Single and double ionization of ammonia by proton collision: experiments and model calculations

W. Wolff [1,*], H. Luna [1,†], L. C. Rodrigues da Silva[1], E. C. Montenegro[1] and H. J. Lüdde[2]

[1]Instituto de Física, Universidade Federal do Rio de Janeiro, Rio de Janeiro, 21941-972, Brazil
[2]Frankfurt Institute for Advanced Studies (FIAS), D-60438 Frankfurt, Germany

Synopsis We report absolute cross-sections of ammonia ionization by proton impact with energies between 130 and 2700 keV (2.3 to 10.4 v_0, where v_0 is Bohr velocity). The experiments were carried out using a time-of-flight spectrometer in combination with a multicoincidence ion detection. The cross-sections were discriminated on the single and double ionization channels with and without molecule fragmentation. From the data we infer the contribution of the outer and inner valence ionization in the fragment-ion production by using a semi-empiric model. The experimental results add relevant information of ammonia considered as a dominat supplier of elemental nitrogen for the formation of molecules across the interstellar medium, on planetary bodies and in the atmosphere of the earth.

Ammonia is common across the interstellar medium, in protostars, comets and meteorites, and on the atmosphere and surface of planetary bodies, *e.g.* Jupiter and Saturn´s moon, Titan [1]. A large fraction of nitrogen available to planet forming regions, such as to our early solar system, is believed to come from dissociated ammonia[2]. Ammonia is the most common alkaline gas of the atmosphere, playing an important role in the atmospheric chemistry and is closely related to ecosystems, were ammonia is exposed to air. In this context, the CLOUD experiment at CERN [3] showed that ammonia increases largely the nucleation rate of atmospheric aerosols, that cause a cooling effect by reflecting sunlight and by seeding cloud droplets.

Here, we present the dependence of the ionization and subsequent dissociation in the proton collision energy varied from 130 to 2700 keV. We discriminate the ion production coming from single and double ionization, not quantified yet in the literature for charged particle interaction. The evolution of the ions abundances with the proton velocity is expressed as relative to the parent ion, NH_3^+, as shown for example in figure 1 for the atomic nitrogen ion, N^+. Additionally we combine the present results with those previously reported for electron impact (fig. 1). Noticeable discrepancies are observed, but these might be due to different experimental procedures. We compare the total double ionization (TDI) cross section with IAM-PCM model calculations [4] and inquire the inner shell contribution of nitrogen by comparing TDI with the K-shell nitrogen ionization cross section.

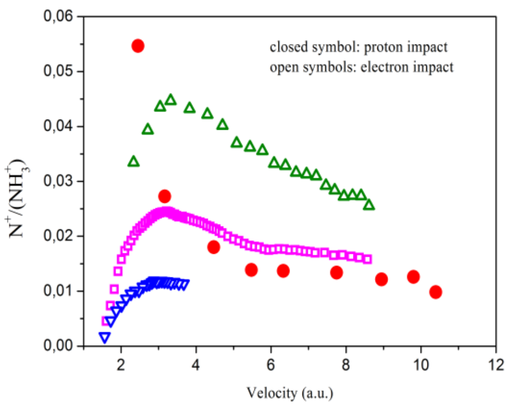

Figure 1. Ratio of N^+ production relative to NH_3^+ as function of the electrons velocity: square, Rao and Srivastava [5]; up-triangle, Bederski, Wojcik and Adamczyk [6]; down-triangle, Märk, Egger and Cheret [7] and protons: circle, present work .

References

[1] Tielens A.G.G.M. 2013 *Rev.Mod. Phys*. **85** 1021
[2] Pontoppidan Klaus M. *et al* 2019 *ApJ* **874** 927
[3] Almeida João *et al* 2013 *Nature* **502**, 359
[4] Lüdde H.J. *et al* 2018 *Eur.Phys. J. B* **91** 99
[5] Rao M.V.V.S. *et al* 1992 *J. Phys. B : At. Mol. Opt. 25 2175*
[6] Bederski *et al* 1980 *Int. J. M. Spectrom Ion Phys*. **35** 171
[7] Märk, T. D. *et al* 1977 *J. Chem. Phys*. **67** 3795

* E-mail: wania@if.ufrj.br
† E-mail: hluna@if.ufrj.br