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Measurement of neutron total cross-section and resonance parameters of xenon

V.R. Skoy [a,b], T.F. Wang [a], G.N. Kim [a,*], Y.D. Oh [c], M.H. Cho [c], I.S. Ko [c], W. Namkung [c]

[a] Department of Physics, Kyungpook National University, Daegu 702-701, Republic of Korea
[b] Frank Laboratory of Neutron Physics, Joint Institute for Nuclear Research, 141980 Dubna, Moscow Region, Russia
[c] Department of Physics, Pohang University of Science and Technology, Pohang 790-784, Republic of Korea

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ABSTRACT

We measured the neutron total cross-sections of natural xenon in the neutron energy region from 0.1 to 40 eV by using the time-of-flight method at the Pohang neutron facility, which consists of an electron linear accelerator, a water-cooled tantalum target with a water moderator, and a 12-m long time-of-flight path. A ^{6}Li–ZnS(Ag) scintillator with a diameter of 12.5 cm and a thickness of 1.6 cm was used as a neutron detector. Notch filters composed of Co, In, Cd were used to estimate the background level and to calculate the neutron flight path length. The present measurement was compared with the existing experimental and the evaluated data. The resonance parameters of Xe isotopes were obtained from the transmission ratio by using the SAMMY code and were compared with other previous results.

1. Introduction

Neutron total cross-sections and resonance parameters are basic quantities of nuclear data, which play an important role in the development and application of the nuclear science and technologies. Precise measurements of neutron cross-sections are of great importance for the safe design of nuclear reactors and for the evaluation of the neutron flux density and the energy spectrum around a reactor. Resonance parameters of isotopic nuclei, which undergo a complex process of evaluation and analysis based on experimental data of transmission measurement or capture measurement, are finding an increasingly important role in practical applications that are concerned with computations of reactor temperature coefficients, neutron reaction yields, self-protection effects and related matters. Particularly, in reactor design, the individual resonance can be very important. Neutron resonance parameters also can provide reliable information for a number of other fields, including fundamental science and medical application.

Recent progress in optical polarization technique of noble gases opens a wide range of their application in applied and fundamental research [1]. Namely, polarized ^{3}He is used both for production of polarized neutron beams [2] and for magnetic resonance imaging of human lungs [3]. The odd isotopes of xenon, ^{129}Xe and ^{131}Xe are useful too. The ^{129}Xe isotope is good for magnetic resonance imaging of human blood system [4]. The ^{131}Xe isotope can be a good candidate of a polarized target for the test of time reversal invariance in reaction of polarized neutrons with polarized nuclei [5]. The neutron polarization p_n can be obtained by measuring the transmission ratios T_0/T, where T_0 and T are the transmissions when neutron passing through an unpolarized- and a polarized-target, i.e. $p_n = \sqrt{1-(T_0/T)^2} = \tanh(p_t n \sigma_p)$, where p_t and n are polarization and density (cm^{-2}) of the target nuclei. Polarization cross-section σ_p equals to the difference of the cross-sections when the spins of the neutron and the nuclear are parallel and anti-parallel. The nuclear polarization p_t is obtained when the polarization cross-section σ_p is known from other experiments, or when we compute σ_p for the strong neutron resonances with known spins and total momentum [6]. The resonance parameters themselves can be extracted from transmission T_0 or taken from the relevant nuclear data bases. This procedure assumes that the total neutron cross-section σ_0 is constant during the transmission measurements. This may be not true if the temperature of target is different during the measurement because of Doppler broadening, which

* Corresponding author. Tel.: +82 53 950 5320; fax: +82 53 955 5356.
E-mail address: gnkim@knu.ac.kr (G.N. Kim).

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happens exactly for optically polarized noble gases. Xenon isotopes ^{129}Xe and ^{131}Xe have strong s-wave low-lying resonances at 9.5 and 14.4 eV, respectively. The resonance at 14.4 eV is extremely strong and its peak cross-section achieves about 70 000 barns. It means that even a small distortion of a resonance shape owing to the Doppler broadening provides a systematic error for the polarization determination. This problem may be solved if one performs a measurement of total cross-section σ_0 at room temperature. Then, one needs to extract the resonance parameters taking into account a particular model of Doppler broadening. After that one can recalculate the resonance shape for any desired temperature and use it as a model of σ_0. This procedure allows us to use the ratio of T_0/T at the same temperatures, where T is a measured transmission with polarized nuclei, and T_0 is calculated with a model of σ_0. Therefore, the measurements of nuclear data for the xenon gas are required because of their insufficient accuracy. A few measurements of the neutron total cross-sections and resonance parameters for xenon gas are reported [7–9].

In the present work, the total cross-sections of natural Xe have been measured in the energy range between 0.1 and 40 eV by the neutron TOF method at the Pohang neutron facility (PNF). The PNF consists of an electron linac, a water-cooled Ta target and a 12 m long TOF path. The characteristics of PNF are described elsewhere [10].

The measured results were compared with other measurements [7–9] and the evaluated data in ENDF/B-VII.0 [11] and JENDL 3.3 [12]. The resonance parameters for Xe isotopes were determined from the fitting of transmission rate by using the Multilevel R-Matrix code SAMMY [13] and compared with those of Mann et al. [8], Mughabghab [14] and Landolt-Börnstein [15] and the evaluated data based on ENDF/B-VII.0 [11] and JENDL 3.3 [12].

2. Experimental procedure

2.1. Pulsed neutrons at the Pohang neutron facility

Since the experimental procedure has been published previously [16], only a general description is given here. The experimental arrangement for the transmission measurements is shown in Fig. 1.

Pulsed neutrons were produced via the photo-nuclear reaction by bombarding metallic Ta target with the pulsed electron beam. The neutron target is located in a position so that the electron beam hits its center. To reduce the γ-flash generated by the electron burst in the target, it is placed 5.5 cm away from the center of neutron guide tube. The target was composed of 10 Ta plates with different thickness and a diameter of 4.9 cm and the total length of neutron target is 7.4 cm. There was a 0.15-cm water gap between Ta plates in order to cool the target effectively [17]. The housing of the target was made of titanium. This target was set at the center of a cylindrical water moderator contained in an aluminum cylinder with a diameter of 30 cm and a height of 30 cm. The total neutron yield per kW of beam power was also measured by using the multiple-foil technique and found $(2.30 \pm 0.28) \times 10^{12}$ n/s [18]. The neutron energy spectrum with the water moderator is shifted to lower energy region because of the effect of moderation by water. To maximize the thermal neutrons in this facility, we have to use water to a level of 3 cm above the Ta target surface [19].

Neutron guide tubes were constructed of stainless steel with two different diameters, 15 and 20 cm, and were placed perpendicularly to the electron beam. Neutron collimation system was mainly composed of H_3BO_3, Pb and Fe collimators, which were symmetrically tapered from a 10-cm diameter at the beginning

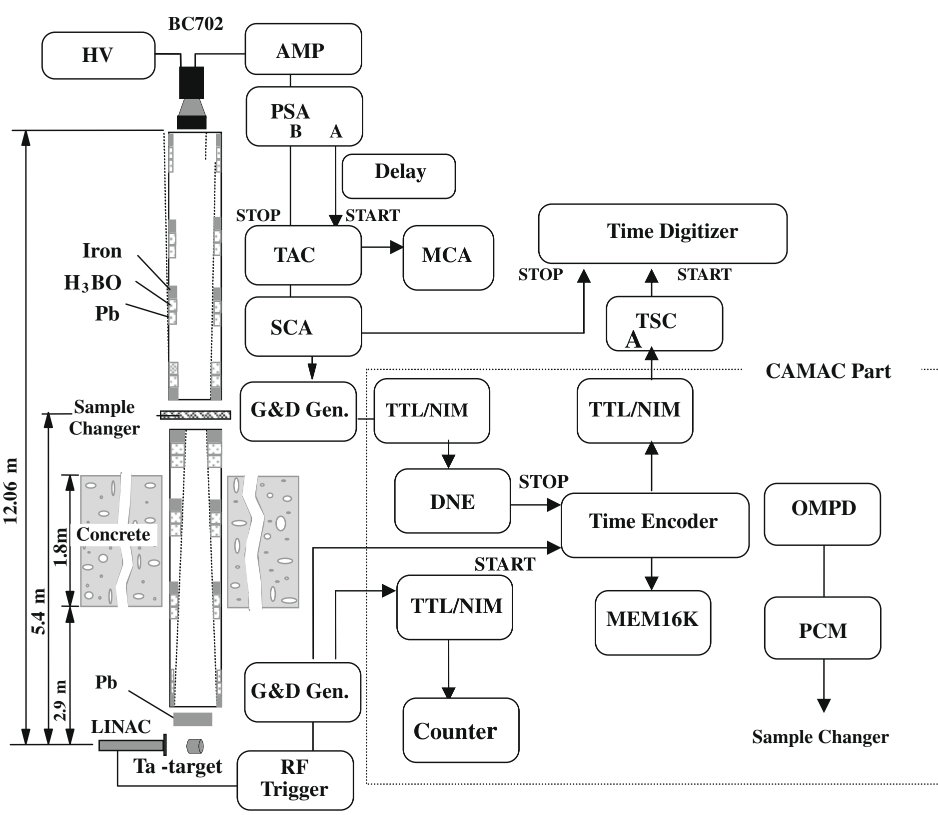

Fig. 1. Configuration of experimental setup and data acquisition system.