The obtained distributions were normalized to the counting rate for the case of total disorientation of the crystal, i.e., practically for an amorphous target. The minimum of the counting rate of the back-scattered positrons is observed when the direction of incidence of the primary beam coincided with the <100> direction of the target crystal, and is due to the effect of channeling of the primary beam of the positron in the crystal. A consequence of the effect of positron channeling is a decrease in the probability of large-angle scattering of the positrons and an increase of the depth of penetration of the positrons into the crystals. The channeling efficiency, determined by the depth of the observed minimum of the distribution, increases with increasing atomic number of the target; this agrees with the conclusions of Linhard's channeling theory [3].

The table lists the values of the width of the minimum ψ_1 at half its depth, calculated in accordance with Linhard's theory for the mean energy of the spectrum of the Na^{22} positrons, and the experimental values of $\Delta\psi$ obtained by us for KCl, KBr, and KI single crystals.

Parameter \ Crystal	KCl	KBr	KI
d	2,81	3,20	3,80
Z_{eff}	14,70	18,00	34,20
ψ_1	1,5°	1,8°	2,6°
$\Delta\psi$	1,6°	2,1°	3,0°

As seen from the table, the observed half-width of the minimum increases with increasing lattice parameter d and effective atomic number Z_{eff} of the crystal. This agrees with the conclusions of the theory. The good agreement between the theoretical and experimental results may mean that the classical approach to the channeling effect is still valid in our case, although the dynamic theory of diffraction of positron waves may offer a more accurate description of this effect.

The observed effect in back scattering of positrons from crystals confirms the previously advanced hypothesis that the influence of positron channeling may become manifest in different processes of their interaction with crystals, making practical use of this effect possible in the future.

[1] A.F. Tulinov, Usp. Fiz. Nauk 87, 585 (1965) [Sov. Phys.-Usp. 8, 864 (1966)].
[2] S. Datz et al., Annual Rev. Nucl. Sci. 17, 129 (1967).
[3] J. Linhard. Kgl. Danske Videnskab. Selskab, Mat. Pys. Medd. 34, N14 (1965).

INFLUENCE OF EXCITATION OF H_2^+ and D_2^+ ON THE CROSS SECTION FOR THEIR DISSOCIATION IN COLLISIONS WITH ATOMS AND MOLECULES IN THE ENERGY REGION FROM 0.1 TO 2 keV

N.N. Tunitskii, E.S. Zhurkin, and M.V. Tikhomirov

Submitted 18 August 1970
ZhETF Pis. Red. 12, No. 6, 312 - 314 (20 September 1970)

It is known that the dissociation of H_2^+ ions by collision with atoms and molecules can occur in two ways, by excitation of the repulsive electron states and by momentum transfer to the nuclei [1]. In the first, the dissociation of H_2^+ occurs predominantly at collision energies from several keV up [2]. A region in which momentum transfer to the nuclei is important is expected to be observed at energies from several dozen to several thousand electron volts. This energy region has not been sufficiently well investigated [3 - 5] and the relative role of the two mechanisms is not clear.

We have investigated the dissociation of weakly-vibrationally-excited H_2^+ and D_2^+ ions and strongly-vibrationally excited D_2^+ ions. The weakly-excited ions $H_2^+(H_2)$ and $D_2^+(D_2)$ were obtained by ionizing hydrogen and deuterium, respectively, by electron impact. The average vibrational-excitation energy of the ions $H_2^+(H_2)$ and $D_2^+(D_2)$, according to [6], is 1.1 - 1.4 eV. The strongly-excited ions were $D_2^+(CD_4)$, obtained by electron bombardment of deuteromethane. These ions, judging from our measurements of their dissociation threshold, are excited on the average 0.8 eV higher than the weakly excited H_2^+ and D_2^+ ions, i.e., they have an excitation energy of about 2 eV, which is close to the estimates of [6 - 7].

The total dissociation cross sections were measured with a previously-described double mass-spectrometer setup [8] that makes it possible to reduce the discrimination effects to a minimum. We used in the measurements the methods involving narrow and wide collector slits. Both methods yielded compatible results.

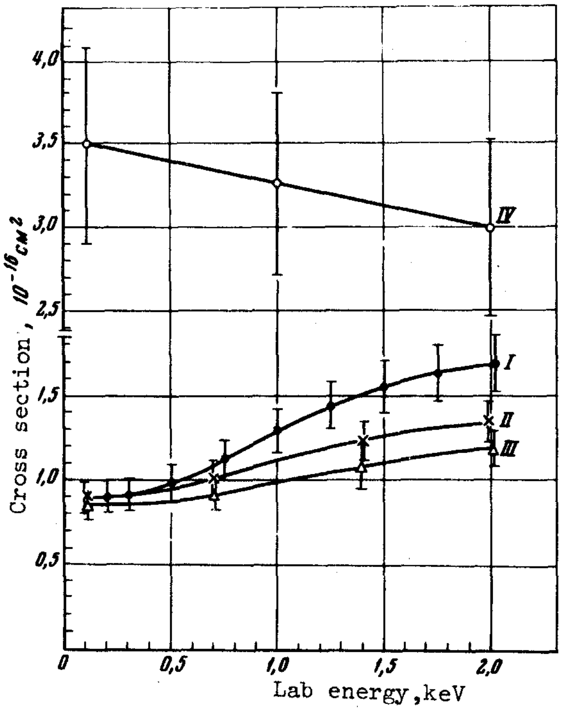
We investigated the following processes:

$$H_2^+(H_2) + H_2 \rightarrow H^+ + H + H_2 \, , \qquad \text{(I)}$$

$$D_2^+(D_2) + D_2 \rightarrow D^+ + D + D_2 \, , \qquad \text{(II)}$$

$$D_2^+(D_2) + Ne \rightarrow D^+ + D + Ne, \qquad \text{(III)}$$

$$D_2^+(CD_4) + Ne \rightarrow D^+ + D + Ne \, . \qquad \text{(IV)}$$



Dissociation cross sections of H_2^+ and D_2^+ vs. kinetic energy for the following processes:

I $- H_2^+ | H_2 | + H_2 \rightarrow H^+ + H + H_2$,
II $- D_2^+ | D_2 | + D_2 \rightarrow D^+ + D + D_2$,
III $- D_2^+ | D_2 | + Ne \rightarrow D^+ + D + Ne$,
IV $- D_2^+ | CD_4 | + Ne \rightarrow D^+ + D + Ne$

The results of measurement of the dissociation cross sections are shown in the figure. It is seen from curves I, II, and III that in the energy range from 0.1 to 2 keV the dissociation cross sections increased monotonically with kinetic energy, and at 2 keV the cross section of process I is somewhat larger than that obtained in [9] (1.4×10^{-16} cm^2), this being apparently connected with the more effective proton gathering. Since the cross section for dissociation by momentum transfer to the nuclei should decrease with increasing ion energy, whereas the cross section for dissociation via electronic transitions should increase [1], and since the curves show no dips, it should be concluded that there exists a region in which both mechanisms are effective.

The energy dependence of the dissociation cross section has an entirely different character in the case of the strongly excited ions $D_2^+(CD_4)$ (curve IV). In this case, a certain drop of the dissociation cross section with increasing energy is observed. It must therefore be assumed that the role of dissociation via momentum transfer to the nuclei is effective in this case in a much wider range of kinetic energies, and plays a relatively larger role than dissociation via electronic transitions. We note here that our estimates of the dependence of the cross section for the dissociation of strongly excited H_2^+ ions by momentum transfer to the nucleus agrees qualitatively with experiment. The differences between the plots of the dissociation cross sections for H_2^+ ions with v = 0 and v = 3, and the strong influence of vibrational excitation on the cross section in the kinetic energy range from 0 to 10 eV, were noted also in [11].

It follows also from the figure that the ratio of the dissociation cross section of the strongly-excited (curve IV) and weakly excited D_2^+ ions (curve III) is equal to 4.1 at low energies and to 2.5 at high energies. The analogous ratio for the dissociation of H_2^+ (H_2) and H_2^+(CH_4) at 3.8 keV energy on Ne is equal to 2.3 [12]. Thus, the dissociation of hydrogen ions at low energies is much more sensitive to the excitation of the initial ions.

[1] E.F. Salpeter, Proc. Phys. Soc. 63a, 1295 (1950).
[2] B. Meierjohann and W. Seibt, Zs. Phys. 225, 9 (1969).
[3] N.N. Tunitskii, R.M. Smirnova, and M.V. Tikhomirov, Dokl. Akad. Nauk SSSR 101, 1083 (1950).
[4] J.Wm. McCowan and L. Kerwin, Can. J. Phys. 42, 972 (1964).
[5] T.F. Moran and D.C. Fullrton, Chem. Phys. Lett. 2, 625 (1968).
[6] V.V. Ivanov, M.B. Tikhomirov, and N.N. Tunitskii, Khikya vysokikh energii (High-energy Chemistry) 3, 312 (1969).
[7] S.E. Kuprianov, Dokl. Akad. Nauk SSSR 158, 942 (1964).
[8] V.V. Ivanov and M.V. Tikhomirov, ibid. 188, 387 (1959).
[9] A.A. Perov, Candidate's dissertation, Moscow Physico-tech. Inst., 1967.
[10] V.I. Gerasimenko and Yu.D. Oksyuk, Zh. Eksp. Teor. Fiz. 48, 499 (1965) [Sov. Phys.-JETP 21, 333 (1965)].
[11] W.A. Chupka, J. Berkowitz, M.F. Russell, VI Internat. Conference of the Physics of Electronic and Atomic Collisions, Cambridge, Massachusetts, USA, 1969, page 71.
[12] S.E. Kuprianov and A.A. Perov, Zh. Fiz. Khim. 38, 2263 (1964).

RESONANT BRAGG SCATTERING OF GAMMA RAYS BY NUCLEI IN HIGH ORDERS OF REFLECTION, AND PRODUCTION OF DIRECTED BEAMS OF PURE MOSSBAUER RADIATION

V.K. Voitovetskii, I.L. Korsunskii, Yu.F. Pazhin, and R.S. Silakov

Submitted 19 August 1970
ZhETF Pis. Red. 12, 314 - 318 (20 September 1970)

On going over to high reflection orders, the intensity of the γ radiation resonantly scattered by nuclei in a single crystal decreased compared with the first order only because of the change of the Lorentz factor[1], whereas the cross section of the Rayleigh scattering by electrons decreases very sharply. This circumstance makes it possible to suppress almost completely the scattering by electrons, at the expense of attenuating the intensity of the radiation reflected by the nuclei only by a factor 2 - 4 compared with the first order, and to observe only nuclear scattering.

Diffraction by nuclei in high orders of reflection makes it also possible to obtain directional beams of pure Mossbauer radiation.

The experimental setup for the observation of Bragg scattering of γ rays by a single crystal is shown in Fig. 1.

---

[1] The resonant-fluorescence cross section depends weakly on the scattering angle.