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ANALOGUE STATES IN ^{47}Ca

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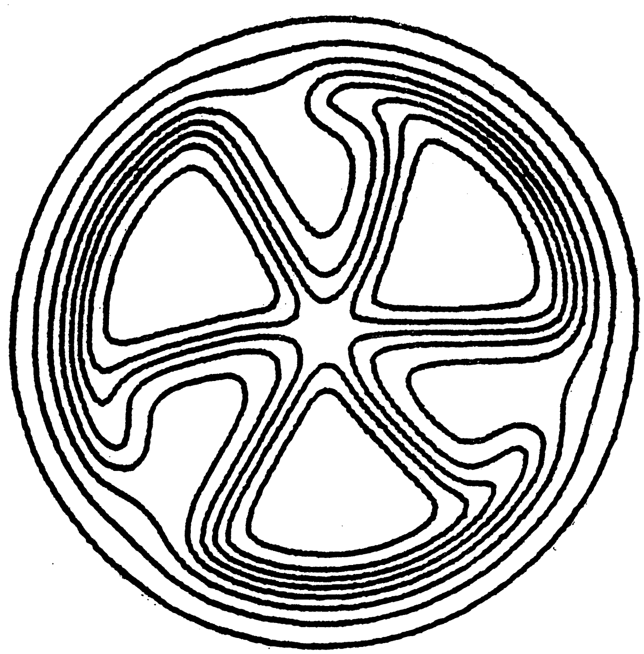

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ABSTRACT

The $^{48}Ca(^{3}He,^{4}He)^{47}Ca$ and $^{48}Ca(p,d)^{47}Ca$ reactions were used to observe six levels in ^{47}Ca above 12 MeV excitation. Analysis of the data has yielded precise excitation energies for the lowest T=9/2 levels in ^{47}Ca, which are analogs of low-lying levels in ^{47}K. Comparison of experimental and calculated Coulomb displacement energies for the K-Ca isotopes is made.

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In this letter we present the results of measurement of six levels in ^{47}Ca above 12 MeV excitation and discuss the Coulomb displacement energy systematics of the analogue states in the odd K-Ca isotopes. The levels in ^{47}Ca were observed by means of the $^{48}Ca(^{3}He,^{4}He)^{47}Ca$ and $^{48}Ca(p,d)^{47}Ca$ reacitons. Beams of 69.7 MeV ^{3}He particles and 40.2 MeV protons from the Michigan State University cyclotron were employed. The outgoing ^{4}He particles and deuterons were momentum analyzed in an Enge split-pole magnetic spectrograph. The detection system consisted of a position-sensitive resistive-wire proportional gas counter backed by a plastic scintillator for time-of-flight information. The method and electronics have been previously described.[1]

Figure 1 shows the spectra of ^{4}He particles from the $^{48}Ca(^{3}He,^{4}He)^{47}Ca$ reaction at 9.0 and 22.5 degrees. The 1.0 mg/cm^2 thick self-supporting ^{48}Ca target which was used contained ^{16}O and ^{12}C from which the calibration lines were obtained. No evidence of strong states was seen from 22. to 46. MeV excitation in ^{47}Ca. In Fig. 2 the spectra of deuterons at 10 and 13 degrees from the $^{48}Ca(p,d)^{47}Ca$ reactions are shown. A 150 $\mu g/cm^2$ carbon-backed ^{48}Ca target was used for this reaction. The Mass-71 values[2] of the ground state masses were used for all relevant masses, while the excitation energies of the calibration levels in ^{11}C and ^{15}O were taken from the compilations of F. Ajzenberg-Selove.[3,4] Table I gives the mass-excesses and excitation energies of the levels above 12 MeV in ^{47}Ca from both the present and previous work.[5]

Experimental Coulomb displacement energies for the lowest $3/2^+$ and $1/2^+$ levels of odd K-Ca isotopes have been extracted and listed in Table II. The value of 6.868 MeV for the $3/2^+$ states is 64 keV smaller than calculations by R. Sherr and G. Bertsch[6] who predict a value of 6.932 MeV.

Calculations for the direct term of the Coulomb displacement energies were made as described by Nolen and Schiffer.[7] A Woods-Saxon well was used to take into account finite binding energy,[7] and a homogeneously charged sperical core of constant radius was assumed. The radius was adjusted to match the experimental values of A=47 for the direct term. Figure 3 is a graph of the displacement energies with solid lines representing the calculations made for the $3/2^+$ and $1/2^+$ levels.

The good agreement of the calculations with the data for masses 41 to 47 indicates that the assumption of a constant radius for the charge distribution of the core is justified in this region. The difference in the calculations between the $1/2^+$ and $3/2^+$ levels is due to the different radii of the $2s_{1/2}$ and $1d_{3/2}$ orbitals. This difference is largest for masses 37 and 39 where the analogue state is formed by the charge exchange of only a $2s_{1/2}$ or $1d_{3/2}$ particle, while in masses 41 to 47, $1f_{7/2}$ particles are also involved. The data reflects the Kahana-Weneser effect,[8] which reduces the dependence of the displacement energy on the orbital radius. The larger displacement energies in mass 39 relative to mass 41 reflect the larger neutron separation energies in ^{39}K and is well reproduced by the calculation. However, the difference between the displacement energies for masses 37 and 41 which is not reproduced in this simple calculation is probably due to a change in the radius of the charge distribution between ^{37}K and ^{41}K. It may be concluded that

the addition of $1f_{7/2}$ neutrons to K and Ca does not significantly affect the radius of the charge distribution. This conclusion is supported by data from electron scattering on the calcium isotopes[9] which indicates nearly no change in the r.m.s. radius of the charge distribution from ^{40}Ca to ^{48}Ca.

REFERENCES

1. E. Kashy, W. Benenson, I.D. Proctor, P. Hauge and G. Bertsch, Phys. Rev. C7, 2251(1973).
2. A.H. Wapstra and N.B. Gove, Nucl. Data A9, 267(1971).
3. F. Ajzenberg-Selove, Nucl. Phys. A152, 1(1970).
4. P. Martin, M. Buenerd, Y. DuPont and M. Chabre, Nucl. Phys. A185, 465(1972).
6. R. Sherr and G. Bertsch, submitted to Phys. Lett. and private communication.
7. J. A. Nolen, Jr. and J.P. Schiffer, Annual Rev. Nucl. Sci. 19, 471(1969).
8. E.H. Auerbach, S. Kahana, and J. Weneser, Phys. Rev. Lett. 23, 1253(1969).
9. H.R. Colard, L.R.B. Elton and R. Hofstadter, Nuclear Physics and Technology; Nuclear Radii, H. Schopper, ed., (Springer-Verlag, 1967), p. 34.
10. W. Benenson, E. Kashy and I.D. Proctor, Phys. Rev. C8, 210(1973).
11. P.M. Endt and C. van der Leun, Nucl. Phys. A124 , 1(1973).
12. A. Saha and Kamal K. Seth results presented at May 1975 Washington APS Meeting and private communication.
13. Nuclear Data Group, Nuclear Level Schemes A=45 through A=257, (Academic Press Inc. 1973).

Table I.--Comparison of the present measurements of excitation energies above 12 MeV in ^{47}Ca to the previous measurements.

Mass Excess (MeV)	Excitation Present	Excitation Previous*	J^{π},T
-29.606±.003	12.737±.005	12.73±.03	$1/2^+$;T=9/2
-29.259±.003	13.084±.005	13.09±.03	$3/2^+$;T=9/2
-29.215±.015	16.128±.015	16.12±.05	
-24.194±.020	18.149±.020	18.11±.05	
-21.898±.020	20.445±.020		
-21.565±.020	20.778±.020		

*Ref. 5.

Table II.--Experimental Coulomb displacement energies for the lowest lying $1/2^+$ and $3/2^+$ levels in the series of odd-mass K-Ca isotopes.

Mass	J^π	Coulomb Displacement Energy (MeV)	References
37	$1/2^+$	7.404±.038	10
37	$3/2^+$	7.392±.025	10
39	$1/2^+$	7.254±.009	2,11
39	$3/2^+$	7.305±.006	2,11
41	$1/2^+$	7.045±.010	2,11,12[a]
41	$3/2^+$	7.021±.010	2,11,12[a]
43	$1/2^+$	6.994±.032	2,11
43	$3/2^+$	6.953±.020	2,11
47	$1/2^+$	6.881±.010	2,13, present work
47	$3/2^+$	6.868±.012	2,13, present work

[a]The excitation energies of the T=3/2; $J^\pi=1/2^+$ and T=3/2; $J^\pi=3/2^+$ levels in ^{41}Ca which were used are 6.822±.010 MeV and 5.817±.010 MeV from reference 12.

Figure Captions

Figure 1--Spectra of ^{4}He particles at $\theta_{Lab}=9°$ and $\theta_{Lab}=22.5°$.

Figure 2--Spectra of deuterons at $\theta_{Lab}=10°$ and $\theta_{Lab}=13°$.

Figure 3--Graph of Coulomb displacement energies for the lowest $J^\pi=3/2^+$ and $J^\pi=1/2^+$ levels of the odd mass Potassium and Calcium isotopes. The solid lines are the results of calculations. The plotted points indicate the experimental values.

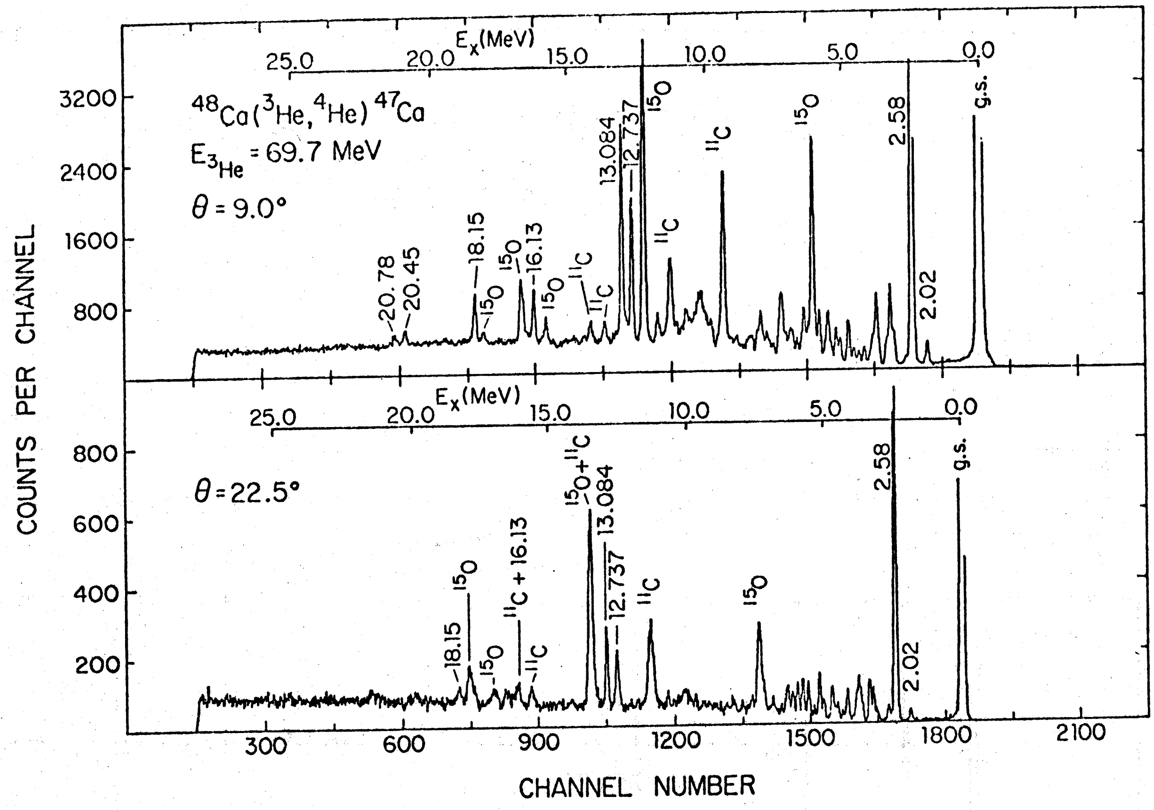
^{48}Ca(^{3}He,^{4}He)^{47}Ca
$E_{^3He}$ = 69.7 MeV
θ = 9.0°
θ = 22.5°
E_x(MeV)
COUNTS PER CHANNEL
CHANNEL NUMBER

Fig. 1

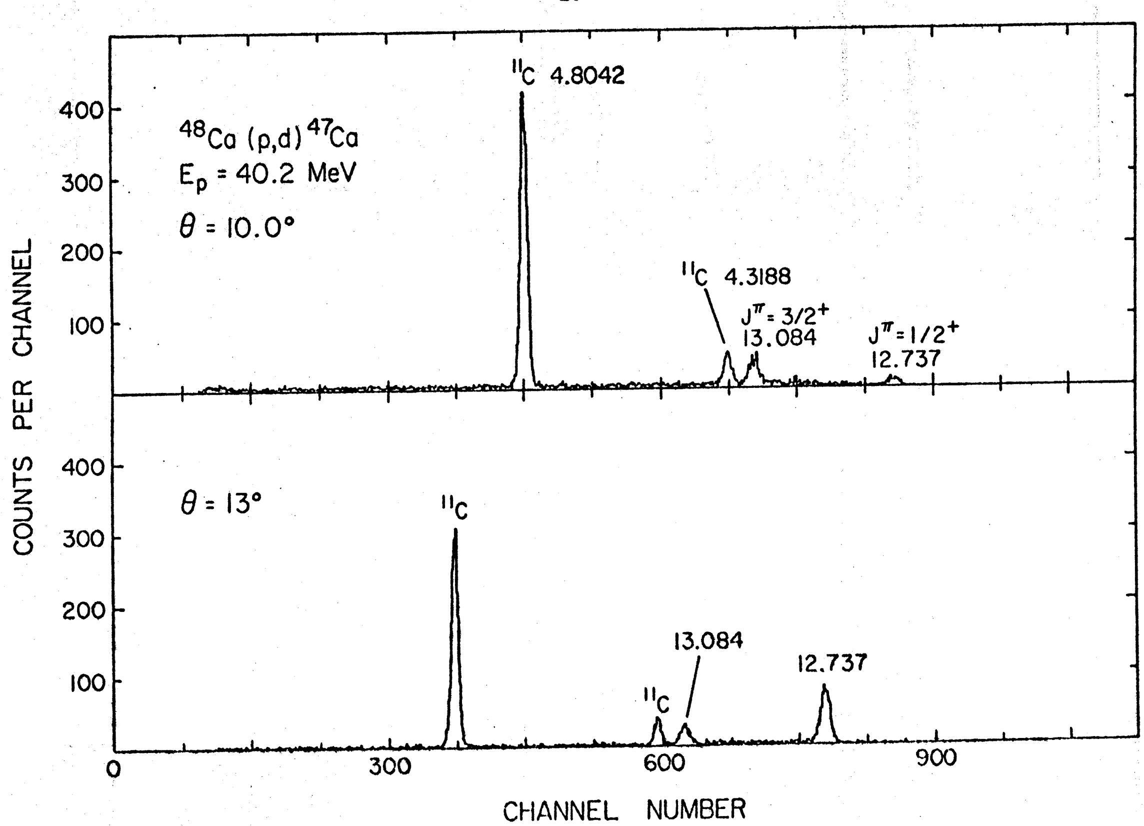
^{48}Ca (p,d) ^{47}Ca
E_p = 40.2 MeV
θ = 10.0°
θ = 13°
^{11}C 4.8042
^{11}C 4.3188
J^π = 3/2$^+$ 13.084
J^π = 1/2$^+$ 12.737
COUNTS PER CHANNEL
CHANNEL NUMBER

Fig. 2

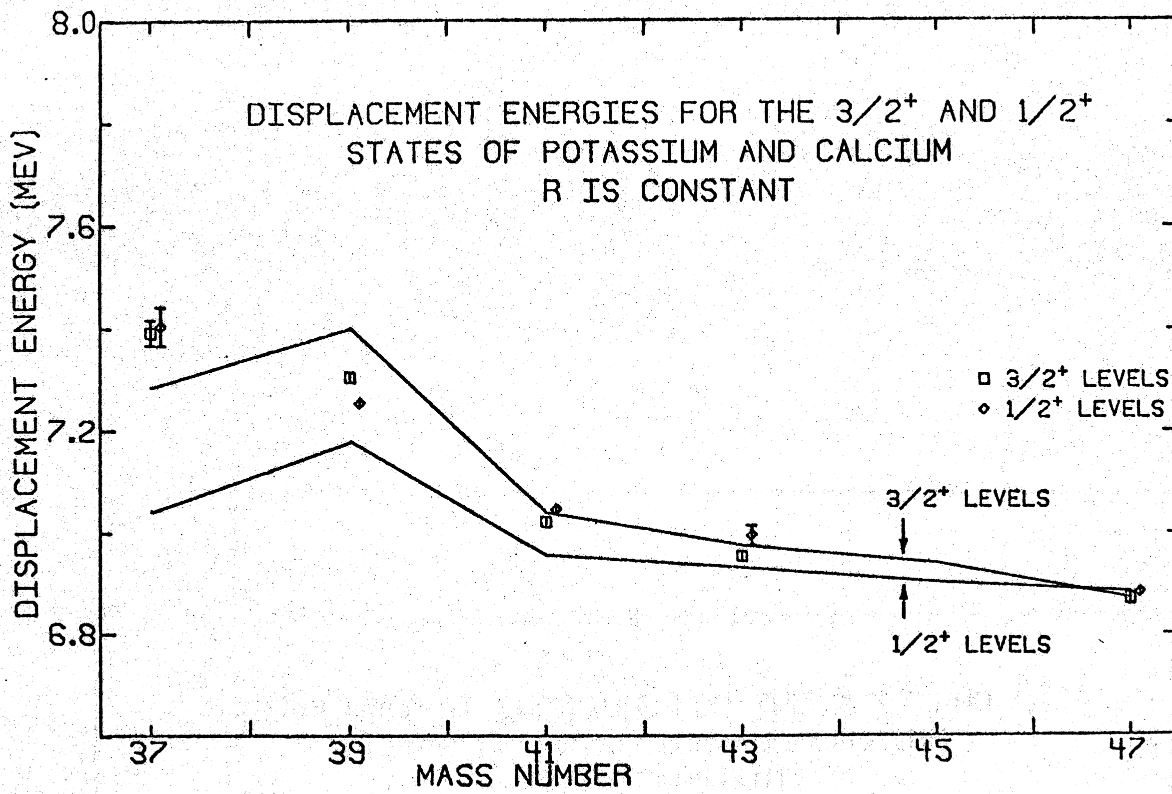
DISPLACEMENT ENERGIES FOR THE 3/2+ AND 1/2+
STATES OF POTASSIUM AND CALCIUM
R IS CONSTANT
DISPLACEMENT ENERGY (MEV)
8.0
7.6
7.2
6.8
3/2+ LEVELS
1/2+ LEVELS
3/2+ LEVELS
1/2+ LEVELS
37
39
41
43
45
47
MASS NUMBER

Fig. 3