Wolfson Department of Chemical Engineering Seminar

Monday, March 31st, 2025 at 13:30

Room 6

Investigation into Heterogeneous (Photo)catalysis and Homochirality in the Origin of Life

Shoval Gilboa

Final PhD Seminar

Advisor: Prof. Yaron Paz

Department of Chemical Engineering, Technion-Israel Institute for Technology

How did life begin? Many hypotheses attempt to explain the origin of life. The RNA world hypothesis suggests that in primordial Earth, simple molecules increased their complexity until the formation of RNA chains. These chains may have resulted in the formation of the first living beings because they are related to the genetic code, DNA, they can catalyze chemical reactions that are essential to a living organism, and they also can self-replicate.

Formamide ($HCONH_2$) is a simple molecule that was shown to be a possible precursor for nucleobases, sugars, and amino acids. In this study, we asked ourselves whether it was possible to find a combination of suitable conditions and a catalyst for the formation of biologic building blocks in a one-pot reaction, from the simple molecule formamide. We looked for a catalyst that may function as a photocatalyst, phosphate-donor, and adsorption site for the formed building blocks, thereby increasing their stability and complexity. Experiments showed for the first time that a one-pot reaction using cerium phosphate as the catalyst led to the formation of essential biomolecules: nucleotides, nucleosides, nucleobases, and amino acids. UV-illumination expanded the product variety and increased yields by 20-40%.

We also studied the product variety formed under different atmospheric conditions: Nitrogen, Argon, and Oxygen. Crucial differences were observed. The amount of phosphate ions released into the experimental solutions was altered depending on the atmosphere and the experimental conditions.

Bio-molecules often exhibit chirality - that affects their function. A collaboration with another group member led us to test whether cerium phosphate (the same catalyst capable of forming different life-building blocks) is enantioselective. Cerium phosphate and titania films were prepared and exposed to racemic amino acid solutions. It was found that cerium phosphate selectively adsorbed L-enantiomers and showed 100% enrichment of D-enantiomers in solution. Titania did not display enantiomeric preference, highlighting cerium phosphate's unique properties.

To conclude, a diverse set of molecules, including nucleotides, amino acids, etc., were formed under the combination of suitable conditions (environment) and catalysts. This co-formation of diverse bio-molecules by the described-above processes suggests that these, or similar, processes, played an important role in early life.