GREEN CHEMISTRY & ENGINEERING IN THE FINAL FRONTIER

Space travel to Mars will be long, arduous and perilous. Bringing all the required supplies on board such a trip is nearly impossible due to the cost, available space, the sheer mass, and the diversity of stuff needed to make such a trip possible. It will therefore be essential for space farers to make some items and supplies on board the Mars space ship, landing vehicle, and the Mars habitats using innovative technologies and what might be considered as unconventional feedstock here on earth. Fortunately, scientists and engineers have been working for several decades on how humans could live sustainably in space and in extra planetary environments and have developed key insights into how to sustain life during long-term space travel.

Sustainable and green chemistry and engineering design principles encourage practitioners to efficiently utilize resources, employ sustainable practices, and to use a life cycle or systems thinking approach to their work. Take some time to familiarize yourselves with these principles; download the design booklet (scroll down the page to the link) and think about how the principles are arranged.

In Dr. Mark Blenner's presentation he discussed several approaches to sustaining life on a long-haul space mission; e.g., the use of Biocatalysis, using waste as a feedstock, and using a systems thinking approach. Think about the various items that you would need to bring with you on a voyage to Mars, the waste that you would be creating along the way (yes, that means human waste) and then think through the discussion questions below with your ACS Student Chapter members.

Remember that in order for this to count as one of your green chemistry activities for the academic year, you need to have 6 Chapter members participate in the discussion and you need to report your key takeaways from the discussion in your Chapter Report at the end of the year*. As you think through these questions, keep asking yourself whether or not we can take what we learn about how to live on a mission to Mars and applying it to living on spaceship earth. Are there key ideas that we need to implement on earth?*

DISCUSSION QUESTIONS

- **What chemistry/chemical technology tools will you have access to or need to maintain? These are generally not extensively used in current chemical processing, but are arguably greener approaches to making things.** (Photochemistry, Electrochemistry, Micellar chemistry; i.e., use of surfactants in water, e.g. see Lipshutz and Handa et al., Biocatalysts vs. organometallic catalysts, Batteries / energy storage devices [e.g., capacitors, etc.] Can you think of any others?)

CONT'D

- **How will you perform separations? What kinds of things will you be able to use?**
  - We rely on gravity for simple separations – what will it be like on Mars or in space? Is there a way to simulate gravity separations in space?
  - Electrochemical processes – e.g. electrophoresis. What other techniques?
  - Could we make use of CO_2 or water? Super/near critical forms of each require pressurization. Could we do this using low DC voltage available from batteries and solar arrays?
  - What key solvents might we want to have?
- **What about pH? How would we control pH**? (Carbonic, formic, acetic, phosphoric vs sulfuric, nitric, etc. and for bases, NaOH, KOH, others)**? How would we use pH differently?**
- **We make use of temperature** (heat, cooling) **and pressure** (vacuum for separations, higher pressure for promoting reactions)**. What would we be able to do on Mars? How is this different from how things are done on the earth? How will we generate energy in Space?**
- **Critical elements –** P, K, Fe, Ca, Mg, etc. **These are critical for life vs. critical for a way of life as on the earth. Note the difference in importance. Where would these elements come from for use in the Mission to Mars?**
- **Critical microbial platforms: e coli, yeast, algae** (green, blue-green, etc.)**, clostridia? What others? Why these? All of these require mineral salts media of some kind. What would be necessary to maintain viable consortia?**
- **Getting into space and travelling through space may require us to think about radical redesign of materials. Take a look at this 2015 TED talk by Neri Oxman at MIT's Idea Lab. Is her approach more sustainable? How many sustainable design principles can you match to the things she is doing?**

Looking for more green chemistry resources or additional activities to do with your ACS Student Chapter? Check out the ACS Green Chemistry Institute's website.