DEVELOPING A SOLID ELECTROLYTE BY INFILTRATING NANOPOROUS SILICA WITH $NaCB_{11}H_{12}$

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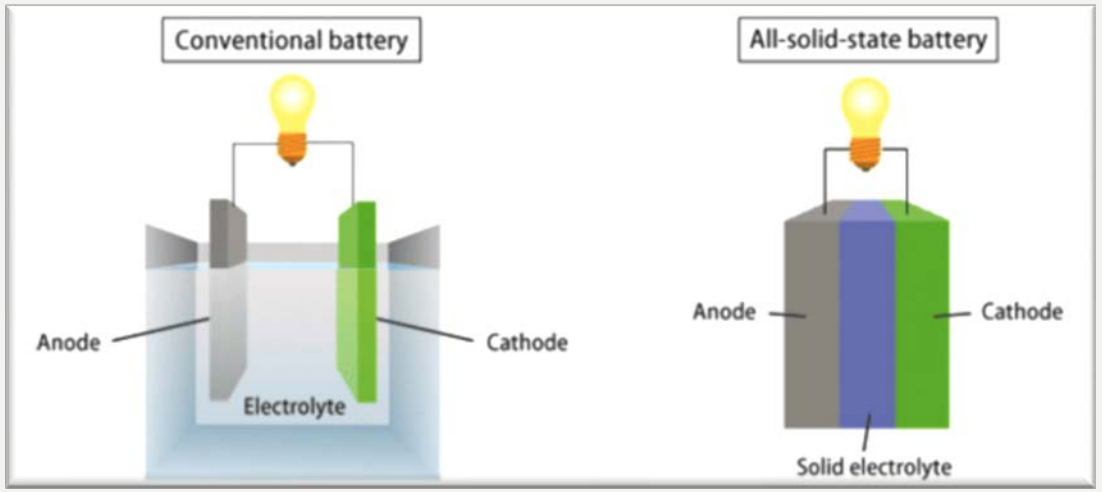
SOLID ELECTROLYTE BATTERIES

- No liquid between anode and cathode
- Conduct electricity through electrolytes
  - Possible solid electrolytes: Sodium salts
- Safer than liquid electrolyte batteries
  - not flammable
  - don't spill: don't damage device
  - don't produce HF

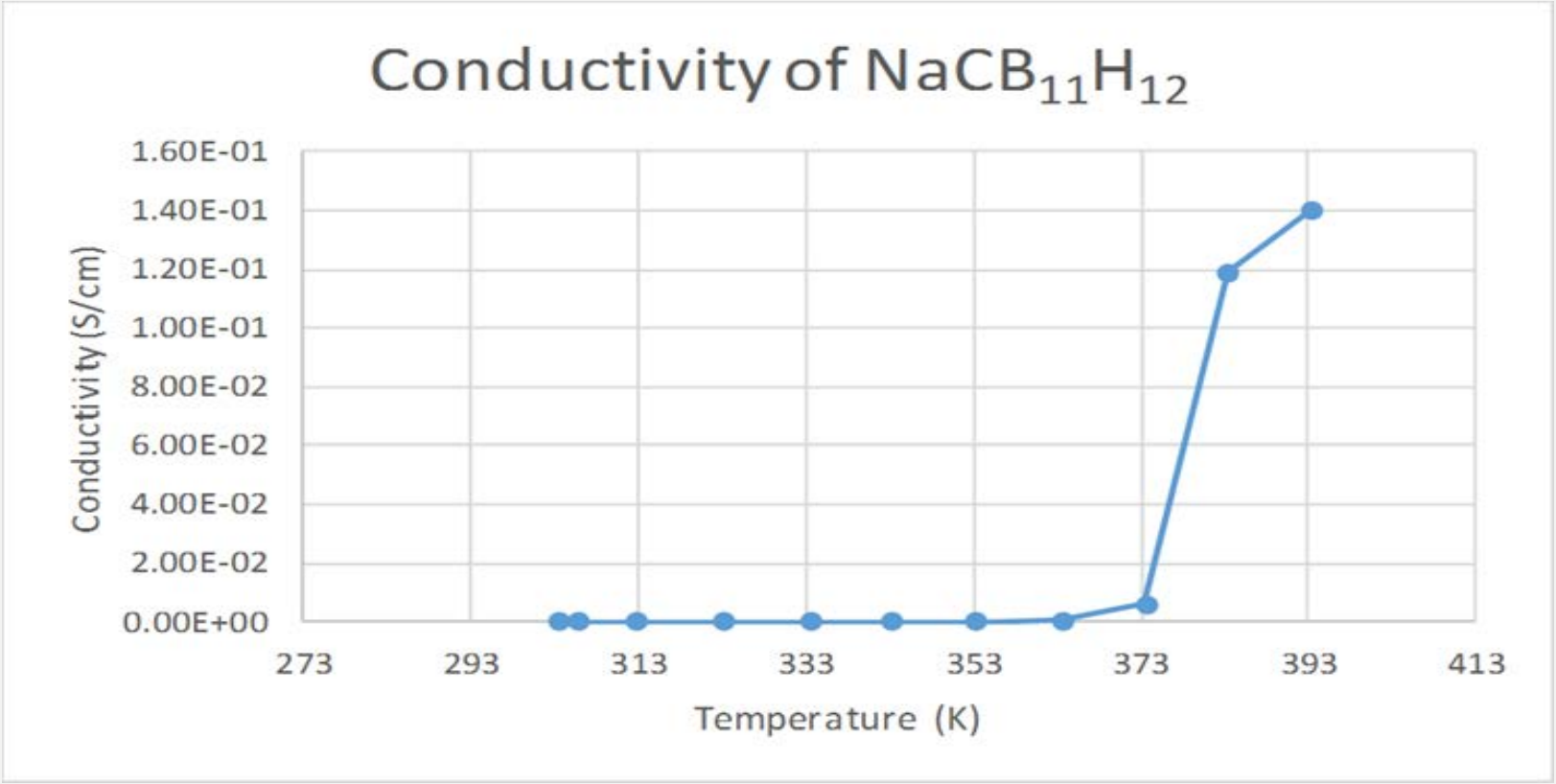


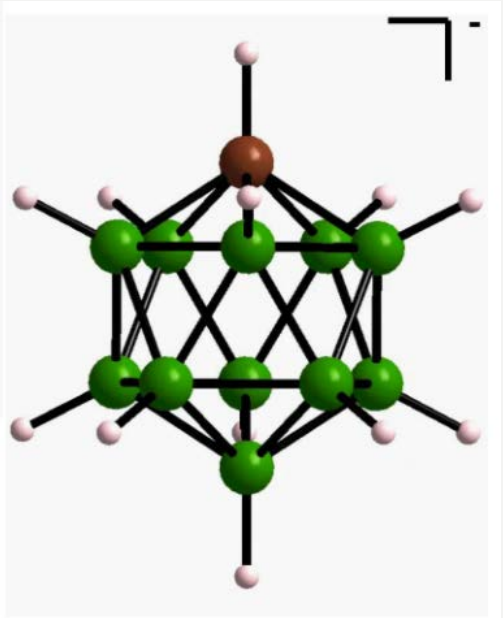
http://www.androidauthority.com

Samsung Galaxy Note 7

Solid electrolyte: $NaCB_{11}H_{12}$

- Possible solid conductor: $NaCB_{11}H_{12}$
- Need a disordered state to conduct
  - State transition occurs around 110˚c (383K)
    - Too high temperature to be useful
- Salt + nonporous silica = conductive material at rt?





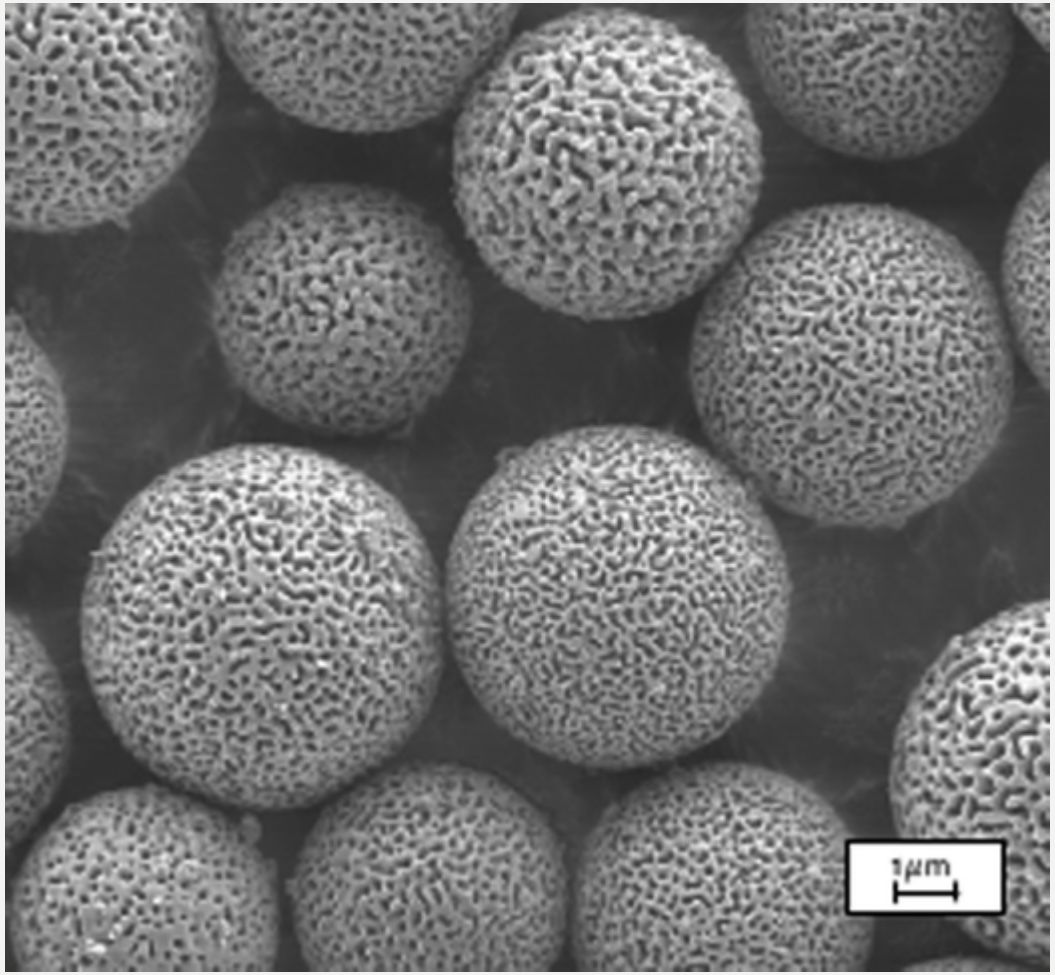
$CB_{11}H_{12}^-$

NANOPOROUS SILICA: SBA-15

- Silica (SiO_2) that has very small (8nm) pores
- Putting salt in nanopores is a form of nanosizing
  - Changes behavior: no bulk behavior

http://www.nature.com

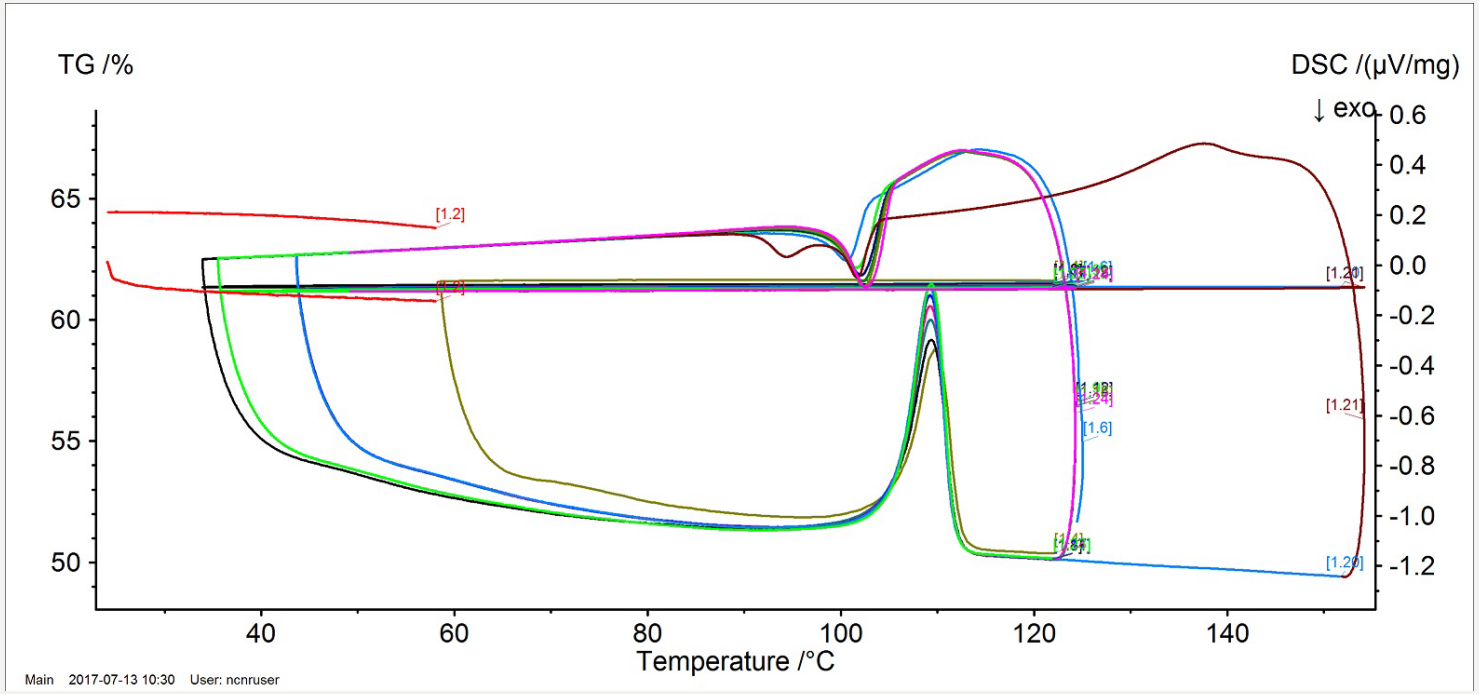
http://pubs.rsc.org



Nanoporous silica under a Scanning Electron Microscope

DIFFERENTIAL SCANNING CALORIMETRY (DSC)

- Increases temperature of substance at a constant rate
- Needs more heat during order-disorder transition
  - Phase change shows up as peak

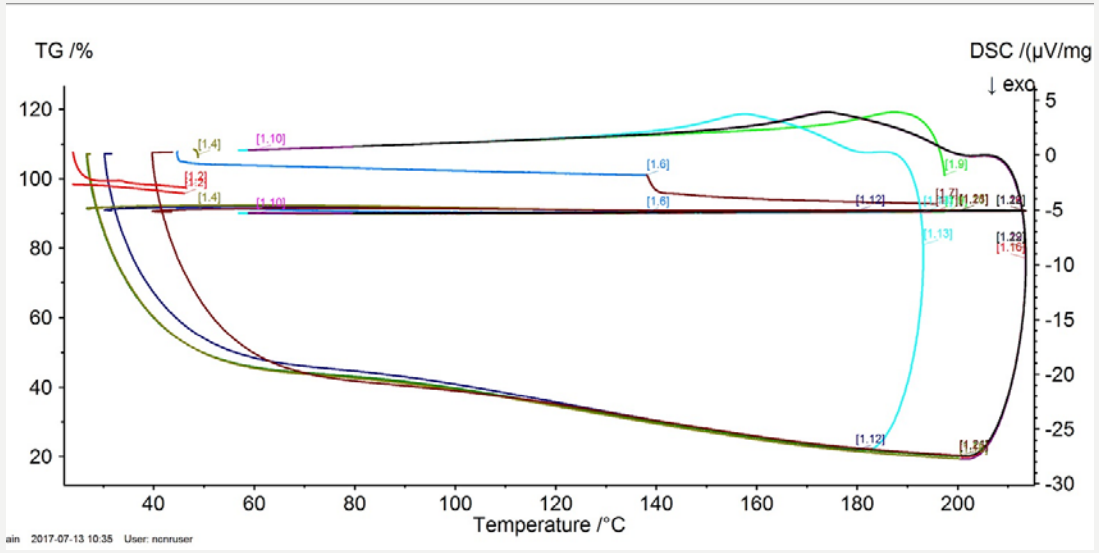


DSC graph for wet sample of $NaCB_{11}H_{12}$

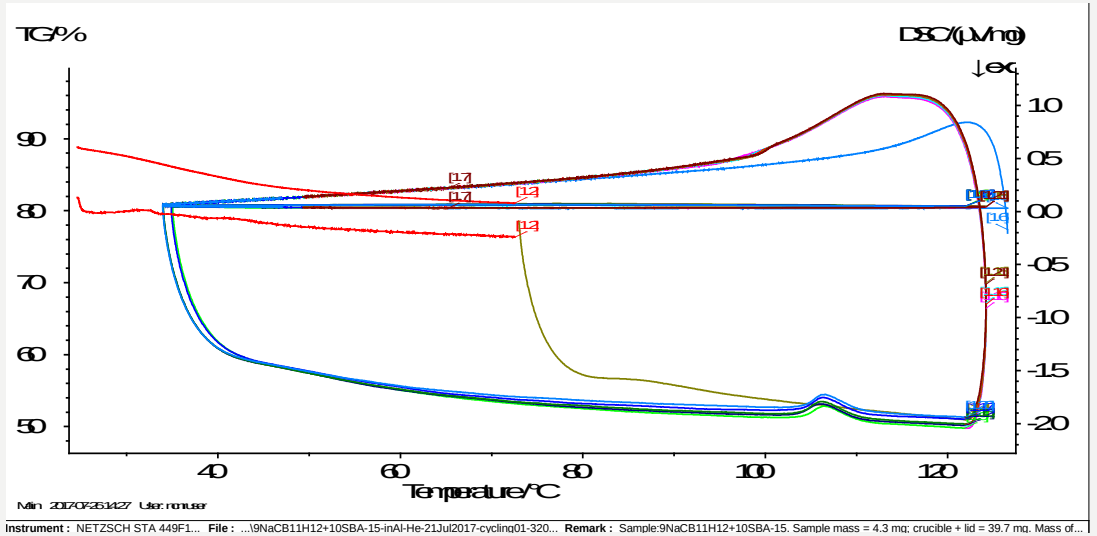
MAKING THE SAMPLES

- Mixed saturated solution of $NaCB_{11}H_{12}$ with SBA-15
  - Solution concentration:
    143g $NaCB_{11}H_{12}$/100g H_2O
  - Various mass ratios
- Tested each with DSC

9:10 $NaCB_{11}H_{12}$:SBA-15 sample



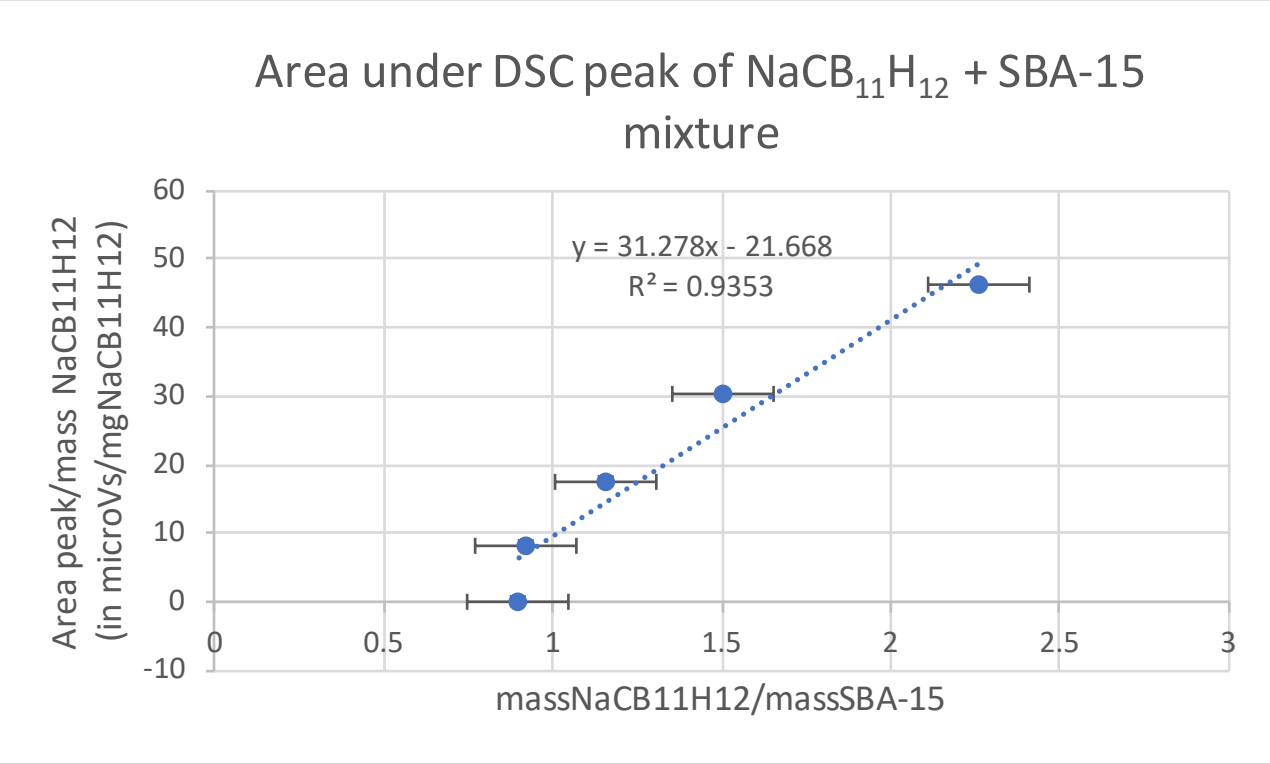
DSC graph for $NaCB_{11}H_{12}$:SBA-15 sample (9:10, w/w)



DSC graph for $NaCB_{11}H_{12}$:SBA-15 sample (11:12, w/w)

MASS RATIO ⇒ PEAK AREA

- Increased area under peak = increased transition energy
  - Amount of $NaCB_{11}H_{12}$ (relative to silica) directly proportional with peak area
- Phase change = bulk behavior
  - Require maximum salt without bulk behavior



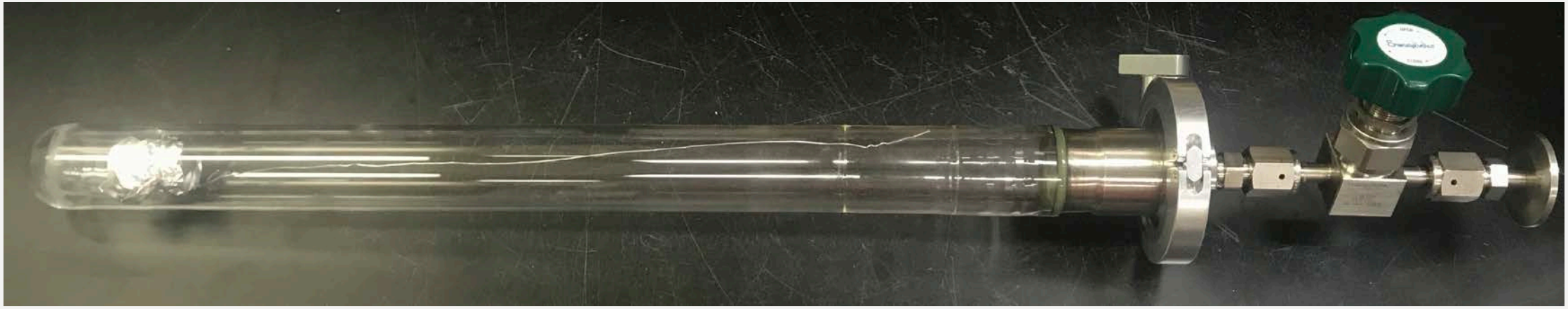
Ratio by mass	massNaCB11H12/ massSBA-15	Area under peak
1:0	undefined	45.76
9:4	2.26	46.19
3:2	1.5	30.33
7:6	1.16	17.6
11:12	0.919	8.321
9:10	0.9	0

MEASURING CONDUCTIVITY: SET UP

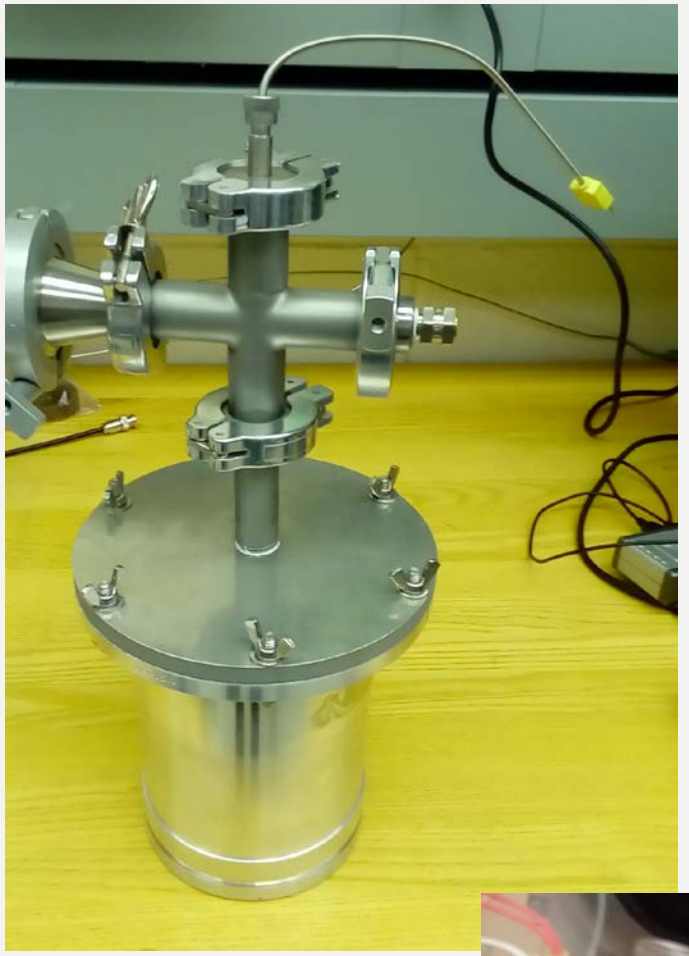
3 zone tube furnace

- Electrolytic cell allows for conductivity testing
- Need to make pellet to put into cell
  - Pelletizer presses molecules close together
- Larger batch to make pellet
  - Needs to be dry—quartz vacuum tube

quartz vacuum tube



Photos by Erin Huang

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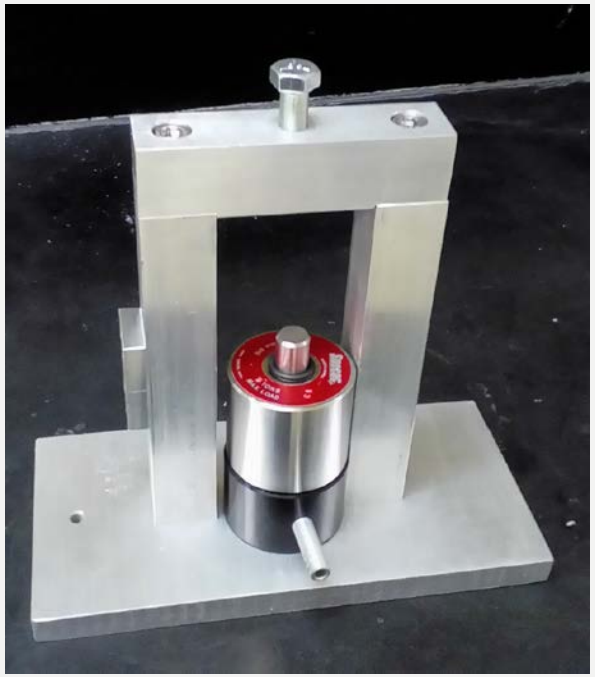
MEASURING CONDUCTIVITY

- Pelletized sample put into electrolytic cell
- Cell heated and cooled
  - 273K - 423K (0˚c - 150 ˚c)
- Conductivity measured over temperature range

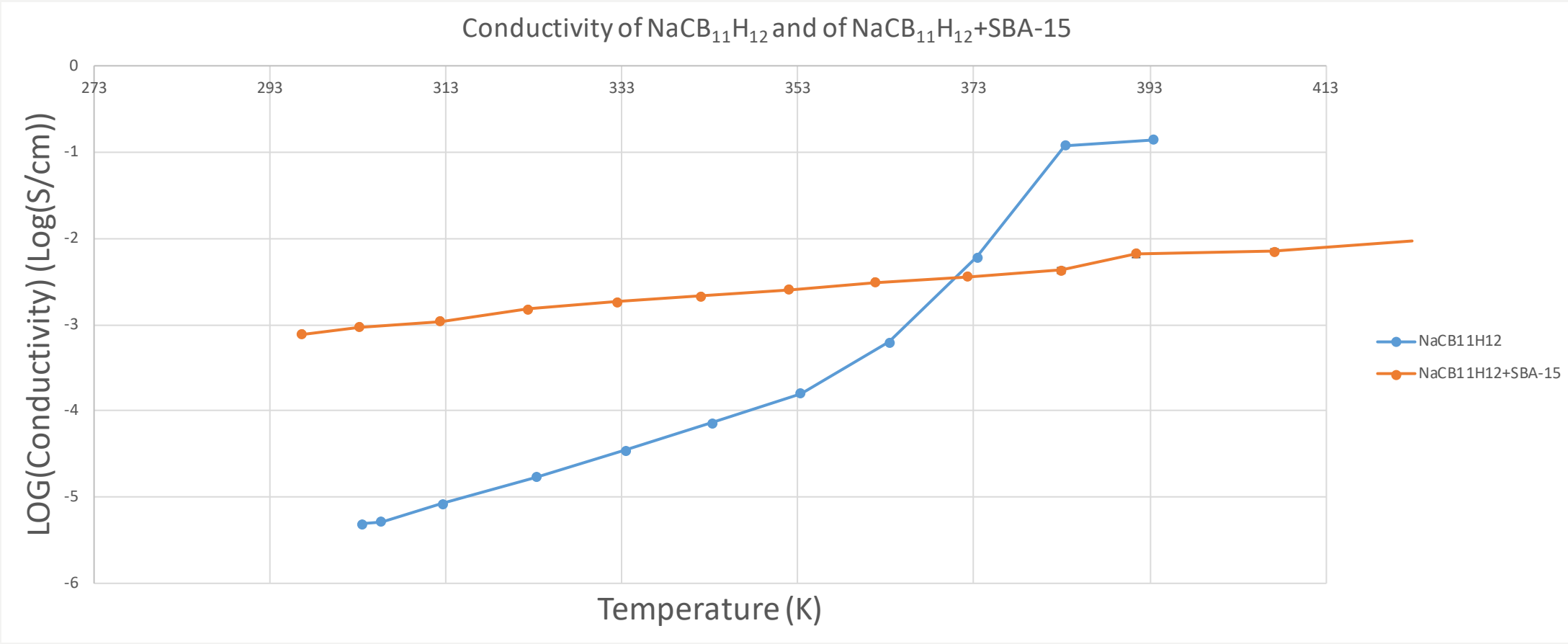


pelletizer

Electrolytic cell

RESULTS

- Electrochemical Impedance Spectroscopy
  - Conductivity can be calculated from impedance
- Conductivity of new mixture v. conductivity of pure $NaCB_{11}H_{12}$
  - **2 orders of magnitude more conductive at room temperature**



CONCLUSION:

- $NaCB_{11}H_{12}$ below 110°c (383K) → poor conductivity
- $NaCB_{11}H_{12}$ above 110°c (383K) → very high conductivity
- $NaCB_{11}H_{12}$ combined with SBA-15 at room temperature → conducts 100x than pure $NaCB_{11}H_{12}$
  - conductivity stays relatively constant form 293-413K.

NEXT STEPS:

- Test conductivity of pure SBA-15
- Test conductivity of $NaCB_{11}H_{12}$+SBA-15 in different proportions
- Use 4nm porous silica instead of 8nm porous silica (SBA-15)
- Add oversaturated solution to silica again after drying

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