High Energy Physics and Nuclear Physics

Volume 21, Number 1

Observation of Beta-Delayed Proton Decay of ^{69}Kr

Xu Xiaoji, Huang Wenxue, Ma Ruichang, Gu Zhongdao, Yang Yongfeng, Wang Yanyu and Dong Chengfu

(Institute of Modern Physics, Chinese Academy of Sciences, Lanzhou, China)

A new group of protons at laboratory energy of 4.07 ± 0.05 MeV with half-life of 32 ± 10 ms was discovered via observing the decay proton spectrum produced in the ^{32}S + Ca reaction. By reaction channel analysis and comparing with theoretical prediction, this new proton radioactivity was assigned to the β-delayed proton decay of ^{69}Kr produced in the ^{40}Ca (^{32}S, 3n) reaction, corresponding to decay of the $T = 3/2$ isobaric analog state in ^{69}Br to the ground state of ^{68}Se. Combining this measurement with the Coulomb displacement energy calculation yields a mass excess for ^{69}Kr of −32.15 ± 0.30 MeV. The partial decay scheme of ^{69}Kr was proposed.

Key words: exotic nuclide, beta-delayed particle decay, mass excess.

The nuclei near the proton drip line with $T_z = -3/2$, $A = 4n + 1$ from ^{9}C to ^{65}Se are all particularly favored with strong β-delayed proton emission [1]. The members of this series beyond ^{57}Zn lie in the edge of the proton drip line; thus, by studying the decay properties of the nuclei in this series systematically, one may obtain the valuable evolutive information on the properties of nuclear decay and nuclear structure towards the proton unstable region. Extending this nuclear series to higher mass, the next member, ^{69}Kr, will be reached which is expected to be also a strong β-delayed proton decay precursor. B. Blank, *et al.* [2] identified ^{69}Kr by using the projectile fragmentation method, but the decay properties of ^{69}Kr have not been investigated experimentally to date. Recently, an experiment was performed at the Institute of Modern Physics (at the Chinese Academy of Sciences) in order to study the decay property of ^{69}Kr. ^{69}Kr was produced via ^{40}Ca (^{32}S, 3n) reaction using 170 MeV $^{32}S^{9+}$

Received August 27, 1996.

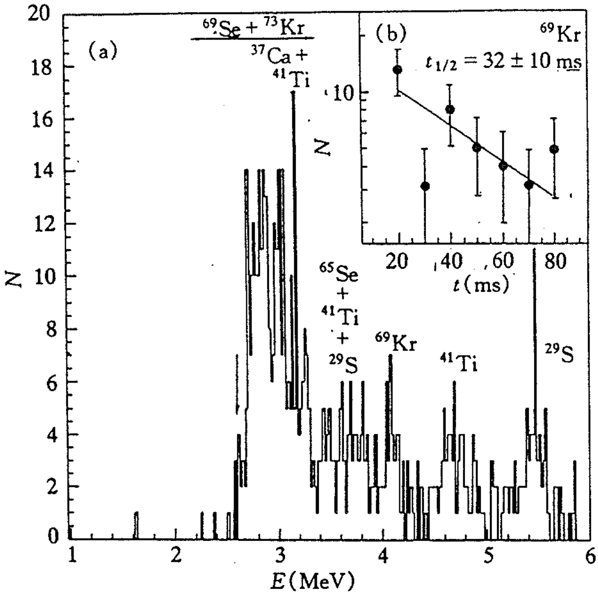

Fig. 1

(a) The delayed proton energy spectrum drawn from 'proton window' in 2D spectrum; (b) the time characteristics of protons from the peak at 4.07MeV in proton energy spectrum. The arrow sign is the point of low energy.

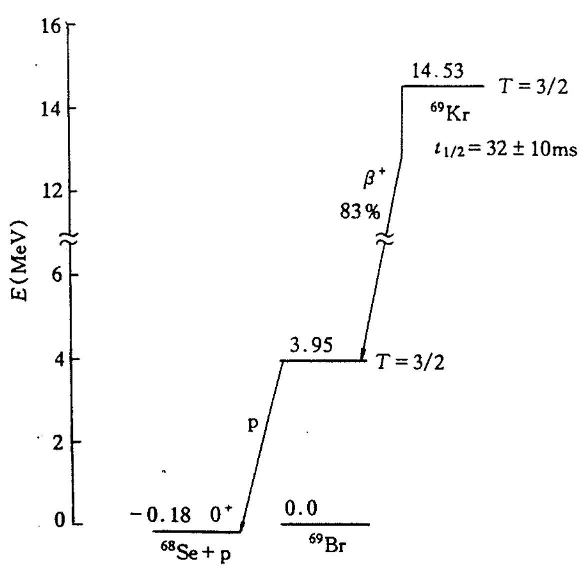

Fig. 2

The proposed partial decay scheme of ^{69}Kr.

beam from the HIRFL bombarding natural calcium target. Because of its noble gas property, Kr cannot be efficiently transported and collected by the helium-jet technique, and it is also very difficult at present to study the decay property of ^{69}Kr via projectile fragmentation method due to its extremely small yield. So, we developed a new method called a pulsed-beam technique, i.e., the target was bombarded periodically by a modulated beam, the detection system was closed in the irradiation period, and the radioactivity collected in the target was detected in the non-irradiation period. Using this method, the nuclide with a half-life on the order of a millisecond can be efficiently detected. A particle telescope consisting of 3 Si (Au) surface barrier detectors was employed for particle identification and energy spectrum measurement for the charged particle decay of produced nuclei. The energy calibration was accomplished by using protons from ^{53m}Co, ^{53}Ni, ^{41}Ti, and ^{29}S produced in reactions of bombarding ^{24}Mg and ^{40}Ca with ^{32}S beam, respectively. The CTDC technique was employed for measuring the time spectrum of the events to obtain the half-life of the nuclide of interest when energy spectrum was measured.

The two-dimensional (2D) charged particle spectrum was obtained by using an integrated beam of 13 mC (the average current is 0.1 eμA) and the delayed proton spectrum drawn from the "proton window" on a 2D spectrum was shown in Fig. 1(a). The peaks at 5.44, 4.73, and 4.64 MeV, and 3.10 MeV in the spectrum are familiar arising from β-delayed proton decays of ^{29}S, ^{41}Ti, and ^{37}Ca, respectively. It is believed that they mainly come from transfer reactions. The spectrum also shows separated peak-structure piled up on a continuum background up to 3.5 MeV which was produced by ^{69}Se β-delayed proton contribution due to the large cross section of 2 pn evaporation channel. In the region over 3.5 MeV up to 3.8 MeV in spectrum, there are complicated structures from ^{41}Ti, ^{29}S, and ^{65}Se. All of these proton radioactivities are well consistent with the expected exit channel.

It is attractive that the spectrum clearly shows a proton peak at 4.07 $\pm$ 0.05 MeV which is different from the ones arising from all known nuclei and its corresponding time spectrum is shown in Fig. 1(b). We assigned this proton peak to the β-delayed proton decay of ^{69}Kr based on the following arguments:

(1) Proton energy of 4.07 $\pm$ 0.05 MeV is consistent with the predicted value of 3.85 $\pm$ 0.53 MeV within 0.22 MeV that is in accordance with the systematic trend in this nuclear series.

(2) With the least-square method to fit the time spectrum shown in Fig. 1(b), the half-life of 32 $\pm$ 10 ms for ^{69}Kr is obtained which is in agreement with the one of 27.7 ms predicted by Tokayoshi, *et al.* [4], and is not in accordance with the ones of the nuclei possibly produced in reactions.

(3) The assignment for ^{69}Kr is also reliably based on the reaction channel analysis which was described as above.

Assuming the log ft = 3.3 for the superallowed transition in ^{69}Kr β-decay, the β transition branching ratio to the IAS in ^{69}Kr was obtained to be 83%. The partial decay scheme of ^{69}Kr was proposed as shown in Fig. 2. It is the first time that β-delayed proton decay of ^{69}Kr was observed in the experiment. Combining the laboratory energy of delayed protons from ^{69}Kr with the Coulomb displacement energy calculation yields a mass excess for ^{69}Kr of -32.15 ± 0.30 MeV. From the absolute efficiency (7.5×10^{-3}) of the pulsed beam method and the proton branching ratio, the experimental cross section for the ^{40}Ca (^{32}S, 3n) ^{69}Kr reaction was obtained to be 15 nb. The ratio of the ALICE prediction (300 nb) to the observed value is 20, which is consistent with the ratios found for the previously discovered members in this series: ^{61}Ge (ratio = 11), ^{65}Se (ratio = 18), and ^{73}Sr (ratio = 10).

REFERENCES

[1] J.C. Batchelder, *et al.*, *Phys. Rev.*, **C47** (1993): p. 2038.
[2] B. Blank, *et al.*, *Phys. Rev. Lett.*, **74** (1995): p. 4611.
[3] R.G. Sextro, R.A. Gough, and J. Cerny, *Nucl. Phys.*, **A234** (1974): p. 130.
[4] T. Horiguchi, T. Tachibana, and T. Tamura, *Chart of the Nucleids 1992*.