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PROTON-NEUTRON TWO-PARTICLE

EXCITED STATES OF (g_{11}^2) CONFIGURATION

9/2⁺9⁺

G. C. Lu, M. S. Zisman, and B. G. Harvey

April 1968

ERNEST O. LAWRENCE
RADIATION LABORATORY

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EXCITED STATES OF $(1g_{9/2})^2_{9+}$ CONFIGURATION*

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ABSTRACT

The (α, d) reaction on separated isotope targets ^{52}Cr , $^{54,56}\text{Fe}$, ^{59}Co , $^{58,60,62}\text{Ni}$, ^{63}Cu , and $^{64,66,68}\text{Zn}$ was studied at 14, 20, 34, and 40 deg. (lab) using a 50-MeV alpha-particle beam from the Berkeley 88-inch cyclotron. Excited states of the residual nuclei with $(\pi 1g_{9/2}, \nu 1g_{9/2})^2_{9+}$ configuration are suggested.

Previous experiments with (α, d) reactions in light nuclei have shown a preference for capturing the two particles in high spin levels of $(J)^2$ configuration.^{1,2} The search has been extended to the medium mass region using the 50-MeV alpha-particle beam of the Berkeley 88-inch cyclotron.

The (α, d) and (α, t) reactions were carried out simultaneously on separated isotope targets ^{52}Cr , $^{54,56}\text{Fe}$, $^{58,60,62}\text{Ni}$, ^{59}Co , ^{63}Cu , $^{64,66,68}\text{Zn}$ at 14, 20, 34, and 40 deg. (lab) to search for levels of $(1g_{9/2})^2_{9+}$ configuration. Identification of the deuterons and tritons was accomplished with a Goulding-Landis particle identifier.³ Excitation energies of the strongly populated levels in the (α, d) reaction are given in Table 1. A typical energy spectrum is shown in Fig. 1. The resolution is about 170 keV.

Following the same method used in establishing the systematic trend of the $(1d_{5/2})_{5+}^2$ configuration of the earlier (α, d) work¹ the $-Q$ -value of formation of the most strongly excited levels, $-Q_f$, is plotted as a function of A_{residual} , as shown in Fig. 2. The regular monotonically-decreasing nature of the points with increasing A is the same as before. This indicates that the levels chosen are probably of similar configuration, possibly $(1g_{9/2})_{9+}^2$. It was found, however, that in ^{54}Mn and ^{56}Co it was necessary to choose the second most strongly populated level in order to obtain a smoothly varying $-Q_f$ vs A_{residual} plot. This is not unreasonable, since the (α, t) spectra (see Fig. 3) show that $1f_{7/2}$ single-particle proton capture predominates over the $1g_{9/2}$ single-particle capture in these nuclides, and thus we might expect large cross sections for levels with the $1f_{7/2}$ proton configuration to appear in the (α, d) reaction in addition to the $(1g_{9/2})_{9+}^2$ levels. In the higher mass region the $1g_{9/2}$ proton capture is predominant and here we find that the most strongly populated level should be chosen.

For the two odd- A targets, ^{59}Co and ^{63}Cu , there are no strongly populated levels in the (α, d) spectra. This is consistent with previous results. For a target with ground state spin $J_c \neq 0$ a multiplet of $(2J_c + 1)$ states can be formed from vector coupling J_c to the total J of the captured pair. In the present case, the ground state spins are $^{59}\text{Co}(J_c = 7/2^-)$ and $^{63}\text{Cu}(J_c = 3/2^-)$ and we expect that the capture strength will be distributed over many states in the multiplet. This has the effect of decreasing the strength of the high-spin level relative to the other states made in the reaction, and a single strongly-excited level is no longer observed.

Due to the large angular momentum transfer in the (α, d) reaction we expect to populate levels with high spin. In the medium mass region, using a simple shell model picture, we might expect levels with $(1f_{5/2})_{5+}^2$, $(\pi 1f_{5/2}, \nu 1g_{9/2})_{7-}$, and $(1g_{9/2})_{9+}^2$ configurations to appear. The $(1f_{5/2})_{5+}^2$ level should not appear strongly in the high A region (e.g., ^{68}Zn) where we have a largely filled $1f_{5/2}$ neutron shell. Since the $-Q_f$ vs A residual plot shows no discontinuity at higher A, the $(1g_{9/2})_{9+}^2$ or $(\pi 1f_{5/2}, \nu 1g_{9/2})_{7-}$ configuration may be indicated.

Conventional shell model calculations were carried out to obtain the residual interaction between the captured proton-neutron pair in the $(1g_{9/2})_{9+}^2$ and $(\pi 1f_{5/2}, \nu 1g_{9/2})_{7-}$ configurations. The potential used was $V_{TE} = -52 \exp(-0.2922r^2)$, $V_{TE}/V_{SE} = 1.6$, $V_{SO} = 0$, $V_{TO} = -1/2 V_{SE}$. This is the potential used by True⁴ in calculating the ^{14}N spectrum except for V_{TO} , which is the lower limit estimated by Redlich.⁵ The harmonic oscillator size parameter, ν , which was estimated from $\nu = (2n+l-1/2)/R^2$, is 0.203 fm^{-2} for $(1g_{9/2})_{9+}^2$ and 0.188 fm^{-2} for $(\pi 1f_{5/2}, \nu 1g_{9/2})_{7-}$. The calculated residual interaction matrix elements are:

$$\left((1g_{9/2})_{9+}^2 \ J=9 \ |V| \ (1g_{9/2})_{9+}^2 \ J=9 \right) = -1.94 \text{ MeV}$$

$$\left(\pi 1f_{5/2}, \nu 1g_{9/2}, \ J=7 \ |V| \ \pi 1f_{5/2}, \nu 1g_{9/2}, \ J=7 \right) = -1.31 \text{ MeV}$$

The above residual interactions can also be calculated empirically from the single particle energies, the mass data, and the experimental excitation energies of the two-particle excited states of these configurations. The results are shown in Table 2. If the states listed in Table 1 are assigned

a $(1g_{9/2})_{9+}^2$ configuration, the experimental value of the residual interaction is about -1 MeV. This is in fair agreement with the value calculated from the shell model. However, the interaction between a $1f_{5/2}$ proton and a $1g_{9/2}$ neutron would be about +0.7 MeV, repulsive, if the levels of Table 1 are assigned to the $(\pi 1f_{5/2}, \nu 1g_{9/2})_{7-}$ configuration. This is in contradiction with the value -1.31 MeV calculated from the shell model.

The contribution of V_{T0} to the total interaction energy is small. In order for the $(\pi 1f_{5/2}, \nu 1g_{9/2})_{7-}$ interaction to be repulsive, i.e., a positive value, an unreasonably strong repulsive triplet-odd potential ($-V_{T0} \geq 18.4 V_{TE}$) has to be used. Hence, from the above arguments, the states listed in Table 1 most likely belong to the $(1g_{9/2})_{9+}^2$ configuration. Experimental determination of the spin of these states in order to verify this assignment will be of great interest.

We would like to thank Dr. M. G. Redlich and Dr. W. W. True for discussions concerning shell-model calculations.

FOOTNOTES AND REFERENCES

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1. E. Rivet, R. H. Pehl, J. Cerny, and B. G. Harvey, Phys. Rev. 141, 1021 (1966).
2. C. C. Lu, and B. G. Harvey, Lawrence Radiation Laboratory Report UCRL-17299, 1967 (unpublished).
3. F. S. Goulding, D. A. Landis, J. Cerny, and R. H. Pehl, Nucl. Instr. Methods 31, 1 (1964).
4. W. W. True, Phys. Rev. 130, 1530 (1963).
5. M. G. Redlich, Phys. Rev. 138, B544 (1965).
6. A. A. Rollefson, R. C. Bearse, J. C. Legg, G. C. Phillips, and G. Roy, Nucl. Phys. 63, 561 (1965).
7. R. H. Fulmer, and A. L. McCarthy, Phys. Rev. 131, 2133 (1963).
8. B. L. Cohen, R. H. Fulmer, and A. L. McCarthy, Phys. Rev. 126, 698 (1962).
9. R. H. Fulmer, A. L. McCarthy, and B. L. Cohen, Phys. Rev. 133, B955 (1964).
10. E. K. Lin, and B. L. Cohen, Phys. Rev. 132, 2632 (1963).
11. C. C. Lu, and B. G. Harvey, (α, t) reaction data to be published.
12. D. D. Armstrong, and A. G. Blair, Phys. Rev. 140, B1226 (1965).
13. Baruch Rosner, and C. H. Holbrow, Phys. Rev. 154, 1080 (1967).
14. A. G. Blair, LADC-6370 (1964).
15. A. G. Blair, Phys. Rev. 140, B648 (1965).
16. M. G. Betigeri, H. H. Duham, R. Santo, R. Stock, and R. Bock, Nucl. Phys. A100, 416 (1967).

Table I. High spin (probably $(1g_{9/2})^2_{9+}$) levels observed in the (α, d) reactions.

Final nucleus	Energy level (MeV)	Q_F (MeV)
^{54}Mn	9.47 ± 0.05	-20.04
^{56}Co	9.92 ± 0.03	-19.85
^{58}Co	6.79 ± 0.03	-18.27
^{60}Cu	5.99 ± 0.03	-18.58
^{62}Cu	4.75 ± 0.03	-17.12
^{64}Cu	4.57 ± 0.03	-16.60
^{66}Ga	2.99 ± 0.03	-16.00
^{68}Ga	2.88 ± 0.03	-15.40
^{70}Ga	2.88 ± 0.03	-14.69

Table II.* Experimental residual interaction energies.

Two-particle excited states	Single particle states [†]		$E(lg_{9/2})_{9+}^2$	$E(\pi 1f_{5/2}, \nu lg_{9/2})_{7-}$	
	Assumed $lg_{9/2}$ neutron states	Assumed proton states		See note	
		$lg_{9/2}$	$1f_{5/2}$	1	2
⁵⁴ Mn: 9.47	⁵³ Cr: 3.70 $9/2+^a$	⁵³ Mn: (6.4) ^f	4.01 ^g (centroid)	-1.6	0.79
⁵⁶ Co: 8.92	⁵⁵ Fe: 3.80 $9/2+^b$	⁵⁵ Co: 6.01 $9/2+^{f,g,h}$	3.58 ^g (centroid)	-1.69	0.74
⁵⁸ Co: 6.79	⁵⁷ Fe: 2.48 $1=?^c$	⁵⁷ Co: 4.60 $9/2+^{h,f}$	2.87 ^h (centroid)	-1.22	0.51
⁶⁰ Cu: 5.99	⁵⁹ Ni: 3.07 $9/2+^d$	⁵⁹ Cu: 2.99 $9/2+^{f,i}$	0.89 $5/2-^{f,i}$	-1.10	1.00
⁶² Cu: 4.75	⁶¹ Ni: 2.13 $9/2+^d$	⁶¹ Cu: 2.71 $9/2+^{f,i}$	0.99 $5/2-^{f,i}$	-1.17	0.55
⁶⁴ Cu: 4.57	⁶³ Ni: 1.7 ^b (centroid)	⁶³ Cu: 2.51 $9/2+^j$	0.97 ^f	-0.7	0.82
⁶⁶ Ga: 2.99	⁶⁵ Zn: 1.04 $9/2+^e$	⁶⁵ Ga: 2.03 $9/2+^{k,f}$	0.19 $5/2-^{k,f}$	-1.21	0.63
⁶⁸ Ga: 2.88	⁶⁷ Zn: 0.64 ^e (centroid)	⁶⁷ Ga: 2.10 ^f	0.38 ^f	-1.09	0.37
⁷⁰ Ga: 2.88	⁶⁹ Zn: 0.44 $9/2+^e$	⁶⁹ Ga: 2.01 ^f	0.58 ^f	-0.71	0.72

* All the energies are in units of MeV.

† Centroid position is used if the single particle strength does not concentrate in one state.

Note 1: Experimental proton-neutron interaction energy assuming two-particle state in the first column is

$$(lg_{9/2})_{9+}^2$$

Note 2: Experimental proton-neutron interaction energy assuming two-particle state in

the first column is $(\pi 1f_{5/2}, \nu lg_{9/2})_{7-}$.

^aRef. 6

^bRef. 7

^cRef. 8

^dRef. 9

^eRef. 10

^fRef. 11

^gRef. 12

^hRef. 13

ⁱRef. 14

^jRef. 15

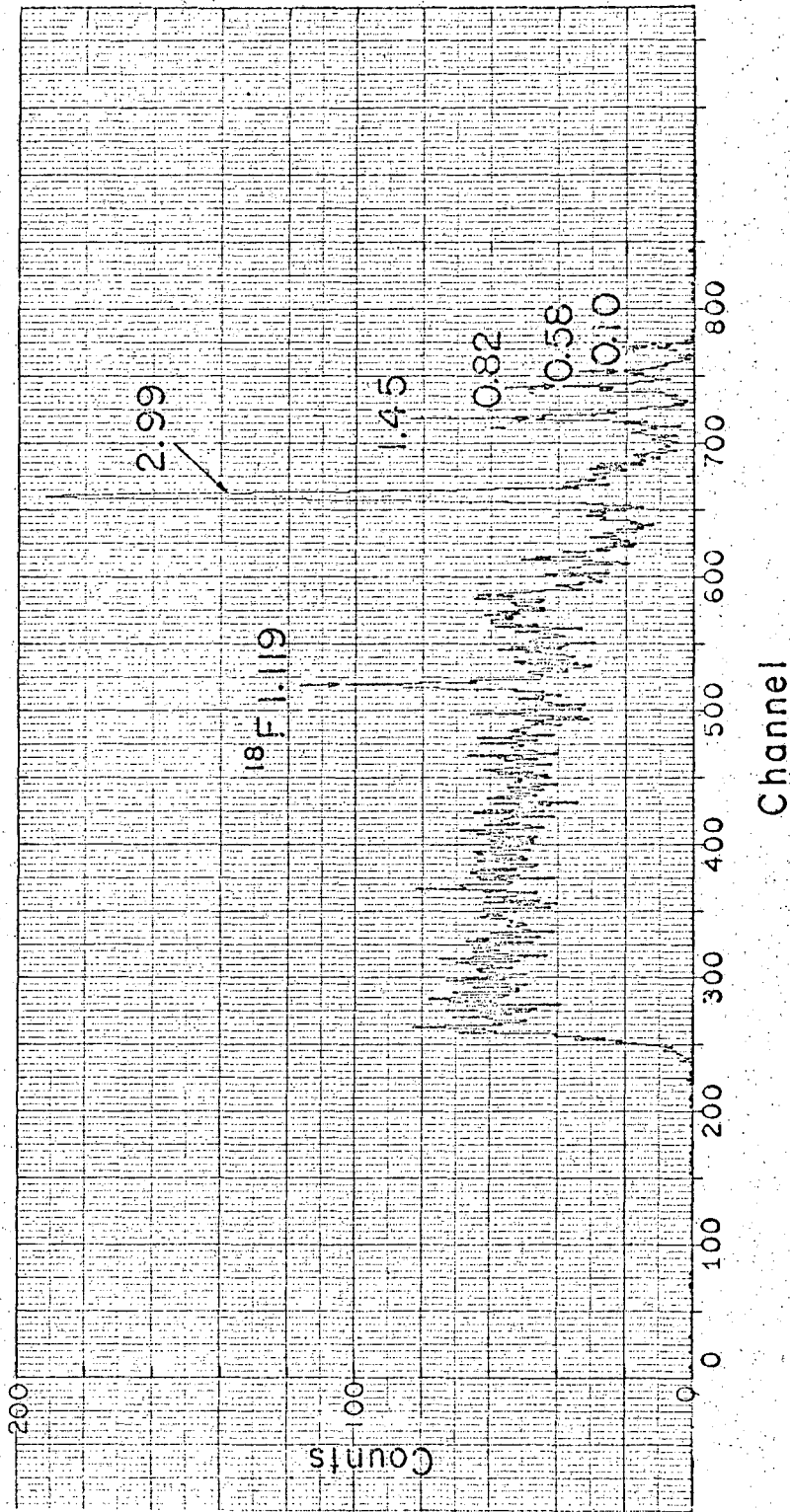
^kRef. 16

FIGURE CAPTIONS

Fig. 1. Deuteron energy spectrum for the reaction $^{64}\text{Zn}(\alpha, d)^{66}\text{Ga}$ at $\theta(\text{lab}) = 20$ deg. with $E(\alpha) = 50$ MeV.

Fig. 2. Relationship between the mass number A of the product nucleus and the Q-value of formation of the levels (probably $(\lg_{9/2})_{9+}^2$) strongly populated by the (α, d) reaction.

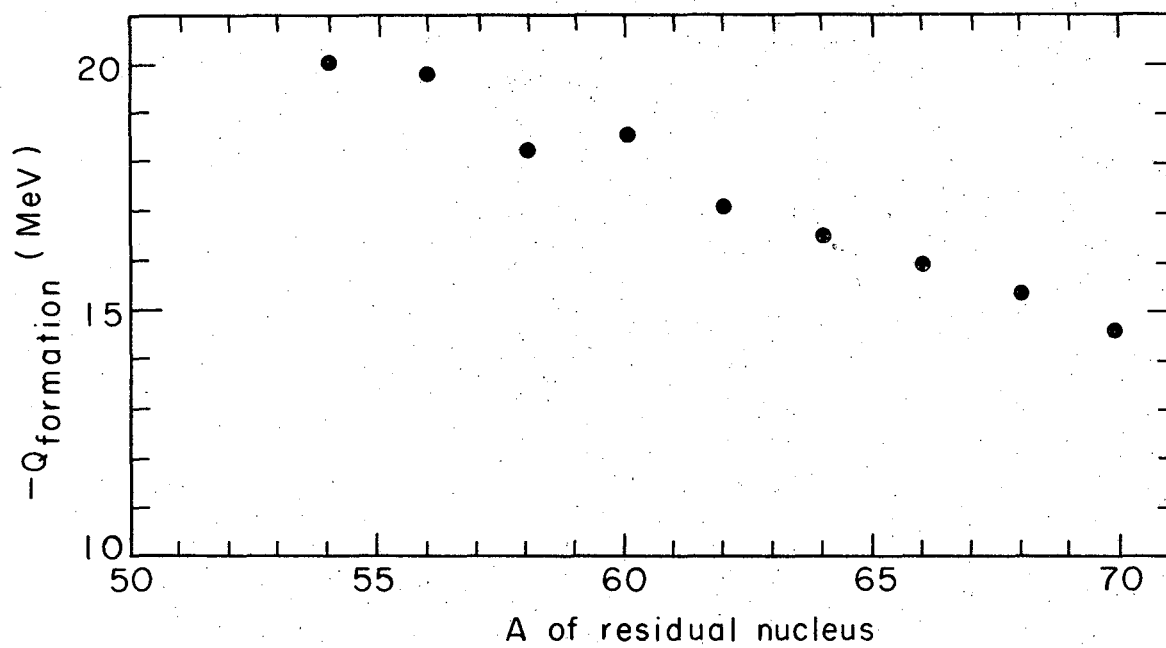
Fig. 3. Triton energy spectrum for the reaction $^{54}\text{Fe}(\alpha, t)^{55}\text{Co}$ at $\theta(\text{lab}) = 14$ deg. with $E(\alpha) = 50$ MeV.



XBL681-1761

Channel

Fig. 1.



XBL681-1760

Fig. 2.

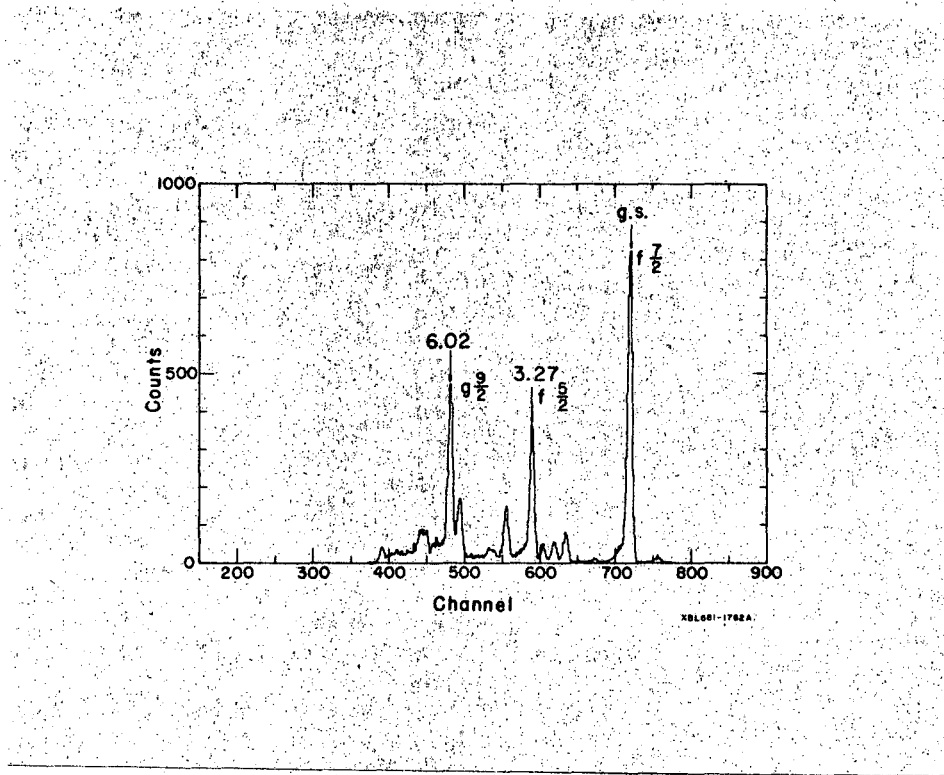


Fig. 3.

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