We note that generation took place near threshold, and therefore one can hope for a still greater increase of the brightness if a more powerful pump source is used.

Thus, the results indicate that the use of a Brillouin laser offers promise of increasing the radiation brightness.

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TWO-NEUTRON DECAY OF NUCLEI

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Double emission of neutrons from the ground state can be observed in nuclei having a large excess of neutrons near the neutron-stability band [1]. The feasibility of such a process is determined by the fact that the binding energy of the even neutron in such nuclei is small, and turns out to be smaller in many cases than the pair energy of the neutrons. As a result of this energy gain, the nucleus (with an even number of neutrons) may turn out to be stable against the emission of one neutron, but unstable with respect to two-neutron decay. It was remarked in [1], however, that owing to the large widths of the states from which the neutrons are emitted, two-neutron decay will always be accompanied by consecutive neutron emission, and it will be impossible to observe this phenomenon in "pure" form.

Let us consider first the feasibility of the two-neutron decay from the energy point of view: we separate the nuclei in which the following conditions are satisfied:

$$\begin{aligned} B_{2n}(Z, N) &= M(Z, N) - M(Z, N-2) - 2m_n > 0, \\ B_n(Z, N) &= M(Z, N) - M(Z, N-1) - m_n < 0, \\ B_n(Z, N-1) &= M(Z, N-1) - M(Z, N-2) - m_n > 0, \end{aligned} \qquad (1)$$

where B_{2n} and $B_n(Z, N)$ are the binding energies of two neutrons and one neutron, respectively, in a nucleus with Z protons and N neutrons (N is always even), M is the mass of the nucleus, and m_n is the mass of the neutron. We use recently published tables [2] of B_n. The nuclei in which relations (1) are satisfied are shown in Fig. 1. Their number reaches 150. The tables of [2] list the mass values that can be predicted with good accuracy. These data terminate at values $Z \simeq 75$ and $N \simeq 150$. It is obvious, however, that relations (1) will be

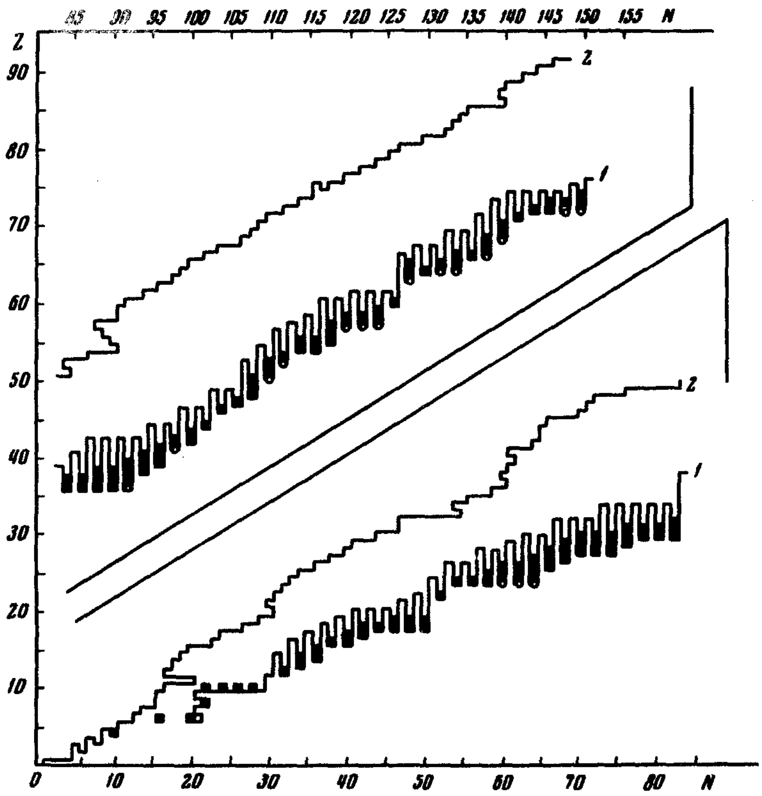

Fig. 1. Region of two-neutron decay. The nuclei given a "pure" two-neutron decay are marked by different symbols corresponding to the different values of ℓ_{n_2}: ■ - $\ell_{n_2} \geq 2$, × - $\ell_{n_2} \geq 3$, o - $\ell_{n_2} \geq 4$; 1 - limit of neutron stability, 2 - limit in the region of the obtained nuclei.

satisfied also at higher values of Z and N. Therefore the number of nuclei that are unstable against double emission of neutrons will be much larger than 150. We note that the choice of their mass formulas will change only the number and location, on the (Z, N) diagram, of the nuclei capable of emitting two neutrons simultaneously.

Let us consider the possibility of "pure" simultaneous emission of two neutrons, without competition on the part of the succeeding decays. To this end it is necessary to stipulate satisfaction of the condition

$$|B_{n_1}(Z,N)| > \Gamma_2/2\,, \qquad (2)$$

where B_{n_1} is the binding energy of the neutron n_1 in the nucleus (Z, N), and Γ_2 is the width of the level of the intermediate nucleus (Z, N - 1) (see Fig. 2).

If the nucleus (Z, N - 1) emits a neutron n_2 in the s state, then the level width $\Gamma_2^{(0)}$ will be equal to the nuclear width ($\sim$6.6 MeV), and the condition (2) will not be satisfied, since $B_{n_1} \lesssim 1.5$ MeV. On the other hand, if the neutron n_2 is emitted with an orbital angular momentum $\ell \neq 0$, then the centrifugal barrier leads to a decrease of the level width, and at certain values of ℓ the inequality $|B_{n_1}| > \Gamma_2^{(\ell)}/2$ will be satisfied, where $\Gamma_2^{(\ell)}$ is the width of the level corresponding to the orbital angular momentum ℓ of the emitted neutron n_2.

The value of $\Gamma_2^{(\ell)}$ can be estimated from the equation

$$\Gamma_2^{(\ell)} = \Gamma_2^{(0)} \lambda_2^{(\ell)} / \lambda_2^{(0)}\,, \qquad (3)$$

where $\lambda_2^{(\ell)}$ and $\lambda_2^{(0)}$ are the penetrabilities of the centrifugal barrier at the values $\ell \neq 0$ and $\ell = 0$, respectively.

Height of Centrifugal Barrier, MeV

ℓ A	2	3	4
10	18,7	37,4	62,4
50	6,4	12,8	21,4
150	4,0	8,1	13,5
150	3,1	6,1	10,2
200	1,5	3,0	4,9

For estimates, we can use the expression for the penetrability of the centrifugal barrier for a square nuclear well (cf., e.g., [3], Ch. 8).

Recognizing that the wave number of the emitted number for the nuclei shown in Fig. 1 is $k = (2m_nB_{n_2})^{1/2}/\hbar < 3.6 \times 10^{12}$ cm^{-1}, and that inside the well we have $K \simeq 1.5 \times 10^{13}$ cm^{-1}, we can write the expression for the barrier penetrability in the form $\lambda_2^{(\ell)} = (4k/K)f_\ell(kR)$, and

$$\Gamma_2^{(\ell)} = \Gamma_2^{(o)} f_\ell(kR)/f_o(kR). \tag{4}$$

The explicit form of the function f_ℓ/kR is given in [3], Ch. 8, and a plot of $f_\ell(kR)/f_0(kR)$ is shown in Fig. 2.

The neutron binding energies of the investigated nuclei are small. For light nuclei, for example, $B_{n_2} < 3$ MeV, and for heavy ones $B_{n_2} < 1.5$ MeV. Therefore, as is seen from a comparison of these values with the tabulated data, which represent the heights of the centrifugal barriers $\hbar^2\ell(\ell + 1)/2m_nR^2$, the neutrons n_2 will in all cases be emitted from under the barrier (at $\ell \geq 2$).

Using Fig. 2, we can obtain with the aid of expression (4) the values of $\Gamma_2^{(\ell)}$ at different values of ℓ, knowing the value of kR for each of the nuclei shown in Fig. 1, and thus determine those values of ℓ for which relation (2) is satisfied.

In Fig. 1, the nuclei corresponding to different ℓ are marked by different symbols. It is seen that more than 1/3 of the nuclei must have values $\ell_{n_2} \geq 2$ in order to be able to observe the two-neutron decay in "pure" form, and about one-half of the nuclei must have $\ell_{n_2} \geq 3$. These limitations do not seem to be unrealistic, especially for the odd-odd and even-odd nuclei under discussion here.

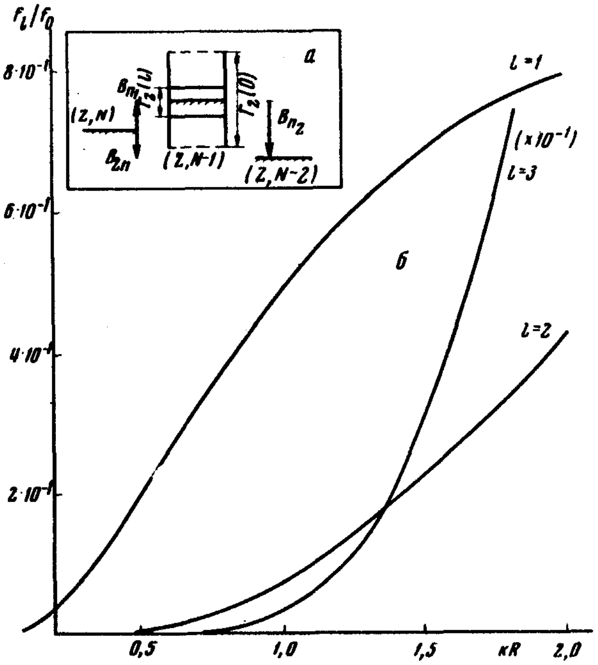

Fig. 2. a) Energy relations in two-neutron decay, b) dependence of the penetrability ratio of kR for different ℓ.

It is possible to separate the cases of two-neutron decay from the background of the simple successive evaporation of two neutrons by using the correlation between the energies of the two neutrons in the double decay. A study of the process of two-neutron decay will make it possible to investigate in detail the neutron stability limit. The behavior of this limit, unlike the proton stability limit, which is determined by the Coulomb interaction of the protons, depends on a number of factors, which can lead, in particular, to the existence of neutron nuclei [5] and distort this limit considerably.

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OPTICAL ORIENTATION OF CARRIERS IN INTERBAND TRANSITIONS IN SEMICONDUCTORS

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Optical orientation, meaning the preferred orientation of the electron spin upon absorption of polarized light, is one of the most fruitful methods of spectroscopy, and is extensively used for the investigation of atoms and ions [1]. Observation of optical orientation in a semiconducting crystal would make it possible to use the methods developed in atomic spectroscopy to investigate semiconductors, and particularly to perform accurate measurements of the lifetime, the spin-relaxation time, the carrier g-factors, etc. So far, however, only one communication was published reporting such investigations in semiconducting crystals [2].

We report here observation of optical orientation of free carriers in Ga_xAl_{1-x} crystals upon excitation of the electrons by circularly-polarized light ($\sigma^\pm$) from the valence band into the conduction band. The degree of orientation was determined from the polarization of the recombination radiation. The investigations were performed on n- and p-type material at 4.2 and 77°K. In particular, an appreciable degree of electron orientation (0.46 ± 0.06) was obtained for the p-type material, and the lifetime of the electrons in the conduction band, $\tau = (1.2 \pm 0.2) \times 10^{-10}$ sec, was determined from the depolarization of the luminescence in a transverse magnetic field.

The luminescence was excited with an He-Ne laser ($h\nu = 1.959$ eV). The composition of the mixed crystals ($x \simeq 0.7$) was chosen such as to make the laser radiation fall in the region of the interband transitions near the intrinsic-absorption edge. The degree of luminescence polarization, $S = |(I_{\sigma^+} - I_{\sigma^-})/(I_{\sigma^+} + I_{\sigma^-})|$, (where $I_{\sigma^\pm}$ is the radiation intensity for the polarization σ^+ or σ^-) was measured with the aid of special modulator, namely a rotating quarter-wave plate. In all the experiments a value $S \neq 0$ was observed only when the excitation was by circularly-polarized light. In the differential spectrum ($I_{\sigma^+} - I_{\sigma^-}$), the sign of the signal changed in this case when the polarization of the exciting light changed from σ^+ to σ^-.