Qualitative Elemental Analyses of a Meteorite Sample Found in Turkey by Photo-activation Analysis Method

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Abstract. In this paper, a meteorite sample provided from TÜBİTAK National Observatory found in Turkey has been investigated by using a clinical linear accelerator that has endpoint energy of 18 MeV, and a high purity Germanium detector for qualitative elemental analysis within photo-activation analysis method. 21 nuclei ranging from $^{24}\text{Na}$ to $^{149}\text{Nd}$ have been identified in the meteorite sample.

1. Introduction

The determination or identification of a sample found in nature whether it is a meteorite or not has been studied in detail over the years by using different experimental methods. As it is so far well established, there are two ways to perform elemental analysis of a sample. First type is based on destructive methods. Such methods used for elemental analysis either damage the sample or allow only surface analysis if not damaging the sample. The second one is based on performing the elemental analysis of a sample non-destructively. Non-destructive methods are very important for the analysis of particularly precise samples. As it is known, these non-destructive methods are also very reliable and accurate.

Among these non-destructive methods, X-ray fluorescence (XRF) is based on emission of characteristic secondary X rays from a material excited with high energy X rays or gamma rays. XRF can be applied non-destructively only when it comes to elemental analyses of very thin surface layers, but for a more detailed elemental analysis, XRF cannot be applied non-destructively.

Another non-destructive method is the neutron activation analyses (NAA). NAA is based on neutron capture of a nucleus. Generated radioactive isotopes emit characteristic gamma rays. Then, the elemental analysis can be performed through analyzing the spectrum obtained from these gamma rays. The disadvantage of this method is that it needs a nuclear reactor or a high flux neutron source, and the availability of these facilities is very difficult and expensive.

Another type of non-destructive methods is photo-activation analysis (PAA). In the PAA method, the nuclei are basically activated through the bremsstrahlung photons obtained from an electron accelerator. The generated isotopes emit characteristic gamma rays with certain energies. These gamma photons are counted by a gamma detector. At the end, the nuclei can be identified through the analyzing the gamma spectra.
The bremsstrahlung photons can be obtained through a clinical linear accelerator (c-LINAC) which is mainly used for medicinal purposes, and the spectra can be analyzed through a gamma detector. In this regard, our center has a c-LINAC and a gamma detector. The neutron separation (γ,n) and proton separation (γ,p) occur in the PAA method. But, for heavy elements such as uranium, also the photo-fission reaction (γ,f) may occur [3].

PAA method has been used since 1970s in the world. For the first time in Turkey, it was carried out by Akdeniz University Nuclear Sciences Research and Application Center (NUBA) using local facilities of the country in 2013 [1]. The PAA method we use to perform elemental analysis is quite suitable for elemental analyses of a sample especially when it comes to precise samples such as meteorites mainly because of its non-destructiveness, cheapness, easy accessibility. It also makes an analysis within a reasonable time. It is able to achieve the identification where other methods fail, and it does not include any radioactive waste either. When only small pieces of the meteorite are available, precise methods such as Photo-activation Analysis (PAA) are extremely suitable [2].

Therefore, in this paper, we have performed the qualitative elemental analyses of a meteorite sample found in Turkey by using the PAA method.

In the next section, we explain our experimental method including property of our setup, activation, measurement and analysis process. Section 3 is devoted to our experimental results. In the final section, we present our summary and conclusions.

2. Material and Method

In our setup, we have used a cLINAC SLI-25 manufactured by Philips Medical Systems (currently part of Elekta TM Synergy TM) as a bremsstrahlung photon source. The cLINAC primary electron beam is generated by an electron gun with an energy of about 50 keV. The electron gun in SLI-25 is a diode design with a 400 Hz pulse repetition frequency.

The detector used is a high purity Germanium detector (HPGe). It is a p-type, coaxial, electrically cooled HPGe detector, placed in a well shielded cavity. The HPGe detector is connected to a set of Nuclear Instrumentation Modules consisting of ORTEC preamplifier, bias supply, spectroscopy amplifier, analog to digital converter and a computer. Data acquisition was carried out with MAESTRO32 software.

2.1. Activation Process
The sample was placed 60 cm away from irradiation region (the end point of the head of the accelerator). Then, the sample was exposed to bremsstrahlung at endpoint energy with 18 MeV, and the reactions were carried out with 10000 Monitor Unit (MU). Monitor Unit is a measure of the radiation dose, and 100 MU equal approximately 1Gy usually at 100 cm from the source.

2.2. Measurement and Analysis of the Spectrum
When the irradiation ended, after the cooling time, the sample was moved to the gamma spectrometer laboratory in order to count with the HPGe detector. The spectrum analysis recorded by the software program of the detector was performed by the gf3 Radware program, compiling the interactive gamma-ray spectrum data graphically.

3. Results

The gamma spectrum of the meteorite sample obtained from analysis with background is shown in Figure 1. As a result of analyses, we present our results in comparison with the literature values taken from National Nuclear Data Center (NUDAT), 21 different nuclei were identified according to energy levels. We also present the type of reactions that have taken place during the irradiation. Table 1 shows all these data. As it is shown in the table, four possible reactions occurred in the experiment.
We have observed \((\gamma,n)\), \((\gamma,p)\) and \((\gamma,\gamma')\) reactions, and also \((n,\gamma)\) reaction due to the secondary neutrons produced by the interaction of bremsstrahlung with other materials in the accelerator.

![Meteorite Spectrum](image)

**Figure 1.** Meteorite Spectrum

**Table 1.** The identified nuclei and their energy levels in the meteorite sample obtained from analysis.

| NUCLEUS | Energy (keV) | REACTION |
|---------|-------------|----------|
| \(^{149}\text{Nd}\) | 114.45 | \((\gamma,n)\) |
| \(^{149}\text{Nd}\) | 211.64 | |
| \(^{149}\text{Nd}\) | 270.82 | |
| \(^{149}\text{Nd}\) | 423.81 | |
| \(^{74}\text{As}\) | 635.08 | |
| \(^{74}\text{As}\) | 596.21 | |
| \(^{47}\text{Ca}\) | 1297.41 | |
| \(^{57}\text{Ni}\) | 127.44 | |
| \(^{57}\text{Ni}\) | 1377.9 | |
| \(^{57}\text{Ni}\) | 1758.06 | |
| \(^{57}\text{Ni}\) | 1919.58 | |
| \(^{85}\text{Sr}\) | 151.29 | |
| \(^{85}\text{Sr}\) | 231.98 | |
| \(^{53}\text{Fe}\) | 377.93 | |
| \(^{63}\text{Zn}\) | 670.15 | |
| \(^{63}\text{Zn}\) | 963.34 | |
| \(^{58}\text{Co}\) | 811.07 | |
| \(^{54}\text{Mn}\) | 834.32 | |
| \(^{34}\text{Cl}\) | 1176.95 | |
| \(^{34}\text{Cl}\) | 2127.67 | |
| \(^{34}\text{Cl}\) | 146.61 | |
| \(^{69}\text{Zn}\) | 438.78 | |
4. Conclusions and Discussion

In this paper, we have used the PAA method in order to identify the nuclei in a meteorite sample. We have used bremsstrahlung photons obtained from a c-LINAC for irradiation and a HPGe detector has been used for counting. We have reported here preliminary results and a detailed analysis of these measured data including the quantitative results will be further investigated.

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References

[1] Boztosun I et al. 2014 Turk. J. Phys. 38 1-9
[2] Řanda Z et al. 2003 Journal of Radioanalytical and Nuclear Chemistry 257 275
[3] Green J et al. 2011 AIP Conf. Proc 1336 497