DISSOCIATION OF H_2^+ *IONS ON COLLISION WITH GAS ATOMS AND MOLECULES*

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Measurements were made of the cross sections for the formation of protons by the dissociation of molecular H_2^+ ions of 10—180 keV energy in hydrogen, nitrogen, helium, and argon. A summary of the published data on these cross sections is given for a wide range of energies.

THE idea of using fast molecular hydrogen ions for injection into plasma traps required a study of the processes of collisional dissociation of these ions in gases over the whole range of kiloelectron-volt energies (10^3—10^6 eV).[1] The so-called cross section for the formation of protons from H_2^+ ions:

$$\sigma_p = \sigma_1 + 2\sigma_2,$$

is of direct interest in injection; here σ_1 and σ_2 are the cross sections of the processes of H_2^+ ion dissociation leading to the formation of one atom and one proton, and two protons, respectively.

Several recent papers have described measurements of the cross section σ_p.[2-11] The early work, in particular ours[2] and Barnett's[3] gave strongly differing values of the cross sections for energies of the order of 100 keV. The principle of the method was the same for all the cited papers. A monokinetic beam of H_2^+ ions passed through a gas target and was then analyzed using a magnetic or electric field. Protons formed by the dissociation of H_2^+ ions were trapped by a Faraday receiver or recorded with a charged-particle counter. The required cross section was determined from the thickness of the gas target and from the ratio of the H_2^+ ion and proton currents.

The main sources of systematic errors in measurements of the cross section σ_p are obviously the following: a) incomplete collection of the protons when the H_2^+ ions dissociate, because the process is accompanied by scattering; b) inaccurate determination of the gas target thickness; c) departure from the single-collision conditions due to insufficiently low gas pressure in the collision chamber. In particular, the systematic errors in Barnett's work[3] were due to causes a) and c), while in our work[2] they were due to b).

The present work was intended to repeat the measurements of the cross section σ_p using the same apparatus as before[2] but taking great care to eliminate the main sources of systematic errors. The gas pressure in the collision chamber was sufficiently low [$(1—3) \times 10^{-4}$ mm Hg] to ensure single-collision conditions. The effective thickness of the gas target was determined from a detailed study of the pressure drop at the collision chamber slits. The current of protons formed by dissociation and the H_2^+ ion current were measured simultaneously. Additional steps were taken to improve the geometry of the apparatus by selecting the optimum dimensions of the collision chamber and receiver slits. It should be noted that the leakage of gas into the analyzer limits the dimensions of the exit slit of the collision chamber. In

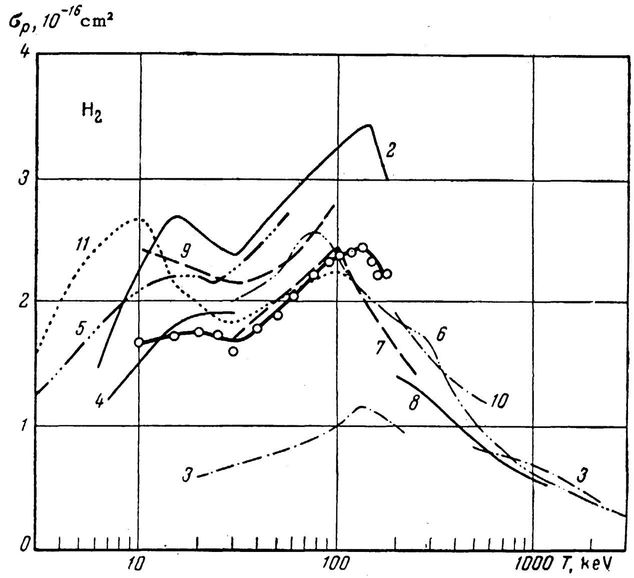

FIG. 1. Cross section for the formation of protons from H_2^+ ions in molecular hydrogen. The thick curve represents the data reported in the present work. The other data are denoted by the numbers of the corresponding literature citations.

view of this, we assumed that the cross section values obtained below 30 keV were lower than their true values. Above 30 keV, we estimated that the random errors in the measurement of σ_p were ± 12%.

Figures 1—4 show the curves obtained in the present work for the dependence of the cross section σ_p on the energy of H_2^+ ions in hydrogen, nitrogen, helium, and argon. As in previous work,[2,4] the cross section σ_p was taken relative to the hydrogen molecule. The figures also include similar curves taken from other sources. The data which differed most strongly,[2] and [3], are given only for hydrogen (Fig. 1). The data of Kupriyanov, Perov, and Tunitskiĭ[5] represent the dissociation of D_2^+ in deuterium. Therefore, their curve was reduced to the equivalent value of the H_2^+ ion velocity, since H_2^+ ions were used in all the other work.

Figure 1 shows that the majority of the curves obtained in recent work lie between the data of Sweetman[6] and our earlier work.[2] Only the curve from the early work of Barnett[3] lies considerably below. The data of the present investigation are in good agreement with Sweetman's curve[6] and the first measurements of Fedorenko.[4] Taken altogether, the various data cover almost the whole range of kiloelectronvolt energies. For hydrogen, the curve has two maxima, which we first discovered and reported.[2] The first maximum is due to the predominant contribution of the process of the dissociation of H_2^+ ions into atoms and protons, and the second is related to the dissociation into two protons. This assumption is confirmed directly by the work of Guidini[7] who measured separately the two cross sections.

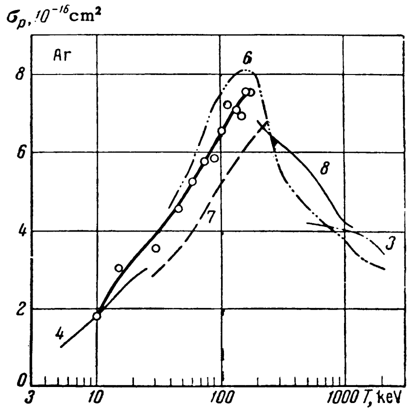

FIG. 4. Cross section for the formation of protons from H_2^+ ions in argon. The notation is the same as in Fig. 1.

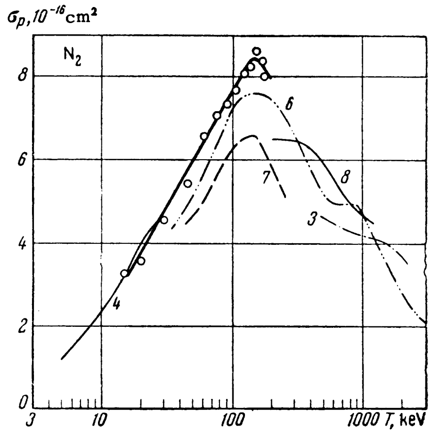

FIG. 2. Cross section for the formation of protons from H_2^+ ions in molecular nitrogen. The notation is the same as in Fig. 1.

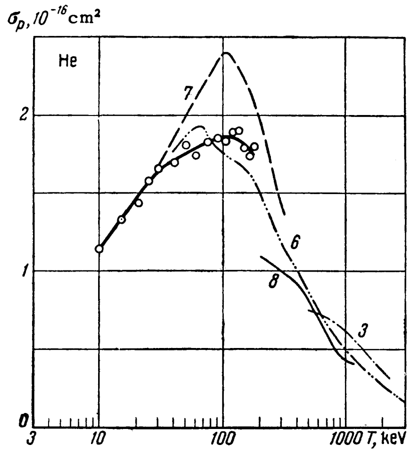

FIG. 3. Cross section for the formation of protons from H_2^+ ions in helium. The notation is the same as in Fig. 1.

In the case of other gases, the recent data agree within the experimental error (cf. Figs. 2—4). In the investigated range of energies, a maximum in the curves of Figs. 2—4 is observed in the 100—200 keV region.

In conclusion, the authors extend their thanks to A. I. Kislyakov who took part in several measurements.

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