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THRESHOLD ELECTRIC FIELD FOR DISSOCIATION OF THE H_2^+ ION

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THRESHOLD ELECTRIC FIELD FOR DISSOCIATION OF THE H_2^+ ION

by

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A B S T R A C T

A study has been made of dissociation by an electrical field of H_2^+ ions formed by the break-up of H_3^+ ions. In the present experiment it is shown that there is a minimum field of $0.96 \pm 0.05 \times 10^4$ V/cm required to cause this field dissociation.

This is consistent with the available theoretical value of 10^4 V/cm which is however uncertain to within a factor two.

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(C/18 IMG)

The results of the present experiment confirm the existence of an electrical field strength of 10^4 V/cm below which no observable field dissociation of H_2^+ into H^0 and H^+ occurs.

A threshold exists as a consequence of the fact that the H_2^+ ion has only a finite number of stable states. The value of the threshold field is very steeply dependent on the energy of the uppermost vibrational level and this has been calculated by Hiskes (1961, 1962). A measurement of the threshold field provides a very sensitive test of the potential assumed in the calculations. The highest vibrational state is that with $v = 18$. To be stable against dissociation, this state may have rotational states with $J = 0, 1, 2$ and 3 only. For a given value of J, the magnetic quantum number m may take any value between $-J$ and $+J$. The level dissociated at the lowest field strength is that with $v = 18, J = 3, m = 0$. The threshold field strength estimated by Hiskes is (within a factor 2) 10^4 V/cm. The fraction of the H_2^+ ions to be found in the $v = 18$ state was estimated by Hiskes to be 2.4×10^{-4} if the ions were formed by electron impact ionization of H_2. If all sixteen substates of $v = 18$ are equally populated then the fraction of the ions in the $v = 18, J = 3, m = 0$ state would be 1.5×10^{-5}.

The field dissociation results of Riviere and Sweetman, (1961) showed that H_2^+ ions obtained from the break-up of H_3^+ ions in passing through a gas target were more highly excited than those obtained direct from the source. In the present experiment use was made of this fact to obtain the largest possible fraction of H_2^+ in the upper states.

H_3^+ ions from an r.f. ion source were accelerated to energies of 300, 400 and 500 keV. Different energies were used to eliminate a possible spurious threshold due to the $v \times B$ field dissociation in the analysing magnets. This field is proportional to the energy since the Larmor radius is constant. After magnetic deflection this beam was partially broken up in a gas target of the order of 10^{15} atoms/cm² of air. The resulting H_2^+ beam was then selected magnetically. The beam was passed through an electrode system similar to one used earlier by Riviere and Sweetman (1961) in which an electric field was applied parallel to the direction of motion over a distance of 1 mm. The beam then passed through a magnetic field in which the H^o, H_2^+ and H^+ are separated and individually detected on CsI scintillation counters (Riviere and Sweetman, 1963). The ratio of the H^o, H^+ coincidence count rates to the H_2^+ current was then measured with and without applying a voltage to the electrodes, and changes in this ratio determined. The results are shown in Fig.1. The ordinates are in relative units on a linear scale.

The error indicated by the bars is mainly due to statistical fluctuations in the count-rate, that is $\pm \sqrt{(A+B)/(A-B)} \cdot 100$ per cent, where A and B are the number of counts with and without field respectively. It can be seen that there is a threshold which is independent of energy at $0.96 \pm 0.05 \times 10^4$ V/cm. This value is consistent with Hiskes' calculations. In order to get a more accurate theoretical value, numerical calculations of the electronic energy of H_2^+ have been performed (to be published soon).

Absolute measurements of the fraction of the total H_2^+ beam dissociated were made at 9×10^4 V/cm at each energy. This fraction was found in each case to be $1.6 \pm 0.2 \times 10^{-4}$. Hiskes' calculation give 1.3×10^{-4} for H_2^+ from electron impact ionization of H_2. Riviere and Sweetman (1961) measured a fraction of 0.7×10^{-4} at this field. However their measurements were made under different conditions and at an H_3^+ energy of 2 MeV.

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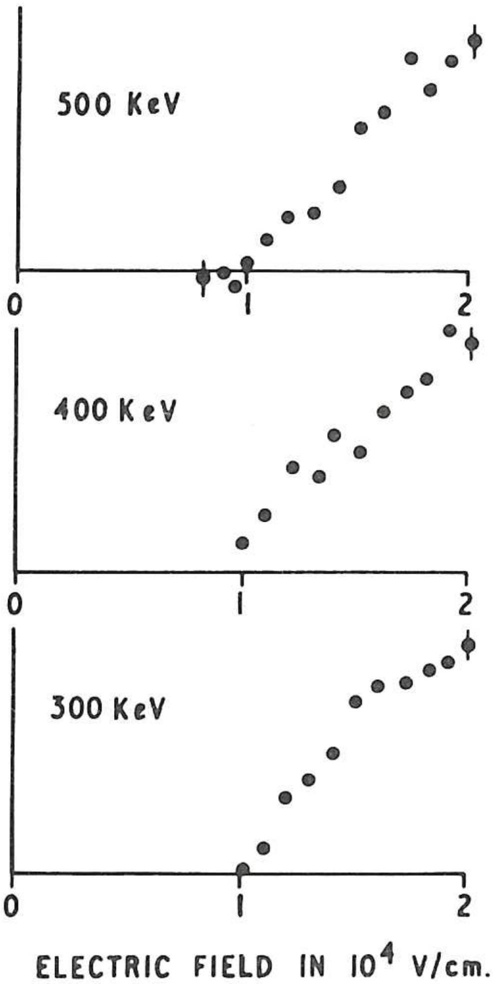

CLM-P 49 Fig. 1

Dissociation of H_2^+ ion beam near threshold for primary H_3^+ beam energies of 300, 400 and 500 keV