APPLICATION OF NEUTRON RESONANCE CAPTURE ANALYSIS FOR THE INVESTIGATION OF THE ELEMENT COMPOSITION OF THE PANEL FROM THE TRIPTYCH (PRESUMABLY 17TH CENTURY)

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The method of Neutron Resonance Capture Analysis (NRCA) is currently being developed at the Frank Laboratory of Neutron Physics (FLNP). The method is fully non-destructive it can be used to determine the bulk composition of objects without preparation or sample taking. The NRCA is based on the registration of neutron resonances and the measurement of the yield of reaction products in the resonances.

In this paper, we describe the application of NRCA for the investigation of an archeological object transferred to the FLNP by the Museum and Exhibition Complex (MVK) "Volokolamsk Kremlin". The object was the panel from the triptych (presumably 17th century) which was found in the Moscow region, Volokolamsk district, Chubarovo village.

1. INTRODUCTION

Neutron Resonance Capture Analysis (NRCA) is applied to determine the elemental composition of objects [1]. The method is non-destructive, doesn’t require special preparation of samples, and allows measuring the bulk composition of objects. All these analysis characteristics listed are useful for the investigation of archeological samples. The method of NRCA is currently being developed at the Frank Laboratory of Neutron Physics (FLNP) [2,3]. It is based on the registration of neutron resonances and the measurement of reaction products yield in these resonances.

In this paper, we describe the application of NRCA for the investigation of an archeological object transferred to the FLNP by the Museum and Exhibition Complex (MVK) "Volokolamsk Kremlin" under terms of a concluded cooperation agreement. In total, 28 fragments of pottery and 25 metal finds were transferred for research.

One of the provided artifacts is the panel of the triptych (Fig.1). The object presumably dates back to the 17th century. The panel was found in the Moscow region, Volokolamsk district, Chubarovo village. Only one panel of the triptych was found in the excavation that is probably due to the Old Believers tradition. According to the tradition, during the wedding ceremony, the girl disassembled the triptych (the three-panel icon) and took one panel with her to her husband's house as a keepsake of her family. The artifacts investigations by various methods and the scientific analysis will reveal the handicraft production centers; clarify the finds dating and their technological schemes.

Fig. 1. The panel of the triptych (presumably 17th century).

2. EXPERIMENT

The sample was irradiated with neutrons by resonance neutron source (IREN) facility and reactions time-of-flight spectrum (n,γ) was registered. The main part of the IREN facility is a linear electron accelerator LUE-200 with a non-multiplying neutron-producing target of the VNZH-90 alloy [4, 5]. The facility parameters were: the average energy of electrons ~ 60 MeV, the peak current ~ 1.5 A, the width of electron pulse ~ 100 ns, and the repetition rate 25 Hz. The total neutron yield was about $3 \cdot 10^{11}$ s^{-1}. The measurements were carried out at 58.6 meters flight path of the IREN 3rd channel. A big liquid scintillator detector was used for the registration of γ-quanta [6]. The sample was placed inside the detector. The neutron flux was permanently monitored by the SNM-17 neutron counter. The signals from the detector and the monitor counter were simultaneously fed to two independent inputs of the time-to-digital converter (TDC). The time-of-flight spectra were stored on a computer disk for later offline processing.

The sample measurements lasted about 98 hours. The resonance energies were determined according to the following formula:

$$E = \frac{5227L^2}{t^2}, \tag{1}$$

where, t – time of flight in microseconds, L – flight path in meters, E – kinetic energy of a neutron in eV.

The resonances of copper and zinc were identified on the time-of-flight spectrum (Fig.2) [7, 8].

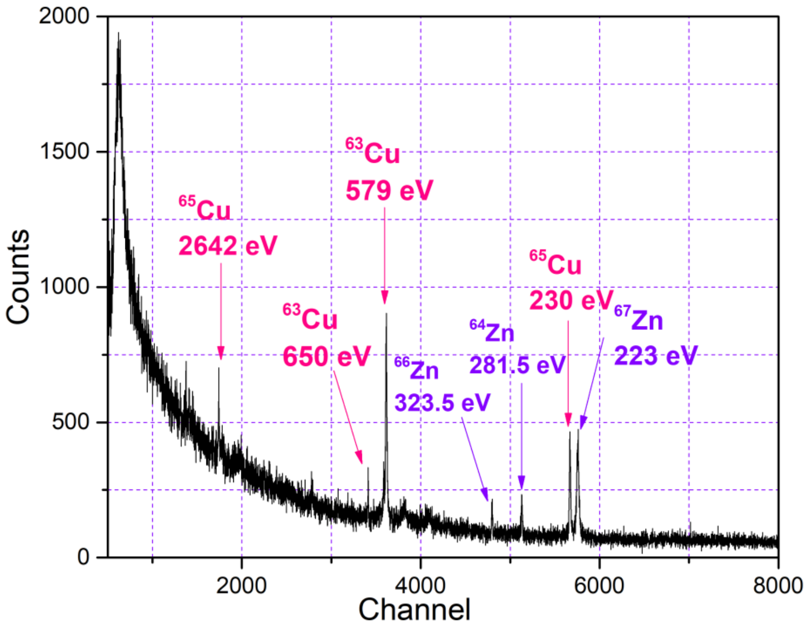

Fig. 2. The part of reactions time-of-flight spectrum (n,γ) obtained in measurements on the panel of the triptych material. The time channel width is 50 ns.

The measurements with standard samples of copper and zinc were made in addition to themeasurement with the investigated sample (Fig. 3, 4).

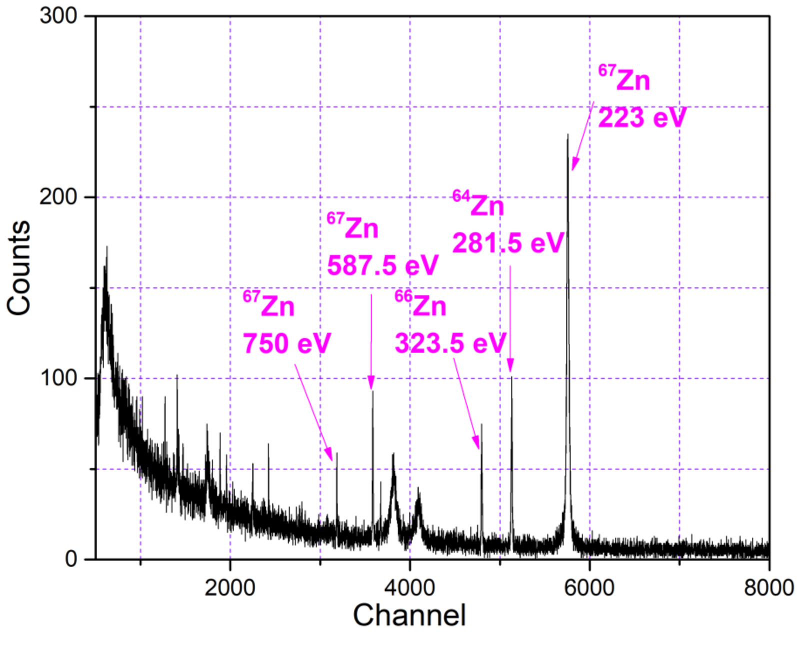

Fig. 3. The part of reactions time-of-flight spectrum (n,γ) of zinc standard sample. The time channel width is 50 ns.

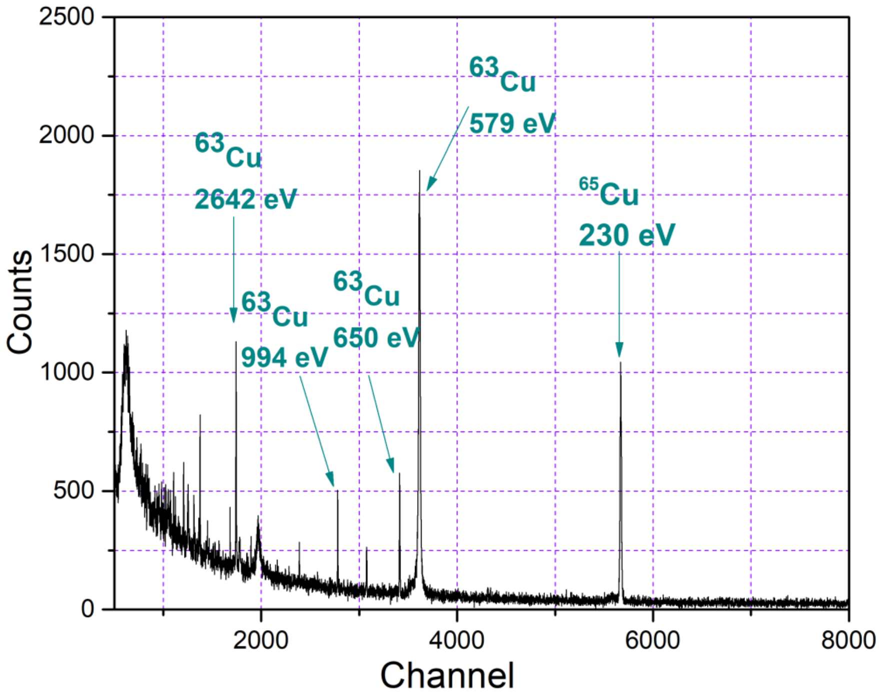

Fig. 4. The part of reactions time-of-flight spectrum (n,γ) of copper standard sample. The time channel width is 50 ns.

3. DATA ANALYSIS AND RESULTS

The number of the element nuclei in the sample was determined by gamma-quanta yield measurement in the resonances. Two resonances of zinc and two resonances of copper were selected during the experimental data analysis. The detector sum of counts in resonance is expressed by the following formula:

$$\sum N = f(E_0) \cdot S \cdot t \cdot \varepsilon_\gamma \cdot \frac{\Gamma_\gamma}{\Gamma} A \,. \tag{2}$$

Here, $f\,(E_0)$ is the neutron flux density at the resonance energy E_0, S – the sample area, t – measuring time, ε_γ – the detection efficiency of the detector radiative capture, $\Gamma\gamma$, Γ – the radiative and total resonance widths.

$$A = \int_{E1}^{E2} [1 - T(E)] dE \tag{3}$$

is a resonance area on the transmission curve, where $E1$, $E2$ – initial and final values of energy range near resonance.

$$T(E) = e^{-n\sigma(E)} \tag{4}$$

the energy dependence of the neutron transmission by the sample; $\sigma(E)$ – the total cross section at this energy with Doppler broadening, n – the number of isotope nuclei per unit area. The value A was determined from experimental data for investigated sample by the next formula:

$$A_x = \frac{\sum N_x \cdot M_s \cdot S_s}{\sum N_s \cdot M_x \cdot S_x} \cdot A_s \tag{5}$$

Here, $\sum N_x$, $\sum N_s$ – counts under the resonance peak of the investigated and standard samples, S_X, S_S – the area of the investigated and standard samples. M_X, M_S – the number of monitor counts during the measurement of the investigated and standard samples.

The A_S value was calculated by means of known resonances and n_S parameters for the standard sample. The n_X value was determined from the investigated sample A_X value. The values of $\sigma(E)$ and A were numerically determined, by using the algorithm which was described in [9]. This procedure is schematically shown in (Fig.5). The analysis results are presented in the Table1.

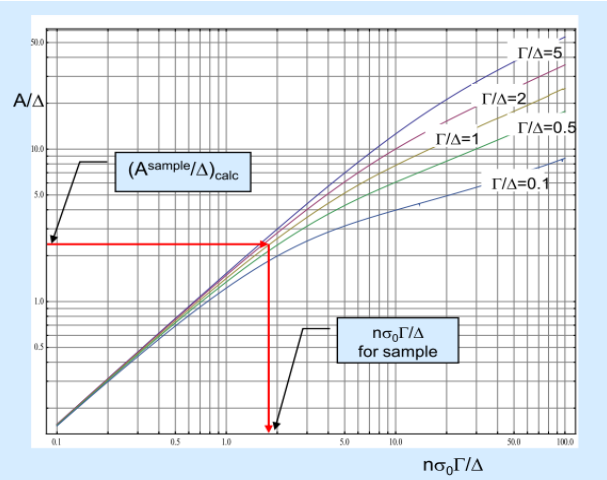

Fig. 5. Dependence of value A on a number of nuclei and resonance parameters [9].

Table 1. Measurements results of the panel of the triptych (presumably 17th century).

№	Element	Mass, g	Weight, %
1	Cu	10.6±2.1	57±11
2	Zn	7.71±0.39	41.5±2.1

4. CONCLUSION

The elemental and isotopic composition of the panel from the triptych was determined by NRCA. The mass of the artifact is 17.22 g. According to the result of the analysis, the value of determining total elements mass coincides with the triptych panel mass within the margin of error.

The elemental composition may help to identify the place of manufacture and the origin of the object. More likely it should be compared to both the local and the Pomor casting (Vygovsky Monastery), the Transfiguration Monastery casting in Moscow, the casting of Vychegda Old Believers.

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