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* Preliminary results of these measurements, at pressures up to 5 kbar, were reported to the 14th All-union Conference on Low-temperature Physics, Khar'kov, June 1967.

DIRECT PHOTODISINTEGRATION OF Li^6

E. G. Mititel and S. F. Timashev
Karpov Physico-chemical Research Institute
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Recent experimental investigations of the process Li^6(π^+, 2p)He^4(ground)* [1] have shown that the decisive role in this reaction is a pole mechanism in which the π^+ mesons interact with a virtual deuteron from the Li^6 nucleus. These experimental data can be used to obtain information on the vertex part of the virtual breakup of Li^6 into an α particle and a deuteron, if the vertex part corresponding to the process $\pi^+ + d \to p + p$ is known. Independent data concerning such a vertex part of the virtual breakup of Li^6 can be obtained by studying other reactions with Li^6, particularly photonuclear ones.

It is impossible as a rule to asses the possible mechanisms of the photodisintegration of Li^6 on the basis of the available experimental data [2-5] (the results are ambiguous). Any particular photodisintegration mechanism can be decisive only for a definite reaction channel and only in a definite range of variation of the kinematic variables.

For this reason, calculation of the total cross sections of the photodisintegration of Li^6, based on the use of one or two diagrams (see [6]), seems to be unjustified.

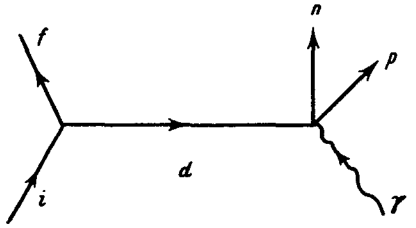

Fig. 1

We consider in this paper the photodisintegration reaction Li^6(γ, np)He^4(ground) in the electric dipole approximation. This approximation is valid up to γ-quantum energies on the order of 20 MeV. The problem consists of finding the regions of the kinematic variable in which the pole mechanism with photodisintegration of the virtual deuteron can be dominating (see Fig. 1, where n, p, d, and γ denote neutrons, protons, deuterons, and the incident γ quanta, and i and f denote the initial (Li^6) and final (He^4) nuclei). A study of the reaction in such a region makes it possible to obtain independently information on the vertex part of the virtual breakup of Li^6 into a deuteron and an α particle. The vertex part corresponding to the photodisintegration of a virtual deuteron should be known in this case. This vertex part can, in turn, be set in correspondence with the diagrams of Figs. 2a - 2c.

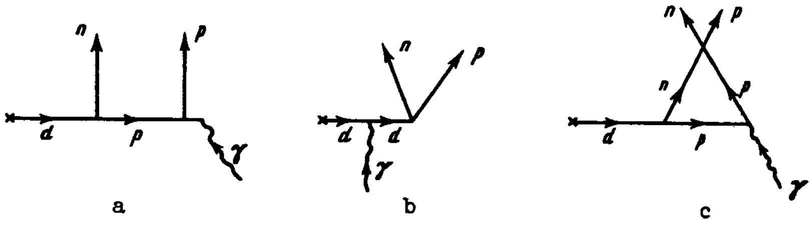

Fig. 2

Unlike the amplitude of the photodisintegration of a free deuteron, it should depend on the variable s_d

$$s_d = p_d^2 - 2m_d E_d, \tag{1}$$

where $\vec{p}_d$, m_d, and E_d are the momentum, mass, and the kinetic energy of the particle d, respectively ($s_d = 0$ for the free deuteron).

We calculated the matrix elements corresponding to the possible diagrams in the reaction under consideration. For the vertex part M_a^{E1} of the absorption of an electric dipole quantum by a particle a with charge e_a, without a change in its internal state, we used the following expression ($h = c = 1$):

$$M_a^{E1} = 2\pi\sqrt{\frac{2}{3}}\frac{l_a}{m_a}\frac{1}{\sqrt{k}}p_a \nu\, Y_{1\nu}\left(\frac{\mathbf{p}_a}{p_a}\right)\delta_{\mu_a \mu_a'}, \quad (\nu = \pm 1), \tag{2}$$

where μ_a and μ_a' are the projections of the particle a before and after absorption of the photon, k is the energy of the photon, and ν its polarization.

We introduce the invariant nonrelativistic kinematic variables

$$\begin{aligned} s_{np} &= 2(m_n + m_p)(E_n + E_p) - (\mathbf{p}_p + \mathbf{p}_n)^2, \\ t_{if} &= 2(m_i - m_f)(E_i - E_f) - (\mathbf{p}_i - \mathbf{p}_f)^2. \end{aligned} \tag{3}$$

They are connected with the relative momentum $\vec{q}$ of the outgoing neutron and proton as follows

$$\mathbf{q} = \frac{1}{2}(\mathbf{p}_p - \mathbf{p}_n) \tag{4}$$

and with the momentum $\vec{p}$ of the recoil nucleus in the laboratory frame by the relations

$$\sqrt{s_{np}} = 2a, \quad \sqrt{-\frac{m_f}{m_i} t_{if}} = p. \tag{5}$$

Calculation shows that a region of kinematic variables in which the pole mechanism dominates exists for the process $Li^6(\gamma, np)He^4$(ground). This region is determined by the relations (6) and (7)

$$2q >> p, \ \kappa \tag{6}$$

here

$$\kappa^2 = 2\frac{m_d m_f}{m_i}\epsilon, \quad \epsilon = m_d + m_f - m_i$$

$$\sin^2 \theta \sim 1 \tag{7}$$

where $\cos \theta = \vec{q}\cdot\vec{k}/qk$ and $\vec{k}$ is the photon momentum.

These conditions denote that the angle χ between the directions of n and p should be close to 180° ($\chi \approx \pi - (1/2)(k + \vec{k}\cdot\vec{p}/k)$), and the kinetic energies of n and p are approximately equal.

In the estimates of the matrix elements we made use of the fact that the reduced γ vertex part [7] corresponding to the virtual decay $Li^6 \rightarrow \alpha + d$ is a relatively large quantity [8] (it was assumed that it is in any case no smaller than the reduced vertex parts of the virtual decays $Li^6 \rightarrow p + He^5$ and $Li^6 \rightarrow n + Li^5$).

Calculation of the matrix element corresponding to the pole diagram 1, with the vertex part of the deuteron photodisintegration represented in the form of the set of diagrams 2a - 2c, shows also that in the region (6) one can choose as this vertex part the amplitude of the electric dipole splitting of the free deuteron. Thus, in the indicated region (6) and (7) of the variations of the kinematic variables, the differential cross section $d\sigma/dqd\Omega_q dp$ of the process $Li^6(\gamma, np)He^4$(ground) will be connected with the differential cross section $d\sigma_{\gamma d}/d\Omega_q$ of the photodisintegration of the free deuteron by the formula

$$\frac{d\sigma}{dqd\Omega_q dp} = \frac{2}{\pi}\frac{qp}{k}\kappa|\gamma|^2 \frac{|f_0(p)|^2}{(p^2+\kappa^2)^2}\frac{d\sigma_{\gamma d}}{d\Omega_q} . \tag{8}$$

Here $f_0(p)$ is the form factor of the vertex part [7] of $Li^6 \rightarrow \alpha + d$ corresponding to zero relative orbital momentum of He^4 and the deuteron.

As indicated above, a parallel study of the reactions $Li^6(\gamma, np)He^4$(ground) and $Li^6(\pi^+, 2p)He^4$(ground) is of undisputed interest for an experimental identification of the mechanisms of these reactions.

The differential cross section can be connected in this case with the corresponding differential cross section $d\sigma'/dq'd\Omega_q'dp'$ of the reaction $Li^6(\pi^+, 2p)He^4$(ground) (the primed indices denote that the corresponding quantities are taken for the reaction (π^+, 2p)).

The indicated differential cross sections of the reactions (γ, pn) and π^+, 2p) should be taken at the same values of the momentum of the recoil nucleus ($p = p' = p_0$). The sought connection is (here $p_\pi >> (m_\pi/m_d)p$):

$$\frac{d\sigma}{dq\,d\Omega_q\,dp}\Big|_{p=p_0} = \frac{q p'_\pi}{k q'}\;\frac{d\sigma_{\gamma d}/d\Omega_q}{d\sigma'_{\pi d}/d\Omega'_{q'}}\;\frac{d\sigma'}{dq'\,d\Omega'_{q'}\,dp'}\Big|_{p'=p_0} \qquad (9)$$

where $d\sigma'_{\pi d}/d\Omega'_{q'}$ is the differential cross section of the process $\pi^+ + d \rightarrow p + p$.

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[*] Here and throughout we have in mind the ground state of the nucleus.

EXCITON LUMINESCENCE IN Cu_2O CRYSTALS

E. F. Gross and F. I. Kreingol'd
Leningrad State University
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Investigations of crystal edge-luminescence spectra yield abundant information on the band structure, the phonon spectrum, and the nature of the defects. Therefore a study of the luminescence of so well-investigated a crystal as cuprous oxide is of great interest. The band scheme of the Cu_2O crystal and its exciton structure were determined by a number of workers by different methods and with a great degree of completeness (see, for example, [1]). However, in spite of numerous attempts, exciton luminescence was never observed in Cu_2O, although the well known infrared luminescence of this crystal was clearly observed [2]. This was quite puzzling, since exciton luminescence is easily observed in other crystals (Si, CdS, ZnS, CuCl, GaP, and others).

We succeeded in finally observing exciton luminescence in Cu_2O crystals grown (from solutions) by a method employed by one of us (F. K.) in investigations of Ag_2O crystals [3].

The luminescence of Cu_2O was investigated at T = 77 and 4.2°K. The luminescence spectrum at T = 77°K reveals a narrow resonance line dure to annihilation of the first term of the "yellow" series of the Cu_2O exciton. In addition, the spectrum contains a number of bands, the most intense of which is at $\lambda = 6169$ Å. A microphotograph of the luminescence spectrum obtained at 77°K is shown in Fig. a. The origin of the luminescence bands observed by us can be explained by taking into account the interaction of the exciton (n = 1) with the phonons. In particular, the $\lambda = 6169$ Å band is the result of radiative recombination of the exciton (n = 1) with simultaneous production of a phonon $\nu_{f_1} \approx 107$ cm^{-1}. This value agrees