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Effective atomic number of some rare earth compounds determined by the study of external bremsstrahlung

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ABSTRACT

In this paper we report the effective atomic number (Z_{eff}) of some rare earth compounds determined from the measured external bremsstrahlung (EB) intensity due to the incident beta particles emitted by the ^{90}Sr-^{90}Y source. For this purpose the two sample method evolved recently by the authors was employed. A high purity germanium detector was used in the present study to improve the resolution of the detection system. The constants lnK, n, C and D for the present geometry and the detector were determined by using the EB intensity measured for the elemental foils Al, Cu, Ag, Sn and Pb of varying thickness. The Z_{eff} values obtained were in good agreement with the Z_{mod} values given by the theoretical expression of Markowicz and Van Grieken. Possible conclusions are drawn based on the present study.

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1. Introduction

Compounds of rare earth elements are not abundantly available in nature. This may be attributed to the fact that their extraction in a state of high purity is rather difficult and not so environmental friendly. However, a vast variety of rare earth samples are being used in many applications of human enterprise particularly in nuclear industry, space research, medicine and biology (Singh, Sandhu, & Singh, 2010, Singh, Sharma, Singh, & Sandhu, 2010). Hence a knowledge on their interaction with electrons as well as X-and gamma photons will be quite useful. Such interactions are usually quantified in terms of the effective atomic number Z_{eff}.

The effective atomic number is a measure of the average number of electrons of the material that participate actively during the interaction. Clearly, since the interaction processes are essentially atomic number and energy dependent, no composite material can be represented by a single Z_{eff} over all energies. This is in sharp contrast to the case of elements. Several techniques have been employed from time-to-time to determine the effective atomic number of composite samples such as alloys, inorganic compounds, biological samples etc (Donativi, Quarta, Cesareo, and Castellano, 2007; Duvauchelle, Peix & Babot, 1999; Kirby, Davis, Grant, & Morgan, 2003; Midgley, 2004, 2005,Manjunathaguru & Umesh, 2006; Prasanna Kumar and Umesh, 2010; Singh et al., 2010).

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Several investigators have used the EB intensity produced due to radiative interaction of the β-particles with the composite materials to determine their effective atomic number (Kurudirek, 2013; Kurudirek & Celik, 2012; Manjunatha, 2013; Manjunatha & Rudraswamy 2007; Shivaramu, 1990). However efforts to determine the Z_{eff} of rare earth samples are very few in literature. This may be due to the fact that such samples are not abundantly available in nature.

In a recent work, (Manjunatha, Sankarshan, and Umesh, 2014) we have shown that the Z_{eff} of such sample could be determined with good accuracy by using a method called "two sample method". In this method, the external bremsstrahlung intensities produced in two targets of the same mass per unit area (one elemental target of known Z and the other sample of interest whose Z_{eff} needs to be determined) are suitably compared to deduce the effective atomic number of the sample of interest.

In the present work, this method has been used to determine the Z_{eff} of several rare earth compounds such as $Y_2\ O_3$, $La_2\ O_3$, $Nd_2\ O_3$, PrO_2, $Sm_2\ O_3$, $Gd_2\ O_3$, $Lu_2\ O_3$, Ce(SO)4, La_2(SO)4. $H_2\ O$, La($O_2\ C_2\ H$)3. $H_2\ O$. For this purpose EB intensity produced in these samples due to the radiative interaction of β-particles emitted by a ^{90}Sr-^{90} Y β-source in their material has been measured with the aid of a high resolution high purity germanium detector. The derived values of Z_{eff} were found to be in agreement with the Z_{mod} values of Markowicz and Van Grieken (1984) within the estimated uncertainties.

2. Experimental details

The experimental set up employed was schematically as shown in Fig. 1. It consists of two sample positions P_1 and P_2 on either side of a 12 cm perspex sheet which was used as a stopper of β-particles. The radioactive source ^{90}Sr-^{90} Y of strength 2μ Ci, half-life 28 years and endpoint energy 2.2 MeV was used as the source of β-particles. This was supplied by the Bhabha Atomic research Centre, Mumbai, India. The source was carefully shielded so as to allow β-particles emitted only in the forward direction to be incident on the target.

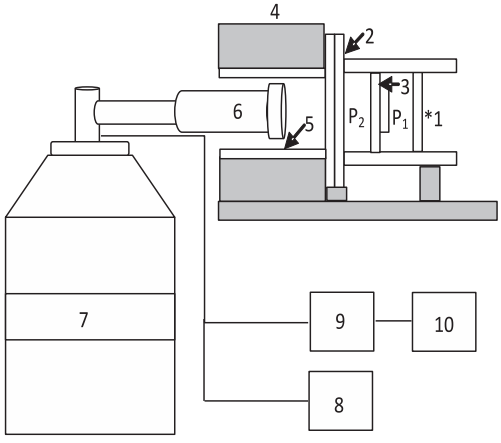

Fig. 1 – Experimental set up: 1. Source position, 2. Perspex Stand, 3. Perspex beta absorber, 4. Lead shielding 5. Aluminium lining, 6. HpGe dector, 7. Liquid Nitrogen Cooling system, P_1 and P_2: sample positions, 8. high voltage supply 9. Spectroscopy amplifier, 10. USB based MCA.

99.9% pure foils of Al, Cu, Ag, Sn and Pb were used in the present study. The rare earth samples of interest to the present work have been procured from the British Drug houses, England and were expected to have a purity of 99.9% as per the manufacturer's specifications. These samples have been listed in Table 2. Each compound in fine powder form was confined in cylindrical plastic containers in the form of sachets and used as the sample. A high purity germanium detector model number gamma-X 23210 supplied by M/S EG and G ORTEC, USA was used as the detector of photons. The detector had a resolution of 2.1*keV* at 1330*keV* and a manufacturer specified efficiency of 23%. The detector signal was suitably amplified by a spectroscopy amplifier and the spectrum was analyzed in a USB based 8*k* multichannel analyzer supplied by the Nucleonix corporation, Hyderabad, India and the spectrum was analyzed in it. The entire experiment was carried out in an air conditioned room where in the mains' voltage was stabilized.

Initially the detector was calibrated by using various gamma sources of energies in the range 59*keV* to 1332*keV* to confirm the linearity and stability of the instrument. In the experiment, spectra were recorded by placing the samples of interest [elemental foils as well as prepared rare earth samples] at the two sample positions P_1 and P_2 corresponding to before and after the perspex beta stopper [see Fig. 1].

The spectrum of EB photons produced in the material of the sample of interest was obtained suitably by subtracting the spectrum obtained at the position P_2 from the corresponding spectrum obtained at the P_1 position. In the meanwhile it was confirmed by the same procedure that the material of the plastic sachet did not produce significant number of EB photons, thus justifying its choice as a container of samples. In this manner, the EB spectra of the elements Al, Cu, Ag, Sn and Pb were determined, for different masses per unit area ρt. Typical EB spectrum obtained in the case of Sn is as shown in Fig. 2.

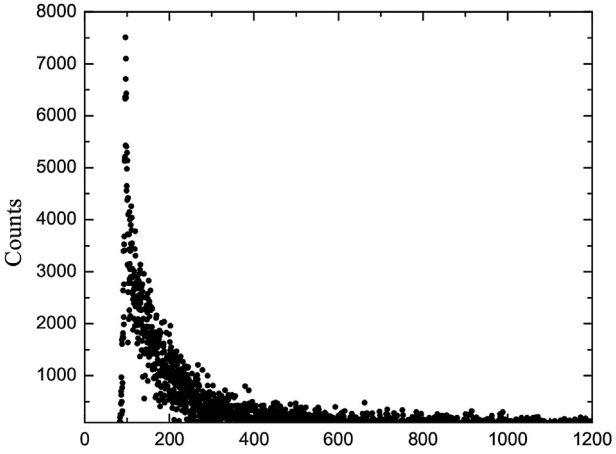

Fig. 2 – Eb spectrum of Sn.

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