Nuclear structure of Sr, Zr, and Mo isotopes

Ashok Kumar and M. R. Gunye
Theoretical Physics Division, Bhabha Atomic Research Centre, Trombay, Bombay 400 085, India
(Received 11 July 1985)

The nuclear structure calculations for strontium, zirconium, and molybdenum isotopes are performed in a large configuration space by employing a quadrupole-plus-pairing-interaction Hamiltonian. The possible factors responsible for the sudden onset of deformation at $N=60$ in these nuclei are pointed out from the systematics of the occupancies of the single particle orbitals derived from the variational microscopic calculations. The energy spectra and the $B(E2)$ values in the doubly even ^{98}Sr, ^{100,102}Zr, and ^{104,106}Mo obtained from the variation-after-projection formalism are in good agreement with the corresponding experimental data.

I. INTRODUCTION

The study of the structure of strontium, zirconium, and molybdenum nuclei is of great interest because of the possible existence of proton subshell closures at $Z=38$ or 40 and neutron subshell closures at $N=50$ or 56. The interest in these nuclei is further augmented by the fact that the neutron-rich Sr, Zr, and Mo isotopes constitute a new region of nuclear deformation.[1,2] In this region, the energies of the 2^+ levels of the doubly even nuclei exhibit a striking feature of quite high values (~ 1 MeV) for isotopes with $N \leq 58$ suddenly changing to very low values (~ 0.2 MeV) for isotopes with $N \geq 60$. This sudden onset of deformation at $N \approx 60$ evident[1] from the drastic lowering of the 2^+ state and the enhanced $B(E2;2^+ \rightarrow 0^+)$ values indicate some characteristic changes in the structure of the nuclei with A around 100.

The sudden onset of deformation at $N \approx 60$ can be clearly understood only after studying the microscopic structure regarding the occupation of single particle levels by protons and neutrons in the region of transition. Some factors responsible for this sudden onset of deformation were identified earlier[3–6] by performing calculations for Zr nuclei in restricted configuration space of $1p_{1/2}$, $0g_{9/2}$, and $1d_{5/2}$ orbitals for protons and $2s_{1/2}$, $1d_{3/2}$, $0g_{7/2}$, and $0h_{11/2}$ orbitals for neutrons by assuming an inert strontium core with $Z=38$ and $N=56$. It was conjectured from the results of these calculations that the deformation in this region of nuclei can be due to the strong n-p correlations when the protons occupy the $0g_{9/2}$ orbital and the neutrons occupy its spin-orbit partner (SOP) the $0g_{7/2}$ orbital. Apart from this correlation between the $0g_{9/2}$ proton and $0g_{7/2}$ neutron orbitals, there can be a significant correlation between the $0g_{9/2}$ proton and $0h_{11/2}$ neutron orbitals as the number of neutrons increases.[4] It should be mentioned here that these conclusions are arrived at by assuming an inert ^{94}Sr core. It must be emphasized that the assumption of $0g_{9/2}$ or $1d_{5/2}$ subshell closure need not be valid, as has been explicitly demonstrated in the case of $0f_{7/2}$ subshell closure in nickel isotopes from the detailed investigations in large configuration space.[7,8]

The motivation of this paper was to investigate the factors responsible for the sudden onset of deformations at around $N=60$ in Sr, Zr, and Mo nuclei by studying the systematic change in the occupancy of the single-particle states from nucleus to nucleus without assuming any subshell closure such as $0f_{5/2}$ for protons as well as $0g_{9/2}$ and $1d_{5/2}$ for neutrons. The calculations are performed in the framework of the Hartree-Fock-Bogoliubov (HFB) formalism in a large configuration space of $0f_{7/2}$, $1p_{3/2}$, $0f_{5/2}$, $1p_{1/2}$, $0g_{9/2}$, $1d_{5/2}$, $0g_{7/2}$, $1d_{3/2}$, and $2s_{1/2}$ orbitals for protons and $0g_{9/2}$, $1d_{5/2}$, $0g_{7/2}$, $1d_{3/2}$, $2s_{1/2}$, $0h_{11/2}$, $1f_{7/2}$, $0h_{9/2}$, $1f_{5/2}$, $2p_{3/2}$, and $2p_{1/2}$ orbitals for neutrons. The energy spectra and the $B(E2;2^+ \rightarrow 0^+)$ values are computed in the variational formalism with angular momentum projection and nucleon number conservation in each state of the nucleus. The results of the energy spectra in the deformed nuclei ^{98}Sr, ^{100,102}Zr, and ^{104,106}Mo are presented in this paper. The details of the calculations are outlined in Sec. II, the results are discussed in Sec. III, and the conclusions are presented in Sec. IV.

II. DETAILS OF THE CALCULATIONS

It is obvious that for realistic nuclear structure calculations in the framework of microscopic many-body theory, one would have to use large configuration space. The computational difficulties involved in performing the variational projection calculations in large configuration space can be somewhat reduced by using a simpler many-body Hamiltonian. In the present calculations, we employ the quadrupole plus pairing $(Q+P)$ interaction Hamiltonian

$$H=\sum \epsilon_\alpha a_\alpha^\dagger a_\alpha - \tfrac{1}{2}\chi \sum q^\mu_{\alpha\gamma} q^\mu_{\delta\beta} a_\alpha^\dagger a_\beta^\dagger a_\delta a_\gamma - \tfrac{1}{2} G \sum (-)^{j_\alpha - m_\alpha + j_\gamma - m_\gamma} a_\alpha^\dagger a_{\bar\alpha}^\dagger a_{\bar\gamma} a_\gamma \, , \quad (1)$$

where q^μ is the quadrupole operator, and χ and G are the strengths of the quadrupole and pairing interactions, respectively. The subscript α in Eq. (1) denotes all the quantum numbers $(n_\alpha, l_\alpha, j_\alpha, m_\alpha)$ necessary for the specification of a spherical single particle state with energy ϵ_α. The state $\bar\alpha$ is connected to the state α by the time reversal operator. The sums in Eq. (1) run over the entire configuration space. The present calculations are performed by following the same procedure as that of Kumar and Baranger[9] with the configuration space of two major shells, one of each parity, for both valence protons and neutrons. In the mass region under investigation, the appropriate major shells for protons are $N=3$ and 4, whereas those for neutrons are $N=4$ and 5. In this configuration space, the values (in MeV) $\chi=57A^{-1.4}$, $G_p=24A^{-1}$, and $G_n=22A^{-1}$ are employed for the strength parameters so as to obtain reasonable agreement with the deformations extracted[1] from experimental $B(E2)$ values for nuclei in the mass region under consideration. The single particle energies are obtained from Nilsson model parameters.[10] This large configuration space would enable us to examine the role played by the following:

(i) the nonclosure of the $0f_{5/2}$ subshell for protons and the $0g_{9/2}$, $1d_{5/2}$ subshells for neutrons;

(ii) the occupancy of the $0h_{11/2}$ neutron orbital;

(iii) the correlations between the $0g_{9/2}$ proton and its SOP $0g_{7/2}$ neutron orbitals in the onset of deformations at $N=60$.

The equilibrium deformation of a nucleus is obtained by minimizing the expectation value of the Hamiltonian of Eq. (1) in the intrinsic HFB state. The final expression for the HFB energy is given by[11]

$$E^{\mathrm{HFB}}=\sum_{i,\tau}\epsilon_{i\tau}v_{i\tau}^2-\tfrac{1}{2}\chi\sum_{\mu}Q_\mu^2-\sum_{\tau}\Delta_\tau^2/G_\tau\ . \tag{2}$$

The sum in the first term of Eq. (2) implies the summation over the deformed proton and neutron orbitals with energy $\epsilon_{i\tau}$ and occupation probability $v_{i\tau}^2$. The intrinsic quadrupole moment Q_μ in Eq. (2) is given by

$$Q_\mu=\sum_{i,\tau}v_{i\tau}^2(q_\mu^\tau)_{ii}\ . \tag{3}$$

The HFB calculations in the $Q+P$ model are carried out self-consistently to determine the energies $\epsilon_{i\tau}$ and the occupation probabilities $v_{i\tau}^2$ from the chemical potentials λ_τ and pairing gaps Δ_τ at the minimum of energy E^{HFB}. The equilibrium deformation parameters for a nucleus are finally obtained from the intrinsic quadrupole moments of Eq. (3) corresponding to the minimum of energy.

The equilibrium deformation calculations by employing the $Q+P$ interaction Hamiltonian in this large configuration space indicate that the nuclei in this mass region prefer a prolate shape. Hence, in order to calculate energy spectra and transition probabilities in the variation after projection (VAP) formalism,[12] the trial wave function is taken to be the good angular momentum state projected from the intrinsic prolate state Φ_0 $(\beta,\Delta_p,\Delta_n,\lambda_p,\lambda_n)$ for the nucleus. The deformation β, the pairing gaps Δ_p,Δ_n, and the chemical potentials λ_p,λ_n are the variational parameters for each angular momentum state J. The suffixes p and n refer to protons and neutrons, respectively. The nuclear energy E^J of the state J is calculated by minimizing the expectation value of the Hamiltonian H in the projected state Ψ_M^J.[13] The energy minima are found by varying the parameters β, Δ_p, Δ_n, λ_p, and λ_n simultaneously. For each set of values of β, Δ_p, and Δ_n the chemical potentials λ_p and λ_n are varied so as to yield the correct number Z of protons and N of neutrons for each angular momentum state J. Since the number projection calculations are laborious in the large configuration space, we have resorted to the number conservation prescription in each projected state. It has been demonstrated that the number conservation prescription is a good and comparatively simpler alternative to improve the quality of agreement between the theoretical and experimental results.[12] The static quadrupole moments and the $B(E2;2^+\rightarrow0^+)$ values are finally computed from the number conserved projected wave functions. The effects of core polarization are simulated by ascribing effective charges[9] for protons and neutrons.

III. RESULTS AND DISCUSSION

The results of the microscopic variational calculations with a $Q+P$ interaction Hamiltonian in large configuration space of $N=3$, 4 major shells for protons and $N=4$, 5 major shells for neutrons with an inert core of $Z=20$ and $N=40$ are presented here. The systematics of nuclear deformations in even-A isotopes of Sr, Zr, and Mo with $50\lesssim N\lesssim 64$ are studied in a variational self-consistent approach as indicated in Sec. II. The present calculations show that all the Sr, Zr, and Mo nuclei with $N\leq58$ are very nearly spherical in shape, whereas those with $N\geq60$ prefer a highly deformed prolate shape. The values of the deformation parameter β, the intrinsic quadrupole moments Q_p,Q_n and pairing gaps Δ_p,Δ_n for protons and neutrons are displayed in Table I for all the nuclei under investigation here. The sudden onset of a large deformation precisely at $N=60$ in Sr, Zr, and Mo isotopes is clearly evident from the results of our calculations in Table I. The large pairing gaps in spherical nuclei are substantially reduced with the onset of deformation in all three sets of nuclei.

The present calculations are performed in a large configuration space without assuming any subshell closure. The reasons for the drastic change in equilibrium deformation at $N=60$ may therefore be clearly brought out by such calculations. The characteristics of the deformation can be understood from the systematics of filling the $1p_{3/2}$ and $0f_{5/2}$ proton subshells and the $0g_{9/2}$ and $1d_{5/2}$ neutron subshells, occupancy of the $0g_{9/2}$ proton and its SOP $0g_{7/2}$ neutron orbitals, as well as the lowering of the $0h_{11/2}$ neutron orbital. The occupancies of various single particle orbitals obtained from our calculations in Sr, Zr, and Mo isotopes are shown in Tables II and III for protons and neutrons, respectively.

It is seen from the occupancies of proton orbitals in Table II that the $0f_{7/2}$ orbital is almost completely filled for all the nuclei. Thus $Z=28$ can be conveniently considered as an inert core for protons in these nuclei. This is, however, not the case for the $Z=38$ core which is often employed in many calculations[3–5] for nuclei in this mass region. It is clear from Table II that both $1p_{3/2}$ and $0f_{5/2}$ orbitals are only partially filled in these nuclei, and as one approaches the isotope with $N=60$, the occupancy of these orbitals is suddenly reduced by a substantial amount. At the same characteristic neutron number, the occupancy of $0g_{9/2}$ and $1d_{5/2}$ orbitals is substantially in-

TABLE I. The equilibrium deformations β, the intrinsic quadrupole moments Q_p and Q_n (in barns), and the pairing gaps Δ_p and Δ_n (in MeV) for protons and neutrons, respectively, are tabulated for Sr, Zr, and Mo nuclei.

Nucleus	β	Q_p	Q_n	Δ_p	Δ_n
^{88}Sr	0.003	0.01	0.01	1.67	1.35
^{92}Sr	0.007	0.03	0.05	1.54	1.92
^{94}Sr	0.01	0.05	0.10	1.48	2.06
^{96}Sr	0.04	0.16	0.34	1.42	2.14
^{98}Sr	0.39	2.01	3.39	1.00	1.26
^{100}Sr	0.44	2.24	3.95	0.97	1.00
^{90}Zr	0.001	0.01	0.01	1.60	1.25
^{94}Zr	0.003	0.02	0.03	1.47	1.85
^{96}Zr	0.006	0.03	0.06	1.41	2.00
^{98}Zr	0.01	0.04	0.10	1.35	2.09
^{100}Zr	0.40	2.17	3.43	1.05	1.21
^{102}Zr	0.44	2.43	4.02	0.91	0.93
^{96}Mo	0.004	0.02	0.03	1.46	1.79
^{98}Mo	0.007	0.03	0.06	1.41	1.94
^{100}Mo	0.01	0.06	0.12	1.36	2.02
^{102}Mo	0.38	2.20	3.36	1.11	1.23
^{104}Mo	0.45	2.62	4.09	0.70	0.87
^{106}Mo	0.43	2.57	4.04	0.79	1.17

creased. At $N=60$, the depletion in the proton number occupying $0f_{5/2}$ and $1p_{3/2}$ orbitals is around 3.0, and this is compensated by an increase of about 2.0 and 0.8 in the occupancy of $0g_{9/2}$ and $1d_{5/2}$ orbitals, respectively. There is also a slight increase in the occupancy of the $0g_{7/2}$ orbital at $N=60$.

The occupancies of the neutron orbitals listed in Table III demonstrate clearly that the $1d_{5/2}$ orbital is only partially filled, to less than half its capacity, in any of the nuclei under investigation. This indicates that the assumption[3–5] of a neutron core with $N=56$ is certainly not valid for these nuclei. The $0g_{9/2}$ orbital is almost completely filled for nuclei with $N\leq 58$. There is, however, a drastic reduction from about 9.3 to 7.3 in the occupancy of this orbital at $N=60$ in all three sets of nuclei. Moreover, the reduced value of 7.3 remains approximately constant for all the higher isotopes with $N\geq 60$. With this characteristic change in the nature of occupancy of the $0g_{9/2}$ neutron orbital at $N=60$, even the assumption of the $N=50$ core for the nuclei in this mass region seems to be unjustified. Thus from the partial occupation of the $0f_{5/2}$ proton orbital and the $0g_{9/2}$ and $1d_{5/2}$ neutron orbitals, one can conclude that the choice of ^{94}Sr as well as ^{88}Sr as an inert core is not satisfactory.

This sudden depletion of protons from the $0f_{5/2}$ orbital and of neutrons from the $1d_{5/2}$ and $0g_{9/2}$ orbitals is a crucial factor responsible for the onset of deformation at $N=60$. The reduction of nucleon numbers in these lower

TABLE II. The occupancies of the single particle orbitals for protons in Sr, Zr, and Mo nuclei.

Nucleus	$0f_{7/2}$	$0f_{5/2}$	$1p_{3/2}$	$1p_{1/2}$	$0g_{9/2}$	$0g_{7/2}$	$1d_{5/2}$	$1d_{3/2}$	$2s_{1/2}$
^{88}Sr	7.73	4.60	3.22	0.93	1.23	0.14	0.10	0.03	0.02
^{92}Sr	7.76	4.67	3.26	0.93	1.12	0.12	0.09	0.03	0.02
^{94}Sr	7.77	4.70	3.29	0.93	1.07	0.12	0.08	0.03	0.01
^{96}Sr	7.78	4.72	3.29	0.92	1.06	0.11	0.08	0.03	0.01
^{98}Sr	7.30	3.48	1.97	0.67	3.09	0.31	0.88	0.18	0.12
^{100}Sr	6.99	3.45	1.93	0.67	3.09	0.45	0.97	0.29	0.16
^{90}Zr	7.80	5.16	3.53	1.30	1.88	0.16	0.11	0.04	0.02
^{94}Zr	7.82	5.24	3.57	1.33	1.75	0.14	0.10	0.03	0.02
^{96}Zr	7.84	5.27	3.59	1.34	1.69	0.13	0.09	0.03	0.02
^{98}Zr	7.85	5.30	3.61	1.35	1.63	0.13	0.09	0.03	0.01
^{100}Zr	7.54	3.71	2.14	0.70	3.81	0.61	0.96	0.36	0.17
^{102}Zr	7.40	3.61	2.01	0.69	3.73	0.79	1.03	0.52	0.22
^{96}Mo	7.86	5.51	3.71	1.60	2.96	0.18	0.12	0.04	0.02
^{98}Mo	7.87	5.53	3.73	1.61	2.92	0.17	0.11	0.04	0.02
^{100}Mo	7.87	5.55	3.74	1.63	2.88	0.16	0.11	0.04	0.02
^{102}Mo	7.67	4.06	2.48	0.77	4.46	0.86	1.00	0.49	0.21
^{104}Mo	7.66	3.75	2.11	0.70	4.63	1.08	1.11	0.70	0.26
^{106}Mo	7.67	3.81	2.19	0.71	4.59	1.04	1.08	0.66	0.25

TABLE III. The occupancies of the single particle orbitals for neutrons in Sr, Zr, and Mo nuclei.

Nucleus	$0g_{9/2}$	$0g_{7/2}$	$1d_{5/2}$	$1d_{3/2}$	$2s_{1/2}$	$0h_{11/2}$	$0h_{9/2}$	$1f_{7/2}$	$1f_{5/2}$	$2p_{3/2}$	$2p_{1/2}$
^{88}Sr	8.73	0.44	0.41	0.08	0.04	0.19	0.04	0.04	0.02	0.01	0.00
^{92}Sr	9.15	1.80	1.68	0.28	0.15	0.65	0.11	0.10	0.04	0.03	0.01
^{94}Sr	9.23	2.55	2.31	0.40	0.22	0.91	0.15	0.13	0.05	0.04	0.01
^{96}Sr	9.29	3.30	2.88	0.56	0.30	1.21	0.18	0.16	0.06	0.04	0.02
^{98}Sr	7.27	3.16	2.05	1.09	0.67	3.20	0.41	1.29	0.37	0.35	0.14
^{100}Sr	7.28	3.25	2.06	1.13	0.70	3.89	0.72	1.51	0.73	0.46	0.27
^{90}Zr	8.86	0.39	0.37	0.07	0.04	0.17	0.04	0.03	0.02	0.01	0.00
^{94}Zr	9.19	1.79	1.68	0.27	0.15	0.63	0.11	0.10	0.04	0.03	0.01
^{96}Zr	9.27	2.55	2.33	0.39	0.21	0.89	0.14	0.13	0.05	0.03	0.01
^{98}Zr	9.34	3.31	2.92	0.52	0.29	1.18	0.17	0.15	0.06	0.04	0.02
^{100}Zr	7.30	3.17	2.05	1.08	0.67	3.21	0.40	1.29	0.36	0.34	0.13
^{102}Zr	7.27	3.24	2.05	1.12	0.71	3.90	0.72	1.52	0.74	0.46	0.27
^{96}Mo	9.24	1.79	1.69	0.26	0.14	0.61	0.10	0.09	0.04	0.03	0.01
^{98}Mo	9.30	2.56	2.34	0.38	0.20	0.87	0.14	0.12	0.05	0.03	0.01
^{100}Mo	9.37	3.32	2.94	0.51	0.28	1.15	0.16	0.15	0.06	0.04	0.02
^{102}Mo	7.43	3.21	2.10	1.08	0.66	3.21	0.35	1.24	0.30	0.31	0.11
^{104}Mo	7.28	3.23	2.04	1.12	0.70	3.92	0.71	1.52	0.75	0.46	0.27
^{106}Mo	7.68	3.73	2.48	1.20	0.71	4.26	0.85	1.55	0.77	0.50	0.27

orbitals is compensated by the increase of protons in the $0g_{9/2}$ and $1d_{5/2}$ orbitals and of neutrons in the $0h_{11/2}$ and $1f_{7/2}$ orbitals for nuclei with $N \geq 60$. The sudden reduction in neutron number of about 2.0 in the $0g_{9/2}$ and 0.9 in the $1d_{5/2}$ orbital is accompanied by the simultaneous enhancement of about 2.0 in the $0h_{11/2}$ and 1.0 in the $1f_{7/2}$ orbital. This sudden substantial increase in the occupancies of the high-j orbitals ($0h_{11/2}$ for neutrons and $0g_{9/2}$ for protons) is an important factor in the onset of deformation at $N=60$. The change in the occupancies of the $1d_{5/2}$ proton and the $1f_{7/2}$ neutron orbital can also contribute to this effect. It should be pointed out here that the occupancy of the $0g_{7/2}$ neutron orbital saturates to about 3.3 at $N=58$ and remains practically constant for all the heavier isotopes in all three sets of nuclei. However, the occupancy of its SOP orbital $0g_{9/2}$ for protons increases suddenly at $N=60$. As a consequence, the enhanced correlations between the protons in the $0g_{9/2}$ orbital and neutrons in the $0g_{7/2}$ orbital can also be one of the factors leading to deformations in this mass region.

The yrast spectra of the neutron-rich deformed isotopes of Zr and Mo nuclei have a rotational character. These energy spectra can be taken as a criterion for testing the validity of our microscopic description of these nuclei with a $Q+P$ interaction Hamiltonian. We have therefore calculated the energy spectra of the deformed even-even nuclei ^{98}Sr, ^{100,102}Zr, and ^{104,106}Mo in the variation after projection (VAP) formalism[12] with angular momentum projection and nucleon number conservation in each state. The nuclear energies are calculated by minimizing the expectation value of the Hamiltonian in Eq. (1) in the projected state by varying the deformation β, pairing gaps Δ_p, Δ_n, and chemical potentials λ_p, λ_n for each angular momentum state J. The results of our calculations in all five nuclei studied here show that the deformation β remains constant for $0 \lesssim J \lesssim 4$ and increases slightly for higher J values. The pairing gap Δ_p for protons remains nearly constant for all the states, whereas that for neutrons decreases for higher ($J \geq 6$) angular momentum states. The variational parameters β, Δ_p, and Δ_n of our microscopic calculations are shown in Table IV for a representative nucleus ^{102}Zr. The computed energy spectra in all five nuclei are compared with the corresponding experimental spectra[1,14] in Fig. 1. It is seen from Fig. 1 that the experimental energy spectra are reproduced reasonably well by our calculations.

TABLE IV. The deformation β, the pairing gaps Δ_p, Δ_n (in MeV), and the calculated and experimental energies (in MeV) for each angular momentum state J in ^{102}Zr.

J^π	β	Δ_p	Δ_n	E^J	
				Calc.	Expt.
0^+	0.43	0.90	1.00	0.00	0.00
2^+	0.44	0.92	0.96	0.14	0.15
4^+	0.44	0.92	0.96	0.46	0.48
6^+	0.46	0.88	0.70	0.90	0.96
8^+	0.46	0.88	0.70	1.44	1.55
10^+	0.48	0.83	0.24	2.04	
12^+	0.48	0.83	0.24	2.67	

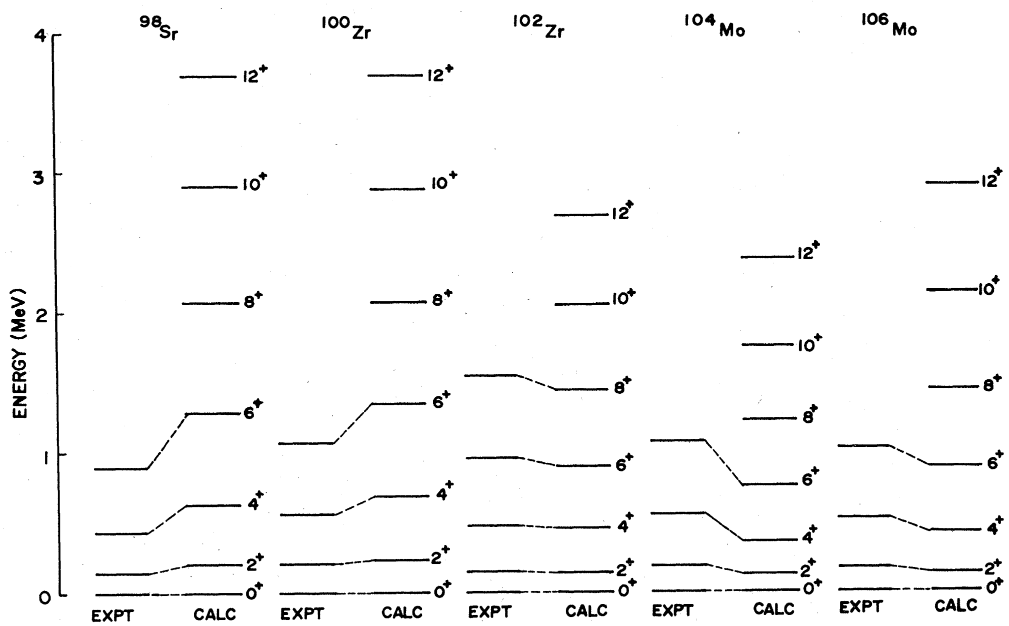

FIG. 1. The calculated energy spectra up to $J=12^+$ in ^{98}Sr, ^{100,102}Zr, and ^{104,106}Mo nuclei are compared with the corresponding experimental energy spectra.

The wave functions of the present microscopic calculations are tested by calculating the transition probabilities in these nuclei. The static quadrupole moments $Q(2^+)$ and the $B(E2;2^+\rightarrow0^+)$ values are calculated from the number conserved projected wave functions. The effects of core polarization are incorporated by ascribing effective charges $e_p=(1+Z/A)e$ and $e_n=(Z/A)e$ for protons and neutrons, respectively. The computed $Q(2^+)$ and $B(E2;2^+\rightarrow0^+)$ values in all five nuclei are displayed in Table V. It is seen from Table V that the calculated $B(E2)$ values are in good agreement with the corresponding experimental[1,14] values.

IV. CONCLUSIONS

The onset of deformation at $N=60$ in the neutron-rich isotopes of Sr, Zr, and Mo is studied in a microscopic variational formulation with a $Q+P$ interaction Hamiltonian. The calculations are performed in a large configuration space of $N=3,4$ major shells for protons and $N=4,5$ major shells for neutrons with an inert core of $Z=20$ and $N=40$. This large configuration space has clearly revealed the role played by the nonclosure of the $0f_{5/2}$ subshell for protons and the $0g_{9/2}$ and $1d_{5/2}$ subshells for neutrons as well as the enhancement in the occupation of the $0h_{11/2}$ neutron orbital in the onset of deformation at $N=60$ in all the three sets of nuclei. The present calculations indicate that the assumption of ^{94}Sr or even ^{88}Sr as an inert core made in the structure calculations of the nuclei in the mass region around $A=100$ is not satisfactory. The sudden depletion of protons from the $0f_{5/2}$ orbital and of neutrons from the $1d_{5/2}$ and $0g_{9/2}$ orbitals at $N=60$ is, in fact, a salient feature in the intrinsic structure of these nuclei. The compensation of this depletion by a substantial increase in the occupancies of the high j orbitals ($0g_{9/2}$ for protons and $0h_{11/2}$ for neutrons) is an important factor responsible for the onset of deformation at $N=60$. The simultaneous increase in the occupancy of the $0g_{9/2}$ orbital for protons and its spin orbit partner $0g_{7/2}$ for neutrons at around $N=60$ also contributes to the onset of deformation. The microscopic description of these nuclei with a $Q+P$ interaction Hamiltonian is amply justified from the calculated energy spectra and transition probabilities. The energy spectra and the $B(E2;2^+\rightarrow0^+)$ values for the deformed even-even nuclei ^{98}Sr, ^{100,102}Zr, and ^{104,106}Mo are calculated in the framework of the variation after projection formalism with angular momentum projection and nucleon number conservation in each state. The experimental energy spectra and the $B(E2)$ values are well reproduced by the present calculations.

TABLE V. The static quadrupole moments $Q(2^+)$ (in e b) and the $B(E2;2^+\rightarrow0^+)$ values (in e^2b^2) for ^{98}Sr, ^{100,102}Zr, and ^{104,106}Mo nuclei.

Nucleus	$Q(2^+)$	$B(E2;2^+\rightarrow0^+)$	
		Calc.	Expt.
^{98}Sr	-1.33	0.22	0.22
^{100}Zr	-1.20	0.35	0.23
^{102}Zr	-1.44	0.51	0.66
^{104}Mo	-1.50	0.54	0.43
^{106}Mo	-1.54	0.58	0.43

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