Shell model description of the low-lying states of the odd-mass I nuclei:$^{121-135}$I

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Introduction

The odd-mass nuclei in the $Z > 50$ transition region show collective features which have generated considerable theoretical interest. Iodine nuclei with $Z = 53$ form an important link in the systematics of the transitional region between the primarily spherical Sn nuclei and the well-deformed La and Ce nuclei. The positive parity band structures originating from the proton $g_{7/2}$ and $d_{5/2}$ orbitals in odd-A iodine isotopes have been extensively studied through experimental measurements as well as theoretical calculations, however, a consistent interpretation for them is still not available. In an earlier study by Gordon *et al.* [1], systematic occurrence of two cascades of $\Delta I = 2$ collective bands built on $g_{7/2}$ and $d_{5/2}$ configurations, respectively was observed in $^{117-127}$I. Later, experimental investigations have reported several new $\Delta I = 1$ interband transitions connecting the two $\Delta I = 2$ cascades, see [2] and references therein. It has been suggested that the two $\Delta I = 2$ cascades may be interpreted as the $\alpha = -1/2$ and $+1/2$ signature partners of a common configuration, forming together a $\Delta I = 1$ band [2]. However, the exact configuration of this $\Delta I = 1$ band is still not known. In the present work we have carried out detailed shell model calculation for Iodine isotopes $^{121-135}$I to interpret the low-lying states of this $\Delta I = 1$ collective band.

Shell Model Hamiltonian

The model space utilized in the calculation consists of $0g_{7/2}$, $1d_{5/2}$, $1d_{3/2}$, $2s_{1/2}$, and $0h_{11/2}$ orbitals for proton as well as neutron particles. The proton and neutron single particle energies have been taken from Brown *et al.* [3] . We used the shell-model code NuShellX@MSU [4]. The residual two-body interaction is obtained starting with a G matrix derived from the Bonn-A nucleon-nucleon interaction [5].

Results and Discussions

A comparison of the experimental [6] and calculated levels of $^{121-135}$I up to an excitation energy of 2 MeV is shown in Fig. 1-2. As seen from these figures, the agreement of the theoretical and experimental data is very good. The ground state spin of $5/2^+$ for $^{121-127}$I, and $7/2^+$ for $^{131-135}$I has been correctly reproduced in our calculations. For ^{129}I the calculations predict a ground state spin of $5/2^+$, whereas the experimentally observed ground state spin is $7/2^+$. This may be attributed to the fact that the energy difference between experimentally observed ground state ($7/2^+$) and first excited state ($5/2^+$) is only 28 keV. The dominent components of the wave function for the ground state are shown in Table I. For $^{131-135}$I the ground state is predominantly $\pi g_{7/2}$ configuration. However, for the $^{121-129}$I the calculations predict a heavy admixture of $\pi g_{7/2}$ and $\pi d_{5/2}$ configurations.

Acknowledgments

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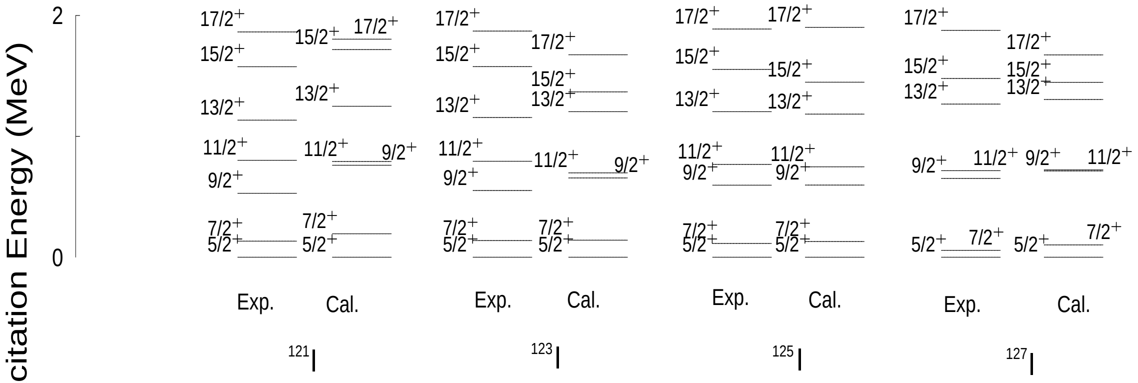

FIG. 1: The experimental and calculated energy levels of $^{121-127}$I.

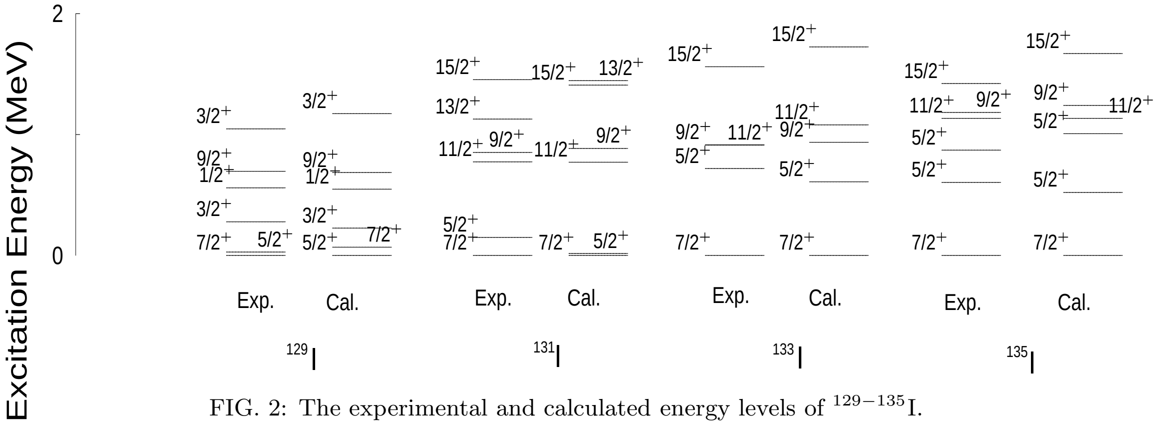

FIG. 2: The experimental and calculated energy levels of $^{129-135}$I.

TABLE I: Wave function components for the ground state of Z = 53 isotopes.

nuclei	J^{π}	Neutron wave function	Proton wave function	Amplitude
^{121}I	$5/2^+$	$(0g_{7/2})^8(1d_{5/2})^6(1d_{3/2},2s_{1/2})^2(0h_{11/2})^2$	$(0g_{7/2})^2(1d_{5/2})^1$	48.18
		$(0g_{7/2})^8(1d_{5/2})^6(1d_{3/2},2s_{1/2})^2(0h_{11/2})^2$	$(0g_{7/2})^3(1d_{5/2})^0$	24.79
^{123}I	$5/2^+$	$(0g_{7/2})^8(1d_{5/2})^6(1d_{3/2},2s_{1/2})^2(0h_{11/2})^4$	$(0g_{7/2})^2(1d_{5/2})^1$	25.09
		$(0g_{7/2})^8(1d_{5/2})^6(1d_{3/2},2s_{1/2})^2(0h_{11/2})^4$	$(0g_{7/2})^3(1d_{5/2})^0$	25.51
^{125}I	$5/2^+$	$(0g_{7/2})^8(1d_{5/2})^6(1d_{3/2},2s_{1/2})^2(0h_{11/2})^6$	$(0g_{7/2})^2(1d_{5/2})^1$	8.71
		$(0g_{7/2})^8(1d_{5/2})^6(1d_{3/2},2s_{1/2})^4(0h_{11/2})^4$	$(0g_{7/2})^2(1d_{5/2})^1$	16.18
		$(0g_{7/2})^8(1d_{5/2})^6(1d_{3/2},2s_{1/2})^2(0h_{11/2})^6$	$(0g_{7/2})^3(1d_{5/2})^0$	33.71
		$(0g_{7/2})^8(1d_{5/2})^6(1d_{3/2},2s_{1/2})^4(0h_{11/2})^4$	$(0g_{7/2})^3(1d_{5/2})^0$	7.21
^{127}I	$5/2^+$	$(0g_{7/2})^8(1d_{5/2})^6(1d_{3/2},2s_{1/2})^2(0h_{11/2})^8$	$(0g_{7/2})^2(1d_{5/2})^1$	4.55
		$(0g_{7/2})^8(1d_{5/2})^6(1d_{3/2},2s_{1/2})^4(0h_{11/2})^6$	$(0g_{7/2})^2(1d_{5/2})^1$	24.08
		$(0g_{7/2})^8(1d_{5/2})^6(1d_{3/2},2s_{1/2})^2(0h_{11/2})^8$	$(0g_{7/2})^3(1d_{5/2})^0$	21.82
		$(0g_{7/2})^8(1d_{5/2})^6(1d_{3/2},2s_{1/2})^4(0h_{11/2})^6$	$(0g_{7/2})^3(1d_{5/2})^0$	19.25
^{129}I	$5/2^+$	$(0g_{7/2})^8(1d_{5/2})^6(1d_{3/2},2s_{1/2})^4(0h_{11/2})^8$	$(0g_{7/2})^2(1d_{5/2})^1$	21.18
		$(0g_{7/2})^8(1d_{5/2})^6(1d_{3/2},2s_{1/2})^4(0h_{11/2})^8$	$(0g_{7/2})^3(1d_{5/2})^0$	43.70
^{131}I	$7/2^+$	$(0g_{7/2})^8(1d_{5/2})^6(1d_{3/2},2s_{1/2})^4(0h_{11/2})^{10}$	$(0g_{7/2})^2(1d_{5/2})^1$	2.88
		$(0g_{7/2})^8(1d_{5/2})^6(1d_{3/2},2s_{1/2})^4(0h_{11/2})^{10}$	$(0g_{7/2})^3(1d_{5/2})^0$	66.75
^{133}I	$7/2^+$	$(0g_{7/2})^8(1d_{5/2})^6(1d_{3/2},2s_{1/2})^4(0h_{11/2})^{12}$	$(0g_{7/2})^3(1d_{5/2})^0$	69.64
^{135}I	$7/2^+$	$(0g_{7/2})^8(1d_{5/2})^6(1d_{3/2},2s_{1/2})^6(0h_{11/2})^{12}$	$(0g_{7/2})^3(1d_{5/2})^0$	95.30