Mutual neutralisation of atmospheric radical ions at the double electrostatic ion storage ring DESIREE

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In the highest layer of Earth's atmosphere, situated approximately 150 km above the surface, particles are exposed to high levels of radiation and are mostly composed of atomic ions, dominated by O^+ and N^+. During the night, these are neutralised through recombination with free electrons or by interactions with anions [1,2], a phenomenon known as mutual neutralisation (MN). The process is straightforward to write out:

$$A^+ + B^- \rightarrow A^* + B$$

i.e the captured electron ends up in an electronically excited state of the neutralised atom.

In lower layers however, less ionising radiation is present, due to the absorption from the F layer and the higher pressure, and it is believed that the most abundant ions are molecular radicals, namely N_2^+, NO^+ and O_2^+ [3]. These highly reactive species also interact with the anions present, and two different outcomes are then possible:

$$AB^+ + C^- \rightarrow AB+C$$
$$AB^+ + C^- \rightarrow A+B+C$$

i.e, the captured electron could also end up on a repulsive potential of the formed molecular neutral, such that it fragments, yielding three products.

At the unique cryogenic electrostatic double storage ring DESIREE, these reactions can effectively be studied [4]. We present here the first merged beams results of several atmospheric molecular radical ions, namely O_2^+, NO^+, and N_2^+ interacting with O^-. The results are interesting, as both processes are observed with very different populations depending on the molecular cation. For the three-body processes, distinct dynamics are observed, with a clear vibrational dependence on the product yield.

[1] J. Qin *et al.*, *J. Geophys. Res. Space Phys.* **120**, 10116 (2015)
[2] M. Poline *et al., Phys. Chem. Chem. Phys.*, **23**, 24607-24616 (2021)
[3] D. Smith and P. Spanel, *Mass Spectrometry Reviews*, **14**, 255-278 (1995)
[4] R. D. Thomas *et al., Review of Scientific Instruments* **82**, 065112 (2011)