Title
OBSERVATION OF NUCLEAR Y RAYS FROM KAON CAPTURE

Author
Wiegand, Clyde E.

Publication Date
1971-12-01

Submitted to Physical
Review Letters

LBL-385
Preprint c.1

OBSERVATION OF NUCLEAR γ RAYS FROM KAON CAPTURE

Clyde E. Wiegand, Jeffrey M. Gallup,
and Gary L. Godfrey

December 1971

AEC Contract No. W-7405-eng-48

DISCLAIMER

OBSERVATION OF NUCLEAR γ RAYS FROM KAON CAPTURE †

Clyde E. Wiegand, Jeffrey M. Gallup, and Gary L. Godfrey

Lawrence Berkeley Laboratory
University of California
Berkeley, California 94720

December, 1971

In connection with the study of kaonic x rays, nuclear γ rays should be seen along with the x-ray spectra, but to date none have been reported. Some specific γ rays following K^- capture have been predicted by Bloom, Weiss, and Shakin[1], but probably because of insufficient experimental effort, their predicted γ-ray lines have not yet been observed. It is known that negative muons and pions when captured by nuclei lead to excited states and several studies of the resulting γ rays have been made.[2]

We report here examples of nuclear γ rays resulting from kaon capture in targets of Cl and S. The most prominent γ-ray line corresponds to decay from the first excited state of $^{32}_{15}P$. Its energy is 78.1 ± 0.3 keV given in the compilation of Endt and Van der Luen[3]. The measured energy of the line in the kaonic spectrum of CCl_4 is 78.1 ± 0.1 keV. See Fig. 1.

The line was first noticed in the kaonic x-ray spectra of $^{40}CaCl_2$ and $^{44}CaCl_2$ in the Berkeley experiments of 1968. The line again appeared in spectra of CCl_4 taken in our 1970-71 experiments. It can also be seen in the kaonic chlorine spectrum of Backenstoss et al[4].

In an effort to determine the origin of the 78 keV line, we made kaonic x-ray spectra of $Na^{35}Cl$ and $Na^{37}Cl$. The 78 keV line appeared in both spectaa with approximately equal intensity which meant that it was extremely unlikely to come from excited states of ^{35}Cl or ^{37}Cl. Examination of a kaonic ^{32}S spectrum revealed the 78 keV radiation with about 0.2 the intensity as obtained from chlorine.

Table I shows some reactions of negative kaons on targets that produced excited nuclei whose gamma rays were observed. The list of alternate reactions is not intended to be complete, only exemplary. The charge exchange reaction is endothermic by about 6 MeV, but because kaons entered the target with an average energy of about 40 MeV, there was sufficient energy to produce $\overline{K^o}$. Reaction energies, Q, were determined from nuclear masses of the Table of Isotopes[5] and hypernuclear binding energies from Davis and Sacton[6]. The Q values depend upon the particular combinations of nucleon, pion, and hyperon charges. Also some of the hypernuclear binding energies were estimated and excitation energies were not included; therefore, the values are approximate. It is apparent that the reaction energies are quite different for the various residual nuclei. Energetically the formation of hypernuclei is an economical way for the nuclear fragments to shed their energy and strangeness. An interesting project will be to investigate experimentally the properties of the residual nuclei.

The question arises as to why more nuclear γ rays have not been seen in the kaonic x-ray spectra. The reasons are: (1) the intensities are small; (2) detectors generally used are most sensitive around 100 to 200 keV and not many nuclear levels are so low in energy; (3) some of the γ-ray lines could be masked by mesonic x-ray lines; (4) mesonic x-ray spectrometers are operated in coincidence with the stopping mesons. Delayed gammas are thus unobservable. Our detectors were sensitive for about 1 μ sec after the kaons stopped. Therefore, longer lifetimes were excluded.

The finding of these γ rays indicates that many more may be expected from the low-lying levels of the nuclei produced.

Table I. Negative kaon reactions that produced nuclei whose γ rays were observed. N stands for nucleon; each reaction has many variations according to the charges of N, π, and Σ involved. Approximate reaction energies, Q, assume that nuclei are left in the ground state and neglect the differences caused by having n, or p, π^+ or π^o, etc. The yield of γ rays is given per stopped K^-. We do not know which reaction truly takes place.

Reaction		Q (Mev) approx.	Approx. $\frac{\gamma \text{ rays}}{K_{stop}}$	Observed γ-ray energy (keV)
$K^- + {}^{35}_{17}Cl$	$\rightarrow {}^{32}_{15}P^* + 2N + \pi + \Sigma$	70	0.05	78.1
	$\rightarrow {}^{32}_{15}P^* + 2N + \pi + \Lambda$	154	"	"
	$\rightarrow {}^{32}_{15}P^* + {}^{3}_{\Lambda}H$	290	"	"
$K^- + {}^{37}_{17}Cl$	$\rightarrow {}^{32}_{15}P^* + 4N + \pi + \Sigma$	55	0.04	"
	$\rightarrow {}^{32}_{15}P^* + 4N + \pi + \Lambda$	135	"	"
	$\rightarrow {}^{32}_{15}P^* + 2N + {}^{3}_{\Lambda}H$	272	"	"
$K^- + {}^{32}_{16}S$	$\rightarrow {}^{32}_{15}P^* + \overline{K^o}$	-6	0.01	"
	$\rightarrow {}^{32}_{\Lambda}P + \pi^o$	152	"	"
	$\quad \hookrightarrow {}^{32}_{15}P^* + \pi^o$	69	"	"
	$\rightarrow {}^{32}_{\Lambda}Si + \pi^+$	147		
	$\quad \hookrightarrow {}^{32}_{15}P^* + \pi^-$	64	"	"
	$\rightarrow {}^{19}_{9}F^* + {}^{13}_{\Lambda}C$	296	0.007 0.01	109.9 197.2
	$\rightarrow {}^{19}_{9}F^* + 2\ {}^{4}He + n + {}^{4}_{\Lambda}He$	259	"	"

FOOTNOTE AND REFERENCES

† Work supported by the U. S. Atomic Energy Commission.

1. S. D. Bloom, M. S. Weiss, and C. M. Shakin, UCRL-73352, August 1971, unpublished.

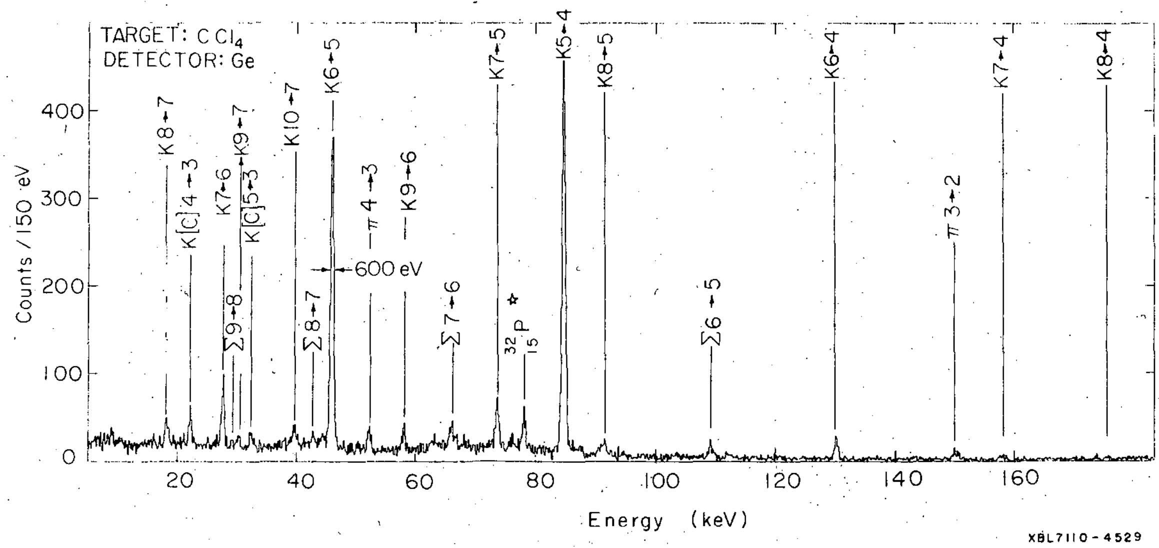
2. See, e.g., G. Backenstoss, S. Charalambus, H. Daniel, W. D. Hamilton, U. Lynen, Ch. von der Malsburg, G. Poelz, and H. P. Povel, Nucl. Phys. A162, 541, (1971); W. J. Kossler, H. O. Funsten, B. A. MacDonald, and W. F. Lankford, Phys. Rev. C 4, 1551 (1971).

3. P. M. Endt and C. Van der Luen, Nucl. Phys. 105 1, (1967).

4. G. Backenstoss, T. Bunaciu, S. Charalambus, J. Egger, H. Koch, A. Bamberger, U. Lynen, H. G. Ritter and H. Schmitt, Phys. Letters, 33B 230 (1970).

5. C. M. Lederer, J. M. Hollander, and I. Perlman, Table of Isotopes, John Wiley and Sons, New York, 1967.

6. D. H. Davis and J. Sacton, in Proceedings of International Conference on Hypernuclear Physics, Argonne National Lab., 1969. Edited by A. R. Bodmer and L. G. Hyman, p. 159.



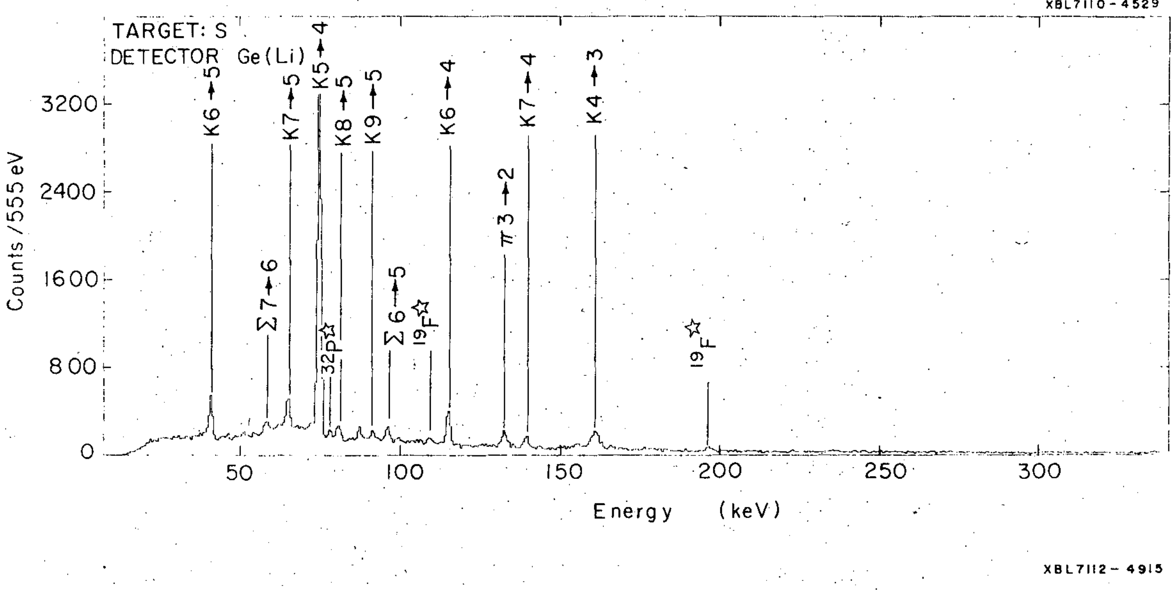


Fig. 1. Kaonic x-ray spectra of CCl_4 and S. The line at 78 keV is attributed to a nuclear γ ray from the first excited level of $^{32}_{15}P$. In the spectrum of S the lines at 110 and 197 keV correspond to the first excited states of $^{19}_{9}F$. The 87 keV line in S probably came from pions (n = 3 → 2) on the Al target holder.

TECHNICAL INFORMATION DIVISION
LAWRENCE BERKELEY LABORATORY
UNIVERSITY OF CALIFORNIA
BERKELEY, CALIFORNIA 94720