Nuclear K Electron Capture

As has frequently been pointed out, one of the simple consequences of Fermi's theory of β-decay,[1,2] taken together with the Dirac theory of the positron, is that positron-active nuclei may capture atomic electrons instead of emitting positrons. Since the nuclei in this case emit no observable particles, the decay must be detected in some unusual manner, as for example, (1), by comparing the rate of growth of the daughter substance with that calculated from the activity of the parent, (2) by counting the number of radioactive atoms formed, and later the number of positrons ejected, or (3) by detecting the x-rays which would result from the refilling of the K shell. Jacobsen[3] has recently attempted to observe the latter in a cloud chamber, using Sc^{43}; he found no evidence in support of the electron capture hypothesis. Walke[4] has recently found that a strong positron activity of 16 days' half-life may be induced in Ti, by deuteron bombardment. Chemical separation indicates that a vanadium isotope is responsible for the activity, whose positrons have an upper limit of 1.05 MV. Since this activity fits the second Sargent curve (instead of the first, as does Sc^{43}), it seemed likely that its ratio of K quanta to positrons would be greater. The results of an experimental attempt to observe the x-radiation are reported below.

A source of radio-vanadium was placed in a magnetic field of about 2000 oersteds, and was surrounded on five sides by 2 mm of aluminum. The gamma-rays passed through 20 cm of He, and 16 cm of air before reaching a Cellophane-walled counter filled with argon at atmospheric pressure.[5] The cathode was of 0.00025 cm Cu, curved to form three-fourths of a cylinder; the radiation had to pass through only 0.0025 cm of Cellophane to reach the active volume of the counter. When thin sheets of Al were introduced between the source and counter, the counting rate fell from 21.3 to 15.4 per second. The soft component responsible for this decrease was all absorbed in 0.0025 cm of Al; the interposition of more Al (up to 0.0075 cm) had no detectable effect upon the counting rate. Fig. 1 is an absorption curve of the soft component; the constant gamma-ray background has been subtracted from all the actual readings. The line has been drawn to fit the highest point, with a slope calculated from the known absorption coefficient of Ti $K\alpha$. 15,000 counts were taken for each point on the curve, and the background and linearity of the counter were frequently checked. The ratio of x-ray counts to gamma-ray counts, after correction had been made for the absorption in the air path and in the Ti, was 1.9. The last correction involved the plotting of an excitation function for the reaction. The source was then replaced by a weaker sample, and the magnetic field removed. The ratio of gamma-ray counts to positron counts was determined by measuring the relative counting rates when the source was bare, and when it was covered with 2 mm of Al. This ratio (corrected for the absorption of the positrons in the air, He and Cellophane) was 0.082. 0.75 of the x-ray quanta should produce photoelectrons in the argon, so it will be assumed that the efficiencies for positron and quantum detection were 100 percent and 75 percent, respectively. The ratio of the numbers of K quanta and positrons is then $1.9\times0.082/0.75=0.21$. This ratio must be divided by the fluorescence yield[6] of the K shell in Ti, to give the relative probability for capture and emission. This yield is 0.21 from data given by Compton and Allison. Therefore, the ratio of the probabilities of K electron capture and positron emission is

$$1.0\pm0.4.$$

This observed ratio of K electron capture to positron emission is of the order of magnitude suggested by the Konopinski-Uhlenbeck modification of the theory proposed by Fermi. To exclude the possibility that the radiation was due to the impact of positrons on Ti, the sample was covered with 0.0025 cm of chromium. This would be sufficient to absorb all the observed Ti K-radiation, and if the effect were of a secondary nature, Cr K-radiation should be produced in almost equal numbers. No such effect could be detected.

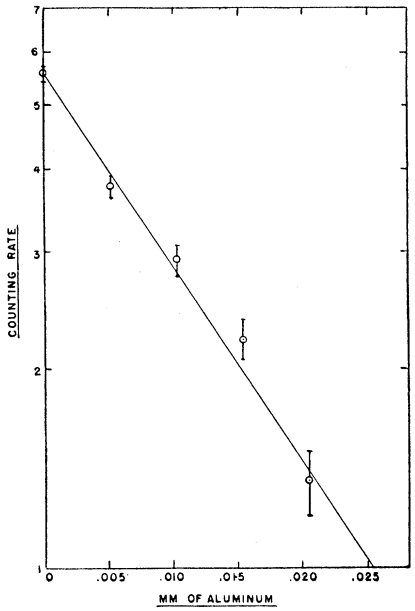

FIG. 1. Absorption curve of soft component of the gamma-radiation.

Note added June 28:

Sizoo[7] has recently shown that if the first and last of three isobaric nuclei with consecutive charge numbers are stable, the second will in most cases be capture-unstable as well as β^--radioactive. The 2.5 day radioactive antimony isotope formed by deuteron bombardment is the second of three isobars, and emits only negative electrons. A search was made for Sn K-radiation from active Sb, but without success. The electrons were stopped with a magnetic field, and the gamma-rays were absorbed in aluminum. No soft component was found which produced as much as 2 percent of the total gamma-ray ionization in a Lauritsen type electroscope. If Sizoo's theory is correct, this must be one of the rare cases where the two lightest isobars are both stable with respect to each other.

In conclusion, the author wishes to express his gratitude to Professor E. O. Lawrence for the privilege of working

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Radioactive Isotopes of Manganese, Iron and Cobalt

We wish to make a preliminary report on the radioactive isotopes of Mn, Fe, and Co produced when Fe is bombarded with 5.5 Mev deuterons (20–60 microampere hours) and when Co is bombarded with neutrons. The decay curves of the chemically separated fractions have been measured with a Lauritsen type electroscope.

Fe: A negative electron activity of approximately 40 days half-life is found in the Fe fraction of the Fe plus deuteron bombardment, either after precipitation (and repeated reprecipitation) as $Fe(OH)_3$ from a solution containing an excess of ammonium salts or after extraction as $FeCl_3$ by shaking with ether. An Fe activity of the same period ($\sim$40 days) has been chemically separated from a sample of CoO that was bombarded intermittently for three months with neutrons ($Be+H^2$) produced in the cyclotron. The conditions of this latter experiment did not allow the detection of the three day Fe isotope reported by Andersen from Co plus neutrons;[1] this isotope definitely was not produced when Fe was bombarded with deuterons.

Co: This fraction of the Fe, after deuteron bombardment, contains an 18.0 hour positron emitter, in agreement with the 18.2 hour period reported by Darling, Curtis and Cork[2] for the same reaction. In addition, there is a complex of longer periods of apparent present half-life between 100 and 200 days. Both electrons and positrons are emitted. Undoubtedly this contains the Co isotope with half-life of a year or more (reported by Sampson, Ridenour and Bleakney[3] from Co plus neutrons), and also a positron emitter of shorter period. Our work also gives support to that of Sampson and co-workers in that Co chemically separated from CoO bombarded with neutrons gives an activity which thus far is consistent with a half-life of over a year. We also find that CoO plus neutrons (without chemical separation) yields a negative electron activity with 11 minutes half-life. This period is in disagreement with the 20-minute value reported by Rotblat[4] for the same reaction but supports the values found by Heyn[5] and by Kikuchi, Takeda and Ito.[6]

Mn: The Fe plus deuteron bombardments show two new periods in the Mn precipitate; a positron emitter of about 5 days half-life and a negative electron emitter of several months period. This fraction also shows a 21-minute activity (of undetermined sign), in agreement with the 21-minute figure given by Darling, Curtis and Cork[2] for the same reaction. In disagreement with the work of Darling and co-workers the well-known 2.5-hour negative electron activity of Mn^{56} is strongly evident in this same fraction, even when very pure Fe is used for the deuteron bombardment. This is due to the reaction $Fe^{56}(n, p)\ Mn^{56}$, at least partially, for there is a large yield of neutrons (as observed in the cloud chamber) accompanying the transmutation of Fe to Co. This supposition is confirmed by the fact that the 2.5-hour activity also appears in a second piece of Fe placed out of the deuteron beam close to the target Fe.

A Mn positron emitter of 46 minutes half-life is produced when Cr is bombarded with deuterons.

A complete description of the work, including the decay curves and a discussion of the probable reactions involved, will be published at a later date.

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Radioactive Antimony Isotopes

Bothe and Gentner[1] have obtained a 13 minute activity by irradiating Sb with the 17 Mev gamma-rays from $Li+H^1$. Heyn[2] has produced a radioactive isotope of 17 minutes half-life and Chang, Goldhaber and Sagane[3] have obtained a 13 minute period by bombarding Sb with the fast neutrons from the $Li+H^2$ reaction. Although Sb has two stable isotopes, Sb^{121} and Sb^{123}, and only one previously known slow neutron activity (2.5 days[4]), all of these workers have concluded that this new activity is due to Sb^{120} because it is not produced by slow neutrons.

We wish to add confirmatory evidence to their supposition. Upon bombarding Sb both with slow neutrons ($Be+H^2$) and 5.5 Mev deuterons from the cyclotron we have produced, and chemically identified as Sb, a new activity of approximately 60 days half-life, in addition to the 2.5 day period. Both of these are found to be negative electron emitters. It is certain that the 2.5 day and 60 day activities must be associated with Sb^{122} and Sb^{124} or *vice versa*, and therefore the 13 to 17 minute period must be assigned to Sb^{120}.

We have confirmed the production of Sb^{120} by bombarding Sb with fast neutrons ($Li+H^2$), and have observed that positrons are emitted. Our value for the half-life is 16 minutes. A chemically identified Sb isotope of the same half-life has also been produced when Sn was bombarded with deuterons. This activity presumably is due also to Sb^{120}, the reaction being $Sn^{119}\ (d, n)\ Sb^{120}$.