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Beta-delayed gamma and proton spectroscopy near the Z = N line

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Abstract. A series of beta decay experiments on nuclei near the $Z = N$ line has been performed using the ISOL technique at the IGISOL facility in Jyväskylä and at ISOLDE, CERN. The decay properties of these neutron-deficient nuclei are important in astrophysics as well as in the studies of isospin symmetry.

PACS. 23.20.Nx Internal conversion and extranuclear effects – 23.40.-s β decay; double β decay; electron and muon capture – 27.40.+z $39 \leq A \leq 58$ – 27.50.+e $59 \leq A \leq 89$

1 Introduction

Nuclei close to the $Z = N$ line provide an opportunity to study symmetry properties of nuclei. For example, the isospin symmetry of transitions can be probed by comparing the Gamow-Teller (GT) strengths of analogous transitions. From an astrophysical point of view, these nuclei are deeply involved in the rapid proton capture (rp) process.

A series of beta decay experiments on nuclei near the $Z = N$ line has recently been performed at the IGISOL facility in Jyväskylä and at ISOLDE, CERN. Since the IGISOL method is fast and not limited by chemical or physical properties of elements, a large variety of nuclei close to the $Z = N$ line can be studied. In the following sections the beta decay studies of ^{31}Cl, ^{58}Zn and selected nuclei close to $A = 80$ are presented.

2 Beta decay of ^{31}Cl

In massive ONe novae, where nucleosynthesis of elements heavier than phosphorous is concerned, two paths for the synthesis of ^{32}S both proceeding via ^{30}P(p,γ) have been suggested [1]. The reaction rate of ^{30}P$(p,\gamma)^{31}$S, which is needed to determine the end-point of that nucleosynthesis cycle, can be inversely studied via beta-delayed proton and gamma decay of ^{31}Cl. This has recently been done at IGISOL where ^{31}Cl ions were produced by a 40 MeV proton beam on a ZnS target. Accelerated and mass-separated 25 keV Cl ions were implanted into a thin carbon foil. The set-up consisted of three double-sided silicon strip detectors backed with thick silicon detectors, the ISOLDE Silicon Ball [2] and a 70% HPGe detector.

Beta decay of ^{31}Cl has been previously studied using the He-jet method. Altogether eight proton peaks were reported in ref. [3] but all peaks except those of 986 keV and 1520 keV were later claimed to have come from ^{25}Si [4]. Due to mass separation at IGISOL, most of the controversial proton peaks can now be confirmed to arise from the decay of ^{31}Cl (see fig. 1).

3 Beta decay of ^{58}Zn

The beta decay of ^{58}Zn can be used to probe the isospin symmetry of transitions. The GT strength of the transitions from ^{58}Zn ($T_Z = -1$) to the states in ^{58}Cu ($T_Z = 0$) can be compared to the GT strength of analogous transitions from ^{58}Ni ($T_Z = +1$) to ^{58}Cu studied via (^{3}He, t) charge-exchange reactions at RCNP in Osaka [5].

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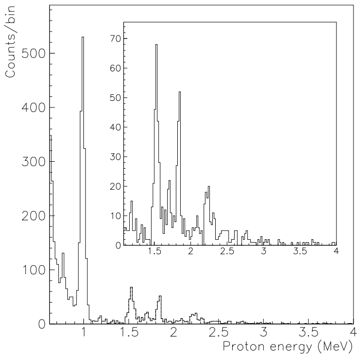

Fig. 1. Beta-delayed protons from mass-separated ^{31}Cl [6]. The inset is an enlargement of the spectrum above 1.1 MeV.

Table 1. The GT strengths B(GT) to the states of ^{58}Cu.

$E_x(^{58}\mathrm{Cu})$	$^{58}\mathrm{Ni}(^{3}\mathrm{He,t})$ [5]	$^{58}\mathrm{Zn}(\beta^+)$ [7]	$^{58}\mathrm{Zn}(\beta^+)$ [6]
0 keV	0.155(1)	< 0.31	< 0.5
1051 keV	0.265(13)	0.54(26)	0.37(10)

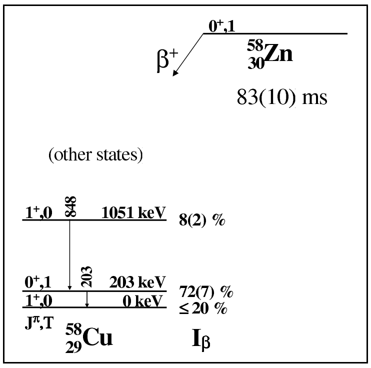

Fig. 2. Beta decay of ^{58}Zn. The half-life of 83(10) ms [6] agrees with the earlier results, 86(18) ms [7] and 83(10) ms [8].

The Zn isotopes were produced via spallation reactions induced by a 1.4 GeV proton beam on a Nb foil target at ISOLDE, CERN. A chemically selective laser ion source was used to purify the ^{58}Zn beam, which was accelerated, mass-separated and implanted into a movable tape. With a set-up consisting of a $4\pi\beta$-detector and two Miniball detectors we could confirm the earlier results concerning the gamma rays and the half-life (see table 1 and fig. 2) but no beta-delayed protons were observed with the ISOLDE Silicon Ball set-up. The proton spectroscopy part was repeated with the ISOLDE Silicon Ball using $^{58}\mathrm{Ni}(^{3}\mathrm{He,3n})^{58}\mathrm{Zn}$ fusion-evaporation reactions to produce ^{58}Zn at IGISOL. The analysis is in progress.

4 Isomers of astrophysical interest at masses A = 81, 85 and 86

The flow of the rp-process beyond the Zr-Nb cycle depends on the spectroscopic properties of the nuclei close to $A = 80$. The beta decays of ^{81}Y, ^{81}Sr, $^{81\mathrm{m}}$Kr, ^{85}Nb, ^{85}Zr, ^{86}Mo and ^{86}Nb have been investigated at IGISOL. A beam of ^{32}S on ^{54}Fe and $^{\mathrm{nat}}$Ni targets was used to produce the isotopes of interest which were accelerated to 40 kV, mass-separated and implanted into a tape at the first detector station which had two HPGe detectors and a plastic scintillator for betas. After some time of accumulation, the implanted ions were delivered to the second station consisting of a low energy Ge detector (LeGe) and the ELLI electron spectrometer which transported electrons to a cooled Si(Au) surface barrier detector.

As a by-product at mass $A = 81$, internal conversion coefficients for a 190.5 keV transition of $^{81\mathrm{m}}$Kr (13.1 s) were determined, $\alpha_K = 0.50 \pm 0.07$ and $\alpha_K/\alpha_{L+M} = 4.7 \pm 0.1$, favouring $E3$ multipolarity. These data were used to calculate the EC branching ratio from $^{81\mathrm{m}}$Kr to $^{81}\mathrm{Br}_{\mathrm{g.s.}}$ ($Q_{\mathrm{EC}} = 471.1$ keV) which is needed for the estimation of the neutrino capture rate on ^{81}Br. Our log ft value of 5.13 ± 0.09 for $^{81}\mathrm{Br}(\nu,\mathrm{e}^-)^{81\mathrm{m}}\mathrm{Kr}$ supports the conclusion that ^{81}Br can be used as a solar neutrino detector.

At mass $A = 85$ a transition with an energy of 69 keV was observed in ^{85}Nb. The measured half-life of the transition was 3.3 ± 0.8 s. Since the multipolarity of the transition is most likely $E2$ or $M2$, the half-life cannot be fully explained by this kind of transition.

The main interest at mass $A = 86$ lies in the half-life of ^{86}Mo, which is a waiting-point nucleus in the rp-process. The weighted average half-life of 19.1 ± 0.3 s confirmed the earlier result [9]. However, the isomeric state with a half-life of 56 s in ^{86}Nb claimed in [9] was not observed.

5 Future prospects

In the future, a chemically selective laser ion source at IGISOL will substantially reduce background contaminants particularly in the region near $A = 80$. In addition, the binding energies and Q-values important both in astrophysical modeling and studies of GT strength can be measured for nuclei in this region at the JYFLTRAP.

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References

1. J. José *et al.*, Astrophys. J. **560**, 897 (2001).
2. L.M. Fraile, J. Äystö, Nucl. Instrum. Methods A **513**, 287 (2003).
3. J. Äystö *et al.*, Phys. Rev. C **32**, 1700 (1985).
4. T.J. Ognibene *et al.*, Phys. Rev. C **54**, 1098 (1996).
5. Y. Fujita *et al.*, Eur. Phys. J. A **13**, 411 (2002).
6. A. Kankainen *et al.*, to be published.
7. A. Jokinen *et al.*, Eur. Phys. J. A **3**, 271 (1998).
8. M.J. López Jiménez *et al.*, Phys. Rev. C **66**, 025803 (2002).
9. T. Shizuma *et al.*, Z. Phys. A **348**, 25 (1994).