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The absorption jump factor of effective atomic number and electronic density for some barium compounds

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ABSTRACT

Some photonic energy absorption parameters such as the mass attenuation coefficient μ_t, the molecular σ_M, atomic σ_A, the electronic cross-sections σ_E, the effective atomic number Z_{eff} and the electron density N_E have been calculated and measured. We have gained the terms jump factor of effective atomic number JZ_{eff} and jump factor of electronic density JN_E to literature with the help of these fundamental parameters. Also, we want to obtain both XAFS effect and the applicability of mixture rule. The most interesting finding in this study is that the trend of the total molecular, atomic and electronic cross-sections is getting beyond the measure by the absorption edge and these cross-sections are affected in the region of absorption edge. The obtained results have been compared with some other theoretical values given earlier.

1. Introduction

For a complex medium, the "effective atomic number (Z_{eff})" is one of more important parameters for representing X-ray or gamma ray interactions with material, e.g. in designs of radiation shielding or in calculations of absorbed dose in radiotherapy. However, as originally stated by Hine (1952) [1], the effective atomic number of a multi-element material is not a constant. For each process that X-ray and gamma ray interact with matter in different ways depending on photon energy such as incoherent and coherent scattering, photoelectric absorption and pair production, the various atomic numbers in the material have to be weighted differently. In other words, this parameter is introduced to describe the properties of composite materials in terms of equivalent elements, which have different atomic numbers. Z_{eff} is not a constant for a given material, but a parameter varying with sample density and photon energy. The measurement or calculation of effective atomic numbers Z_{eff} is a pioneer step for many fields of scientific applications. Various researchers have determined effective atomic numbers for some materials [2–17]. Also, effective atomic numbers of some compounds can be determined with the help of a practical method by İçelli [18]. However, in the literature, there is no specific study related to the absorption jump factor and measured molecular, atomic and electronic cross-sections around the K absorption edge of absorbers. In order to fill this gap, a correlation between absorption jump factor (J) and measured effective atomic number was obtained by Polat and İçelli [19,20] around the K absorption edge of absorber materials. In the study, the term JZ_{eff} was introduced in order to represent the correlation between absorbsion jump factor and effective atomic number. In addition to this term, now, we want to determine another term as "JN_E". Like JZ_{eff}, the term JN_E stands for jump factor of effective electron density near the K absorption edge. The effective electron number or electronic density N_E (number of electrons per unit mass) of a material can be derived from the effective atomic number. The parameter N_E is also a highly beneficial parameter for many fields of scientific applications.

One way to obtain jump factor of effective atomic number is "gamma ray attenuation method". In this method, the attenuation of gamma photons with different energies around the K absorption edge is measured. We have measured absorption jump factor using mass attenuation coefficient near the absorption edge. If photon energy is just sufficient to expel electrons from a specific inner level in the atom, the jumping occurs. The jumping is similar to a step function. In the jumping region, there are simple abrupt discontinuities in the absorption coefficients. The fine structure consists of such deviations coming from the simple step function as well as the deviations both in the abrupt rise and in the region on the high-energy side of the rise. In general, the fine structure is confined to within ~200 eV of the edge [21]. XAFS (X-Ray Absorption Fine

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Structure), i.e., the oscillatory structure in the X-ray absorption coefficient, contains a lot of quantitative information concerning the structure of absorbing atom [22]. The important aim of this study, by demonstrating the effect of XAFS on JZ_{eff} and JN_E, is to support the systematic investigation of the lately published study in Refs. [19,20]. Briefly, we can say that there is a correlation between the effective electron number and the absorption jump factor, and this is the first time we have measured the JN_E values of some selected barium compounds at <100 keV energies. It is important that the determination of JN_E is a new study but the the experimental geometry and the method used are the same that of Refs. [19,20].

Barium is an alkaline earth metal that is not available purely in nature. It takes place in compounds with other chemicals such as sulfur, carbon and oxygen. It is used widely for both medical and diagnostic industry as well as ceramics, glass manufacturing, paint,

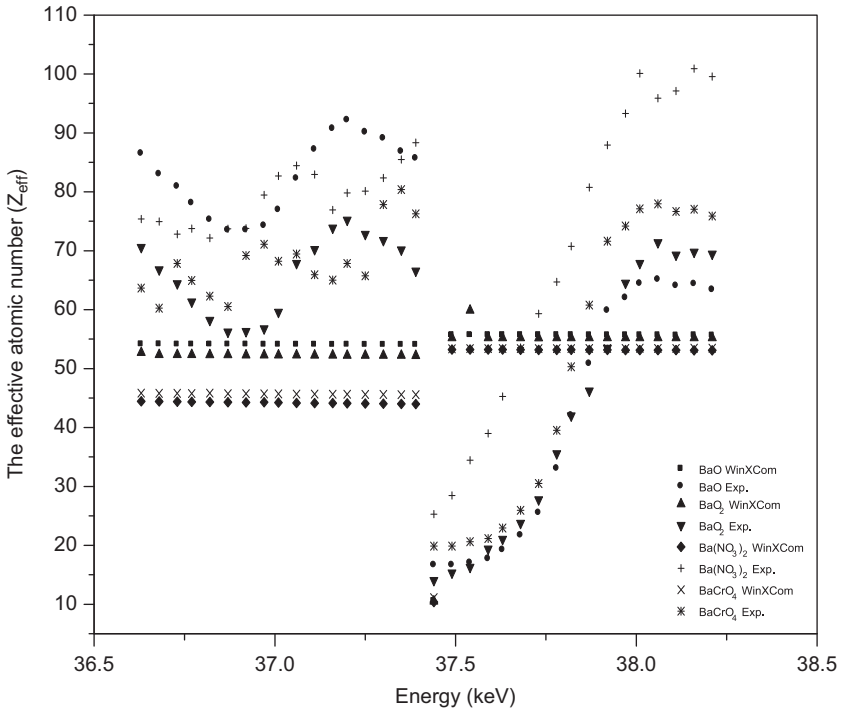

Fig.1. The effective atomic numbers of compounds versus photon energy, around K absorption edge.

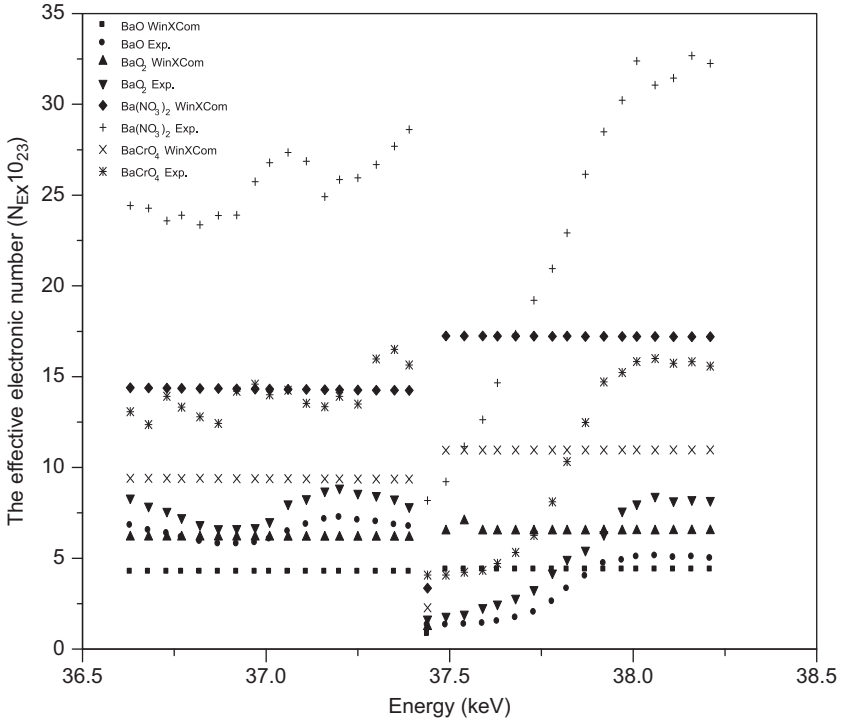

Fig. 2. The effective electronic number of compounds versus photon energy, around K absorption edge.