Characterisation of the non-yrast levels in ^{102}Mo.

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Abstract

This proposal aims to use the ^{100}Mo(^{18}O,^{16}O)^{102}Mo reaction at a beam energy of ~50 MeV to populate low-lying non-yrast states in ^{102}Mo. The technique of gamma-ray spectroscopy will be used to enhance the level scheme and level lifetimes of the order of ps will be measured using the Bucharest plunger.

Introduction

The region of the nuclear chart around neutron-rich A~100 nuclei is one where the nuclear shape changes quite dramatically. Figure 1 shows the energies of the 2_1^+ states for even-A Ru, Mo, Zr, Sr and Kr nuclei. The sudden drop in the 2_1^+ energy in Zr and Sr between N=58 and N=60 indicates a sharp change to prolate deformation. (The Grodzins' formula [1] gives a β_2 deformation of $\sim$ 0.35 and 0.45 respectively for the N=60 nuclei ^{100}Zr and ^{98}Sr.) In the case of the Pd and Mo nuclei, figure 1 shows that the transition is more gentle with the E(2_1^+) of 297 keV in ^{102}Mo corresponding to a Grodzins' estimate [1] of $\beta_2 \sim 0.3$.

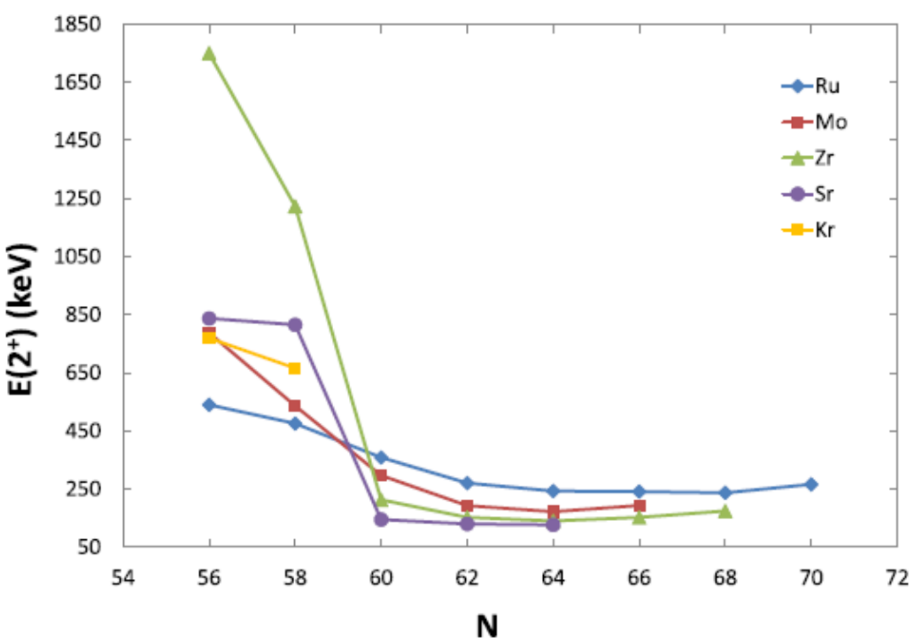

Figure 1: The energy of the 2_1^+ state, as a function of N, for even-A Ru, Mo, Zr, Sr and Kr nuclei.

Hutter et al. [2] have considered ^{102,104,106}Mo as possible examples of the X(5) dynamical symmetry [3]. Figure 2 (taken from [2]) shows the energy of the yrast levels in ^{102,104,106}Mo (normalised to E(2_1^+)) compared to predictions of vibrational and rotational limits and of the dynamical symmetry X(5). The figure shows that the energies of the yrast states in ^{104}Mo lie closest to the predictions for X(5) but that ^{102}Mo is intermediate between the vibrational limit and X(5). However, the systematics of the transition probabilities in the yrast band in ^{104}Mo are more consistent with a rotational description than X(5) (see figure 5 of [2]). This is confirmed in table 1 which lists the relative B(E2) values in the yrast bands for ^{102,104,106}Mo. The table shows that, while the values for the B(E2;$4_1^+ \rightarrow 2_1^+$)/B(E2;$2_1^+ \rightarrow 0_1^+$) ratio for all three nuclei are consistent with the X(5) prediction, it is only for ^{102}Mo that the B(E2;$6_1^+ \rightarrow 4_1^+$)/B(E2;$2_1^+ \rightarrow 0_1^+$) value agrees with the X(5) prediction. It should be noted however that the error on this value is so large that it is also in agreement with the ratio obtained using the Alaga rule (last column of table 1). The aim of this proposal is not to address the yrast structure of ^{102}Mo but figure 2 and table 1 do indicate that X(5) is an appropriate framework within which to discuss the level scheme of ^{102}Mo.

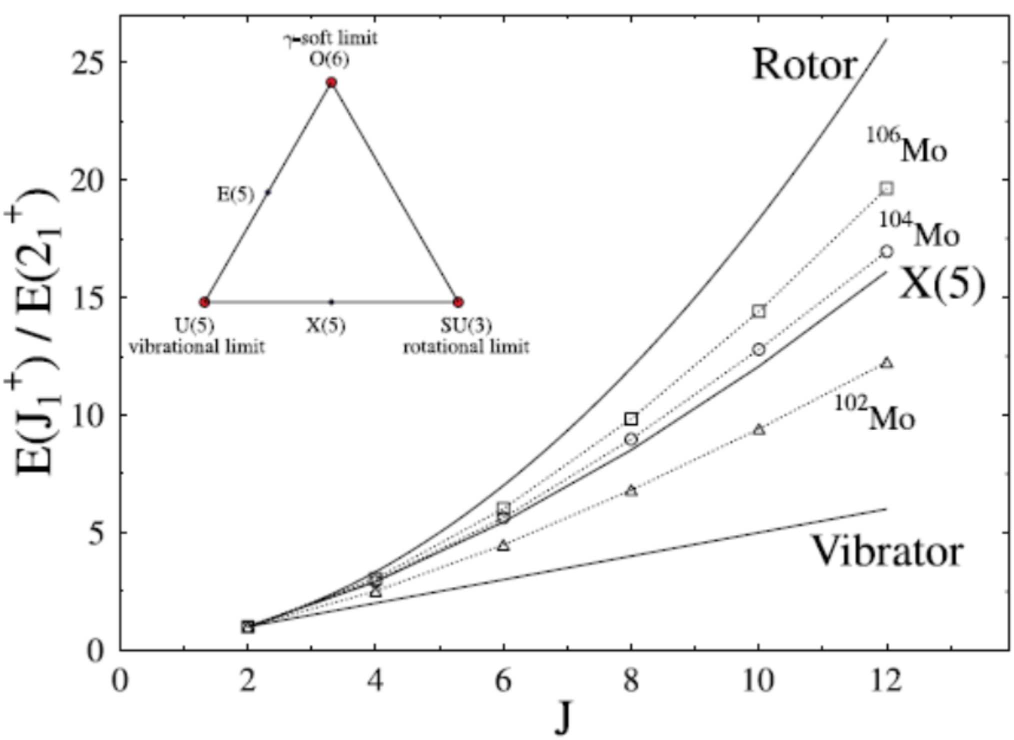

Figure 2: The ratio of the energy of the yrast levels to the E(2_1^+) for ^{102,104,106}Mo compared to predictions of vibrational and rotational limits and of the dynamical symmetry X(5). Figure taken from [2].

Aside from the yrast structure in ^{102}Mo, there is a $J^\pi = 0^+$ bandhead at 698 keV which has a measured lifetime (shown in table 2) of $\tau = 40(16)$ ps [7]. This level decays to the 2_1^+ with a B(E2) strength of 70 (30) Wu. A possible candidate for the $J^\pi = 2^+$ level built on this state is observed at 848 keV but as yet no transition has been observed between the two states. An alternative candidate, which does decay to the 0_2^+ state, does exist at 1144 keV but this $2_2^+/0_2^+$

Ratio	^{102}Mo [8, 7]	^{104}Mo [4]	^{106}Mo [5]	X(5)	Alaga
$B(E2;4_1^+\to2_1^+)/B(E2;2_1^+\to0_1^+)$	1.27(29)	1.42(13)	1.39(28)	1.60	1.43
$B(E2;6_1^+\to4_1^+)/B(E2;2_1^+\to0_1^+)$	1.88(53)	1.42(13)	1.29(55)	1.98	1.58
$B(E2;8_1^+\to6_1^+)/B(E2;2_1^+\to0_1^+)$	0.79(13)	0.74(7)	0.63(9)	2.28	
$B(E2;10_1^+\to8_1^+)/B(E2;2_1^+\to0_1^+)$		0.78(8)	0.72(10)	2.51	

Table 1: Ratios of B(E2) values in ^{102,104,106}Mo compared to the X(5) predictions and the rotational Alaga Rules.

Level energy [keV]	J^π	τ [ps]	Ref
297	2_1^+	180 (6)	[7]
698	0_2^+	40 (16)	[7]
743	4_1^+	18 (4)	[7]
1328	6_1^+	3.2 (9)	[8]
2019	8_1^+	2.6 (4)	[7]

Table 2: Known level lifetimes in ^{102}Mo.

energy splitting is not consistent with that observed in the yrast band. In both ^{104}Mo and ^{106}Mo, a 2_2^+ level exists below the first excited 0^+ state and presumably forms the bandhead of the gamma band. No such structure has yet been observed in ^{102}Mo although candidates do exist for the 2^+ (the aforementioned 1144 keV state) and the 3^+ at 1245 keV. The first aim of this proposal is therefore to use standard gamma-ray spectroscopy techniques to confirm the low-lying non-yrast structure in ^{102}Mo.

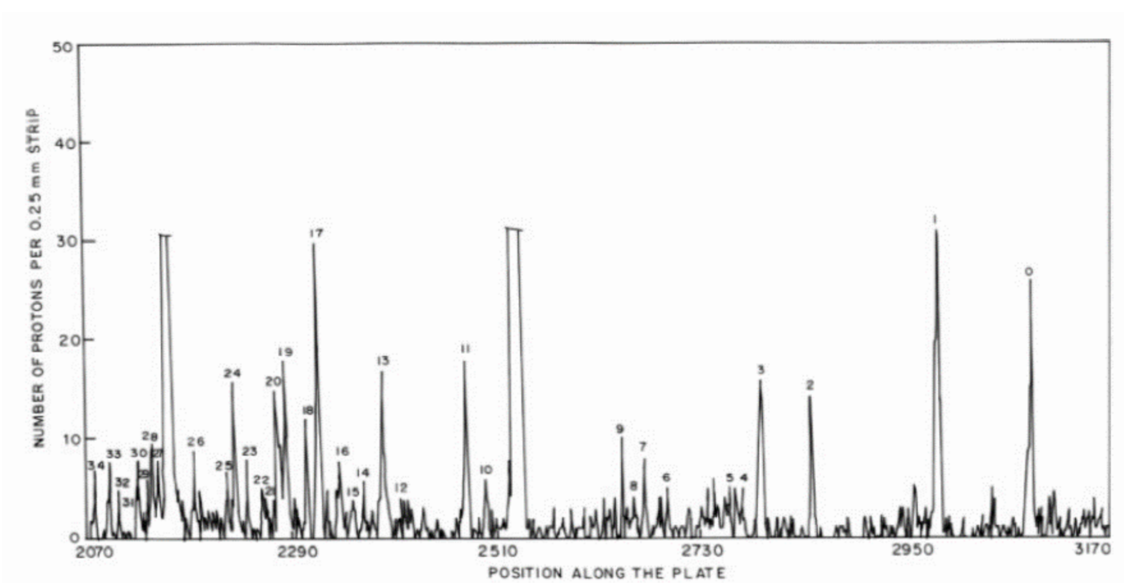

Figure 3: Energy spectrum of protons from the ^{100}Mo(t,p)^{102}Mo reaction at a triton beam energy of 12 MeV and a lab angle of 20°. Figure taken from [6].

A subsequent aim is to measure the lifetimes of levels populated strongly in the reaction. Figure 3 (taken from [6]) shows the spectrum obtained from a (t,p) reaction on ^{100}Mo. The peak labelled '0' is the ground state and the strong peaks labelled 1,3,11 and 13 correspond to the $J^{\pi}= 2^{+}$ states at 297, 850, 2248 and 2366 keV, respectively. The peak labelled '2' is the $J^{\pi}= 0^{+}$ state at 698 keV and '17' is the $J^{\pi}= 3^{-}$ state at 2522 keV. The lifetimes of the states labelled '1' and '2' in figure 3 are listed in table 2 but those of the 2_2^+ (#3) and 3_1^- (#17) states are not known. Based on extrapolation from analogous levels in ^{100}Mo, it is expected that they should be in the tens of ps range and form the main focus of this proposal. The $J^{\pi}= 2^{+}$ levels at 2248 (#11) and 2366 keV (#13) should also be populated sufficiently strongly in the experiment to enable their lifetime to be measured. Figure 4 shows the detailed predictions of the X(5) symmetry with which the measured transition probabilities will be compared.

Experimental proposal

We propose to use the ^{100}Mo(^{18}O,^{16}O)^{102}Mo reaction to populate low-lying non-yrast states in ^{102}Mo. This is analogous to a (d,p) reaction and is the same as that used at Bucharest recently in the very successful study of low-lying spin-zero states in ^{66}Ni [9]. The Coulomb barrier for ^{100}Mo(^{18}O,^{16}O)^{102}Mo is $\sim$ 51 MeV so we request an ^{18}O beam energy of 50 MeV.

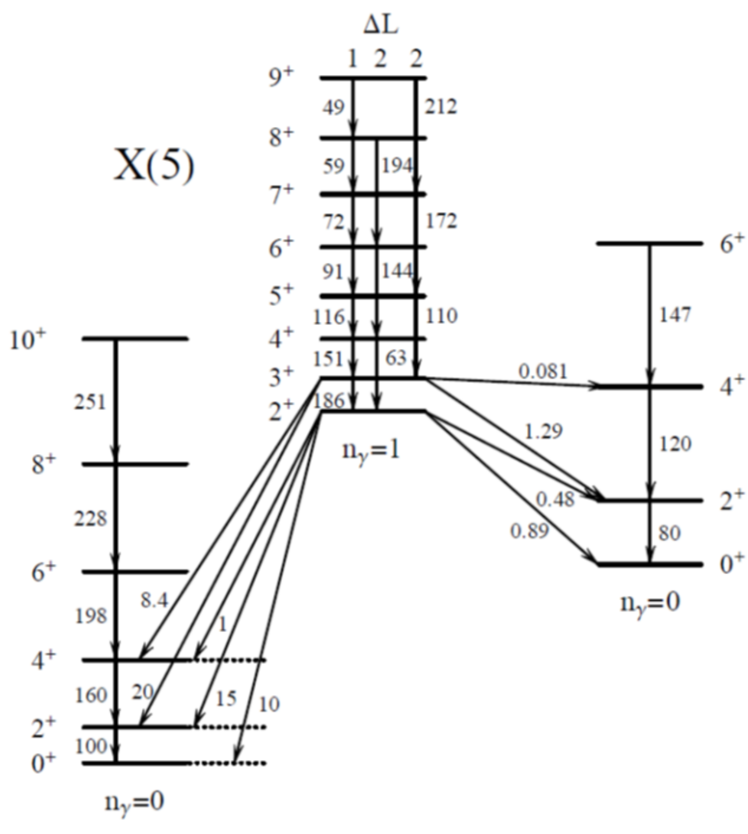

Figure 4: Energy and B(E2) predictions of X(5). Figure taken from [10].

In order to extend the known level scheme we request 3 days of beam time using a thick target to measure the gamma-ray decay from excited states. In particular, we wish to measure the intensity of the so-far-unobserved transition between the 2_2^+ and 0_2^+ states to establish whether these levels do form a band structure.

Following the thick target measurement, we request 7 days of beam time using a thin target and the Bucharest plunger to measure the lifetimes of levels in the ps regime.

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