

## Cross checking of monitor reactions at RIKEN AVF cyclotron using 50 MeV alpha particle beams

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In the frame of a bilateral agreement between the Hungarian Academy of Sciences (HAS) and the Japan Society for the Promotion of Science (JSPS), experiments were performed to determine activation cross sections for a variety of radionuclides, which were produced in alpha particle induced nuclear reactions on  $^{27}\text{Al}$ ,  $^{\text{nat}}\text{Ti}$ ,  $^{\text{nat}}\text{Cu}$ ,  $^{\text{nat}}\text{Pd}$ ,  $^{\text{nat}}\text{Cd}$ ,  $^{116}\text{Cd}$ , and  $^{\text{nat}}\text{Ge}$  target materials, using the conventional stacked-foil-target technique and activation method. Experiments were performed during two separate beam time allocations in January 2015 and in December 2015. In both series of experiments alpha particle beams with  $E_{\alpha} = 51.2$  MeV energy were used, measured by the time of flight method. Irradiations took place in a special vacuum chamber for irradiation times of one or two hours with a beam current of 50 nA. The activity of the irradiated target foils was assessed by high purity Ge gamma-spectrometers. Decay of the produced radionuclides was followed for several half-lives in order to identify the sources of the possible interfering gamma radiations accurately. Reactions on the  $^{27}\text{Al}$ ,  $^{\text{nat}}\text{Ti}$ , and  $^{\text{nat}}\text{Cu}$  target materials are most frequently used for monitoring the beam parameters, such as actual beam energy, beam intensity, or energy loss of the bombarding particles in the irradiated target material. Recommended cross section values are provided for those monitor reactions by the International Atomic Energy Agency (IAEA)<sup>(1)</sup> and are freely available on the Internet. Since the recommended data available by IAEA were evaluated one by one, independently, a cross-check of the reaction cross section is advised. The aim of our measurements regarding the  $^{27}\text{Al}$ ,  $^{\text{nat}}\text{Ti}$ , and  $^{\text{nat}}\text{Cu}$  targets was to contribute the cross-checked data sets to the database maintained by the Nuclear Data Section (NDS), IAEA and extend the energy range of the recommended data up to 50 MeV, where necessary. A stack containing thin Al, Ti, and Cu metallic foils was irradiated to cross-check the  $^{27}\text{Al}(\alpha, x)^{22,24}\text{Na}$ ,  $^{27}\text{Al}(\alpha, x)^{24}\text{Na}$ ,  $^{\text{nat}}\text{Ti}(\alpha, x)^{51}\text{Cr}$ ,  $^{\text{nat}}\text{Cu}(\alpha, x)^{66}\text{Ga}$ ,  $^{\text{nat}}\text{Cu}(\alpha, x)^{67}\text{Ga}$ , and  $^{\text{nat}}\text{Cu}(\alpha, x)^{65}\text{Zn}$  monitor reactions. As indicated by the first preliminary results shown in Figs. 1 and 2, there is only a small inconsistency among the recommended values of the investigated monitor reactions. Experimental data measured on  $^{27}\text{Al}$ ,  $^{\text{nat}}\text{Ti}$ , and  $^{\text{nat}}\text{Cu}$  in the same stack show that the recommended values provided in the IAEA database are relatively in good agreement. However, the shapes of the recommended curves and the new experimental data show some deviations, which require further analysis and verification.

Preliminary data show that the amplitude of the recommended excitation functions and the experimental values have maximum difference of 7%, which should be confirmed later, since some of the data collection is still running and data evaluation is in progress.

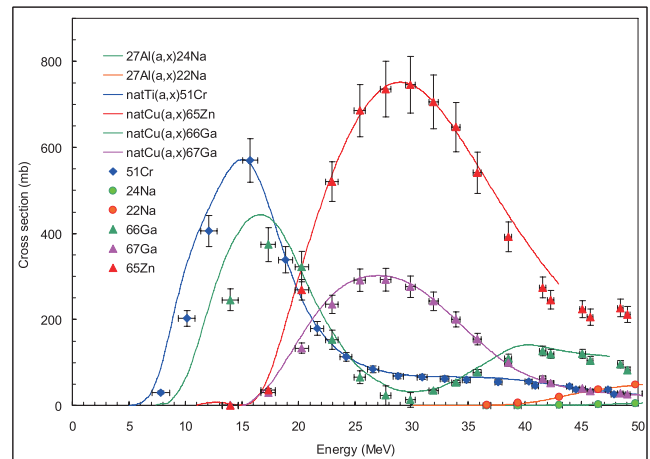


Figure 1. Preliminary results are shown on cross section data for the  $^{27}\text{Al}(\alpha, x)^{22,24}\text{Na}$ ,  $^{\text{nat}}\text{Ti}(\alpha, x)^{51}\text{Cr}$ ,  $^{\text{nat}}\text{Cu}(\alpha, x)^{66,67}\text{Ga}$ , and  $^{\text{nat}}\text{Cu}(\alpha, x)^{65}\text{Zn}$  reactions. Solid curves denote the IAEA recommended values, which are in acceptable agreement with our measurements; however, the shape of the excitation functions should be confirmed.

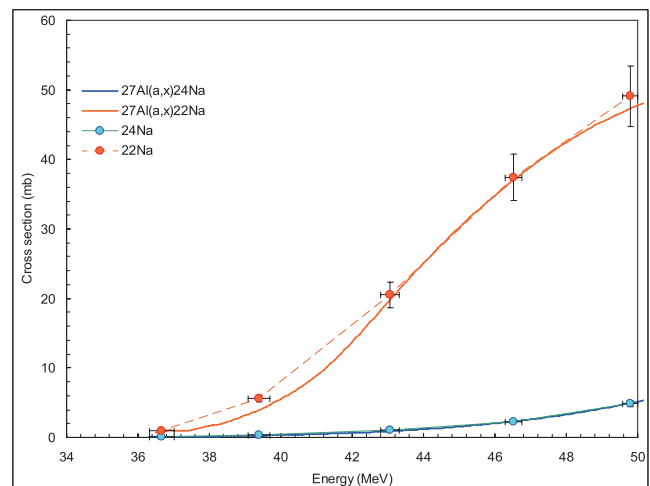


Figure 2. Preliminary results are shown on cross section data for the  $^{27}\text{Al}(\alpha, x)^{22,24}\text{Na}$  reactions. Solid curves denote the IAEA recommended values. The shape of the excitation functions should be confirmed.

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### Reference

1) [https://www-nds.iaea.org/medical/monitor\\_reactions.html](https://www-nds.iaea.org/medical/monitor_reactions.html)