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Research Article

EFFECTIVE ATOMIC NUMBER OF SOME SAMPLES DETERMINED FROM MEASURED EXTERNAL BREMSSTRAHLUNG YIELD

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ABSTRACT
In this paper, we report the effective atomic number, Z_{eff} of some inorganic compounds such as Sodium chromate, Barium peroxide and solder lead which is an alloy. For this purpose, first, the external bremsstrahlung (EB) intensity produced due to beta particles emitted by the ^{90}Sr - ^{90}Y radioactive source in standard elemental foils such as Al, Cu, Ag, Sn and Pb of varying thicknesses was determined. The variation of this EB intensity per unit area per atom of the targets (radiators) was studied as a function of their masses per unit area as well as their atomic number, Z. The resulting ln-ln plots were linear. By a suitable regression analysis, a relation for the atomic number of the radiator was derived in terms of the measured EB intensity. The EB intensity produced in the same experimental set up due to inorganic compounds and solder lead was used in this relation to determine their effective atomic number. The results were found to be in good agreement with the theoretical values.

Key Words: *External Bremsstrahlung, Effective Atomic Number, Inorganic Compounds, Alloys*

INTRODUCTION
External Bremsstrahlung (EB) theories have been developed by Bethe and Heitler (1934), Sauter (1934), Sommerfeld (1931) and others. A comprehensive summary of EB theories and experiments is included in review articles of Kotch and Motz (1959), Tseng and Pratt (1971) and also by Evans (1976).

The total intensity I (energy yield) of thick target EB produced by β particles in a target of atomic (molecular) weight 'A' and mass per unit area 't' is given by the expression (after including the attenuation of the x-rays in the target material)

$$\frac{I}{N} = KZ^{n} e^{-\Sigma t} \quad \text{..... (1)}$$

where Z is the atomic number of the target material, The proportionality constant K is the energy yield constant and Σ is the mass attenuation coefficient, t is the mass per unit area and $N=N_0t/A$, is the number of atoms(molecules) per unit area of the target.

In terms of natural logarithms, (1) can be written as

$$\ln(I/N) = \ln(KZ^{n}) - \Sigma t \qquad (2)$$

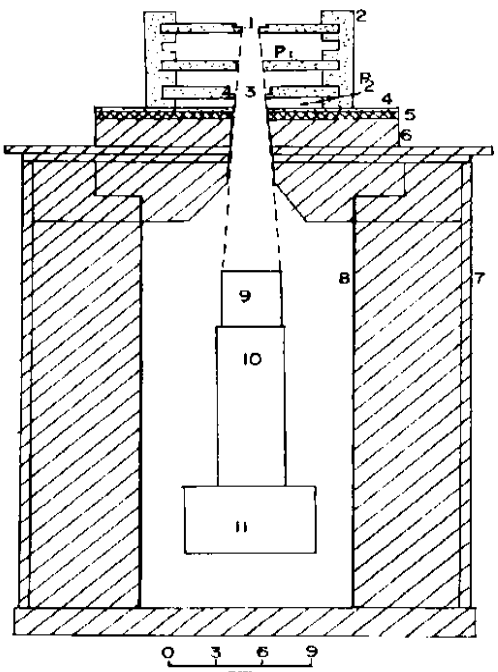
In the present study, (2) is made use of to determine the effective atomic number of inorganic compounds. The Z_{eff} values of the compounds obtained from the experimental data on bremsstrahlung yield of elements and compounds are presented and are compared with those obtained from expressions for Z_{mod} According to Markwicz and Van Grieken (1984) the modified effective atomic number of a compound or mixture is given by

$$Z_{mod} = \frac{\sum_{i=1}^{l} \frac{W_i' Z_i^2}{A_i}}{\sum_{i=1}^{l} \frac{Wi\, Zi}{Ai}} \qquad (3)$$

Where '*i*' is the number of elements in the compound or mixture, and *Wi'*, A_i and Z_i are the weight fraction, the atomic weight, and atomic number of the ith element, respectively. The modified effective atomic number, Z_{mod} is defined in such a way that the yield of a mixture or chemical compound agrees with that of a pure element with Z= Z_{mod}. This expression of Z_{mod} is known to be applicable for bremsstrahlung processes in compounds, mixtures, and alloys.

MATERIALS AND METHODS

The experimental arrangement used is as shown in the figure 1.



1. Source position;
2. Perspex stand;
3 .Target position
4. Perspex sheet;
5. Aluminum plate;
6. lead plate;
7. Lead Shield
8. Aluminum lining;
9. Na (I)Tl crystal
10. Photomultiplier and
11. Preamplifier
12. P_1 andP_2 are positions of the β absorber

Figure 1: External Bremsstrahlung production Set up

A ^{90}Sr- ^{90}Y pure β source (half life 28 yrs) kept in a Perspex holder serves as source of beta particles. All sides of the beta source were covered by Perspex so as to stop beta particles in all directions except in the forward direction and there by minimize extraneous EB production from the surrounding material. A 12mm thick Perspex sheet is kept between the source and the detector and the surrounding material. All EB measurements were made using a scintillation detector. The scintillation detector consists of a (2"X2") NaI (Tl) crystal coupled to a suitable photomultiplier tube. A difference method is adopted to eliminate the internal bremsstrahlung from the source and thereby determine the actual EB intensity produced in the target. First the integrated EB intensity is measured by keeping the target at position P_1,(Fig1) this intensity includes IB and the EB produced in the target by beta particles. Next the intensity is measured keeping the target in position P_2, which is only due to the IB from the source attenuated in the same thickness (mass per unit area) of the target. The EB produced in the Perspex is expected to be negligible compared to that produced in higher Z targets used in the experiment. The difference of these two intensities gives the EB intensity, I, produced in the target by the incident β particles. Experimentally, values of ln (I/N) were determined for several masses per unit area of the samples. The experiment was conducted for Al, Cu, Ag, Sn and Pb targets. Target compounds such as sodium chromate, barium peroxide in fine powder form were filled in Perspex planchets of 1 cm diameter. The solder lead was a self-supporting target. The thickness of these samples was so chosen that it could stop all the beta particles. The source was placed in a Perspex stand at a distance of 12.5 cm above the face of the detector. The target was placed between the detector and the source. The geometry was carefully adjusted to see that crystal was fully exposed to the EB emitted from the target. The MCA was calibrated using various gamma sources of energies ranging between 122 and 1330 keV before and after experiment to check the linearity and stability of the instrument.

RESULTS AND DISCUSSION

The values of ln (I/N) were then plotted as a function of the masses per unit area of the targets. The plots were linear as shown in Fig. 2 (a, b&c). By a suitable regression analysis, the best fit values of the slopes (Σ) and intercepts ($\ln KZ^n$) were determined. Further, the $\ln(KZ^n)$ values of the elemental targets were plotted versus lnZ (Fig.3). These plots were linear with lnK as the intercept and n as slope. The best fit values of lnK and n for the present source, geometry and target combination were determined by a linear least square fitting. These values shown in Fig 3 were valid for any target of atomic number Z in the range 13-82. Further, from $\ln(KZ^n)$ values of the samples, their Z_{eff} values were evaluated from the best fit values of lnK and ‘n’ already determined for the elemental targets. These values are shown in Table 1 along with the theoretical values obtained from expressions (3) for Z_{mod}. A good agreement is noticed between the two sets of values.

Table1: Experimental ln KZ^n values for the elemental foils

S.No.	Element	Atomic number Z	ln KZ^n
1	Aluminum	13	-29.291
2	Copper	29	-27.693
3	Silver	47	-26.732
4	Tin	50	-26.609
5	Lead	82	-25.624

Table 2: Effective atomic number of compounds

Sl.No.	Compounds	$\ln KZ^n$	Z_{mod} (eq.3)	Z_{eff}
1	Sodium chromate	-26.04	13.79	14.02
2	Barium peroxide	-26.80	45.33	45.43
3	Solder lead	-29.14	66.4	66.38

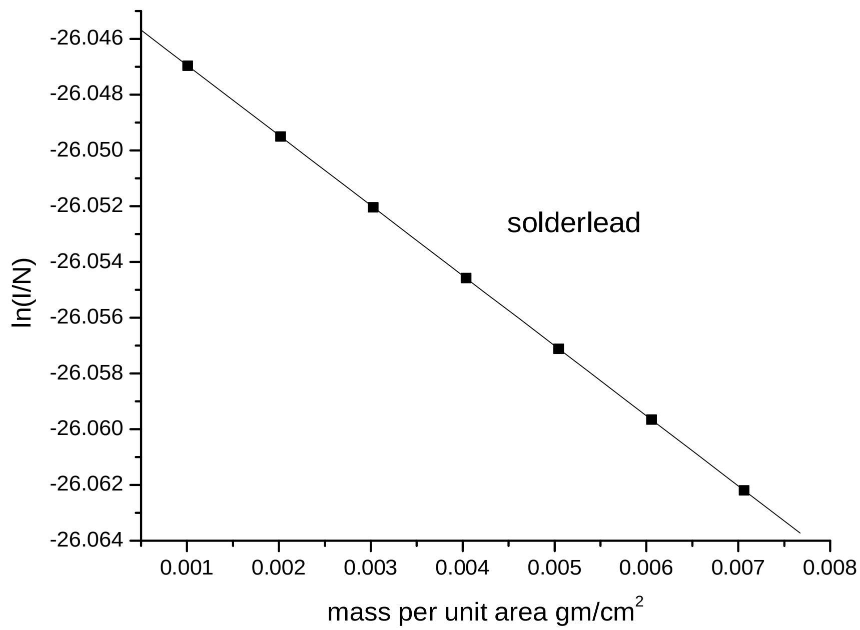


Figure 2a: Plot of ln(I/N) versus mass/unit area in gm/cm^2 for solder lead

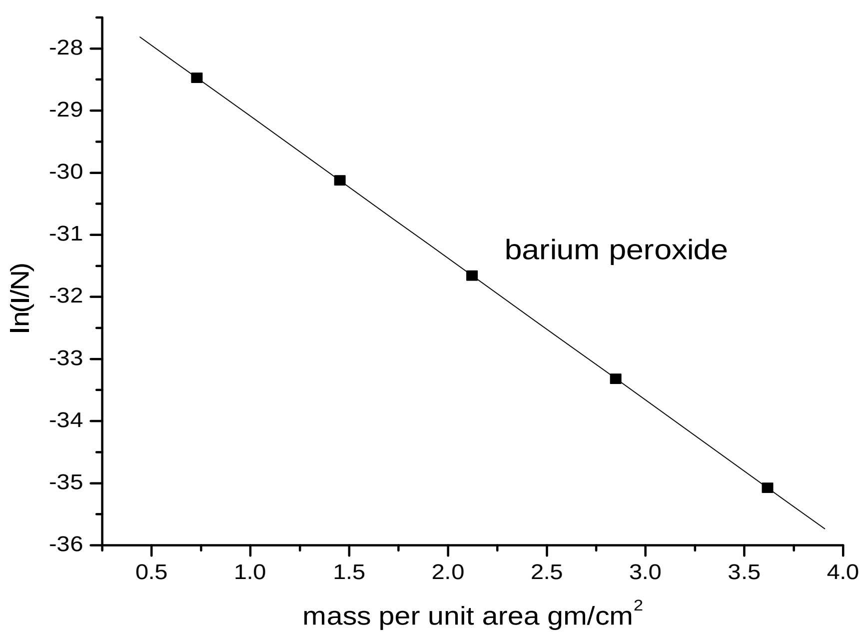


Figure 2b: Plot of ln(I/N) versus mass/unit area in gm/cm^2 for Barium peroxide

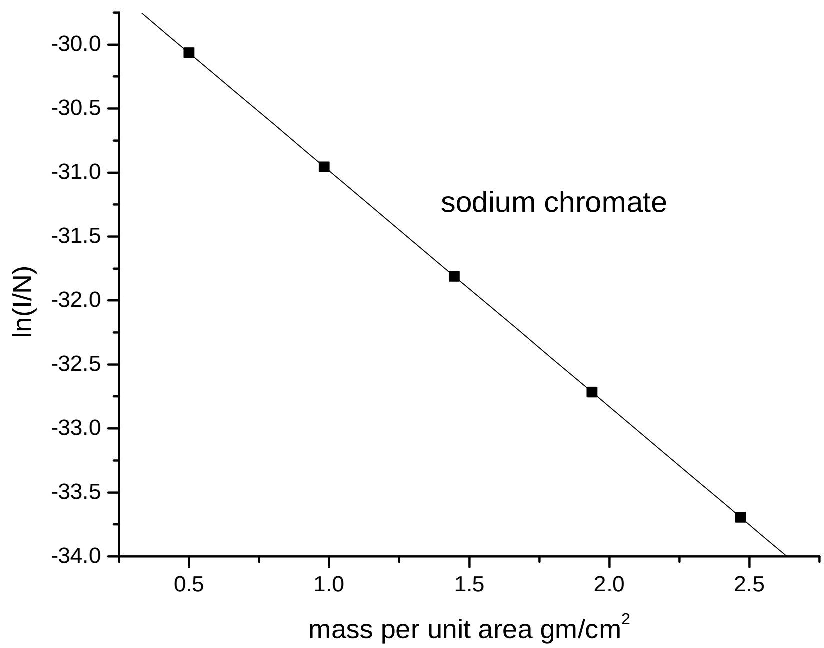


Figure 2c: Plot of ln(I/N) versus mass/unit area in gm/cm^2 for Sodium Chromate

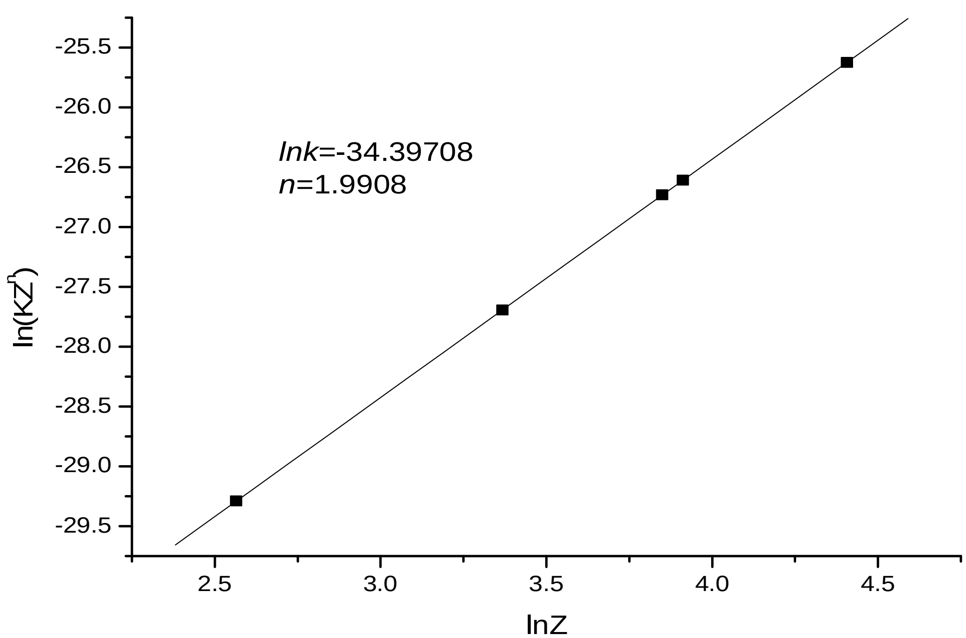


Figure 3: Plot of ln(KZ^n) versus lnZ for elements

CONCLUSIONS

Thus, it has been possible in the present work to determine the Z_{eff} of some inorganic compounds and an alloy by making use of the property of the atomic number dependence of external bremsstrahlung. Further work with other samples and sources is in progress.

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