New Nuclide, Krypton-74*

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A new nuclide of krypton, Kr^{74}, has been produced by high-energy proton interaction with strontium. It was found to have a half-life of (20±1) minutes and to decay by (3.1±0.1)-Mev positrons. No gamma rays in the energy range 0.04 to 4.0 Mev were observed. Evidence for the production of Kr^{75} was also observed. Calculations indicate an upper limit for the half-life of (0.8±0.4) minutes.

INTRODUCTION

A NEW neutron-deficient nuclide of krypton, with a half-life of 20 minutes, has been produced by proton bombardment of strontium. Search for this nuclide was prompted by the results of the experiments performed in determining the half-life and radiations of Kr^{76}.[1] In the course of these experiments an activity of shorter period was observed on several occasions. It became the object of this new study to ascertain if a more neutron-deficient isotope of krypton could be produced, and if so to determine its half-life and characterize its radiation properties.

The available beta-decay energies for the isobaric nuclides with $A=74$ are listed in Table I. The values listed are either taken from the tables of Cameron[2] or experimental disintegration Q values taken from Strominger *et al.*[3] If the nuclide masses for the isobar $A=74$ are plotted versus mass number two parabolas are obtained, as would be expected. In view of the fact that Kr^{74} has 4.00-Mev decay energy to Br^{74}, and that 1.02 Mev of this can be used for positron creation, it might be predicted that the half-life of Kr^{74} would be long enough to observe.

EXPERIMENTAL PROCEDURE

The Kr^{74} was produced by proton bombardment of strontium oxide. On several occasions targets of $SrCl_2$ or pure strontium metal were used. All bombardments were carried out using 400-Mev protons from the Carnegie Institute of Technology synchrocyclotron. The target was made by wrapping 200 mg of SrO powder in an envelope of 1-mil aluminum foil. The foil was clamped to the end of the cyclotron probe and exposed to the internal proton beam for periods of one hour.

TABLE I. Beta-decay energies for isobars $A=74$.

Nuclide	Kr^{74}	Br^{74}	Se^{74}	As^{74}	Ge^{74}	Ga^{74}	Zn^{74}
Positron beta-decay energy (Mev)	4.00	6.30	Stable	2.56			
Negatron beta-decay energy (Mev)				1.36	Stable	5.82	1.88

After irradiation the SrO was transferred to a distilling flask together with NaBr solution to act as hold-back carrier for the bromide activities. The distilling flask was attached to an all glass gas-collecting system in which provision was made for flowing helium or nitrogen gas through the system to carry the radioactive krypton. The system consisted of a train of traps. The first two traps contained CaO and ascarite at dry-ice temperature which served to remove water vapor, CO_2, and bromine which may have been carried along with the carrier gas. This was followed by a series of U-tube traps containing silvered activated charcoal at liquid nitrogen temperatures. Finally at the end of the train was an evacuated glow discharge tube. With helium slowly flowing through the system, water was introduced and the distilling flask was heated to dissolve the SrO and boil out the krypton activities. The krypton was adsorbed on the charcoal traps at liquid nitrogen temperature and subsequently desorbed at elevated temperatures. Finally the krypton was allowed to enter the glow discharge tube where it was deposited on a 1-mil aluminum foil cathode (1 cm×2 cm) according to the procedure originally described by Hyde and Mathur.[4] The krypton was deposited on the aluminum foil by being accelerated through a potential of 600 volts and at pressure of 0.1 micron. This produced a radioactive sample of krypton imbedded in the aluminum where it remained throughout the duration of the experiments.

The radiations emitted from this krypton sample were detected by means of an end-window Geiger-Muller counter (Tracerlab TGC-2) having a 1.9-mg/cm² mica window.

RESULTS

The radioactivity observed could be resolved into five components: the first with a half-life of 20 minutes followed by groups having half-lives of 1.2 hour, 17 hours, 34 hours, and 57 hours. These half-lives could be assigned to 1.2-hour Kr^{77}, 17-hour Br^{76} (from the decay of Kr^{76}), 34-hour Kr^{79}, and 57-hour Br^{77}. The

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[2] A. G. W. Cameron, Can. J. Phys. **35**, 1021 (1957).
[3] D. Strominger, J. M. Hollander, and G. T. Seaborg, Revs. Modern Phys. **30**, 585 (1958).
[4] E. K. Hyde and H. B. Mathur, Phys. Rev. **96**, 126–129 (1954).

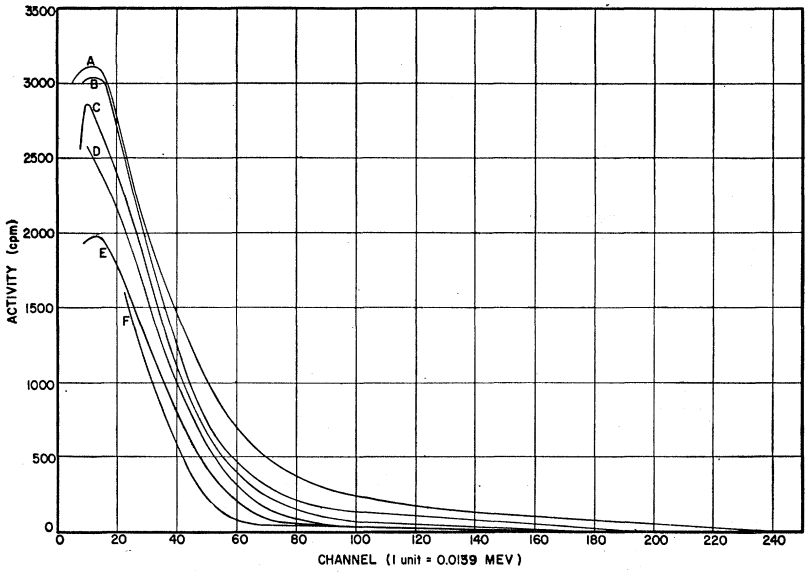

FIG. 1. Beta spectra of krypton sample as a function of time. Curve A, initial time, within 5 minutes of separation. Curve B, 0.40 hr later. Curve C, 1.35 hr after initial time. Curve D, 3.0 hr. Curve E, 7.0 hr. Curve F, 14.0 hr.

unidentified 20-minute activity was observed on a total of seven runs detected in this manner.

To determine the mass number of this 20-minute activity a series of daughter-isolation experiments was performed. The krypton activity from the gas collection system was adsorbed on a silvered activated charcoal storage trap at liquid nitrogen temperature from which it was then transferred through a glass line consisting of a series of five glass U-tube traps each filled with silvered activated charcoal, held in place by glass wool, and fastened to a Cenco Hyvac pump. Every 15 minutes a krypton-bromine isolation was made by moving the liquid nitrogen from one trap to the next. This separation is based on the procedure of Dropesky and Wiig[5] which assumes complete desorption of krypton from charcoal at elevated temperatures and the complete retention of the bromine daughters by the use of silvered charcoal. The radioactivity of each U-tube was measured with the Geiger-Muller counter. All five curves were resolvable into half-lives of 36 minutes, 17 hours, and 57 hours. These can be assigned to the bromine isotopes Br^{74}, Br^{76}, and Br^{77}, respectively. A graph of the yields of Br^{74}, extrapolated to the time of bromine-krypton separation versus the time of parent-daughter separation gave (20 ± 1) minutes for the half-life of Kr^{74}.

On several occasions the silvered charcoal from the storage trap was counted directly. Activities due to Br^{74}, Br^{76}, and Br^{77} were observed as well as a 1.6-hour period due to Br^{75}. However, Br^{75} was never observed in any of the U-tube traps. From this information, and the times of transferring krypton from trap to trap, it was possible to calculate an upper limit for the half-life of Kr^{75} as equal to or less than (0.8 ± 0.4) minutes.

The gamma-ray spectrum of Kr^{74} was investigated by use of a thallium-activated NaI crystal connected to a 256-channel pulse-height analyzer. The krypton source for these experiments was prepared by depositing the Kr^{74} on the aluminum foil cathode of the glow discharge tube. The analyzer was adjusted to detect gamma-rays in the energy range 0.04 to 4.0 Mev. Gamma rays at

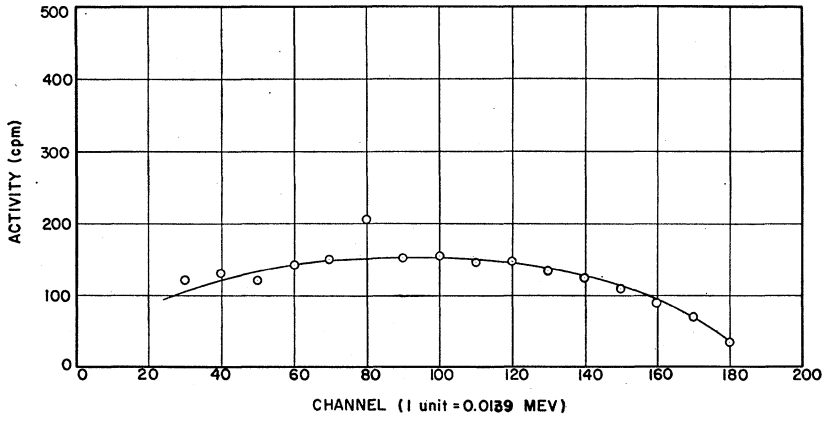

FIG. 2. Beta spectrum of Kr^{74}.

[5] B. Dropesky and E. O. Wiig, Phys. Rev. 88, 683 (1954).

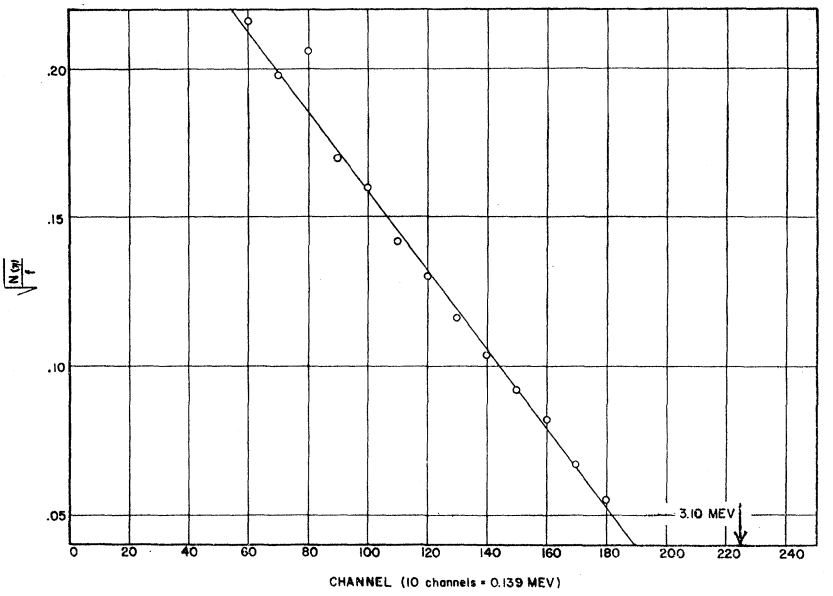

FIG. 3. Fermi plot of Kr^{74} beta transition.

energies 44 kev, 110 kev, 131 kev, 260 kev, 510 kev, and 760 kev were observed. All the gamma rays other than the one at 510 kev can be attributed to previously known krypton isotopes. The 44-kev and 260-kev are found in the decay of Kr^{79} while the 110-, 131-, and 760-kev peaks arise from the decay of Kr^{77}.

The 510-kev peak was counted as a function of time and the peak height was observed to decay with a 20-minute followed by a 1.2-hour half-life. Resolution of the curve yielded a half-life for the shorter component of (20±7) minute. No other gamma rays were observed to decay with a 20-minute half-life.

The beta spectrum of Kr^{74} was investigated by use of a $\frac{1}{4}$-in. anthracene crystal connected to a photomultiplier tube and used with the 256-channel analyzer. The anthracene crystal was tested by running beta spectra of Cs^{137}, Bi^{210}, and Pa^{234}. Fermi-Kurie plots of these spectra gave maximum beta-energy end points which, when plotted versus channel position, gave a straight line indicating linearity of the crystal with energy. The krypton-74 source was prepared in the same manner as for the gamma-ray analysis.

The beta spectrum from the krypton source would be expected to be quite complex because of the number of different beta groups present. During the decay of Kr^{74} one would also expect to observe the positrons from Kr^{77} (1.86 Mev), Kr^{79} (0.60 Mev), and the Br^{76} daughter of Kr^{76} (3.57 Mev, 1.7 Mev, 1.1 Mev, and 0.6 Mev) besides any positrons associated with Kr^{74}. In order to find the contribution of Kr^{74} betas to this complex beta spectrum, a time analysis of many beta spectra over a period of 12 hours was performed (Fig. 1). Decay curves of the activity versus time, for every 10 channels, from channel 60 to 180 were then constructed and resolved into the various components. A typical decay curve showed a long-lived activity, presumably due to the 3.57-Mev positron of Br^{76}, followed by the 1.2-hour (1.86-Mev $\beta+$) Kr^{77} and finally a 20-minute period. The activity of the 20-minute period was extrapolated back to the end of bombardment and the extrapolated values plotted versus energy to give a beta spectrum for the 20-minute Kr^{74} decay (Fig. 2).

A Fermi-Kurie plot was constructed from this 20-minute activity and is shown in Fig. 3. Analysis of the Fermi plot yielded a maximum beta energy of (3.1 ±0.1) Mev and showed that the decay was associated with no other electrons of energy greater than 1.0 Mev.

The total decay energy of Kr^{74} is 4.12 Mev. The predicted decay energy as given by Cameron[2] is 4.0 Mev. The logft value for this beta transition is calculated as[6] 5.3 corresponding to an allowed (normal) decay. Kr^{74}, being an even-even nuclide, would be expected to have a spin of 0 and an even parity. This transition to Br^{74} would thus be expected to be accompanied by a spin change, ΔI, of 0 or 1 with no parity change. Nordheim's rules predict a ground-state spin of $I=1$ and even parity for Br^{74} in agreement with this beta transition.

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[6] S. A. Moszkowski, Phys. Rev. **82**, 35 (1951).