Coulomb excitation of levels in ^{95}Mo and ^{97}Mo[†]

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The properties of the low-lying levels of ^{95}Mo and ^{97}Mo have been investigated via Coulomb excitation which was effected by bombarding isotopically enriched thick targets with 6.0 to 10.0 MeV α particles and 43.4 MeV ^{16}O ions. Sixteen transitions in ^{95}Mo and twenty three transitions in ^{97}Mo were observed resulting from direct $E2$ excitation of eight excited states up to an excitation energy of 1073.7 keV in ^{95}Mo, and of thirteen excited states up to an excitation energy of 1515.5 keV in ^{97}Mo. Angular distribution measurements were carried out for several transitions in both nuclei to aid in the assignment of spins and to yield the $E2$ and $M1$ contents in these transitions. The level structure of ^{95}Mo and ^{97}Mo and the measured $E2$ and $M1$ transition rates are compared with the predictions available for these nuclei.

[NUCLEAR REACTIONS ^{95,97}Mo(α, $\alpha'\gamma$), E = 6–10 MeV; ^{95,97}Mo(^{16}O, ^{16}O$'\gamma$), E = 43.4 MeV; measured $\sigma(E_\gamma, \theta_\gamma)$, ^{95,97}Mo deduced levels, $B(E2)$, $B(M1)$, $T_{1/2}$, J, π, γ mixing, γ branching. Enriched targets.]

I. INTRODUCTION

It has become increasingly apparent from recent experimental studies[1–6] that the molybdenum nuclei provide several interesting features for nuclear model calculations. Several theoretical efforts to explain the nuclear structure of ^{95}Mo and ^{97}Mo have appeared in the literature.[7–10] A pure shell-model approach developed by Bhatt and Ball[7] and Vervier[8] as well as a theoretical development by Kisslinger and Sorensen,[9] using a pairing-plus-quadrupole interaction, do not successfully account for the complexity of these nuclei. A more recent investigation by Choudhury and Clemens,[10] carried out within the framework of the unified model, seems to give a better fit to the experimental level scheme of ^{95}Mo, but totally fails in explaining the rather complicated structure of ^{97}Mo as revealed in recent Coulomb excitation experiments[5] and in an (α, xn) reaction study.[4] This failure could be explained by the simple assumptions used by those authors to deduce the level scheme of ^{97}Mo. Choudhury and Clemens[10] calculated also the $E2$ and $M1$ transition rates for several transitions in ^{95}Mo as well as in ^{97}Mo and it is evident that a precise measurement of these quantities would give a more stringent test to their theoretical predictions. A direct approach to the ascertainment of level properties is through Coulomb excitation. Information on the γ-ray transition probabilities of γ rays deexciting levels in ^{95}Mo is very limited. The only ones previously reported are the $B(E2\uparrow)$ values for the 203 keV level,[11] and for the 786, 974, and 1073 keV levels.[12] However, the last values[12] are suspect since they were extracted with NaI(Tl) detectors, and the close proximity of other states in the ^{95}Mo level structure, not separable with this type of counter, could have yielded an incorrect interpretation of their Coulomb excitation data. In this paper we report the results of Coulomb excitation experiments on ^{95}Mo performed with α particles and the use of high-resolution large-volume Ge(Li) detectors. Furthermore, information on spins of the excited states and the multipolarity of the decay radiations both in ^{95}Mo and ^{97}Mo was obtained by angular distribution measurements carried out with α beams. The $B(E2\uparrow)$ values attached to the states of ^{97}Mo were reported in a previous paper.[5] These results will be presented here again in their slightly revised and extended version, since further measurements on this nucleus revealed new γ rays and new excited states in its level structure.

II. EXPERIMENTAL PROCEDURE AND RESULTS

Coulomb excitation was effected by bombarding thick targets of isotopically enriched ^{95}Mo (97%) and ^{97}Mo (93%), as well as a thick target of natural molybdenum, with 6 to 10 MeV α particles. These targets were in the form of self-supporting metallic rolled foils having a thickness of 45 mg/cm^2. Singles spectra of the deexcitation γ rays were observed with a 45 and a 36 cm^3 Ge(Li) detectors having 2.0 keV resolution at 1.33 MeV, and placed 10 cm from the target at an angle of ±55° with re-

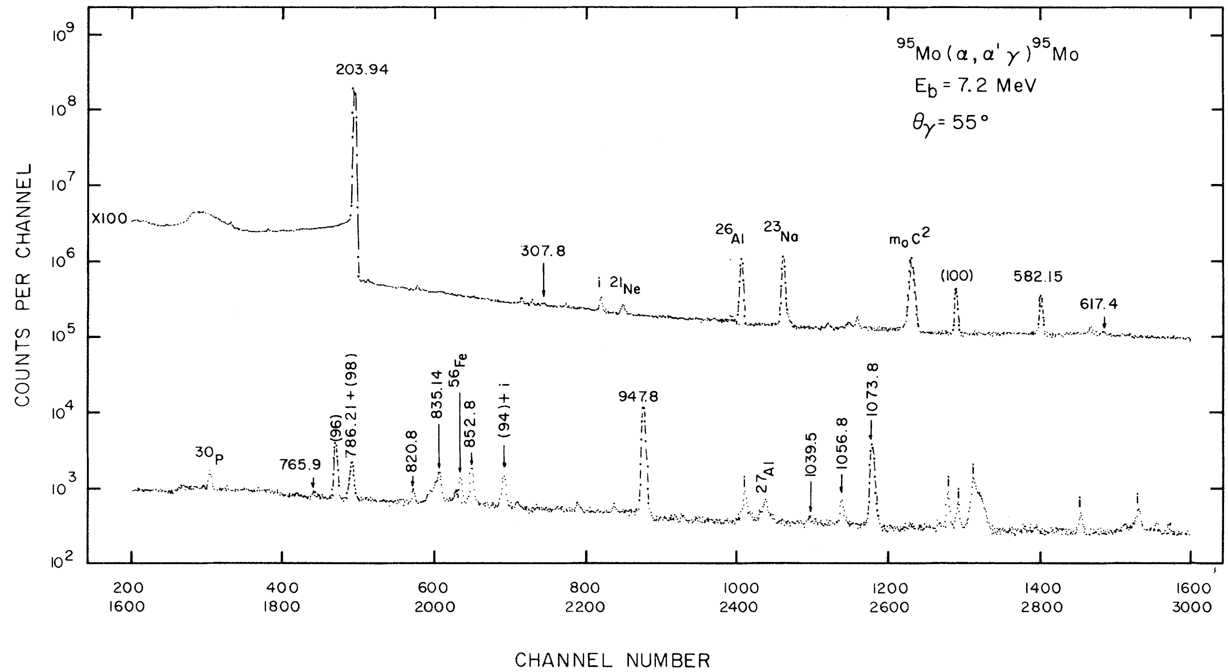

FIG. 1. Direct pulse-height spectrum of the γ rays for 8 MeV α particles on a ^{95}Mo target. Energies are in keV. The unlabeled peaks have unknown origin.

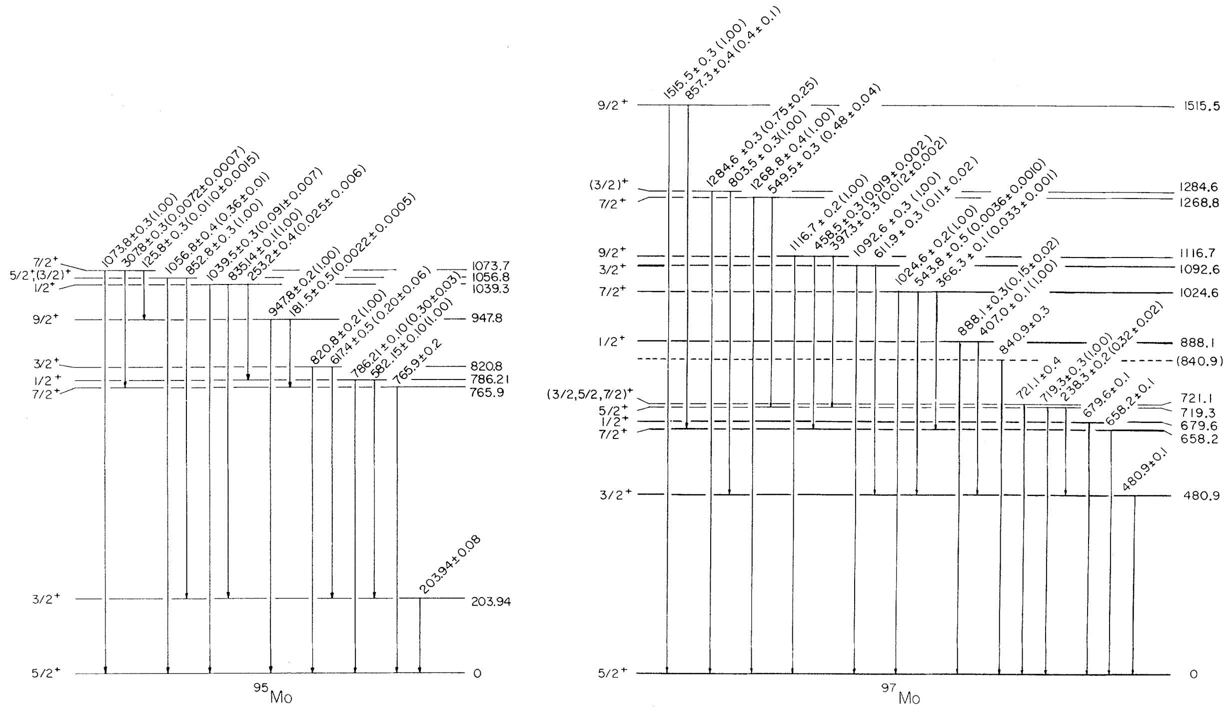

FIG. 2. Level schemes of ^{95}Mo and ^{97}Mo as deduced from the present Coulomb excitation measurements.

spect to the incoming beam. Some measurements were also performed with a 43.4 MeV ^{16}O beam. With ^{16}O ions multiple Coulomb excitation becomes important, and it is difficult to extract $B(E2)$ values from the γ-ray yields because states can be populated by more than one multistep process. However, heavy ion projectiles greatly enhance the excitation cross sections and, thus, are particularly useful in detecting states which are weakly excited with α particles. The ^{16}O measurements enabled us to gain additional information on $B(E2)$ values and branching ratios of very weakly excited states in ^{95}Mo and ^{97}Mo.

A. γ-ray spectra and γ-ray yields

A representative γ-ray spectrum, resulting from bombardment of a ^{95}Mo enriched target with 8 MeV α particle is shown in Fig. 1 (a γ-ray spectrum of ^{97}Mo has been shown elsewhere[5]). The γ rays which are attributed to ^{95}Mo and ^{97}Mo are presented in the level schemes of Fig. 2.

The energy values given in Fig. 2 have been deduced by taking as internal reference points the 778.22 keV photopeak due to the Coulomb excitation of ^{96}Mo[1] and the 1460.75 keV photopeak due to the disintegration of ^{40}K. Furthermore, the energy values of the 203.94, 582.15, and 947.8 keV transitions of ^{95}Mo, measured very precisely by Chilosi, Eichler, and Aras,[13] have been also used as internal reference points. The energies of the 786.21 and 835.14 keV γ rays have also been taken from Chilosi *et al.*,[13] since the former transition is not separated from the 787.5 keV γ ray due to the Coulomb excitation of ^{98}Mo[6] and the latter transition is always mixed with an impurity. The intensity values given in Fig. 2 have been deduced in the present work with the expection of the 786.21 keV transition in ^{95}Mo which have been calculated considering the intensity ratio between the 582 and 786 keV γ rays given by Cesareo, Langhoff, and Flammerseld.[14] With respect to our previous investigation on the level structure of ^{97}Mo,[5] two new states at 840 and 1284 keV were found in this work. Comments on individual levels will be given below.

Thick target γ-ray yields for excitation of levels in ^{95}Mo and ^{97}Mo were measured with 6 to 10 MeV α particles in steps of 1 MeV. The yields were obtained by correcting the areas under the full energy peaks for detector efficiency, absorption of γ rays by the target and target chamber, internal electron conversion, and cascade transitions from the higher energy levels. Details on

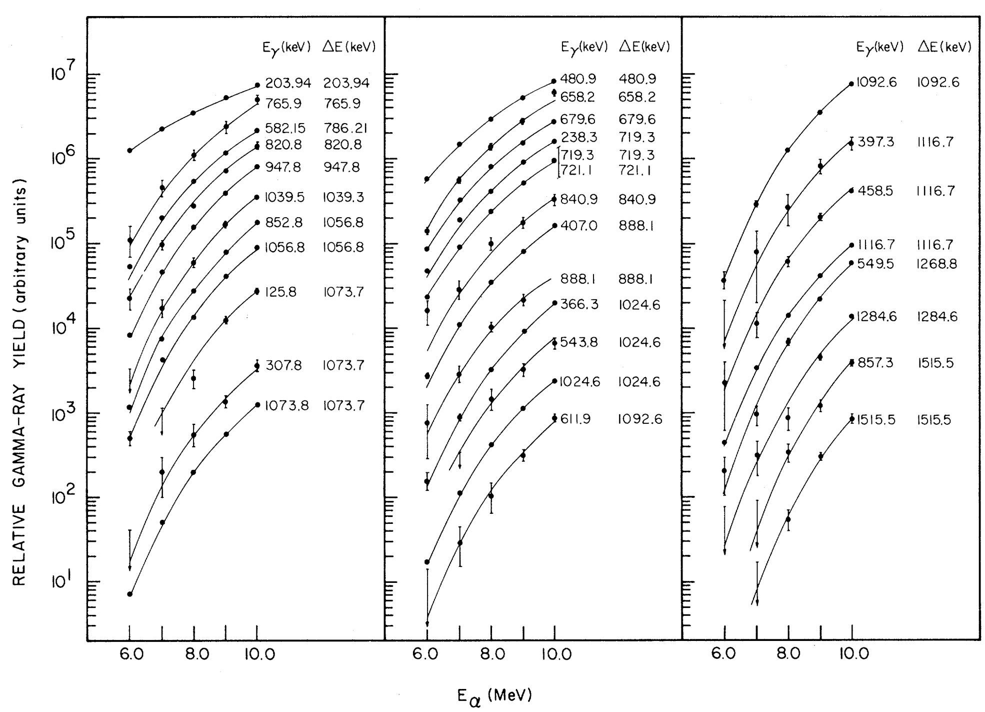

FIG. 3. Relative thick-target yields of γ rays observed in the present Coulomb excitation study. The solid curves represent the theoretically predicted $E2$ excitation thick-target yields, whereas the points represent the data obtained at each α-particle bombarding energy. ΔE and E_γ denote the excitation energy of the state and the γ-ray energy, respectively.

TABLE I. Summary of $B(E2\uparrow)$ values for levels in ^{95}Mo and ^{97}Mo observed via direct $E2$ Coulomb excitation with α particles.

^{95}Mo		^{97}Mo	
Level energy (keV)	$B(E2\uparrow)$ (10^{-50} e^2 cm^4)	Level energy (keV)	$B(E2\uparrow)$ (10^{-50} e^2 cm^4)
203.94	3.80 ±0.24	480.9	2.05 ±0.11
765.9	<0.013	658.2	0.047±0.007
786.21	0.325±0.020	679.6	0.46 ±0.03
820.8	0.060±0.015	719.3	0.39 ±0.03
947.8	5.25 ±0.25	721.1	0.168±0.015
1039.3	0.55 ±0.10	(840.9)	0.030±0.007
1056.8	1.30 ±0.07	888.1	0.182±0.020
1073.7	3.86 ±0.21	1024.6	4.53 ±0.24
		1092.6	0.344±0.025
		1116.7	4.56 ±0.32
		1268.6	0.95 ±0.20
		1284.6	0.42 ±0.09
		1515.5	0.53 ±0.08

the methods of calculation have been already reported.[1,6] The resultant net yield measured for each observed transition in ^{95}Mo and ^{97}Mo is plotted as a function of α-particle energy in Fig. 3. The $B(E2\uparrow)$ values extracted from the γ-ray yields by means of the first-order perturbation theory of Alder *et al.*[15] are summarized in Table I.

Each $B(E2\uparrow)$ value, shown in Table I, represents a weighted average of values obtained for each α-particle energy. The yields were observed to vary with the ^{4}He energy, within the relative errors, as predicted by the first-order $E2$ perturbation theory[15] in spite of the fact that by bombarding the targets with α particles at 9 and 10 MeV, transitions produced by the reactions ^{95}Mo(α, $n\gamma$)-^{98}Ru and ^{97}Mo(α, $n\gamma$)^{100}Ru could be detected in the γ-ray spectra. The identification of these transitions was facilitated by a recent investigation of the level structure of ^{98,100}Ru, through ^{94,96}Mo-(α, $2n\gamma$) reactions, by Lederer, Jaklevic, and Hollander.[3] The presence of these transitions arising from nuclear reactions shows that nuclear force effects may play a role in the interaction between projectile and target nucleus. However, these effects appear to be negligible since the excitation functions of the strongly excited levels do not diverge from those predicted by the first-order $E2$ perturbation theory[15] up to a bombarding energy of 10 MeV. Thus, one is justified to employ these functions up to this energy in the calculation of the $B(E2\uparrow)$.

The experimental errors shown in Table I do not include the error introduced by the reorientation effect which is difficult to evaluate since the static quadrupole moment of the various levels is not known. However, the effect due to a static quadrupole moment of 1 eb on the excitation probability of each of the levels in ^{95}Mo and ^{97}Mo, excited by α particles, was calculated. It was found that the inclusion of this static quadrupole moment value changes the respective cross sections by less than 3%. Theoretical calculations[10] predict that in general the static quadrupole moment val-

TABLE II. Angular distribution results on ^{95}Mo.

E_γ (keV)	$(a_2A_2)_{\rm exp}$ [a]	$(a_4A_4)_{\rm exp}$ [a]	a_2	a_4	$J_i \to I_f$	δ
203.94	−0.045±0.002	−0.010±0.002	0.327	0.020	$\frac{3}{2}^+ \to \frac{5}{2}^+$	0.4 to 1.4
582.15	0.002±0.010	0.007±0.013	0.784	−0.044	$\frac{1}{2}^+ \to \frac{3}{2}^+$	
820.8	−0.030±0.055	0.030±0.068	0.799	−0.048	$\frac{3}{2}^+ \to \frac{5}{2}^+$	0.15±0.17 or $2.7^{+2.5}_{-1.0}$
852.8	0.051±0.009	0.035±0.011	0.882	−0.073	$\frac{3}{2}^+ \to \frac{3}{2}^+$ or	0.42±0.07 or $6.7^{+4.5}_{-2.0}$
					$\frac{5}{2}^+ \to \frac{3}{2}^+$	0.02±0.08 or $3.6^{+2.1}_{-1.1}$
947.8	0.154±0.002	−0.004±0.002	0.846	−0.062	$\frac{9}{2}^+ \to \frac{5}{2}^+$	0.01±0.01 [b]
1056.8	−0.151±0.019	0.027±0.024	0.882	−0.073	$\frac{3}{2}^+ \to \frac{5}{2}^+$ or	$0.81^{+0.37}_{-0.28}$
					$\frac{5}{2}^+ \to \frac{5}{2}^+$	$-0.55^{+0.31}_{-0.45}$
1073.8	−0.077±0.003	−0.008±0.004	0.887	−0.075	$\frac{7}{2}^+ \to \frac{5}{2}^+$	0.72±0.11

[a] The experimental errors quoted for a_2A_2 and a_4A_4 are statistical only.
[b] $\delta(M3/E2)$.

TABLE III. Angular distribution results on ^{97}Mo.

E_γ (keV)	$(a_2A_2)_{exp}$ [a]	$(a_4A_4)_{exp}$ [a]	a_2	a_4	$J_i \rightarrow J_f$	δ
238.3	0.056 ± 0.013	0.024 ± 0.017	0.754	−0.036	$\frac{5}{2}^+ \rightarrow \frac{3}{2}^+$	0.06 ± 0.06 or $2.9^{+0.6}_{-0.4}$
366.3	0.047 ± 0.019	0.009 ± 0.025	0.871	−0.070	$\frac{7}{2}^+ \rightarrow \frac{7}{2}^+$	$-0.55^{+0.48}_{-0.73}$
397.3 [b]	0.180 ± 0.068		0.853	−0.064	$\frac{9}{2}^+ \rightarrow \frac{5}{2}^+$	-0.05 ± 0.17 [c]
407.0	0.005 ± 0.021	-0.008 ± 0.028	0.824	−0.055	$\frac{1}{2}^+ \rightarrow \frac{3}{2}^+$	
480.9	0.131 ± 0.002	0.001 ± 0.002	0.611	−0.008	$\frac{3}{2}^+ \rightarrow \frac{5}{2}^+$	-0.47 ± 0.03 or -4.4 ± 0.4
679.6	0.011 ± 0.005	-0.015 ± 0.006	0.735	−0.032	$\frac{1}{2}^+ \rightarrow \frac{5}{2}^+$	
719.3	0.009 ± 0.011	0.003 ± 0.014	0.754	−0.036	$\frac{5}{2}^+ \rightarrow \frac{5}{2}^+$	0.47 ± 0.10 or $-10.5^{+4.5}_{-4.0}$
721.1	-0.021 ± 0.015	-0.017 ± 0.022	0.755	−0.037	$\frac{3}{2}^+ \rightarrow \frac{5}{2}^+$ or $\frac{5}{2}^+ \rightarrow \frac{5}{2}^+$ or $\frac{7}{2}^+ \rightarrow \frac{5}{2}^+$	0.19 ± 0.09 or $2.4^{+0.7}_{-0.5}$ 0.22 ± 0.14 or $-3.0^{+1.0}_{-2.5}$ 0.08 ± 0.23 or $4.2^{+\infty}_{-2.4}$
857.3 [b]	0.158 ± 0.056		0.952	−0.098	$\frac{9}{2}^+ \rightarrow \frac{7}{2}^+$	-0.40 ± 0.10 or $-4.7^{+1.5}_{-3.0}$
1024.6	-0.071 ± 0.003	-0.001 ± 0.004	0.871	−0.070	$\frac{7}{2}^+ \rightarrow \frac{5}{2}^+$	$0.54^{+0.24}_{-0.14}$
1092.6	0.233 ± 0.020	0.000 ± 0.028	0.892	−0.077	$\frac{3}{2}^+ \rightarrow \frac{5}{2}^+$	$-0.51^{+0.15}_{-0.24}$ or $-3.7^{+1.5}_{-3.9}$
1116.7	0.163 ± 0.004	0.001 ± 0.006	0.899	−0.079	$\frac{9}{2}^+ \rightarrow \frac{5}{2}^+$	0.00 ± 0.01 [c]
1284.6 [b]	-0.163 ± 0.032		0.899	−0.079	$\frac{3}{2}^+ \rightarrow \frac{5}{2}^+$	$0.81^{+0.42}_{-0.30}$
1515.5 [b]	0.156 ± 0.070		0.952	−0.098	$\frac{9}{2}^+ \rightarrow \frac{5}{2}^+$	0.05 ± 0.15 [c]

[a] The experimental errors quoted for a_2A_2 and a_4A_4 are statistical only.
[b] Angular distribution results obtained with 10 MeV α particles.
[c] $\delta(M3/E2)$.

ues are smaller than 1 eb hence their effect will be always within the experimental errors attached to the $B(E2\uparrow)$ values. Furthermore, the possible effect due to the quadrupole moment of the ground state of ^{95}Mo and ^{97}Mo (0.12 and 1.1 eb, respectively[16,17]) was also calculated. It was found again that this effect is also well within the experimental errors of the $B(E2\uparrow)$ values.

B. Angular distributions

Angular distributions of some of the deexcitation γ rays of ^{95}Mo and ^{97}Mo were measured at four angles (0, 30, 60, and 90°) with the 45 cm^3 Ge(Li) detector at a distance of 15 cm from the target. This large distance was chosen to reduce the finite-angle correction and the effect of any possible uncertainty in the positioning of the target. A 9 MeV α beam was used to carry out these experiments, and in the case of ^{97}Mo some measurements with 10 MeV α particles were also performed. In this case the spectra were acquired with the Ge(Li) detector placed at angles of 0 and 90° only. The target was always placed at 45° with respect to the incident beam so as to insure an equal geometry at 0 and 90° and a negligible difference in the γ-ray absorption from the target and target chamber at any angle. A second Ge(Li) detector (the 36 cm^3 one) was also placed at −90° with respect to the incoming beam. This detector was used as monitor to normalize the measurements at each angle. The total incident charge was also collected for the same purpose. The results of these measurements were fitted to the formula $W(\theta)=1+\sum_{k=2,4} a_k Q_k A_k P_k(\cos\theta)$ where θ is the γ-ray angle relative to the beam direction, Q_k is the attenuation coefficient of the γ-ray counter,[18] a_k is the Coulomb excitation particle parameter, A_k is the γ-γ directional correlation coefficient for an equivalent cascade, and P_k is the Legendre polynomial. The final results for ^{95}Mo and ^{97}Mo are summarized in Tables II and III.

The spin sequence(s) of the cascade, previously known or proposed from the present measurements, is (are) given in the sixth column, whereas the measured mixing ratios $E2/M1$ (or $M3/E2$) are presented in the seventh column. The δ sign has been determined following the convention of Rose and Brink[19] where the mixing ratio is defined by $\delta=\langle I_i \| \lambda+1 \| I_f\rangle / \langle I_i \| \lambda \| I_f\rangle$. The value for the 203 keV transition in ^{95}Mo is in agreement with the result of McGowan and Stelson[11] ($\delta=-0.6\pm0.2$; the difference in sign is due to the different sign convention used by those authors) who have measured the angular distribution and the polarization of this transition. However, the 203 keV level has a half-life of 0.756 nsec,[20] which is sufficiently long to introduce in the angular distribution of the 203 keV transition an attenuation caused by the deorientation of the excited state. Thus, we have calculated the mixing ratio from the known half-life[20] and the $B(E2\uparrow)$ value measured by us. This procedure yields a more precise δ value equal to 0.63 ± 0.04.

Extensive angular distribution measurements on transitions deexciting levels in ^{95}Mo and ^{97}Mo have been recently performed by Mesko *et al.*[4] Usually their δ values are in disagreement with those found in the present investigation. In Coulomb excitation measurements, the angular distributions are treated by an exact procedure and their analysis is relatively simple.[15] However, Mesko *et al.*[4] obtained their mixing ratio values from angular distributions on emitted γ rays from nuclear states formed in Zr(α, xn) reactions. It is not possible, in this case, to calculate precisely the alignment of the formed excited states. Mesko *et al.*[4] employed the approximation that the actual angular distributions are attenuated by a factor α_k with respect to those due to completely aligned excited states. These authors suppose that this attenuation factor is a smooth function of the spin of the levels and completely independent on their energy. This approximation is certainly justified for levels with high angular momentum since their alignment is almost total. However, the levels of interest in the present investigation have low angular momentum ($I\leq\frac{7}{2}$) and are very little aligned. Indeed, our results show that this approximation should be taken with caution. For instance, the $a_2 A_2$ value obtained by us for the 480 keV transition in ^{97}Mo (9 MeV α particles) is equal to 0.131 ± 0.002. The δ value obtained by Mesko *et al.*[4] for the same transition would correspond to an a_2A_2 coefficient equal to 0.00 to 0.05 which is completely outside the possible experimental errors.

III. DISCUSSION

A. Level properties

The properties of the levels and γ rays shown in Fig. 2 are summarized in Table IV. The admixtures, $\delta=(E2/M1)^{1/2}$, listed in column 4 are those measured by us or those found in previous investigations (see footnotes of Table IV). The reduced $E2$ and $M1$ transition rates are given in column 5 and 6, respectively, whereas the final column gives the half-life of the levels. The δ values quoted in square brackets are considered less probable since they would yield $M1$ transition probabilities strongly hindered. This kind of hindrance is rarely encountered.[21] The transition whose $E2/M1$ mixing is not known, have been assumed as pure $M1$ transitions. In fact, the relationship

$$\frac{T^{E2}}{T^{M1}}=\delta^2=\frac{3}{100}\left(\frac{\Delta E}{\hbar c}\right)^2\frac{B(E2\downarrow)}{B(M1\downarrow)}$$

shows that for constant $E2$ and $M1$ reduced transition probabilities, the $M1$ content of low energy transitions will be favored with respect to the $E2$ content ($\%M1/\%E2\propto\Delta E^{-2}$). The $B(E2\downarrow)$ values corresponding to pure $E2$ transitions are given in Table V together with their enhancement factors.

Since the most collective transition observed in the present investigation is equal to ~25 W. u. (Weisskopf unit), it can be concluded that the $M1$ component must dominate in these transitions (with the exception of the 458 and 611 keV transitions). It should be mentioned that Behar, Garber, and Grabowski[22] recently measured a δ value equal to $-19\leq\delta\leq-0.64$ $[M1+(30\leq E2\leq 99.7)\%]$ for the 219 keV transition of ^{95}Mo. The choice of the smallest $E2$ content (30%) for this transition would yield a $B(E2\downarrow)$ value equal to $0.29^{+0.31}_{-0.15}$ e^2b^2 (corresponding to 111^{+82}_{-56} W. u.), which is unusually large.

The δ value $3.6^{+2.1}_{-1.1}$ of the 852 keV transition in ^{95}Mo and the δ value $2.9^{+0.6}_{-0.4}$ of the 238 keV transition in ^{97}Mo have not been included in Table IV since they would give unrealistic values for the $E2$ reduced transition probabilities. In fact, the former would yield $B(E2\downarrow)=0.42^{+1.65}_{-0.26}$ e^2b^2 (i.e., $1.6^{+4.4}_{-1.0}\times10^2$ W. u.) and the latter would yield $B(E2\downarrow)$

TABLE IV. Summary of level and γ-ray properties in ^{95}Mo and ^{97}Mo.

E_i (keV)	E_γ (keV)	$J_i^\pi \to J_f^\pi$	δ	$B(E2\downarrow)$ ($10^{-50}\ e^2\,\mathrm{cm}^4$)	$B(M1\downarrow)$ $\left[\left(\frac{e\hbar}{2Mc}\right)^2\right]$	$T_{1/2}$ (psec)
			^{95}Mo			
203.94	203.94	$\frac{3}{2}^+ \to \frac{5}{2}^+$	0.63 ± 0.04 [a]	5.70 ± 0.36	$(4.21 \pm 0.22) \times 10^{-3}$	756 ± 14 [a]
765.9	765.9	$\frac{7}{2}^+ \to \frac{5}{2}^+$	<0.05 [b]	<0.010	$4.3^{+2.4}_{-1.5} \times 10^{-2}$	$2.05^{+1.10}_{-0.70}$ [b]
786.21	582.15	$\frac{1}{2}^+ \to \frac{3}{2}^+$	$0.266^{+0.052}_{-0.040}$ [c]	$1.0^{+0.6}_{-0.4}$	$(3.2 \pm 0.6) \times 10^{-2}$	4.4 ± 0.6
	786.21	$\frac{1}{2}^+ \to \frac{5}{2}^+$	$E2$	0.98 ± 0.06		
820.8	617.4	$\frac{3}{2}^+ \to \frac{3}{2}^+$	-2.00 ± 0.22 [c]	>0.3	$>2.4 \times 10^{-4}$	<18
				$[0.07^{+0.07}_{-0.04}]$	$[4.6^{+5.8}_{-2.8} \times 10^{-3}]$	$[120^{+70}_{-40}]$
	820.8	$\frac{3}{2}^+ \to \frac{5}{2}^+$	0.15 ± 0.17	0.090 ± 0.023	$>3.1 \times 10^{-3}$	
			$[2.7^{+2.5}_{-1.0}]$		$[5.7^{+12.5}_{-4.7} \times 10^{-5}]$	
947.8	181.5	$\frac{9}{2}^+ \to \frac{7}{2}^+$	Assumed $M1$		$(6.1 \pm 1.7) \times 10^{-3}$	2.34 ± 0.11
	947.8	$\frac{9}{2}^+ \to \frac{5}{2}^+$	$E2$	3.15 ± 0.15		
1039.3	219.4 [d]	$\frac{1}{2}^+ \to \frac{3}{2}^+$	Assumed $M1$		$3.2^{+2.4}_{-1.6} \times 10^{-2}$	0.23 ± 0.06
	253.2	$\frac{1}{2}^+ \to \frac{1}{2}^+$	Assumed $M1$		$(2.3 \pm 1.1) \times 10^{-1}$	
	835.14	$\frac{1}{2}^+ \to \frac{3}{2}^+$	0.038 ± 0.019 [c]	$0.07^{+0.14}_{-0.05}$	$(2.6 \pm 0.7) \times 10^{-1}$	
	1039.5	$\frac{1}{2}^+ \to \frac{5}{2}^+$	$E2$	1.65 ± 0.30		
1056.8	852.8	$\frac{5}{2}^+ \to \frac{3}{2}^+$	0.02 ± 0.08	<2.1	$2.3^{+8.5}_{-1.3} \times 10^{-1}$	$0.20^{+0.26}_{-0.16}$
	1056.8	$\frac{5}{2}^+ \to \frac{5}{2}^+$	$-0.55^{+0.31}_{-0.45}$	1.30 ± 0.07	$3.3^{+15.5}_{-2.4} \times 10^{-2}$	
1073.7	125.8	$\frac{7}{2}^+ \to \frac{9}{2}^+$	Assumed $M1$		$4.7^{+2.3}_{-1.5} \times 10^{-1}$	0.46 ± 0.12
	307.8	$\frac{7}{2}^+ \to \frac{7}{2}^+$	Assumed $M1$		$2.1^{+0.9}_{-0.6} \times 10^{-2}$	
	1073.8	$\frac{7}{2}^+ \to \frac{5}{2}^+$	0.72 ± 0.11	2.90 ± 0.16	$4.5^{+2.1}_{-1.3} \times 10^{-2}$	
			^{97}Mo			
480.9	480.9	$\frac{3}{2}^+ \to \frac{5}{2}^+$	-0.47 ± 0.03	3.07 ± 0.17	$(2.2 \pm 0.4) \times 10^{-2}$	13.0 ± 2.1
658.2	177.97 [e]	$\frac{7}{2}^+ \to \frac{3}{2}^+$	$E2$	$7.9^{+4.7}_{-2.9}$		2.0 ± 0.5 [f]
	658.2	$\frac{7}{2}^+ \to \frac{5}{2}^+$	0.04 ± 0.01 [f]	0.035 ± 0.005	$6.9^{+2.3}_{-1.4} \times 10^{-2}$	
679.6	679.6	$\frac{1}{2}^+ \to \frac{5}{2}^+$	$E2$	1.38 ± 0.09		28.3 ± 1.9
719.3	238.5	$\frac{5}{2}^+ \to \frac{3}{2}^+$	0.06 ± 0.06	<4.2	$6.9^{+5.0}_{-2.5} \times 10^{-2}$	10.4 ± 4.4
				$[<0.5]$	$[(1.3 \pm 0.3) \times 10^{-2}]$	$[56 \pm 5]$
	719.3	$\frac{5}{2}^+ \to \frac{5}{2}^+$	0.47 ± 0.10	0.39 ± 0.03	$6.4^{+4.7}_{-2.4} \times 10^{-3}$	
			$[-10.5^{+4.5}_{-4.0}]$		$[1.3^{+2.9}_{-0.7} \times 10^{-5}]$	
721.1	721.1	$(\frac{3}{2})^+ \to \frac{5}{2}^+$	0.19 ± 0.09	0.252 ± 0.023	$2.5^{+7.3}_{-1.5} \times 10^{-2}$	$4.0^{+5.2}_{-3.0}$
			$[2.4^{+0.7}_{-0.5}]$		$[1.6^{+1.2}_{-0.7} \times 10^{-4}]$	$[100 \pm 15]$
888.1	407.0	$\frac{1}{2}^+ \to \frac{3}{2}^+$	Assumed $M1$		$(2.1 \pm 0.5) \times 10^{-1}$	2.5 ± 0.6
	888.1	$\frac{1}{2}^+ \to \frac{5}{2}^+$	$E2$	0.55 ± 0.06		
1024.6	366.3	$\frac{7}{2}^+ \to \frac{7}{2}^+$	Assumed $M1$		$8.0^{+5.4}_{-3.4} \times 10^{-2}$	$0.32^{+0.25}_{-0.13}$
	543.8	$\frac{7}{2}^+ \to \frac{3}{2}^+$	$E2$	$1.3^{+1.4}_{-0.8}$		
	1024.6	$\frac{7}{2}^+ \to \frac{5}{2}^+$	$0.54^{+0.24}_{-0.14}$	3.40 ± 0.18	$8.5^{+7.9}_{-3.6} \times 10^{-2}$	
1092.6	611.9	$\frac{3}{2}^+ \to \frac{3}{2}^+$	Assumed $M1$		$1.3^{+1.6}_{-0.7} \times 10^{-2}$	$1.3^{+1.2}_{-0.6}$
	1092.6	$\frac{3}{2}^+ \to \frac{5}{2}^+$	$-0.51^{+0.15}_{-0.24}$	0.52 ± 0.04	$1.7^{+1.8}_{-1.0} \times 10^{-2}$	

TABLE IV *(Continued)*

E_l (keV)	E_γ (keV)	$J_i^\pi \to J_f^\pi$	δ	$B(E2\downarrow)$ (10^{-50} e^2 cm^4)	$B(M1\downarrow)$ $\left[\left(\frac{e\hbar}{2Mc}\right)^2\right]$	$T_{1/2}$ (psec)
1116.7	397.3	$\frac{9}{2}^+ \to \frac{5}{2}^+$	$E2$	5.8 ± 1.4		1.15 ± 0.08
	458.5	$\frac{9}{2}^+ \to \frac{7}{2}^+$	Assumed $M1$		$(6.5 \pm 1.2) \times 10^{-3}$	
	1116.7	$\frac{9}{2}^+ \to \frac{5}{2}^+$	$E2$	2.74 ± 0.19		
1284.6	1284.6	$(\frac{3}{2})^+ \to \frac{5}{2}^+$	$0.81^{+0.42}_{-0.30}$	0.63 ± 0.14	$1.1^{+2.3}_{-0.7} \times 10^{-2}$	$0.43^{+0.54}_{-0.28}$
1515.5	857.3	$\frac{9}{2}^+ \to \frac{7}{2}^+$	-0.40 ± 0.10	$0.30^{+0.33}_{-0.19}$	$(1.0 \pm 0.5) \times 10^{-2}$	1.6 ± 0.4
			$[-4.7^{+1.5}_{-3.0}]$	$[2.1 \pm 1.0]$	$[5.0^{+9.0}_{-4.0} \times 10^{-4}]$	
	1515.5	$\frac{9}{2}^+ \to \frac{5}{2}^+$	$E2$	0.32 ± 0.05		

[a] The δ value of the 203.94 keV transition has been calculated from the $B(E2\uparrow)$ measured in the present work and from the half-life of the 203.94 keV level as given in Ref. 20.
[b] The δ value of the 765.9 keV transition has been calculated from the $B(E2\uparrow)$ measured in the present work and from the half-life of the 765 keV level as given in Ref. 29.
[c] See Ref. 22.
[d] The 219.4 keV transition has not been observed in the present work. The calculations have been carried out considering the intensity value given in Ref. 13.
[e] The 177.97 keV transition has not been observed in the present work. The calculations have been carried out considering the intensity value given in Ref. 34.
[f] The δ value of the 658.2 keV transition has been calculated from the $B(E2\uparrow)$ measured in the present work and the half-life of the 658.2 keV level as given in Ref. 35.

$=1.49^{+1.06}_{-0.53}$ e^2b^2 (i.e., 560^{+400}_{-200} W. u.) or 0.29 ± 0.05 e^2b^2 (i.e., 110 ± 20 W. u.) depending on the $E2/M1$ ratio of the 719 keV transition. These are exceptionally high enhancement factors encountered only in very deformed nuclei.[21]

By comparing photopeak shapes obtained by Coulomb exciting enriched targets of ^{95}Mo and ^{97}Mo with ^{16}O ions, it was possible to discard the δ value $-3.7^{+1.5}_{-3.9}$ of the 1092 keV transition in ^{97}Mo. In fact, when these particles are used, several photopeaks show a Doppler broadening at the base of the peak due to the recoil motion of the target nucleus. The larger the fraction of the displaced transition the shorter is the half-life of the level. The comparison of the peak shapes shows that the Doppler shift of the 1092 keV transition is much broader than that of the 947 keV transition (^{95}Mo, 2.34 psec) and comparable to the displacement of the 1116 keV transition (^{97}Mo, 1.15 psec). Thus, only the δ value $-0.51^{+0.15}_{-0.24}$ ($1.3^{+1.2}_{-0.6}$ psec) is possible for the 1092 keV transition for the other value would yield a half-life equal to $5.9^{+1.0}_{-1.1}$ psec.

^{95}Mo nucleus. All the levels Coulomb excited in the present investigation have been observed both in the decay of ^{95g,m}Tc (Refs. 13 and 14) and in $(\alpha,n\gamma)$ experiments.[2,4] With the exception of the 1073 keV state, these levels are excited also in (d,p) and (d,t) reaction measurements.[23,24] Previous Coulomb excitation measurements on ^{95}Mo were performed by McGowan and Stelson,[11] Alkhazov, Erokhina, and Lemberg,[12] and more recently by Bond.[25] The agreement with the results of McGowan and Stelson[11] [203 keV, $B(E2\uparrow) = (3.5 \pm 0.3) \times 10^{-2}$ e^2b^2] and Bond[25] [203 keV, $B(E2\uparrow) = 4.3 \pm 0.5$; 765 keV, $B(E2\uparrow) = < 0.05$; 786 keV, $B(E2\uparrow) = 0.3 \pm 0.1$; 947 keV, $B(E2\uparrow) = 5.0 \pm 0.5$; 1073 keV, $B(E2\uparrow) = 4.0 \pm 0.5$ in units of 10^{-2} e^2b^2] is excellent. On the other hand, the agreement is poor with the results of Alkhazov *et al.*[12] [786 keV, $B(E2\uparrow) = 2.0 \pm 0.5$;

TABLE V. $B(E2\downarrow)$ and $B(E2\downarrow)/B(E2)_{\rm s.p.}$ values calculated for the transitions assumed as pure $M1$ transitions in Table IV.

Isotope	E_γ	$B(E2\downarrow)$ (10^{-50} e^2 cm^4)	$B(E2\downarrow)/B(E2)_{\rm s.p.}$ [a]
^{95}Mo	125.8	42^{+21}_{-13}	$(1.6^{+0.8}_{-0.5}) \times 10^4$
	181.5	0.27 ± 0.07	$(1.05 \pm 0.27) \times 10^2$
	219.4	$0.95^{+0.90}_{-0.48}$	$3.7^{+2.7}_{-1.9} \times 10^2$
	253.2	5.2 ± 2.5	$(2.0 \pm 1.0) \times 10^3$
	307.8	$0.32^{+0.14}_{-0.09}$	$1.2^{+0.5}_{-0.3} \times 10^2$
^{97}Mo	366.3	$0.85^{+0.58}_{-0.36}$	$3.2^{+2.2}_{-1.4} \times 10^2$
	407.0	$1.8^{+0.5}_{-0.4}$	$6.8^{+1.9}_{-1.5} \times 10^2$
	458.5	0.045 ± 0.008	17 ± 3
	611.9	$0.050^{+0.064}_{-0.028}$	19^{+24}_{-11}

[a] $B(E2)_{\rm s.p.} = e^2/4\pi[(3/5)^2]R_0^4$, where $R_0 = 1.2A^{1/3}$ fm.

947 keV, $B(E2\uparrow)=3.2\pm0.7$; 1073 keV, $B(E2\uparrow)=2.9\pm0.6$ in units of 10^{-50} $e^2\,cm^4$] particularly for the 786 keV level. The spin $\frac{7}{2}^+$ for the 765 keV level has been established by circular polarization[26–28] and resonance fluorescence[29] measurements. The spin of the 786 ($\frac{1}{2}^+$) and 1039 ($\frac{1}{2}^+$) keV levels has been determined recently by Behar *et al.*[22] by angular correlation and polarization experiments. Previous angular correlation measurements on the 582-203 keV cascade yielded a spin $\frac{1}{2}^+$ for the 786 keV state as well.[20,30] Spins $\frac{1}{2}$, $\frac{3}{2}$, $\frac{5}{2}$, or $\frac{7}{2}$ for the 820 keV level are consistent with the present angular distribution measurements whereas either spin $\frac{3}{2}$ or $\frac{5}{2}$ is consistent for the 1056 keV level. However, Behar *et al.*[22] establish the spin of the 820 keV level as $\frac{3}{2}^+$ and this assignment is confirmed by a recent ^{94}Mo(^{13}C, ^{12}C)^{95}Mo reaction study.[31] On the other hand, Dielh *et al.*[24] favor a spin $\frac{5}{2}^+$ for the 1056 keV level from the value of the ratio $S(d,t)/S(d,p)$.

Spins $\frac{7}{2}^+$ or $\frac{9}{2}^+$ were previously suggested for the 947 keV level.[13,23,24] Our angular distribution measurements are consistent only with a $\frac{9}{2}^+$ assignment for the 947 keV level, and a $\frac{7}{2}^+$ for the 1073 keV level, in agreement with the results of Mesko *et al.*[4] and Lederer, Jaklevic, and Hollander.[2]

^{97}Mo nucleus. Since our previous investigation on the level structure of ^{97}Mo[5] another level at 1284 keV has been excited. Furthermore, the existence of a level at 840 keV is also suggested. Either spin $\frac{3}{2}$ or $\frac{5}{2}$ for the 1284 keV level is consistent with our A_2 value for the 1284 keV γ ray (see Table III). However, an appreciable fraction of the $2d_{3/2}$ single-particle state has been assigned to a level at 1.27 MeV.[32,33] This state cannot be the 1268 keV level since, being excited directly in the ^{97}Nb decay,[34] its spin must be either $\frac{7}{2}^+$ or $\frac{9}{2}^+$. Hence, spin $\frac{3}{2}^+$ for the 1284 keV level has been taken as the most probable one. A weak transition at 840 keV was observed only in the ^{97}Mo spectra. This transition has not been reported in any earlier studies of ^{97}Mo and cannot be fitted between any two known levels of this nucleus. The yield of this transition as a function of projectile energy is consistent with an $E2$ excitation of a possible new state at 840 keV. It is for this reason that the existence of such a state is proposed in this investigation. It is clear, however, that this is merely a suggestion and much additional information is needed to confirm or reject it.

Previous Coulomb excitation measurements on ^{97}Mo were performed by Alkhazov *et al.*[12] who Coulomb excited two levels at 0.67 and 1.02 MeV [$B(E2\uparrow)=0.54\pm0.17$ and 4.3 ± 0.9 in units of 10^{-50} $e^2\,cm^4$]. These authors associated the 0.67 MeV level to the 658 keV state which is strongly excited in the ^{97}Nb decay.[34] However, our results show that their level should be associated to the 679 keV state. With this in mind, the agreement between their results and ours becomes satisfactory.

The present angular distribution results establish the spin of the 480 keV state as $\frac{3}{2}$. The A_2 and A_4 coefficients for the 480 keV transition are consistent with either of the two δ values shown in Table III. These δ values would yield half-lives equal to 13.0 ± 2.1 psec ($\delta=-0.47\pm0.03$) and 68 ± 5 psec ($\delta=-4.4\pm0.4$). However, Bond[35] has recently measured the half-life of some levels in ^{97}Mo by the Doppler shift attenuation method following the Coulomb excitation of levels in ^{97}Mo by ^{35}Cl projectiles. This author obtained a half-life for the 480 keV level equal to 8.50 ± 0.35 psec. Hence, the larger δ value can be discarded. The 658 keV level is very weakly excited in the Coulomb excitation measurements. The calculated mixing ratio of the 658 keV transition (see footnote in Table IV) is in agreement with one of the two possible values measured by Behrens and Brodt,[36] i.e., $\delta<0.07$. The angular distributions of the 679 and 407 keV transitions are, within the experimental errors, isotropic, supporting spin $\frac{1}{2}$ for the 679 and 888 keV levels. This assignment is in agreement with data from the reaction ^{96}Mo(d,p)^{97}Mo[32] which revealed that the $3s_{1/2}$ quasiparticle excitation is split between levels at about 690 and 890 keV.

The angular distribution of the 238 keV transition is neither consistent with spin $\frac{1}{2}$ nor $\frac{7}{2}$ for the 719 keV level. Furthermore, the placing of the 397 keV cascade transition from the 1116 keV state ($\frac{9}{2}^+$ see below) limits the spin of the 719 keV level to $\frac{5}{2}^+$.

The present angular distribution results are consistent with spins $\frac{3}{2}$, $\frac{5}{2}$, or $\frac{7}{2}$ for the 721 keV level. However, a level corresponding to the excitation of a neutron in the $2d_{3/2}$ shell has been observed by Kent, Cohen, and Moore[33] at 0.73 MeV. If the suggestion of a $\frac{5}{2}^+$ spin for the 719 keV level holds, it is reasonable to propose a spin $\frac{3}{2}^+$ for the 721 keV level.

The 1024 and 1116 keV levels are directly excited by allowed β transitions in the decay of ^{97}Nb.[34] This establishes the spin of those states as either $\frac{7}{2}^+$ or $\frac{9}{2}^+$. Considering only these two possibilities, the present angular correlation measurements are consistent only with spin $\frac{7}{2}^+$ for the 1024 keV level and spin $\frac{9}{2}^+$ for the 1116 keV level, in agreement with the results of Mesko *et al.*[4] and Lederer *et al.*[2]

The present angular distribution results establish the spin of the 1092 keV level as $\frac{3}{2}$. This state, whose existence was proposed also by Mesko *et al.*,[4] has not been observed in any other previous study of the ^{97}Mo level structure.

The spin of the 1268 and 1515 keV levels is either $\frac{7}{2}^+$ or $\frac{9}{2}^+$ since they are excited by allowed β transitions in the decay of ^{97}Nb.[34] However, Mesko *et al.*[4] strongly favor a $\frac{7}{2}^+$ assignment for the 1268 keV level. From our Coulomb excitation experiments very little can be said on the properties of this state for it is very weakly excited and no angular distribution measurements could be performed on the transitions deexciting this level. On the other hand, our angular distribution measurements on the 1515 keV transition, carried out with 10 MeV α particles, are consistent only with spin $\frac{9}{2}^+$ in agreement with the proposition of Mesko *et al.*[4] These authors also fitted a 246.4 keV γ ray between this level and the 1268.8 keV state. This transition was not detected in the present work.

B. Comparison with nuclear models

The level schemes of ^{95}Mo and ^{97}Mo calculated for the configurations $(\pi p_{1/2})^2\,(\pi g_{9/2})^2\,(\nu d_{5/2})^3$ (^{95}Mo)[7,8] and $(\pi p_{1/2})^2\,(\pi g_{9/2})^2\,(\nu d_{5/2})^{-1}$ (^{97}Mo)[8] are shown in Figs. 4 and 5 (^{95}Mo and ^{97}Mo, respectively), together with the experimental level schemes obtained in the present investigation.

The only apparent success of these calculations is the prediction of the low-lying $\frac{3}{2}^+$ state in ^{95}Mo. This state corresponds essentially to a $|(g_{9/2})^2{}_0\,(d_{5/2})^3{}_{3/2};\frac{3}{2}\rangle$ configuration. Vervier[8] calculated the $E2$ and $M1$ reduced transition probabilities for the 203 keV transition deexciting the 203 keV state in ^{95}Mo. The $B(E2)$ and $B(M1)$ values are 8.9 ($10^{-2}\,e^2\mathrm{b}^2$) and 8×10^{-3} $[(e\hbar/2Mc)^2]$ which should be compared with the 5.70 ± 0.24 and 4.49 ± 0.12 values determined in this work. The order of magnitude for the $B(M1)$ is correct but the $B(E2)$ value is too large considering that the same type of calculation predicts $B(E2)$ values for the even-even molybdenum nuclei 30 to 50% lower than those experimentally measured.[1,6] As already stated by Vervier, these calculations could be improved by the inclusion of more single-particle states as $1g_{7/2}$, $3s_{1/2}$, and $2d_{3/2}$ in the excitation spectrum of the neutrons.

Kisslinger and Sorensen (KS)[9] have predicted levels in ^{95}Mo and ^{97}Mo by considering a short-range pairing force and a long-range quadrupole force interacting with a spherical core. The KS predictions are compared with the experimental level schemes of ^{95}Mo and ^{97}Mo in Figs. 4 and 5. From an inspection of Figs. 4 and 5, one can conclude that the model of KS gives a poor description of the nuclear structure of both ^{95}Mo and ^{97}Mo. This conclusion is also borne out by the $B(E2)$ values recently calculated by Reehal and Sorenson[37] for some transitions in ^{95}Mo and ^{97}Mo. The $E2$ transition rates calculated by these authors are shown in Table VI with the $B(E2)$ deduced in the present experiment. Since the correspondence

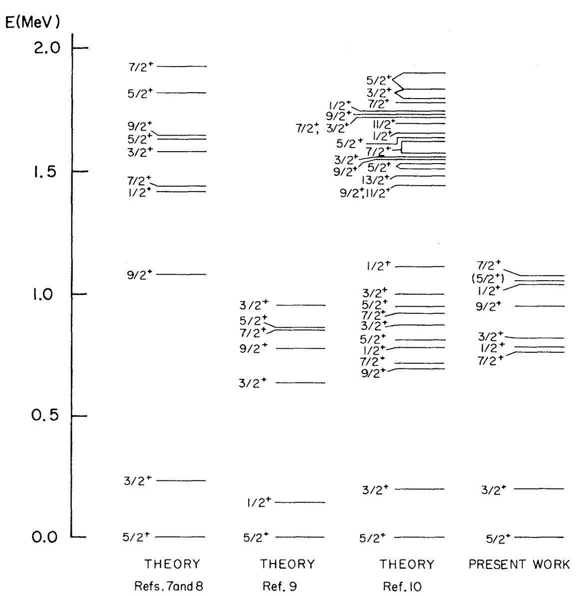

FIG. 4. Comparison of the level scheme of ^{95}Mo as evinced in this investigation with the theoretical level schemes deduced by Bhatt and Ball (Ref. 7), Vervier (Ref. 8), Kisslinger and Sorensen (Ref. 9), and Choudhury and Clemens (Ref. 10).

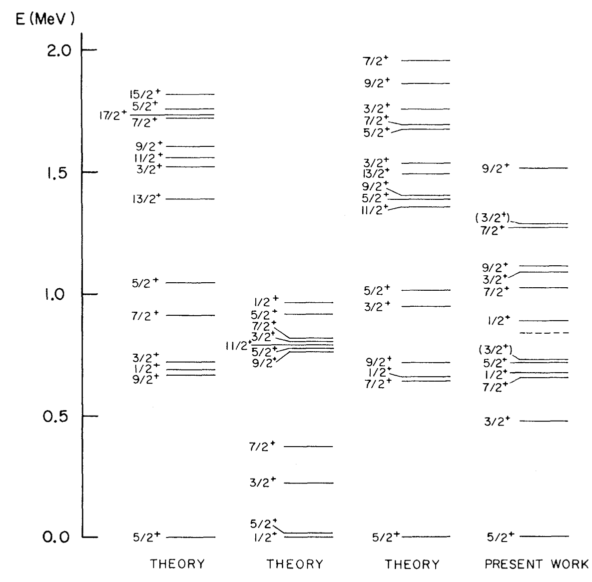

FIG. 5. Comparison of the level scheme of ^{97}Mo as evinced in this investigation with the theoretical level schemes deduced by Vervier (Ref. 8), Kisslinger and Sorensen (Ref. 9), and Choudhury and Clemens (Ref. 10).

TABLE VI. Comparison between the $B(E2; J_i \to J_f)$ values experimentally determined in this work and those calculated by Reehal and Sorensen for ^{95}Mo and ^{97}Mo.

Isotope	$J_i^\pi \to J_f^\pi$	$B(E2;J_i\to J_f)_{th}$ (10^{-50} e^2 cm^4)	E_γ (keV)	$B(E2;J_i\to J_f)_{exp}$ (10^{-50} e^2 cm^4)
^{95}Mo	$\frac{3}{2}^+ \to \frac{5}{2}^+$	2.42	203.94	5.70 ±0.36
			820.8	0.090±0.023
	$\frac{1}{2}^+ \to \frac{5}{2}^+$	12.1	786.21	0.98 ±0.06
			1039.3	1.65 ±0.30
	$\frac{1}{2}^+ \to \frac{3}{2}^+$	10.8	582.15	$1.0^{+0.6}_{-0.4}$
			835.14	$0.07^{+0.14}_{-0.05}$
	$\frac{7}{2}^+ \to \frac{5}{2}^+$	1.18	765.9	<0.010
			1073.8	2.90 ±0.16
^{97}Mo	$\frac{3}{2}^+ \to \frac{5}{2}^+$	0.72	480.9	3.07 ±0.17
			1092.6	0.52 ±0.04
	$\frac{1}{2}^+ \to \frac{5}{2}^+$	8.82	679.6	1.38 ±0.09
			888.1	0.55 ±0.06
	$\frac{7}{2}^+ \to \frac{5}{2}^+$	0.18	658.2	0.035±0.005
			1024.6	3.40 ±0.18
	$\frac{7}{2}^+ \to \frac{3}{2}^+$	5.84	177.97	$7.9^{+4.7}_{-2.9}$
			543.8	$1.3^{+1.4}_{-0.8}$

between the experimental and theoretical levels is not completely evident, we have sometimes considered the first two states with the same spin. An inspection of Table VI shows that the results of Reehal and Sorensen are not in agreement with experiment.

It is also interesting to compare our data with the predictions of the core excitation model.[38] According to this model a multiplet of excited states of spins $\frac{1}{2}$, $\frac{3}{2}$, $\frac{5}{2}$, $\frac{7}{2}$, and $\frac{9}{2}$ should arise from coupling a $2d_{5/2}$ neutron (or hole) to the 2^+ core state identified with the first 2^+ level in the neighboring even nucleus (^{94}Mo and ^{96}Mo, respectively). The $B(E2\downarrow)$ of these states should be nearly equal to the $B(E2; 2^+ \to 0^+)$ value for the even-core nucleus. These levels should not be excited in one particle transfer reactions. $M1$ transitions are allowed between members of this multiplet of levels (if ΔI permits), whereas ground state $M1$ transitions are strictly forbidden. Finally, the sum of the reduced $B(E2\uparrow)$ transitions should be equal to the $B(E2; 0^+ \to 2^+)$ value for the even-core nucleus. The comparison of the $B(E2\uparrow)$ values with the core-excitation predictions is summarized in Table VII where the factor F_{ph} is the ratio $B(E2\downarrow)/B(E2; 2^+ \to 0^+)_{\text{core}}$. The $B(E2; 2^+ \to 0^+)$ value is taken for the next lowest even-mass nucleus, i.e., ^{94}Mo and ^{96}Mo (see Refs. 1 and 6). Furthermore the $B(E2\downarrow)/B(E2)_{\text{s.p.}}$ and $B(M1\downarrow)/B(M1)_{\text{s.p.}}$ ratios are also included in the table.

An inspection of Table VII shows that both in ^{95}Mo and ^{97}Mo the levels with spins $\frac{3}{2}^+$, $\frac{7}{2}^+$, and $\frac{9}{2}^+$ (at 203, 1073, and 947 keV in ^{95}Mo, and at 480, 1024, and 1116 keV in ^{97}Mo) have a sufficiently large value of F_{ph} to be associated with states due to the excitation of the core. On the other hand, the probable $\frac{5}{2}^+$ 1056 keV level in ^{95}Mo does not show much of a collective nature (F_{ph} $=0.30$), and the 719 keV ($\frac{5}{2}^+$) level in ^{97}Mo is certainly not consistent with the core excitation model ($F_{ph}=0.069$). Furthermore, it seems that the core-excitation strength of the $\frac{1}{2}^+$ member of the multiplet is shared between pairs of levels both in ^{95}Mo and ^{97}Mo (the 786 and 1039 keV levels, and the 679 and 888 keV levels, respectively).

These findings are consistent with (d, p) reaction data. In fact, the 203 and 947 keV levels in ^{95}Mo are very weakly excited in (d, p) reaction work[23] and the 1073 keV state is not observed at all, whereas the 786 and 1039 keV states display relatively large (d, p) spectroscopic factors (0.37 and 0.19, respectively). This might indicate that the wave functions describing these levels contain significant mixing of core-excitation and single-quasiparticle component of the $3s_{1/2}$ shell. The 765 ($\frac{7}{2}^+$) and 820 keV ($\frac{3}{2}^+$) levels show relatively large spectroscopic factors (0.18 and 0.25, respectively) indicating that these levels might arise as a result of the excitation of a neutron in the $1g_{7/2}$ and $2d_{3/2}$ shells. The 1056 keV ($\frac{5}{2}^+$) level was not observed in the ^{94}Mo(d, p) reaction work.[23]

A similar picture exists also in ^{97}Mo. In fact, Hjorth and Cohen[32] have determined a $S(d, p)$ value equal to 1.28 for a $\frac{7}{2}^+$ level at 0.699 MeV which, most probably, corresponds to the very weakly Coulomb excited level at 658 keV. This level can be associated to the excitation of a neutron in the $1g_{7/2}$ shell. The $\frac{1}{2}^+$ levels excited at 0.699 and 0.893 MeV, corresponding to our levels at 679 and 888 keV, have spectroscopic factors of 0.55 and 0.11, respectively. As in ^{95}Mo, it is probable that these two levels display appreciable mixing of core-excitation and single-quasiparticle component. The 480 ($\frac{3}{2}^+$), 1024 ($\frac{7}{2}^+$), and 1116 keV ($\frac{9}{2}^+$) levels have not been observed by these authors, and this is consistent with their collective properties. No definite conclusion can be drawn for the 719 ($\frac{5}{2}^+$) and 721 keV ($\frac{3}{2}^+$) states. Information on the $M1$ transition rates of transitions decaying to the ground state in ^{95}Mo and ^{97}Mo is shown in Table VII, and the data on the $M1$ transition rates of transitions between excited states are summarized in Table VIII.

An inspection of Table VII and VIII shows that the predictions of the core-excitation model are

TABLE VII. Enhancements and hindrances of $E2$ and $M1$ transitions to the ground states of ^{95}Mo and ^{97}Mo.

Isotope	E_{level} (keV)	J^{π}	F_{ph} [a]	$B(E2\downarrow)/B(E2)_{\text{s.p.}}$ [b]	$B(M1\downarrow)/B(M1)_{\text{s.p.}}$ [c]
^{95}Mo	203.94	$\frac{3}{2}^{+}$	1.31 ± 0.11	22.1 ± 1.4	$(2.35 \pm 0.12) \times 10^{-3}$
	765.9	$\frac{7}{2}^{+}$	<0.002	<0.04	$2.4^{+1.3}_{-0.8} \times 10^{-2}$
	786.21	$\frac{1}{2}^{+}$	0.22 ± 0.02	3.8 ± 0.2	
	820.8	$\frac{3}{2}^{+}$	0.020 ± 0.006	0.35 ± 0.09	$>1.7 \times 10^{-3}$ [d]
	947.8	$\frac{9}{2}^{+}$	0.72 ± 0.06	12.2 ± 0.6	
	1039.3	$\frac{1}{2}^{+}$	0.38 ± 0.08	6.4 ± 1.2	
	1056.8	$(\frac{5}{2})^{+}$	0.30 ± 0.03	5.0 ± 0.3	$1.8^{+8.7}_{-1.3} \times 10^{-2}$
	1073.7	$\frac{7}{2}^{+}$	0.66 ± 0.06	11.2 ± 0.6	$2.5^{+1.2}_{-0.7} \times 10^{-2}$
^{97}Mo	480.9	$\frac{3}{2}^{+}$	0.54 ± 0.05	11.6 ± 0.6	$(1.2 \pm 0.2) \times 10^{-2}$
	658.2	$\frac{7}{2}^{+}$	0.006 ± 0.001	0.13 ± 0.02	$3.9^{+1.3}_{-0.8} \times 10^{-2}$
	679.6	$\frac{1}{2}^{+}$	0.24 ± 0.02	5.2 ± 0.4	
	719.3	$\frac{5}{2}^{+}$	0.069 ± 0.008	1.47 ± 0.11	$3.6^{+2.6}_{-1.3} \times 10^{-2}$ [d]
	721.1	$(\frac{3}{2})^{+}$	0.044 ± 0.005	0.95 ± 0.09	$1.4^{+4.0}_{-0.8} \times 10^{-2}$ [d]
	888.1	$\frac{1}{2}^{+}$	0.096 ± 0.013	2.1 ± 0.2	
	1024.6	$\frac{7}{2}^{+}$	0.60 ± 0.05	12.8 ± 0.7	$4.7^{+4.4}_{-2.0} \times 10^{-2}$
	1092.6	$\frac{3}{2}^{+}$	0.091 ± 0.009	1.95 ± 0.14	$1.0^{+1.0}_{-0.6} \times 10^{-2}$
	1116.7	$\frac{9}{2}^{+}$	0.48 ± 0.05	10.3 ± 0.7	
	1268.6	$\frac{7}{2}^{+}$	0.13 ± 0.03	2.7 ± 0.6	
	1284.6	$(\frac{3}{2})^{+}$	0.11 ± 0.03	2.4 ± 0.5	$6.0^{+13.0}_{-4.0} \times 10^{-3}$
	1515.5	$\frac{9}{2}^{+}$	0.056 ± 0.010	1.2 ± 0.2	

[a] F_{ph} is the ratio $B(E2\downarrow)/B(E2;\, 2^+ \to 0^+)$. The $B(E2;\, 2^+ \to 0^+)$ values are taken for the next lowest even-mass nuclei, i.e., ^{94}Mo and ^{96}Mo (see Refs. 1 and 6).

[b] For the definition of $B(E2)_{\text{s.p.}}$ see Table V.

[c] $B(M1)_{\text{s.p.}} = e^2/4\pi[(\frac{3}{4})^2] \times 10[(\hbar/2Mc)^2]$.

[d] Only the more probable $B(M1\downarrow)$ values has been considered for these transitions. See Table IV and text.

partially supported by the experimental data. The ground-state $M1$ transitions are retarded. However, this hindrance is expected also within the framework of the shell-model, since $M1$ transitions are allowed only for levels corresponding to the excitation of the $d_{3/2}$ shell. It appears that the less retarded $M1$ transitions are those between "members of the multiplet." The fact that the 253 keV transition in ^{95}Mo is so strong can be explained by the possible sharing of the one-phonon state between the 786 and 1039 keV levels. The $B(M1)$ values of the 835 and 582 keV transitions (^{95}Mo) show that the 1039 keV level has a larger component of the one-phonon state than the 786 keV level. This conclusion is consistent with the F_{ph} and $S(d,p)$ values attached to these states. Finally, we compare the prediction that the sum of the observed $E2$ strengths should be equal to that of the 2^+ state of the neighboring even-nuclei (this, in absence of polarization of the nucleus by the odd-nucleon which would give rise to a static quadrupole moment Q_g for the ground state of the odd-A nucleus). Although the complete set of the multiplet members is not well delineated in both nuclei, the above rule should be applicable under the assumption that all the $E2$ excitation strength is derived from core excitation. The results are shown in Table IX.

It appears that the $\sum B(E2\uparrow)$ over the observed states in ^{95}Mo and ^{97}Mo falls far short of such expectations. Attributing the "missing" fraction of the $\sum B(E2\uparrow)$ to the ground-state quadrupole strength $B(E2;\, I_g \to I_g)$, which is given by

$$B(E2;\, I_g \to I_g) = \frac{5}{16\pi}\, \frac{(I_g+1)(2I_g+3)}{I_g(2I_g-1)}\, Q_g^{\,2} \ ,$$

TABLE VIII. Hindrances of $M1$ transitions between excited states of ^{95}Mo and ^{97}Mo.

Isotope	E_γ (keV)	$E_{l_i} \to E_{l_f}$	$J_i^\pi \to J_f^\pi$	$B(M1\downarrow)/B(M1)_{s.p.}$
^{95}Mo	125.8 [a]	1073 → 947	$\frac{7}{2}^+ \to \frac{9}{2}^+$	$2.6^{+1.3}_{-0.8} \times 10^{-1}$
	181.5 [a]	947 → 765	$\frac{9}{2}^+ \to \frac{7}{2}^+$	$(3.4 \pm 1.0) \times 10^{-3}$
	219.4 [a]	1039 → 820	$\frac{1}{2}^+ \to \frac{3}{2}^+$	$1.8^{+1.3}_{-0.9} \times 10^{-2}$
	253.2 [a]	1039 → 786	$\frac{1}{2}^+ \to \frac{1}{2}^+$	$(1.3 \pm 0.6) \times 10^{-1}$
	307.8 [a]	1073 → 765	$\frac{7}{2}^+ \to \frac{7}{2}^+$	$1.2^{+0.5}_{-0.3} \times 10^{-2}$
	582.15	786 → 203	$\frac{1}{2}^+ \to \frac{3}{2}^+$	$(1.8 \pm 0.3) \times 10^{-2}$
	617.4 [b]	820 → 203	$\frac{3}{2}^+ \to \frac{3}{2}^+$	$>1.3 \times 10^{-4}$
	835.14	1039 → 203	$\frac{1}{2}^+ \to \frac{3}{2}^+$	$(1.5 \pm 0.4) \times 10^{-1}$
	852.8	1056 → 203	$(\frac{5}{2})^+ \to \frac{3}{2}^+$	$1.3^{+4.8}_{-0.7} \times 10^{-1}$
^{97}Mo	238.5 [b]	719 → 480	$\frac{5}{2}^+ \to \frac{3}{2}^+$	$3.9^{+2.8}_{-1.4} \times 10^{-2}$
	366.3	1024 → 658	$\frac{7}{2}^+ \to \frac{7}{2}^+$	$4.5^{+3.0}_{-1.9} \times 10^{-2}$
	407.0 [a]	888 → 480	$\frac{1}{2}^+ \to \frac{3}{2}^+$	$(1.2 \pm 0.3) \times 10^{-1}$
	458.5 [a]	1116 → 658	$\frac{9}{2}^+ \to \frac{7}{2}^+$	$(3.6 \pm 0.7) \times 10^{-3}$
	611.9 [a]	1092 → 480	$\frac{3}{2}^+ \to \frac{3}{2}^+$	$7^{+9}_{-4} \times 10^{-3}$
	857.3 [b]	1515 → 658	$\frac{9}{2}^+ \to \frac{7}{2}^+$	$(6 \pm 3) \times 10^{-3}$

[a] These γ rays have been assumed as pure $M1$ transitions. See Table IV.

[b] Only the more probable $B(M1\downarrow)$ value has been considered for these transitions. See Table IV and text.

we have calculated this factor from the known static quadrupole moment of the ground state of ^{95}Mo and ^{97}Mo.[16,17] The results are shown in the third column of Table IX. In ^{95}Mo the Q_g value is not sufficient to warrant agreement with the theory, whereas in ^{97}Mo the $B(E2; I_g \to I_g)$ term is already larger than the $B(E2; 0^+ \to 2^+)_{\text{core}}$. The static quadrupole moment values which would warrant agreement with the theory have been calculated and are shown in the last column of Table IX. For ^{97}Mo this calculated value is not very different from the experimental one.[17] This arises from the fact that the ground-state quadrupole strength $B(E2; I_g \to I_g)$ varies rapidly with small variations in Q_g.

TABLE IX. Comparison of the sum of the observed $E2$ strengths in ^{95}Mo and ^{97}Mo with $B(E2; 0^+ \to 2^+)_{\text{core}}$.

Isotope	$\frac{\sum B(E2)\ ^a}{B(E2;\ 0^+ \to 2^+)_{\text{core}}}$	$\frac{B(E2; I_g \to I_g)_{\text{exp}}}{B(E2;\ 0^+ \to 2^+)_{\text{core}}}$	$Q_{g\,\text{calc}}$ (eb)
^{95}Mo	0.70 ± 0.06	0.02 ± 0.01	0.49 ± 0.06
^{97}Mo	0.52 ± 0.06	$1.2^{+0.5}_{-0.4}$	0.70 ± 0.05

[a] The sum $\sum(E2\uparrow)$ does not include the $B(E2; I_g \to I_g)$ term; the $B(E2; 0^+ \to 2^+)_{\text{core}}$ values have been taken from Refs. 1 and 6. See also Table VII.

In conclusion, few of the predictions of the core-excitation model are in agreement with experiment for ^{95}Mo and ^{97}Mo, and considerable mixing of states should be invoked to explain the level properties of these nuclei.

The most recent theoretical investigation on the level structure of ^{95}Mo and ^{97}Mo is that carried out by Choudhury and Clemens[10] within the framework of the unified model. The calculated level schemes of ^{95}Mo and ^{97}Mo are compared with the experimental ones in Figs. 4 and 5.

The experimental level density in ^{95}Mo is well reproduced by the calculations of Choudhury and Clemens.[10] The fact that the existence of the $\frac{3}{2}^+$ level at ~200 keV is well predicted by the model is a direct consequence of the introduction in the calculations of the configuration $(2d_{5/2})^{-3}{}_{3/2}$. Even though the level sequence is not respected, all the levels observed below 1.2 MeV seem predicted at approximately the proper energy. The theory fails to give agreement with experiment in ^{97}Mo. Only the first $\frac{7}{2}^+$ and $\frac{1}{2}^+$ calculated levels seem to be consistent with states observed experimentally at approximately the same energy. As a more stringent test of the theoretical calculations of Choudhury and Clemens,[10] the calculated electromagnetic transition rates for ground-state transitions both in ^{95}Mo and ^{97}Mo were compared with those deduced in this experiment. The results of this comparison are summarized in Table X.

An inspection of Table X shows that all the $M1$ transition rates are retarded in agreement with experiment. However, this hindrance is due to the fact that $M1$ transitions are forbidden between the principal components of the wave functions describing these levels. Thus, the calculated $M1$ transition probabilities depend on the amplitude of the weaker components and are very sensitive to small variations in the wave functions. Furthermore, the magnetic dipole operator is a function of an effective orbital and spin gyromagnetic factors for the particles, and of a gyromagnetic factor of the core. These quantities could be considered as parameters of the calculations, hence the comparison with the $M1$ transition probabilities is not very significant and does not yield very useful information on the nuclear level properties.

As can be seen from Table X, all the calculated $E2$ transition rates are enhanced. In fact, even if the level energy is much displaced with respect to the calculated energy, all these levels contain a very important part of the one-phonon state. Thus, even for the 203 keV level in ^{95}Mo the $E2$ transition probability arises from the collective component of the wave function. Hence, these $E2$ transition probabilities show that all these levels should correspond to the most collective states excited in

TABLE X. Comparison of the theoretical and experimental electromagnetic transition rates for ground-state transitions in ^{95}Mo and ^{97}Mo.

Isotope	E_l [a] (keV)	$J_i^\pi \to J_f^\pi$	$B(E2\downarrow)_{th}$ (10^{-50} e^2 cm^4)	$B(E2\downarrow)_{exp}$ (10^{-50} e^2 cm^4)	$B(M1)_{th}$ [$(e\hbar/2Mc)^2$]	$B(M1\downarrow)_{exp}$ [$(e\hbar/2Mc)^2$]
^{95}Mo	203.94 (201)	$\frac{3}{2}^+ \to \frac{5}{2}^+$	5.7	5.70 ± 0.36	1.6×10^{-3}	$(4.21 \pm 0.22) \times 10^{-3}$
	947.8 (695)	$\frac{9}{2}^+ \to \frac{5}{2}^+$	5.4	3.15 ± 0.15		
	1039.3 (782)	$\frac{1}{2}^+ \to \frac{5}{2}^+$	4.2	1.65 ± 0.30		
	1073.7 (720)	$\frac{7}{2}^+ \to \frac{5}{2}^+$	5.0	2.90 ± 0.16	6.6×10^{-4}	$4.5^{+2.1}_{-1.3} \times 10^{-2}$
^{97}Mo	480.9 (948)	$\frac{3}{2}^+ \to \frac{5}{2}^+$	3.3	3.07 ± 0.17	2.5×10^{-1}	$(2.2 \pm 0.4) \times 10^{-2}$
	679.6 (662)	$\frac{1}{2}^+ \to \frac{5}{2}^+$	6.9	1.38 ± 0.09		
	719.3 (1019)	$\frac{5}{2}^+ \to \frac{5}{2}^+$	2.8	0.39 ± 0.03	7.2×10^{-2}	$6.4^{+4.7}_{-2.4} \times 10^{-3}$ [b]
	1024.6 (646)	$\frac{7}{2}^+ \to \frac{5}{2}^+$	7.2	3.40 ± 0.18	1.8×10^{-1}	$8.5^{+7.9}_{-3.6} \times 10^{-2}$
	1116.7 (720)	$\frac{9}{2}^+ \to \frac{5}{2}^+$	5.9	2.74 ± 0.19		

[a] The energy values in parentheses are those predicted by Choudhury and Clemens (see Ref. 10).

[b] Only the more probable $B(M1\downarrow)$ value has been considered for these transitions. See Table IV and text.

this experiment. Under this assumption the first $\frac{7}{2}^+$ level, predicted at 720 keV (^{95}Mo) and 646 keV (^{97}Mo) should be associated to the 1073 (^{95}Mo) and 1024 keV (^{97}Mo) levels, and not to the 765 (^{95}Mo) and 658 keV (^{97}Mo) levels. Similarly, the first $\frac{3}{2}^+$ state predicted at 948 keV in ^{97}Mo shows an $E2$ transition probability which is more consistent with the 480 keV observed level than with the 1092 keV state. The $\frac{9}{2}^+$ levels predicted at approximately 700 keV in both nuclei should correspond to the excited 947 (^{95}Mo) and 1116 keV (^{97}Mo) levels. Finally, an inspection of Table X shows that the calculated $E2$ transition rates are larger than those deduced experimentally, with the exception of the first excited levels in ^{95}Mo and ^{97}Mo. This in spite of the fact that we have chosen the levels with the most enhanced $E2$ transitions.

The logical conclusion arising from the aforementioned points is that the validity of the model of Choudhury and Clemens[10] is less evident when the comparison between the theoretical and experimental electromagnetic transition rates is carried out. This also for ^{95}Mo for which there was apparent agreement with experiment in the placing of levels.

C. Comparison with the level structure of ^{99}Ru and ^{101}Ru

As a conclusion of the present work, we would like to compare the level schemes of ^{95}Mo and ^{97}Mo with those of ^{99}Ru and ^{101}Ru. In Fig. 6 the level schemes of ^{95}Mo and ^{97}Mo are shown with those of ^{99}Ru and ^{101}Ru as deduced in Coulomb excitation work.[39] The spin-parity assignment for some levels in ^{99}Ru and ^{101}Ru is due to Lederer *et al.*[2] who studied these nuclei by the ^{98,100}Mo-$(\alpha, 3n\gamma)$ reaction. Except for the fact that the ruthenium isotopes generally display a more pronounced collective nature, and that their level energies are lower than those for the molybdenum isotopes, several common properties appear in these four nuclei whose neutron number ranges from 53 to 57, i.e., 3 to 7 neutrons outside the magic shell of $N=50$. For instance: (i) The ground-state has spin $\frac{5}{2}^+$; (ii) the first excited state has spin $\frac{3}{2}^+$, it is strongly collective and lies at a much lower energy than the other states; (iii) the first $\frac{7}{2}^+$ state is very weakly Coulomb excited; (iv) there are three excited levels which display more of a collective nature than the others, i.e., the first $\frac{3}{2}^+$ and $\frac{9}{2}^+$ levels, and the second $\frac{7}{2}^+$ level.

The $\frac{5}{2}^+$ spin of the ground state in ^{95}Mo, ^{97}Mo, and ^{99}Ru is explained by the shell model[40] which predicts that the first 5 neutrons outside the 50 neutron magic shell fill up the $2d_{5/2}$ shell. Hence, the ground state of these nuclei shows a neutron configuration $(2d_{5/2})^3{}_{5/2}$ or $(2d_{5/2})^5{}_{5/2}$. If more neutrons are added, the shell model predicts that the pairing energy will be larger for the two neutrons in the $1g_{7/2}$ shell than in the $2d_{5/2}$ shell. Thus, the ground-state configuration of ^{101}Ru will be $(1g_{7/2})^2{}_0$ $(2d_{5/2})^5{}_{5/2}$. A similar situation exists also in ^{105}Pd (59 neutrons) and even in ^{107}Cd (61 neutrons). For these nuclei the ground-state configuration is, most probably, $(1g_{7/2})^4{}_0$ $(2d_{5/2})^5{}_{5/2}$ and $(1g_{7/2})^6{}_0$ $(2d_{5/2})^5{}_{5/2}$.[40]

The first $\frac{7}{2}^+$ excited state, which is weakly excited in Coulomb excitation, could be associated to the excitation of an unpaired neutron of the $2d_{5/2}$ shell to the $1g_{7/2}$ shell. This suggestion is supported for the molybdenum isotopes by the results extracted in (d, p) reaction experiments.[23,32] Lederer *et al.*[2] excited levels with large angular momentum values in all these nuclei, and proposed the existence of a set of states with spins $\frac{7}{2}^+$, $\frac{11}{2}^+$, and $\frac{15}{2}^+$ forming a band having as band-head the aforementioned $\frac{7}{2}^+$ level. These authors suggest that this band could arise from the coupling of the unpaired neutron in the $1g_{7/2}$ shell to the configuration $(2d_{5/2})^{2\text{ or }4}_{0^+,2^+,4^+}$. However, one could consider the coupling of this unpaired neutron to the proton configuration $(1g_{9/2})^{2\text{ or }4}_{0^+,2^+,4^+,6^+,8^+}$, or to the quadrupole vibrations of the even core. Under this assumption, the $\frac{19}{2}^+$ and $\frac{23}{2}^+$ levels observed in ^{95}Mo and ^{97}Mo could be included in this same band. If such a band exists, one should have also a band built on the ground state with spins $\frac{5}{2}^+$, $\frac{9}{2}^+$, $\frac{13}{2}^+$, $\frac{17}{2}^+$, ... which could explain the collective char-

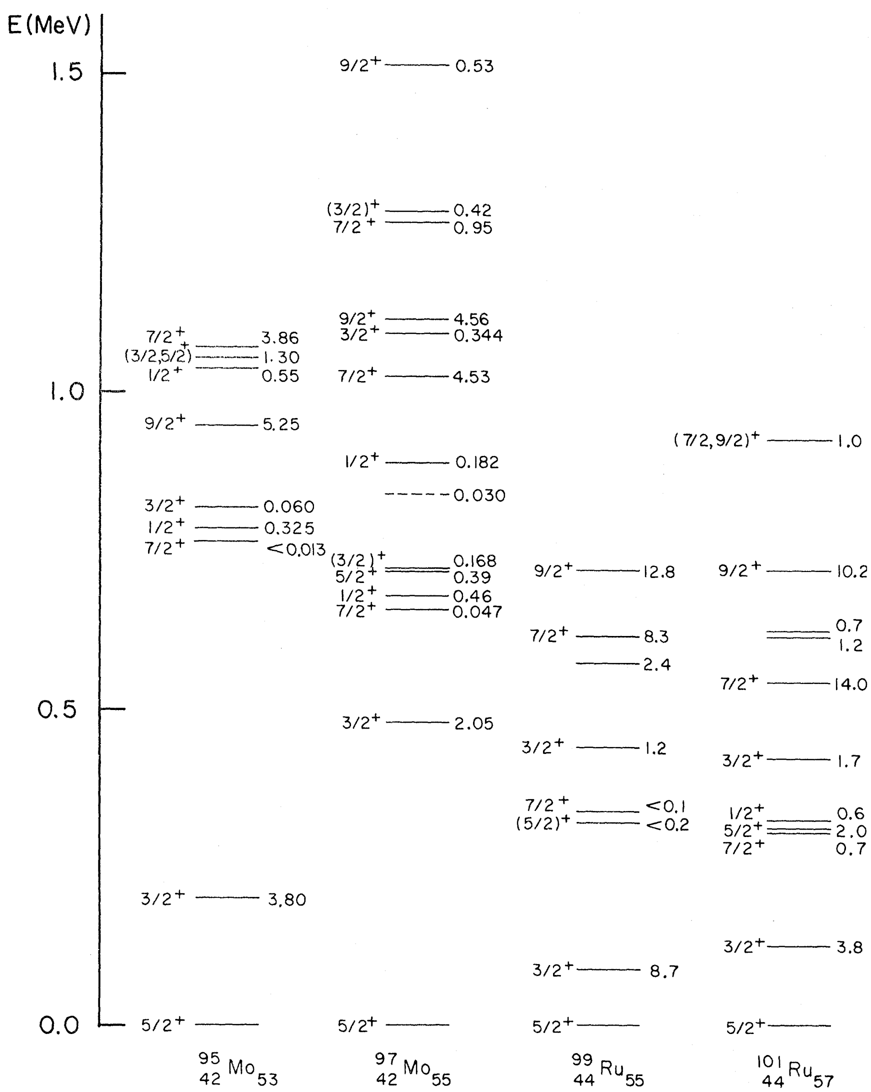

FIG. 6. Comparison of the level schemes of ^{95,97}Mo as evinced in this investigation with those of ^{99,101}Ru obtained by Coulomb excitation measurements (see Ref. 39). The spin assignment for some levels of ^{99}Ru and ^{101}Ru is due to Lederer *et al.* (Ref. 2), whereas the $B(E2\uparrow)$ values are those obtained in Ref. 39.

acter of the first $\frac{9}{2}^+$ level. Lederer *et al.*[2] have observed in ^{95}Mo and ^{97}Mo levels with spins $\frac{13}{2}^+$ and $\frac{17}{2}^+$ which could be associated with this ground-state band. If two distinct bands exist, intraband $M1$ transitions should be forbidden whereas $E2$ transitions should be strongly favored between members of the same band ($\Delta I = 2$). Thus, in order to have a better understanding of the level structure of these nuclei, it would be very interesting to determine the transition rates between the levels with large angular momenta.

The calculations of Vervier,[8] Bhatt and Ball,[7] as well as of Choudhury and Clemens[10] show that the low-lying $\frac{3}{2}^+$ level in ^{95}Mo is due essentially to the neutron configuration $(2d_{5/2})^{\pm 3}{}_{3/2}$. However, in ^{97}Mo, ^{99}Ru, and ^{101}Ru there are five neutrons in the $2d_{5/2}$ shell, and it is not possible to have a $J = \frac{3}{2}$ coupling. Vervier[8] and Choudhury and Clemens[10] show that in ^{97}Mo the coupling of neutrons in the configuration $(2d_{5/2})^5{}_{5/2}$ to the configuration $(1g_{9/2})^2{}_{2^+}$ or to the even core gives rise to a first excited state $\frac{3}{2}^+$ at much higher energy. Since the $1g_{7/2}$ shell is very close to the $2d_{5/2}$ shell, one can explain the $\frac{3}{2}^+$ level by supposing that the configuration of the ground state of the nuclei with 55 and 57 neutrons is given by $(1g_{7/2})^2{}_0(2d_{5/2})^3{}_{5/2}$ and $(1g_{7/2})^4{}_0(2d_{5/2})^3{}_{5/2}$, respectively. Thus, the $\frac{3}{2}^+$ excited state would have the same origin as that for ^{95}Mo, i.e., the coupling of three neutrons in the $2d_{5/2}$ shell. Under this hypothesis, the first $\frac{5}{2}^+$ excited state observed in ^{97}Mo, ^{99}Ru, and ^{101}Ru, at a close energy to the first $\frac{7}{2}^+$ level, could arise from the $(2d_{5/2})^5{}_{5/2}$ configuration. In this case, it is normal that this $\frac{5}{2}^+$ level is not observed in ^{95}Mo, since this nucleus has only three neutrons outside the magic shell $N = 50$.

With the exception of the existence of a ground-state band $\frac{5}{2}^+$, $\frac{9}{2}^+$, $\frac{13}{2}^+$, ... which could explain the collective nature of the first $\frac{9}{2}^+$ excited state, we have no ready explanation for the existence of the collective levels $\frac{7}{2}^+$ (second one) and $\frac{9}{2}^+$ placed at an energy slightly higher than that of the 2^+ state in the even nuclei. If these levels are supposed to arise from the coupling of the first 2^+ state of the core, or of a proton configuration $J = 2^+$ with the neutron configuration of the ground state, one should also observe collective levels with spin $\frac{1}{2}^+$, $\frac{5}{2}^+$, and $\frac{3}{2}^+$. However, the $\frac{3}{2}^+$ level should be placed at much higher energy than that of the first $\frac{3}{2}^+$ excited state.

It is evident that the Coulomb excitation measurements indicate that the ^{95,97}Mo and ^{99,101}Ru nuclei share many similarities which should be helpful in the development of a more sophisticated model valid in this region of nuclei.

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