Feasibility Study of Fast Neutron Activation Analysis of Iron with $LaBr_3$:Ce Scintillation Detector

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Introduction

- A $LaBr_3$:Ce scintillation detector has superior characteristic of linearity in the γ-ray energy and good energy resolution about 3% in FWHM for the 661.7-keV γ-ray energy of Cs-137.
- The $LaBr_3$:Ce scintillation detector has a relatively high intrinsic background radiation due to La-138 and Ac-227.
- For fast neutron activation analysis (FNAA) with the $LaBr_3$:Ce scintillation detector, the intrinsic background radiation of the detector should be considered.
- We investigated the feasibility of fast neutron activation analysis of iron with the $LaBr_3$:Ce scintillation detector.

Materials & Methods

Experimental Setup

- Intrinsic background of a $LaBr_3$:Ce scintillation detector was measured with a high-purity germanium (HPGe) detector as shown in the Fig. 1. The measurement time was 268,000 s.

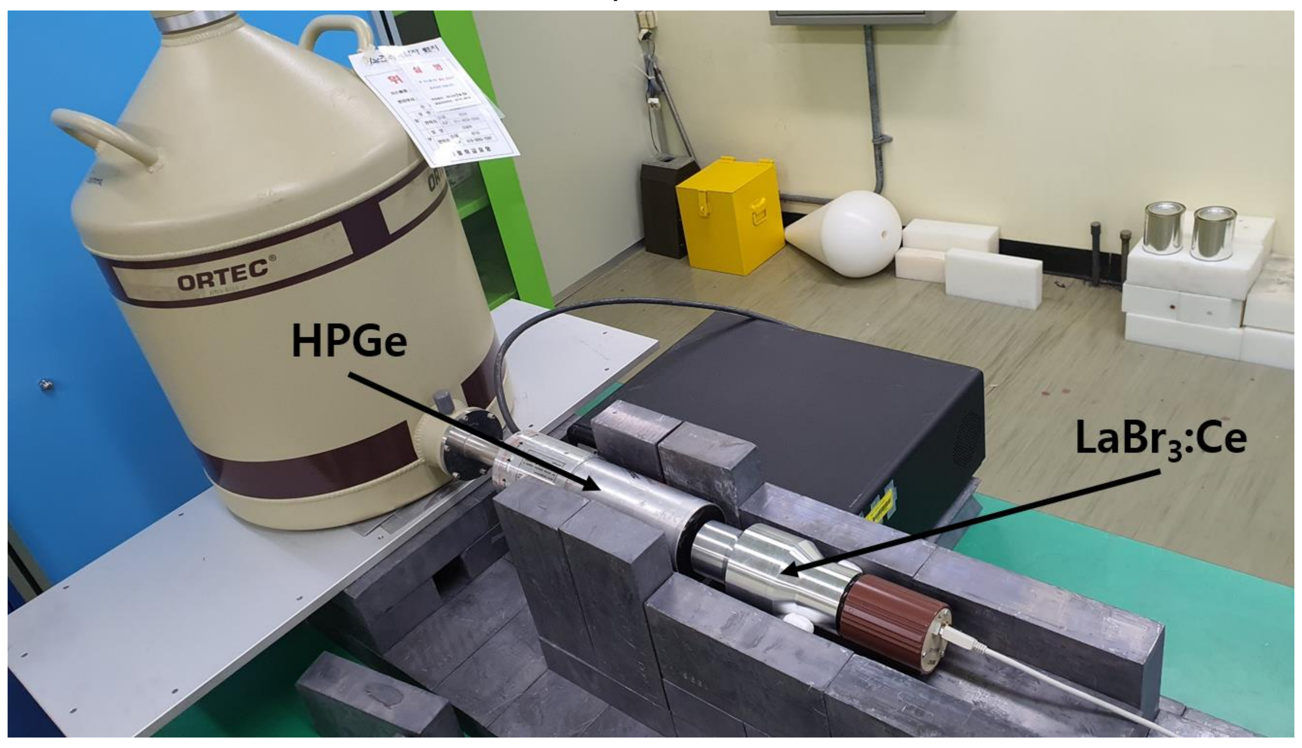

Fig. 1. $LaBr_3$:Ce scintillator and HPGe detector deployment

- An iron sample was irradiated with a Ra-Be neutron source as shown in Fig. 2. The measurement time was 80,000 s.

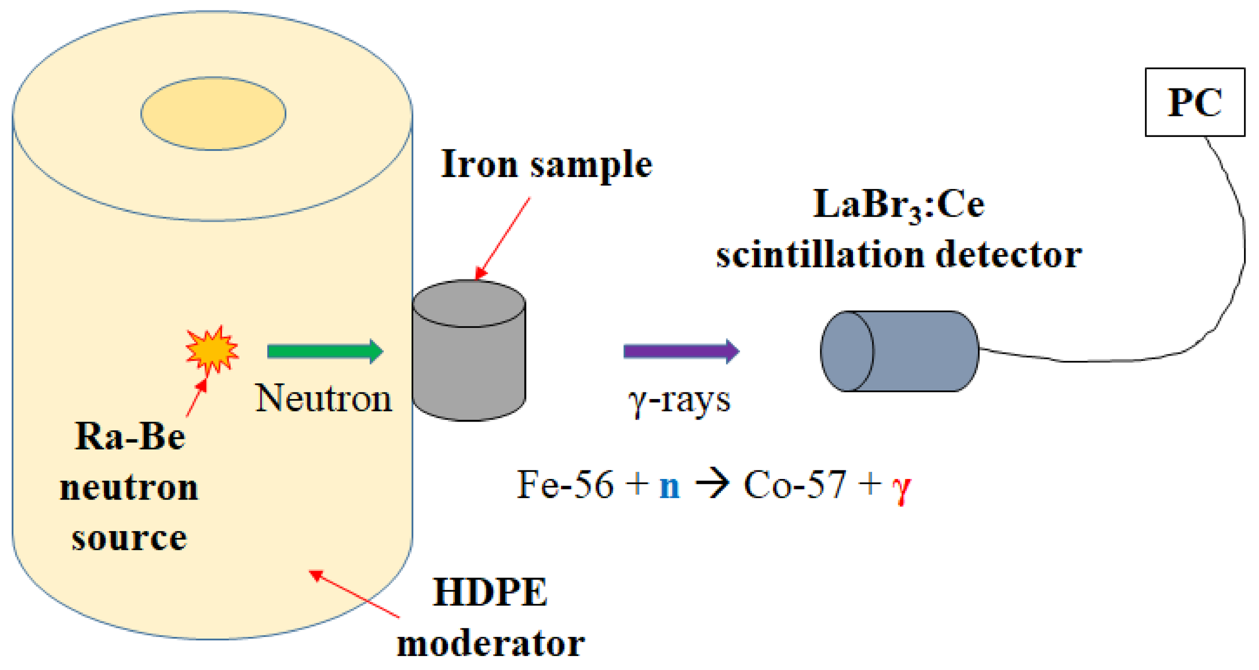

Fig. 2. Setup for FNAA on an iron sample

Energy Calibration

- Intense γ-ray peaks from an Eu-152 source (121.78, 344.28, 778.9, 964.08, 1112.1, and 1408.0 keV) were used to calibrate the detectors.

Results

- The peak energies of intrinsic background (γ-ray of 788.7 and 1436 keV) except for the low energy X-ray and α-particles inside the $LaBr_3$:Ce crystal were verified with the HPGe detector. The peak energies of α-particles are shifted depending on the number of impurities in the $LaBr_3$:Ce crystal [1].

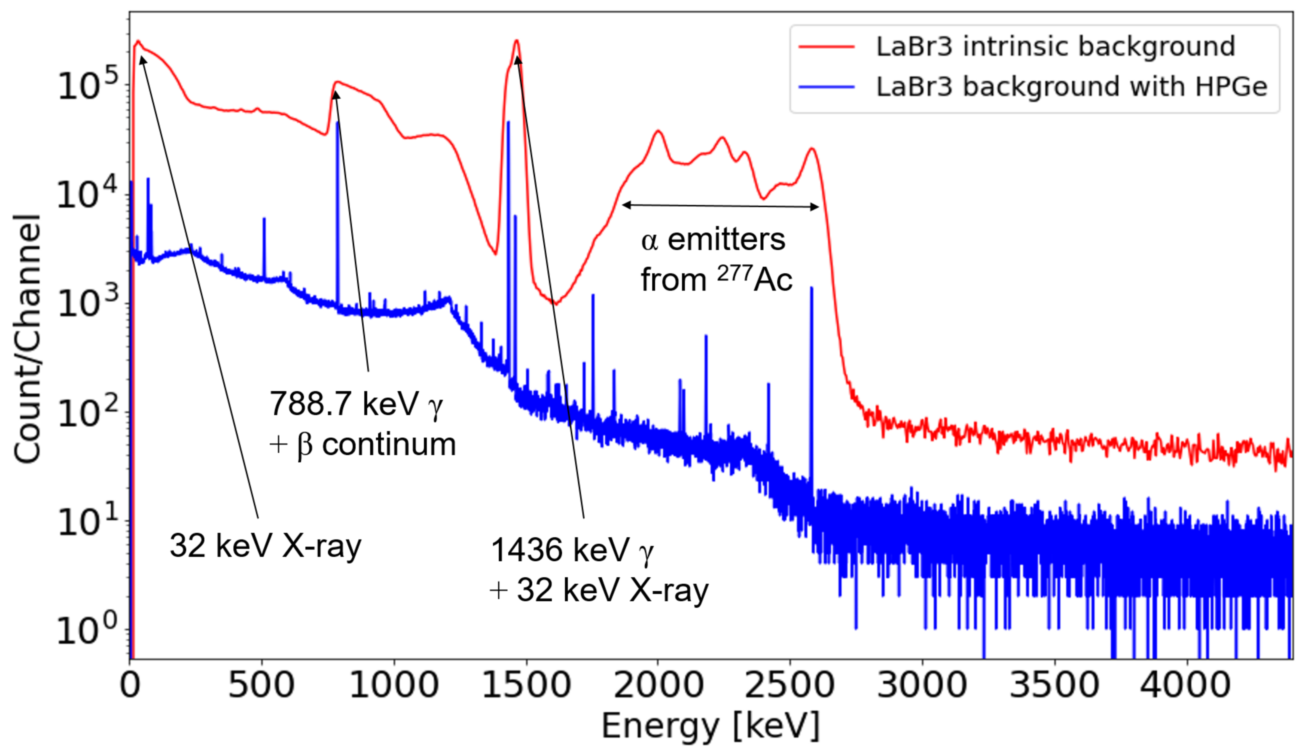

Fig. 3. The background spectra measured with $LaBr_3$:Ce and HPGe detectors

- The spectrum of the iron sample (blue) shows one singular peak, which did not occur in the spectrum without the iron sample (red) in Fig. 4. This peak was estimated as the γ-ray peak of 1238 keV induced from (n, γ) reaction in ^{56}Fe.

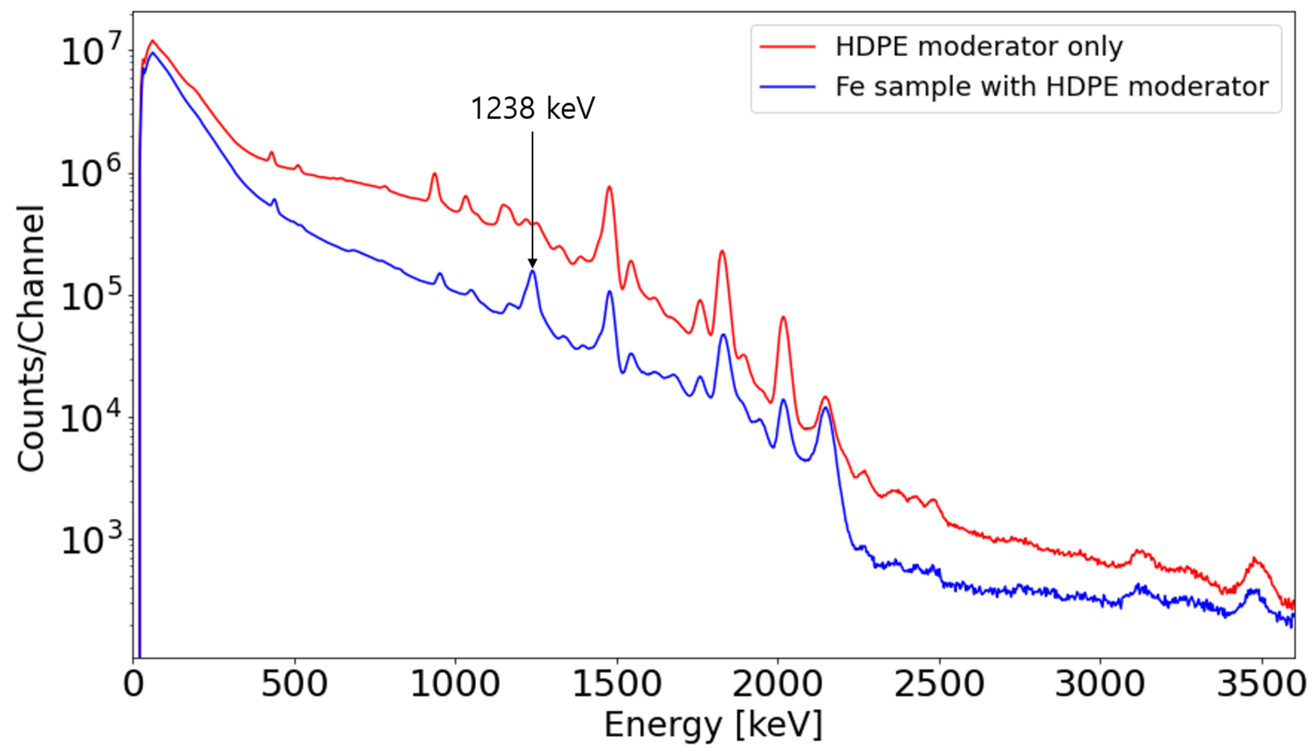

Fig. 4. Spectra of γ-rays from iron sample irradiated with Ra-Be neutron source

Discussion

- One singular peak of 1238 keV showed the feasibility of FNAA of iron.
- The spectra of the irradiated iron sample showed different peaks compared to the intrinsic background in $LaBr_3$:Ce.
- The intrinsic background of $LaBr_3$:Ce was negligible in this experiment.
- However, there are some questions remaining :
    - The energy calibration of $LaBr_3$:Ce is dependent on the temperature so that the calibrated energies are not accurate.
    - Verification of whether other peaks are from HDPE moderator is required.

Conclusions

- The intrinsic background of $LaBr_3$:Ce scintillation detector and the feasibility of FNAA of iron were observed.
- For the further quantitative analysis of each γ-ray peaks, the precise neutron spectrum will be studied.

References

[1] Shangqing Sun, etc., Study on the γ+X, γ+β, γ+α coincidence summing effects of the intrinsic background instrument spectrum of a $LaBr_3$(Ce) scintillation counter, Korean Physical Society, Vol. 77, No. 12, pp. 1091-1099, 2020.

[2] Zeljko Ilic, etc., Prompt gamma rays induced by inelastic scattering of fission neutrons on iron, Radioanalytical and Nuclear Chemistry, Vol. 325, pp. 641-655, 2020.