Electron Capture and Internal Conversion in Gallium 67

In order to establish the fact that nuclei may decay by the capture of orbital electrons, it will be necessary to prove that a nucleus with charge Z transforms into one with charge $Z-1$, and that the characteristic radiation of an atom with charge $Z-1$ is emitted after the process. The K radiation of approximately correct wave-length has been detected in several cases recently[1–3] and has been offered as evidence for the existence of K electron capture. But unless one can show that there are no internally converted gamma-rays from the radioactive body under consideration, the evidence cannot be given too much weight, as it is well known that x-radiation follows internal conversion. Recent experiments have shown that x-rays having the correct absorption coefficients in Al for Fe, Ni, Cu, and Zn $K\alpha$ are emitted by these elements, respectively, after bombardment with high energy deuterons. These x-rays follow both electron and positron periods, which would cast doubt on their interpretation in terms of K electron capture.

An isotope which seems to capture K electrons as well as emit conversion electrons, may be formed by deuteron bombardment of Zn. The activity, of 83 hours half-life, has the chemical properties of Ga, as shown by the solubility of its chloride in ether. It has been assigned to Ga^{67} by Mann,[4] who bombarded Zn with alpha-particles, and separated Ga by chemical means. The radiations emitted are a soft group of electrons, a soft x-ray, and one or two gamma-rays. The electrons have too small an energy for even the first Sargent curve, so their absorption curve was investigated quite carefully. They are absorbed as an 85 kv line spectrum of beta-rays, and this has been confirmed by Mr. E. M. Lyman and Mr. D. C. Kalbfell, who used beta-ray spectrographs with a Geiger counter and a photographic plate, respectively. The spectrum consists of two lines at 90 and 99 kv—corresponding to K and L conversion of a 100 kv line. The 90 kv line is the stronger, as would be expected.

The x-radiation can be shown to be Zn $K\alpha$ and $K\beta$, without question, by absorption measurements in Ni and Cu foils. The wave-lengths of the Zn K lines lie between the critical absorption edges of Ni and Cu, so Ni is several times as effective an absorber. In addition, the absorption edge of Cu splits the K doublet of Zn, so its absorption curve may be resolved into two components giving approximately the correct intensity ratio of $K\alpha$ to $K\beta$.

The gamma-ray absorption curves in Pb and Cu indicate an energy of 0.2–0.3 Mev. Transition curves from Pb to Al show an electron group of this energy and one of lower energy, probably due to the unconverted fraction of the 100 kv line.

It is then evident that a substance which has been shown to be Ga by chemical methods decays into a Zn isotope, as shown by x-ray spectroscopy, and during the process, emits no positrons. (None were observed in a cloud chamber, and no trace of the annihilation radiation could be detected.) In order to show definitely that the transformation is by K electron capture, it is necessary to examine the relative intensities of the various radiations. Perhaps the most direct method would be to show that the x-rays often come off in pairs—one due to an electron captured by the nucleus, and the other due to the converted electron. This will be attempted with the aid of coincidence counters in the near future. From considerations of the geometry of the electroscope and the absorption coefficients, it can be shown that the excitation of the K shell is more frequent than necessary to explain the number of conversion electrons, by about 50 percent. The gamma-ray intensity is more difficult to estimate, but it seems to be roughly equal to that of the electron and x-rays. Professor Oppenheimer and his students have calculated the internal conversion coefficient for a 100 kv γ-ray in zinc, for various orders of multipole, and find that it could easily be 80 percent.

All the data reported above are in agreement with the view that Ga^{67} transforms into Zn^{67} by electron capture, and then emits a K x-ray quantum in half of the cases. (Auger coeff.$=0.5$.) Then the excited state of the Zn^{67} emits either or both a 100 kv and a 0.2–0.3 Mev gamma-ray quantum, the 100 kv line being highly internally converted. Finally another 0.5 quantum of Zn K radiation is emitted.

It is a pleasure to thank Mr. E. M. Lyman and Mr. D. C. Kalbfell for examining the activated zinc in spectrographs of their design, and Professor E. O. Lawrence and Professor J. R. Oppenheimer for continued interest in the problem. The work has been aided by grants from the Research Corporation, the Chemical Foundation, and the Josiah Macy, Jr. Foundation.

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March 15, 1938.

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Suggestion Regarding the Nature of the Heavy Electron

The existence of heavy particles whose mass appears to be between that of the electron and the proton is indicated by a number of recent experiments on cosmic rays.[1] Jauncey[2] has proposed a theory of the nature of such particles, based on the idea of the addition of photon energy to an electron in the form of increased mass. This theory admits of resultant particles of any mass, depending upon the energy of the captured photon.

An alternative idea is offered in the present note. Relative to an observer at rest, the mass of an electron moving with a speed v is given by

$$m=\frac{m_0}{[1-(v/c)^2]^{\frac{1}{2}}}. \quad (1)$$

The de Broglie wave-length associated with an electron is

$$\lambda=h/mv. \quad (2)$$

Elimination of v between (1) and (2) yields

$$\frac{m}{m_0}=\frac{1}{[1-(h/mc\lambda)^2]^{\frac{1}{2}}}. \quad (3)$$