

Cross sections for the CH_2^+ formation pathways via CH_4 fragmentation by electron impact

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Synopsis The mechanisms for CH_2^+ production, due to methane fragmentation by electron impact in the 22 to 400 eV energy range, were investigated using the DETOF technique. Absolute cross sections for the two possible channels, $\text{CH}_4^+ \rightarrow \text{CH}_2^+ + \text{H}_2$ and $\text{CH}_4^+ \rightarrow \text{CH}_2^+ + 2\text{H}$, and the corresponding kinetic energy distributions of CH_2^+ were obtained. Furthermore, the average kinetic energy release of H_2 and H neutrals for these two reactions were estimated as 0.04 eV and 2.1 eV, respectively. The dynamics governing these two pathways is discussed.

Methane is the major organic compound detected in many astrophysical environments, such as Titan's and the outer planets' atmospheres, and has also direct application in the physics of tokamak plasma devices.

For these reasons, its ionization and subsequent fragmentation by different projectiles have been the subject of many studies. Recently, the kinetic energy release (KER) of methane fragments produced in collision with electrons has been determined [1]. It was observed that two energy distributions contribute to the formation of CH_2^+ , corresponding to different and well-known fragmentation pathways: (1) $\text{CH}_4^+ \rightarrow \text{CH}_2^+ + \text{H}_2$, and (2) $\text{CH}_4^+ \rightarrow \text{CH}_2^+ + 2\text{H}$.

In this work, these channels are thoroughly analyzed using the DETOF (Delayed Extraction Time-Of-Flight) technique, which can not only provide the disentanglement of the different energy distribution of slow fragments produced in a collisional process, identifying the different fragmentation pathways, but also measure the absolute cross section for each energy distribution of a fragment [2].

In short, the experimental setup consists of a pulsed electron gun operating, in this work, in the 22 to 400 eV energy range and a standard time-of-flight (TOF) spectrometer coupled with a gas cell. The DETOF technique consists in gradually and systematically increasing the delay time between the electron beam and the extraction field that guides the positively charged fragments into the TOF drift tube, in order to allow the faster fragments enough free flight time to leave the collection region. Thus, this delay time works as a velocity selector and the energy distributions can be obtained.

The absolute cross sections measured for the CH_2^+ fragment as a function of the electron

impact energy can be seen in Figure 1, as well as the cross sections corresponding to fragmentation pathways (1) and (2).

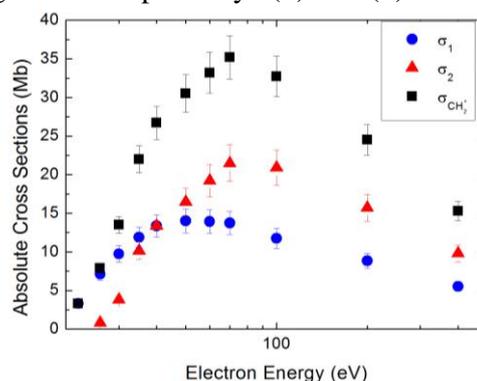


Figure 1. Absolute cross sections for CH_2^+ (black squares) and its two fragmentation pathways: σ_1 (blue circles) and σ_2 (red triangles), corresponding to channels (1) and (2), respectively.

The kinetic energy distribution associated to reaction (1), responsible for the release of a Hydrogen molecule, corresponds to very slow fragments, with a supra-thermal average energy of 0.04 eV, while the kinetic energy distribution associated to reaction (2), in which two Hydrogen atoms are produced, accounts for faster fragments, with average kinetic energy of 0.2 eV produced via pathway (2). It is noteworthy from Figure 1 that pathway (2) has a later onset than (1), but becomes more important as the impact energy increases. The kinetic energies of the neutral fragments were also obtained, being 0.3 eV for the hydrogen molecule in (1) and 2.1 eV for each hydrogen atom of (2).

References

- [1] B Wei *et al* 2013 *J. Phys. B: At. Mol. Opt. Phys.* **46** 215205
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