



Synthesis of $\text{AlO}(\text{OH})$ Boehmite Nanoparticles

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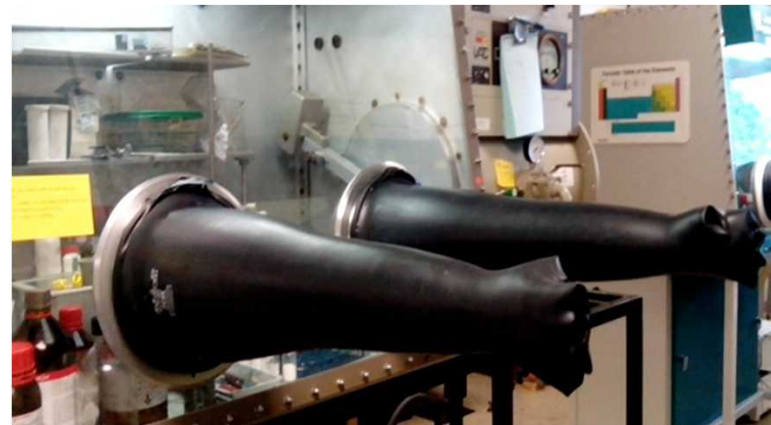
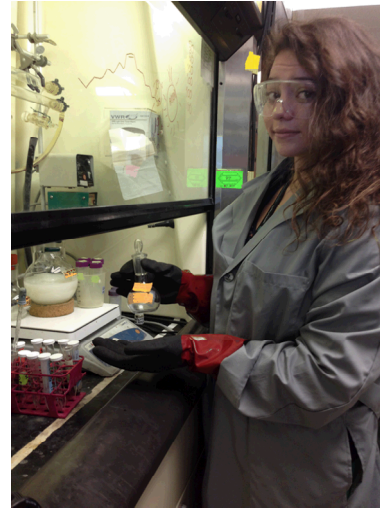
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Safety Training

- NANO100 – Nanotechnology Safety Awareness
- Facilities Operations Notebook (FON)
- CHM 100 – Chemical Safety
- CHM 103 – Site Specific Chemical Safety
- BEA 100 – Beryllium Awareness
- Material Safety Data Sheets (MSDS)
- ESH 100 – Environmental Safety and Health Awareness
- ENV 112 – Hazardous Waste and Environmental Management
- Cryogen Safety
- Pressure Safety Orientation



Boehmite ($\text{AlO}(\text{OH})$) Applications

Mineral found in nature

Electronics



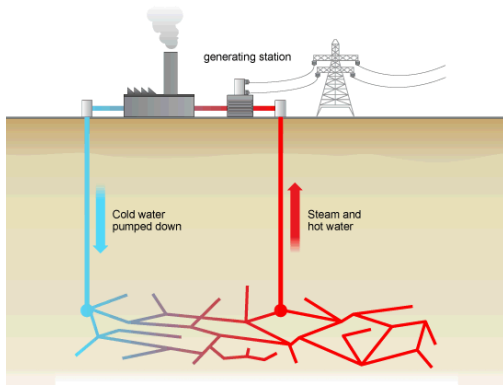
Chemical Coatings



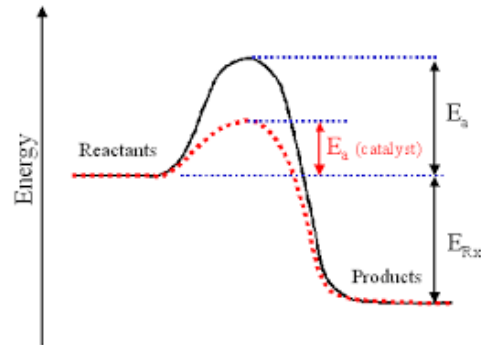
Porosity



Geothermal



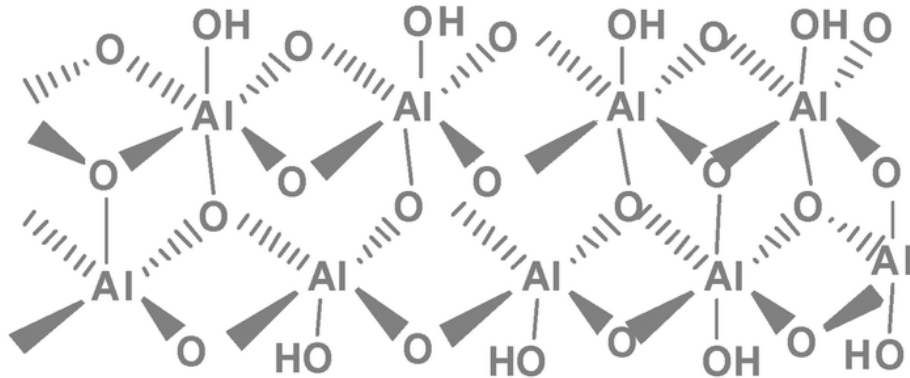
Catalyst



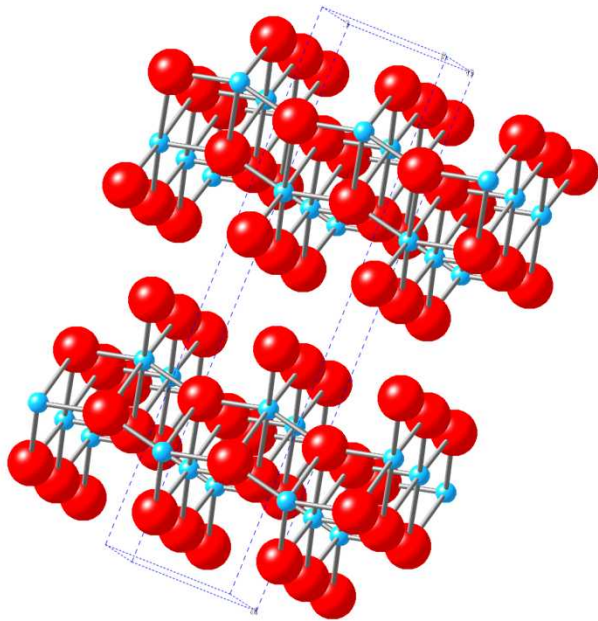
Mechanical Strength



Structure of Boehmite $[\text{AlO}(\text{OH})]$



- Octahedral Layers
- Orthorhombic Dipyramidal

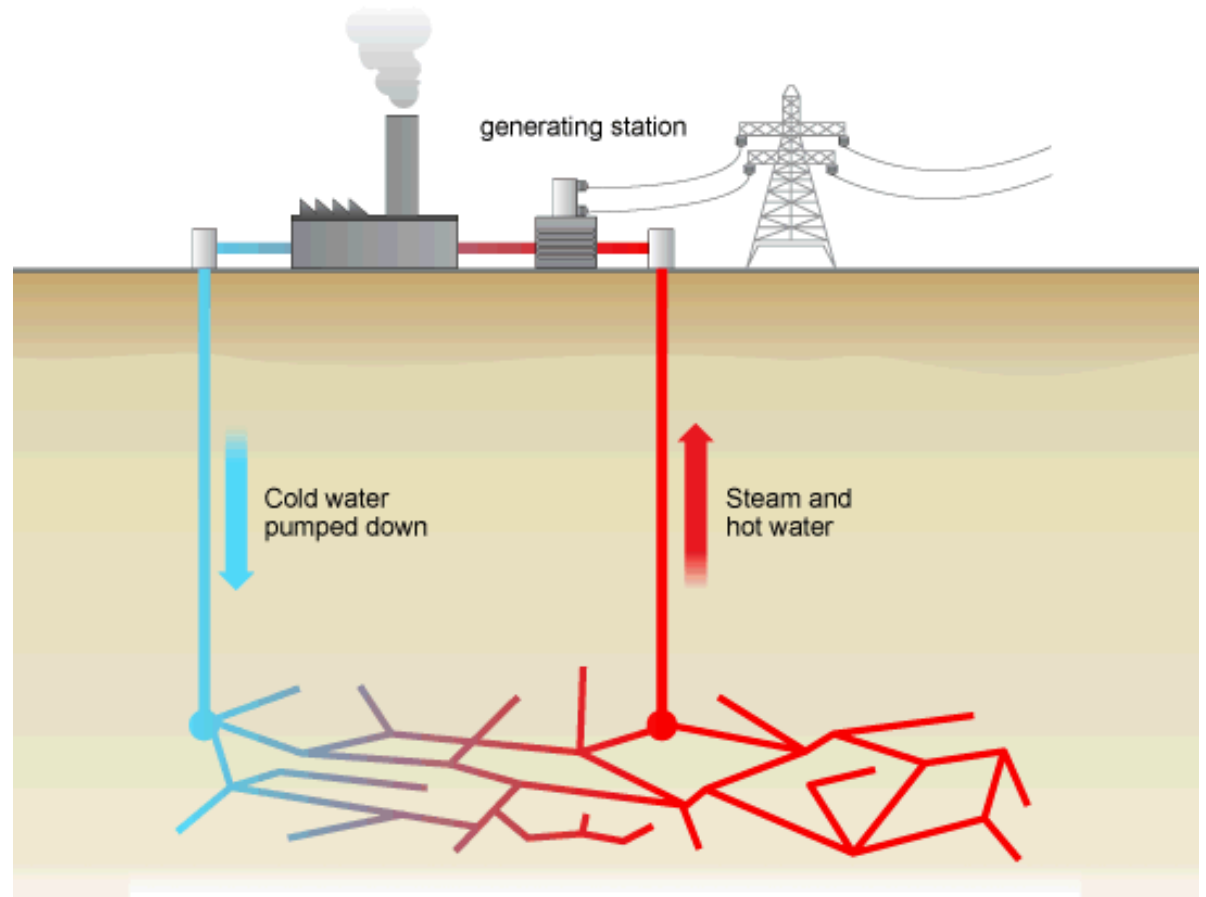


Aluminum 
Oxygen 



Geothermal Energy

- Benefits
 - Renewable
 - Abundant Supply
 - Dependable
- Drawbacks
 - Expensive
 - Drilling is Difficult
 - Location Specific
- Solutions
 - Efficiency
 - Use of Proppants

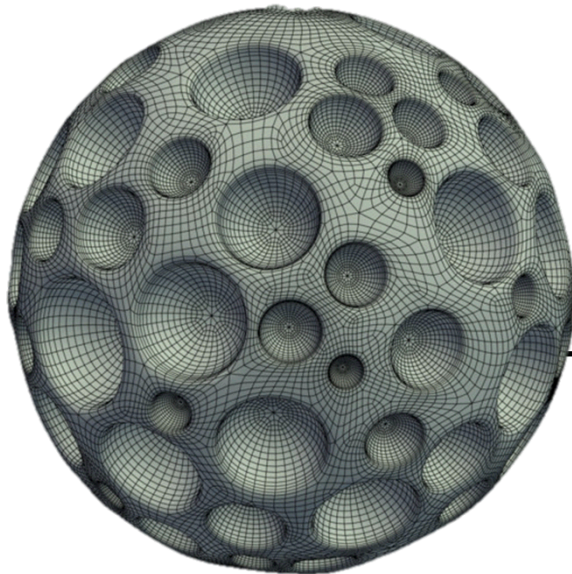


How does fluid flow underground?

Tagged Nanoparticle Proppants

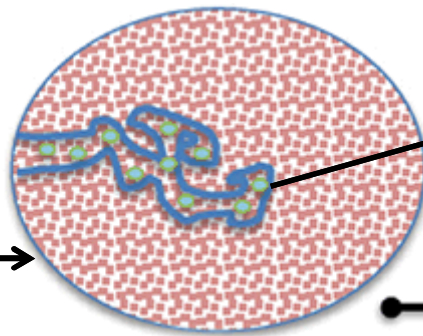
$$1 \text{ Nanometer} = \frac{1}{1,000,000,000} \text{ Meter}$$

Proppant



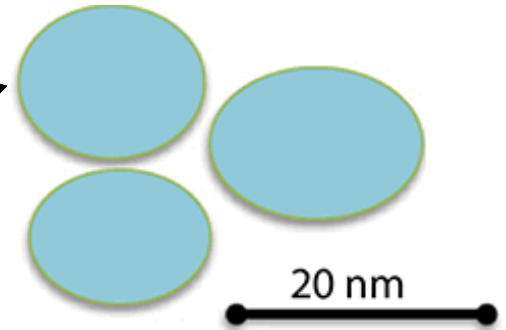
1 mm

Pore of Proppant



5 μm

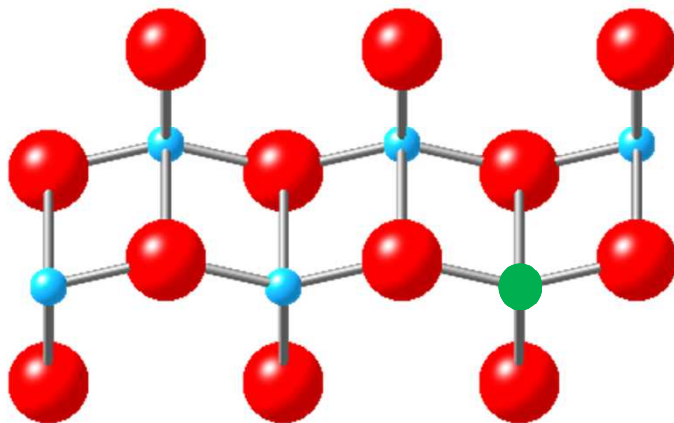
Nanoparticles



20 nm

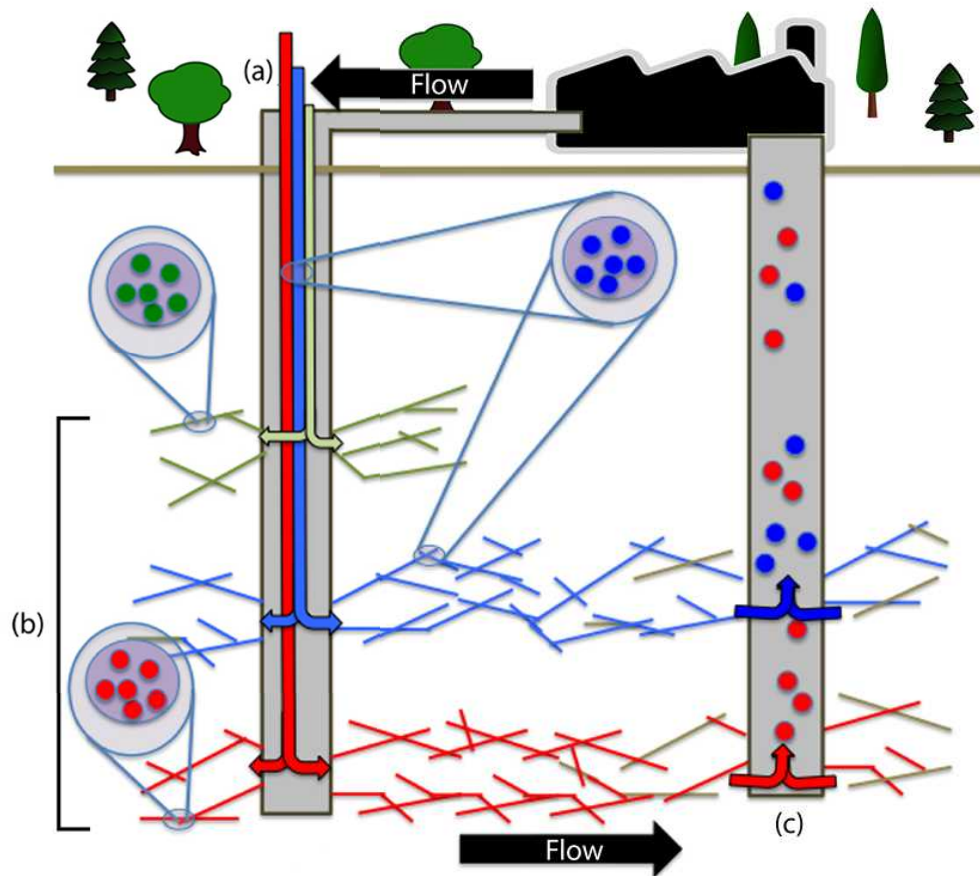
Doping Nanoparticles

- Doping Boehmite with lanthanides
- Use for nanoparticle tracking



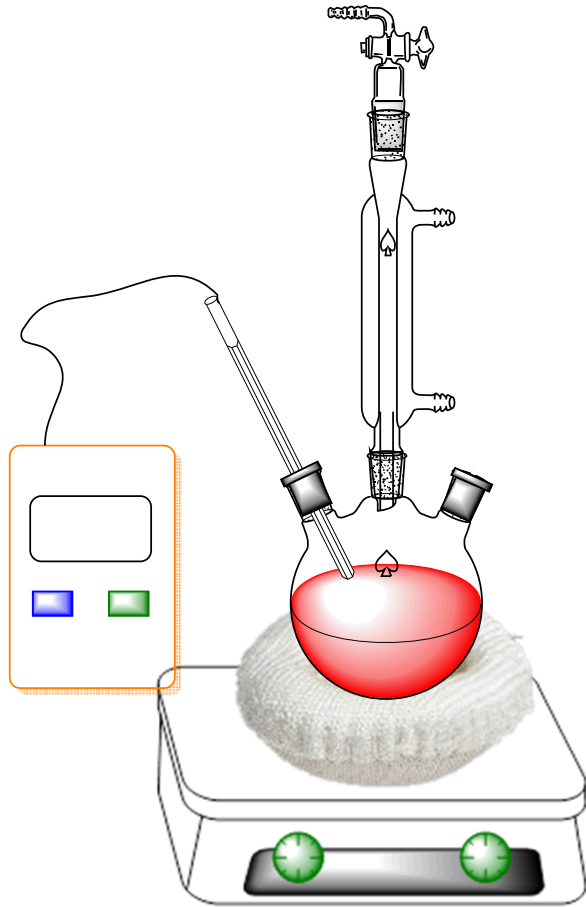
Ce - 101 pm
Lu - 86.1 pm
Al - 53.5 pm
(Shannon-Prewitt)

http://www.knowledgedoor.com/2/elements_handbook/shannon-prewitt_effective_ionic_radius_part_3.html#oxygen



Reaction Methods

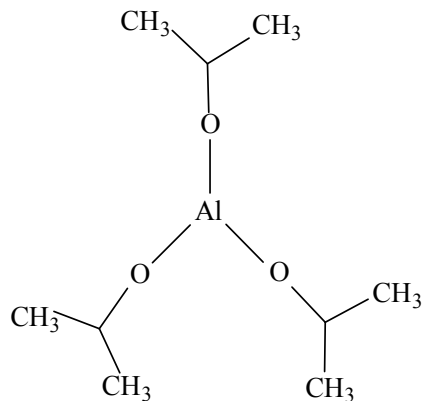
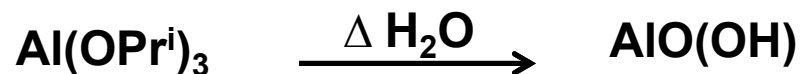
Solution Precipitation (SPPT)



Solvothermal



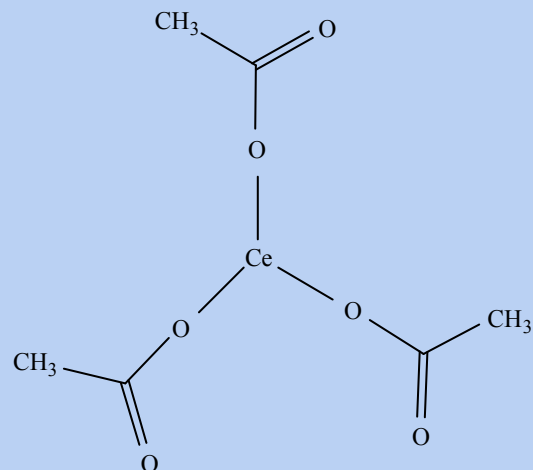
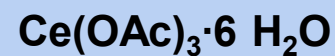
General Reaction Route



Aluminum Isopropoxide

Cerium Acetate Hydrate

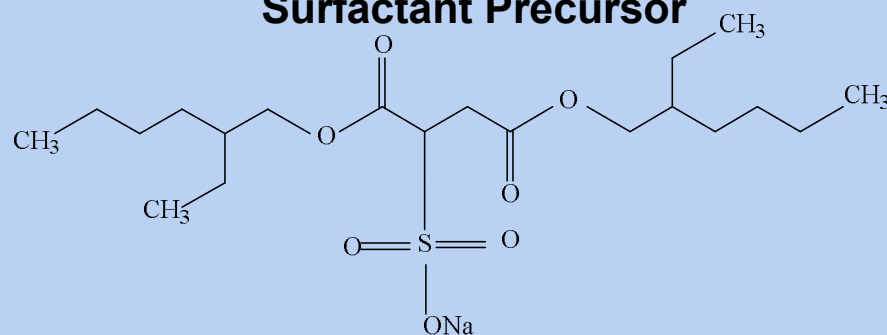
Dopant precursor



Diethylsulfosuccinate Sodium Salt

NaAOT

Surfactant Precursor



Characterization

Powder X-ray Diffraction (PXRD)

-confirm a product by finding its crystal structure and phase



Transmission Electron Microscopy (TEM)

-used to find shape and size of nanoparticles



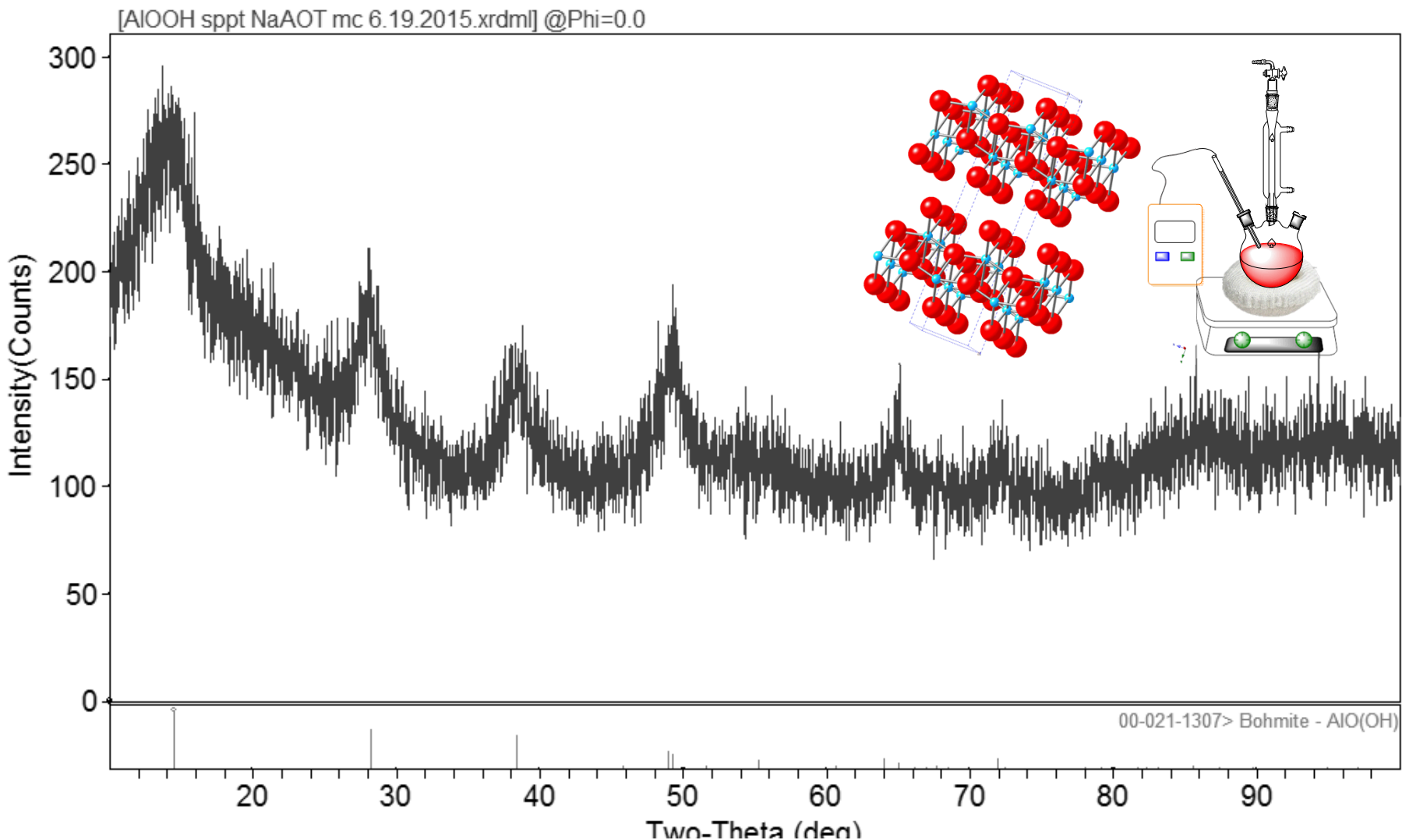
Fourier Transform Infrared Spectroscopy (FTIR)

-used to identify bonds within a structure



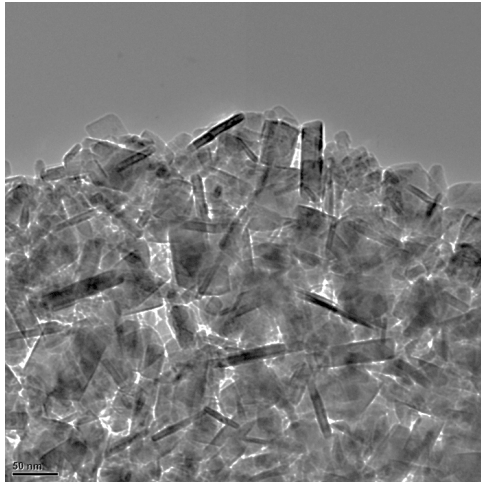
PXRD Examples

AlO(OH) w/NaAOT SPPT 48hrs at 94.5°C

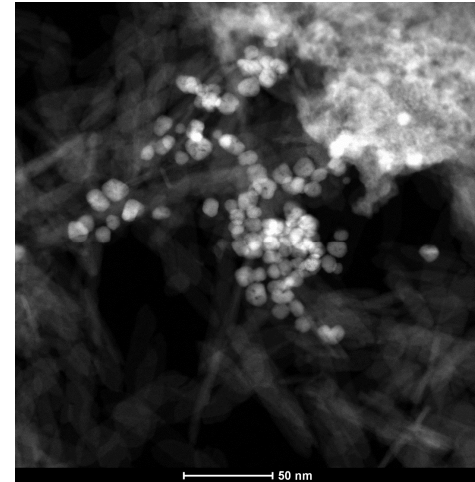


TEM Examples:

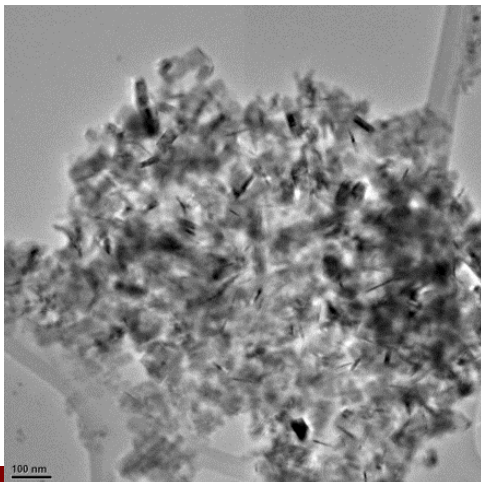
AlO(OH) I 24hrs



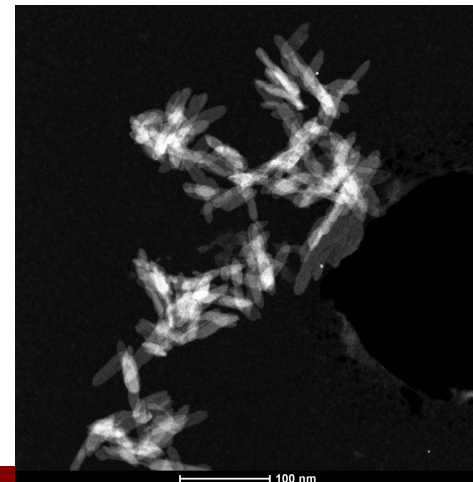
AlO(OH):Ce 10% 24hrs



AlO(OH) I 12hrs

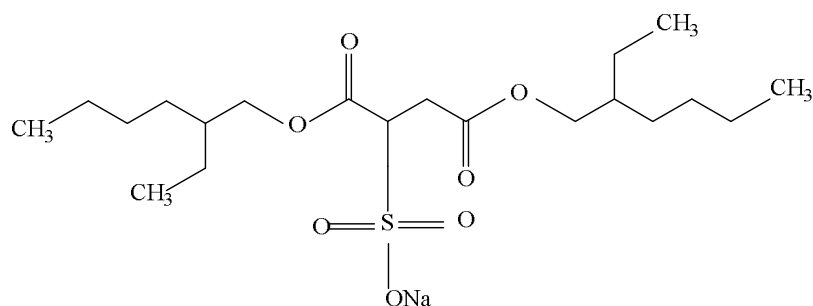


AlO(OH): Lu 10% I 24hrs at 180°C

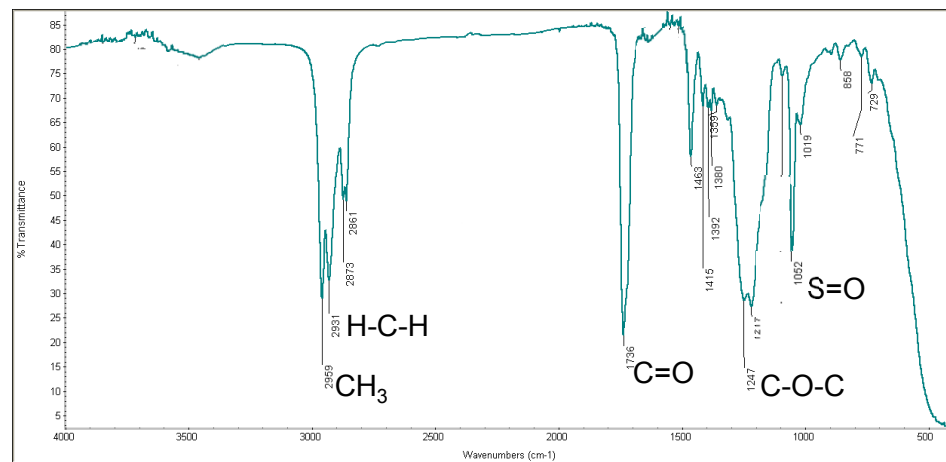


Fourier Transform Infrared Spectroscopy (FTIR)

NaAOT

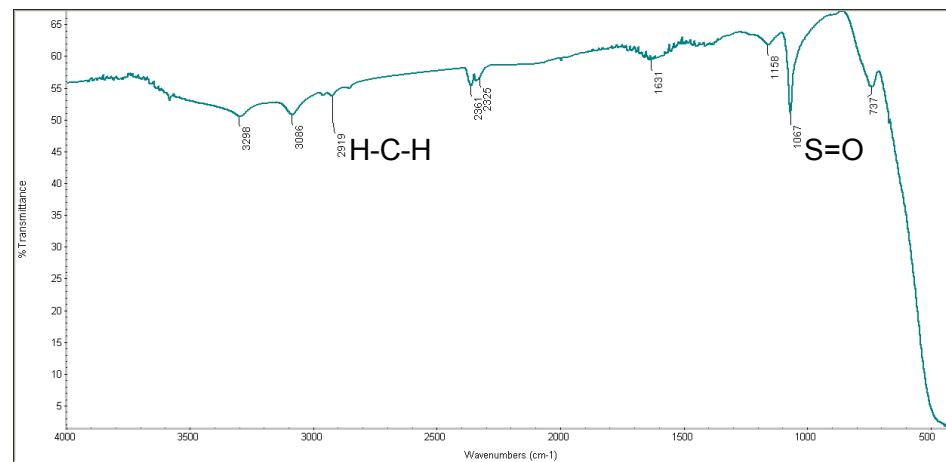
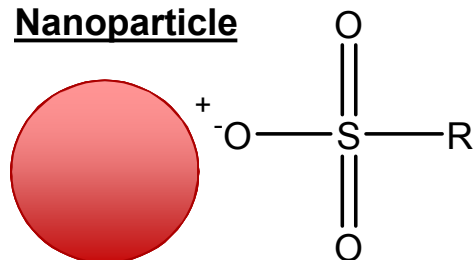


NaAOT "neat"



AlO(OH):Ce 10% Solvothermal 24hrs

Nanoparticle



What I Learned

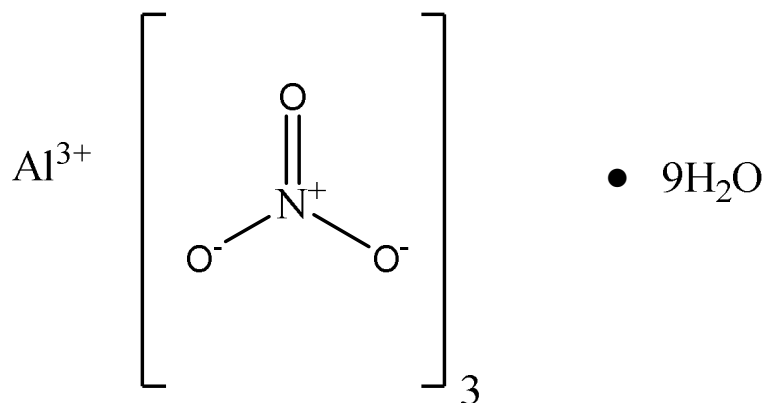
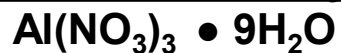
- Boehmite has an orthorhombic dipyramidal structure with octahedral layers
- NaAOT didn't play a role in the reaction
- DI water worked best as a solvent
- Time as well as temperature is a huge factor to Boehmite morphology
- The atomic radii ratio difference may be why we were not successful



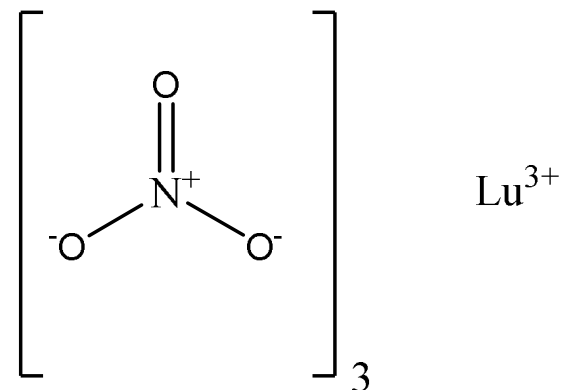
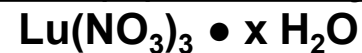
Questions?

Precursors

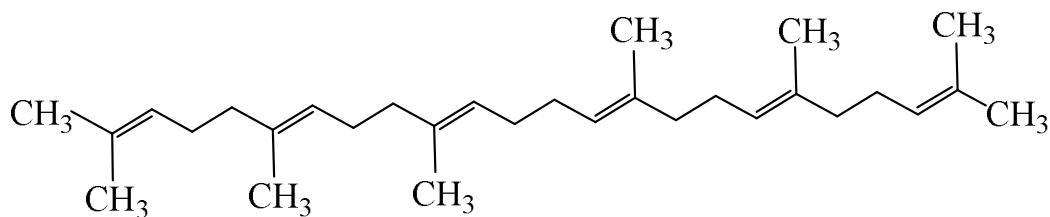
Aluminum Nitrate Nonahydrate



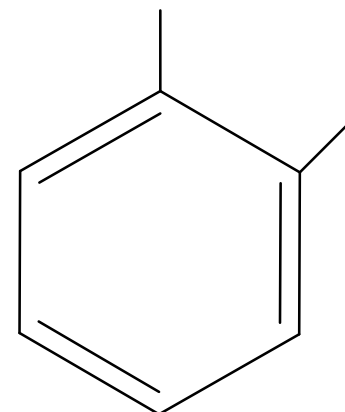
Lutetium (III) Nitrate Hydrate



Squalene [C₃₀H₅₀]

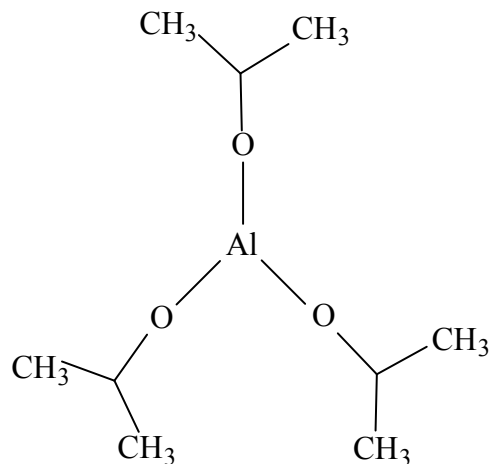


Xylene [C₈H₁₀]

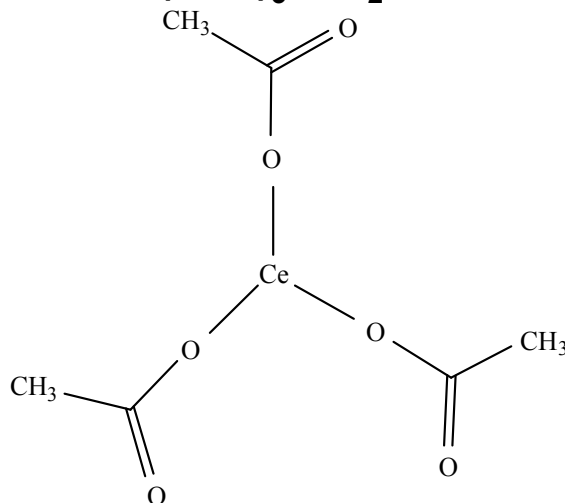
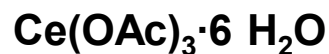


Precursors

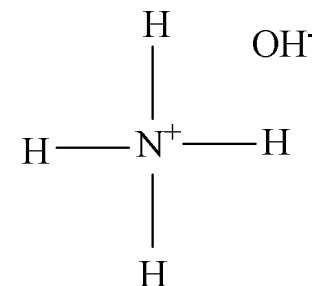
Aluminum Isopropoxide



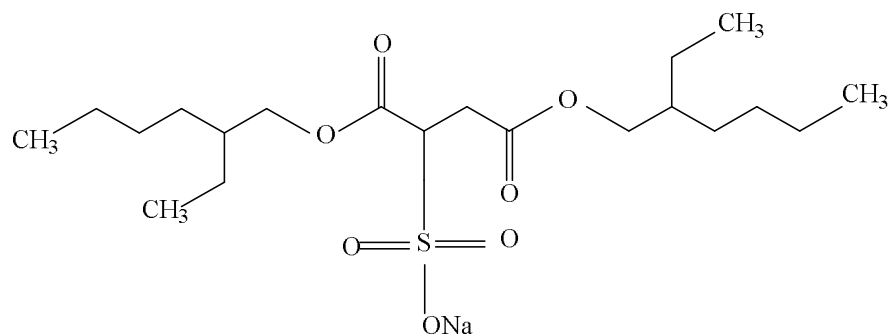
Cerium Acetate Hydrate



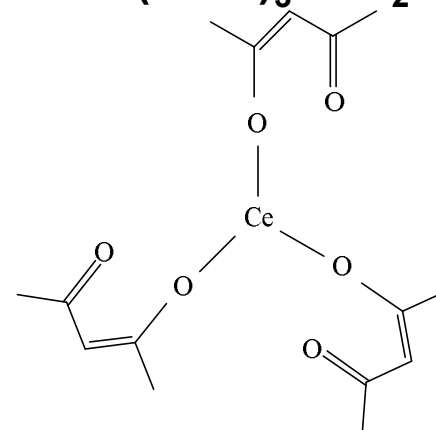
Ammonium Hydroxide



Diocylsufosuccinate Sodium Salt **NaAOT**



Cerium (III) Acetylacetonate Hydrate $\text{Ce}(\text{acac})_3 \cdot x \text{H}_2\text{O}$



Synthesis of Boehmite [AlO(OH)]

Precursors	Solvent	Time	Temperature(°C)	Method	Boehmite?
Al(OPri) ₃ + Na(AOT)	H ₂ O	48hrs	94.5	SPPT	Yes (PXRD)
Al(OPri) ₃	H ₂ O	24hrs	180	Solvothermal	Yes (PXRD / TEM)
Al(OPri) ₃	H ₂ O	12hrs	180	Solvothermal	Yes (PXRD / TEM)
Al(OPri) ₃	H ₂ O	48hrs	94.5	SPPT	Yes (PXRD)
Al(OPri) ₃	Oleic Acid	1hr	195	SPPT	No (PXRD)
Al(OPri) ₃	C ₃₀ H ₅₀	1hr	285	SPPT	
Al(OPri) ₃	H ₂ O+ C ₈ H ₁₀	1hr	94.5	SPPT	Yes (PXRD)
Al(NO ₃) ₃	H ₂ O + C ₈ H ₁₀	1hr	94.5	SPPT	No (PXRD)
Al(NO ₃) ₃	H ₂ O + C ₃₀ H ₅₀	2hrs	120	SPPT	No (PXRD)

Boehmite Doping

Precursor	Solvent	Time	Temp. (°C)	Method	Boehmite?	Doped?
$0.95\text{Al}(\text{OPri})_3 + 0.05\text{Ce}(\text{OAc})_2 + \text{NaAOT}$	H_2O	24hr	190	Solvothermal	Yes (PXRD)	No (PXRD)
$0.9\text{Al}(\text{OPri})_3 + 0.1\text{Ce}(\text{OAc})_2 + \text{NaAOT}$	H_2O	24hrs	190	Solvothermal	Yes (PXRD)	Cerium Oxide (PXRD)
$0.9\text{Al}(\text{OPri})_3 + 0.1\text{Ce}(\text{OAc})_2 + \text{NaAOT}$	H_2O	48hrs	94.5	SPPT	No (PXRD)	No (PXRD)
$0.9\text{Al}(\text{OPri})_3 + 0.1\text{Ce}(\text{acac}) + \text{NaAOT}$	H_2O	48hrs	94.5	SPPT	Yes (PXRD)	Cerium Oxide (PXRD)
$0.9\text{Al}(\text{OPri})_3 + 0.1\text{Ce}(\text{acac}) + \text{NaAOT}$	H_2O	24hrs	190	Solvothermal	Yes (PXRD)	Cerium Oxide (PXRD / TEM)
$0.9\text{Al}(\text{OPri})_3 + 0.1\text{Lu}(\text{NO}_3)_3 + \text{NaAOT}$	H_2O	24hrs	190	Solvothermal	Yes (PXRD)	No (PXRD)
$0.95\text{Al}(\text{OPri})_3 + 0.05\text{Lu}(\text{NO}_3)_3 + \text{NaAOT}$	H_2O	24hrs	190	Solvothermal	Yes (PXRD)	No (PXRD)