Study of ^{24}Mg (p, γ)^{25}Al resonance reaction at lab energy E_p^{lab} = 223 keV

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Introduction

The observations of Globular cluster M13 redgiants indicate that the abundance of Mg+Al is approximately constant whereas simultaneously those exhibit large variations in Al. This indicates that all stars of this cluster initially had same amount of Mg, but the production of Al from Mg varied. Recent observations also show that there exists anti-correlation between abundance of ^{24}Mg and Al, but the abundance of ^{25}Mg+^{26}Mg remains almost constant over a large variation of Al abundance, which is difficult to understand, since the reaction rates of ^{25}Mg +p and ^{26}Mg + p are predicted to be larger than that of ^{24}Mg + p. It is understood that a better agreement between observation and model prediction can be achieved by increasing the ^{24}Mg +p reaction rate [1].

Thus, in stellar temperature T_9 = 0.02 - 0.06 the reaction rate of ^{24}Mg+p is very important to be measured. Direct capture and the lowest lying resonance at E_p^{lab}=223 keV, both contribute to the rate of this reaction. Accurate calculation of the resonance wing contribution requires information about resonance parameters, such as total width of the populated level which in turn is related to the level life-time.

Several attempts were made by different groups (D.C.Powell et. al [1], Dworkin et. al [2]), to measure the life-time of the E_x =2485 keV level of ^{25}Al populated by ^{24}Mg (p, γ)^{25}Al resonance reaction. But all the previous results contained about 50% uncertainty. Motivation of the present work was to evaluate the life-time of the E_x = 2485 keV level of ^{25}Al with a better accuracy using Doppler Shift Attenuation Method (DSAM) [3].

Experimental set-up

For the measurement of the life-time of the 2485 keV resonance level of ^{25}Al, we have recently performed a proton induced reaction at TIFR, Mumbai with a 400 kV ECR ion source-based low-energy ion accelerator [4]. We have used an evaporated Mg target (~100 µg/ cm2) on Ta backing (prepared at TIFR target laboratory) for this experiment. The target was bombarded by proton beam of 230 keV energy with beam current of ~1 µA. We have placed two HPGe detectors with 30% relative efficiency at ~7 cm away from the target (Fig1) to capture the γ rays of interest.

Fig 1: Beamline and detector position**.**

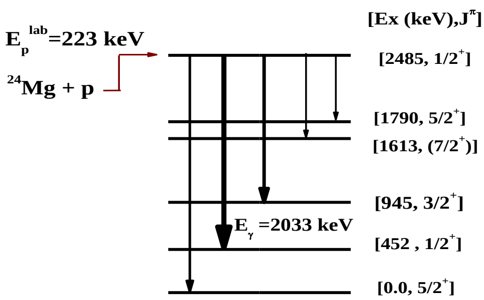

Fig 2: Level scheme of ^{25}Al. (All transitions are not shown)

To reduce the uncertainty in measuring life-time data were taken at four different detector positions. Observation of 2033 keV γ ray (the intense one from that level, I= 81.7%) (Fig2) confirms the production of 2485 keV energy level of ^{25}Al through resonance reaction. The data are analyzed using INGASORT [5].

Results and Discussion

In this experiment, the 230 keV proton feeds the E_x = 2485 keV state of ^{25}Al ($Q_{p\gamma}$= 2271 keV), which decays by emission of γ rays. The amount of Doppler Shift (Eq. 1) depends on the life-time of the E_x = 2485 keV energy level, detection angle and the attenuation of the recoil through the backing material. Thus by measuring the Doppler Shift of the γ ray having energy 2033 keV (E_x = 2485 keV to E_x = 452 keV transition) at different angular positions the life-time of the desired level can be calculated [1] by using Eq. (1),

$$E_\gamma(\theta) = E_\gamma^0\,(1+\beta\,P\,F(\tau)\cos\theta) \qquad (1)$$

where, the θ is the angular position of the detector with respect to the beam direction, β is the recoil velocity in the backing material (calculated using the code PACE IV) in unit of c, P is a (calculated) correction factor due to the finite size of the detector. At this stage of the analysis we set it to be unity. E_γ^0 is the un-shifted γ energy (here 2033 keV) and F(τ) is the attenuation factor defined as the ratio of the observed average Doppler shift and the calculated maximum Doppler shift [1].

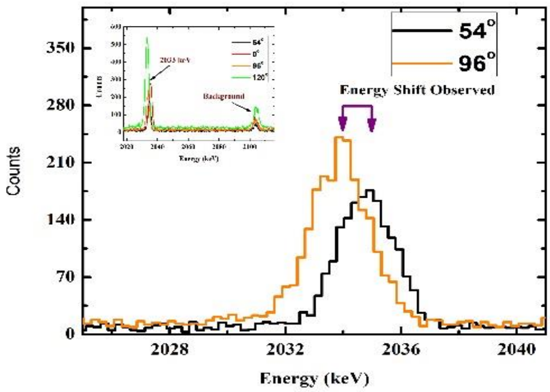

Fig3: Centroid Shift at different angular position.

Fig.3 shows the shift of the desired γ energy for different detector position. Precise calibration and proper extraction of centroid positions at these angles have played an important role in the analysis. We have used ^{152}Eu source for calibration.

Determining the centroid shift at different angular position, observed centroid Vs cos θ plot is made (Fig.4), slope of which gives the experimental F(τ) = 0.86±0.03 as per Eq. 1. The error in the cos θ value is due to the detector opening angle.

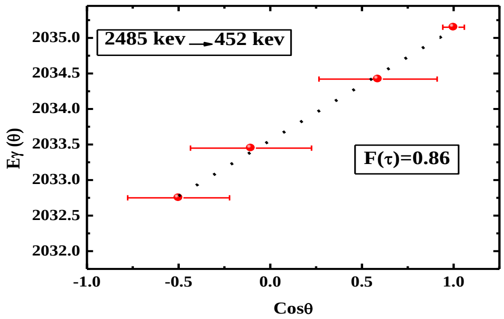

Fig 4: Observed Doppler shifted γ energies as a function of cosine of angular position.

On the other hand theoretical attenuation factor can be calculated using the information of stopping potential of the recoil in the substrate material as per Eq. (2) [1],

$$F(\tau) = \frac{1}{\tau\, v(0)} \int_0^{\infty} \overline{v(t)\cos\varphi(t)}\;\; e^{-t/\tau} dt \quad (2)$$

where φ is the angle of divergence of the recoil nuclei from the original direction of motion.

Calculation of the dependency of attenuation factor with level life-time is in progress. Comparing this with the experimentally obtained attenuation value we will be able to evaluate the life-time of the E_x = 2485 keV level of ^{25}Al.

Acknowledgement

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