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ABSTRACT

The mass 37 isospin quartet has been completely determined, thus furnishing another test of the isobaric multiplet mass equation. A three-counter-telescope, particle identifier system determined the ^{37}Ca mass excess via the $^{40}Ca(^{3}He,{}^{6}He)^{37}Ca$ reaction. The lowest T = 3/2 states of ^{37}Ar and ^{37}K were located through the $^{39}K(p,{}^{3}He)^{37}Ar^{*}$ and $^{39}K(p,t)^{37}K^{*}$ reactions.

†Work performed under the auspices of the U. S. Atomic Energy Commission.

Probably SESSION II.b.

If not, Session I.b.

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The mass of ^{37}Ca is of interest for several reasons: it permits a check on the systematic prediction of neutron-deficient masses;[1] it is an ingredient in the determination of accurate ft-values in the decay of ^{37}Ca, which is the mirror reaction for a solar neutrino experiment in progress;[2] and, in conjunction with other data, it enables a further study to be made of the isobaric multiplet mass equation (IMME).[3] Although the two previous investigations of complete isospin quartets (masses 9 and 13)[4] have shown agreement with the IMME within experimental errors, a test among isobars possessing greater Coulomb energy seems desirable. The previously reported members of the mass 37 isospin quartet are ^{37}Cl (stable) and the T = 3/2 state in ^{37}K at 5.030±0.018 MeV.[5]

The (^{3}He, ^{6}He) reaction, which has been used previously to measure the masses of ^{9}C and ^{13}O,[4] was used to obtain the mass of ^{37}Ca. Since a preliminary experiment had shown that the $^{40}Ca(^{3}He,^{6}He)^{37}Ca$ reaction had a cross-section of about 0.2 μb/sr (10 times lower than the $^{12}C(^{3}He,^{6}He)^{9}C$ reaction), two independent particle identifier systems capable of analyzing such low yield nuclear reactions were employed; each consisted of two ΔE detectors and an E detector (see Ref. 6). Each system also employed a pile-up rejector to restrict all allowed events to within a single beam burst and a rejection detector to eliminate long-range particles. Diffused silicon transmission counters of an optimal thickness for ^{6}He and a ^{6}Li calibration group were used.

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Figure 1 shows a particle identifier spectrum from the bombardment of ^{40}Ca with 55.9 MeV ^{3}He ions from the Berkeley 88-inch cyclotron. As is indicated in Fig. 1, a "background" still appears in the ^{6}He region of the identifier spectrum. This background is due to chance coincidences between a helium-3 particle and a deuteron from a single beam burst which produce an energy loss and hence an identification signal similar to that of a ^{6}He particle. (Also seen on Fig. 1 are counts due to ^{3}He-p and ^{3}He-^{3}He chance coincidences.) In order to reduce this background, an on-line computer was used to record complete information (both ΔE counter energy signals, the total energy signal, and the particle identifier signal) on all the events in the ^{6}He region of the particle identifier spectrum. These E vs ΔE data were later analyzed in detail and permitted the rejection of some of the events as not being ^{6}He ions.

Figure 2 presents ^{6}He energy spectra from the two independent systems. Typical energy resolutions (FWHM) were 180 keV for ^{6}He and 240 keV for ^{6}Li. There are two sharp states in each spectrum, corresponding to the ground and first excited states of ^{37}Ca. The average cross-section for the ^{37}Ca ground state transition at 11.2 degrees lab was 0.175 μb/sr and the experimental mass excess of ^{37}Ca was found to be -13.24±0.05 MeV (^{12}C = 0). Hence ^{37}Ca is stable to proton emission by 3.8±1.0 MeV (the mass excess of ^{36}K is known to only ±1.0 MeV);[7] the predicted proton binding energy for ^{37}Ca is 2.9±1.5 MeV.[1] An excitation of 1.62±0.03 MeV for the first excited state of ^{37}Ca is consistent with the known[8] first excited state of the $T_z = +3/2$ nucleus ^{37}Cl at 1.725 MeV.

The lowest T = 3/2 levels of ^{37}Ar and ^{37}K were located via the $^{39}K(p,^{3}He)^{37}Ar^{*}$ and $^{39}K(p,t)^{37}K^{*}$ reactions. A standard particle identifier fed by a dE/dx-E semiconductor counter telescope distinguished the tritons and helium-3 particles emergent from a K_2O target which was bombarded with 45 MeV protons. Two sharp states appeared in the expected region with excitations of 5.010±0.030 and 5.035±0.025 MeV in ^{37}Ar and ^{37}K, respectively.[9] The angular distributions of these two states confirm that they are the ^{37}Cl ground state analogue levels. Assuming the charge independence of nuclear forces, transitions to analogue states in ^{37}Ar and ^{37}K proceed from identical initial to final states through only ^1S, T = 1 pickup of two nucleons. Therefore identical cross-sections are expected for these transitions, after phase-space and isospin coupling corrections are included. Experimentally, transitions to these states do possess essentially identical L = 0 angular distributions.

It has been shown[3] that if nuclear forces are charge independent the masses of the members of an isobaric multiplet are related by the IMME:

$$M = \underline{a} + \underline{b}\,T_z + \underline{c}\,T_z^2 \quad .$$

This equation can be tested by predicting the ^{37}Ca mass from the other three members of the quartet. Using our experimental excitations for the T = 3/2 levels in ^{37}Ar and ^{37}K and the mass excess of ^{37}Cl, the ^{37}Ca mass excess is calculated to be -13.24±0.12 MeV, which is in excellent agreement with the experimental value. Thus, within the relatively large experimental uncertainties, the IMME holds for the isospin quartet of highest Z in which all four masses are immediately measurable by the techniques reported herein.

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FIGURE CAPTIONS

Fig. 1. Three-counter particle identifier spectrum from 55.9 MeV ^{3}He ions on ^{40}Ca.

Fig. 2. Two independent ^{6}He energy spectra from $^{40}Ca(^{3}He, ^{6}He)^{37}Ca$ at 11.2 degrees.

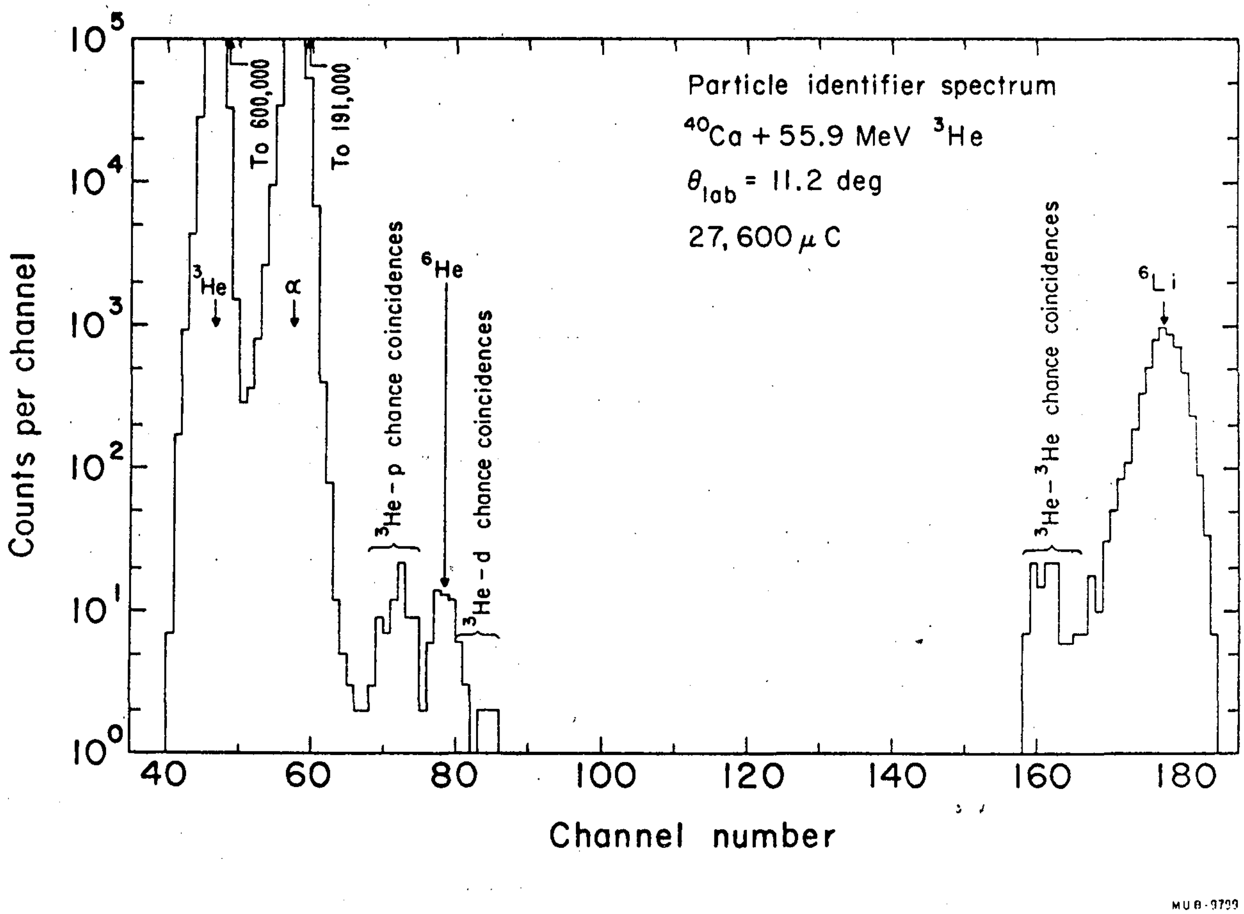
Particle identifier spectrum
40Ca + 55.9 MeV 3He
θlab = 11.2 deg
27,600 μC
To 600,000
To 191,000
3He
α
6He
6Li
3He - p chance coincidences
3He - d chance coincidences
3He - 3He chance coincidences
Counts per channel
Channel number
10^0
10^1
10^2
10^3
10^4
10^5
40
60
80
100
120
140
160
180
MUB-9799

Fig. 1

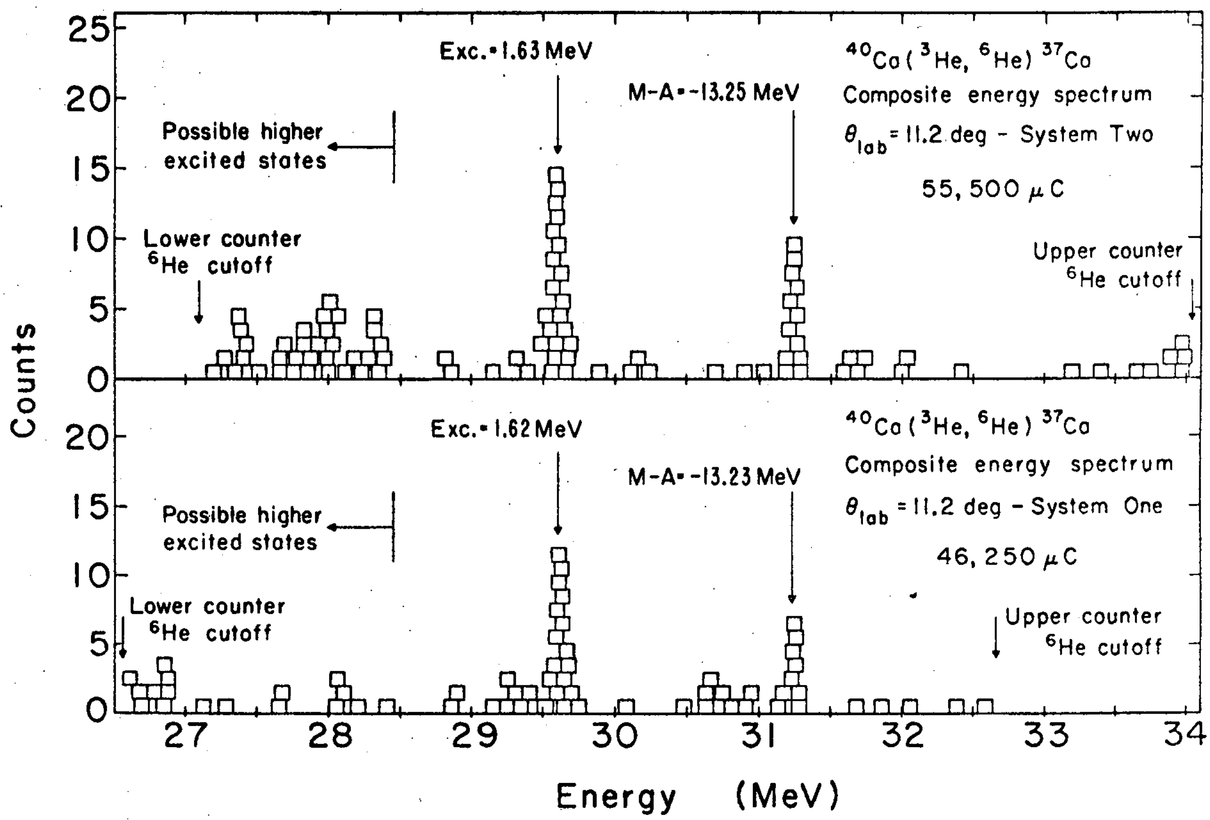
Exc. = 1.63 MeV
M-A = -13.25 MeV
^{40}Ca (^{3}He, ^{6}He) ^{37}Ca
Composite energy spectrum
θ_{lab} = 11.2 deg - System Two
55, 500 μC
Possible higher excited states
Lower counter ^{6}He cutoff
Upper counter ^{6}He cutoff
Exc. = 1.62 MeV
M-A = -13.23 MeV
^{40}Ca (^{3}He, ^{6}He) ^{37}Ca
Composite energy spectrum
θ_{lab} = 11.2 deg - System One
46, 250 μC
Counts
Energy (MeV)
MUB-9797

Fig. 2