Calculation of Nuclear Transitions by Potential Energy Surface Mapping

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**Background**

A coherent state technique is used to generate an Interacting Boson Model (IBM) Hamiltonian energy surface that simulates a mean field energy surface [1]. This allows for the prediction of the low lying energy spectra and electromagnetic transition rates that are of interest in nuclear and astrophysics.

The IBM-1 Hamiltonian is used which does not distinguish between protons and neutrons. The IBM is based on the approximation that pairs of nucleons behave like bosons with either angular momentum 0 or 2. Creation operators for the two spins are denoted by \( \hat{s}^+ \) and \( \hat{d}^+ \) respectively [2].

\[
\hat{H}_{IBM}(\zeta, \chi) = c \left( 1 - \zeta \hat{d} \cdot \hat{d}^{\dagger} + \frac{\zeta^2}{4N_B} \right)
\]

The IBM Hamiltonian is used to create IBM energy surfaces.

The expectation value of the IBM Hamiltonian is defined as a function of three parameters \( \zeta, \chi \) and \( c_B \). The \( \zeta - \chi \) Casten triangle vertices define the vibrational, rotor and \( \gamma \)-soft limits [3].

**Mapping Procedure**

Potential energy surfaces are generated using the IBM Hamiltonian for a varied values of \( c_B, \zeta, \chi \). The number of Bosons depends on the number of valence nucleons. These are compared with nuclear potential energy surfaces generated using the Tilted Axis Cranking (TAC) code.

The differences between the IBM potential and that generated in the TAC are calculated at each point where the TAC potential is 1 MeV or less. The optimal parameters have the lowest difference sum and minima that occur at the same \( \zeta_B \) value are chosen as the best fit [4]. The energy scale \( (c B) \) is determined by the first \( 2^+ \) energy determined in TAC.

**Resulting Spectra**

Various krypton, molybdenum, palladium, cadmium, gadolinium, dysprosium and erbium nuclei have been successfully mapped. Relatively good agreement exists for the energy levels. Transition rates are often within an order of magnitude when compared to experiment.

**Future Plans**

- Improve on the mapping minimization procedure.
- Use TAC generated \( B(E2) \) values to determine the beta scaling parameter \( (c B) \). This would leave just 2 unknowns.
- Add another term to Hamiltonian to account for triaxiality, which will bring down the \( \gamma \)-band [5,6].
- Use these new tools to look at some interesting nuclei like \( ^{156,158}\text{Gd} \) and \( ^{162}\text{Dy} \) and determine if this collective model can describe these nuclei. If this doesn’t some hybrid approach will need to be created.