DIFFERENTIAL CROSS-SECTIONS OF THE 1434 keV GAMMA EMISSION FROM THE $^{51}V(p,\gamma)^{52}Cr$ REACTION

V.N. Bondarenko, V.I. Sukhostavets, S.N. Utenkov, N.A. Kochnev, D.V. Medvedev
National Science Center "Kharkiv Institute of Physics and Technology", Kharkiv, Ukraine

INTRODUCTION

Registration of gamma radiation from nuclear reactions is widely used for the analysis of chemical elements in materials (PIGE technique: proton induced γ-ray emission [1]).

The reaction $^{51}V(p,\ \gamma)^{52}Cr$ with reaction energy Q=+10.51 MeV is the most promising for the analysis of such an element as vanadium. Among the set of gamma lines in the emission spectrum from this reaction, one of the most intense is the line 1434 keV, which corresponds to the $E2$ transition from the first excited state of ^{52}Cr to the ground state.

The aim of the presented work was to measure the differential cross sections of the generation of gamma quanta with energy E_γ=1434 keV in the $^{51}V(p,\ \gamma)^{52}Cr$ reaction in the proton energy range E_p=1.1-2.2 MeV, which corresponds to the ^{52}Cr nucleus excitation energy range E_x=11.6-12.7 MeV, for the registration angle $\theta=90^0$ relative to the beam.

EXPERIMENT

The measurements were performed on the proton beam of the ESU-5 accelerator of NSC KIPT.

The measurements were performed in a geometry in which the beam falls on the target at an angle $\varphi=45^0$ relative to the normal to the target, and the detector was installed on the side opposite to this normal, also at an angle of 45^0 to it. Accordingly, the angle at which the detector was placed relative to the beam was $\theta=90^0$, and the registered gamma radiation did not pass through the substrate material, but fell into the detector located outside the target chamber, through a 100 µm beryllium window in the chamber wall.

The target holder was electrically connected to the target chamber, which was connected to the ground through a current integrator. A negative potential of 300 V was applied to the guard ring located in front of the target chamber to suppress the flow of secondary electrons knocked out of the target by the beam protons.

The measurements used a target made of natural vanadium, deposited by electrolytic method on a tantalum substrate with a thickness of 0.3 mm. The relative content of the ^{51}V isotope in natural vanadium is f=0.9975. The target thickness $t=5.5\times10^{21}$ at./m^2 (about 76 nm) was measured using Rutherford backscattering on a helium ion beam with an energy of 1.6 MeV.

In the used measurement geometry, the proton energy loss in this target was about 9 keV at an energy of 1.1 MeV and 6 keV at an energy of 2.2 MeV.

Gamma radiation was recorded using a Ge(Li) detector with a volume of 80×10^{-6} m^3 with an energy separation of 7 keV at an energy of 1.33 MeV.

To determine the energy dependence of the efficiency ε(Eg) of the spectrometer, the ZSGD sources ^{133}Ba, ^{152}Eu, ^{242}Am were used. The obtained efficiency value for the energy E_γ=1434 keV was 0.00127.

The energy calibration of the accelerator was carried out using the known resonances 991.9 and 1683.6 keV of the $^{27}Al(p,\ \gamma)^{28}Si$ reaction.

In the laboratory coordinate system, the differential cross section $d\sigma(E_p,\theta)/d\Omega$ of the generation of gamma quanta with energy E_γ from the reaction (p,γ) averaged over the thickness t of the target was determined from the general expression

$$N_\gamma(E_p,\theta) = N_p \frac{d\sigma_\gamma(E_p,\theta)}{d\Omega}\Omega_{eff}\frac{ft}{\cos\varphi}, \qquad (1)$$

where N_γ is the number of registered gamma quanta with energy E_γ; N_p is the number of protons incident on the target during the spectrum acquisition; $\Omega_{eff}=4\pi\varepsilon(E_\gamma)$ is the effective solid angle of the detection system; f is the relative abundance of the isotope on which the reaction occurs; φ is the angle of incidence of the beam on the target relative to the normal to the target.

As usual, the value of N_p was determined from the relation $N_p=q/e$, where q is the integral electric charge collected on the target during exposure to the proton beam; e is the elementary electric charge.

The errors of the parameters of formula (1) were: 1% (integral charge); 7% (spectrometer registration efficiency); 5% (target thickness). The mean-square error in determining the area of the N_γ peak in the gamma spectrum varied from 5% at the maxima of the measured excitation function to 15% at the minima. As a result, the total average error in measuring the cross sections was 17%.

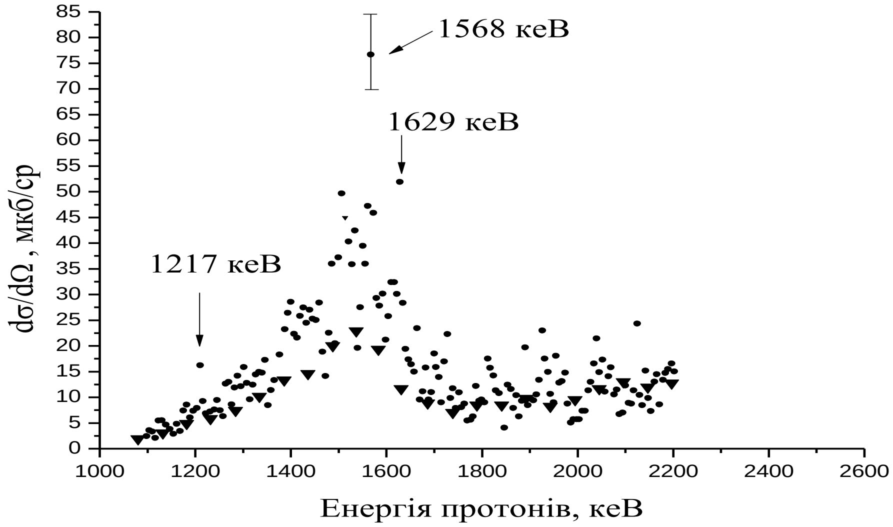
MEASUREMENT RESULTS AND DISCUSSION

Figure presents the excitation functions for the $^{51}V(p,\ \gamma)^{52}Cr$ reaction.

The more blurred nature of the second energy dependence is explained by the fact that in [3] a target 25 times thicker than the one used by us was used.

The obtained results on the energy dependence of the differential cross sections of the generation of gamma quanta with an energy of 1434 keV in the $^{51}V(p,\gamma)^{52}Cr$ reaction complement the existing data on similar cross sections and can be used both in the analysis of vanadium and in other applications.

It can be assumed that the most acceptable for the analysis is the proton energy of about 1650 keV, at which the yield from this reaction is sufficiently high, and the neutron yield from the concomitant $^{51}V(p,n)^{51}Cr$ reaction is low.



Energy dependences for the reaction cross sections $^{51}V(p, \gamma)^{52}Cr$:
• – differential cross sections of the generation of gamma quanta from this reaction with an energy of 1434 keV, measured in this work, registered at an angle $\theta=90^0$ with respect to the beam (arrows indicate a number of resonances known from the literature [2]); ▼ – full reaction cross sections normalized to 4π from work [3]

REFERENCES

1. M. Nastasi, J.W. Mayer, Y. Wang. *Ion beam analysis:fundamentals and applications* // CRC Press, 2014, p. 472.
2. I. Demeter et al. *Investigation of γ spectra of certain (p,γ) resonances* // Acta Phys. Hung. 1971, v. 30(1), p. 1-9.
3. J.L. Zyskind et al. *Competition effects in proton-induced reactions on ^{51}V* // Nucl. Phys. 1980, A343, p. 295.