

"Basic Research in Physics" at CYRIC

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I. 3. "Basic Research in Physics" at CYRIC

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From fiscal year 2004, we have carried out the radioactive isotope (RI) production experiment at CYRIC for one of the themes in the “Basic Research in Physics (*Butsurigaku kiso kenkyuu*)”. The main objective of the theme is to learn radiation detection techniques. As the practice of the radiation detection and measurement, the sealed checking sources are usually used. But the hand-made RI sources more stimulate the students’ interests. RI production is the demonstration of a modern alchemy that means the conversion of atom which cannot be achieved by conventional chemical methods. An iron plate becomes radioactive after the irradiation of proton beams of 20 MeV. Students identify the radioactive nuclide by the energy spectrum of emitted gamma-rays and reconfirm it by its half life measured by the attenuation of gamma-ray intensity with the course of time¹⁾. After 3 terms of the experiment, we found some problems as the following list.

1. Produced RI: ^{56}Co is identified by the energy spectrum and the half life, and then we have concluded that $^{56}\text{Fe}(p, n)^{56}\text{Co}$ reaction changes the iron nucleus. However it is still qualitative and with less physical meaning.
2. Because the systematic errors in measurements of counting rates are large compared to the half life of ^{56}Co (77.3 days), the measured half life of ^{56}Co is deviated by the slight changes of the experimental conditions.

This year, we used thin iron plates stacked along the proton beam for the measurement of the RI production cross sections which vary with the energy of incident proton. By introducing the idea of the reaction cross section, students can qualitatively access the scale of the nucleus. And the energy loss: the principle of the radiation detection is qualitatively treated by calculating mean energy of proton in each thin iron plate. Vanadium plates were also prepared to produce ^{51}Cr via (p, n) reaction. Its half

life is 27.7 days²⁾, that means more than 50% decrease of the gamma-ray intensity can be measured in 4 weeks.

The measured cross sections of $^{56}\text{Fe}(p, n)^{56}\text{Co}$ reaction with respect to the incident proton energies are compared with the reference values in Fig. 1. The students' results and the reference values show a good agreement. By assuming the maximum cross section of $^{56}\text{Fe}(p, n)^{56}\text{Co}$ reaction is the cross section of spherical ^{56}Fe nucleus, its radius was measured as 3.8 fm. The radius of ^{56}Fe estimated by using $1.25A^{1/3}$ rule is 4.8 fm. Thus they are in the same order. From this result, it is shown that the assumption was not so wrong. The measured count rates of 0.32 MeV-gamma ray from ^{51}Cr and the exponential curve fitted to the data are shown in Fig. 2. A half life of ^{51}Cr obtained from 7 measurements in 5 weeks was 26.4 ± 0.1 (stat.) days. Supposing the difference of 1.3 day from the reference value is one standard deviation, a systematic error of each measurement was estimated to be 5 %. It is too large to measure the life time of ^{56}Co within a reasonable accuracy, however it is sufficient to measure the life times of RI's with life times similar to or shorter than ^{51}Cr .

This year, we carried out the RI production experiment at CYRIC for one of the themes in the "Basic Research in Physics (*Butsurigaku kiso kenkyuu*)". We continue to modify and improve it aiming that the students can touch the essence of the physics of nuclei and nuclear reactions and better understand the method of experiments.

References

- 1) Kanda H., *et al.*, CYRIC Annual Report 2004 (2004) 9.
- 2) WWW Table of Radioactive Isotopes. URL: <http://ie.lbl.gov/toi/>.
- 3) Experimental Nuclear Reaction Data. URL: <http://www.nndc.bnl.gov/exfor/exfor00.htm>.

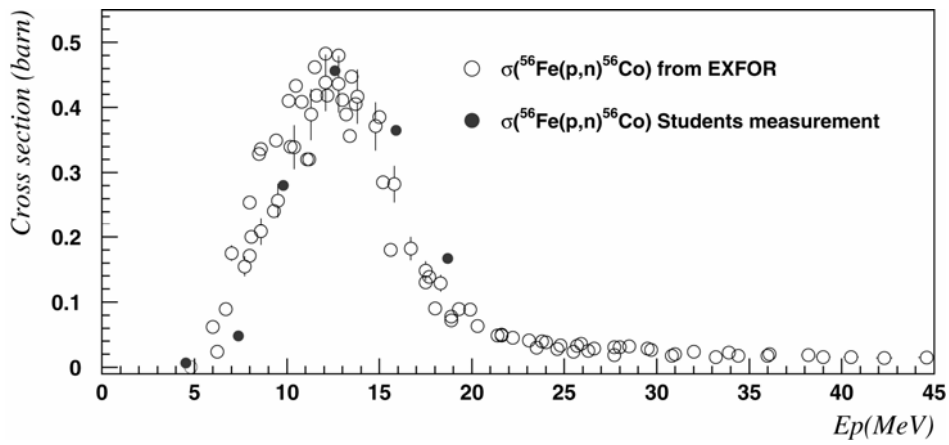


Figure 1. The cross sections of $^{56}\text{Fe}(p, n)^{56}\text{Co}$ reaction with respect to the incident energy of proton. Open circles are the reference data from Experimental Nuclear Reaction Data Library³⁾ and red closed circles are the data from students' measurement.

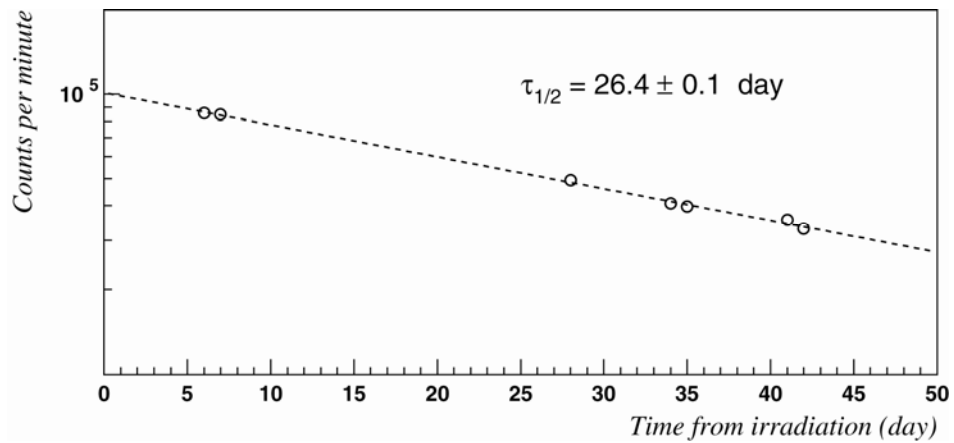


Figure 2. Count rates of 0.32 MeV gamma-ray from ^{51}Cr with respect to the time after proton irradiation. An exponential curve is fitted to the data points and the half life of 26.4 days was obtained.