Nuclear Instruments and Methods in Physics Research A 613 (2010) 251–256

Contents lists available at ScienceDirect

Nuclear Instruments and Methods in Physics Research A

journal homepage: www.elsevier.com/locate/nima

Effective atomic number study of various alloys for total photon interaction in the energy region of 1 keV–100 GeV

Murat Kurudirek [a,*], Mehmet Büyükyıldız [b], Yüksel Özdemir [a]

[a] Faculty of Science, Department of Physics, Ataturk University, 25240 Erzurum, Turkey
[b] Faculty of Education, Department of Science, Ağrı İbrahim Çeçen University, 25240 Ağrı,Turkey

ARTICLE INFO

Article history:
Received 22 October 2009
Received in revised form
17 November 2009
Accepted 22 November 2009
Available online 26 November 2009

Keywords:
Alloys
Effective atomic number
Photon interaction
K-absorption edge

ABSTRACT

Effective atomic numbers of various alloys have been calculated by using a direct method for total photon interaction ($Z_{PI_{eff}}$) in the energy region of 1 keV–100 GeV. Significant variations in $Z_{PI_{eff}}$ observed for alloys in different energy regions are mainly dominated by photoelectric and pair production processes. Besides, the $Z_{PI_{eff}}$ has been found to vary with the composition of alloys. Comparisons with experiments have been carried out for calculated values of $Z_{PI_{eff}}$. Also, the energy dependence of $Z_{PI_{eff}}$ with respect to the atomic number of constituent elements present in the alloys and K-absorption edge effects on effective atomic numbers where there exists more than a single value of effective atomic number at a specific energy have been discussed for the given alloys.

1. Introduction

Photon interaction in different materials finds its utilization in many fields like medicine, physics, industry, agriculture, etc. The most relevant parameter determining the photon interaction in the material is the mass attenuation coefficient. The mass attenuation coefficient (μ/ρ) that is a measure of probability of interactions of incident photons with the thickness (g/cm^2) of target material is of importance in dosimetry, radiography, radiation shielding, computerized tomography, etc. [1]. It follows from the above that μ/ρ is a basic quantity used in calculations of the penetration of photons in biological, shielding and other materials [2]. While the extensive and accurate data sets are available for elements [3–7], studies in composite materials such as different alloys are meager due to difficulty in procuring targets in suitable form for experiments [8].

In composite materials like alloys, it is quite reasonable to define an effective atomic number, Z_{eff} to describe the properties of an alloy in terms of an equivalent element. Effective atomic number of an alloy, which is a very useful parameter for many fields of scientific applications, is similar to that atomic number of elements. However, on the basis of Hine's expression [9] that the effective atomic number of a material composed of several elements cannot be expressed by a single number, it can be concluded that it is an energy-dependent parameter due to different partial photon interaction processes with matter for which the various atomic numbers in the material have to be weighted differently. Effective atomic number is also a convenient parameter that in some cases, viz. designing radiation shielding, computing absorbed dose, energy absorption and build-up factor, represents radiation interaction with matter. In some cases, in order to have an initial information about the chemical composition of a material the Z_{eff} can be utilized. For example, the materials having large Z_{eff} generally correspond to the inorganic compounds and metals, while a small Z_{eff} ($\leqslant 10$) is an indicator of organic substances [10].

Several investigators have contributed to find the effective atomic numbers in different alloys [11–13]. However, these studies seem to be restricted to a limited energy range and also most of them have focused on interpolation procedures and semi-empirical relations. Thus, there needs to be some confirmation of the results in a continuous energy range by using a direct method. Also, while determining the effective atomic number of an alloy it should be reasonable to take into account the absorption edges of elements constituting the alloys where there exists more than a single effective atomic number. From this point of view, we found it interesting to study the photon interaction in terms of effective atomic number for various alloys in an extended energy range including the K-absorption edges of elements present in the alloys.

In the present study, the effective atomic numbers of various alloys have been calculated for total photon interaction at photon energies from 1 keV to 100 GeV using mass attenuation coefficients from WinXCom computer program [6,7]. Comparisons with experiments have been made at some photon energies wherever possible for the given alloys. Moreover, the effect of absorption edges on effective atomic number has been discussed.

* Corresponding author. Tel.: +90 442 2314167; fax: +90 442 2360948.
E-mail address: mkurudirek@gmail.com (M. Kurudirek).

0168-9002/$ - see front matter © 2009 Elsevier B.V. All rights reserved.
doi:10.1016/j.nima.2009.11.061

2. Calculation method

The total mass attenuation coefficients of elements present in the alloys have been obtained from the WinXCom [6,7] computer program. These coefficients were then used to calculate the effective atomic numbers of alloys for photon interaction with the help of the following practical formula [20]:

$$Z_{PI_{eff}} = \frac{\sum_i f_i A_i \left(\frac{\mu}{\rho}\right)_i}{\sum_j f_j \frac{A_j}{Z_j} \left(\frac{\mu}{\rho}\right)_j} \quad (1)$$

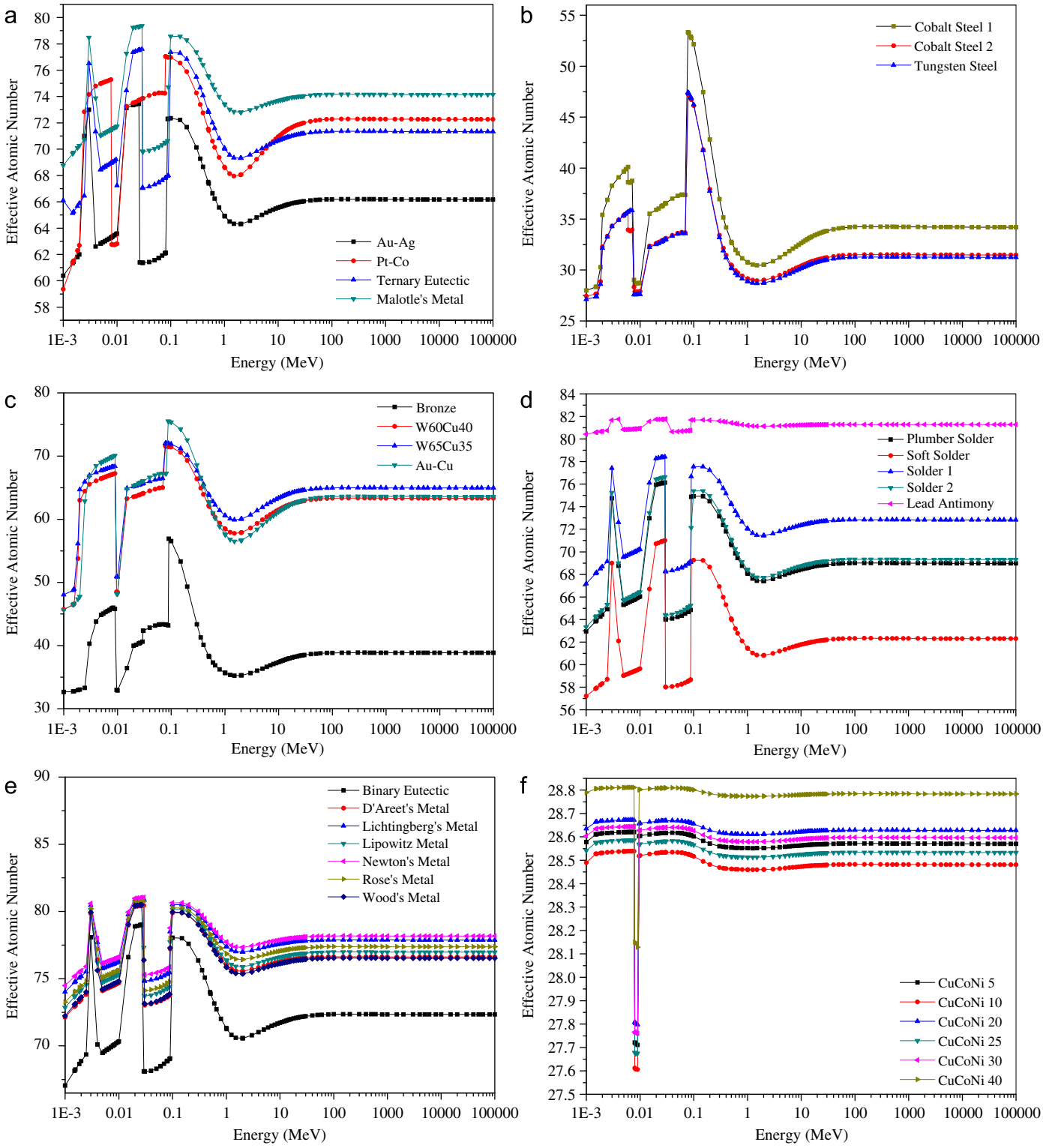

Fig. 1. (a–i) Effective atomic numbers of the given alloys for total photon interaction from 1 keV to 100 GeV.