Energetic electron collisions with water molecules: elastic collision and ionization in the magnetosphere at the orbit of Enceladus

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1 Introduction

Saturn's inner magnetosphere is rich in water group neutrals (H_2O, OH, and O) originated from Enceladus (~3.95 Rs). It has been suggested that these neutrals play the dominant role in loss of plasmas [e.g., Paranicas et al., 2007; 2008, *Sittler et al.,* 2008]. Little has been reported on a quantitative study of the electron loss process due to electron-neutral collisions. *Tadokoro and Katoh* [2014] performed one dimensional test-particle simulation regarding 1keV electrons to examine the time variations of equatorial pitch angle distribution and electrons within loss cone through pitch angle scattering due to electron-H_2O elastic collisions around Enceladus. Chemical reactions in plasmas depend on electron energy. At energies above several hundred eV, ionization is the dominant chemical reaction rather than elastic collision. In this study, we report on the current state of development of the simulation code regarding ionization and show a result of estimation of auroral brightness by electron precipitation due to elastic collision.

2 Simulation model

Following the method of *Tadokoro and Katoh* [2014], we use one dimensional test-particle simulation code for monoenergetic electron along Saturn's dipole magnetic field line around Enceladus. Trajectories of the electrons are computed by considering under a dipole magnetic field.

$$m\, dv/dt = q\left(\vec{E} + v \times \vec{B}\right) ,$$

where B is the magnetic field. We assume that the electric field (E) is zero in this study. In this study, we assume that the initial pitch angle distribution is isotropic distribution. The number of electrons used in this simulation is 500,000. A trajectory trace is terminated when a calculation time is over ~380s. The end of calculation time corresponds to the time scale of the co-rotating flux tube passing through the region of the dense H_2O around Enceladus.

The collision is solved by a Monte-Carlo procedure. The collisional frequency, f_{col}, between an electron and H_2O molecule can be given by

$$f_{col} = n\sigma v,$$

where n is the neutral H_2O density, σ is the cross section, and v is the relative velocity between an electron and neutral H_2O. The H_2O density model used in this simulation is the same as the model based on observations used in *Tadokoro and Katoh* [2014].

3 Auroral brightness due to elastic collision

If the elastic collision occurs, then we conduct a calculation of scattering angle based on the differential cross sections. The total and differential cross sections for elastic collisions based on the experimental data are given by *Katase et. al.* [1986].

Using the calculated electron loss rate (elastic collision) in ~380 sec as a function of electron energy in the range from 500 eV to 50 keV and the modeled electron flux base on observations [*Cravens et al.,* 2011], we derive auroral brightness. As a result, the auroral brightness through pitch angle scattering due to elastic collisions is estimated to be ~2.6[R].

4 Simulation code development regarding ionization

In this study, we assume that the product ion after ionization is H_2O^+ as

$$H_2O + e(1^{st}) \rightarrow H_2O^+ + e(1^{st}) + e(2^{nd})$$

where $e(1^{st})$ shows the incident electron, $e(2^{nd})$ shows the secondary electron. We trace the trajectory of the incident electron. The ionization cross section based on the experimental data is given by *Itikawa and Mason* [2005]. If the ionization occurs, then we conduct a calculation of electron energy loss. We assume that the incident electron energy after ionization impact decreases by 12.6eV (ionization energy) and secondary electron energy. The secondary electron energy is solved by a Monte-Carlo procedure using singly differential cross section [*Itikawa and Mason,* 2005]. In actual ionization, the energy of the incident electron decreases with each ionization. It is necessary to use ionization cross sections of secondary electrons considered the energy decrease. We found that the method using linear interpolation is significantly different from the experimental cross section. The fitting using interpolation method is a subject for future works.

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