Negative ions in space

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Existence of negative ions in space has been discussed for a long time. Although 15 positive ions have been known in interstellar space, the first identification of the negative ion C_6H^- was carried out quite recently(2006).

The late type carbon star IRC+10216 is well known to be one of the richest molecular source. So far more than 53 molecular species were identified in IRC+10216. During spectral line survey observations in the frequency region between 28 and 50 GHz by using the Nobeyama 45-m radio telescope, Kawaguchi et al.[1] found a series of unidentified lines with a spectral pattern of a $^1\Sigma$ linear molecule. The rotational constant was determined to be 1376.864 MHz. Later, Aoki [2] carried out ab initio calculations to find a candidate to explain the magnitude of the rotational constant and concluded that the C_6H^- anion is a probable candidate. In 2006, McCarthy et al. [3] succeeded to detect the rotational lines of C_6H^- by laboratory millimeter wave spectroscopy and Fourier transform microwave (FT MW) spectroscopy and established that the C_6H^- anion is the carrier of the unidentified species with the rotational constant.

Following to C_6H^-, the C_4H^-, C_8H^-, C_3N^- anions have been detected in IRC+10216 and other sources. The C_8H^- detection [4] and search for $C_{10}H^-$ with the Nobeyama 45-m telescope will be presented. Table 1 lists the electron affinities of the C_nH (C_nN) radicals and dipole moments of C_nH^- (C_nN^-), where n=odd (for C_nH) and n=even (for C_nN) chain molecules are not listed because of less abundances.

Table 1. Electron affinity(EA) of $C_nH(N)$, dipole moment (μ) of $C_nH(N)^-$, and column density(*N*) in IRC+10216

(C_nH)	n=2	4	6	8	10	(C_nN) 1	3	5	
EA of C_nH	2.96	3.56	3.81	3.97	3.9	3.86	4.6	4.5	(eV)
μ of C_nH^-	3.4	5.9	8.2	10.4	12.7	0.6	3.1	5.2	(Debye)
N of C_nH	5000	2980	80	5.5		640	310	6	($\times10^{12}$ cm^{-2})
N of C_nH^-	<0.4	0.71	6.9	2.6		<16	1.6	<1	($\times10^{12}$ cm^{-2})
Ratio[a]	<1/12500	1/4200	1/12	1/2		<40	1/194	<1/6	

[a][anion]/[neutral]

We discuss about production reactions related to the observed abundances listed in Table 1 and spatial distributions of negative ions and neutral species in IRAC+10216. When we consider star forming region like as Orion KL, above anions are expected to be less because of small abundances of carbon chain molecules. On the other hand, the positive ion HCO^+ is abundant with a column density of 3 x10^{14} cm^{-1}, so we will discuss about existence form of negative charge in star forming regions.

References

[1] Kawaguchi,K., Kasai, Y., Ishikawa, S., Kaifu, N. 1995, PASJ, 47, 853
[2] Aoki, K. 2000, Chem. Phys. Lett., 323, 55
[3] McCarthy, M. C., Gottlieb, C. A., Gupta, H., & Thaddeus, P. 2006, ApJ, 652, L141
[4] Kawaguchi, et al. 2007, PASJ, 59, L57