Chemical Synthesis in Space: Advances from (Photo-)Electrochemical Water-Splitting and CO_2 Reduction in Reduced Gravitation

Katharina Brinkert[1,2*]

[1]*ZARM - Center of Applied Space Technology and Microgravity, University of Bremen, Bremen, 28359, Germany*

[2]*Department of Chemistry, University of Warwick, Coventry, CV4 7AL, UK*

The Artemis programme has introduced a new era of space exploration that leads humanity back to the Moon and in a second stage, to Mars. For these endeavors, new life support as well as energy conversion and storage technologies are required that operate reliably and continuously in the harsh environments present on the lunar and Martian surfaces - as resource resupplies from Earth will be significantly restricted or not possible at all. Electrochemical devices for the production and recycling of oxygen, hydrogen and carbon dioxide as well as water are hereby key, although they suffer from inefficiencies and increased energy inputs in the reduced gravitational environment present in space: due to the severely reduced buoyancy force, the gas-liquid phase separation is impeded [1,2] and produced gas bubbles adhere to the electrode surface. Moreover, macroconvectional processes are absent and reactions are solely diffusion-controlled.

Here, we will discuss recent advances in (photo-)electrochemical water-splitting [3,4] and CO_2(g) reduction realised in a microgravity environment (10^{-6} *g*) that is generated for 9.2 s at the Bremen Drop Tower, Germany. By combining electrode surface-functionalization [5] with magnetically-induced convection [6], it is that (photo-)electrolytic oxygen and hydrogen production as well as the reduction of gaseous CO_2 can be realised even in reduced gravitational environments at terrestrial efficiencies. Moreover, we will discuss the sustainable synthesis of more complex chemicals in this environment, providing a new application route for photoelectrochemical devices that could contribute to a more lightweight and compact electrochemical design for terrestrial and space applications alike.

References

[1] Matsushima, H., Fukunaka, Y., Kuribayashi, K. (2006), *Electrochim. Acta* **51**, 4190-4198.

[2] Samplatsky, D. J., Dean, W. C. (2002), Tech. Rep. 2002-01-2360, SAE International.

[3] Akay Ö., Monfort-Castillo M., St. Francis T., Becker J., Saravanabavan S., Romero-Calvo Á., Brinkert K. (2025), *Nat. Chem.* **17**, 1673-1679.

[4] Ross B., Haussener S., Brinkert K. (2023), *Nat. Commun.* **14** (3141).

[5] Akay, Ö. et al (2021), *Adv. Sci. 9*, e2105380.

[6] Romero-Calvo, Á., Akay, Ö., Schaub, H., Brinkert, K. (2022), *npj Microgravity* **8**, 1-10.