Preparation of a liquid nitrogen target for measurement of γ-ray in the $^{14}N(n,\gamma)^{15}N$ reaction as an intensity standard in energy region up to 11 MeV

M. Hirano[1], H. Obayashi[1], H. Sakane[2], M. Shibata[2], K. Kawade[2] and A. Taniguchi[3]
[1]*Department of Nuclear Engineering, Nagoya University.*
[2]*Department of Energy Engineering and Science, Nagoya University.*
[3]*Research Reactor Institute, Kyoto University.*
e-mail: h952535b@mbox.media.nagoya-u.ac.jp

For determination of relative γ-ray intensities up to 11 MeV in the $^{14}N(n,\gamma)^{15}N$ reaction, we have developed a liquid nitrogen (N_2) target which contain no hydrogen (H) to improve the accuracy of γ-ray intensities. The ratio of the relative uncertainties for the liquid nitrogen to that for the melamine ($C_3H_6N_6$) widely used was improved by a factor of 2 above 2.2 MeV and a factor of 3 - 6 below 2.2 MeV. It has been shown that the liquid nitrogen target is useful for reduction of the 2.2 MeV γ-ray from the $^{1}H(n,\gamma)\,^{2}H$ reaction and improvement of statistics.

1 Introduction

The high energy γ-rays are important in the fields of prompt neutron capture γ-ray analysis and nuclear spectroscopy of unstable nuclei. To obtain the γ-ray intensities measured with HPGe detectors, the detection efficiencies in energy region up to 10 MeV are needed. Standard radioactive nuclides such as ^{133}Ba, ^{152}Eu, ^{60}Co and ^{56}Co are used in the energy region below 3.2 MeV, but above 3.2 MeV it is difficult to find suitable radioactive sources that have reasonably long half-lives. Hence, the capture γ-rays emitted from the $^{14}N(n,\gamma)\,^{15}N$ reaction are used, because of (1) it emits the intense γ-rays which are well spaced in the energy range between 1.7 and 10.8 MeV and (2) the level scheme is relatively simple. The γ-ray intensities in this reaction with accuracy of 1 - 3% were reported by Kennett *et al.*[1)] and Jurney *et al.*[2)]. But there are some discrepancies between them, and re-measurement is strongly desired.

Melamine ($C_3H_6N_6$) has been widely used as a nitrogen target. However, since hydrogen in melamine has large total cross sections, the large attenuation of neutron fluence rate in the target is serious problem. Moreover, intense γ-ray emitted from the $^{1}H(n,\gamma)^{2}H$ reaction causes increasing of background. In order to resolve these problems, we tried to develop a target system of liquid nitrogen.

2 Experiments

Experiments were carried out by using thermal neutron beam at KUR E-3 neutron guide tube. The neutron fluence rate is about 4×10^{6} n/cm^{2}·s.

The liquid nitrogen target system is shown in Fig. 1. Capture γ-rays emitted from ^{15}N were measured with 22% and 38% HPGe detectors that are located at 10 cm from the target. A target vessel made of polyethylene ($2\times8\times8$ cm^{3}, 20μm thickness) filled with liquid nitrogen is placed on the neutron beam. It is surrounded by enriched ^{6}LiF-box ($10\times10\times10$ cm^{3}, 0.5 cm thickness) that have a neutron incident window (2×10 cm^{2}). The HPGe detectors are shielded with ^{6}LiF-box from scattered neutrons in the target.

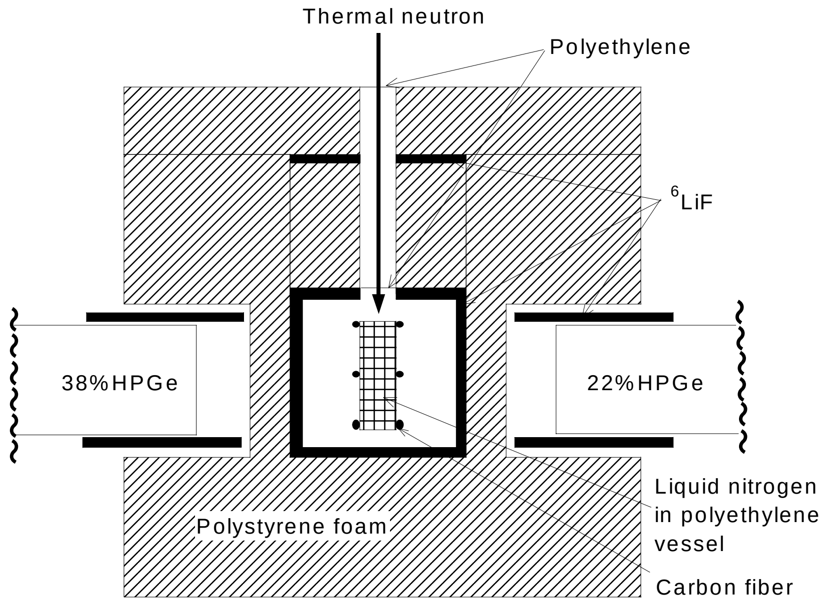

Fig.1 Schematic plane view of a liquid nitrogen target system.

A 5 *l* reservoir vessel is connected to the target vessel and supplies liquid nitrogen to target. The reservoir vessel needs to be filled with liquid nitrogen every 10 hours. A drop-lid divides the reservoir vessel from the target vessel as shown in Fig. 2, and reduces a leak of scattered neutrons to negligible small.

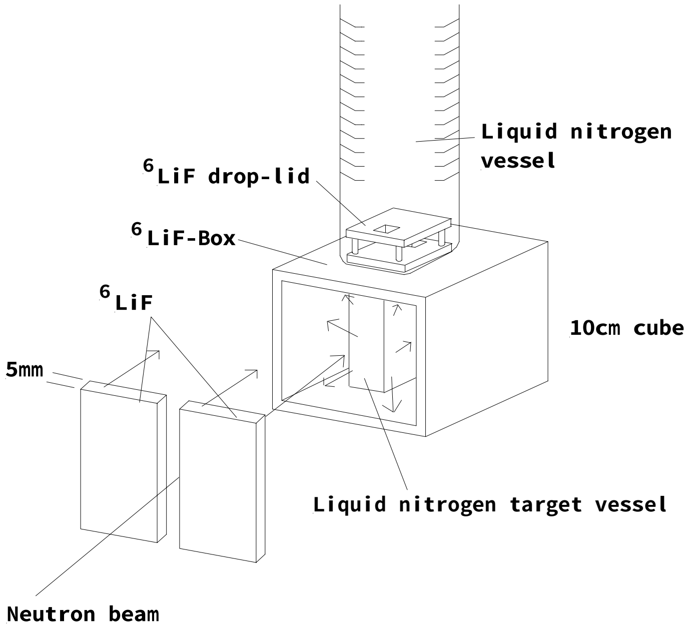

Fig.2 A view of ^{6}LiF-Box and ^{6}LiF drop lid.

The polyethylene foam was used as thermal shield material for suppressing the accumulation of frost around the target. The counting rate of 2.2 MeV γ-ray from ^{2}H was low, but it gradually increased in 70 hours.

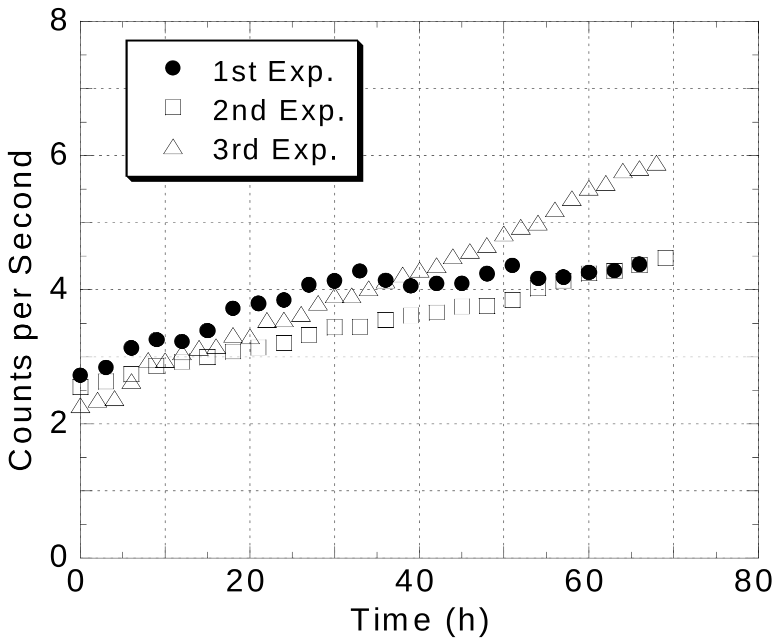

Fig. 3 The peak counting rate of 2.2 MeV γ-ray increased owing to the accumulation of frost around target vessel.

3 Results and discussion

The liquid nitrogen target system well worked for about 70 hours. The singles spectra obtained with the melamine and the liquid nitrogen is shown on liner scale in Fig. 4. The peak counting rate obtained with the liquid nitrogen was 4 times larger than that of the melamine. In the melamine, 2.2 MeV γ-ray emitted from ^{2}H dominated in the total counting rate. In the liquid nitrogen, the γ-ray of 2.2 MeV was reduced to 1/7. The 1.999 MeV γ-ray was clearly observed, which plays an important role in the determination of γ-ray intensities. Moreover, 1.073, 1.988, 2.030, 2.262, 2.293, 3.856 and 8.569 MeV γ-rays were also much clearly observed.

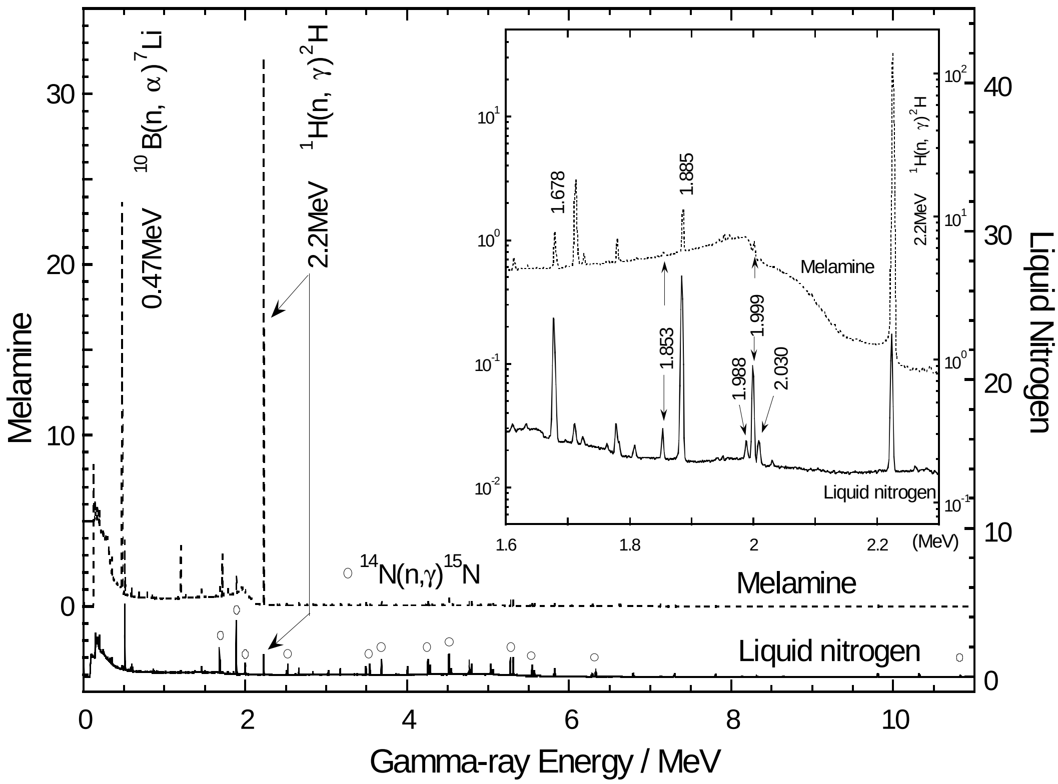

Fig. 4 The γ-ray spectra of liquid nitrogen (right scale) and melamine (left scale) obtained with HPGe detector. The partial figure of the energy region below 2.2MeV are inserted.

Fig. 5 shows the ratios of the relative uncertainties for melamine to that for liquid nitrogen. It was improved by a factor of 2 above 2 MeV and a factor of 3～6 below 2 MeV.

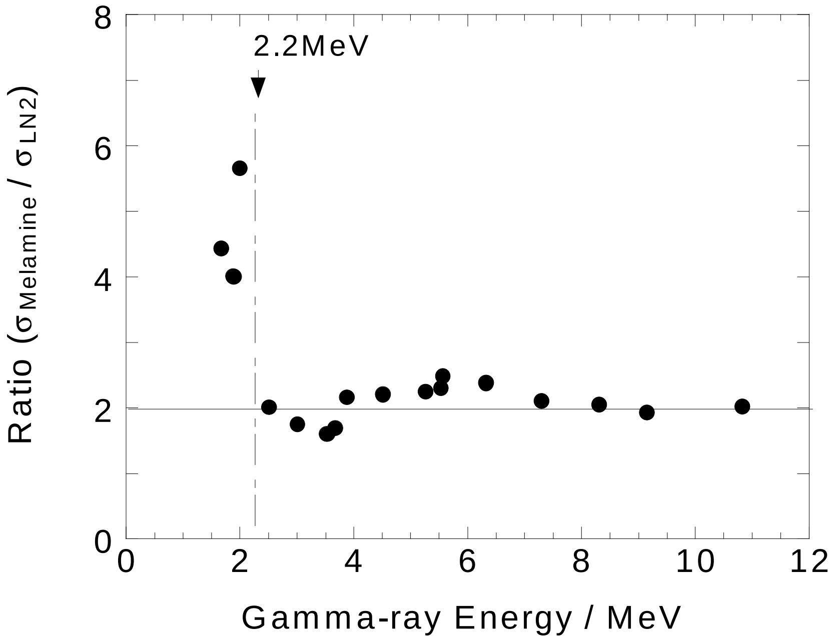

Fig. 5 The ratio of relative uncertainty for melamine to that for liquid nitrogen was improved by a factor of 2 above 2 MeV and a factor of 3-6 below 2 MeV. Dotted line means a position of 2.2 MeV γ-ray from the $^{1}H(n,\gamma)^{2}H$ reaction.

We tentatively determined the γ-ray intensities by the balance method[1)], which simultaneously determine the γ-ray intensities and the efficiency function of the detector by requiring an intensity balance for each level. The level scheme that was used in the balance method is shown in Fig. 6. The γ-rays marked with * are those clearly observed in this work.

The comparison of our tentative results obtained from melamine and liquid nitrogen is shown in Fig. 7. It is shown that there are up to about 10% discrepancies between them.

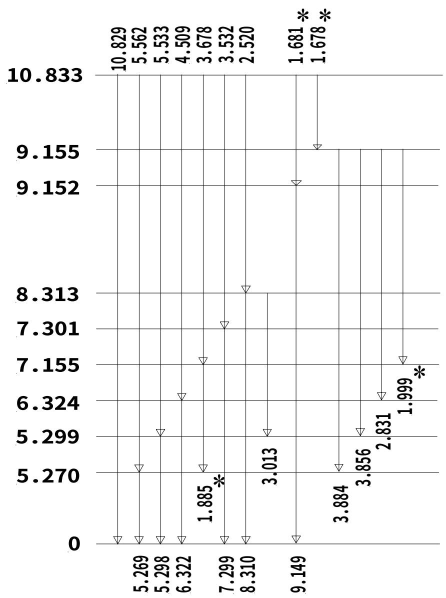

Fig. 6 The level scheme for ^{15}N

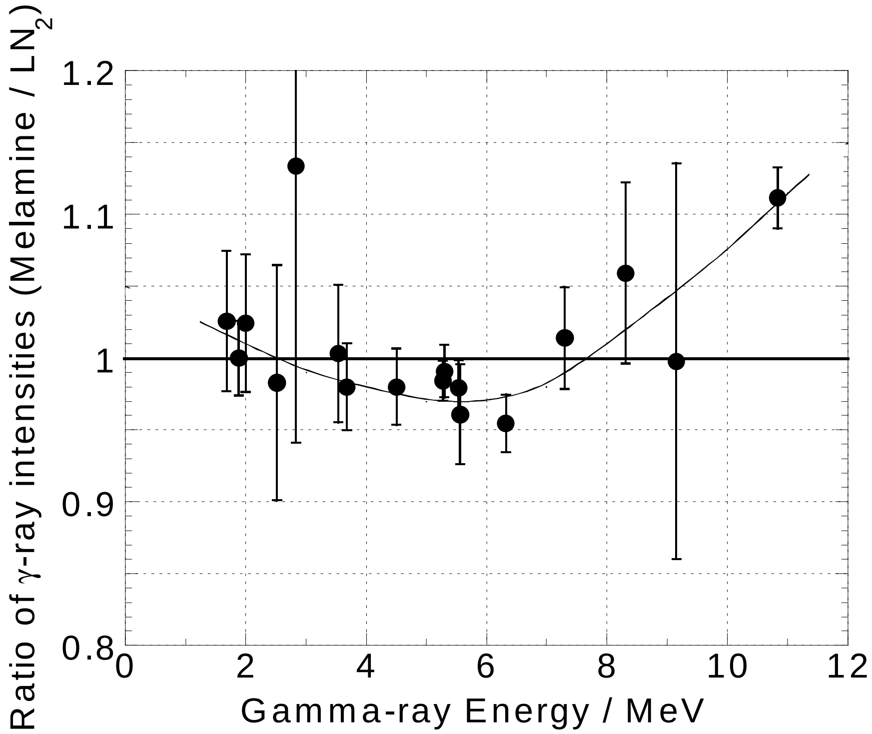

Fig. 7 Comparison of γ-ray intensities determined by melamine and liquid nitrogen. Solid line are given for eye guide.

4 Conclusion

We have proposed the liquid nitrogen target for determination of γ-ray intensities up to 11 MeV in the $^{14}N(n,\gamma)^{15}N$ reaction. It is recognized that the liquid nitrogen target is very useful for improvement of statistics and reduction of the background from $^{1}H(n,\gamma)^{2}H$ reaction.

We are planning to measure capture γ-ray by using thermal neutron at KUR B-4 neutron guide tube (5×10^{7} n/cm^{2}·s). More statistical improvement is expected.

References

1) T. J. Kennett, W. V. Prestwich and J. S. Tsai, *Nucl. Instr. Meth.*, A249, 366-378, 1986.

2) E. T. Jurney, J. W. Starner, J. E. Lynn and S. Raman, *Phys. Rev.*, C56, 118-134, 1997.