Chemical reaction research to evaluate extraterrestrial samples

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Researchers have identified a new test case that could be used for evaluating extraterrestrial samples for evidence of life. The new test could ultimately allow the use of simpler analytical instrumentation on future space missions.

In the search for life on other planets, astrobiologists regard liquid water and chiral biomolecules to be critical components. "Yet because chiral molecules can be made synthetically as well as biologically, it's not enough to just find them on other planets. We need to show a change of chirality over time," said Tracey Thaler, a graduate student at Georgia Tech's School of Chemistry and Biochemistry. She works with Professor Andreas Bommarius in the School of Chemical and Biomolecular Engineering.

Thaler has investigated racemization – the conversion of an optically active compound to a racemic form, which has no optical rotation – as a new approach for analyzing samples in outer space. "Because this type of reaction is found only in biological systems, it could serve as a marker for extraterrestrial life," Thaler explained. She will present results from the study on Thursday, March 30, at the 231st American Chemical Society National Meeting in Atlanta.

The study is part of a collaborative effort with Professor Rick Trebino's research group in Georgia Tech's School of Physics. The two research groups are trying to improve analytical instruments used on space missions, research that is sponsored by NASA. Chromatography, the current method used to evaluate extraterrestrial samples on space missions, is a tedious process, Bommarius explained. Another drawback, researchers must know in advance the specific compounds they're looking for, which isn't always possible. In contrast, polarimetry, a method for measuring optical activity, does not require knowledge of the structure being analyzed. But because existing polarimeters have performance limitations, Georgia Tech researchers are developing a more sensitive polarimeter that can detect smaller concentrations of optically active compounds. Thaler's work serves as a test bed for such an instrument.

"Tracey's study is significant because it marks the first time that racemization has been looked on as a sign of life on other planets," Bommarius said. "What's more, she has identified two new media in which the enzyme mandelate racemase is active."

Mandelate racemase (MR) is an enzyme that catalyzes the racemization reaction for the substrate mandelic acid. Mandelate is one the simplest chiral molecules and has a large specific optical rotation, making it well-suited for polarization analysis, Thaler explained.

An important part of the study was to determine if MR reactivity could occur at subzero temperatures found on planets like Mars or moons like Titan, Europa or Enceladus, where recent data shows water is likely to exist.

After a number of unsuccessful attempts with organic cryosolvents – the most common medium to probe enzyme activity at low temperatures – Thaler achieved MR reactivity in two unconventional media. They were concentrated ammonium salt solutions and water-in-oil microemulsions (anionic surfactant Aerosol OT and non-ionic surfactant Triton X-100). Racemization occurred in temperatures as low as -30 degrees Celsius. This was promising because both the microemulsions and the concentrated salt solutions are expected to form on other planets and moons.

Another auspicious finding: Measurements for the activation parameters (thermodynamics) in the ammonium salt solutions and water-in-oil microemulsions were very similar. "This tells us that racemization is not only possible in other media, but thermodynamic parameters found in these media are similar to those found in media that's normally used," Thaler said.

The next step will be to use the MR system with the new polarimeter being developed by Trebino's group while Thaler and other members of Bommarius' team explore additional enzyme systems that might also be good test models.

Source: Georgia Institute of Technology