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PROMPT ELECTRON SPECTRA FROM Cf^{252} FISSION FRAGMENTS*

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Recent measurements of the spectra of prompt gamma rays accompanying fission[1] have pointed out the possibility of extending the methods of nuclear spectroscopy into the region spanned by the prompt fission products of Cf^{252}. We have followed up this advance with the measurement of the electron spectra originating from the internal conversion of prompt gamma rays from Cf^{252} fission fragments of selected mass in the energy range extending from 30 to 1000 keV. The initial results are quite encouraging with respect to the possibility of charge identification and internal conversion coefficient measurement and it is expected that these studies will yield considerable information concerning the de-excitation processes of primary fission fragments.

An inhomogeneous magnetic field of configuration proposed by Malmfors[2] was used to steer the electrons around a block of lead, which shielded the electron detector from fission fragments and gamma rays. In our case, a wide range of energies and a large solid angle of electrons precess in trochoidal orbits in the fringing field of a large electromagnet. A weightless Cf^{252} source was mounted inside a brass vacuum chamber, which was positioned between the pole faces of the magnet. A lithium-drifted silicon electron detector was mounted inside the vacuum chamber 90° around the magnet from the fission source. This arrangement allowed the detection of electrons without the interference of fission fragments and gamma rays. The fragment energies were measured by two phosphorous-diffused silicon detectors mounted on both sides of the fission source on a line perpendicular to the median plane and at a distance of 1.8 cm.

A triple coincidence was required between the two fragments and the electrons. For geometrical reasons only electrons emitted within one nanosec can precess into the detector. That is, the high magnetic field configuration prevents electrons more distant than about 1 cm from the median plane from reaching the electron detector. The data (E_{f_1}, E_{f_2}, E_β) were recorded individually, event by event, in a multi-dimensional pulse height analyzer and stored on magnetic tape. The neutron-corrected masses were then deduced by a method of successive approximations using the coincident fragment energies and the neutron data of Bowman et al.[3] Finally, the electron events were sorted with respect to coincident fragment mass into mass intervals of two units by using an IBM 7094 computer.

The unsorted electron spectrum for the energy region between 30 and 300 keV is shown in Fig. 1. The highest electron intensity appears at 105 keV. Some structure is apparent although no discrete peaks are discernable. When, however, the electron events are sorted with respect to mass as in Fig. 2, an improvement in definition is achieved. Although well-defined structure is present, the spectra are obviously quite complex. No discrimination is made between electrons coming from the light fragment and the complimentary heavy fragment of each coincident pair. This, in conjunction with a mass resolution of ±2 units, results in the possibility of the existence of components in the spectra arising from 10 to 15 nuclides in each mass interval.

The geometry of the system was such that only electrons which were emitted near 90° with respect to the fragment flight path were accepted into the spectrometer; however, the finite size of the fragment detectors and the rather large acceptance angle of the magnetic field introduced considerable angular dispersion from a strictly 90° configuration. Those electrons which were accepted having angles other than 90° with respect to the fragment trajectory were shifted in energy due to the fragment motion. This effect resulted in a considerable broadening of the electron peaks and is the predominant contributor to the experimental resolution.

Our initial efforts at analysis of these spectra have been focused on the energy region between 300 and 600 keV for the 107-111 and 137-141 mass intervals. It is interesting to compare these electron spectra (Fig. 5) with the previously reported gamma spectrum[1] obtained with a NaI detector in this same energy region (Fig. 3). There is a general similarity between the low-resolution gamma spectra of Fig. 3 and the electron spectra of Fig. 5, notably the presence of the three complex peaks in Fig. 3 (376, 472, and 583 keV), and their counterparts in the electron spectra at the energies expected for K conversion lines.

Recent measurements of the gamma-ray spectra in this region with a lithium-drifted germanium detector have resulted in a very great improvement in resolution. Spectra are shown in Fig. 4a and 4b for the cases of the light fragment traveling toward the gamma detector and the heavy fragment traveling toward the gamma detector, respectively. Individual gamma peaks are well resolved and by comparing Fig 4a with Fig. 4b the energies can be corrected for Doppler shift and the gamma-ray peaks identified with heavy or light fragments. The corresponding peaks in each spectra have been labeled alphabetically. Inspection of Fig. 4 shows three peaks identified with light fragments (E, I, L) and twelve identified with heavy fragments located in the region of interest. Using the gamma-ray energies as determined from these spectra, the expected location of the associated K and L conversion lines have been plotted below the electron spectra in Fig. 5 assuming a most probable heavy Z of 53 or 54 and a most probable light Z of 44. As a rough guide the line lengths are taken from the intensities of the gamma rays in Fig. 4b, although we do not wish to imply that all conversion coefficients would be similar.

This initial analysis has been aimed solely at displaying general structural features and the correspondence between the electron spectra and the gamma spectra from prompt fission fragments. It is expected, however, that further experimental refinements will eventually result in assignments of atomic number for various gamma rays and in multipolarity assignments through conversion coefficient determinations. Further experimentation with conversion electrons may also prove very useful in the determination of fragment excited state lifetimes.

FOOTNOTES AND REFERENCES

*Work done under the auspices of the U. S. Atomic Energy Commission.

1. H. R. Bowman, S. G. Thompson, and J. O. Rasmussen, Phys. Rev. Letters <u>12</u>, B522 (1964).
2. K. G. Malmfors, Arkiv for Fysik, Band 13, No. 21 (1957).
3. H. R. Bowman, J. C. D. Milton, S. G. Thompson, W. Swiatecki, Phys. Rev. <u>129</u>, 2133 (1963).

FIGURE CAPTIONS

Fig. 1. Unsorted prompt electron spectrum from Cf^{252} fission fragments.

Fig. 2. Prompt electron spectra from Cf^{252} fission fragments for selected mass intervals.

Fig. 3. Prompt gamma ray spectra from Cf^{252} fission fragments for mass ratio = 1.30.

——— heavy fragment toward detector

----- light fragment toward detector

Fig. 4. Prompt gamma ray spectra from Cf^{252} fission fragments for mass interval 109-111 (137-139).

a) light fragment moving toward gamma detector

b) heavy fragment moving toward gamma detector

Fig. 5. Electron spectra showing K and L line positions as determined from gamma-ray energies.

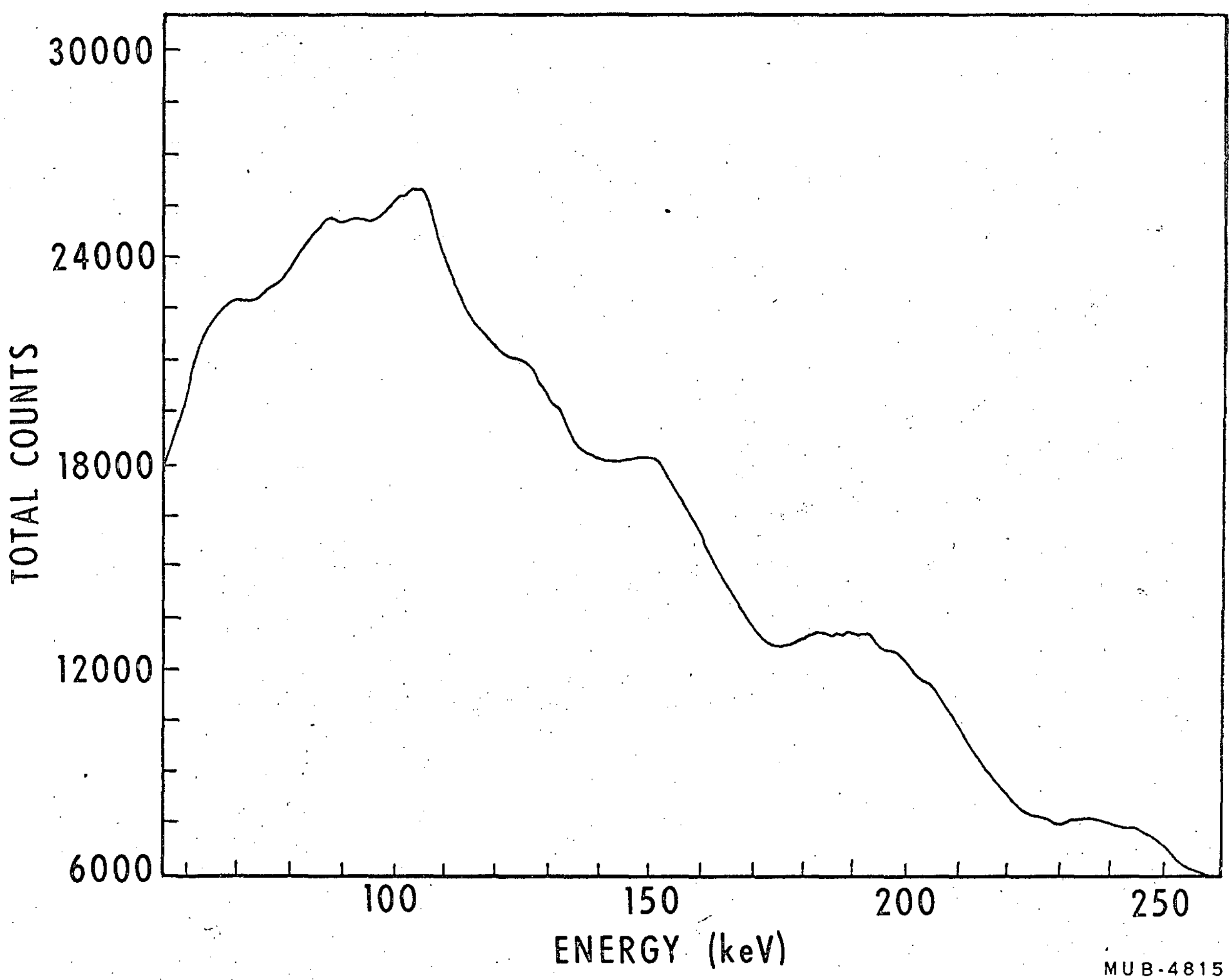
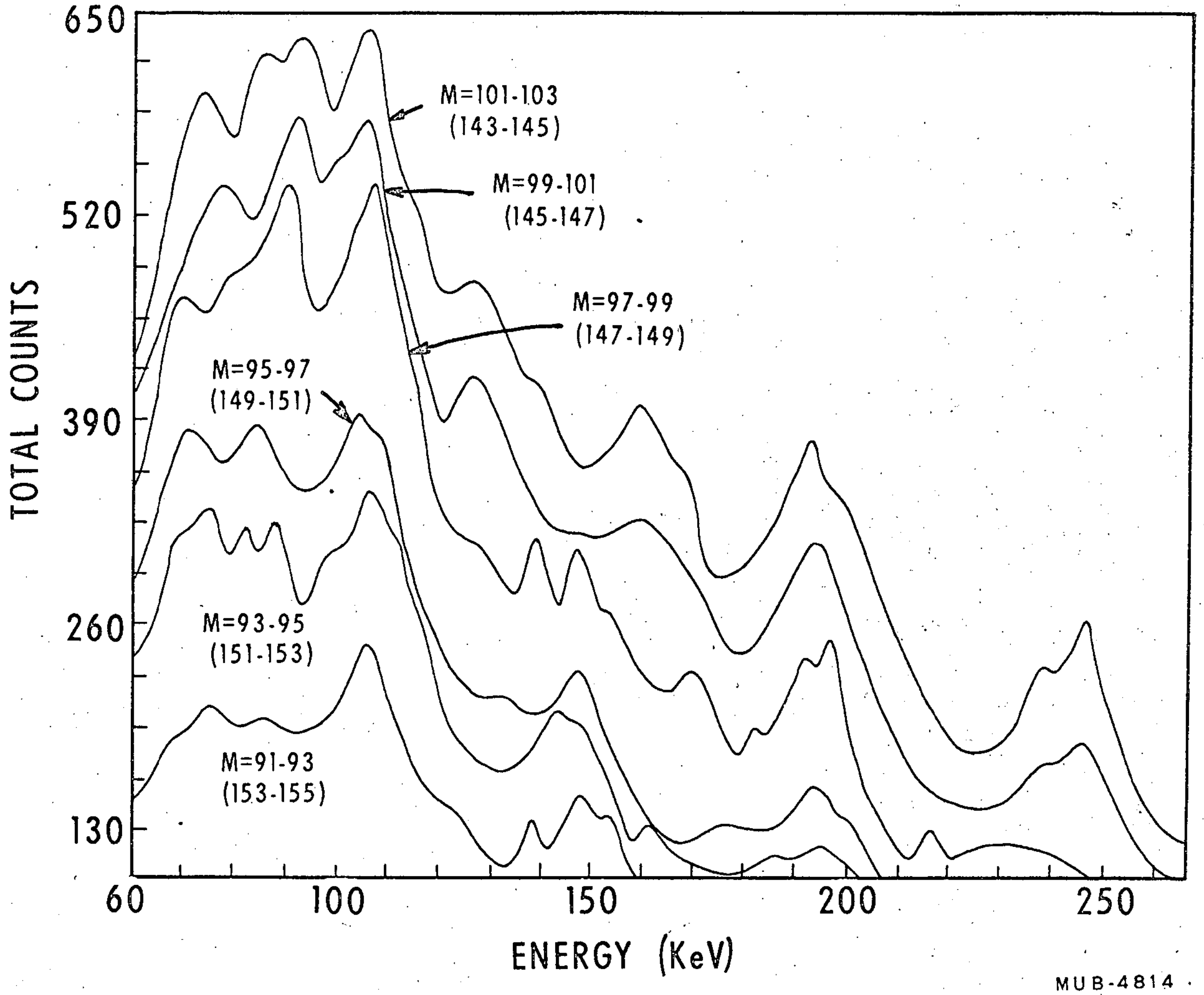

30000
24000
18000
12000
6000
TOTAL COUNTS
100
150
200
250
ENERGY (keV)
MUB-4815

Fig. 1



650
520
390
260
130
TOTAL COUNTS
60
100
150
200
250
ENERGY (KeV)
M=101-103
(143-145)
M=99-101
(145-147)
M=97-99
(147-149)
M=95-97
(149-151)
M=93-95
(151-153)
M=91-93
(153-155)
MUB-4814

Fig. 2

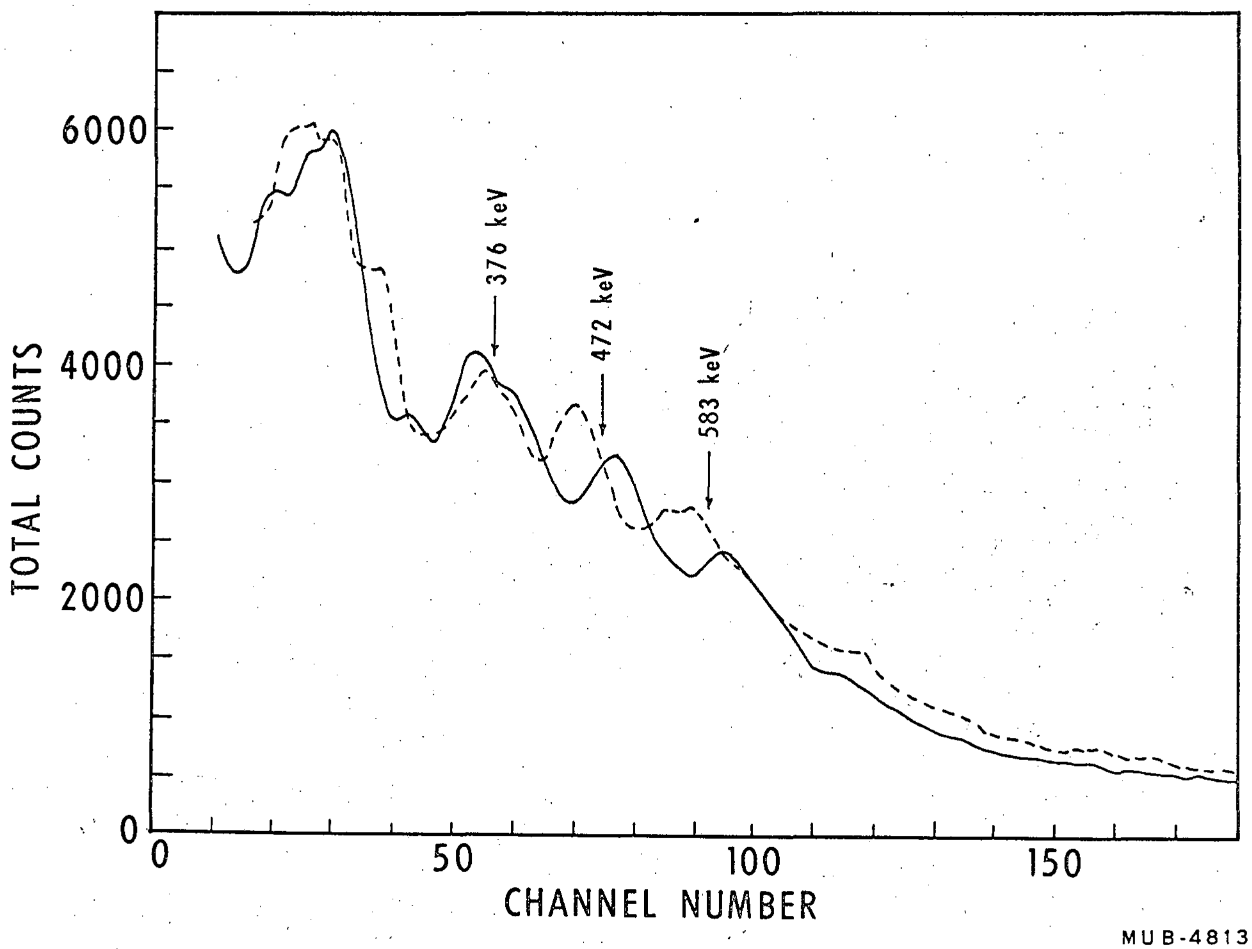

6000
4000
2000
0
TOTAL COUNTS
0
50
100
150
CHANNEL NUMBER
376 keV
472 keV
583 keV
MUB-4813

Fig. 3

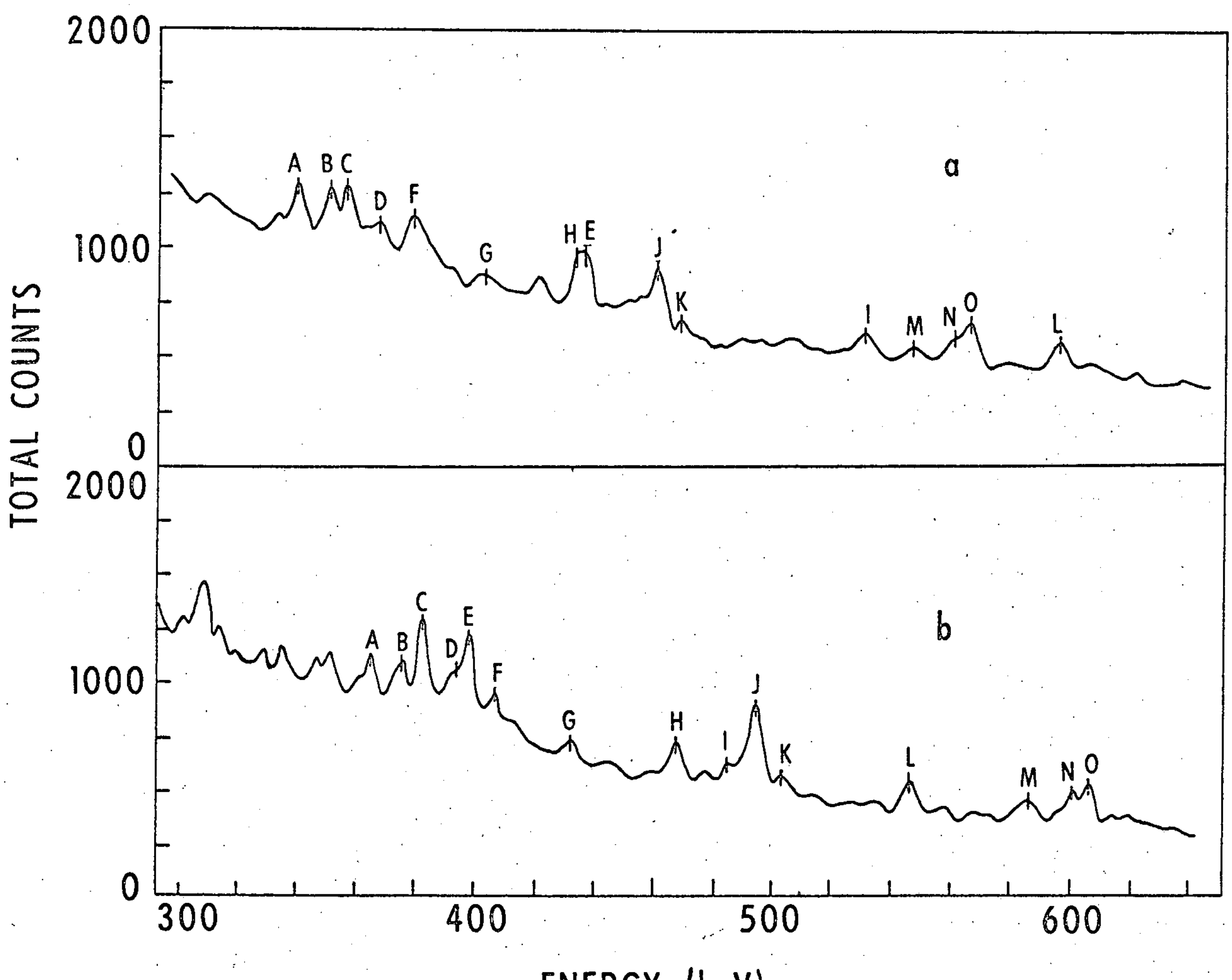
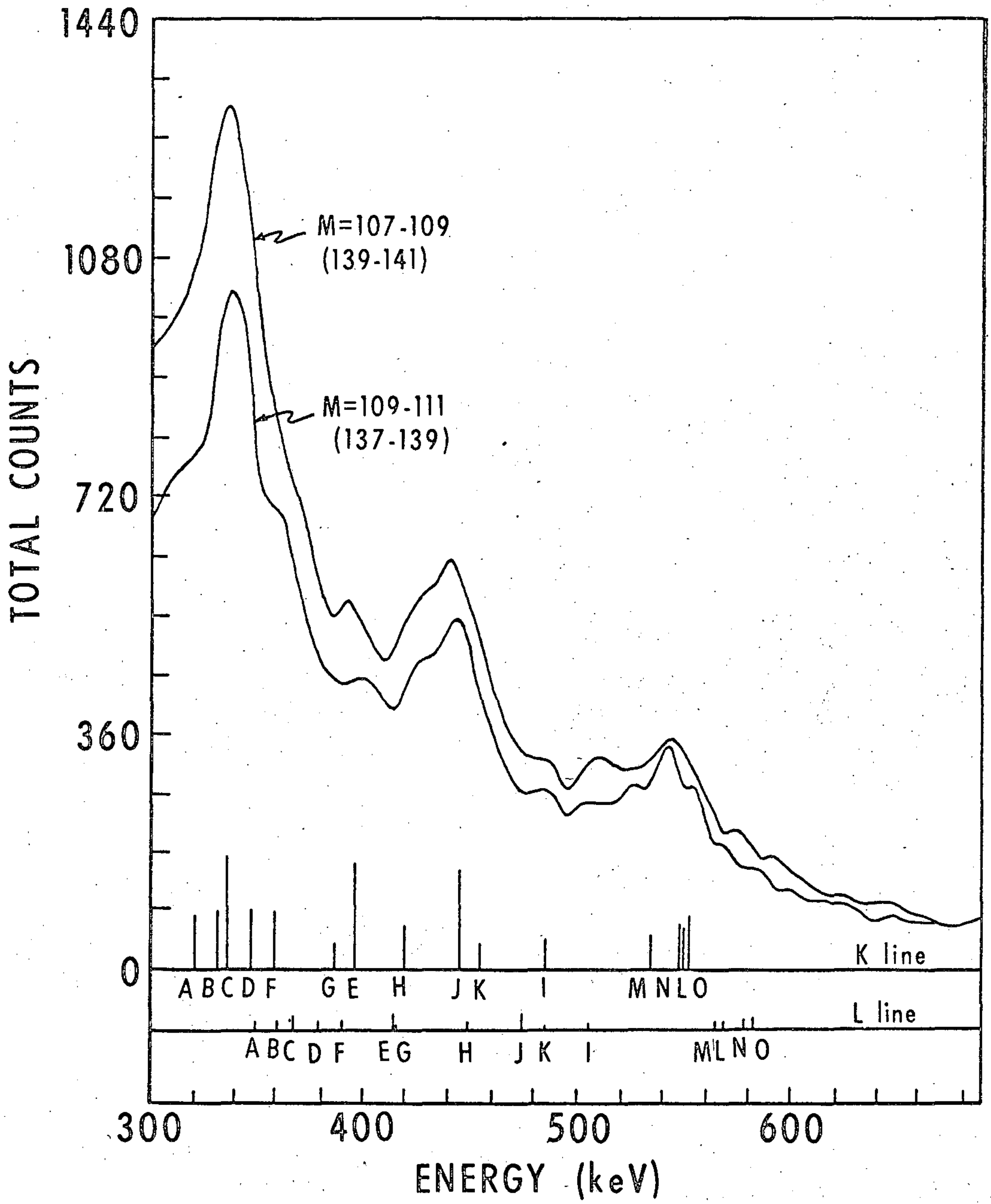

2000
1000
0
2000
1000
0
TOTAL COUNTS
a
b
A
B
C
D
E
F
G
H
I
J
K
L
M
N
O
300
400
500
600
ENERGY (keV)
MUB-4812

Fig. 4



MUB-4811

Fig. 5