A Feasibility Study of a Portable Alpha Particle Spectrometer

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1. Introduction

Alpha spectroscopy is widely used for detecting undeclared nuclear facilities, activities, and materials [1]. Due to the heavy equipment required to carry out this technique, its applications is limited [2-4]. With the goal of quickly and efficiently responding to undeclared nuclear facilities, activities, and materials, the present authors have designed and built a portable α-particle spectrometer.

The initial objective of the design was to reduce the size and weight of the device as much as possible. Based on design studies, an actual portable α-particle spectrometer was built, tested, and compared with results gained from a laboratory α-particle spectrometry system. The test results showed that the portable α-particle spectrometer has potential to quickly and efficiently identify α-particle emitting nuclides on site during nuclear safeguards inspection.

2. Methods and Results

2.1 Construction of a Portable α-particle Spectrometer

The main design objective of the portable α-particle spectrometer was to reduce total size and weight still remaining a feasible tool.

The newly developed α-particle spectrometer consists of a PIPS α-particle detector (A450-18 AM, Canberra), a charge sensitive preamplifier (CR-110, Cremat), a shaping amplifier (CR-200, Cremat), a multi-channel analyzer (K-102, Kromek), a vacuum pump (MD 1 VARIO-SPTM, Vacuubrand), and a palmtop PC with operating software.

All components were placed inside a container. The integral design, with an actual photo of the portable α-particle spectrometer, is shown in Figure 1.

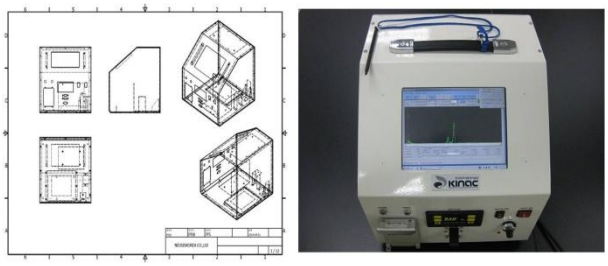

Fig. 1. A schematic drawing (left) and actual photo (right) of the portable α-particle spectrometer.

This new portable α-particle spectrometer is featured by its compact size (30 cm x 30 cm x 30 cm), lower weight (14 kg), and possibility of movement. It can be operated at normal temperature and a maximum intensity of up to 1.0 torr air pressure.

A PIPS detector is employed because it has a larger depletion layer (140 μm), thick enough to completely stop α-particles, as well as a very thin dead layer (only 50 nm), showing a negligible contribution to the total counts.

Another feature of this portable apparatus is the small vacuum pump (4.1kg) and are the minimized use of electronics. To avoid external noise or physics impact, the high voltage supplier and other signal electronics are placed separately on two circuit boards and surrounded by metal (Al) cases. The vacuum pump employed can attain a significantly higher speed and provide a vacuum of 0.75 torr.

The user interface, consist of an 8-inch LCD touch screen embedded in the spectrometer. Digitized output data via the MCA are directly displayed on that screen or transferred to a personal laptop via a USB bus installed in the apparatus.

2.2 A Feasibility Study

To evaluate the potential of the portable α-particle spectrometer, a feasibility test was performed. The ratio between ^{235}U and ^{238}U was respectively calculated via a laboratory α-particle spectrometry system (Lab system) and the newly developed portable spectrometer for the same sample.

Certain requirements need to be met before the α-particle spectrometry process can be used to analyze an isotopic composition of uranium from an air sample. These requirements include: 1) an air sample to be collected nearby a suspect area, 2) the air sampling filter is ashed, 3) the ash is dissolved in to a solution, and 4) only uranium is chemically separated from impurities and the other α emitting radio-nuclides. 5) The extracted uranium is deposited onto the surface of a metal disk by using electrodeposition equipment in order to avoid self-absorption of α-particles. 6) The isotopic composition of the extracted uranium sample is then analyzed through the system.

Since an air sample from a suspected area cannot be normally obtained, the following experimental process was conducted: 1) a liquid uranium sample was absorbed into a filter, 2) the filter was ashed and collected, 3) a uranium air sample was collected from the sample of fly ash, and the following processes were the same as the actual one [Figure 2].

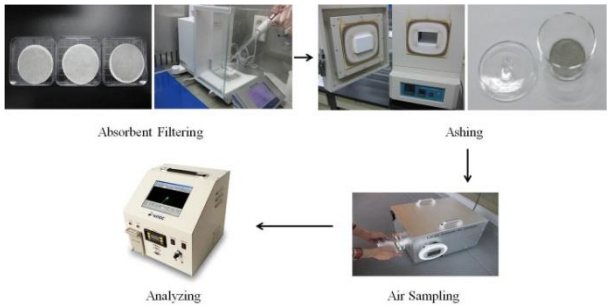

Fig. 2. The experimental processes used for this study.

For this experience, two liquid uranium samples were prepared. The known enrichment values were 2.210 % and 4.099 %. Each sample was converted into an air sample and measured by the laboratory α-particle spectrometry system and the portable spectrometer, respectively. The measurement time was set at 80,000 seconds for each system. The obtained spectra are shown in Figure 3 and 4.

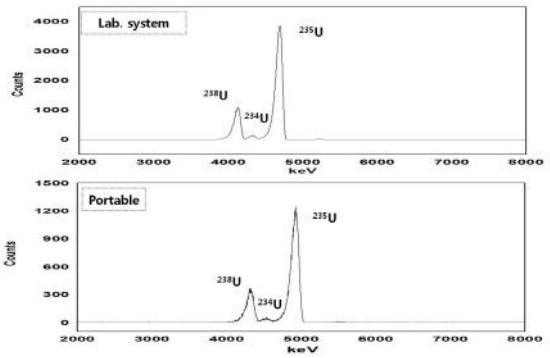

Fig. 3. The obtained spectrum from the 2.210 % enriched uranium sample.

The enrichment value was calculated based on the counting ratio between ^{235}U and ^{238}U. The calculated enrichment values of ^{235}U were 2.049 % and 1.868 % for the laboratory spectrometry system and the portable spectrometer, respectively.

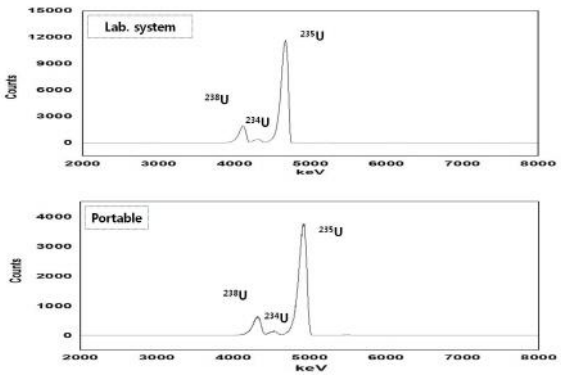

Fig. 4. The obtained spectrum from the 4.099 % enriched uranium sample.

For the 4.099 % sample, the enrichment values for each system were calculated to be 3.253 % and 3.083 %.

As shown in Figure 3 and 4, the enrichment values calculated from the spectra of the portable α-particle spectrometer were slightly underestimated when compared to that of the laboratory system. That problem was possibly caused by the different setups for each region of interest (ROI) on the each system.

3. Conclusions

This study was conducted in order to develop a new portable α-particle spectrometer with the purpose of detecting undeclared nuclear facilities, activities, and materials on site quickly and efficiently. All heavy and large components, which are typically required for a laboratory such as a α-particle spectrometry system, were minimized and placed in a small container with a weight of 14 kg and a size of 30 cm x 30 cm x 30 cm.

In the feasibility study, the calculated enrichment values of ^{235}U obtained from the portable α-particle spectrometer were 1.868 % and 3.083 %, similar to the results from a commercial spectrometry system used in laboratories, 2.049 % and 3.253 %. These differences were possibly caused by different channel setups for each system.

In conclusion, this study showed that the newly developed portable α-particle spectrometer, employing a small vacuum pump and minimized electronics, has shown considerable potential to quickly detect undeclared nuclear facilities, activities, and materials on site. Further steps will be needed to demonstrate this new portable spectrometer in an actual environment.

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