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Non-Aqueous Life: The Search for Life Beyond the Comfort of Water

Luke T. Vandevere

Malvern Preparatory High School

ABSTRACT

This paper explores the concept of life beyond Earth, and beyond the common belief that life can only exist and thrive around liquid water. Recent scientific inquiries suggest that life could be possible in environments that do not contain liquid water. This greatly expands the potential for habitats beyond our planet and the few other planets found within the "Goldilocks zone". The paper also explores potential solvents for life, such as methane, ammonia, and hydrogen sulfide. In particular, the paper delves into hydrogen sulfide (H_2S) as a plausible alternative to water as a solvent for life in the universe, given its similar properties to water and its abundance in the universe. Additionally, the essay challenges the concept of the "Goldilocks zone," suggesting that by replacing the target compound, water, with methane or other chemicals like ammonia or hydrogen sulfide, the Goldilocks zone could expand or contract which greater allows for the possibility of life on planets that are further or closer away from their stars. The search for extraterrestrial life requires an open mind and a willingness to explore alternative possibilities beyond the traditional belief that water is the only solvent capable of supporting life.

Introduction

Water has long been considered a necessary ingredient for life; therefore, the search for extraterrestrial life has been primarily focused on life forms that are based around water. However, recent discoveries in the scientific world have challenged this assumption, and there is now evidence to suggest that life may be possible in environments that lack liquid water. The implications of this discovery are profound, as it greatly expands the potential habitats for life beyond our planet and opens up so many new possibilities for research in astrobiology.

Methane and ammonia as a replacement for water

Life on Earth is based on carbon chemistry and requires a solvent with which chemical reactions can take place. Water is widely considered the most suitable solvent for life, due to its unique chemical properties. However, it is possible that other solvents may also be capable of supporting life.

One example of a potential solvent for life is liquid methane. Methane is a highly flammable gas at room temperature, but in the cold environments of outer space, it can exist as a liquid. Some moons in our solar system, such as Titan, have methane lakes and seas on their surfaces. It is possible that life forms on Titan and other methane-containing planets could use liquid methane as a solvent, instead of water.

Another potential solvent for life is liquid ammonia. Ammonia is a highly polar molecule, with strikingly similar properties to water. It has been suggested that life forms could exist in environments where ammonia is liquid, such as the polar regions of gas giants like Jupiter, and beneath the dense atmospheres in liquid oceans on planets like Neptune and Uranus.

Hydrogen sulfide as a plausible replacement for water

Hydrogen sulfide (H_2S) has been proposed as a possible alternative to water as a solvent for life in the universe. While water is essential for life as we know it, the possibility of life being based upon other solvents has been a subject of scientific inquiry for decades now. Hydrogen sulfide is an intriguing possibility as it has similar properties to water, such as a similar shape. The main difference between H_2S and H_2O is that H_2S lacks hydrogen bonds. Due to its relatively weak intermolecular forces, H_2S boils at about −60 °C, which could make it a potential solvent for life on planets that are extremely cold, or that are far away from their sun.

Another advantage of hydrogen sulfide as a solvent for life is its abundance in the universe. H_2S is a common molecule found in various environments like volcanic hot springs and the atmospheres of gas giants like Jupiter and Saturn. This abundance increases the likelihood of the existence of H_2S-based life in the universe.

Moreover, H_2S has been shown to have some cytoprotective properties, acting as an antioxidant and protecting cells from oxidative stress. This suggests that organisms in environments with high levels of H_2S may have developed unique mechanisms to protect themselves against its toxic effects, which could have interesting implications for the evolution of life in other environments.

To sum up the H_2S argument, while the idea of life being based on hydrogen sulfide is still hypothetical, there are several reasons why it is a plausible possibility. The similar properties of H_2S to water, its abundance in the universe, and its potential cytoprotective properties make it an intriguing possibility for alternative forms of life.

Finally, there is the possibility of life existing in non-aqueous environments that lack any liquid solvent. These environments could be extreme, such as high temperatures or pressures, where life forms could exist in a solid state or gaseous state. This scenario seems unlikely, but given the broad definition of life, almost anything is possible in that sense.

Building off of the foundation of the Goldilocks zone

The widely accepted concept of the "Goldilocks zone" proposes that life is likely to exist only within a specific range of distance from a star. This zone is characterized by the presence of ***liquid*** water on a planet, as opposed to water in a solid or gaseous state. However, it is important to note that the Goldilocks zone is primarily based on the commonly accepted, yet potentially erroneous assumption that life requires liquid water to survive and propagate.

While the Goldilocks zone could be seen as wrong, hence the new theory of non-aqueous life, one could alter the distance of the Goldilocks zone by replacing the variable of water with methane or other chemicals like ammonia or hydrogen sulfide. For methane, the Goldilocks zone would be approximately 5 to 20 AU. This range is *astronomical* in comparison to the Goldilocks zone of water, which is 0.5 AU to 3 AU (The Goldilocks zone is highly debated upon, even still to this day. Some sources suggest that the Goldilocks zone is between 0.95 AU and 1.67 AU; Others assume that it is from 0.9 to 1.2 AU. I use 0.5 to 3.0 AU because it is the broadest value.). The Goldilocks zone for methane would be approximately 5 to 15 AU. Methane and Ammonia both have Goldilocks zones that are very far away from the sun, this is a complete juxtaposition of hydrogen sulfide's calculated Goldilocks zone, 0.2 AU to 1.2 AU. (All calculations are based on the Kopparapu et al Goldilocks formula (2013).

Conclusion

In conclusion, the search for extraterrestrial life is a complex and multifaceted endeavor that requires an open mind and a willingness to explore alternative possibilities. While water is often considered the universal solvent and the primary requirement for life as we know it, there are other molecules that share similar properties and could potentially support life. As demonstrated in this paper, ammonia, methane, and hydrogen sulfide are three such molecules that have been suggested as possible solvents for alternative forms of life.

Although these solvents are less common than water and are found in more extreme environments, they offer unique advantages that may make them suitable for life to emerge and evolve. Each of these solvents has unique chemical properties that allow them to interact with biomolecules in a similar manner as water, and they can provide protection and stability for the building blocks of life.

In light of these findings, it is important to broaden our search for worlds habitable for alien life beyond the traditional "Goldilocks Zone" for water-based life. By considering alternative solvents and other environmental factors, we can increase the likelihood of discovering extraterrestrial life and expanding our understanding of the universe.

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