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THE EFFECT OF THE $Z = 64$ SUBSHELL ON IBA CALCULATIONS

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A recently proposed scheme for IBA calculations near $Z = 64$ which involves a drastic change in the proton boson number is critically examined. It is shown that this scheme is in disagreement with the experimental trends observed for the E2 transition rates.

From the early days of its development, the neutron-proton interacting boson model (IBA-2) has been closely related to the shell-model [1–3]. A trivial aspect of this relation is the number of bosons assigned to any particular nucleus. The usual procedure is to determine this number simply by counting the number of valence particle (or hole) pairs in the relevant neutron and proton shells. Thus, the possibility of a shell closure at $Z = 64$ [4] is of great importance for both shell-model and IBA-2 calculations for nuclei in the Gd region. The corresponding energy gap between the $Z = 50–64$ and $Z = 64–82$ quasi-degenerate shells may be reflected in the values of the IBA parameters derived from the spectra of these nuclei, and in particular, the boson number appropriate to each nucleus may be affected. In fact, in his early study of Nd, Sm and Gd isotopes with $N > 84$, Scholten [5] has noted an unusual dependence of the parameters on neutron and proton numbers and suggested that this behaviour may be due to the subshell closure at $Z = 64$.

In a recent letter, Gill et al. [6] study this idea in greater detail and conclude that the observed trends in the spectra of Ba–Sm isotopes with $84 < N < 90$ are well described when the number of valence protons is counted relative to $Z = 64$. For the heavier isotopes (with $N > 88$), the n–p interaction is assumed to obliterate the gap and the full $Z = 50–82$ shell is referred to. A recent analysis [7] of magnetic moments of 2_1^+ states in these nuclei appears to support this claim.

However, a closer examination of the consequences of the approach advocated in ref. [6] reveals that although it yields parameters that behave in accord with the microscopic expectations, it also leads to a contradiction with experimental observations. It appears, therefore, that its present form cannot provide a useful scheme for detailed calculations concerning nuclei in the Gd region.

The main point of departure of the calculations in ref. [6] from the earlier version [5] is the drastic change in the number of bosons. For protons, this number drops from 3 to 1 as one moves from Ba to Sm, as compared to an increase from 3 to 6 which is appropriate to the full $Z = 50–82$ shell. This results in very different expectations for the dependence of the E2 transition rates on Z. $B(E2, 2_1^+ \rightarrow 0_1^+)$ values are known to increase rapidly with boson number in all limits of the IBA. Remarkable examples of such a dependence on N_ν for Xe, Ba and Ce isotopes with $N < 82$ can be found in ref. [5]. Fig. 1 shows a comparison of the experimental values of $B(E2, 2_1^+ \rightarrow 0_1^+)$ as a function of Z with the results of IBA-2 calculations using the parameter sets of refs. [5,6]. For the Ce isotopes (which were not calculated in ref. [5] the parameters of an earlier work of Gill et al. [9], in which the full proton shell is considered, have been used. The calculations have been performed for the isotones with $N = 86$, which best show the effects of the $Z = 64$ subshell [6], and with $N = 88$, for which more accurate data are available. The value $e = 0.12\ eB$ for the boson effec

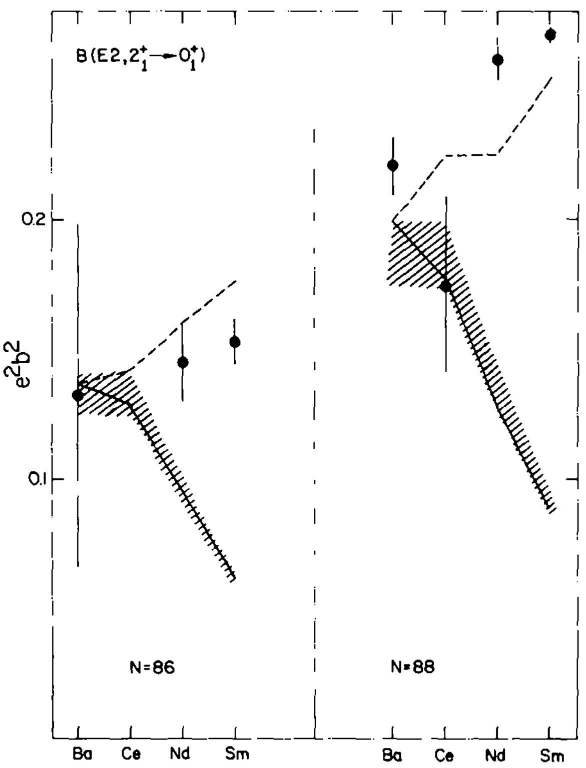

Fig. 1. Comparison of experimental [8] $B(\mathrm{E2}, 2_1^+ \to 0_1^+)$ values for the isotonic chains with N = 86 and N = 88 with IBA-2 results using the parameter sets of refs. [5,6,8]. The solid line represents the trend expected from the Z = 64 subshell closure, while the dashed line corresponds to the full Z = 50–82 shell. The hatched area displays the range of B(E2) values corresponding to the range of χ_π values allowed in ref. [6], with the solid line resulting from the χ_π values that are favoured by the fit to the energy levels. The value e = 0.12 eb for the boson effective charge [5] has been used for all nuclei.

tive charge, derived in ref. [5] for the lighter isotopes (N < 82) has been used for all nuclei. The two sets of parameters yield the same results for the Ba isotopes, because Z = 56 corresponds to N_π = 3 under both prescriptions.

Although the large error in the value for ^{142}Ba hampers definite conclusions for the N = 86 chain, the data do not support the predicted sharp decrease in the B(E2) values with increasing Z, based on the assumption of the Z = 64 subshell closure. The more accurate data for N = 88 which suggest a slightly higher value for the effective charge, clearly favour the predictions of the earlier calculations [5], with the full Z = 50–82 shell. It should be stressed that although the details of the curves depend slightly on the particular choice of the IBA-2 parameters (namely those employed in refs. [5,6,9], the general trend is independent of it and follows directly from the assumptions concerning the number of bosons. This is illustrated in the hatched area in fig. 1 which represents the range of B(E2) values corresponding to the (large) ranges allowed in ref. [6] for the parameter χ_π. Similarly, it is unlikely that one can reproduce the experimental B(E2) trend (while leaving the excitation energies unaffected) by changing some other IBA parameters. Transition rates between higher-lying states can provide further sensitive tests of the effects of the change in the number of bosons. Thus, the experimental $B(\mathrm{E2}, 4_1^+ \to 2_1^+)$ in ^{148,150}Sm also support the full-shell calculation. Unfortunately, the experimental situation does not allow a systematic comparison of the form described above.

It is interesting to compare the present results with the magnetic moments analysis of ref. [7] which supports the Z = 64 subshell assumptions. In this analysis the effective g-factors (g_π and g_ν) are assumed to be constants, and the variation in the magnetic moments is attributed to a change in the boson number. This is analogous to the assumption of a constant boson effective charge e in the present work. Evidently the M1 and E2 operators are sensitive to different components in the wavefunctions. It is hard to judge, on the basis of these phenomenological studies alone, the validity of the assumptions concerning the constancy of g_π, g_ν and e in these nuclei. It appears unlikely, however, that an increase in the boson effective charge can counter-balance the decrease in the E2 matrix elements that follows from the Z = 64 subshell closure.

To conclude, it has been shown that the assumption of a drastic effect of the subshell closure at Z = 64 on proton number proposed in ref. [6] is in conflict with the experimental observations on a quantity that is most sensitive to it, namely the E2 transition rate. Although the IBA parameters evidently depend on the underlying shell structure, the elucidation of the precise manner in which this happens in the complicated region under consideration still awaits detailed microscopic calculations. Such calculations may shed some light on the problem of the effective number of boson in the IBA [10]. Additional information on the electromagnetic properties of these nuclei may also be of great interest in this context.

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