PREEQUILIBRIUM MODEL CALCULATIONS OF γ-SPECTRUM FROM ^{3}He+^{25}Mg REACTION AT $E_{\mathrm{LAB}} = 29.9$ MeV *

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High energy γ-ray cross section obtained from ^{3}He + ^{25}Mg reaction at $E_{\mathrm{lab}} = 29.9$ MeV exhibits an enhancement as compared to statistical model predictions including giant resonance strength functions. Within the preequilibrium exciton model approach which takes into account level density parameters and pairing for individual nuclei and uses the giant dipole resonance parameters found at lower excitation energy a satisfactory description of the γ-ray energy spectrum is obtained.

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1. Introduction

In light nuclei at low bombarding energies ($E/A \sim 4$ MeV/nucleon) the experimentally observed γ-ray spectrum from ^{3}He-induced reaction can be well described by statistical decay model in which an excitation of giant resonances built on excited states is taken into account [1]. However, it has been pointed out already several years ago that for higher ^{3}He energies a strong nonstatistical contribution is apparent at high E_γ [2]. Recently this behaviour (for $E_\gamma >$22 MeV) has been observed for γ-spectra obtained from highly excited ^{28}Si populated in ^{3}He- and ^{4}He-induced reactions [3].

The ^{25}Mg(^{3}He, γ) experimental data were obtained at the Tandem Accelerator Laboratory in Garching as a part of a larger project concerning an investigation of high energy γ-spectra from various light- and heavy-ion induced reactions. A 2.02 mg/cm^2 isotopically enriched ^{25}Mg target was bombarded with a beam of 29.9 MeV ^{3}He ions. This reaction populates initial states of the composite system at 50 MeV. The γ-rays from the decay of

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this highly excited nucleus were detected in a 27 cm $\times$ 33 cm NaI(Tl) crystal surrounded by a plastic anticoincidence shield. Additional lead shields were used in order to reject cosmic-ray events and low energy γ-ray background. In order to separate prompt γ-rays produced in the target from neutron induced events a standard time-of-flight technique with the pulsed beam has been applied. A detailed off-line analysis allowed to eliminate pile-up, summing and residual cosmic-rays background events.

2. Preequilibrium model calculations

Our analysis is based on a preequilibrium exciton model into which a contribution from γ-ray emission (competing with nucleon emissions) was incorporated [5, 6]. In this formulation an occurrence of γ-ray emission at all stages, *i.e.* from an initial exciton state to a fully equilibrated compound nucleus, is taken into account. In order to calculate the γ-emission energy spectrum one uses an exact solution of the time-integrated master equations of the exciton model for an arbitrary initial configuration [8]. To do this one has to supply nucleon [7] and γ-emission rates [6] . The letter contains the photoabsorption cross section which is taken in the form of the Lorenzian describing the giant dipole resonance (GDR).

In our calculations ten nuclei forming a reaction chain, *i.e.* from the composite system ($A = 28$, $Z = 14$) down to (A-3, Z-3) were taken into account, the neutron and proton inverse cross sections were calculated internally and the constant $K' = 100$ MeV^3 for the transition matrix element has been taken from the literature. In the conventional preequilibrium model calculations one usually takes a value for the single-particle level density $g = A/13$ and ignores pairing. It has been shown, however, that such approach leads to inconsistencies particularly for low excitation energies [9]. Therefore in our case we have used an extended version of the PEQAG2 code in which single particle level density parameters and pairing energies for individual nuclei were applied [10]. For this purpose we made use of recently published phenomenological systematics of the nuclear level density parameters [11]. In the calculations of the prequilibrium γ-ray spectrum we have adopted the following GDR parameters: E_{GDR}=18.1 MeV, $\Gamma_{\mathrm{GDR}} = 11.4$ MeV and $S_{\mathrm{GDR}} = 1.0$. They were found from fits of standard CASCADE calculations to the experimental ^{3}He+^{25}Mg γ-ray energy spectrum at $E_{^3\mathrm{He}} = 11.9$ MeV [4]. At this relatively low incident energy, which corresponds to the formation of the compound nucleus ^{28}Si at 34 MeV, one expects that fusion dominates in the entrance channel. In the CASCADE calculations discrete level parameters for low excitations and appropriate level density parameters for higher excitations were applied for all nuclei in the decay chain. Fig. 1 gives a comparison of the γ-ray spectrum calculated within the pree-

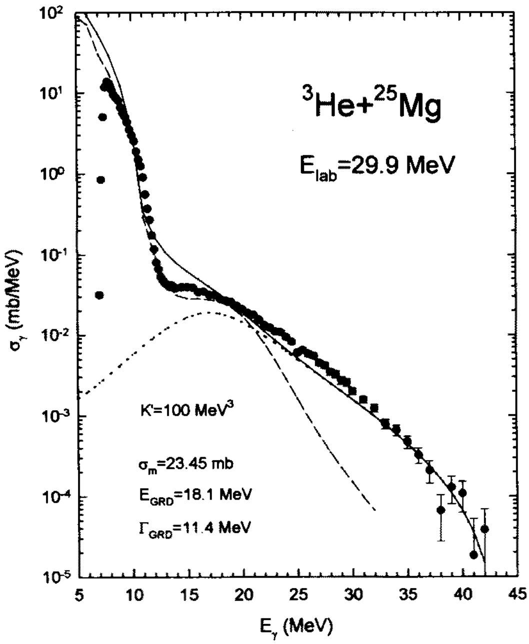

Fig. 1. A comparison of measured γ-ray spectrum from ^{3}He+^{25}Mg reaction with calculations. Preequilibrium exciton model - solid line, spectrum of γ-rays emitted from the initial composite system - dotted line, pure statistical model calculations - dashed line.

quilibrium model approach (this includes also an equilibrium contribution) with the experimental data. Also shown in this figure is the pure equilibrium model γ-ray spectrum at this energy as predicted from CASCADE. In these calculations we have also included a possibility of presence of giant quadrupole resonance (GQR). The parameters of the isovector and isoscalar GQR were taken from literature systematics for ground state. Even then the calculated spectrum underpredicts the high energy tail.

3. Conclusions

It has been shown that within the preequilibrium exciton model a satisfactory description of the γ-ray energy spectrum from ^{3}He + ^{25}Mg reaction at $E_{\rm lab}$ = 29.9 MeV is obtained. Therefore at this excitation energy of the composite system an excess of the cross section (as compared to what is predicted from purely statistical model) can be fully ascribed to preequilibrium gammas. These high energy γ-rays are predominantly emitted from various preequilibrium states of the initial composite system (see Fig. 1).

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