Detection of Heavy Metal Content in Environmental Samples through Neutron Activation

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1.1 The neutron Activation Analysis

The neutron activation analysis is a method that allows determination of the qualitative and quantitative characteristics of elements regarding the measurement of the radiation properties from radionuclides formed by irradiating samples by neutrons.

This method is based on a collision between a neutron and an atom nucleus. When it happens, a new compound emits a prompt gamma ray and a prompt particle. Later, it will become a radioactive nucleus that emits a delayed gamma ray and a beta particle. Afterward, it will stabilize in a product nucleus.

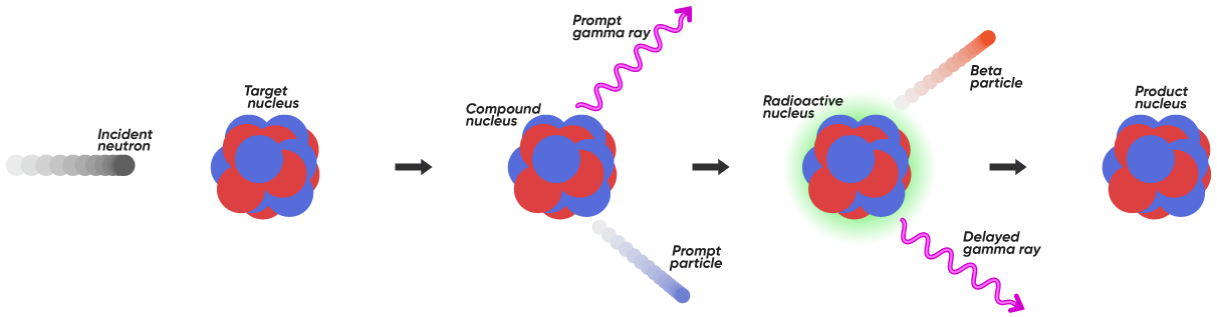


Fig. 1: Diagram of collision.

Neutron activation analysis can be performed in different ways, but it is based on the measurement of radiation released by the decay of radioactive nuclei because of material irradiation. A research reactor is the most suitable source of neutrons for its application.

The way how it could be performed depends on the radiation level to be measured of each element. Furthermore, the nature and the extent of interference that comes from other elements in the sample.

This method is the most widely used application of research reactors and most of its methods are non-destructive, based on the detection of gamma radiation emitted by the irradiate sample during or after irradiation.

1.2 Prompt Gamma Neutron Activation Analysis (PGNAA)

Prompt gamma neutron activation analysis (PGNAA) is an analytical method that works by bombarding sample material with neutrons in order to detect the prompt of the first gamma rays emitted after this neutron's absorption.

PGNAA is applicable to elements with high or extremely high neutron capture-sections. In other words, this technique only works with elements that have an important measure of probability that photons interact with matter by this process. That is to say, with elements whose neutrons are more likely to absorb radiation.

On the other hand, delayed gamma ray neutron activation analysis cannot be measured because of the low probability of these neutron elements to absorb radiation.

1.3 Instruments and Data Collection

In this research, the measurements used were performed by a device called ZEBRA from RWTH Aachten University and AINT. ZEBRA is composed of a sample compartment, a neutron generator and a detector.

In order to do the analysis, the sample has to be deposited into the sample compartment. Then, the neutron generator begins to work, emitting a source of neutrons that interact with the target nucleus of the sample. This interaction produces the said gamma-rays that will be captured by a high purity crystal. This crystal exposed to the rays produces photons that are measured by the detector. Finally, the detector is the one that gives the data to be studied.

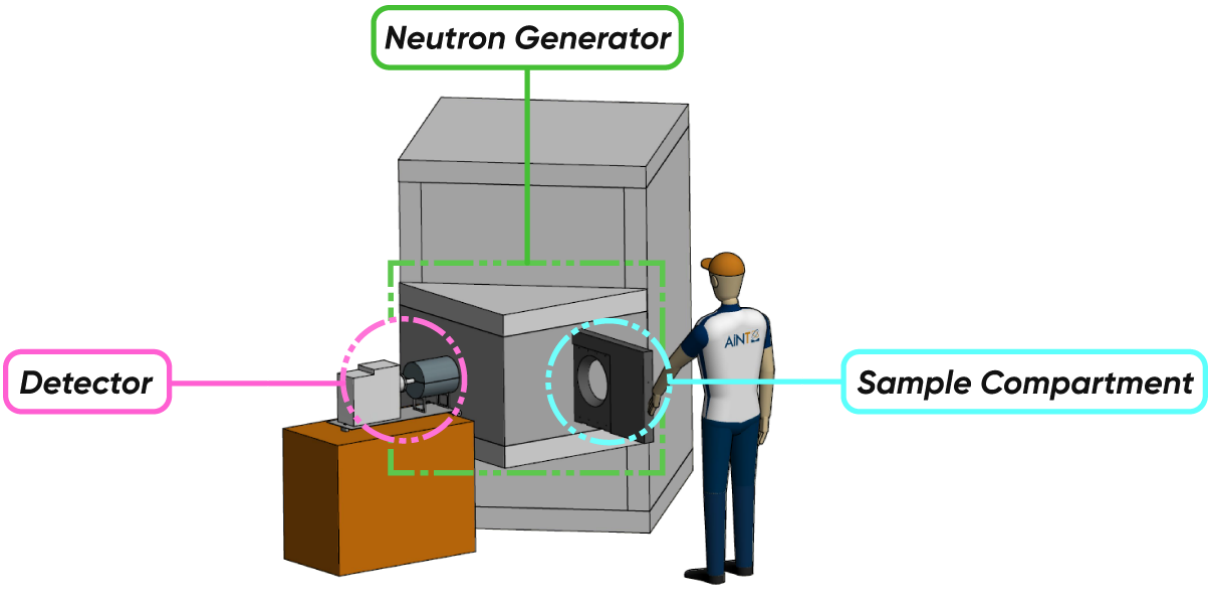
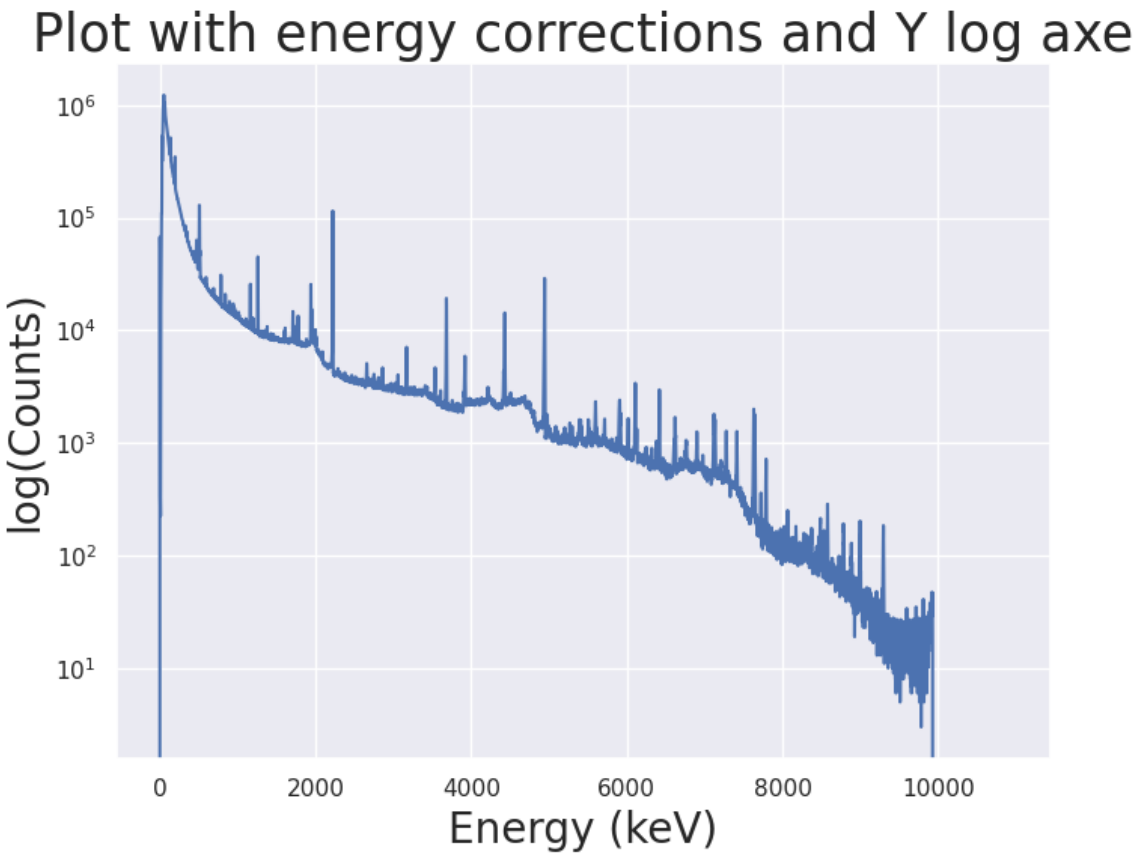


Fig. 2: ZEBRA device.

1.4 Data Analysis

In the measures given, it is noticeable that the measured spectra of gamma rays has peaks. All of the peaks are consistent with the elements of the periodic table. In this line of thought, it is possible to know the composition of a sample when we compare its peaks with the peaks of elements in the periodic table.



2. Problems

The purpose of this work is to know the composition of the sample given from the ZEBRA. In order to do this, there are already the measurements or data from the detector and now there is a need to compare these results.

When ZEBRA gives the data in a comma-separated values (CSV) file, it can be introduced in Python.

First, the libraries are imported in Python. The ones used in this work are:matplotlib, seaborn, numpy and scipy.

Then all the data needs to be uploaded. Thus, the referential table of energies in isotopes and gamma spectrum data are added. Once the data is in the system, the

values have to be fixed and detailed into columns in order to establish an energy spectrogram and consequently find the position of each peak.

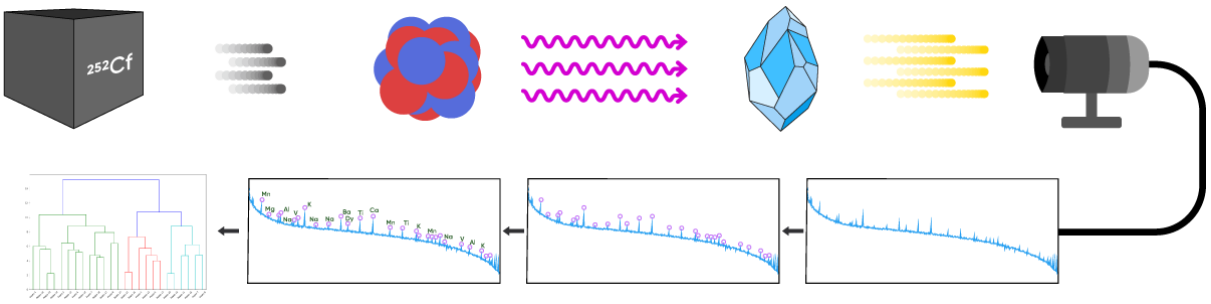
Afterward, the gamma distribution peaks of the sample have to be calculated and compared to know its composition. To identify the elements, we should compare the peaks found with a table of known characteristic peaks. It is generated a list with all the components with the spectrum sample and the reference value of each element. The spectrum peaks are found and these values are in the energy range.

There is a need to find the isotopes that look like each given peak. This is made with a function that calculates the match between two spectrum peaks. To identify the elements, we should compare the peaks found with a table of known characteristic peaks. In order to do this, the two spectrum must have the same shape without doubt. Then, it is evaluated if they have the same isotopes and compute the similitude grade. The isotopes that make discrepancies from the first spectrum to the second one are saved and the code returns the results.

Finally, arrays are made and then the final compare results are printed.

All of our work with the code can be found in the following google colab:

https://colab.research.google.com/drive/1R6Coso6f1yYPm_IVmX6hRVHsYU73cCNt



3. Conclusion

PGNAA is a great non-intrusive method for determining the composition of a sample. This method could be improved with detectors that are more precise so that the uncertainty for some peaks is reduced and the elements precisely determined. Also we considered other ways to know the composition of the sample by calculating the area under the curve of the peaks, but due to lack of time we could not advance further in the idea. In the same way, we urge others to delve deeper into this alternative.

4. References

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