Isospin Mixing in A=46, T=1 Isobaric Multiplet


INTRODUCTION

The exchange symmetry between neutrons and protons is one of the most important principles in Nuclear Structure Physics. The Coulomb interaction between protons breaks this symmetry and hence mixes isospin. Another source of isospin mixing could arise from any charge asymmetry or charge dependence of the nucleon-nucleon interaction itself. Indeed, it has been suggested [1] that such isospin mixing could give rise to any charge asymmetry of isospin mixing, which could arise from any charge asymmetry of isospin-mixing, and that the resulting symmetries can be examined by investigating the quantity, both the purity of isospin and the extent of the isobaric multiplet

\[ J^\pi \]

where \( J^\pi \) is the isobaric multiplet.

We have performed an experiment in order to obtain a high precision measurement of the B(E2)s for the \( J^\pi = 2^+ \to 0^+ \), \( \Delta T = 0 \), \( T = 1 \) transitions across the A=46 isobaric multiplet \( ^{46}\text{Cr} \rightarrow ^{46}\text{V} \rightarrow ^{46}\text{Ti} \) with the purpose of measuring the level of violation of isospin symmetry. A firm conclusion about the linearity of the B(E2) values with \( T_z \) was impossible from already existing data [5–7] given the errors on the \( ^{46}\text{V} \) and \( ^{46}\text{Cr} \) as reported Fig.1.

EXPERIMENTAL METHOD

The experiment presented in this report has been performed with the AGATA-FRS-LYCCA setup [4] and the SIS accelerator facility at GSI. A 600 MeV/A \( ^{58}\text{Ni} \) beam with an intensity of around 1 \( \times \) 10^9 ions/spill impinged on a 2.5 g/cm² Be target and the isotopes resulting from the fragmentation reaction were separated and identified with the double-stage magnetic spectrometer FRS [3] by means of the \( \Delta p = \Delta E \) – \( Bp \) method.

Two scintillators placed in the second and in the fourth focal planes permitted to measure the time of flight of the ions, while their position in the fourth focal plane is given by two Time Projection Chambers (TPCs). Combining these informations it is possible to achieve identification in mass over charge (A/q). The atomic number Z is obtained from the double-stage magnetic spectrometer FRS [3] by means of the Bp – \( \Delta E \) – \( Bp \) method.

Three different settings have been used during the experiment in order to transmit, respectively, \( ^{46}\text{Ti} \), \( ^{46}\text{V} \) and \( ^{46}\text{Cr} \) secondaries beams.

The \( 2^+ \) states of interest have been populated by means of Coulomb excitation reactions from the three analogue \( 0^+ \) states employing two different techniques and targets:

1. A stack of three gold foils at a fixed distance has been used with the \( ^{46}\text{V} \) secondary beam in order to study the \( 2^+ \) state lifetime through a \( \gamma \)-ray Doppler Shift technique. The targets thicknesses were (750+750+500) mg/cm² in order to maximize the

Fig. 1. Known BE(2) values in the A=46, T=1 multiplet.
Fig. 2. $^{46}$Cr A/Q vs Z plot. An unambiguous isotope separation is achieved.

lineshape variation with lifetime.

2. A single gold target of 500 mg/cm$^2$ has been employed with the more exotic $^{46}$Cr secondary beam, due to the lower production rate. In this case the B(E2) has to be extracted from the Coulex cross section.

The $^{46}$Ti nucleus has been studied with both techniques to have a good reference value.

The outgoing ions were identified by the LYCCA detector. The atomic number of the nucleus is obtained by measuring the energy loss in the DSSSDs detectors and the residual energy in the CsI detectors placed in a wall $\sim 3.6$ m after the secondary target.

The outgoing ion trajectory can be reconstructed from the positions given by the DSSSDs wall detectors and by another DSSSD detector placed close to the secondary target. Finally, two plastic scintillator placed respectively before the target and close to the wall permit to perform a time-of-flight measurement.

The $\gamma$ rays produced by the reaction have been detected by the $\gamma$-ray array AGATA, which in this experiment was composed of 5 double clusters and 4 triple clusters placed at forward angles with respect to the beam direction. The high resolution in the interaction position of the incident $\gamma$ ray and the tracking procedure offered by the AGATA array allows a precise Doppler correction, which is particularly important in this kind of reactions, where the velocity of the outgoing ions is $\sim 0.5$ c.

PRELIMINARY RESULTS

Gating on a specific isotope in FRS A/Q vs Z matrix and on the corrisponding Z number in the E-dE Lycca spectrum it is possible to obtain the $\gamma$-ray spectrum relative to the reaction of interest. The event-by-event time of flight measurement permits to calculate the outgoing beta and therefore to perform the Doppler correction of the $\gamma$ ray emitted in flight. A further gate on the $\gamma$-ray time reduces the background discarding events which are not in coincidence with the reaction. The preliminary spectrum relative to the 892 keV, $2^+ \rightarrow 0^+$ transition in $^{46}$Ti is presented in Fig.3.

Fig. 3. $^{46}$Ti $\gamma$-ray spectrum obtained by gating on E-dE Lycca plot and on $\gamma$-ray time.

By knowing the number of counts in the incoming and outgoing gates and the area of the Coulex peak it is possible to obtain the cross section and therefore the B(E2) value for the transition of interest.

The lifetime of the $2^+$ state in $^{46}$V, which is known to be around 8-9 ps, can be determined from the line shape obtained from the triple gold-foil stack measurement.

The analysis is still ongoing for the single target Coulomb excitation reaction as well as for the triple stack lineshape measurements.

CONCLUSIONS

The $J^P = 2^+ \rightarrow 0^+$ transitions in the A=46 isobaric multiplet, $^{46}$Ti – $^{46}$V – $^{46}$Cr have been studied using two different techniques in order to achieve a high precision measurement of the B(E2) values. A $\gamma$-ray Doppler shift method has been applied to $^{46}$V and $^{46}$Ti employing a triple gold-foil stack target while the more exotic $^{46}$Cr has been studied through a coulex reaction on a single gold target. Preliminary spectra are reported.