of the plane of polarization of the order of one angular degree per centimeter can be obtained (under optimal conditions) in rather weak fields (in InSb at 4°K, for example, at $E \approx 10^{-4}$ V/cm). It is also seen from these formulas that in the considered region of weak external electric fields the polarization-plane rotation produced in an electromagnetic wave by this field is proportional to the square of the field intensity.

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TWO-PROTON RADIOACTIVITY OF NUCLEI HEAVIER THAN TIN

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In our earlier papers, devoted to a prediction of the existence and properties of a new type of spontaneous transmutation of 2p-radioactive elements [1 - 4], it was emphasized that this phenomenon is characteristic of neutron-deficient isotopes of light even elements up to tin ($Z < 50$), and gives way to α decay in heavier nuclei. Later on other workers [5] stated that the region of possible applicability of two-proton radioactivity is even more limited, to $Z < 38$. A more detailed analysis of the properties of neutron-defficient isotopes of elements heavier than tin leads, however, to the conclusion that a unique two-proton radioactivity should be quite abundant also in the region $Z = 50 - 82$, in which approximately half the total number (approximately 60) of 2p-radioactive nuclei of the even elements lie.

The unique feature of two-proton decay in the region $Z < 50$ is the fact that here all the 2p-active isotopes can decay also in the usual single-proton manner, with emission first of one (even) and only then of a second (odd) proton, with decay energy $Q_{p_{even}}$ and $Q_{p_{odd}} = Q_{p_{even}} + E_{pair}$ respectively in the first and second decay events.

However, frequently the direct two-proton decay, with energy $Q_{2p} = Q_{p_{even}} + Q_{p_{odd}} = 2Q_{p_{even}} + E_{pair}$, which exceeds in the cases in question the pairing energy E_{pair} for protons, is exponentially predominating over the p-decay (and α decay).

Comparing the expressions for the constants of the proton, biproton, and α decays in the presence of a Coulomb barrier only:

$$\lambda \approx 10^{22}\{\exp - \frac{2Ze^2\sqrt{m}}{\hbar}\frac{F}{\sqrt{Q}}[\arccos x^{1/2} - x^{1/2}(1 - x)^{1/2}]\}\sec^{-1}$$

where m is the proton mass, Q the decay energy, and $x = Q/U_{C.max}$ the ratio of Q to the maximum height of the Coulomb barrier (we neglec the energy of the nuclear recoil during decay, and also the charge of the emitted particle compared with Z), we can readily verify that the main difference between the three types of decay lies in the factor F, which is equal to $\sqrt{2}$ for p decay, 4 for 2p decay, and $4\sqrt{2}$ for α decay. If this were the only difference, then equal rates of p, 2p, and α decay would correspond to the condition $Q_\alpha = 2Q_{2p} = 16Q_p$. It is precisely such a condition ($Q_{2p} = 8Q_p$) which we considered earlier [3,4] by way of an approximate criterion of exponential predominance of 2p decay over a chain of two proton decays. It must be recognized, however, that $(U_{c.max})_\alpha \approx (U_{C.max})_{2p} \approx 2(U_{c.max})_p$, and therefore, if the foregoing relation holds between the values of Q, we get the condition $x_\alpha \approx 2x_{2p} \approx 8x_p$. Therefore α decay and two-proton decay overtake the emission of single protons at noticeably lower decay energies than $16Q_p$ or $8Q_p$, respectively. The relations $Q_{2p} \approx f(Q_p)$, $Q_\alpha = f(Q_p)$, and $Q_\alpha = f(Q_{2p})$, corresponding to equalization of the rates of the three types of decay at Z = 20 - 80, are shown in Fig. 1.

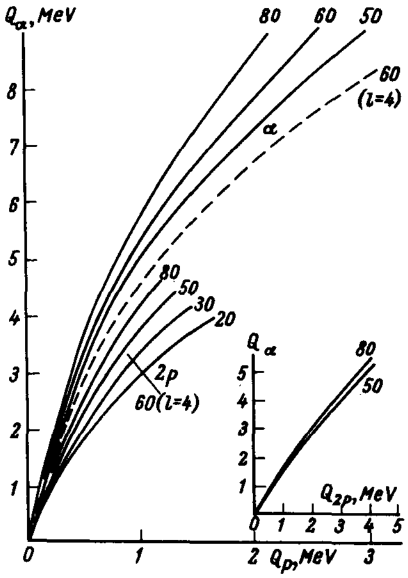

Fig. 1. Connection between the energies of α decay (Q_α), two-proton decay (Q_{2p}), and proton decay (Q_p), corresponding to the equality of the rates of these three types of decay for a pure Coulomb barrier, and also for the particluar case $\ell = 4$ (Z = 60), when a centrifugal barrier exists also for sincle protons. The curves in the main part of the figure show the connection between Q_{2p} and Q_p. In the right side of the figure is shown the connection between Q_α and Q_{2p}.

It must also be borne in mind that the presence of a centrifugal barrier besides the Coulomb barrier suppresses first of all just the single-proton decay (see in this connection [6]) and theregy contributes further to the predominance of α and two-proton decay. An illustration is the dashed curve in Fig. 1 for the case Z = 60 and $\ell = 4$ (emmission of protons from the g-shell).

Figure 2 shows nuclei for which 2p decay should predominate, with the mass numbers in the parentheses corresponding to those cases in which not only two-proton but also ordinary proton decay are energetically feasible, that is, $Q_{2p} > E_{pair}$. The decay energies were taken from the papers of Cameron[7], Seeger[8], Janecke[9], and our articles [1 - 4]. The data are plotted for nuclei with $Z \leqslant 76$. It is not excluded, however, that even heavier 2p-radioactive nuclei exist, for example, Pt^{160,161} or Hg^{163,164}. The daughter nuclei - the products of the 2p-decay - are as a rule also radioactive, and in the region Z > 50 they are characterized by two types of transmutations, α and β^+ decay. Sometimes two successive two-proton decays are apparently also possible, as in the case Os$^{157} \xrightarrow{2p}$ W$^{155} \xrightarrow{2p}$ Hf^{153}.

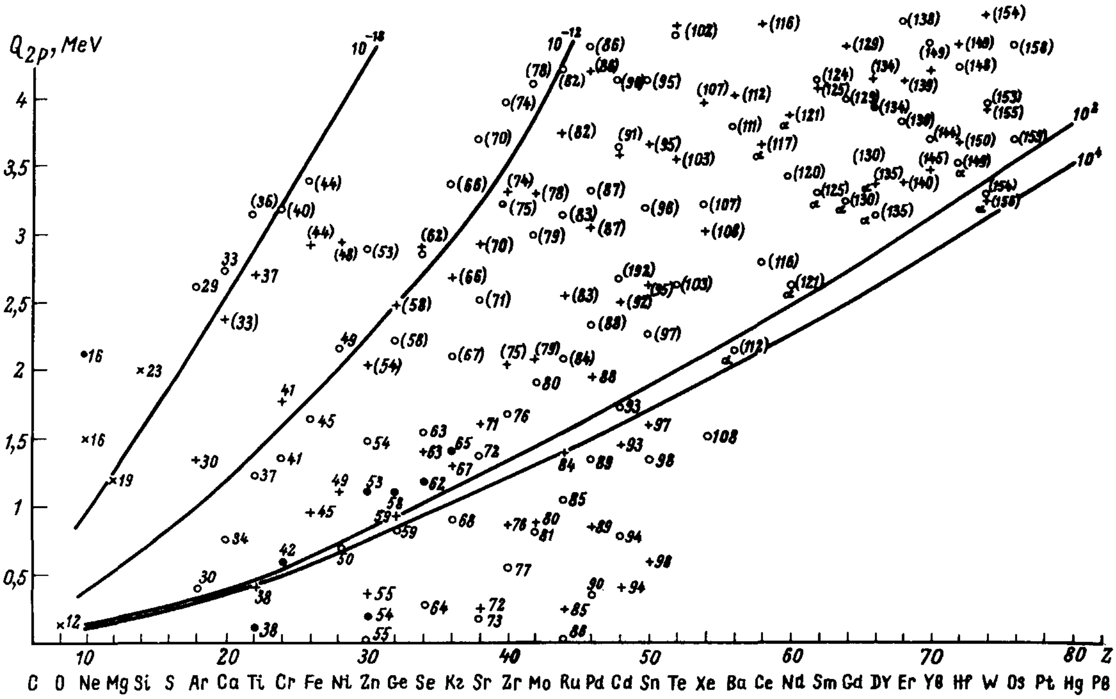

Fig. 2. Summary of data on the energies of two-proton decay of neutron-deficient isotopes of the even elements from oxygen to osmium (Z = 8 - 76). + - [7], • - [1 - 4], x - [9], o - [8]. The four curves correspond to the calculated values of the potential time $\tau = 10^{-18}$, 10^{-12}, 10^{2}, and 10^{4} sec for a pure Coulomb barrier. The index α denotes the possible strong competition on the part of α decay.

The question remains of how to distinguish two-proton radioactive decay from a chain of two successive p-decay events in experiments. The usual delayed-coincidences method is frequently inapplicable here because of the extreme speed of emission of the second proton in the chain ($\tau \approx 10^{-19} - 10^{-20}$ sec). However, the energy and angular characteristics of the emitted protons are perfectly reliable criteria. In place of the two lines characterizing a chain of successive p-decays in the proton spectrum, with energies $Q_{p_{even}}$ and $Q_{p_{odd}}$, the most probable proton energy in two-proton decay is $Q_{2p}/2 = (Q_{p_{even}} + Q_{p_{odd}})/2$. Two-proton decay leads also to exceedingly strong angular and energy correlations between the emitted protons [3, 4, 6]. For a pure Coulomb barrier, the unpairing of the biprotons occurs on the inner boundary of the barrier; the half-width of the energy distribution is then

$$\Delta E_p \approx 2\sqrt{\ln 2}\, Q_{2p}[\frac{\hbar\sqrt{Q_{2p}}}{6\pi Ze^2\sqrt{m}}]^{1/2}$$

and the half-width of the distribution with respect to the angles between the directions of the two protons is $\Delta\theta \approx 2\sqrt{3/Q_{2p}}$(MeV). If a centrifugal barrier is also present, for the single protons emitted from the shell with orbital angular momentum ℓ, the unpairing of the biprotons occurs either under the barrier, at a distance $r_0 = \hbar(m\epsilon_0)^{-1/2}[\ell(\ell + 1)]^{1/2}$ from the center of the nucleus, where $\epsilon_0 \approx 70$ keV is the energy of the virtual singlet level of the nucleon-nucleon system, or else on the outer boundary of the potential barrier R_{max}, if $r_0 > R_{max}$.

As a result, the half-width of the energy distribution is $\Delta E_p \approx \sqrt{\epsilon_0 Q_{2p}}$ and the half-width of the angular distribution is $\Delta\theta \approx \sqrt{\epsilon_0/Q_{2p}}$, which corresponds to $\Delta E_p \approx 0.38 - 0.60$ MeV and $\Delta\theta \approx 0.19 - 0.12$ in the region $Z > 50$, when $E_{pair} \approx 2$ MeV $< Q_{2p} < 5$ MeV, as would be the case for a barrierless emission of a virtual singlet diproton or dineutron.

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CONCERNING THE OBSERVATION OF TRANSITIONS BETWEEN HYPERFINE SUBLEVELS OF PARAMAGNETIC ATOMS

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A detailed study of the parameters of hyperfine splitting of the energy sublevels of atoms yields data on electron-nuclear interactions, on the state of the electron shell of the investigated atom, on the character of intermolecular interactions, etc.

Many papers have been published recently on electron paramagnetic resonance (EPR) in atoms introduced into various matrices, as a rule inert [1 - 3]. In such experiments, the electron-nuclear interactions lead to the presence of a hyperfine structure of the absorption curve. The energy of the electron-nuclear interaction is determined from the distance between the absorption lines in terms of the magnetic field.

For the purpose of accurately determining the hyperfine interaction in the hydrogen atom, Wittke and Dicke [4] described the results of observations of transitions with $\Delta M = 0$ in a longitudinal magnetic field of 0.006 Oe.