Colliding the pyridyne molecules with a low energy cations

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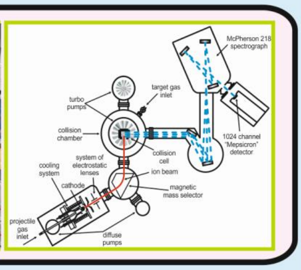
Abstract

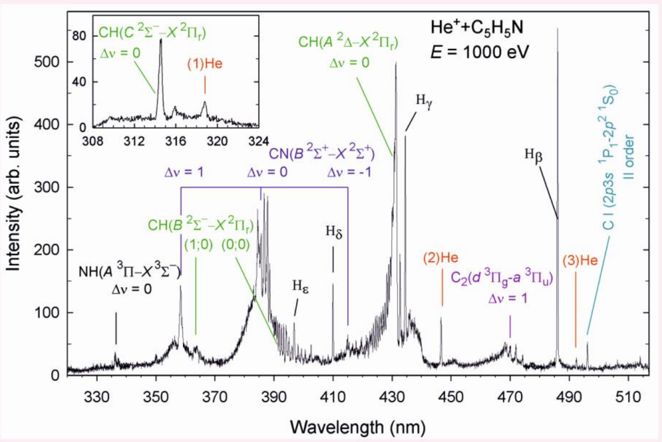
Carbon-rich meteorites contain many biologically relevant organic molecules. The most recent studies have provided evidence of extraterrestrial amino acids, nucleobases, and ribose in those primitive rocks. Thus it is believed that meteorites could have been carriers of biological material needed to create life on the early Earth. But the question arises: how these molecules were formed and how they could have survived the bombardment of the solar wind consisting of photons, electrons, protons, and a few percents of heavier nuclei. The laboratory investigations of collisions of the DNA, amino acids, and vitamins building blocks or their analogs with a different kind of radiation may shed some light on these issues. Therefore, in the present communication, we present results of collisions of low energy H^+, H_2^+, He^+ cations with the pyridine molecules, the heteroaromatic building blocks of vitamins, pharmaceuticals, and agrochemicals.

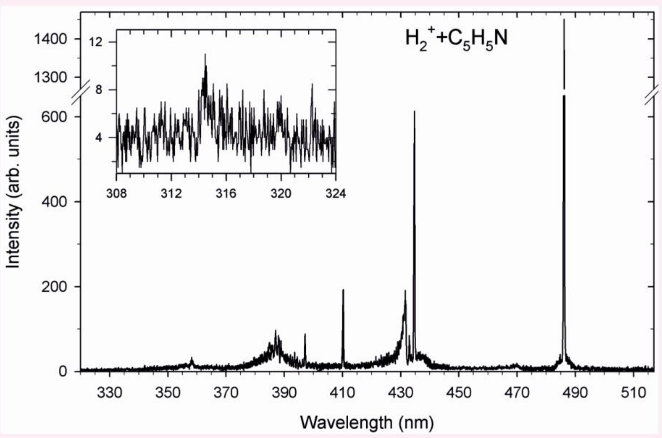
Experimental technique

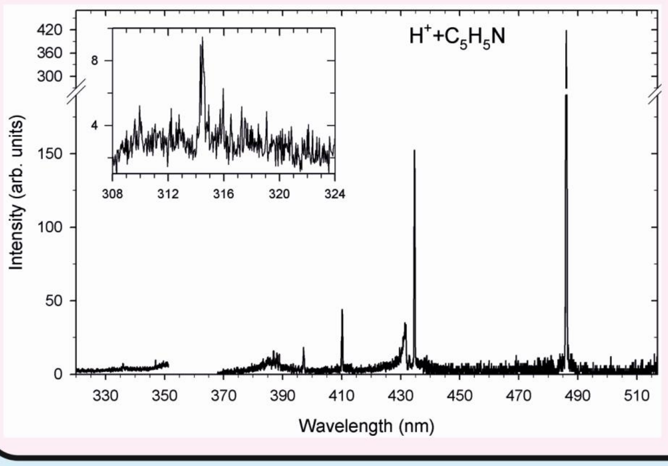
The measurements were carried out using collision-induced luminescence spectroscopy [1]. the apparatus consisted of four parts: an ion source, a mass selector, a collision chamber, and an optical spectrometer. The ions were generated from the helium gas utilizing the Colutron hot cathode discharge. Then, they were directed into a 60° magnetic mass selector, which separated them according to the m/q ratio. In the collision cell, the ions impinged upon the vapors of the target molecules leading to their fragmentation. The emission of the products generated in the excited states was detected with a sensitive multi-channel photon detector mounted in the optical spectrometer. The spectrometer operated on two gratings. The 1200 lines/mm grating allowed us to measure the high-resolution collision-induced luminescence spectra Δλ of 0.4 nm (FWHM), which were appropriate for the accurate identification of the spectral components. The second grating, 300 lines/mm, was used to measure luminescence spectra in the 180-540 nm wavelength range and obtain the relative intensities of the emission lines.



Luminescence spectra







(a) The emission spectrum obtained for collisions with the He^+ ions reveals the formation of hydrogen H(*n*), *n*=4–9, and carbon C($2p3s$ $^1P_1$) atoms, and rotationally and vibrationally excited diatomic CH($A^2\Delta$, $B^2\Sigma^-$, $C^2\Sigma^+$), CN($B^2\Sigma^+$), and C_2($d^3\Pi_g$) fragments from pyridine. Apart from the molecules mentioned, the NH radicals are identified by detection of the $A^3\Pi \rightarrow X^3\Sigma^-$ emission, which emerges from 326 nm up to 345 nm [2]. Since the skeleton of the pyridine molecule consists of five CH units and one N heteroatom and has not got the NH structural entities, the appearance of the luminescence from the excited NH($A^3\Pi$) is visible evidence of a chemical bond rearrangement process in which one of the hydrogen atoms migrates prior to the dissociation.

Figure (a) also shows the production of helium atoms excited to the $1s4d$ $^1D_2$, ^3D states. Since He atom is not incorporated into the chemical structure of the pyridine molecule, the observation of its emission lines clearly indicates the transfer of an electron from the pyridine molecule to the He^+ cation.

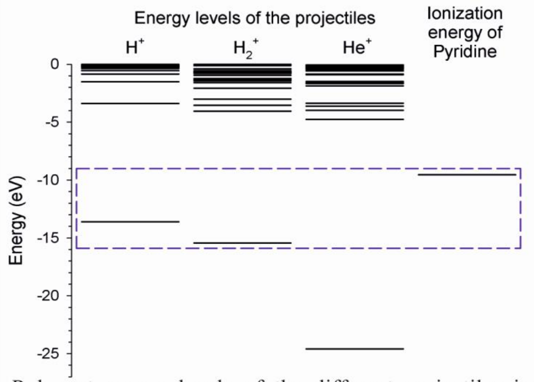
The emission spectra obtained for collisions with the (b) H_2^+ and (c) H^+ ions are presented for comparison.

It is seen that the spectra obtained in the H_2^+ and H^+ collisions are less complex and contain luminescence from fewer fragmentation products than the spectrum recorded for the He^+ cations.

This may suggest the importance of different collisional processes in these impact systems.

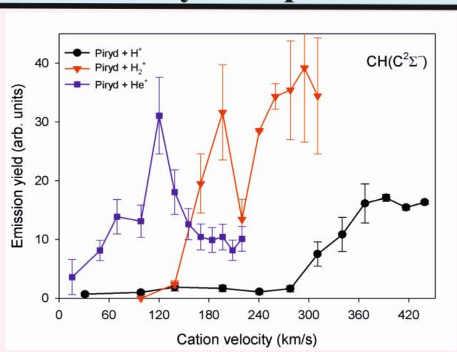
Minor fragmentation of pyridine and enhanced production of hydrogen atoms in the H_2^+ and H^+ collisions may indicate that the charge transfer mechanism may govern in these impact systems.

Collisional processes



Relevant energy levels of the different projectiles in comparison with the vertical ionization energy of pyridine. The dashed rectangle contains the levels into which resonant or quasiresonant electron transfer is possible.

Emission yield spectra



Figures display the velocity dependences of the emission yields for the excited CH($C^2\Sigma^-$) fragments obtained in collisions of pyridyne with the H^+, H_2^+, He^+ cations. The observed rapid increase of the emission yields occurring at lower velocities may be regarded as an indication of the complex formation before dissociation [1,2].

Acknowledgements

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References

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[2] T. J. Wasowicz et al 2016 J. Phys. Chem. A **120** 964.