EGU2020-10457
https://doi.org/10.5194/egusphere-egu2020-10457
EGU General Assembly 2020

Meteor Ablated Phosphorus as a Source of Bioavailable P to the Terrestrial Planets

Kevin Douglas[1], Thomas Mangan[1], Jaun Diego Carrillo-Sanchez[1], David Bones[1], Wuhu Feng[1,2], Mark Blitz[1,2], and John Plane[1]
[1]School of Chemistry, University of Leeds, Leeds, LS7 9JT, United Kingdom
[2]National Centre for Atmospheric Science, University of Leeds, Leeds, LS2 9JT, United Kingdom

Phosphorus, P, is a key biological element with major roles in replication, information transfer, and metabolism. Interplanetary dust particles (IDPs) contain ~0.8 % P by elemental abundance, and meteoric ablation in a planetary atmosphere is a significant source of atomic P. Orthophosphate (oxidation state +5) is the dominant form of inorganic P at the Earth's surface, however, due to their low water solubility and reactivity, such P(V) salts have a poor bio-availability. Less oxidised forms of P (oxidation state ≤ +3) are however far more bio-available. Previous studies have focused on the direct delivery of P to the surface in meteorites. In contrast, the atmospheric chemistry of P has so far been ignored.

The vaporized P atoms entering the upper atmospheres of the terrestrial planets will undergo chemical processing to form a variety of compounds in which P may exist in different oxidation states due to the presence of both oxidizing and reducing agents. Initial oxidation of P will proceed to produce PO_2. From PO_2, an exothermic route to phosphoric acid (H_3PO_4) exists via the formation of $HOPO_2$; however, the bio-available compound phosphonic acid (H_3PO_3) should also form via HPO_2.

Using a combination of both experiment and theory, rate coefficients for the reactions of meteor ablated P have been determined. Using a pulsed laser photolysis-laser induced fluorescence (LIF) technique, the reactions of P, PO, and PO_2 with atmospherically relevant species have been studied as a function of temperature for the first time. Rate coefficients for the subsequent reactions of PO_2 leading onto to phosphoric and phosphonic acid were calculated from high-level electronic structure calculations.

In addition to understanding the reaction kinetics, the delivery of P to the upper atmospheres of Earth, Mars, and Venus via the ablation of IDPs has also been investigated. Using a meteor ablation simulator, micron-size particles were flash heated, and the ablation of PO and Ca recorded simultaneously by LIF. These ablation profiles were used to validate the output of a Chemical Ablation Model (CABMOD), a thermodynamic model that predicts the ablation rates of different elements from IDPs. By combining CABMOD with an astronomical model of dust sources, the global injection rates of P into the atmospheres of Earth, Mars, and Venus has been estimated to be 0.017, 1.15×10^{-3}, and 0.024 t d^{-1} (tonnes per Earth day) respectively.

The results from the kinetics experiments, together with the P injection rates from CABMOD, have been input into a global chemistry-climate model of the Earth's atmosphere (WACCM). Using WACCM, the relative amounts of phosphoric and phosphonic acid produced from meteor ablated P in the Earth's atmosphere can be assessed. Preliminary results indicated that both H_3PO_4, and the bio-available H_3PO_3 are formed, with around a third of the ablated P ending up as H_3PO_3. Further work is also underway to determine where on the Earth's surface H_3PO_3 will be deposited, to understand how accretion rates would have differed on the early Earth, and to input the P chemical scheme into a Mars atmospheric model.