APPLICATION OF BaF₂ SCINTILLATOR TO OFF-LINE GAMMA-RAY SPECTROSCOPY

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Total cross sections of the monitoring reaction $^{27}$Al(d, 3p 2n) $^{24}$Na at 3.0 AGeV and 3.65 AGeV were determined from direct gamma-ray counting of irradiated targets with a spectro-meter using a large volume BaF₂ scintillation crystal. Cross sections of $14.1 \pm 1.3$ mb and $14.7 \pm 1.2$ mb are compared with previous data at other energies.

1. Introduction

Increasing interest in BaF₂ crystals as scintillators for gamma-ray spectroscopy is caused by their attractive properties [1 - 3]: short radiation length ($X_0 = 2.05$ cm), high density ($\rho = 4.88$ g/cm$^3$) as well as light output and detection efficiency. Because of its fast component ($\lambda = 220$ nm, $\tau = 600$ ps), the BaF₂ crystal offers several times better time resolution than NaI(Tl) at the expense of slightly worse energy resolution. The presence of the fast component allows very good timing characteristics comparable to those obtained with a fast plastic scintillator. A practical advantage of BaF₂ is its mechanical and chemical stability. The crystal is nonhygroscopic and resistant to radiation damage. For applications to gamma-ray spectroscopy, it is also important that the mean neutron capture cross section of barium for low energy neutrons is more than 10 times lower than that of iodine.

Recently, it has been reported on the first experience of large volume BaF₂ applications to in-beam gamma-ray spectroscopy [4]. In the present work we report on the application of the large volume BaF₂ scintillator to off-line gamma-ray spectroscopy. Using a scintillator of this type and conventional electronics, as well, we have measured the cross sections of the monitoring reaction $^{27}$Al(d, 3p 2n) $^{24}$Na at relativistic energies via the induced $^{24}$Na activity in the irradiated aluminium target. The significance of the cross section measurement of the above reaction is connected with a precise monitoring of a deuteron beam flux by means of the well-known activation technique. According to the unique properties of BaF₂ scintillation crystal, its application to this experimental technique may be desirable.

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2. Experiments and results

The experiment was performed in an external beam of the Dubna synchrophasotron. The target stacks consisting of three 20 mg/cm² thick aluminium foils of high purity, were irradiated with 3.0 A GeV and 3.65 A GeV deuterons. The outer guard foils were used for recoil loss compensation; the central foil was analysed. The diameter of the target discs was 3.2 cm. They were positioned so that the beam passed through the centre. The irradiation periods were equal to \( \approx 10^{13} \) total flux particles in both irradiations. The beam flux has been monitored detecting neutrons formed in an interaction of the primary beam with the Pb-converter by using absolute calibrated fission chambers KNT-8 [5].

After the irradiations, the central aluminium foils in both target stacks were gamma-ray counted on a spectrometer with a barium fluoride scintillation detector. The BaF₂ crystal of about 150 cm³ in volume, carefully polished and covered by a PTFE reflector, was optically coupled to a Philips XP 2020 Q quartz-window photomultiplier. A standard divider chain without any special gain stabilization system was used. At a typical bias voltage of 2000 V the current in the divider chain about 2 mA was found to be sufficient for stable operation during the measurements with high counting rates of about 1.5 kHz. The anode signals were fed into an ORTEC 572 amplifier and transferred to a 4096-channel pulse-height analyzer through conventional electronics.

![Gamma-ray spectrum from the aluminium target irradiated with 3.65 A GeV deuterons taken with a 150 cm³ BaF₂ detector.](image)

Fig. 1. Gamma-ray spectrum from the aluminium target irradiated with 3.65 A GeV deuterons taken with a 150 cm³ BaF₂ detector.

1) The obviously used energy unit AGeV means energy in GeV per nucleon.