Research Article

Journal of Applied Sciences

Discrepancy in the k0-values of 134Cs, 152Sm, 75Se and Experimental Implementations in k0 Standardization Techniques

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Received Date: June 16, 2024
Accepted Date: June 18, 2024
Published Date: July 18, 2024

ABSTRACT

Background and Goals : Accurately determining the k0-values of 134Cs, 152S, and 75Se produced by the (n,() reaction is a difficulty for k0 users using k0 standardization procedures. Neutron activation analysis (NAA) is performed to determine elemental concentrations using these values. This study's goal was to assess the true gap between the k0-values of 134Cs, 152Smand 75Se utilizing K0-user certified reference materials (CRMs). Supplies and Procedures: Utilized were the CRMs SMELS I and III and NIST 1633b Coal fly Ash.These samples were exposed to radiation for seven hours in the inner channel using the Nigerian Research Reactor (NIRR-1) at half-full power (15 kW) and a neutron flux of 5×1011 n/cm2 s. The evaluation was conducted in accordance with the approved guidelines. Findings: The empirical and experimental calculations values of 152Sm, 75Se, and 134Cs were contrasted with suggested data. The experimental k0 value for 152Sm (103 keV) was significantly different from the suggested values for 134Cs and 75Se. In conclusion, 152Sm displayed a large deviation whereas the k0 values of 134Cs and 75Se contrasted favorably with the suggested values. For every nuclide, the empirical computation yielded a large discrepancy.

Keywords : Neutron activation analysis, certified reference material, Nigerian research reactor, k0-values, k0 standardization

INTRODUCTION

Nigeria Research Reactor-1 (NIRR-1) is a low power, miniature neutron source reactor (MNSR) with a single central control rod (CCR) that executes In addition to acting as a neutron source1, it has safety and regulatory purposes. Strong neutron absorbers that are able to be added to or removed from the reactor core are called CCRs. They are employed to correct for the extra reactivity required for sustained core operation and to modify the reactor's power level in order to activate the core, meet load requirements, and terminate reactor 2. For application in Neutron Activation Analysis (NAA), Jonah et al. 2,3 have standardized NIRR-1 using the relative and k0-standardization methods.Co-irradiating the sample and a neutron fluence rate monitor allowed NAA to apply the k0-standardization approach and determine a composite nuclear constant4,5, by which standards are not used. Upon obtaining an accurate composite nuclear constant, these are employed to assess the nuclide concentration. The k-values, the sub-cadmium-to-epithermal neutron flux ratio , and the epithermal neutron flux shape factor (") are crucial variables employed in the application of the k0-standardization concept7,8. For the sake of applicability and standardization, these parameters, which vary depending on the irradiation facility, must be established. The following neutron spectrum characteristics in the inner and outer irradiation channels were calculated using the CD-ratio for the multi-monitor approach and published elsewhere3 in order to expand its use to include the k0-standardization method.The outcomes were The findings were compared to the neutron spectrum parameters of other reactor facilities with comparable core configurations that may be found in Kennedy et al.'s literature, including the Slowpoke and Miniature Neutron Source Reactor facilities.The issue of how accurate the k0-values available in NAA procedures are is a challenge in the efforts to apply the k0-standardization idea in many laboratories globally. literature were used order to generate precise outcomes9. De Corte and Simonits10 noted that there are disparities and inconsistencies in several of the suggested k0-values listed in the Atomic and Nuclear Data Tables. According to Moens et al. (5), Simonitts et al. (2011), and De Corte and Simonits (2010), the k0-values in the Atlas of Neutron Resonances don't match the advised data. According to these observations, the goal of this work is to ascertain the k0-values of the three nuclides that have been reported to be inconsistent: 134Cs, 152Sm, and 75Se. The suggested Synthetic Multi-element Standard (SMELS) by NIST-1633b (Coal Fly Ash), a standard reference material, and the k0-users for the validation of the k0-NAA method were employed.12, 13.Using the NIRR-1 facilities, the k0 values of the discrepant nuclides 134Cs, 152Sm, and 75Se—were acquired experimentally for this work. Except for 152Sm, whose divergence was 28%, the experimental k0 values reported from this investigation were in good agreement with the suggested values.In addition, there was a significant difference between the study's findings and the empirically determined values for each nuclide's peak energy, ranging from 18.29 to 39.53%. Thus, this study demonstrated the inaccuracy of the nuclear data and noted that the k0 values must be determined experimentally in order to use the data.

MATERIALS AND METHODS

Based on a phenol formaldehyde resin (Bakelite), the Synthetic Multi-elemental Standards (SMELS) Type I and III were weighed and an amount was measured. The gauged Samples were tampered with using 30 distinct substances in addition to the NIST 1633b (Coal Fly Ash). The polyethylene films used to cover the samples had been properly cleaned and prepped for radiation. In 2017, 12,2, the NIRR-1 was used to do the irradiation at a half-full power of approximately 15 kW with a neutron flux of 5×1011 n/cm2 sec.In the inner irradiation channel B-2, the samples were exposed to radiation for seven hours. The samples were exposed to radiation for two days following irradiation before being counted in order to determine 152Sm. For thirty minutes, each sample was tallied using a vertical dipstick and the GEM-30195 HPGe Coaxial.The irradiated samples were stored for 15 days prior to measurement utilizing the GEM-30195 HPGe in order to determine the values of 134Cs and 75Se. Every sample was counted in order to 60 minutes. The elements Sc, Ce, Co, Cr, Eu, Gd, Lu, Ba, Mo, Nd, Rb, Sb, Ta, Tb, Th, Yb, Zn, Cd, Fe, Sr, Ag, Hf, Ir, Hg, Zr, Te, and Os are also determined using this process. All of the irradiated-induced activities were measured using the GEM-30195 HPGe Coaxial, vertical dipstick detector (ORTEC), depending on the irradiation regime. The detector has a 30% relative efficiency and a resolution of 1.95 Kev at 1.33 MeV for 60Co. The MAESTRO emulation software, which is compatible with the gamma-ray acquisition system used in this work,Software was employed to identify and evaluate the peaks14, 15. The GEM-30195 HPGe Coaxial detector's efficiency in relation to source-detector geometries wasfound by use common gamma-ray sources16, to ascertain the k0-values. Using gamma ray sources, the HPGe detector's entire energy peak efficiency at its 1 and 5 cm geometry was found. An efficiency curve was then fitted for each geometry to identify the efficiencies of the disparate nuclides.Equation 1 was utilized to determine the specific activity (Asp) of the activation product of the element of interest.First, P c SP N t A SDCW.The neutron spectrum is required for the concentration calculation equation based on the k0-standardization approach using the Høgdahl convention for the so-called 1/v nuclides.parameters17, which are the thermal-to-epithermal neutron flux ratio and the shape factor of the epithermal neutron flux ("), which are estimated using a 1/E1+" distribution. Numerous authors, such as De Corte et al. (13, 18, Jonah et al. 2, and Rossbach and Blaauw 7), listed the ways to get these neutron spectrum parameters using the experimental techniques that were necessary for both the Wescott formalism and the Høgdahl convention. However, it had been suggested that the Cd-ratio for multi-monitor approach be used for neutron spectrum monitoring with NIRR-1 and other similar reactors with steady neutron flux characteristics. Additionally, this technique had been noted The present study employed the neutron spectrum parameters (f and ") in the inner irradiation channel (B2) of NIRR-1 for NAA applications.Cu foil is used as the monitor in the k0-standardized approach, with published results3. The Hogdahl formalism's Eq. 2 was used to impute the evaluated particular activity in order to determine the experimental k0-values:

RESULTS AND DISCUSSION

Using Certified Reference Materials, the k0-values of the discrepant nuclides 134Cs, 152Sm, and 75Se have been remeasured (experimentally); Artificial Multi-ElementNIST 1633b, Standard (SMELS) I and III, Fly Ash from coal. Table 1 displayed the empirical deviation (%) and experimental deviation (%) from De Corte and Simonits10's suggested values. The results indicate that the uncertainties in the recommended and experimental results could stem from peak analysis or the calculation of neutron flux parameters f and ", which are utilized in the assessment procedure.Table 1 displays the experimentally obtained k0 value of 152Sm, which demonstrated the largest percentage divergence of 28.14% when compared to the recommended values of De Cort and Simonits10. The 134°Cs of Simonits and De Cort 10. When compared to recommended values, the 134Cs k0 value at the peak energy of 802 keV displayed the second-highest variation, measuring 4.38%. The small deviations for the other 134Cs peak lines (562, 569, and 602 keV) were 3.38, 0.27, and 1.89%, respectively.Table 1 displayed the percentage deviation of the nuclides for each of the nuclides under study as a function of their individual peak lines. Table 1 demonstrated how the trial values and the empirically calculated values differed from the suggested values by percentage. Table 1 shows that the empirical computed deviations from the recommended were as follows: 39.52% for 152Sm at 103 keV, 24.55 and 18.29% for 75Se at 136 and 401.7 keV, and 18.34, 21.16, 19.19, and 22.16% for 134Cs at 562, 569, 602, and 802 keV, respectively. The distribution of the k0 values as determined by this study's experiments9, taking into account the empirical computed, and Fig. 1 displayed the suggested k0 values 10. As can be seen, for every peak line of 134Cs and 152Sm, there was a significant difference between the predicted k0 values and the advised, experimental values. This same finding of significant discrepancies that surfaced when comparing the computed and advised k0-values was also documented by Moens et al. 5. It demonstrated the inaccuracy of the nuclear data, according to Moens et al. 5. According to Moens et al.(5), the experimental determination of the k0 For the data to be used in k0-standardization computations, values must be completed. This was consistent with the research, as it was determined that the disparity between the suggested parameters and the computed k0 values were extremely high.To demonstrate how many of the data totally agreed with one another, the distribution of the k0 values between the recommended and the experimental k0 values has been shown as shown in Fig. 2.The results of this investigation compared well with the recommended data for most of the nuclides, as shown in Fig. 2, with the exception of 152Sm, whose recommended k0-value is 2.31×10G1.Table 1 shows that the experimental value obtained was 1.66×10G1, which represents a 28% variation.Fig. 3 showed the link between the experimental and empirical estimated k0 values as well as the percentage deviation from the suggested values. As can be observed in Fig. 3, all of the nuclides in our study had significant deviations from the empirically estimated values. This shown that before using the data in the k0 standardization procedure, a great deal of work should be focused on the experimental determination of the k0 values. It also showed that determining elemental concentrations by empirical computation will result in a significant disparity. This investigation showed that all of the examined nuclides, with the exception of 152Sm, exhibited good agreement with the suggested numbers. All of the peak lines in this investigation and the measured k0 values of 134Cs agreed fairly well. It was noted that the exception of the gamma line of 602 and 802 keV (134Cs), the uncertainties of the k0 values of 134Cs for other peak lines were larger in comparison to this study. The kind of detector that was employed in each case could be the cause of the variations. As a result, there was excellent agreement between the measured value and the suggested data in the work's results. This demonstrated the precision of the irradiation and analytical procedures used in the laboratory to determine the elemental concentrations and the equipment utilized for this task.

CONCLUSION

It is concluded that before using the data in the k0, experimental determination for these disparate nuclides should be carried out rather than empirical computations. method of standardization. The information gathered from this study will help determine elemental concentrations, and in the author's laboratory, the established protocols will be used to determine the concentrations of other nuclides, including Sc, Ce, Co, Cr, Eu, Gd, Lu, Ba, Mo, Nd, Rb, Sb, Ta, Tb, Th, Yb, Zn, Cd, Fe, Sr, Ag, Hf, Ir, Hg, Zr, Te, and Os.

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