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Ionization and electron capture for H^+ collisions with CO at low keV energy

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Abstract

We have investigated the total relative ionization and dissociative electron capture cross section for proton collisions with CO within the energy range of 2 keV to 10 keV. Time of flight mass spectroscopy was employed in the measurements of CO^+, O^+ and C^+ and the contribution of the different channels was evaluated. Ionization was found to be the dominant reaction channel as expected, while the C^+ ionic fragments intensity was found to be higher than those of O^+.

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1. Introduction

Protons among other ions are the primary constituents of the solar wind and are important in diagnosing photon emission from distant objects. In order to model this emission from bodies exposed to the solar wind (e.g., comets and planetary upper atmospheres), relative, absolute and differential cross sections of fragment ions are needed for each incident solar-wind ion and charge state. Since CO is one of the major constituents of the comet's neutral atmosphere near the Sun, has a large ionization potential (14.0139 eV), and the solar photoionization rates are low, charge exchange in collisions of solar-wind H^+ ions with CO is the main mechanism for the production of CO^+.

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Due to its fundamental interest, the data are important for our understanding of the interaction of the solar wind with comet type atmospheres in order to have a clear image of the charge exchange observed in the interaction of protons with gases in comets.

Charge-exchange cross sections have been reported previously and mostly for total electron capture. Nevertheless, when data are needed for a specific application, there is the need for new measurements when: either the energy range has not been covered, discrepancy among researchers, or the need for fragments channels and ratios.

High energy measurements have been reported for the total cross section. For example, Rudd et al [1] at 5 keV to 150 keV, McNeal [2] for 1 keV to 25 keV and Kusakabe et al [3] for 0.2 keV to 4.2 keV. Kimura et al [4] reported the results of an *ab initio* calculation of the $H^+ + CO$ reaction. In particular, the theory shows a slow broad plateau in the cross section within the energy range of 3 keV to 10 keV.

Cadez et al [5] reported total proton–electron capture cross sections at energies between 2.5 keV and 7 keV on CO, Lindsay et al [6] reported total electron capture for 1 keV to 5 keV for $H^+ + CO$, and Gao et al [7] for 1.5 keV for $H^+ + CO$. Berkner et al [8] measured the total cross section between 0.15 keV to 10 keV.

We know of several experimental investigations for ionization and electron capture leading to CO^+, C^+, and O^+: the first is that of Browning and Gilbody [9] for 5 keV and 45 keV, the second is that of Shah and Gilbody [10] for 10 keV to 98 keV and the third is that of Afrosimov et al [11] for 5 keV to 50 keV.

A similar investigation was undertaken by Knudsen et al [12], however, for the higher energy of 50 keV to 6000 keV.

The present work illustrates detailed measurements of the relative dissociative electron capture for the $H^+ + CO$ collisions within the energy range of 2 keV to 10 keV.

We have investigated previously the ionization and dissociative electron capture and ionization of CH_4 [15] and CO_2 [14] by proton impact employing a pulsed interaction region technique and time of flight mass spectroscopy. In the present work, we use the same method to investigate the low keV energy ionization and dissociative electron capture of carbon monoxide by proton impact.

2. Experimental apparatus and procedure

In our previous work [13-15] we have given details of the experimental apparatus as well as the experimental procedure.

Both projectile ions and resulting neutrals as well as the pulsed and accelerated target ions and fragments are then detected using time of flight mass spectroscopy. The proton beam was constantly monitored and recorded. The mass scale of the spectrum is calibrated and the efficiency of detection was evaluated. Background signal was taken into account in evaluating the absolute cross sections after normalization to previously measured total cross sections.

3. Results and analysis

A typical time of flight (TOF) spectra for protons in collisions with CO is shown in figure 1, and it illustrates a satisfactory level of resolution as well as channels CO^+, C^+, and O^+. The observed TOF spectra include the contribution from the CO ionization and dissociation and the contribution from the background. The presence of N_2 and H_2O in the vacuum chamber contribute to the background signal. The background spectra is recorded and subtracted from the spectra of the CO gas. The small contribution of N_2^+ and any signal from the presence of H_2O was found to be below the detection limit. The N_2^+ contribution to the total signal was taken into account in evaluating the relative total cross sections of the fragment ions. To obtain the relative cross sections, first the background was removed from all the peak areas; then, for all the collisional energies, a normalization was made to the same proton current and target gas pressure.