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Study on Moderation Properties of Cold Mesitylene using KUANS

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Abstract. Neutron moderation properties from the cold mesitylene moderator have been studied. Kyoto University Accelerator driven Neutron Source has been used for these experiments. The container of the mesitylene moderator is situated in front of the polyethylene moderator and the change of the time of flight spectrum has been recorded as a function of the temperature of the mesitylene moderator. By fitting the Maxwell distribution to the obtained TOF spectra, the neutron temperature corresponding to the mesitylene temperature is estimated.

1 Introduction

In recent years, compact neuron sources have been developed. In spite of their low neutron flux, they may be useful by specific scientific domains. For study of nano-scale structure in materials using small angle scattering, or reflectometry, cold neutrons are commonly used because the separation between the incident and the diffracted neutron beams are roughly proportional to the wavelength and larger and easier to measure with cold neutrons.

For producing such long-wavelength neutrons, cold neutron sources (CNS) are employed. For most of such CNS, liquid hydrogen or solid CH_4 are used as cold moderator. For compact sources, however, such materials are not suitable because a) they are gas in room temperature and the volume change is quite large when they become liquid or solid, and b) they are explosive in the gas state. Mesitylene having three metyl's around the benzene ring and staying liquid over a large range of temperatures has been suggested as a good moderator for small neutron sources [1].

In the present study, we measured the wavelength distribution from the cooled mesitylene moderator in order to clarify the moderation properties for neutrons of cold mesitylene using Kyoto University Accelerator-driven Neutron Source (KUANS).

In KUANS neutrons are produced by ^{9}Be(p, n)^{9}B reaction using pulsed 3.5MeV-proton beam. The neutrons are moderated by the polyethylene and the moderated neutrons are emitted to the direction perpendicular to the proton beam [1].

2 Measurements

Figure 1 shows schematic view of the experimental set-up for the present measurements.

The mesitylene moderator is situated in front of the polyethylene moderator having the size of 120x120x85 mm^3 in room temperature. The mesitylene container with 25(t)x96(w)x100(h) mm^3 is held in a vacuum container with the size of 43(t)x123(w)x155(h) mm^3. The moderators are surrounded by the graphite reflector.

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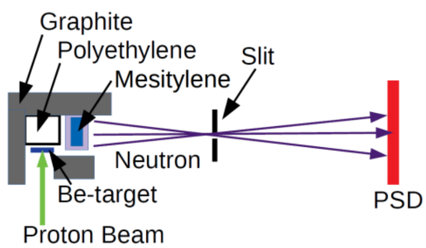

Fig. 1. Experimental set-up of the present study.

The neutrons emitted from the moderator surface go through the 20 (h)x5 (w) mm^2-slit situated at 1710 mm from the moderator surface and are detected with 3He 1-dimensional position sensitive detector (PSD) at 1546 mm from the slit. With the PSD, it is possible to measure 1-dimensional `pin hole image' over the moderator as well as the time of flight (TOF) spectrum. The TOF spectra presented in this report are taken from the mesitylene area of the PSD data. Total flight length is 3256mm and T0 (time between the system trigger and emission of thermal neutron from the moderator) is 70 μs for KUANS. The repetition rate and pulse width of the proton pulse are 100Hz and 60μs, respectively. Average proton current was about 60 μA. Since the time bin for TOF measurements is 10 μs, 6 successive channels of TOF data are arithmetically averaged.

Mesitylene moderator was cooled with cryostat from room temperature to 28K. During cooling process (about 10hr), the accelerator was operated, and the neutron spectra were measured. The TOF data are summed up for

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every 30min during when the temperature changes about 10 degree in kelvin. We adopt mean temperature for each TOF data.
The TOF spectra of neutron from the mesitylene moderator for the mesitylene temperature T_M =251, 204, 141, 84, 28K are shown in Fig. 2. Change of the spectrum is small for over 200K which is close to the melting point of mesitylene. As the T_M decreased, the peak intensity is lowered and shifted to the longer wavelength side.

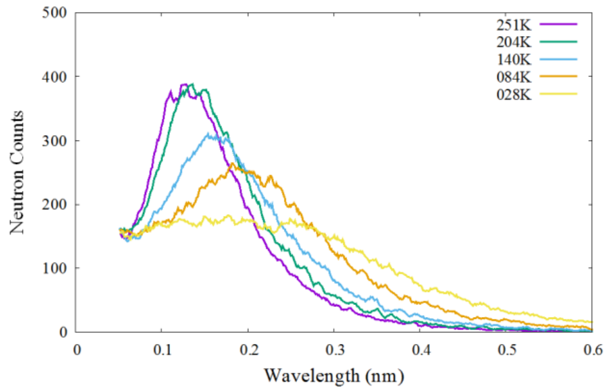

Fig. 2. TOF neutron spectra for various temperature of the mesitylene moderator.

The relative neutron intensity versus wavelength for T_M= 204, 141, 84, 28K comparing to that for 251K is shown in Fig. 3.

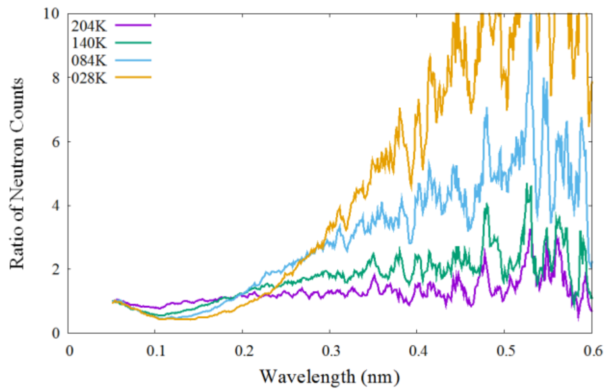

Fig. 3. Relative neutron intensity for some temperature comparing to that for 251K.

For wavelength longer than 0.25nm, the ratio is larger than unity and increases as the wavelength becomes longer and as T_M lowers. At the lowest temperature of 28K and at wavelength of 0.4nm, neutron intensity is six times higher compard to that at 251K.

3 Discussion

In order to obtain the neutron temperature, we fit a Maxwell distribution to the neutron wavelength distribution shown in Fig.2. The aim of the fit is to obtain the temperature of the neutrons T_n in the cold mesitylene moderator. Hence the fitting is carried out for neutrons with wavelength longer than 0.2nm. Examples of the fit results are shown in Fig.4. The fit function is the neutron flux and has the following form for neutron wavelength of λ:

$$\phi(\lambda) = \frac{A}{\lambda^5} \exp\left[-\frac{T_0}{T_n}\left(\frac{\lambda_0^2}{\lambda^2}\right)\right] \tag{1}$$

where λ_0=0.178nm, and T_0=300K are the wavelength and corresponding temperature for 25meV-neutron. The fit parameters are A and T_n, the latter of which represents the moderated neutron temperature.

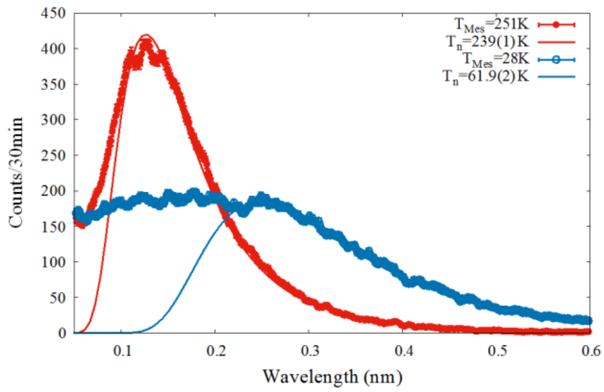

Fig. 4. Examples of Maxwellian fit to neutron TOF data shown in Fig.2 in the 251K (red) and 28K (blue) case.

The red and blue line in Fig.4 represent the spectrum for T_M=251K and 28K, respectively. For the former case T_n=239K, and for the latter T_n=61.9K, respectively. There may be two reasons why T_n is higher than T_M : (1) Because the number of excitation levels around several meV range in mesitylene is not enough, some neutrons are emitted before being fully moderated. (2) Thickness 25mm of the mesitylene moderator container is not enough for full moderation of neutron. Hence the discrepancy between the fit function and TOF spectrum in the short wavelength range is due to the under-moderation of the neutrons.
Repeating the same procedure for other temperature of mesitylene, the relation between T_M and T_n has been obtained. The result is shown in Fig.6.

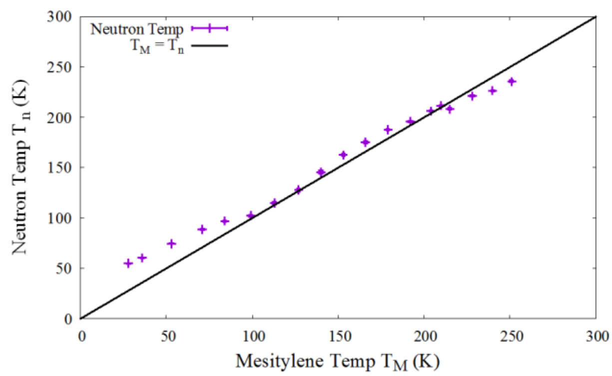

Fig. 6. The relation between T_M and T_n.

In the figure, the solid line stands for the relation $T_M = T_n$. When T_M>100K, T_n changes along T_M, which means that the neutron temperature follows the mesitylene temperature.

On the other hand, when T_M<100K there appears discrepancy between T_M and T_n, which means that at low mesitylene temperature neutrons are under-moderated; their temperature stays above the mesitylene temperature. In spite that, cooled mesitylene enables us to obtain an increase of flux of long wavelength neutrons with the factor 10 at 0.5nm compared to ambient temperature.

The slowing down distance for mesitylene is estimated to be about 6cm, since that for H_2O is about 5cm and is reverse proportional to the hydrogen density (6.7×10^{22}, 5.19×10^{22} for H_2O and mesitylene, respectively) [3]. The size of the mesitylene container is 25x96x100 mm^3 in the present experiments, and the `thickness' 25mm is too short for fully moderation. The neutron flux may be improved if the neutron is emitted the `side' of the container.

4 Conclusions

Neutron TOF spectra from the mesitylene moderator cooled from the room temperature to 28K were measured. Measured spectra have changed corresponding to the mesitylene temperature. As the mesitylene temperature decreases, the peak of the spectrum shifts to longer wavelength side, and the neutron counts in the wavelength range longer than 0.2nm increases. At 0.4nm, the ratio of the neutron counts from the cooled mesitylene against uncooled mesitylene becomes about 6. The neutron counts with the wavelength over 0.2nm, is well reproduced by the Maxwellian distribution. From the fit, neutron temperature is obtained and is almost the same in the temperature range above 100K, and the difference appears under 100K. The neutron flux may be improved by the optimization of the arrangement of the moderator system.

Acknowledgement

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References

1. Lourdes Torres, J.R. Granada, *Physica B: Condensed Matter*, **385-386**, Part 2, 2006, pp 1306-1308.
2. S. Tasaki et al., proceedings of Ucans III&IV, *Physics Procedia **60***, 2014, pp 181-185.
3. J. R. Lamarsh, *Introduction to Nuclear Reactor Theory*, Addison-Wesley Publishing Company Inc., Massachusetts, USA 1965.