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Phosphoric acid in Venus's atmosphere: Volatilization and reduction with siderophilic minerals

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Phosphorus (P) is a minor element in the solar system but plays a significant role in modern biochemistry [1]. On the Earth, P is stored primarily as a solid mineral such as apatite. However, P may exist on Venus in the gas phase due to the planet's extremely high pressure and scorching surface conditions, or possibly as a biosignature (Greaves et al. 2020). The predominant P species that has been observed on Venus is phosphoric acid (H_3PO_4). In this study, we demonstrate how phosphoric acid undergoes changes under Venus's surface conditions (460 °C) in reaction with minerals. After heating, H_3PO_4 volatilizes through a mineral sheet and forms a "shell" cover. ^{31}P-NMR results indicate that this shell consists mainly of polyphosphates and cyclic phosphates, such as pyrophosphate, triphosphate and trimetaphosphate (Fig 1a, c). This suggests the during the heating reaction, H_3PO_4 undergoes polymerization into polyphosphates. In addition, ^{31}P-NMR results for the mineral sheet indicate that iron rich-minerals may facilitate the reduction of H_3PO_4 into P^{3+} species, ultimately forming iron-nickel phosphides (Fig 1b, d). This result may indicate that it is plausible for H_3PO_4 to reduce into phosphides on Venus's surface.

[1] Pasek, M. A. Rethinking early Earth phosphorus geochemistry. *Proc Natl Acad Sci U S A*. *105*(2008): 853-858.

[2] Greaves, J. S., et al. Phosphine gas in the cloud decks of Venus. *Nat Astron*. *5*(2021): 655-664.

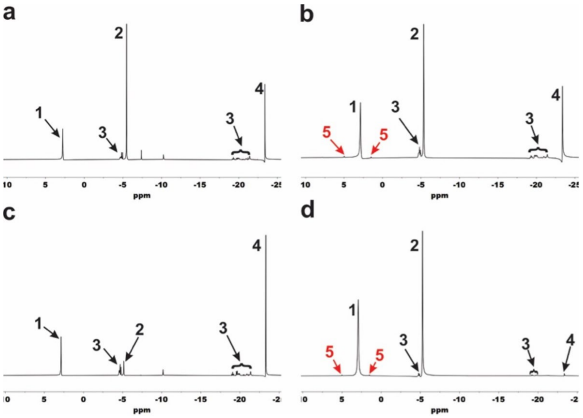

Fig 1. ^{31}P-NMR spectra for phosphoric acid reaction with iron-rich minerals at 460°C form layered materials. The reaction time for all experiments was 5 days. P species where phosphoric acid mixed with Fe-forsterite mixing (molar ratio 1:1) in a) "cover" layer. And b) 'underlying layer'. P species from phosphoric acid mixed with Fe-Ni-forsterite mixing (molar ratio 1:0.3:1) in c) 'cover layer' and d) in 'underlying' layer. Peaks are identified as (1) orthophosphate, (2) pyrophosphate, (3) triphosphate, (4) trimetaphosphate, (5) phosphite.