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On the role of electron-driven processes in planetary and cometary atmospheres

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Electrons in the solar wind and photoelectrons produced by sunlight, sometimes accelerated in the magnetosphere, produce ionisation, dissociation and excitation of atoms and molecules in planetary and cometary atmospheres. These primary electrons, and secondary electrons from ionisation, interact further, progressively losing energy until reaching thermal equilibrium. The product ions and excited species take part in chemical reactions, producing new species. Thus electron-driven processes are significant in determining the populations of minor species and the rates of energy transfer in upper-planetary and cometary atmospheres. The radiation emitted by excited species is valuable in remote sensing. Thus modelling of electron-driven processes is necessary in both observing and understanding these atmospheres. This requires detailed simulation of a large number of electron-impact processes and subsequent radiative and collisional processes, including chemical reactions, which have a vast range of time scales from nanoseconds to days. In most cases thermal equilibrium is not attained, so a statistical-equilibrium calculation is employed. Some vibrational excitations and the products of many slower reactions do not reach statistical equilibrium, hence non-equilibrium calculations are also required. In all such calculations the availability of accurate atomic and molecular data, such as electron-impact cross sections, is critical. Here we show the parallel application of new electron-impact excitation cross sections and enhanced computational techniques in a number of examples, including the determination of the abundance of carbon monoxide in comet Hale-Bopp, electron heating rates in the atmosphere of Titan, predictions of infrared emissions from the upper atmospheres of Mars and Venus and non-equilibrium processes in the atmosphere of Jupiter.