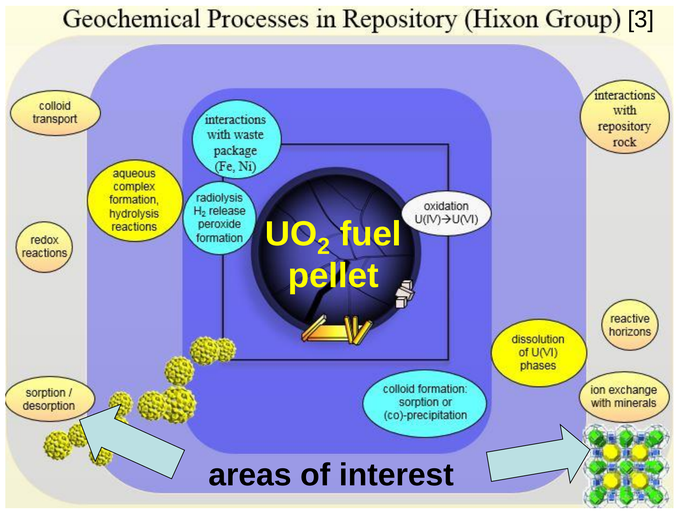
Radioactivity in the Environment

Characterizing minerals and modeling their interaction with radionuclides

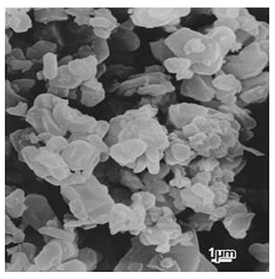
John Gensic,[1,2] Teresa Baumer,[2] Amy Hixon[2]
[1]Penn HS, [2]University of Notre Dame RET

Introduction and Goals of Research

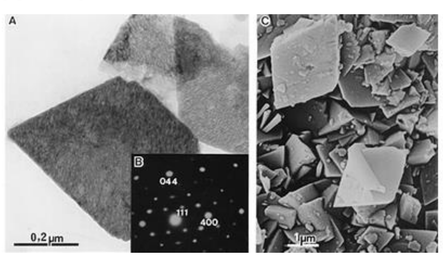
- Learn more about interaction between radioactive elements and the environment
- Characterize minerals in the environment: alpha alumina α-Al_2O_3, gamma alumina γ-Al_2O_3, gibbsite $Al(OH)_3$, and bayerite α-$Al(OH)_3$
- Model interaction of minerals and radioactive elements
- Europium used as an analog for plutonium because the two species can share a common oxidation state of +3
- Accurate surface areas of minerals were determined in order for experiments to control for reactive sites



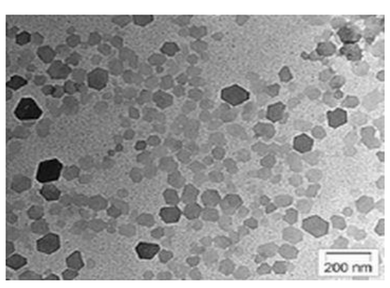
minerals to characterize…



SEM of alpha alumina (Al_2O_3) [1]



Gamma Al_2O_3 A. TEM; B. selected area electron diffraction pattern; C. SEM [1]



TEM image of gibbsite $Al(OH)_3$ [2]

Methods

surface area determination of the minerals to normalize future sorption

dry in oven: 1-2 g of sample 24 h @100 C

degas: pull vacuum over sample 8-24 h

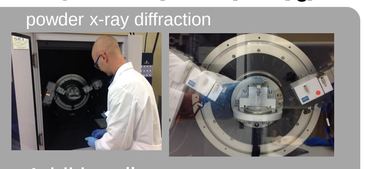
analyze surface area

hydrate mineral γ-Al_2O_3 in different pH's to study transition to bayerite (α-$Al(OH)_3$)

hydrate mineral: ~0.200 g γ Al_2O_3; 0.1 M NaCl; 4 samples at pH 3; 4 samples at pH 10

rotate for 8, 14, 30, and extended days

analyze: powder x-ray diffraction

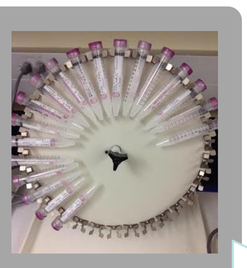


Additionally…
thermogravimetric analysis (TGA)
infrared spectroscopy (IR)

sorption experiment

setting up curve: 5 m^2/L α-Al_2O_3; Eu 1x10^{-5} M; 0.01 M NaCl; adjust pH to step up from 3 to 11, 2 samples at each pH

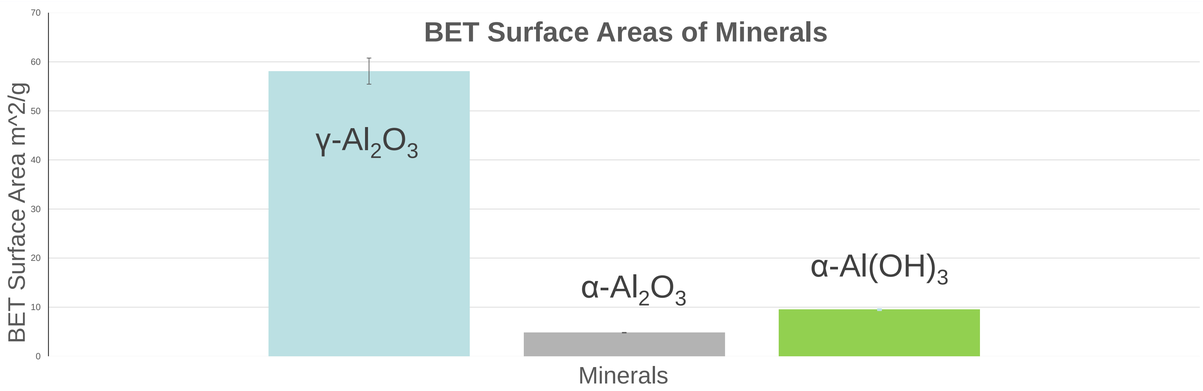
rotate for 8, 14, 30, and extended days



sampling: ~1 mL sample ~ 4 mL HNO_3 + yttrium

analyze % sorption: inductively coupled plasma-optical emission spectroscopy (ICP-OES)

Results

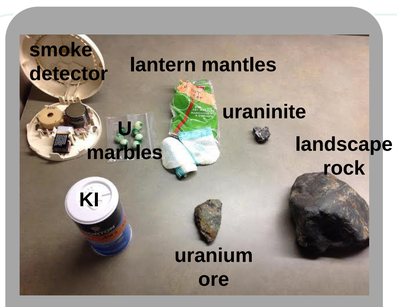


powder x-ray diffraction (PXRD) results

- The surface area data provides confidence in designing future sorption experiments that control for reactive sites on minerals.
- The pXRD results confirm the composition of the samples being used in sorption experiments. Future sorption experiments will have higher reliability.

Lesson 1: Radiation Sources, Types, and Biology

What is radiation? How does it behave? How does it impact life?



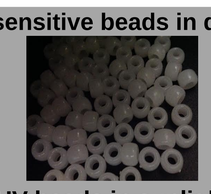
radioactivity demonstrations

Goal: Students describe natural radiation, shielding effects, and distance patterns of radiation.

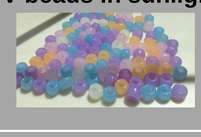
radioactivity vs. combustion

Goal: Students measure differences between radioactivity and combustion using sensor technology.

UV sensitive beads in dark



UV beads in sunlight



ionizing vs. nonionizing radiation

Goal: Students describe biological impacts of radiation types and classify radiation as ionizing or non-ionizing

Lesson 2: Socio-Scientific Inquiry

"Should nuclear energy be a part of a state's plan to reduce greenhouse gas emissions?"

Positions for using more nuclear energy	Positions against using more nuclear energy
Ecologist *reduce greenhouse gases, reduce climate change *reduce coal ash spills 	**Ecologist** *nonrenewable *cleaner options available, waste storage? 
Businessman *supply energy for growing economy *jobs 	**Political spokesperson** *terrorist targets *proven track record of fossil fuels 
Environmental engineer *proven safety record in US *sustainable inexpensive energy source 	**Biologist** *link between radiation, mutations, cancer *CO_2 helps plants grow 
Family bread winner *knows people who died in coal mine *wants less expensive electricity 	**Property owner** *contamination during transport and accidents *lower property values 

1st
- Entry event-introduction to the driving question
- Watch the background video for every role
- Assign roles to groups of students

2nd
- Research the question from one assigned perspective
- Plan questions to ask other perspectives
- Present evidence from assigned perspective to the class

3rd
- Form and articulate personal position based on evidence presented
- Use personal position to find real audience via email, phone, etc.
- Reflect on process

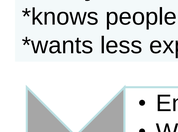
Lesson 3: Model Environmental Engineering Task

In a model system, what are the most effective methods of containing radioactive waste?
Goal: Minimize spread of tablet coloring "radioactive waste"

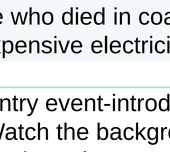
radioactive waste and the environment → containment engineering options → environmental forces to test

redesign

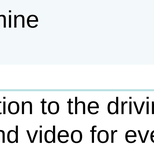
"radioactive waste"



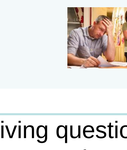
sand and water "environment"



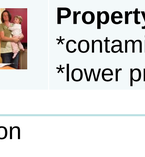
aluminum foil $10



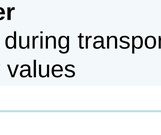
sponge $5



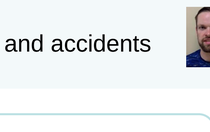
clay $4



"flooding"



"earthquake"



References

1. Santos, P. Souza; Santos, H. Souza and Toledo, S.P.. Standard transition aluminas. Electron microscopy studies. *Mat. Res.* [online]. 2000, vol.3, n.4 [cited 2015-07-24], pp. 104-114 . Available from: <http://www.scielo.br/scielo.php?script=sci_arttext&pid=S1516-14392000000400003&lng=en&nrm=iso>.
2. Image from http://pubs.rsc.org/services/images/RSCpubs.ePlatform.Service.FreeContent.ImageService.svc/ImageService/Artmage/2007/SM/b704742h/b704742h-f1.gif
3. Image courtesy of Dr. Amy Hixon

Acknowledgements

- Teresa Baumer for taking time to answer my questions, teaching me new skills, and correcting my misunderstandings.
- Dr. Amy Hixon for allowing me to work in the lab, letting me observe lab meetings, and fielding my questions
- Center for Sustainable Energy at Notre Dame
- National Science Foundation