8 V. L. Ginzburg, *Theory of Propagation of Radiowaves in the Ionosphere*, Moscow-Leningrad, State Technical Publishers, 1949.

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76

Concerning Even-Even Nuclei having the Characteristic 2+ for the Second Excited State

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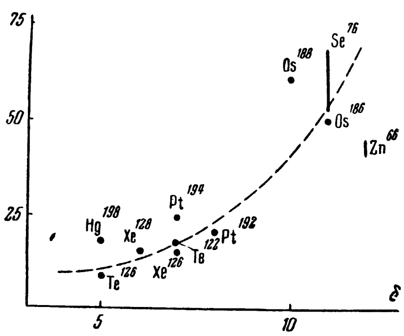
T is well known[1,2] that even-even nuclei, as a rule, have in the ground state zero spin and positive parity, (characteristic 0^+), and in the first excited state spin equal 2 and also positive parity (characteristic 2+). Such a general rule does not exist for the second excited states, where characteristics 4+ and 2+ are encountered with equal frequency and also others. If the sequence of characteristics 0+, 2+, 4+ (corresponding to the ground and the first two excited states) is successfully explained, at least in the region of strongly deformed nuclei, by the generalized nuclear model proposed by Bohr and Mottelson[3] the sequence 0+, 2^+, 2^+, does not have at the present time a satisfactory explanation. It is of interest to examine experimental data pertaining to nuclei now known to have such a sequence of characteristics (nuclei: Fe^{56}, Zn^{66}, Se^{76}, Kr^{84}, Cd^{110}, Sn^{116}, Te^{122} Te^{126}, Xe^{126}, Xe^{128}, Os^{186}, Os^{188}, P^{192}, Pt^{194}, Pt^{196}, Hg^{198}, Hg^{200}).

It can be noticed that nuclei with $Z > 36$ are grouped in the immediate vicinity of values $Z = 50$ and $Z = 82$ at which the successive proton shells become filled. This location of these nuclei can be connected with their deformation. Inasmuch as the deformation parameters of these nuclei are unknown, the quantity $\delta = (\Delta Z + \Delta N)/2$ is taken conditionally as a measure of deformation, where ΔZ is the absolute value of the difference between Z of the nucleus and the value of Z nearest to it corresponding to a filled shell; ΔN is the analogous quantity for the number of neutrons. For all the examined nuclei, $4 \leq \delta \leq 12$. The sequence of characteristics 0+, 2+, 2+ is not encountered in nuclei situated close to the "two magic ones" ($\delta = 4$) nor in strongly deformed nuclei ($\delta = 12$).



It can be assumed that this interval corresponds to nuclei of intermediate deformations, where the binding of the nucleons to the surface is not yet sufficient for the appearance of rotational levels, but the overall properties of the nuclei already manifest themselves. The excitation in this case can be either of a mixed nature, when, together with the overall excitation, there is also a change in the configuration of the nucleons, or it can be purely collective excitation, not of a rotational but of a vibrational nature. The ratio of energies of the second and first excited states, which is in most of the studied nuclei close to 2, points in favor of the vibrational nature of the excitation.

For the investigated nuclei the intensity of the direct transition from the second excited state to the ground state (2+ – 0+) is frequently comparable with the intensity of the cascade (2+ – 2+) transition and sometimes even exceeds it. This is in contradiction with the concept of single particle transition (Weisskopf's formula[4]). Besides, it is known that the first transition in the cascade 2+ – 2+ represents generally a mixed transition $E^2 + M$. There is thereby exhibited a characteristic increase in the relative intensity of the direct transition with increase of δ. The indicated dependence is shown in the Figure, which represents data on 11 nuclei for which the relative intensities have been reliably measured (intensity of direct transition in % relative to cascade along the axis of ordinates). The dotted curve indicates the possible average form of this dependence.

Such a redistribution of intensities of two competing transitions in favor of the direct transition with the increase of δ can be explained by the increased contribution of component $E2$ to the mixed transition 2+ – 2+ with increased deformation. Theoretical basis for such an increase was given by Shapiro[5]. Unfortunately, there are no sufficiently reliable experimental data at the present time concerning the magnitude of $E2$ in mixed transitions, making it impossible to relate the value of $E2$ to the deformation of the nucleus. However, an explanation of the increase in intensity of the direct transition with increased deformation can be given independently of the composition of the mixed transition 2+ – 2+. As was shown recently by Ford and Levinson[6], considerable increase in the probability of $E2$ transition may take place even in the case of relatively slight deformed nuclei. The intensity of the direct transition $E2$ can thereby exceed considerably the cascade transition, even if the latter has the nature of a pure transition $M1$. Apparently, also in this case, the relative intensity of the direct transition must increase with the increase in the deformation of the nucleus.

For some of the studied nuclei there are also known to exist higher excitations in addition to the two lower excited states having characteristics 2+. Inasmuch as the characteristics of the two lower excitations are equal, transitions from any higher level take place with the same change in spin and parity. If the multipole order of both transitions of such a pair were equal, the higher energy quantum, i.e., the transition to the first excited state, would always have the greater intensity. Actually, however, there are cases in which the inverse ratio of intensities is observed. Such a case was noted earlier by the authors[7] in the example of the Pt^{192} nucleus. Similar relation of intensities is observed for certain transitions of excited states of Pt^{194} and Os^{188}. The anomalous ratio of intensities can be connected with either additional selection rules (for example, type K forbiddenness[8]) or with the different nature of competition between the transitions.

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1 M. Goldhaber and A. Sunyar, Phys. Rev. **83**, 906 (1951).
2. G. Scharff – Goldhaber, Phys. Rev. **90**, 587 (1953).
3 A. Bohr and B. Mottelson, Kgl. Don. Math – Fys. Medd. **27**, 16 (1953).
4 J. Blatt and V. Weisskopf, *Theoretical Nuclear Physics*.
5 I. S. Shapiro, J. Exptl. Theoret. Phys. (U.S.S.R.) 30, 975 (1956); Soviet Phys. JETP **3**, 779 (1956).
6 K. Ford and C. Levinson, Phys. Rev. **100**, 1 (1955).
7 Deliagin, Kuznetsova and Shpinel', Izv. Akad. Nauk SSSR Fiz. Ser. **20**, 909 (1956).
8 Alagie, Alder, Bohr and Mottelson, Kgl. Dan Mat. Fys. Medd, **29**, 9 (1955).

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80

Dependence of the Polarization of (D + D) Neutrons on the Energy of the Deuterons.

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THE method described in detail in Ref. 1 made possible polarization measurements of (D + D) neutrons and their dependence on energy D. We had at our disposal a tabular accelerator of the Institute of Chemical Physics, Academy of Sciences, USSR, which yields deuterons of 1800 kev maximum energy.

Polarization measurements were made with thick and thin zirconium targets. In all measurements the turning center of the counters was located at an angle of 49° to the neutron beam and the turning angle $\varphi_\infty = 22°$. The cut-offs of the five discriminator channels were equal to 0.4; 0.5; 0.6; 0.7; 0.8. Computations of the maximum polarization of (D + D) neutrons was made from the asymmetry data measured in channels with cut-offs 0.4 and 0.7. The channel with cut-off 0.4 corresponded to poorer geometry at which the widening of the solid angle $\Delta\Omega$ [see Eq. (1), Ref. 1] was equal to 19°. For the channel of cut-off 0.7 this angle was 11°. In all experiments the values of P_{max}, obtained for both these channels, were in satisfactory agreement. In the following presentation of results, the mean value of P_{max} for these two channels is used, while the experimental errors in P_{max} correspond only to the statistical inaccuracies of the measurements.

Results of asymmetry measurements with the thick target are shown in Table 1.

The maximum polarization of (D + D) neutrons computed from these data is shown in Fig. 1. Computations were made for energy $E_d = 2/3\, E_d^*$. Such averaging corresponds to the linear dependence of the effective cross section of the reaction on the deuteron energy and somewhat decreases the uncertainty existing in those experiments introduced by the thick target. The results shown in Fig. 1 should thus be regarded as the "exit" polarization for a thick target at the corresponding deuteron energies.

In the second series of experiments, a thin