Non-Toxic Renewable Energy Storage via the Solar Thermal Decoupled Electrolysis of Iron Oxide

Jackson King, Paul Smith, Luke Venstrom, Peter Krenzke, Valparaiso University

Solar Energy

Advantages:
- Renewable
- High Potential

Disadvantages:
- Discontinuous
- Uneven Distribution

How can we harness solar?

Solar fuels: take the sun to where it's needed!
- Energy stored in chemical bonds lasts longer
- Flexible demand-based distribution

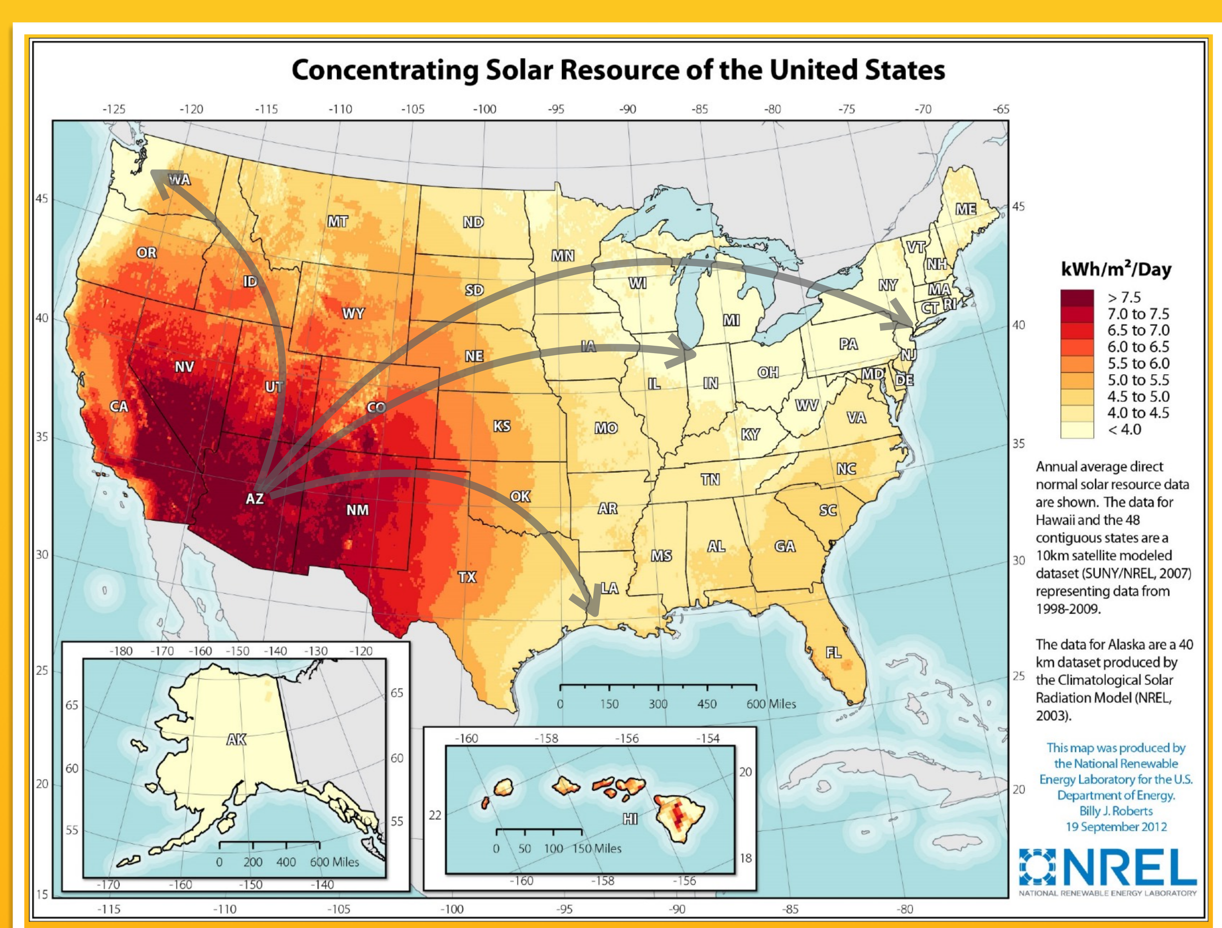

Figure 1: Solar resource concentration map of the United States.

1. Reduction: Removal of Oxygen

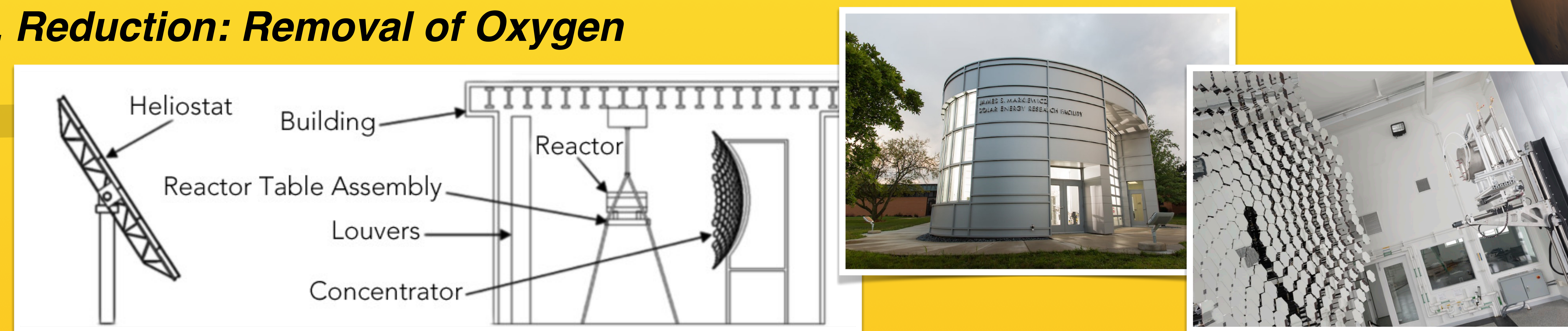

Figure 3: Conceptual diagram of a solar furnace (left) and photos of the exterior (middle) and interior (right) of the SERF research facility.

Iron Oxide Advantages

- Non-Toxic
- Abundant
- Cheap
- Interplanetary Applications

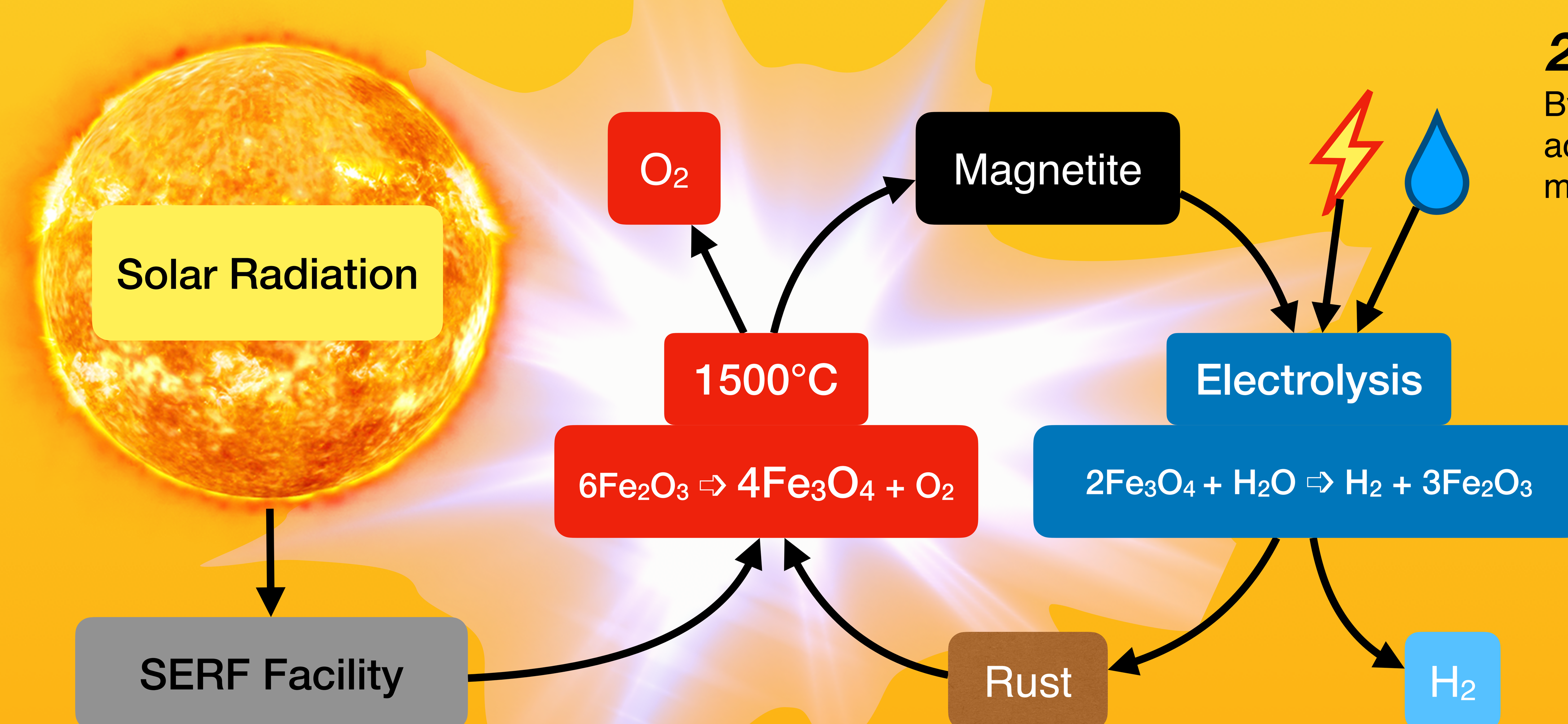

Figure 2: Conceptual outline of the proposed iron oxide system. [1,2]

2. Magnetite Dissolution

By itself, water is unable to sufficiently dissolve magnetite. Boiling etidronic acid [3] was able to adequately accomplish this at a ratio of 21.5 grams of magnetite per liter of 6% etidronic acid.

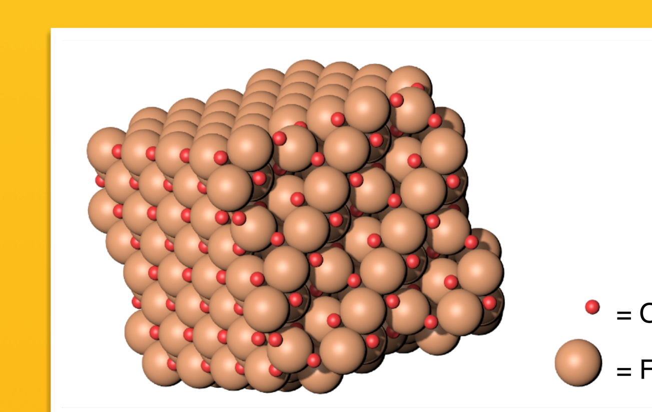

Figure 4a: Simulated crystal structure of magnetite. (COD 1011032)

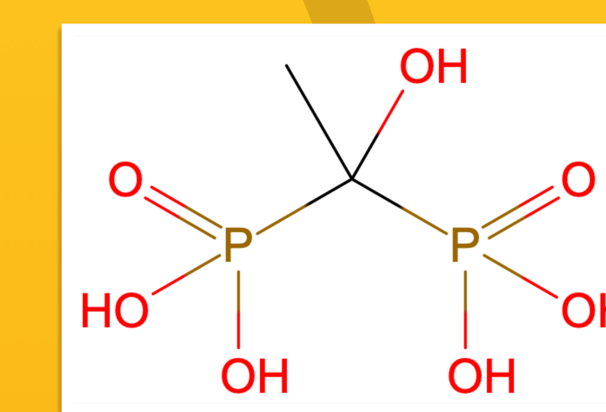

Figure 4b: Molecular Structure of Etidronic Acid (EDA).

3. Oxidation: Production of Hydrogen

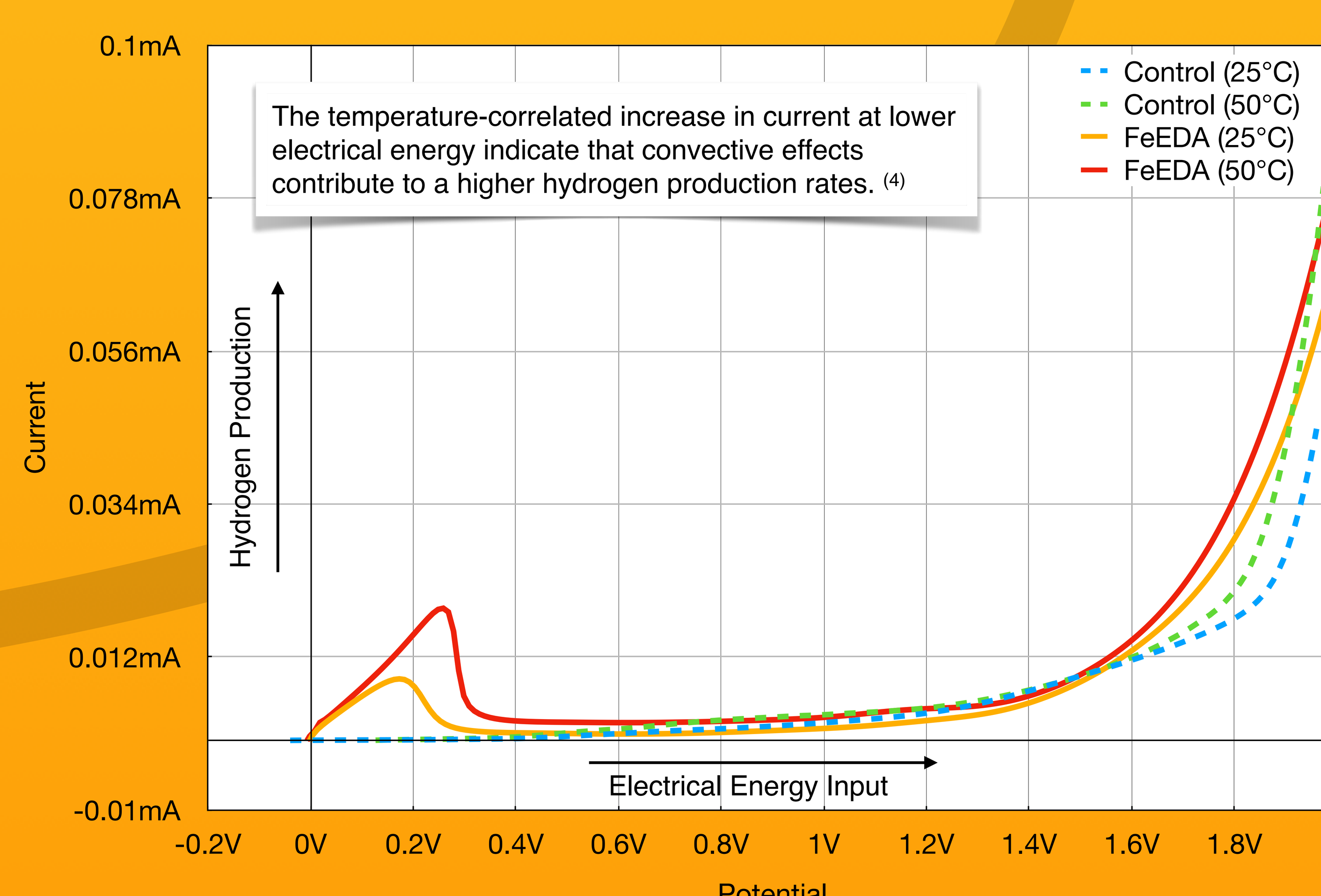

Figure 5: Linear sweep voltammogram (LSV) of electrolysis performed with platinum electrodes in etidronic acid (control) and iron etidronate solution.

4. Precipitation of Rust

A promising method of recovering a reusable precipitate was investigated by raising the pH of the solution to 13 (**Figure 6**). Once isolated, the sample was heated to 800°C and yielded a phase-pure rust X-ray diffraction pattern (**Figure 7**).

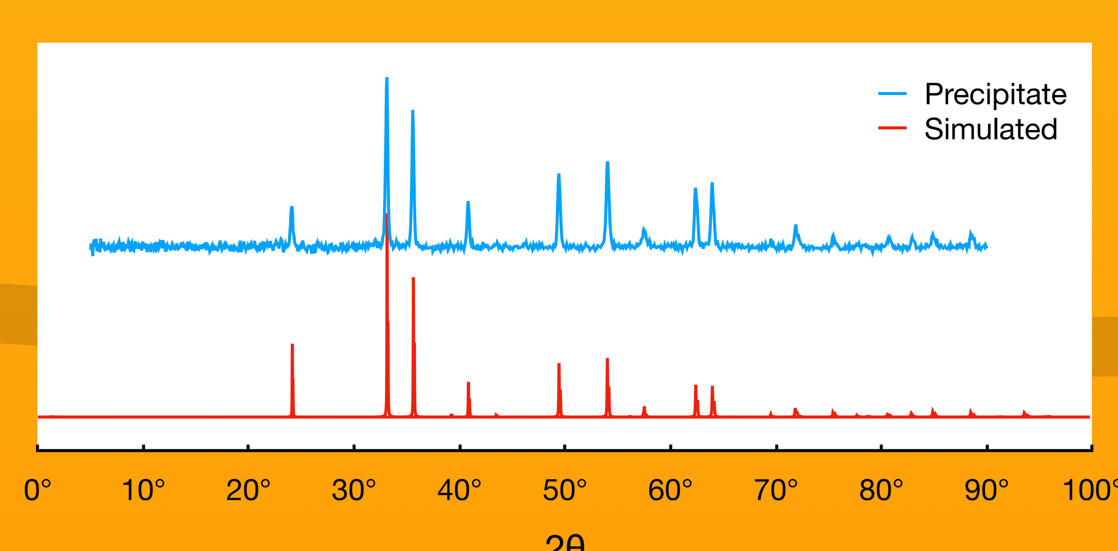

Figure 7: X-ray diffraction pattern of the recovered precipitate and simulated pattern of Fe_2O_3 (COD 9000139).

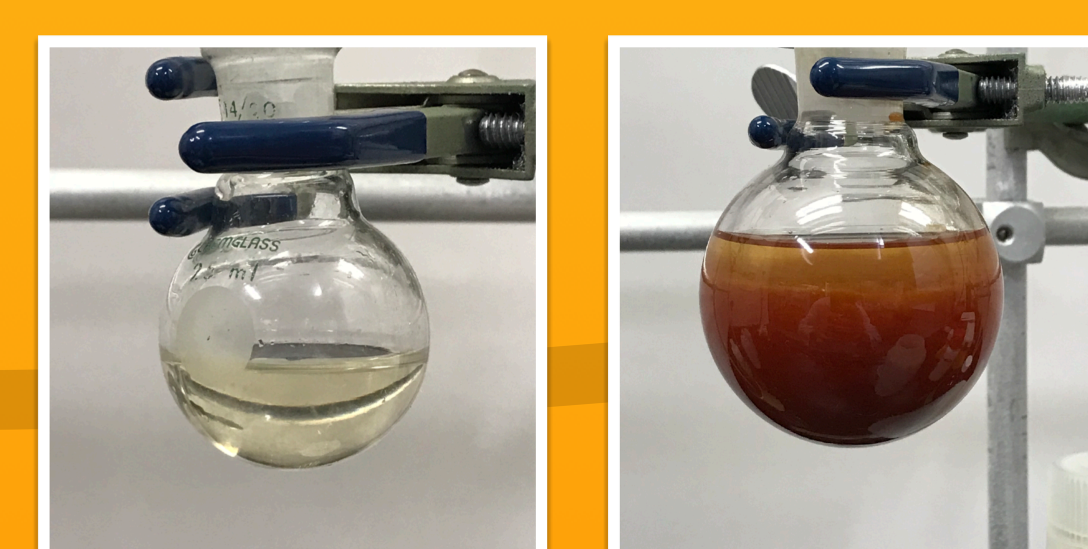

Figure 6: Iron etidronate solution before (left) and after (right) pH was raised to 13.

Looking Forward:

- Investigating the molecular geometry of species present in the iron-etidronic acid solution and the subsequent color changes that occur.
- Testing conditions and materials required for optimal hydrogen production; pH, temperature, pressure, electrode material, etc.

References/Acknowledgements:

1. Palumbo, Robert; Diver Richard B.; Larson, Carol L.; Coker, Eric N.; Miller, James E.; Guertin, J.; Schoer, Jon; Meyer, M.; Siegel, Nathan P. Solar thermal decoupled water electrolysis process I: Proof of concept. *Chemical Engineering Science.* **2012.** 84, 372-380. DOI: 10.1016/j.ces.2012.08.023
2. Nudehei, Shahin.; Larson, Carol L.; Prusinski, W.; Kotfer, D.; Otto, J.; Beyers, E.; Schoer, Jon; Palumbo, Robert. Solar thermal decoupled water electrolysis process II: An extended investigation of the anodic electrochemical reaction. *Chemical Engineering Science.* **2018.** 181, 159-172. DOI: 10.1016/j.ces.2017.12.032
3. Frost, Jack G.; Knox, John A.; Martin, Larry D.; all of Duncan, Okla. Method for removing magnetite scale. U.S. Patent WO 3854996, December 17, 1984.
4. Silcox, Rachel; Engerer, Laura K.; Nudehei, Shahin; Smith, Paul; Schoer, Jon; Krenzke, Peter T.; Palumbo, Robert; Venstrom, Luke J. Solar thermal decoupled water electrolysis process III: The anodic electrochemical reaction in a rotating disc electrode cell. *Chemical Engineering Science.* **2020.** 227. 115885. DOI: 10.1016/j.ces.2020.115885

This research was made possible through funding provided by the Indiana Space Grant Consortium.

VALPO

UMD DULUTH