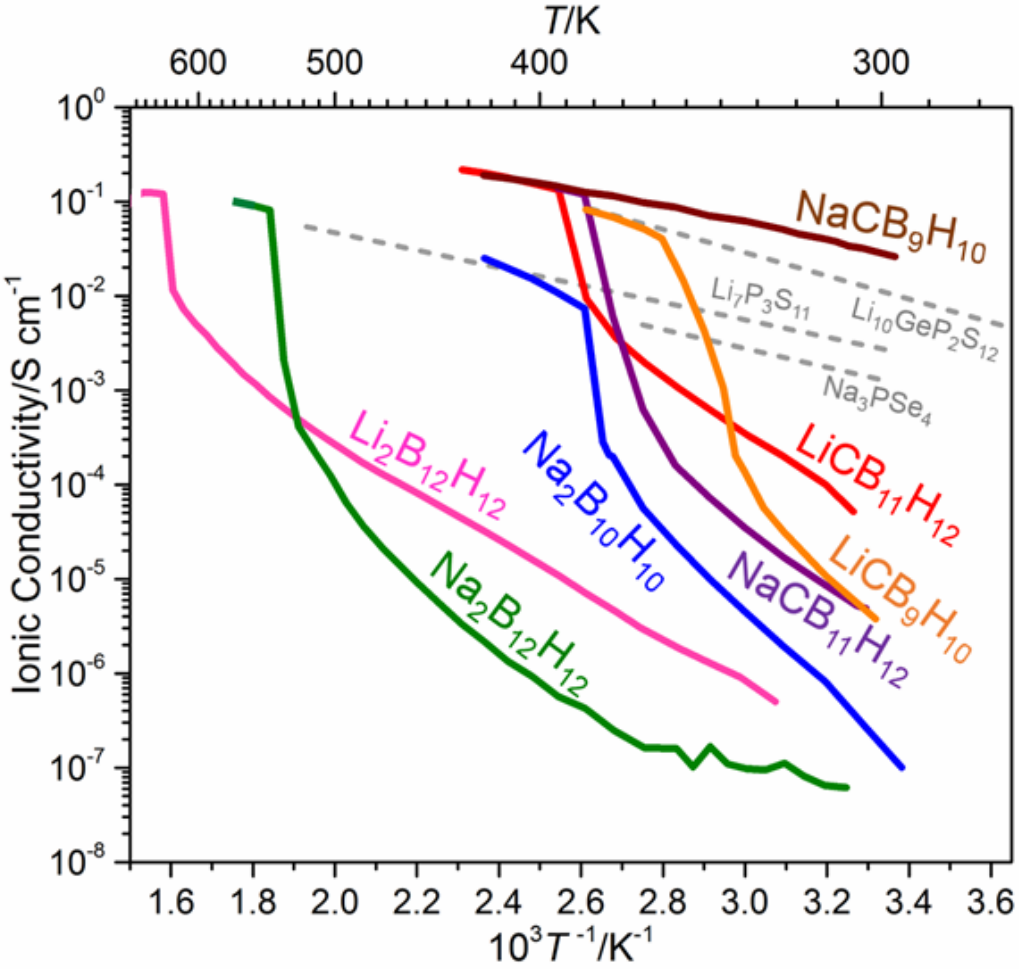
Goal: Solid State batteries

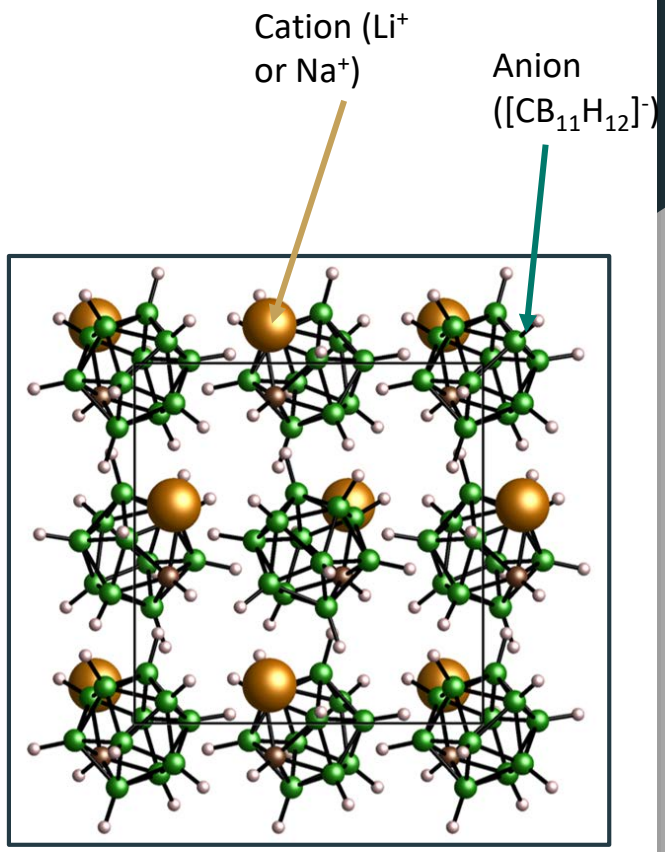
- Safer
- Non-hazardous, non-flammable
- Possibly cheaper
- Sodium: more eco-friendly

commons.wikimedia.org/wiki/File:Spilled_Battery.JPG



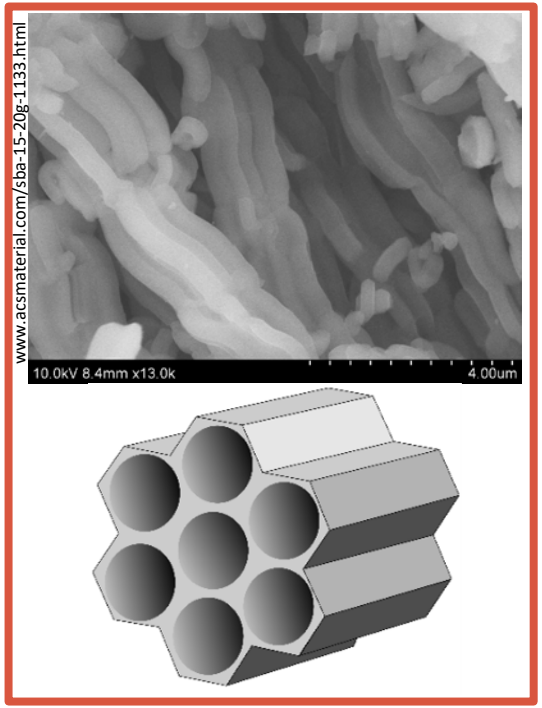
Graph provided by Terrence Udovic



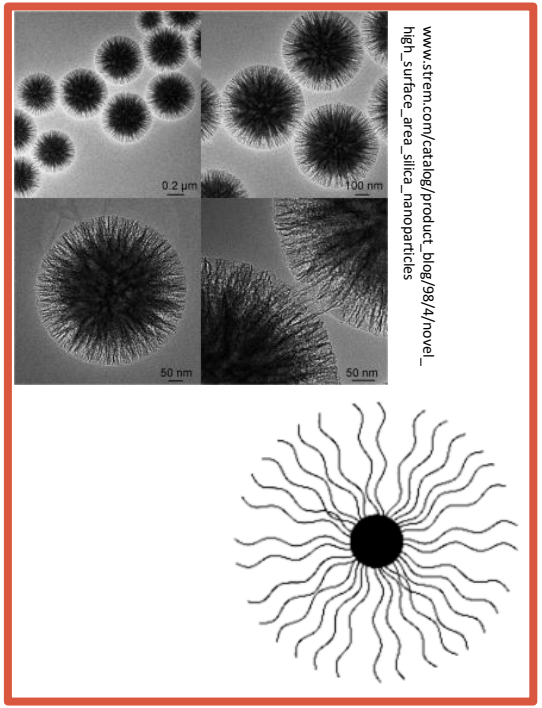


Images courtesy of Dr. Terrence Udovic

Materials: Silica (SiO_2)



SBA-15 (8nm and 12 nm pores)



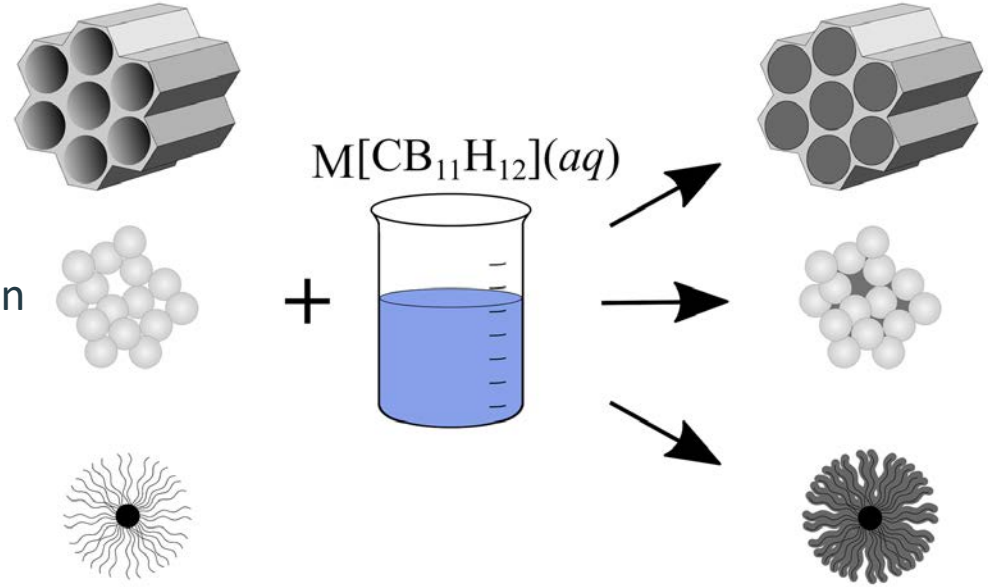
High Surface Area (HSA) Silica (900-1100 nm particles)

Porous SiO_2 disks (made of 7nm and 13 nm spheres)

Digital drawings courtesy of Mikael Andersson

Methods: combining salt + silica

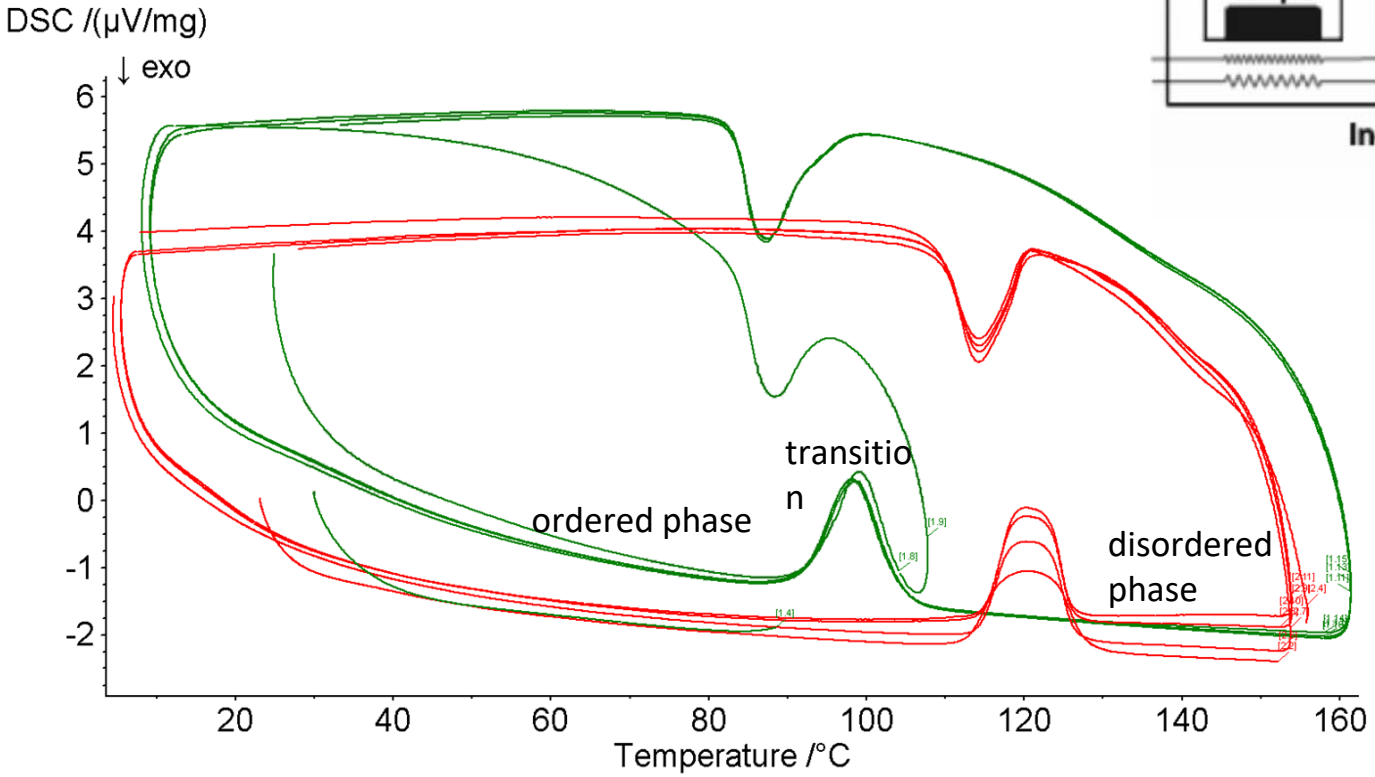
- Purpose: nano-confine the salt so disordered state is favoured
- Method
  - Make saturated solution
  - mix into silica
    - Or add by capillary action
  - Dry under vacuum

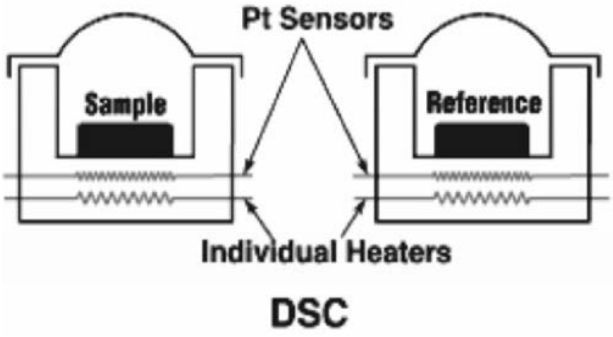


Original schematic provided by Mikael Andersson

How do we know it works?

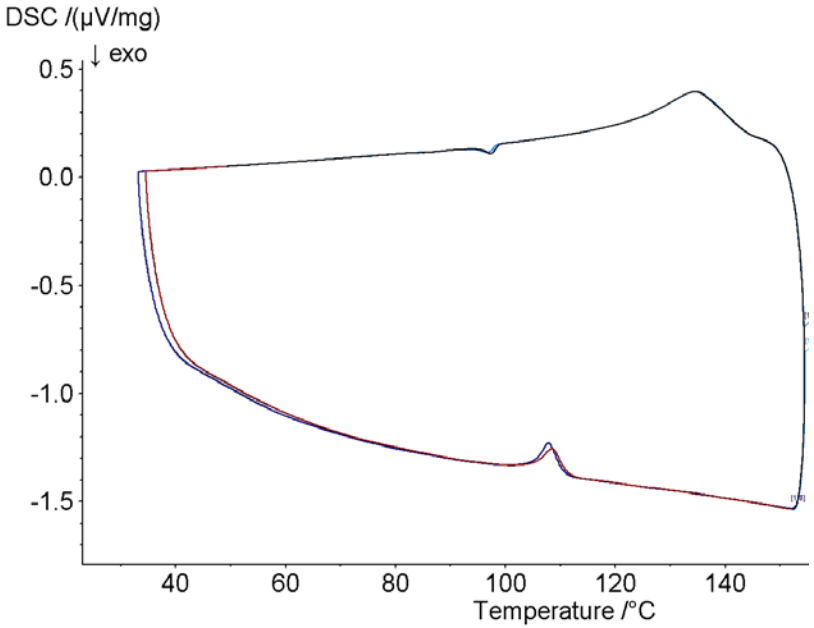
Differential Scanning Calorimetry





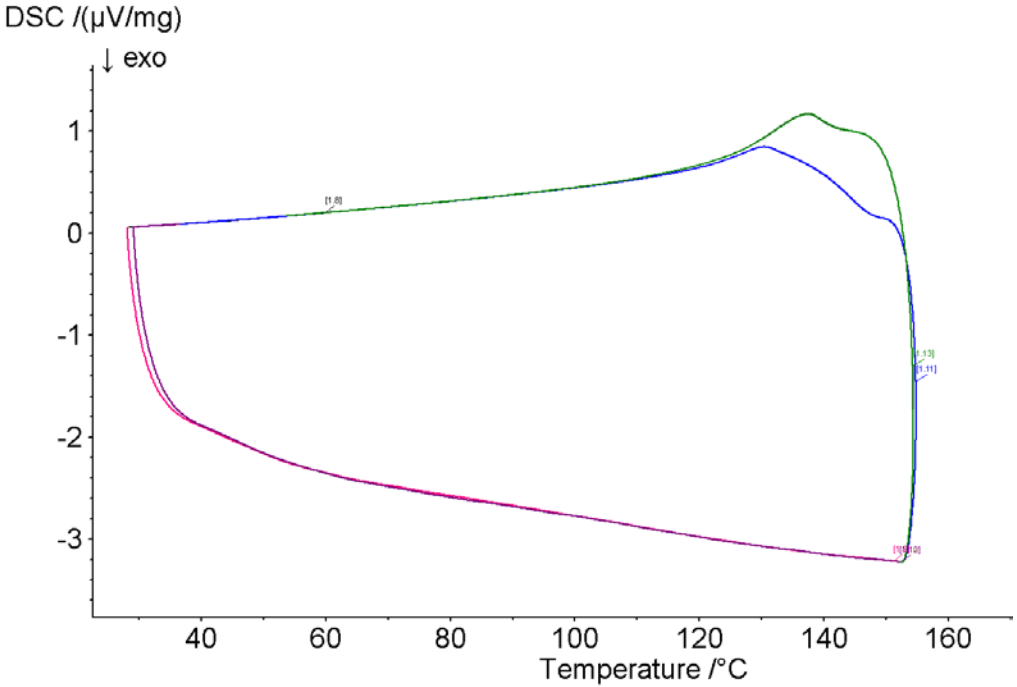
Green (left peaks) = bulk $NaCB_{11}H_{12}$

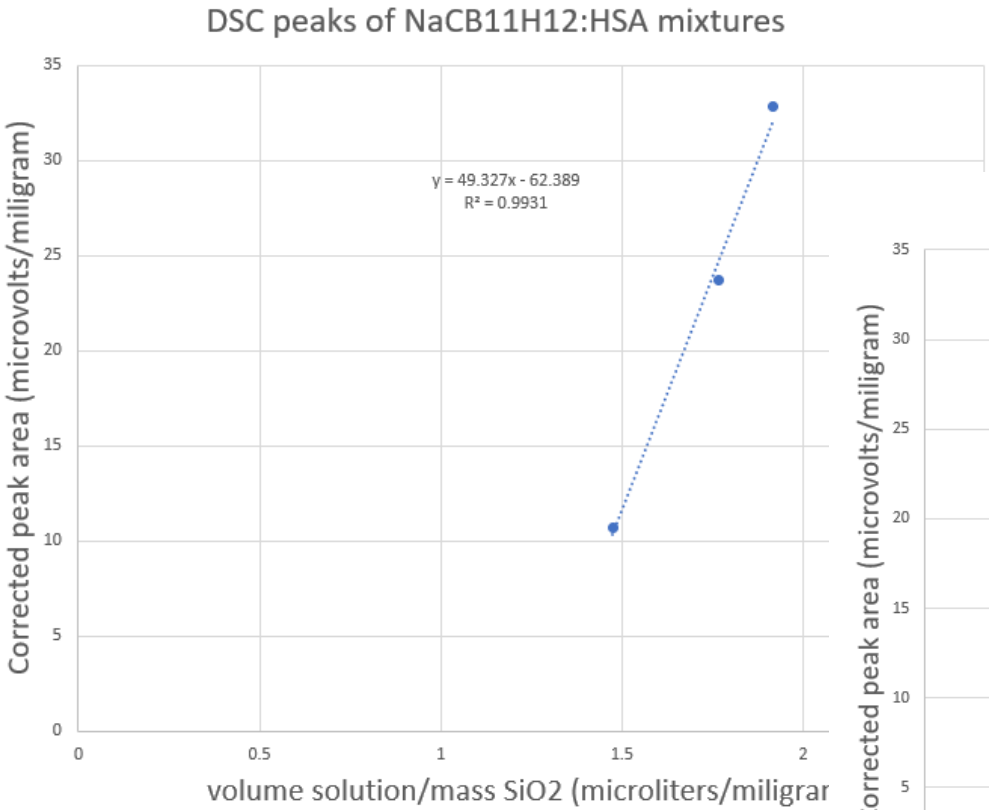
Red (right peaks) = bulk $LiCB_{11}H_{12}$



1.8 $NaCB_{11}H_{12}$: 1 HSA SiO_2

1 $NaCB_{11}H_{12}$: 1 HSA SiO_2

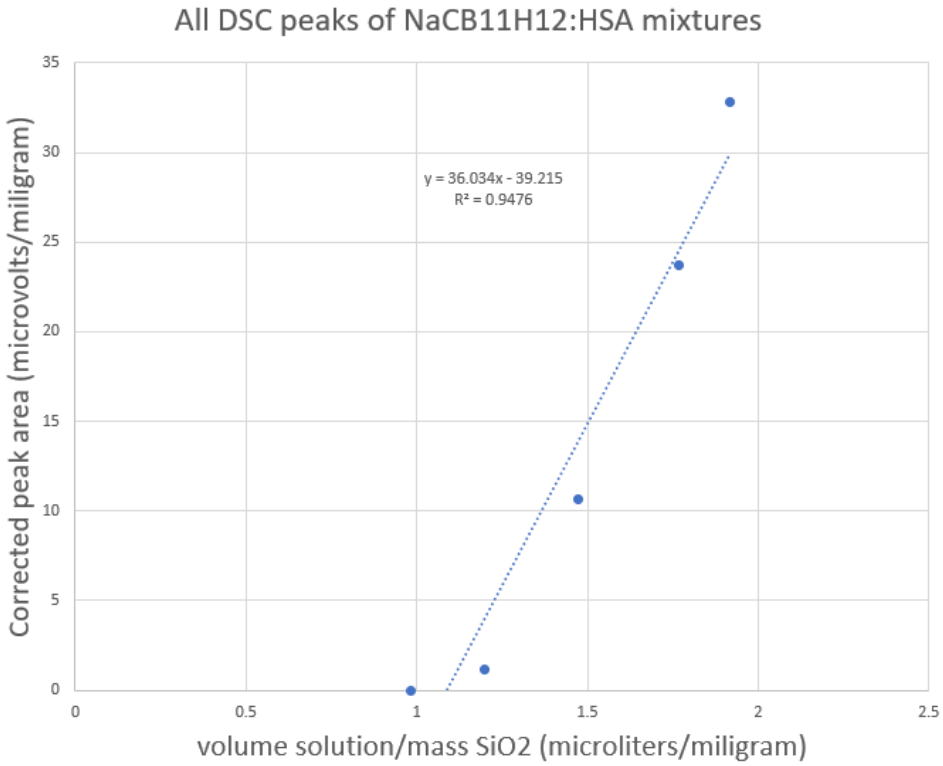




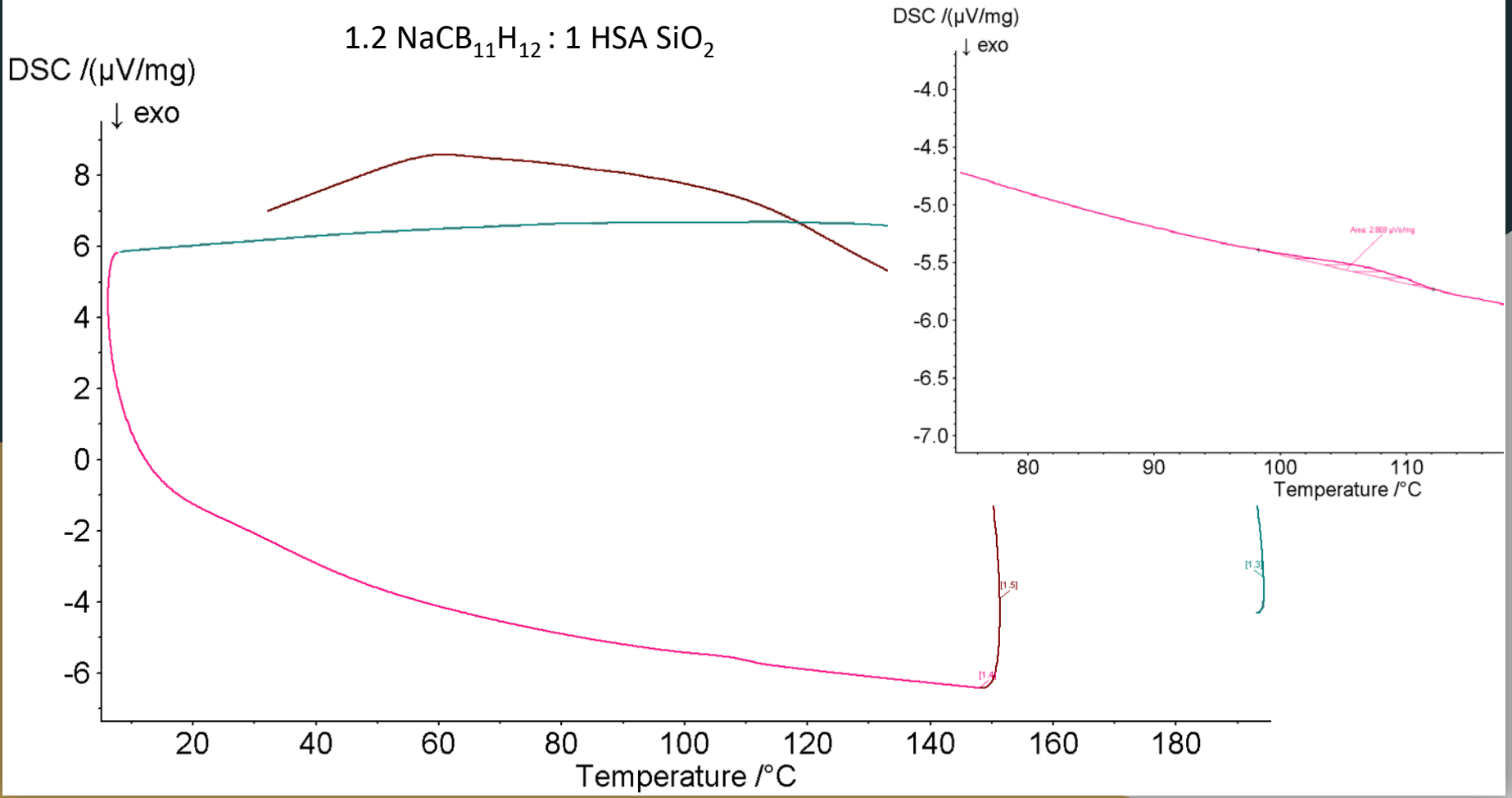
Graph used to estimate correct volume/mass ratio.

X-int = 1.265 µL solution/mg SiO_2

Graph including all final DSC results for Na--:HSA ratios



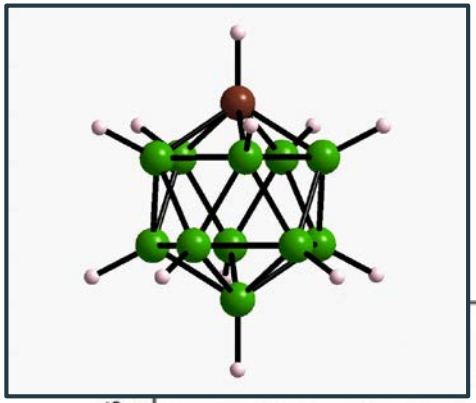
1.2 $NaCB_{11}H_{12}$: 1 HSA SiO_2

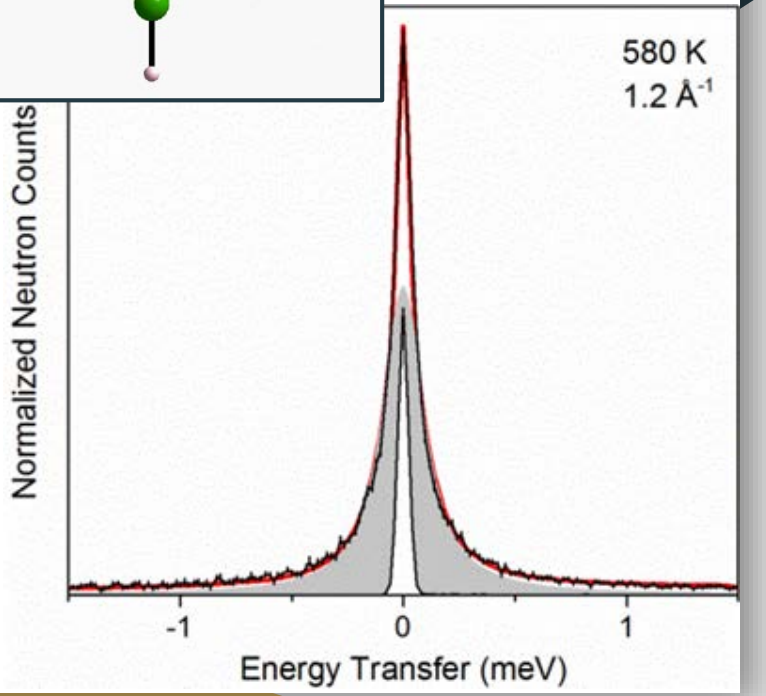


Quasielastic Neutron Scattering

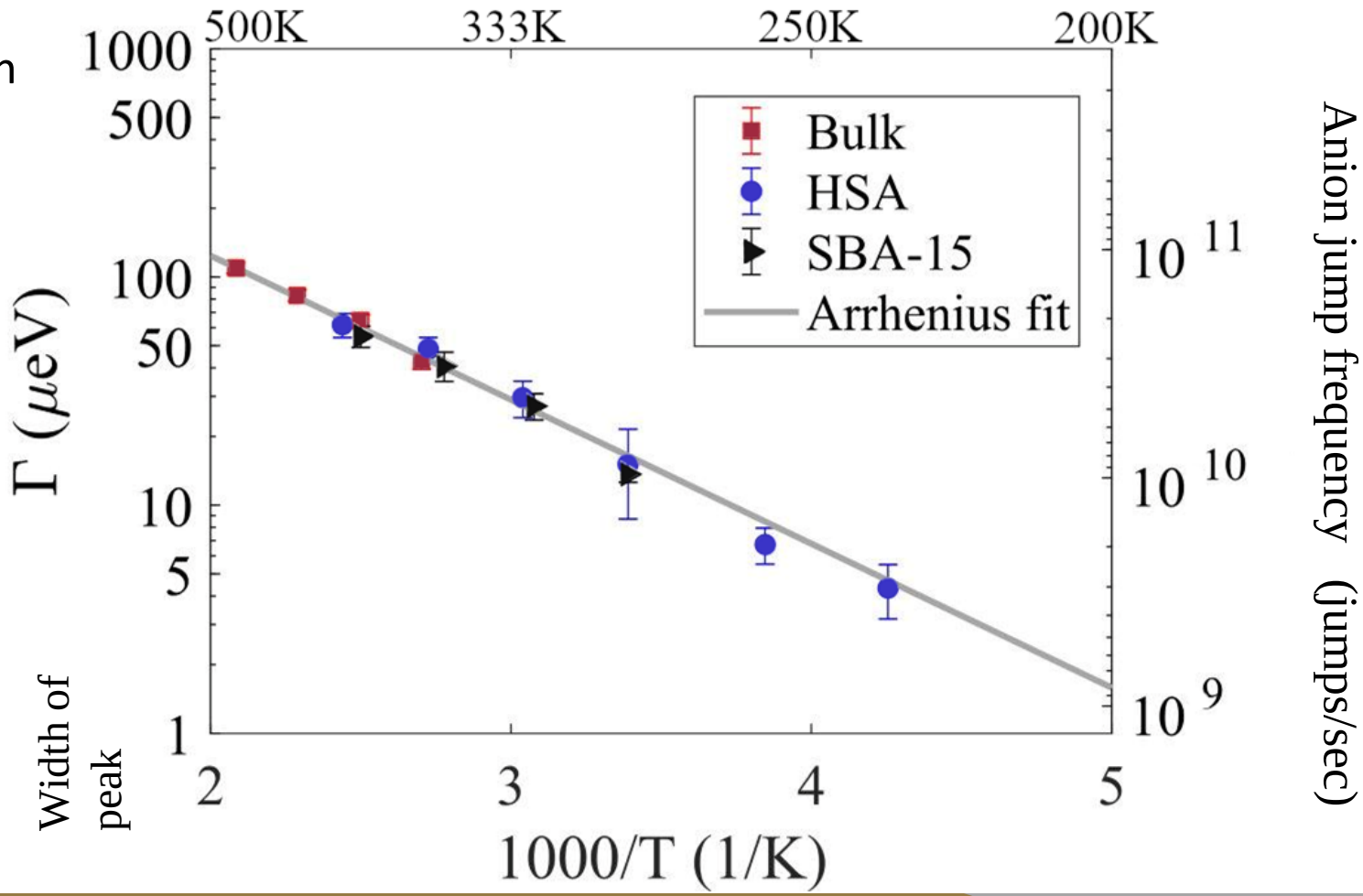
- High Flux Backscattering Spectrometer (HEBS)
- Disk-chopper Spectrometer (DCS)

- Measures hydrogen dynamics
  - No movement → elastic (no E change)
  - Movement → inelastic (E lost or gained)
  - More movement → broader peak

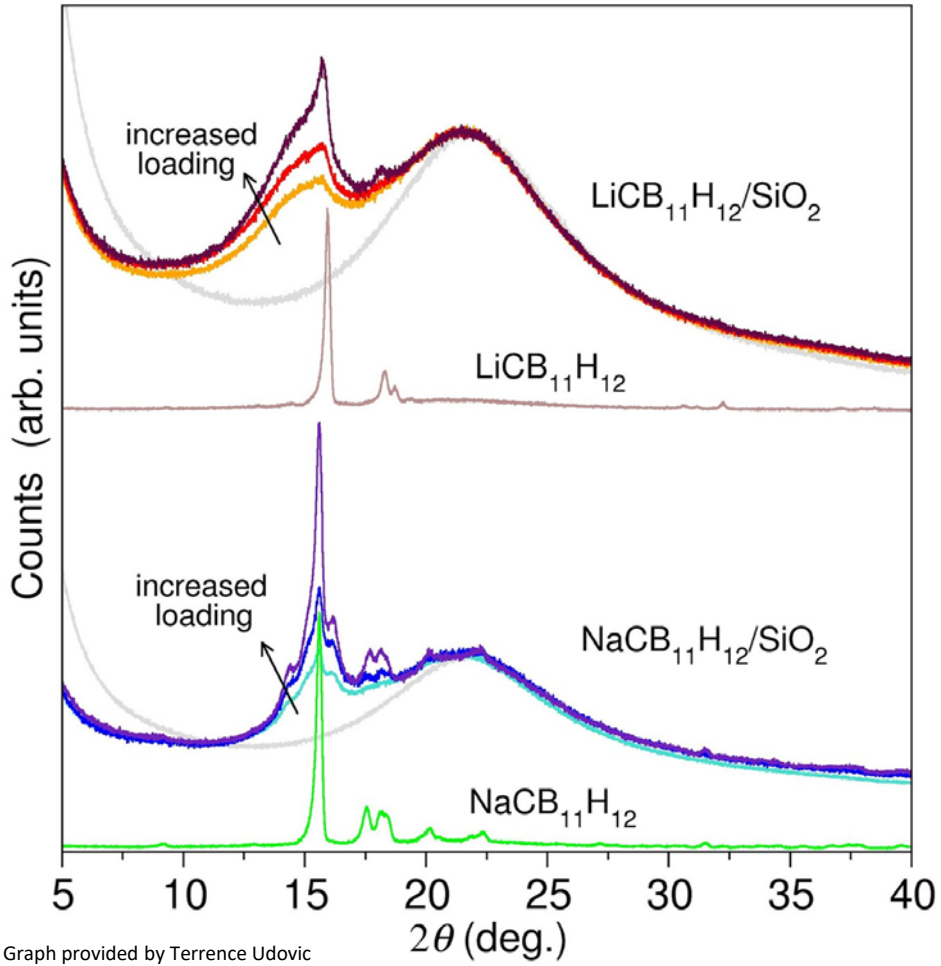




Speed of anion rotation over temperature range



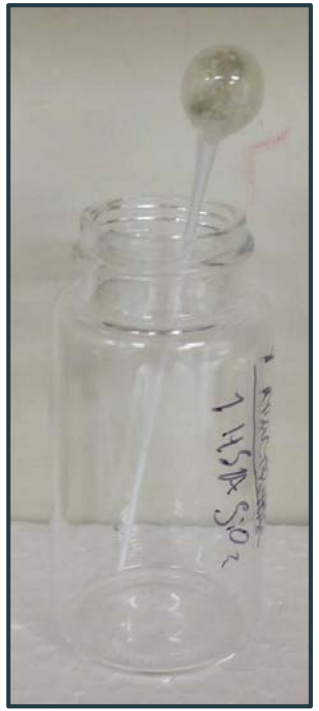
X-ray Crystallography



Graph provided by Terrence Udovic

1.5 Li-- : 1 HSA
1.2 Li-- : 1 HSA
1 Li-- : 1 HSA
$LiCB_{11}H_{12}$ hydrate

1.8 Na-- : 1 HSA
1.2 Na-- : 1 HSA
1 Na-- : 1 HSA
$NaCB_{11}H_{12}$ hydrate



True test: Conductivity

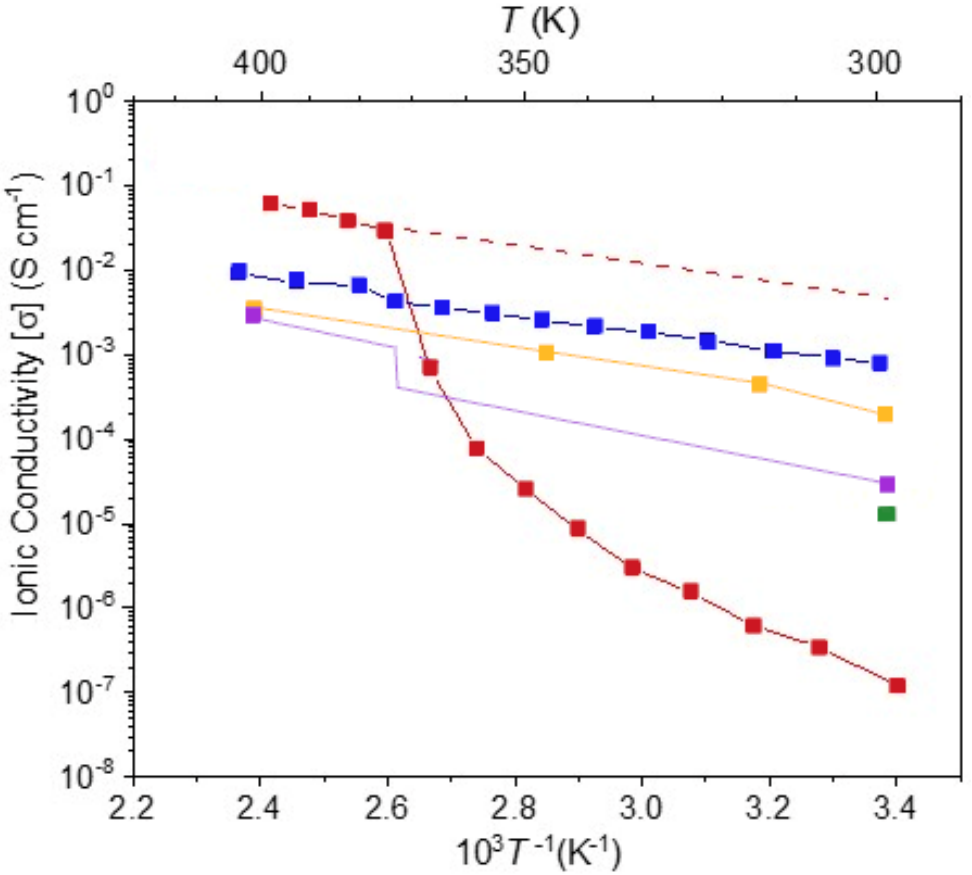
Blue = $NaCB_{11}H_{12}$ in SBA-15 with 8nm pores

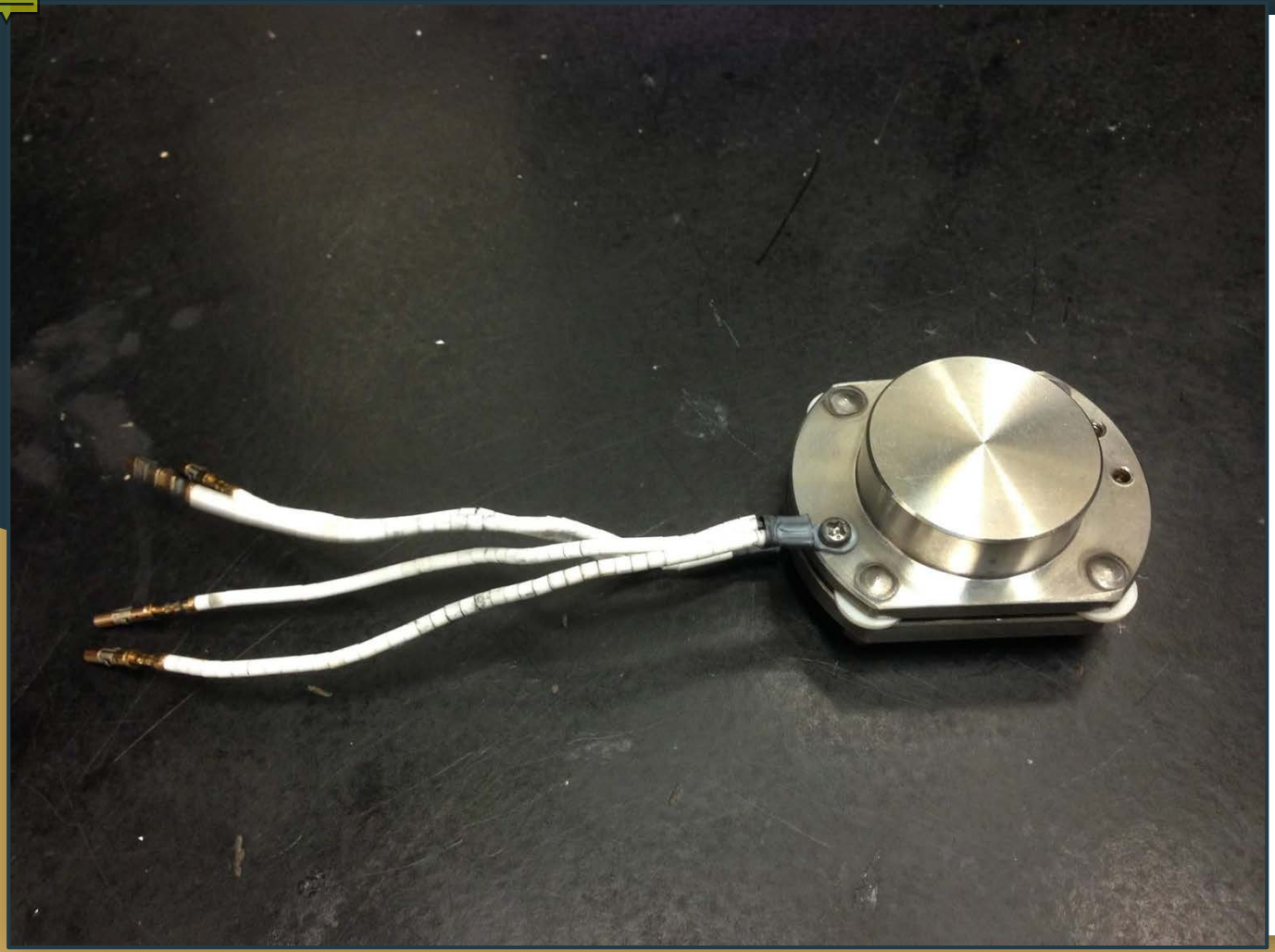
Red = $NaCB_{11}H_{12}$

Green = Once-filled porous SiO_2 disk

Orange = 1.5 µL solution $NaCB_{11}H_{12}$ / 1 mg HSA SiO_2

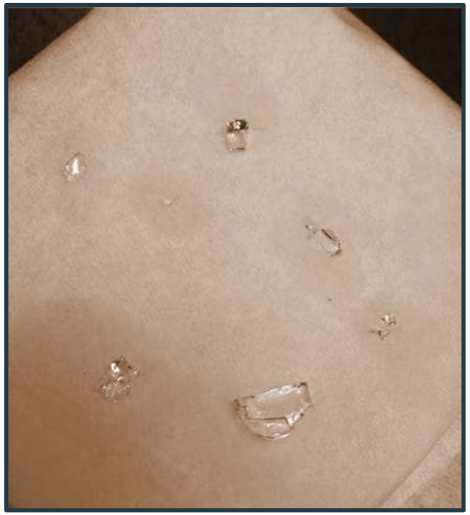
Purple = 1.8 µL solution $NaCB_{11}H_{12}$ / 1 mg HSA SiO_2





Possible Next Steps

- Measure conductivity of more samples
  - Loading samples more than once
  - 12nm SBA-15
  - More durable SiO_2 disks
- More compressive force on HSA SiO_2
- Different system for measuring conductivity - larger temperature range
- Looking at filled silica under microscope



References & Thank You

Terrence Udovic

Mikael Anderson

Juscelino Leão

- Dimitrievska M, Shea P, Kweon K, Bercx M, Varley J, Tang W, Skripov A, Stavila V, Udovic T, Wood B. 2018. Carbon Incorporation and Anion Dynamics as Synergistic Drivers for Ultrafast Diffusion in Superionic $LiCB_{11}H_{12}$ and $NaCB_{11}H_{12}$. Advanced Energy Materials. 8(15):1703246.
- Tang W, Unemoto A, Zhou W, Stavila V, Matsuo M, Wu H, Orimo S, Udovic T. 2015. Unparalleled lithium and sodium superionic conduction in solid electrolytes with large monovalent cage-like anions. Energy & Environmental Science. 8(12):3637-3645