Planetary Atmosphere Chemistry: A Glimpse into Discoveries and Future Directions

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Abstract

Drawing from observations by Mariners, Pioneers, Vikings, Voyagers, Pioneer Venus, Galileo, Venus Express, Curiosity, Cassini, New Horizons, and a myriad of both orbital and ground-based observatories, this presentation offers an overview of the pivotal chemical processes defining planetary atmospheres. With insights garnered since the dawn of the space age, we now possess a holistic understanding of atmospheric chemistries, from the rudimentary compositions of giant planets to the intricate atmospheres of terrestrial planets and smaller celestial bodies. This understanding crystallizes into four core concepts:

1. The resilience of planetary atmospheres against constituent escape to space.

2. The significance of equilibrium chemistry in delineating chemical species distribution.

3. The influences of disequilibrium chemistry, resulting in significant variances from equilibrium states.

4. The distinct role of terrestrial biochemistry, rendering Earth's atmospheric chemistry unparalleled in its cosmochemical interactions. This is evident in Earth's atmosphere where potent reducing and oxidizing agents coexist. For instance, nitrogen variants in Earth's atmosphere span eight oxidation states, from ammonia to nitric acid. Life harnesses solar energy to propel otherwise improbable chemical reactions, marking a unique photochemical facet exclusive to Earth within our Solar System.

As we venture beyond, exploring exoplanets with instruments like Kepler, TESS, HST, Spitzer, JWST, and upcoming missions such as Roman and Ariel, the atmospheres within our Solar System become vital reference points. These exoplanetary explorations challenge and refine our existing knowledge. Ultimately, our quest seeks to decipher: Are we singular in this vast cosmos? What constitutes planetary habitability? How does life emerge? And, pondering the fate of life on Earth, where do we stand?

行星大气化学：探索发现与未来方向

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摘要

通过Mariners、Pioneers、Vikings、Voyagers、Pioneer Venus、Galileo、Venus Express、Curiosity、Cassini、New Horizons以及众多的轨道和地面天文台的观测，本文提供了定义行星大气的关键化学过程的概览。从太空时代开始的洞察中，我们现在对大气化学具有全面的理解，从巨大行星的基础组成到地球行星和更小的天体的复杂大气。这种理解凝结为四个核心概念：

1. 行星大气对组成部分逃逸到空间的抵抗力。

2. 平衡化学在划定化学物种分布中的重要性。

3. 平衡状态中的非平衡化学的影响，导致与平衡状态的显著差异。

4. 地球生物化学的独特作用，使地球的大气化学在宇宙化学相互作用中无与伦比。这在地球大气中是显而易见的，其中强烈的还原和氧化剂共存。例如，地球大气中的氮变体跨越了从氨到硝酸的八个氧化状态。生命利用太阳能推动其他情况下不可能发生的化学反应，在我们的太阳系内，这标志着独特的光化学方面。

随着我们使用Kepler、TESS、HST、Spitzer、JWST以及即将到来的Roman和Ariel等工具探索外行星，太阳系内的大气成为重要的参考点。这些外行星的探索挑战并完善我们现有的知识。最终，我们的探索寻求解密：我们在这个浩瀚的宇宙中是否孤单？什么构成行星的宜居性？生命如何出现？考虑到地球上的生命命运，我们站在哪里？