REGISTRATION OF GAMMA RAYS FROM THE REACTION $^{16}O(N,P)^{16}N$ ON THE DIRECT NEUTRON BEAM OF CASCADE GENERATOR KG-2.5

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Abstract

In the present work the results of analysis of the oxygen content in the water with the help of gamma-rays registration from the reaction 16O(n, p)16N is described. The samples were installed permanently on the direct beam of neutrons generated by the reaction 7Li(d, n) in the cascade generator KG-2.5 (IPPE). A comparison was carried out with experimental data obtained by the activation method in similar experimental conditions.

The method of determination of oxygen in the samples is based on the reaction $^{16}O(n,p)^{16}N(\beta-)$. A beam of neutrons generated in the reaction ^{7}Li (d,n) on the cascade generator KG-2.5 was used for irradiation of the sample. The energy distribution of neutrons from the target in the case of deuterons with an energy of 0.7 MeV is shown in Figure 1. There is a homogeneous group of neutrons in the region of 14 MeV (the channel of reaction $^{7}Li(d,n)^{8}Be$) and a continuous spectrum of neutrons with energies ranging from very small up to 14 MeV. The total neutron yield from this reaction for deuterons with an energy of 1 MeV and a thick target is about $3\cdot10^{7}$ neutrons/μA/sr.

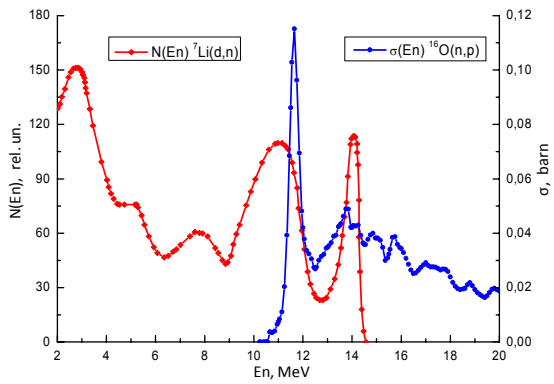

Figure 1: The energy spectrum of neutrons in the $^{7}Li(d,n)$ at an angle $\theta=0^{0}$ at Ed=0,7 MeV and a cross section of reaction $^{16}O(n,p)^{16}N$.

The same figure shows a cross section of the reaction $^{16}O(n,p)^{16}N$. It is seen that only a small fraction of the total neutron spectrum is effective for generating reaction $^{16}O(n,p)$ (~ 15%). The rest of the neutrons generates the background component of the resulting gamma-spectra, which is caused by the reactions (n,γ), (n,2n), (n,α), (n,p) of setup constructional materials (including detector materials), which generate a spectrum of gamma rays in the range of 0-3 MeV. There is an opportunity to distinctly register gamma rays with energies 7.12 and 6.13 MeV produced by beta decay of ^{16}N. [1]

Methodical difficulty of this experiment is the intensity of gamma background caused by the above reactions. These gamma rays produce a large load electronic path of the spectrometer. It leads to a distortion of the response function of the spectrometer and bandwidth of gamma spectroscopy system.

One of the consequences of high load detector is, for example, blocking the registration of high-energy gamma rays. The parameters of the electron spectrometric channel and of the detector shielding was optimized to solve this problem (choosing the correct amplifier and its mode of operation, the choice of parameters for the formation and registration of signals). There was also selected the optimum exposure time mode irradiation of samples and recording the spectra of gamma-ray induced activity.

The water was selected as a sample. The permanently installed water sample was irradiated for 10 s. Time of measurement of the induced activity was 100 s. The experimental scheme for the case of a stationary target is presented in Figure 2.

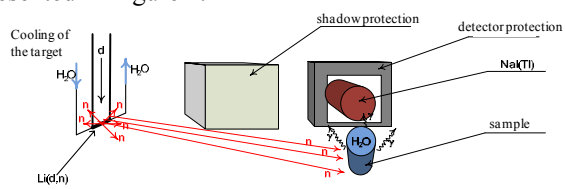

Figure 2: The experimental scheme for the identification of oxygen on the direct beam accelerator. NaI(Tl) - 100x100.

A similar experiment was carried out in the absence of the sample (background measurement). The results are shown in Figure 3.

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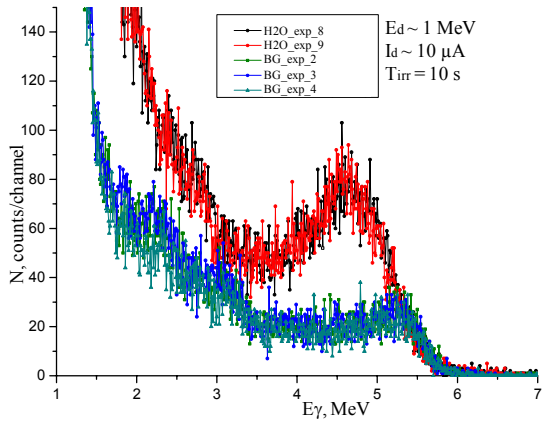

Figure 3: The energy distribution of gamma rays in the range of 0-20 s registered after irradiation the sample H_2O by neutrons from the reaction $^{7}Li(d,n)$ for 10 s. NaI(Tl) -100x100.

The figure shows that the number of gamma rays corresponding to the double peak emission of gamma rays is significantly higher than the number of pulses background. High-energy gamma rays in the background spectrum is due to the reactions of the isotopes of oxygen, which is part of the atmosphere and the reflector (MgO_2) crystal NaI(Tl) [2]. The selection of the time dependence of pulses belonging to the energy range 3.5-6 MeV was conducted to determine the decay rate of activated nuclei ^{16}N. The resulting decay curve for one cycle of measurements is shown in Figure 4.

The resulting decay curve of gamma activity was processed to evaluate the half-life of the induced activity. The processing of decay curves showed that the half-life of accumulated activity is 7.14 ± 0.39 s and belongs to the nuclei of ^{16}N.

For demonstration of the possible use of this method for practical applications was carried out continuous irradiation of the pipeline through which water moves from the target to the neutron detector.

Figure 5 shows the scheme of an experiment to determine the induced activity of water moving in the pipe from the accelerator target to the neutron detector.

The results of the experiment are shown in Figure 6. The difference in the number of counts in the peak is due to the fact that the curves are not normalized to the total neutron flux. Some difference may also be due to the fluctuation of water flow in the pipeline. One of the curves was obtained at a reduced flow rates.

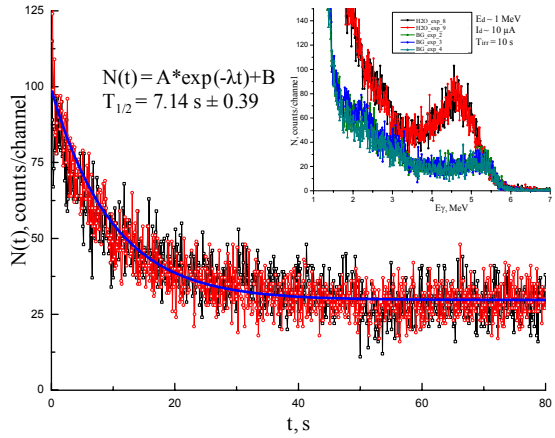

Figure 4: The decay curves of gamma-activity of nuclei ^{16}N accumulated in the reaction $^{16}O(n,p)^{16}N$. Energy window: 3.5-6 MeV. NaI (Tl) -100x100.

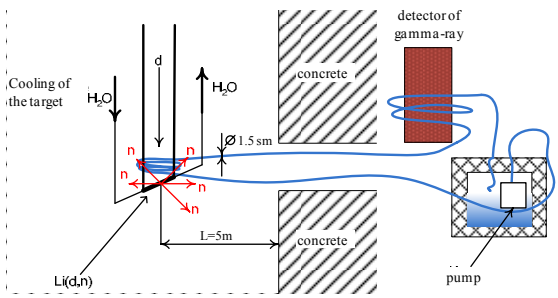

Figure 5: Scheme of the experiment to determine the induced activity of water in the pipeline. NaI (Tl) -100x100.

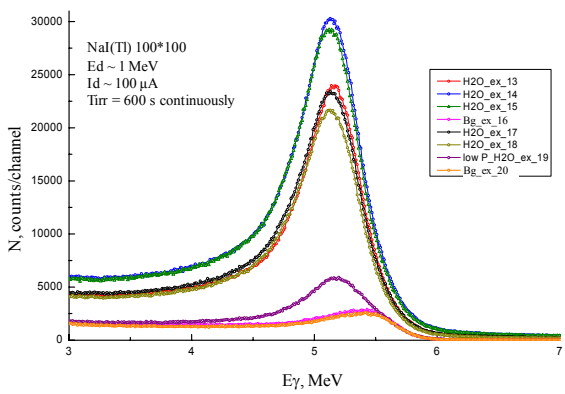

Figure 6: The energy distribution of gamma rays registered during continuous irradiation of water flow by neutrons from the reaction $^{7}Li(d,n)$. The irradiation time of 600 seconds. NaI(Tl) -100x100.

Figure 6 shows that there is a significant excess of the number of counts of reaction $^{16}O(n,p)^{16}N$ in the sample over the count number of background. The effect will be greatly enhanced in the case of detectors with higher energy resolution - BGO or lanthanum bromide.

This method may obtain application in actual practical applications, not only in the nuclear industry, but also in the oil and gas industry. A compact 14 MeV neutron

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generator is used as the neutron source - neutrons generated by the reaction T(d,n). Currently, these generators are produced by the domestic industry. The intensity of the neutron flux is approximately 10^9-10^{10} neutrons/s.

The following are the possible practical applications related to the registration of induced activity ^{16}N:

- ✓ Creating a device for determining the velocity and flow rate (oil and gas) in pipelines. (Contents of oxygen. Flow rate and liquid).
- ✓ Source of High-Energy Gamma-rays (2.75, 6.13 and 7.11 MeV) for the calibration of the energy scale of gamma spectrometers.
- ✓ Monitoring the spatial distribution of oxygen in the fuel rods.
- ✓ Certification of the chemical composition of irradiated fuel rods, which must be disposed.

It should be noted that the present measurements were carried out in the presence of a large background of gamma radiation. A similar situation will occur with irradiated fuel.

REFERENCE

[1] http://www.nndc.bnl.gov/endf/b7.1/download.html

[2] N.A. Vartanov, P.S. Samoilov. “Practical methods of scintillation gamma spectrometry”. Atomizdat, Moscow, 1964.

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