Production cross sections of (d,x) reactions on natural ytterbium[†]

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The method for obtaining accurate information of light-charged-particle-induced reaction cross sections has generated significant interest in the nuclear data community because these reactions are being increasingly used in nuclear medicine, accelerator and nuclear technology, and the testing of nuclear reaction theories. Recently, we investigated deuteron-induced reaction cross sections from various target elements because measured data of the (d,x) processes are limited compared to those of (p,x) processes. A survey of literature shows that several investigations have been conducted for the ^{nat}Yb(d,x) reactions leading to various applications. As an example, the production of the ^{177}Lu radionuclide via the ^{nat}Yb(d,x) reaction finds applications in internal radiotheraphy and imaging procedures [1,2]. Its half-life is long enough to allow sophisticated preparation (e.g., shipping, labelling, purification etc.) for use without any significant loss of activity. ^{177}Lu can be produced in principle in several ways. Currently, a large scale production of ^{177}Lu is in practice by using only the high flux nuclear reactor via the direct ^{176}Lu$(n,\gamma)^{177}$Lu or indirect ^{176}Yb$(n,\gamma)^{177}$Yb$\rightarrow^{177}$Lu routes followed by a complex separation procedure of ^{177}Lu from the Yb isotopes [3]. On the other hand, the carrier-free ^{177}Lu is available in the charged-particle irradiations on various targets, though its activity is relatively lower than those in the reactor productions. However, it may be possible to overcome this deficiency with recent high-power accelerator technologies, which enable large scale and on-site productions of ^{177}Lu leading to its various practical applications.

The objective of the present study was to report the latest cross sections of the ^{nat}Yb$(d,x)^{169,170,171,172,173,174m,174,176m,177g}$Lu and ^{169,175,177}Yb reactions that were measured with a high precision over the energy range of 2–24 MeV using the AVF cyclotron facility of the RIKEN RI Beam Factory, Wako, Japan. Details on the irradiation technique, radioactivity determination, and data evaluation procedures are available in Ref.[4]. Owing to the space limitation of this report, we present only the ^{nat}Yb$(d,x)^{177g}$Lu cross sections and the deduced yield in Figs. 1 and 2, respectively. Measured cross sections with an overall uncertainty of about 12.8% are listed in Ref.[4]. The cross-sections were normalized by using the ^{nat}Ti$(d,x)^{48}$V monitor cross sections recommended by IAEA. Measured data were critically compared with the available literature data, and an overall good agreement was found. However, only partial agreements were obtained with the data extracted from the TENDL-2013 library based on the TALYS code. The deduced thick-target yields indicate that a low amount of no-carrier-added radioactivity of ^{177g}Lu (2.4 MBq/μA-h) could be obtained by irradiating an enriched ^{176}Yb target with 11-MeV deuteron energy from a cyclotron.

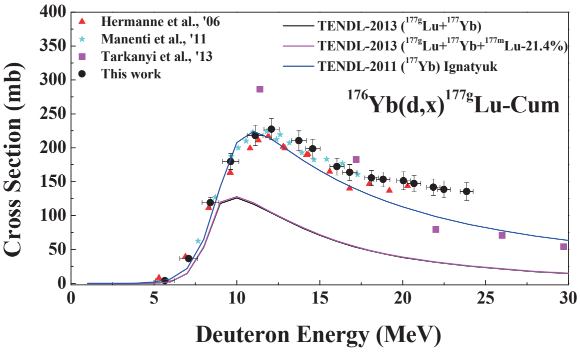

Fig. 1. Excitation function of the ^{nat}Yb$(d,x)^{177g}$Lu reaction.

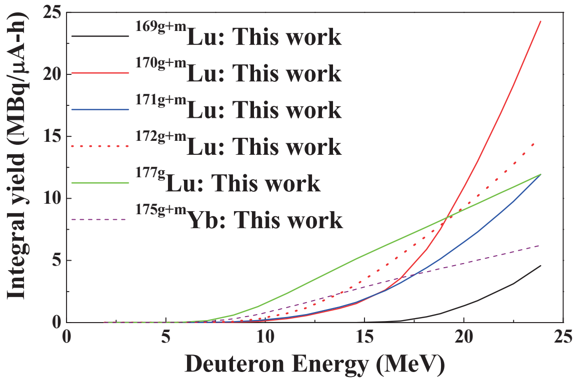

Fig. 2. Physical thick target yields for the $^{169g+m,170g+m,171g+m,172g+m,177g}$Lu and $^{175g+m}$Yb radionuclides.

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[†] Condensed from the article in Nucl. Inst. Meths. B. **335**, 8 (2014).

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