Reduced transition probability B(E2) in even-even Ti isotopes

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Introduction

The properties of first excited states and associated quadrupole deformation parameter are very important in nuclear physics. Accurate knowledge of these properties is necessary for continuing development of nuclear model calculations and theoretical understanding of many interesting phenomena in the quantum world. The quadrupole collectivity measurements of atomic nuclei started in 1950's [1]. The nuclei were extensively studied among the valley of stability region and many nuclear structure phenomena, such as, nuclear shell closure were identified and explained in the frame work of the nuclear shell model.

In stable nuclei, large gaps exist between nuclear shells of magic proton or neutron number. These gaps result in large transition energy values between the ground and first excited states, relatively low quadrupole collectivities and small neutron capture cross sections. Due to nuclear structure effects the value of magic number is not preserved but evolve for unstable nuclei. Therefore nuclear properties of the first excited 2_1^+ states in even-even nuclei provide important information on evolution of nuclear properties and shell model studies.

Neutron rich Ti isotopes are particularly interesting because they are existing with two proton excess near the magic number proton 20. Since the nuclei in excited state will be hot rotating due to higher agitation of nucleons (higher internal excitation), a temperature of optimum value is included in the suitable statistical model and the excited levels are calculated. From these energies the E_γ values are calculated and is used in different formulae for B(E2) values.

For an electromagnetic transition from an initial nuclear state *i* (where the nucleus is at rest) to nuclear state f, the momentum of the nucleus in state *f* (after the transition) and the emitted gamma ray are equal and opposite. The electromagnetic transition between them can take place only if the emitted gamma ray carries away an amount of angular momentum ℓ such that $J_f = J_i + \ell$ which means that $|J_i - J_f| \leq \ell \leq J_i + J_f$ where $J = |J|$. The gamma transition rate is determined by the transition energy ΔE, the multipolarity, and a factor that depends upon the details of the internal nuclear structure[2].

The lifetime of an excited state decaying by γ-ray emission is determined by the transition energy, its multipolarity and the transition matrix elements. It should be noted that E2 transitions are often enhanced by an order of magnitude compared to the single particle estimates. This enhancement of these specific transitions stems from collective nuclear motion and the enhancement is particularly strong for nuclei that lie in between major shell closures.

Formalism

A lot of literatures are available for reduced transition probability. As our preliminary work, we have followed three formulae for deducting the reduced transition probability B(E2)↑and are,

$$E(2_1^+).B(E2;0^+\rightarrow 2^+) = 3.242\,.Z^2A^{-\frac{2}{3}}.$$

$$[1.000 - 0.0608(N-\overline{N})] \quad \ldots(1)$$

$$B(E2)\uparrow = 3.26\,.E^{-1.0}\,Z^2A^{-0.69}e^2b^2 \quad \ldots(2)$$

$$B(E2)\uparrow = (2.57\pm 0.45)\,.E^{-1.0}\,Z^2A^{-2/3}e^2b^2 \quad \ldots(3)$$

The Mean life time for such transition are calculated from,

$$\tau_{\gamma[PS]} = 40.81X10^{13}XE^{-5}/B(E2)\uparrow e^2b^2 \quad \ldots(4)$$

The formula (1) is taken from ref.[3,4], which is obtained in the phenomenological relation between B(E2) and E(2_1^+)and the formula(2 &3) are from ref.[5], and the mean life time formula (4) resulted from the B(E2) values of Bohr & Mottelson[6]. The main purpose of this study is to incorporate and compare the prediction by statistical approach. The optimum temperature for the formation of Ti in supernova is T=0.5MeV, according to our previous calculations. Hence the transition energy (in MeV) has been obtained from our statistical model code at T=0.5 MeV, and an attempt was made with the above formulae.

Results

The higher B(E2) value at A=50(Fig.1.a) shows a strong shell gap at N=28, the neutron magic number and such gaps are also possible at N=22 and 38. The slightly higher B(E2) value at A=38 and 56 resembles the new exotic neutron magic nos N=16 and 34 respectively as what obtained for Ni and Ca nucleus. The E_γ values for the 0→ 2^+ transition is plotted in Fig.1.b., which is the mirror image of the B(E2) plot, since E_γ has the power of –ve value.

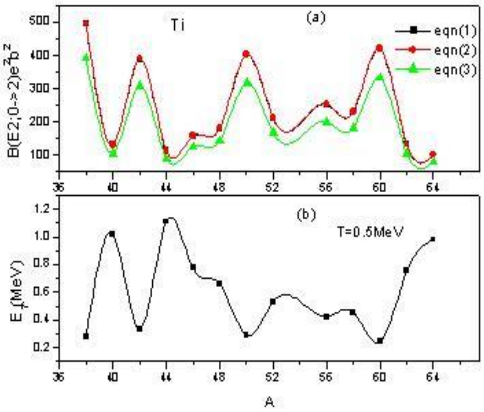

Fig. 1 Electric quadrupole transition probability of Ti (a) and transition energy (b) of Ti isotopes with N=16-42.

To find, which parameter can influence the electric quadrupole transition, we have analysed the nuclear level density obtained for all the isotopes A=38-64 through our statistical model calculations and found that the change in level density parameter ’a’ with N, coincides with the B(E2) plot which is derived from the nuclear level density,

$$\rho(U) = exp\frac{[2(a(U-E_i)^{1/2}]}{12(2\sigma^2)^{1/2}a^{1/4}(U-E_i)^{5/4}}$$

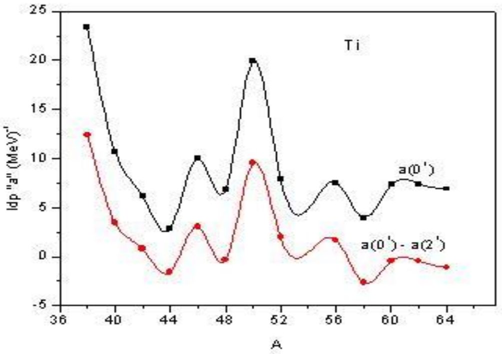

Fig. 2 Level density parameter ‘a’ of Ti which resembles the Electric quadrupole transition probability B(E2).

It is interesting to note that the reduced transition probability B(E2) depends upon the initial state (I_i) of the system before transition or the difference between the initial and final state of transition (I_i-I_f) and not only on the final state(I_f) and it hold good for N ≥ Z cases.

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