Restoration of isospin symmetry in ^{32}S at finite temperature

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Introduction

The isospin quantum number (I) in nuclear physics was introduced by Heisenberg about 80 years ago [1] and it has played an important role in nuclear structure studies. It is preserved by the nuclear interactions. However, the presence of long range Coulomb interaction breaks the symmetry; the most important being the isovector Coulomb interaction which mixes states separated by ΔI = 1. Despite being a small effect, isospin mixing is important in connection with two basic quantities in physics, namely, the spreading width of isobaric analog states (IAS) [2] and the u-quark to d-quark transition matrix element V_{ud} in the Cabibbo-Kobayashi-Maskawa (CKM) matrix [3]. In general, isospin mixing can be studied by utilizing the transitions which would have been forbidden if isospin mixing does not take place. The γ-decay associated with the isovector giant dipole resonance (IVGDR) is one such transition that can be used to study the isospin mixing in self-conjugate (N = Z) nuclei at high excitations. Owing to the E1 nature, the γ-transition between the states of same I are forbidden in N = Z nuclei resulting in the suppression of yield of high energy γ-rays as compared to non self-conjugate nuclei. However, in presence of isospin mixing the yield is enhanced. This technique was first utilized by Harakeh *et al.* [4] and later was modified by Behr *et al.* [5]. In this paper, we report on the measurement of isospin mixing at E* = 40.2 MeV in ^{32}S for which only one measurement exists at 58.3 MeV [6].

Experimental details

The experiment was performed at Variable Energy Cyclotron Centre (VECC), Kolkata. Self-supporting ^{27}Al (I = 1/2) and ^{28}Si (I = 0) targets were bombarded with α-beam (I = 0) of energies 35 and 38 MeV to produce ^{31}P (I = 1/2) and ^{32}S (I = 0) compound nuclei at the same excitation energy and angular momentum, respectively. ^{31}P was populated as a reference nucleus to extract the GDR and other statistical model parameters required for the analysis of ^{32}S. The high energy γ-ray spectra from the decay of IVGDR were measured using a part of the LAMBDA spectrometer [7] arranged in a 7×7 matrix and placed at a distance of 50 cm from the target at an angle of 90° with respect to the beam axis. The spectrometer was surrounded by a 10 cm thick passive lead shield to block the γ-ray backgrounds. A 50 element multiplicity filter, divided in two parts of 25 detectors each and placed on top and bottom of the target chamber in 5×5 matrix at a distance of 5 cm from the target, was utilized for precise measurement of angular momentum populated as well as to take start trigger for time of flight (TOF) measurements. The data were acquired using a VME based data acquisition system. Only those events for which at least one from both the top and bottom multiplicity filter fired in coincidence with one of the detectors of LAMBDA spectrometer above a threshold of $\sim$ 4.0 MeV were recorded. The time spectrum of the cyclotron radio frequency (RF) was also recorded with respect to the multiplicity filter to further ensure the selection of beam related events. The

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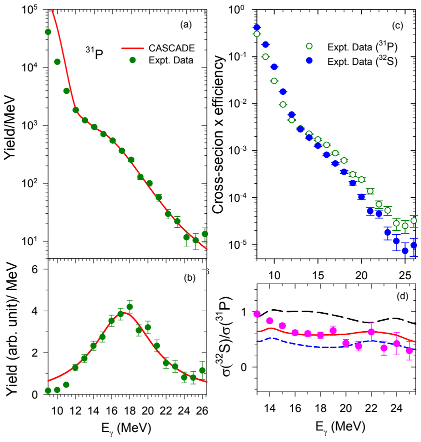

FIG. 1: (a) Experimental γ-ray spectrum of ^{31}P along with the best fit CASCADE spectrum. (b) Linearized spectrum for ^{31}P (c) Experimental $\sigma_\gamma \times \epsilon_{in}$ for ^{31}P (green open circles) and ^{32}S (blue filled circles). (d) Experimental ratio (pink filled circles) of the high energy γ-ray cross-section of ^{32}S and ^{31}P along with the CASCADE predictions for different $\Gamma_>^\downarrow$. $\Gamma_>^\downarrow = 0$ keV for blue short dashed line (zero mixing), $\Gamma_>^\downarrow = 24$ keV for red solid line and $\Gamma_>^\downarrow = 10$ MeV for black long dashed line (full mixing).

evaporated neutron energy spectra were measured, in coincidence with the multiplicity γ-rays, using a liquid scintillator based neutron TOF detector. It was placed at the backward angle of 150° and at a distance of 150 cm from the target.

Data analysis and inferences

The high energy γ-ray spectra were reconstructed using cluster summing technique [7] in which each detector was required to satisfy the condition of prompt time gate and pulse shape discrimination (PSD) gate to reject of neutron and pile-up events, respectively. The neutron TOF spectra were converted to neutron energy spectra taking the prompt peak as time reference. The $n - \gamma$ discrimination was done using PSD technique comprising of TOF and zero crossover time (ZCT). The experimentally measured fold distribution was mapped into angular momentum space using a realistic technique [8]. The statistical model calculations were performed using a modified version of the code CASCADE in which isospin quantum number has been taken into account [5]. The nuclear level density (NLD) parameters were extracted by comparing the CASCADE neutron spectra (after correcting for detector efficiency) with the experimental ones for precise determination of nuclear temperature as well as to put a vital constraint in the analysis of high-energy γ-ray spectra. The IVGDR parameters were extracted by comparing the CASCADE high energy γ-ray spectra (after folding with the detector response function) with the experimental spectrum of ^{31}P with the assumption that isospin is fully conserved. Utilizing these parameters, the isospin mixing was deduced from the ratio of the high energy γ-ray cross sections of ^{32}S and ^{31}P by varying the Coulomb spreading width ($\Gamma_>^\downarrow$) in the CASCADE code. The comparison of our results with that of Ref. [6] indicates that $\Gamma_>^\downarrow$ remains nearly constant with temperature and isospin mixing decreases with the increase in temperature. This is owing to the fact that the competition between the time scale associated with the Coulomb spreading width and the compound nuclear decay width leads towards the restoration of isospin symmetry [9, 10]. These interesting results will be discussed in detail during the symposium.

References

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