degree of polarization of the neutrons for deuteron energies of the order of 8 Mev where, according to the data of Galonsky and Johnston,[1] the existence of resonance is assumed, which corresponds to the level of the He^5 nucleus at 22 Mev (probably $D_{5/2}$).

At the present time we are continuing measurements of the polarization of neutrons of the reaction $D(T, n)He^4$ for high energy deuterons.

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SPONTANEOUS RADIATION OF A PARAMAGNETIC IN A MAGNETIC FIELD

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THE problem of spontaneous emission in the radioband was considered in the papers by Dicke[1] and the author.[2,3] It was shown there that if a system of identical quantum objects* that possess two energy levels E_1 and E_2 ($E_1 < E_2$), are situated in a volume, the linear dimensions of which are much smaller than the wavelength, such a system can radiate coherently. The intensity of the radiation of the system may be proportional not to the number of objects, n, but to its square, n^2. States in which the system radiates in proportion to n^2 were called "superradiant." If originally all objects were in the upper energy state then after a time[3]

$$\tau_{r,0} = \ln n / n\gamma_0 \tag{1}$$

the system goes over into the "superradiant" state. Here γ_0 is the natural line width of one object. After a time $2\tau_{r,0}$ the system goes over into the lower energy state. Here $\tau_{r,0}$ may be sufficiently small.

Using the theory referred to, the following method of exciting electromagnetic radiation by means of a paramagnetic in a magnetic field is proposed.

We place the paramagnetic in a magnetic field. The electrons† of the paramagnetic will then have two energy levels with an energy difference equal to $E_2 - E_1 = \hbar\omega = g\beta H$, where β is the Bohr magneton, g a factor on the order of unity, and H the magnetic field strength. Let the temperature of the paramagnetic be nearly zero (the generalization to the case of finite temperatures is obvious); the magnetic moments of all the electrons are then arranged along the magnetic field. This will be the lowest energy state of the systems. Let us now reverse the direction of the magnetic field. Such a reversal must be sufficiently fast compared to the thermal relaxation time τ and the time $\tau_{r,0}$ of the radiation, and sufficiently slow compared to the period of radiation, $\tau_{rad} = 2\pi/\omega$, i.e., the reversal time τ_H must satisfy the inequalities

$$\tau_H \lesssim 2\tau_{r,0}; \quad \tau_H \ll \tau, \quad \tau_H \gg \tau_{rad}. \tag{2}$$

After such a reversal, all electrons are in the upper energy state. Let us assume now that the dimensions of the paramagnetic are much smaller than the wavelength of the radiation $\lambda = 2\pi c/\omega$. After a time $\tau_{r,0}$ the system will then go over into the superradiant state. The intensity of the radiation will be equal to

$$I = \omega^4 |\mu_{12}|^2 n^2 / 3c^3, \tag{3}$$

where μ_{12} is the dipole moment of the transition $1 \rightarrow 2$. It is equal to the Bohr magneton β as far as order of magnitude is concerned.

After the system has radiated, over a period $2\tau_{r,0}$, all the energy, which is equal to $A = n\hbar\omega$, and has gone over into the lower energy state, the magnetic field is reversed anew and the system again starts to radiate.

If we reverse the magnetic field with a frequency $f \approx \frac{1}{2}(\tau_H + 2\tau_{r,0})$ the system will in this way emit an average power on the order of

$$W = n\hbar\omega / (\tau_H + 2\tau_{r,0}). \tag{4}$$

The peak power must be determined here by Eq. (3).

Let us make some estimates. Let $\omega = 6.3 \times 10^{10}\,\text{sec}^{-1}$ (wavelength $\lambda = 3$ cm) and $n = 10^{17}$ (this is a fully attainable number of electrons in a volume of order $(0.7)^3 \approx 0.35\,\text{cm}^3$). We have then $\gamma_0 \approx |\mu_{12}|^2\omega^3/\hbar c^3 \approx 0.9 \times 10^{-12}$, $2\tau_{r,0} \approx 0.9 \times 10^{-3} \approx \tau_H$, while the average power is equal to $W = 0.7 \times 10^{-3}$ w and the peak power $I \approx 2 \times 10^{-2}$ w.

The line width will be of the order[2,3] $\gamma = n\gamma_0 \approx 10^5 \sec^{-1}$.

Finally we note that one can use the Stark effect to excite radiation in a similar manner in an electrical field.

The author thanks Professor V. L. Ginzburg for discussing the present paper.

*The role of such objects can be played by molecules in a gas, nuclei or electrons in a paramagnetic, ferromagnetic or ferrite, and so on.

†Below we shall speak about electrons, to fix our ideas, although all this applies equally well to nuclei, ions, and so on.

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SCATTERING OF DEUTERONS BY DEUTERIUM AND TRITIUM AT LOW ENERGIES

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RECENTLY, a remarkable number of measurements were completed on the effective cross sections of the reactions $H_1^3(d,n)He_2^4$ (Ref. 1) and $He_2^3(d,p)He_2^4$, (Ref. 2) which have maximum yield in the low energy region. The experimentally measured values of the cross section are well described by the resonance formula of Wigner and Eisenbud[3] for a single level. In this case, as is to be expected when one starts from the hypothesis of charge invariance, the resonance parameters (obtained from analysis of the reaction) which correspond to the levels of the compound nuclei He_2^5 and Li_3^5 agree within the limits of accuracy with which they are determined. It is natural to expect that the resonance scattering D — T and D — He^3, if the approach of Wigner and Eisenbud is valid for such light nuclei, should be described by the same parameters as the reactions. The scattering of D — He^3 was investigated experimentally by Freier and Holmgren.[4] In the present work, the cross section of D — T scattering was measured at an angle of 90° in the energy interval 30 — 300 kev (center of mass system). In line with this, in the process of working up the method, we measured the scattering cross section of deuterons on deuterium in the energy range for the deuterons from 100 to 600 kev at an angle of 67° in the center-of-mass system. The results obtained for 600 kev agreed with the data of Heydenburg and Roberts.[5]

Utilization of the method possessed certain characteristics which permitted us to complete the measurements at very low energies (down to 70 kev) in the region of resonance of the D — T reaction. The intensity of the beam of bombarding particles was determined by the yield of nuclear reactions which accompany the reaction. In order to be certain of separating the extraneous pulses, coincidences were recorded between the scattered particles and the recoil nucleus. The scattered particles were recorded by proportional counters which were not isolated from the gas target by a small window and were filled, together with the target, to a pressure of 2 — 5 mm of mercury.

The results of the measurement for the D — D scattered are shown in Fig. 1 and those for the D — T scattering in Fig. 2. In both cases, the ratio of the measured cross section to the effective cross section of scattering by a Coulomb field at the same angle is shown.

At small energies, it must be expected that the nuclear D — D scattering will consist of S-scattering in the singlet and quintuplet states. Phase analysis of the data of Eisenbud and Roberts on D — D scattering at 900 kev supports this assumption and allows us to determine the phase for the quintuplet state. This phase essentially determines the scattering cross section.

Measurements of the cross section for a single angle, carried out in the present research, allow only an estimate of the phase in the quintuplet state. The values obtained under the assumption that the phases in both states are the same, corre-

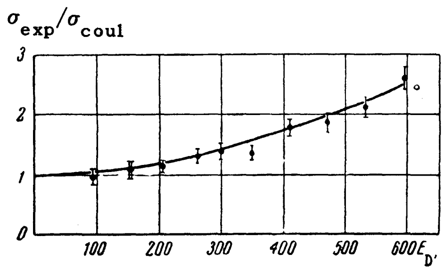

FIG. 1. ● — data of present research; ○ — data of Heydenburg and Roberts.