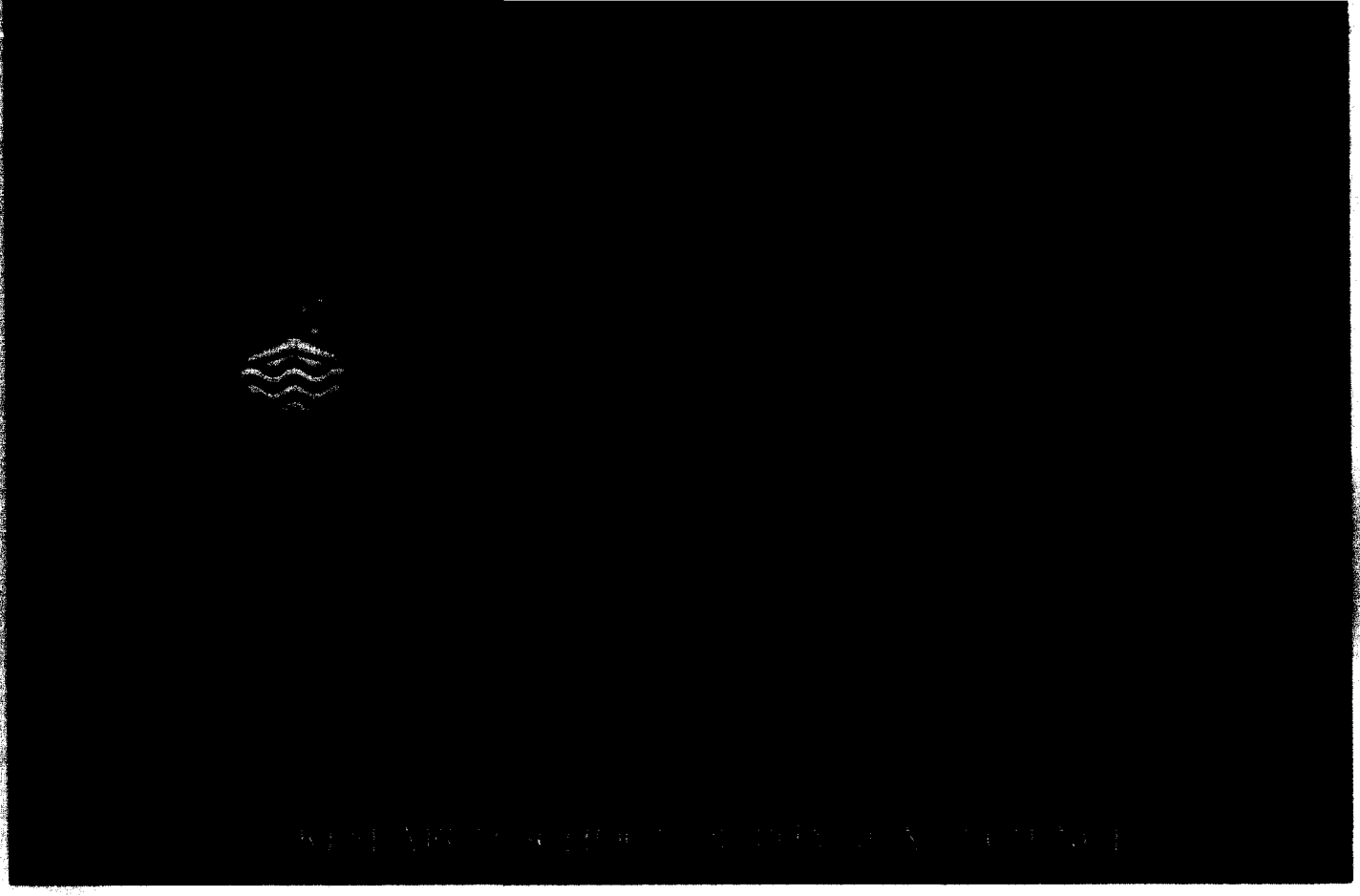

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MASS OF ^{48}K

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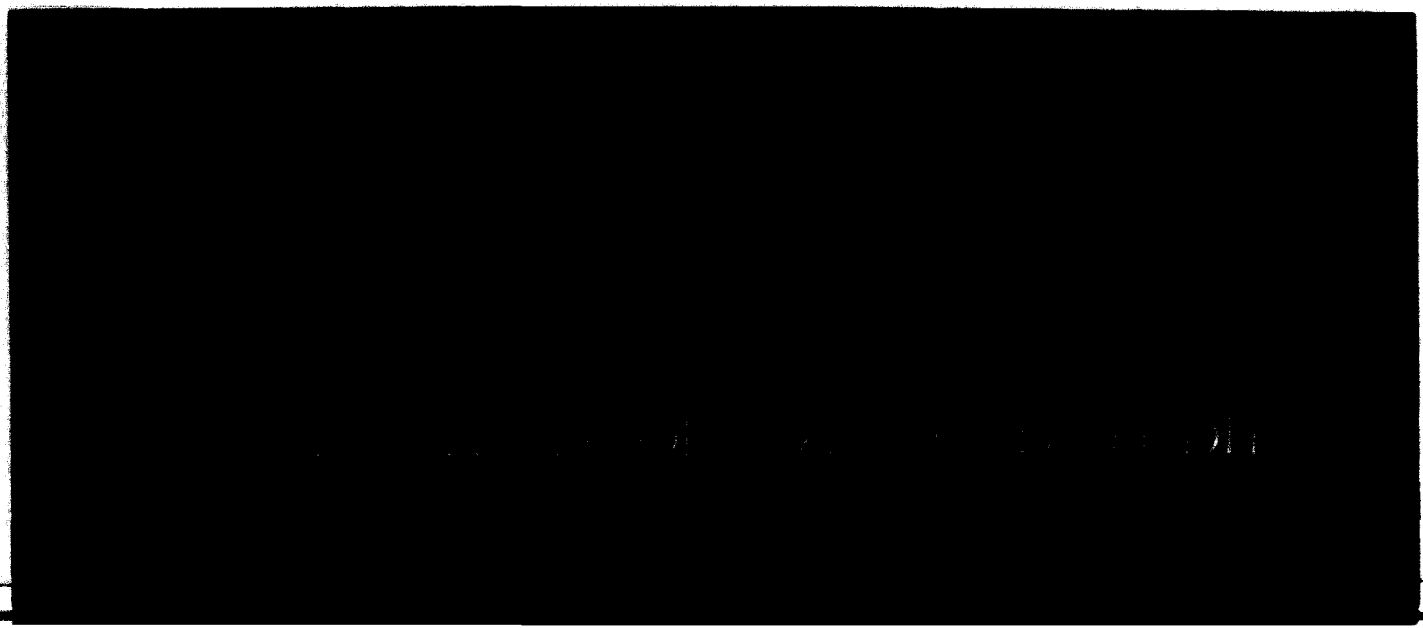

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Abstract

The mass excess of ^{48}K was measured to be -32.117 ± .027 MeV using the $^{48}Ca(^{7}Li,^{7}Be)^{48}K$ reaction at 52 MeV. The result is consistent with predictions and a previous less accurate measurement. There is evidence for an excited state in ^{48}K at 0.58 MeV.

NUCLEAR REACTION $^{48}Ca(^{7}Li,^{7}Be)^{48}K$, E = 52 MeV; measured $\sigma(23.75°)$, $\sigma(27.75°)$, deduced mass ^{48}K, E_x of excited state. Enriched target.

1. INTRODUCTION

Mass measurements of neutron rich nuclei provide important links in systematic mass predictions and tests for detailed shell effect calculations. An improved value for the mass of ^{48}K would be a particularly useful case since it spans the closed shells at N = 28 and Z = 20. Thus it should provide a test of mass calculations[1-4] which vary by 1.6 MeV for ^{48}K. The mass of ^{48}K has been measured by the β end point method to ± 0.5 MeV[5]. An unsuccessful attempt[6] to obtain a smaller error was made using the $^{48}Ca(^{7}Li,^{7}Be)^{48}K$ reaction at 36 MeV. The availability of the higher energy of 52 MeV and superior detection equipment in a well-instrumented magnetic spectrometer encouraged the current work.

2. EXPERIMENTAL METHOD

The reaction $^{48}Ca(^{7}Li,^{7}Be)^{48}K$ was studied using a 52 MeV ^{7}Li beam from the A.N.U. 14UD pelletron accelerator. Typical currents were 150 na on a target of 200 $\mu g/cm^2$ of 98% isotopically enriched ^{48}Ca evaporated on a 15 $\mu g/cm^2$ carbon foil. The target was stored and transferred under vacuum to minimize oxidation and was surrounded by a liquid nitrogen cooled shroud to minimize carbon buildup and enhance target stability. The reaction products were magnetically analysed by a 90 cm Enge split pole spectrometer using a 4.5° horizontal acceptance angle and a solid angle of 4.15 msr.

A gas-filled proportional counter[7] was located in the focal plane. Each detected ion, after emerging from the entrance window at about 45°, passes under the first resistive position wire which is placed in the focal plane for the reaction. The position signal P_1 provides the Bρ information. Subsequently, the particle passes under two electrodes which collect the ΔE_1 and ΔE_2 signals used to establish the rate of energy loss for the Z determination, and a second resistive wire generating a position signal P_2.

P_2 in combination with P_1, gives angle of incidence information which identifies those events in correct kinematic focus. Unfocussed contaminant events can be kinematically reconstructed as an aid in energy calibration and as a check upon the proper assignment of peaks in the spectrum. Beyond the second wire, the ^{7}Be ion stops in the gas. The total ionization is measured by an electrode below the particle trajectory to give the total energy signal, E. The five parameters P_1, P_2, ΔE_1, ΔE_2 and E were recorded in event mode on magnetic tape via an HP2100 computer for later analysis. For an ion of mass m and charge q, $m/q^2 = (B\rho)^2/2E$ was calculated and an on-line digital gate set around the ^{7}Be peak.

Off-line analysis consisted of recomputing m/q^2 with E corrected for the argle dependent energy loss in the entrance window. The Z of the particle, $mZ^2 \propto \Delta E \cdot E$, was obtained from $\Delta E_1 \cdot E$ and $\Delta E_2 \cdot E$ where the ΔE's were also angle corrected. Figure 1 shows $\Delta E_1 \cdot E$, m/q^2 and the gated ^{7}Be m/q^2 spectrum. The mass identification of ^{7}Be is clearly unambiguous.

Strong confirmation that a peak in the P_1 spectrum arises from the reaction of interest is obtained from a plot of P_2-P_1 vs P_1 as shown in the top of figure 2. With the focal plane detector placed with wire 1 at the focal plane for the ^{48}Ca(^{7}Li,^{7}Be) reaction, ^{7}Be ions from a single state will all cross wire 1 at a single point and have a range of P_2 signals corresponding to their various angles of incidence at the focal plane. Such events form a vertical locus in this plot. Events out of kinematic focus, e.g. ^{16}O(^{7}Li,^{7}Be)^{16}N, lie along sloping lines. The P_1 spectrum for such events can be reconstructed from the data by "rotating" the sloping line about the mean ray position. This produces an energy spectrum for the contaminant reaction whose peak positions are consistent with the energy scale described below.

The energy scale was established by observing the ^{63}Cu(^{6}Li,^{7}Be)^{62}Ni

reaction at $\theta_{lab} = 20°$ with a 39 MeV beam using a 110 $\mu g/cm^2$ 95% isotopically enriched copper target. The first two states of ^{62}Ni and their associated Be*'s, span the position region of the ^{48}K ground state with no change of the magnetic field in the spectrometer. The focal plane detector was left in the focus position for the $^{48}Ca(^7Li,^7Be)$ reaction and the horizontal entrance slits narrowed to 0.9° in order to select the mean ray. A calibration spectrum is shown in figure 3. The accuracy of this technique was established by first cycling the accelerator analysing magnet to maintain a reproducible calbiration[8] and then observing the $^{63}Cu(^6Li,^7Be)$ spectrum. The analysing magnet was recycled for the $^{48}Ca(^7LI,^7Be)^{48}K$ reaction. After cycling a third time, the $^{63}Cu(^7Li,^7Be)^{62}Ni$ reaction was repeated. The overall energy difference between the two $^6Li + ^{63}Cu$ observations was 15 keV.

In fact, the procedure described above was used three months after a preliminary observation of ^{48}K. On this first occasion, the $^{48}Ca(^7Li,^7Be)$ reaction was observed at 23.75° and 27.75° and then followed by the calibration with the $^{63}Cu(^6Li,^7Be)$ reaction. The energy of the ground state of ^{48}K on the two runs differed by only 14 keV.

The mass excess of ^{48}K can be expressed in terms of the masses of ^{62}Ni, ^{63}Cu, ^6Li, ^7Li and ^7Be[9]. The uncertainties of these values contribute ±5 keV to the ^{48}K mass uncertainty.

The target thickness energy loss was measured by noting the shift of the elastically scattered ^6Li peak position observed at $\theta_{lab} = 20°$, for a 90° rotation of the target from 45° beam incidence. The ^7Be energy loss was calculated from the ^6Li data and the results of Northcliff and Schilling[10]. The thicknesses, averaged for the appropriate lithium entrance channel and ^7Be exit channel, were 62 keV ± 3 keV for the ^{63}Cu target and 104 keV ± 3 keV for the ^{48}Ca target. This latter thickness includes the effect of the carbon backing and whatever oxidation that may have occurred.

The contribution to the mass uncertainty due to angle errors is based on accumulated experience with the apparatus with various beams at numerous times. The absolute zero degree error was measured to be less than ±0.07°. An angular scale error would affect both the ^{48}Ca and ^{63}Cu data in the same way. Thus the difference between the energy change with angle was used to infer a ±5 keV error for a 0.1° uncertainty. An angular reproducibility error of 0.05° is appropriate for the apparatus. This error must reflect itself in the reproducibility measurement of the $^{63}Cu(^{6}Li,^{7}Be)$ reaction and is thus included in the measured ±15 keV.

3. RESULTS

The energy spectra observed at $\theta_{lab} = 23.75°$ and $\theta_{lab} = 27.75°$ for the $^{48}Ca(^{7}Li,^{7}Be)^{48}K$ reaction are shown in the middle and bottom respectively of figure 2. The centre of mass cross section at 23.75° was 4 μb/sr and at 27.75°, 1.5 μb/sr as determined from a comparison of ^{6}Li elastic scattering at 34 MeV with the data of Culter[11]. The peaks associated with the kinematically focussed loci of figure 2 are identified as states in ^{48}K and their excitation energies marked.

The mass excess of ^{48}K was measured to be -32.117 ± .027 MeV. The contributions to the probable error are:

1)	Absolute beam energy uncertainty	20 keV
2)	Total system reproducibility	15 keV
3)	Target thickness	6 keV
4)	Angle of observation	5 keV
5)	Mass uncertainties of other reaction products	5 keV
6)	Statisitical centroid error	5 keV.

Comparison with the predicted and measured mass values is given in table 1. The mass excess found in this work agrees within errors with that obtained from the β end point measurement of Multhauf et al[5] and is in closest

agreement with the droplet plus shell correction calculation of Groote et al[2]. This agreement is welcome since this caluclation includes shell effects which ought to be very important for the $2p_{3/2}$ proton hole and the $1f_{7/2}$ neutron configurations. The apparent discrepancy of 0.65 MeV with the Comay-Kelson extrapolation[4] is well within their expected uncertainty of 1.2 MeV. The assumption of a similar uncertainty for the Jänecke estimate[3] accommodates this calculation as well. Indeed these two extrapolations which include nuclei in both adjacent shells should give reliable mass estimates. The inclusion in mass extrapolation calculations of the accurate mass value for ^{48}K should improve mass estimates in this region of the periodic table.

We would like to thank Professor Kirby Kemper for suggesting this experiment and Arthur Johnston for useful discussions of the interpretation of the focal plane detector data.

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TABLE 1.

^{48}K mass excess in MeV

Myers[1]	Groote, Hilf, Takahashi[2]	Jänecke[3]	Comay, Kelson[4]	Multhauf et al[5]	$^{48}Ca(^{7}Li,^{7}Be)^{48}K$
Droplet Model	Droplet + Shell	Garvey-Kelson	G-K Ensemble Averaging	β end point	
-31.33	-32.27	-32.92	-32.76 ± 1.2	-32.22 ± 0.5	-32.117 ± .026

FIGURE CAPTIONS

Figure 1. ^{7}Be identification for the $\theta_{Lab} = 23.75°$, $^{48}Ca(^{7}Li,^{7}Be)^{48}K$ data. Top: ΔE_1-E and window for Z determination. Middle: m/q^2 for all the data. Bottom: m/q^2 gated by ΔE_1-E and ΔE_2-E. The group marked ^{8}Be is consistent with simultaneous detection of two α-particles.

Figure 2. Top: ^{7}Be ions in kinematic focus for $^{48}Ca(^{7}Be,^{7}Li)^{48}K$ form vertical loci. The sloping loci are from the out of focus $^{16}O(^{7}Li,^{7}Be)^{16}N$ reaction. Middle: $\theta_{Lab} = 23.75°$ for the data in the top of the figure. Bottom: $\theta_{Lab} = 27.75°$ The peaks from the ^{16}O target contaminant have moved to lower channels.

Figure 3. Position spectrum for the $^{63}Cu(^{6}Li,^{7}Be)^{62}Ni$ calibration reaction.

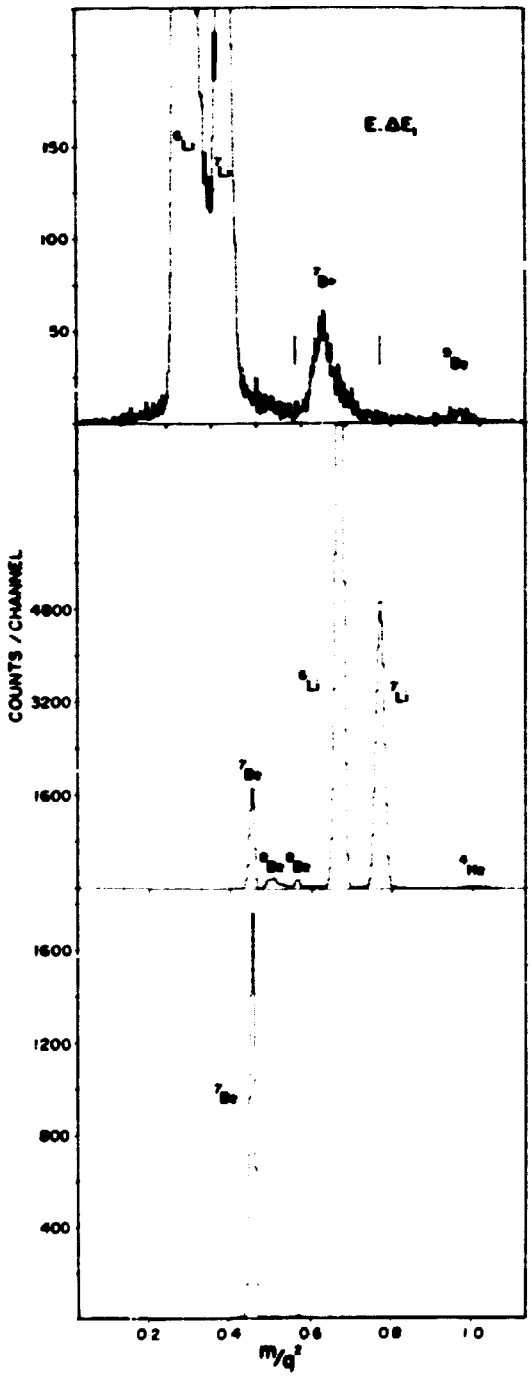
E.ΔE
150
100
50
COUNTS / CHANNEL
4800
3200
1600
1600
1200
800
400
02
04
06
08
10
m/q²

FIGURE 1

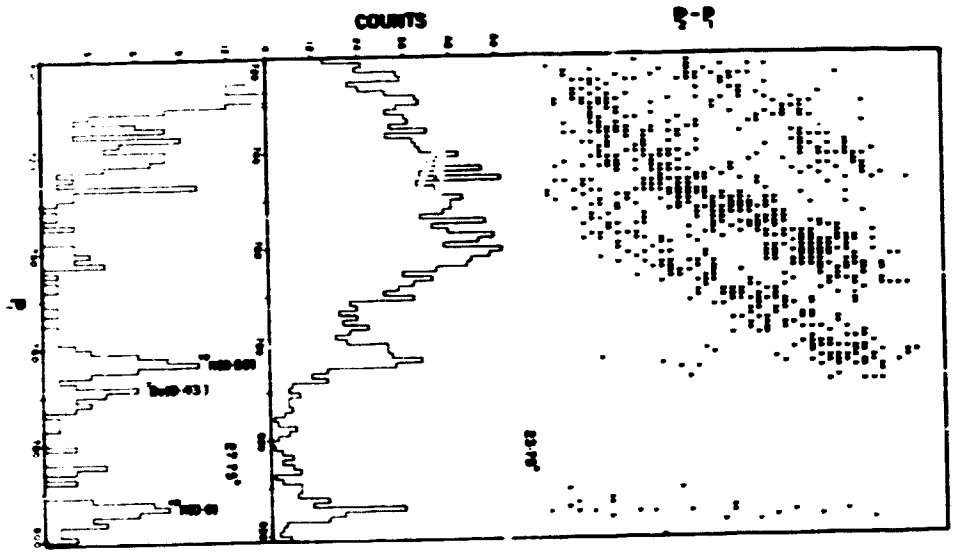

FIGURE 2

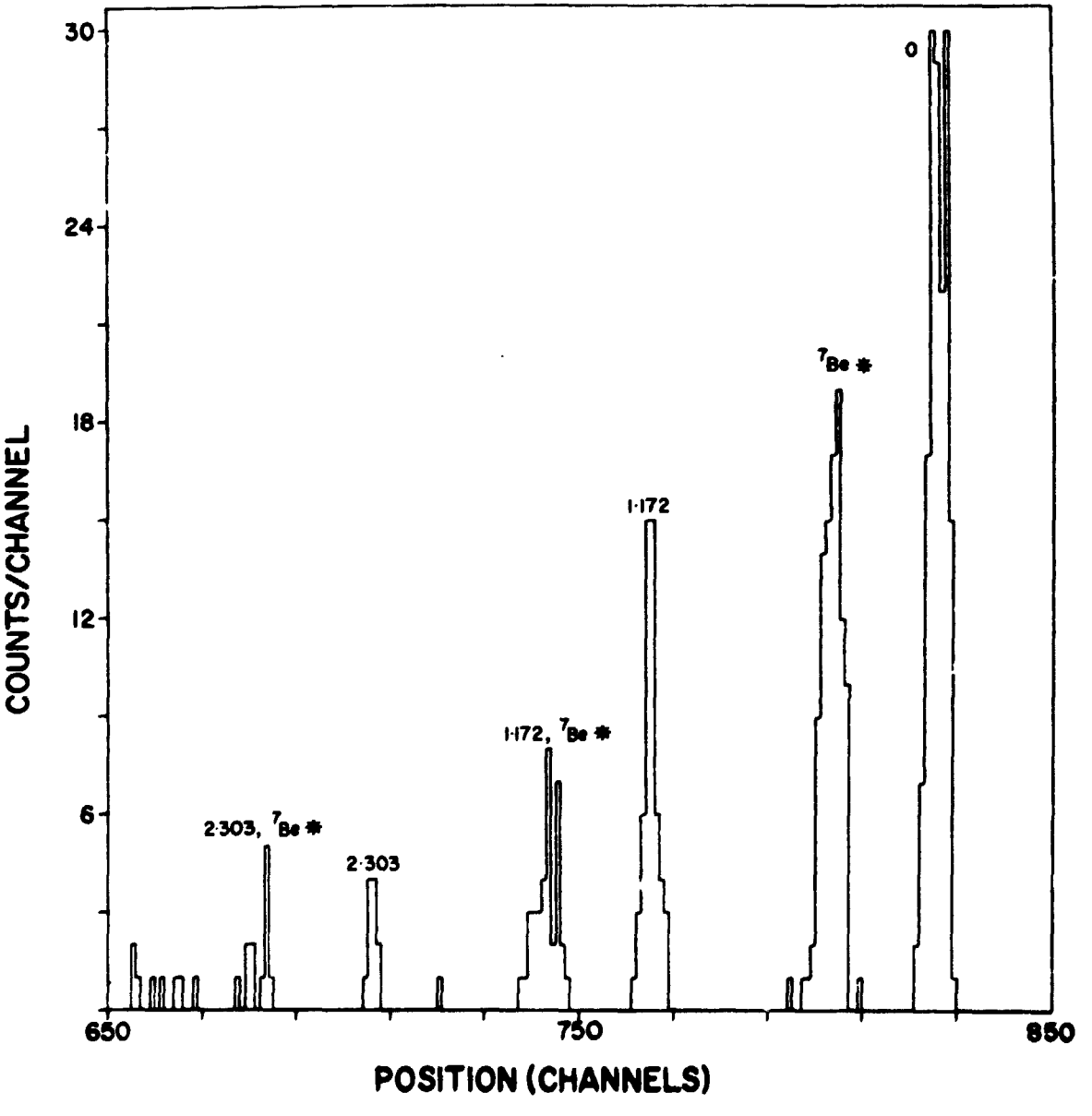
30
24
18
12
6
COUNTS/CHANNEL
650
750
850
POSITION (CHANNELS)
0
^{7}Be *
1·172
1·172, ^{7}Be *
2·303
2·303, ^{7}Be *

FIGURE 3