

Modeling of electron interactions in the Earth's mesosphere

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A recently-proposed method [1] for computational modeling of electron interactions in low-pressure gases is applied to various processes in the Earth's mesosphere. In this method electrons in different subranges of energy are treated in the same way as species in chemical models, allowing time-step simulation of a system where chemical reactions and electron interactions are occurring simultaneously and are interrelated.

The method is applied to mesospheric phenomena that are not fully understood, such as the D-region ledge in electron density and observations of OH in vibrational level 10. Sources of vibrational excitation in the nighttime mesosphere include impact of electrons produced in ionization by Lyman- α radiation, cosmic rays and astronomical X-rays, and chemical production of vibrationally-excited OH. Vibrational excitation can be transferred between different species and lost via radiative decay, VT (vibrational-translational) transitions or superelastic collisions with electrons. An illustrative example of the calculation is presented for the electrons produced in the ionization of NO by Lyman- α radiation. It is normally assumed that the electrons rapidly decline to the ambient neutral temperature through elastic and inelastic collisions, with the recombination rate (and hence the electron density) determined by this temperature. It is also assumed that the vibrational excitation produced is transferred by VT transitions to the kinetic energy of the gas. These processes are simulated in detail to determine the relative effect of the different pathways involved. Accurate atomic and molecular data are required for these calculations, such as the cross sections for vibrational excitation of N₂ [2] and O₂ [3]. A second example is to simulate the distribution of vibrational excitation produced by the reaction: $\text{H} + \text{O}_3 \rightarrow \text{OH}(v) + \text{O}_2$ where $v = 5 - 9$. The vibrational energy is then lost through radiative decay or transferred to other species. The possible transfer of some of this energy to electrons by superelastic collisions is investigated.

[1] L. Campbell, D.L. Muccignat and M.J. Brunger, *Atoms* **10**, 62 (2022).

[2] L. Campbell, M.J. Brunger, D.C. Cartwright and P.J.O. Teubner, *Planet. Space Sci.* **52**, 815 (2004).

[3] D.B. Jones, L. Campbell, M.J. Bottema, P.J.O. Teubner, D.C. Cartwright, W.R. Newell and M.J. Brunger, *Planet. Space Sci.* **54**, 45 (2006).