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EFFECT OF CHARGE PARITY IN X-RAY SPECTRA OF FISSION PRODUCTS

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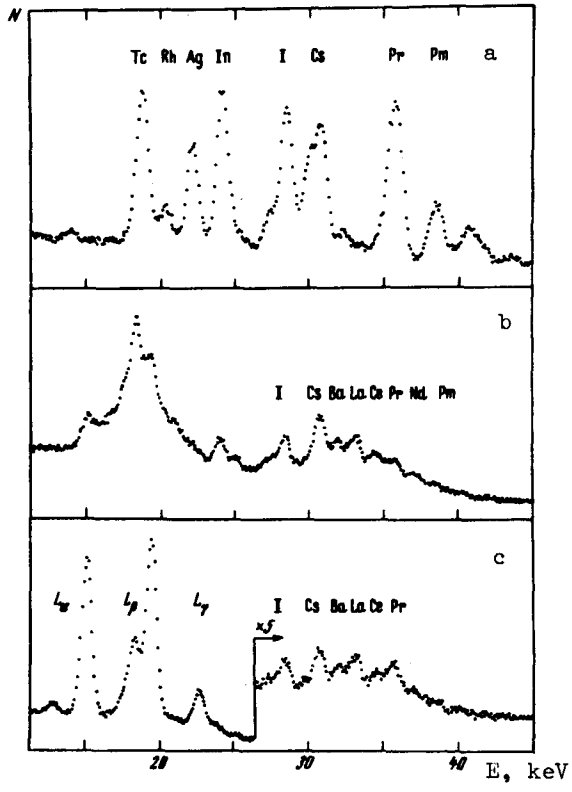
At the present time, in connection with the new possibilities uncovered by semiconductor high-resolution spectroscopy techniques, research on the x-rays accompanying the radioactive decay of atomic nuclei is being diligently pursued. We have investigated the x-ray spectrum of fission products, using the semiconductor soft-electromagnetic-radiation spectrometer developed by us earlier [1] and employed previously to determine the fluorescence yield of the L_2 subshell of curium [2]. We report here the first experimental results.



X-ray spectra: a) K series of secondary fission products, b) fission-fragment series, c) total spectrum of Cf^{252} target.

We investigated the x-rays from the products of the spontaneous fission of Cf^{252}. To this end, the fragments were accumulated on an aluminum foil placed over an open Cf^{252} source, after which the foil was placed near the window of a semiconductor spectrometer. The time of accumulation of the products, as well as the time between the end of the accumulation and the measurement of the x-ray spectra, ranged from one hour to one month. Figure a shows the energy distribution of the x-ray quanta of the fission products, obtained 12 hours after a 30-day accumulation. Although the absolute and relative intensities of the individual spectral lines, which can be seen in the figure, are significantly different for different accumulation durations and delays prior to measurement, this distribution reflects quite well the most interesting feature, namely that the spectrum contains only the characteristic radiation of products with odd charge. We see the lines of the Kα transitions of $_{43}Tc$, $_{45}Rh$, $_{47}Ag$, $_{49}In$, $_{53}I$, $_{55}Cs$, $_{59}Pr$, and $_{69}Pm$ (the Kβ lines appear as kinks on the Kα lines or between the Kα lines of the elements with large Z), and there are no lines of the neighboring even elements (in this case, with intensity $\gtrsim 0.1$).

The observed radiation is the result of internal conversion in β decay

to the excited levels of the nucleus. The number $N_k(z, t)$ of x-ray quanta emitted by a product with charge Z at an instant of time t is determined by the number $N(Z - 1, A_i, t)\lambda(Z - 1, A_i)$ of parent atoms that decay at that instant by the probability $W_k(Z, A_i)$ of populating the excited levels of the daughter nucleus and their conversion on the K-shell, and by the fluorescence yield $\omega_k(Z)$ for this shell:

$$N_k(Z, t) = \omega_k(Z) \sum_{A_i} \bar{W}_k(Z, A_i) N(Z - 1, A_i, t) \lambda(Z - 1, A_i)$$

(the summation over the mass number A_i of the fission product takes into account the possibility of a product with charge Z being produced in several neighboring isobar chains). The fluorescence yield is a smooth function of the charge, and the β activity of the products, at the considered accumulation and storage times, apparently shows likewise no noticeable fluctuations from one atomic number to another (the larger stability, and consequently the "survival-ability" of nuclei with even Z, may come into play) at much larger times. The observed charge parity effect must therefore be attributed to internal conversion. Indeed, in a chain of isobars with even A, the decay of an even-Z product results in odd-odd nuclei, and the density of the lower levels of these nuclei is in general twice that of the even-odd or odd-even nuclei, and is much higher than for even-even nuclei (nucleon pairing effect). It can therefore be assumed that when a nucleus with an odd number of protons is produced (as a result of chains with even A), the conversion probability is particularly large, for the factor $\bar{W}_k$, which takes internal conversion into account, is a sum over all the excited levels E_i to which the β decay takes place:

$$\bar{W}_k = \sum_i p(E_i) \alpha_k(E_i),$$

where $p(E_i)$ is the probability of decay to a level with energy E_i, and α_k is the internal conversion coefficient, which increases rapidly with decreasing E_i ($\alpha_k \sim E^{-2}$). One cannot exclude a possible role of some other still-unknown factors, which increase the internal-conversion probability in β decay to a nucleus with odd Z, for example the larger probability of decay to excited levels, or the larger difference in the angular momenta of the ground and excited states of the odd protons compared with the odd neutrons.

An increased x-ray emission from nuclei with odd charges was observed also in a study of electromagnetic transitions in fragments, which are the primary products of fission (i.e., nuclei after the emission of the prompt neutrons, but prior to the β decay) [3]. These transitions occur within a time on the order of 10^{-10} - 10^{-9} sec after the fission act. The energy distribution of the characteristic K radiation of the primary products, which includes all the transition within a time shorter than 10^{-6} sec, was measured by us with the same spectrometer and is shown in Fig. b. Figure c shows the complete spectrum of the electromagnetic radiation of a Cf^{252} target, including the L-series of Cm^{248} (produced by β decay), and also the K series of the x-rays of the primary and secondary fission products. Both figures show clearly the even-odd fluctuations in the x-ray intensities, and confirm the data of [3], but these fluctuations are much smaller than those observed for the secondary products alone. Further study is needed to determine the degree to which the difference in the strength of the charge-parity effects is connected with the differences of the excitation energies, or of the angular momenta and with the nucleon compositions of the parimary and secondary products.

In conclusion, the authors thank N.A. Perfilov, B.S. Dzhelepov, and M.A. Mikhailova for interest in the work and for useful discussions.

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LOCALIZED CHARACTER OF ELECTRONIC STATES IN THE HIGHLY CONDUCTING COMPLEX TCNQ WITH DITOLUOLCHROMIUM AT LOW TEMPERATURES

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1. Complex compounds of tetracyanoquinodimethane (TCNQ) with typical composition R^+TCNQ^- (simple salts) and $R^+(TCNQ)_2^-$ (complex salt), where R is the molecule of the second component of the complex, are of interest as objects possessing a noticeable electric conductivity of the quasi-one-dimensional type (a survey of their properties is given in [1]). A general feature of the crystal structure of these compounds is the presence of weakly coupled stacks of TCNQ molecules, along which electrons supplied by the second component of the complex can move more or less freely.

From the point of view of formal agruments of the band theory, at least some of the TCNQ complexes should be metals, but actually the temperature dependence of their conductivity, measured on single crystals, is of the activation type in the greater part of the temperature band. One of the causes of such a behavior might be the transition from the metallic (or almost metallic) state to a state of a Mott insulator with electrons localized on the sites. The presently known x-ray data show that in well-conducting complex TCNQ salts all the TCNQ molecules in the stack have at room temperature a uniform molecular geometry, intermediate between $TCNQ^0$ and $TCNQ^-$ [2], which is evidence of delocalization of the outer electron. We do not know, however, whether such a delocalization is maintained at low temperatures.

This question can be answered in some cases by measuring the paramagnetic shifts of the proton-resonance lines of the TCNQ molecules in well-conducting complex salts. We report here the results of an NMR study of a complex of TCNQ with ditoluenchromium (DTC) with composition $(DTC)(TCNQ)_2$. These results indicate that at low temperatures the external electron in this well-conducting complex salt is localized at every other TCNQ molecule.

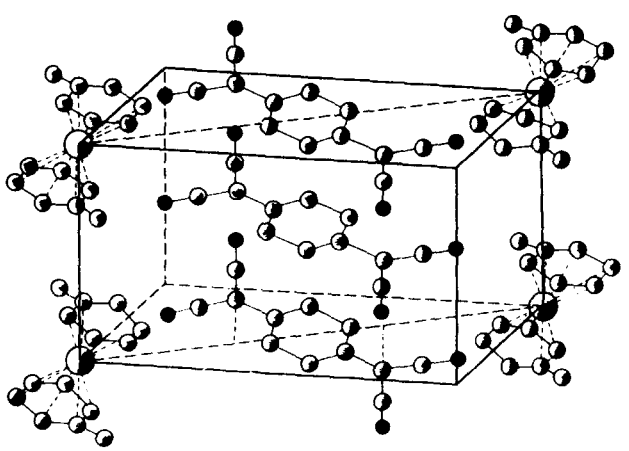

Fig. 1. Structure of unit cell of the $(DTC)(TCNQ)_2$ complex. We have omitted from the figure, for clarity, certain DTC molecules located at each vertex of the parallelepiped.