Student questions: Alexandra Navrotsky colloquium on "Materials of the Universe"

1/22/20

Note from Prof. Navrotsky: "Here are responses. My style is to keep them short. Hope they help."

Alex, Do you believe it is possible for planets to originate closer/further from their sun, and slowly over a long period of time move outward or inward while orbiting-causing the status of habitability to change, and in turn causing new life and/or extinctions?yes it appears possible and there may be some evidence for it, especially that some large Jupiter-like planets may have strted out closer to their suns, although all such scenarios are somewhat model dependent.

How possible is it, if technology permits, that humans may end up mining other planets for resources when we run out of certain resources here on planet Earth? Yes, the issue is not necessarily running out of resources on Earth but finding possible new and diferent resources and, especially, mining resources "locally" for sustainable operations on the moon or other planets. The time scale fo this may be as short as decades snd your generation may well see it. The long and short of it is economics- if there turns out to be money to be made, it will happen. The privatization of space and planetary exploration is an exciting step in that direction.

Were the planets in our solar system ever similar? If no, is there any possibility of ever coming to that? There is evidence that Mars was once wetter and with more of an atmosphere and that Venus may not have been the runaway greenhouse planet it now is. Also Earth's atmmosphere has changed with time- for example the absence of oxygen before the "great oxygenation event" which may have been induced (and oxygen levels maintained) by photosynthetic organisms.

Is there any particular reason for Jupiter's (Saturn?) rings? Several of the outer planets have rings. The reasons rings can be maintained are a complex balance of physics but it is not clear when they are initiated, how long they last, and, in many cases, exactly what they are made of.

As a Geochemist, I believe that you know that life can be found in different environments, from the deep sea to areas around vulcanoes. I would like to know if you as a geochemist taking in consideration the extreme temperatures that life was found on Earth, what other planet would you consider having life in extreme conditions? It is not clear at present whether Mars ever had life. It almost certainly had running water on the surface. Some of the deep undeground oceans on the moons of the outer planets are propoased to have possiibly habitable environments . With the thousands of explannets, some seemingly in the so-called habitable zones of distance from their suns, there must be some candidates, past present, and future. To me it is highly unlikely that tlife is a singular event on only one planet (ours) . But defining what is life and how much it can differ in different environments are big open questios.

From the basic introduction you presented us about planets, would you agree with the theory that our solar system only has IX planets? I've been reading that scientists believe that there is a planet X whose orbit is very irregular and that takes around 300k years to make a full lap around the sun. What do you have to say about it, since you have experience in this matter from what I could see. Part of the issue is how one defines a planet versus a comet or asteroid. So Pluto is or is not planet depending on your definition.Detailed analysis of what are finally gravitaitonal anomalies requiring the presence of a significant mass "out there domewhare" from part of the argument far a planet X.

You mentioned actinides as something you would study the thermodynamics of, what do you hope to discover from your research? Interesting chemistry , geochemical implicaions, and applicaions to nuclear energy (nuclear reactors, nuclear waste immobilization, and dealing with contmination).

What plans are in place if society runs out of various critical materials? I see no evidence that society plans for anything, climate change, the coronavirus or other diseeases, let alone resources. Certainly there are efforts to use and recucle critical elemnts more efficeintly and to find substitutes, so we will adapt. Again the issue is largely one of economics.

What kinds of observations of exoplanetary systems would need to be made to test some of your hypotheses about material formation in extreme environments? Various spectroscopic studies that giveinfo on compositons of atmospheres and surfaces, right now capablities are quite limited but are expected to grow

To what extent can we recreate the conditions of planetary formation in the lab? Cold envirionments are not a major experimental problem though relatively litle systematic work has been done. Hot corosive ones are and very hot high pressure ones are lstill limited. Staic measurements to perhap 2-3 megabars and 5000 K but with poor control, dynamic ones (shock waves, nuclear explosons)can go higher but for times of seconds at most. The real issue is knowing T and P and its trajectory up and down with time as well as its spatial heterogeneity. One is often limited to very small samples (micrograms in diamond anvil cell experiments for example). So theory and experiment must wor together to simulate really extreme conditons.

On the slide where you mentioned alternative chemistries, what would be a career path for researching organisms potentially found on different planets that are not carbon based? This is still closer to science fiction than to science.

Can you tell me a little about the D" zone in the Earth? Briefly a very chemically active zone near the core-mantle boundary where molten metal may react with solid silicate and all sorts of transport pheo=nomena and seismic activity are possible

What are some potential applications and roles of nano-materials regarding space exploration of exoplanets? Better detectors and sensors and spectrosopic and imaging techniqus

How would an undergraduate student such as myself get involved in various projects concerning the ASU Material Science Intiative? Contact Prof William Petuskey

Have we characterized the diversity of planets in any other solar systems, and are they comparable to the diversity of our own solar system? Yes several solar systems contain more than one planet and yes they are as or more diverse than ours

How might finding life on a planet or asteroid affect our decisions to mine or utilize resources there in the future?consider how we make decisions here on Earth , always a tradeoff with many different points of view.

What kind of evidence is there for these carbon-based, possibly diamond dominated planets?not sure if any exoplanets have been propsed to be like this, both cosmochemical and geochemical evidence points at the possiblity

In terms of exoplanets being gateways for new materials, would that possibly entail new elements we are not aware of, or just elements in different combinations/forms/expressions that previously seen?the same elemnts as we run out of stability for higher atomic numbers so all stable elements are already known

How did your studies lead you towards nanogeosciences? I'm curious about your education path!look up my cv

What kind of work would undergrad and grad students do in the MotU lab? Materials synthesis and characterization, geochemical studies with various faculty and their graduate students

Do we have any special material we are working on that shows promising to become the next material to make our space ships out of? some new alloys are being studied. We need lighter and more radiation resistant materials, vraious things are under investigation

Do you think we need to mine our asteroid belt in search of new material?i only if it pays

What are some of the more interesting planet properties that you think are possible? We talked about the wide variety a bit but besides mentioning archetypes (frozen balls, high diamond planets, waterballs) it seems there's a lot more alien planets that could form under unlikely circumstances.question is too vague and open ended

You say thermodynamic data is essential to good materials processing, and this makes sense. I have minimal/no background in material sciences – what other data is essentially important to the construction/research/development of new materials for spacefaring ships besides the aforementioned thermodynamic data? I can not think of anything (I'm sure other important data exists), but that makes sense as I have negligible domain knowledge. Go study some thermodynamics

Are there any special requirements that classify a material as “critical”? simply that if it were less available or we ran out of it, critcal technologies wold be distupted . For example, shortage of lithium would mean less availability of lithium ion batreis

Are there specific outer bodies that the center is focusing on, such as Europa or Venus?Different faculty in SESE study different bodies, look on the SESE website

Do you believe it is possible that water on our planet will become scarce enough, or compromised enough that we will one day mine water from other parts of our solar system? Under the assumption we do not desalinate the oceans. maybe

Has anyone done calorimetry measurements in extreme environments? If so, where there any notable discoveries? Many experiments on materials preserved from extreme environments, Calorimetric tudies have characterized the stablity of materials in the Earth’s mantle, melting of materials at very high temperatures, and response of materials to radiaiton , to name a few.

What new equipment/techniques will MoTU be used in the near-future?
There is a multi-anvil press in storage that could be utilized.many methods especially with new faculty. Question too general to answer briefly

Will MoTU have other groups (groups working on NASA missions, NEXSS, etc) incorporated into it? Already does

The Earth is made up of mostly Oxygen and Silicon, is this true with solid planets that are larger/smaller than Earth? Rocky earth-like planets yes (by definiton). Mercury, Venus, Mars and exoplanets somewhat smaller and somewhat larger than Earth

How can you accurately predict the composition of planets that are light-years away?Accurately may be too strong a word, but one can put on constraints when one knows the mass and radius of a planet. Data of course comes from remote sensing but also from theoretical modeling and geochemical/cosmochemical constraints.

For what planet do you think we will need to make the next planet-inspired new material to explore that planet? My guess would be Venus

Do you believe that carbon will be a key element used in creating a material that can withstand high pressures and temperatures to explore planets with extreme conditions? Yes i because it is a light element good for use in space and because, in additon to diamonnnd, there are many carbides with promising properties under extreme conditions.

Is there any evidence that might suggest undiscovered materials on known exoplanets?yes simply because the conditos are beyond those for which we know what materials would be stable

What is the likelihood of sourcing materials from other planets (within my lifetime)?With the privatization of space exploration I would give it a 50/50 chance, but it is your generation that will make it happen.

What other material synthesis do you predict will have a commercial impact in the future that is not currently significant? Complex combinations of organic, biological, and norganic materials made by intentional tailored processing/

What kind of conditions necessary would you need to have a planet with a core of diamond? A core is by definition different from the material above it, So a diamond rich planet may have plentiful diamond at depth witout a separate core.

In an article titled "Sci-fi evolves into technology with new ASU Center for Materials of the Universe" written by a clinical associate professor of the School of Molecular Sciences by the name of Jenny Green, she refers to MotU as a "one-of-a-kind center". What were some of the main triggers for conception of this research and education initiative?too long a story to repeat here., but my having been at ASU at the start of my career and keeping track of ideas and people here are a large part of it.

Does the cross disciplinary research into the materials of the extreme nucleide social dimensions including justice and environmental interactions? Potentially through interaction with other centers focusing on sustainability

How do you foresee geopolitics playing a role in exploration for new materials and natural resources?yes strongly of course

What recent advancements do you think have potential to lead us down the road to mining in other plaints?Technology may already be available or can be developed, the driver is need and economics

Do you believe we will run out of rare earth minerals, or that it will just become too expensive to mine on earth. Right now it is not knowe if there are concentrations of rare earths (ores) on other planets that would be feasible to mine. We do not “run out of” elemetns if we can find better ways to reprocess and reuse them, so solving the problem on Earth is more reasonable.