# Manifestations of the electron binding energies in the spectra of incoherently scattered gamma rays

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In the spectra of $\gamma$ rays with energies 412, 482, and 662 keV scattered by Pd, W, and Pb samples, we observed steps at energies lower than the initial values by amounts corresponding to the binding energy of the $K$ electrons. This effect is ascribed to participation of the $K$ shells in the incoherent scattering of the $\gamma$ rays.

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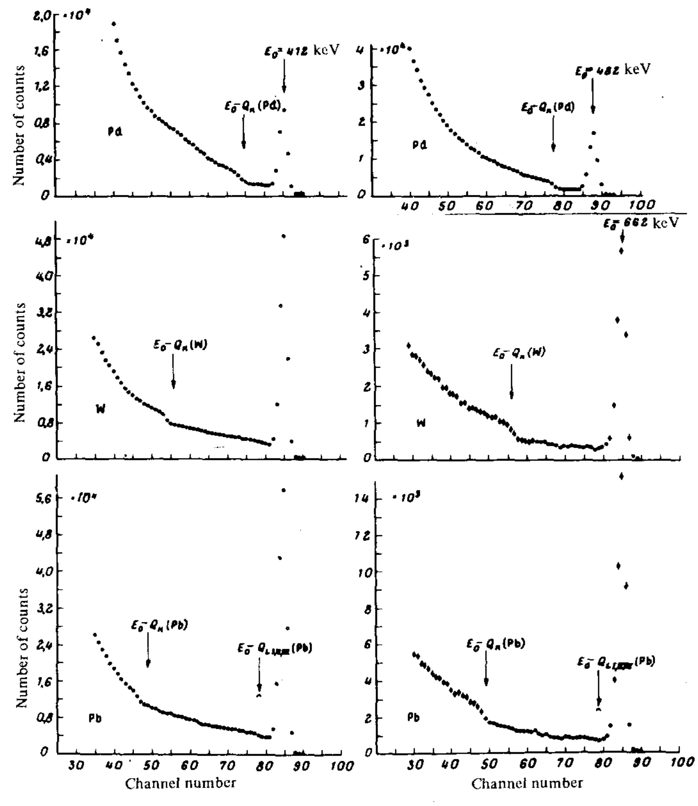
We have investigated the energy spectra of $\gamma$ rays with initial energies 412 keV ($^{198}$Au), 482 keV ($^{181}$Hf), and 662 keV ($^{137}$Cs), scattered through an angle ~90° by Pd, W, and Pb samples of natural isotropic composition. As seen from the figure, the spectra exhibit irregularities in the form of steps in the region between the peaks of the Compton and Rayleigh scattering. The positions of these irregularities correspond to the energies $E_0 - Q_k$, where $E_0$ is the initial energy of the $\gamma$ rays and $Q_k$ is the binding energy of the $K$ electron in the atom of the corresponding scatterer. In the case of lead, one can apparently speak of manifestation of analogous steps at the energy $(E_0 - Q_L)$, where $Q_L$ is the average binding energy of the electrons in the $L$ shell.

The measurements were performed with a coaxial Ge(Li) detector of volume ~25 cm$^3$ for the first two $\gamma$ sources and ~50 cm$^3$ for the third. At the indicated energies, the width of the apparatus line at its half-height was approximately 6.5 keV.

To decrease the loading with soft $\gamma$ and x rays, lead filters 3–5 mm thick were placed in the entrance window of the protective lead shield of the detector. Thin (~0.3 mm) foils of Cu and Cd, lining the internal surface of the protective screen, served for the same purpose. The sources, with activities from 0.3 to 1.0 Ci, were placed in the lead "shack" with a collimator, which produced at its output a beam of $\gamma$ rays that was completely subtended by the scatterer plates. The angular divergence of the beam in the scattering plane was ~15°.

The energy region in which the aforementioned irregularities are observed is inaccessible to $\gamma$ rays scattered by the free electrons, since it corresponds to an interaction in which the $\gamma$ quantum loses a much lower energy than in the Compton effect. One of the processes that lead to the appearance of radiation in the region of interest to us is incoherent scattering by bound electrons. The minimum energy lost by the $\gamma$ quantum in such a scattering event should be quite close to the binding energy of the scattering electron (it should not be distinguishable from it under the condition of our experiment); obviously, it is impossible to transfer to the $K$ electron an energy lower than $Q_k$. This leads therefore to a simple interpretation of the spectra shown in the figure. No $\gamma$ quanta that experience incoherent scattering by $K$ electrons can enter the energy interval from $E_0 - Q_k$ to $E_0$. This region of the spectrum corresponds to $\gamma$ rays that are incoherently scattered by electrons of higher shells. On the other hand, the jumplike change of the intensity of the scattered $\gamma$ radiation at the lower limit of the indicated interval corresponds to inclusion of the $K$ shell in the scattering process. An analogous explanation can also be offered for the less strongly pronounced irregularities, at the energy $(E_0 - Q_L)$, in the spectra pertaining to the lead scatterer.

It should be noted that the photoelectrons produced by the $\gamma$ rays incident on the scatterers give rise to a bremsstrahlung that is indistinguishable, under the conditions of our experiment, from scattered $\gamma$ rays




Measured sections of the spectra of the scattered 412-, 482-, and 662-keV $\gamma$ rays. The arrows show the positions of the energies of the primary $\gamma$ quanta, and also of the energies that differ from the primary by an amount of the binding energy of the electron in the $K$ or $L$ shell.

ing the same energy. This radiation can introduce into the measured spectra a contribution that recalls the steps observed by us, because the end-point energy of the bremsstrahlung is also equal to $E_0 - Q_i$, where $Q_i$ is the binding energy of the electron in the $i$th shell. Data on the bremsstrahlung yield,[1] on the cross section of the photoeffect in the energy region of interest to us,[2] and on the specific energy loss of the photoelectrons in the medium[3] have made it possible to estimate the contribution of the bremsstrahlung radiation to the production of the observed irregularity in the spectra. For the case of a lead scatterer and $E_0 = 482$ keV, we have calculated the ratio of the yield of the bremsstrahlung of the $K$ photoelectrons in an interval 10 keV from the upper limit of its spectrum to the yield of the $\gamma$ quanta that experience Rayleigh scattering, data on which are obtained by interpolation of the results of[4,5]. It turned out that this value amounts to not less than 1/10 of the experimentally observed value (in the calculation of the corresponding ratio from the experimental data, it was assumed that the elastic-scattering peak is due entirely to the Rayleigh scattering of the $\gamma$ rays, which under our conditions is fully justified). In spite of the low accuracy of the present estimate (~40%), we can state with complete assurance that the bremsstrahlung of the photoelectrons plays only a minor role in the observed effect.

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