Indian J. Phys. **44**, 68–70, (1970)

Effective atomic numbers for scattering processes of gamma rays in alloys

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(*Received* 10 *July* 1970)

An effective atomic number for gamma ray interaction is defined for a material composed of several elements, to represent the attenuation properties of the material. Unlike the atomic number in the case of an element, the effective atomic number of such a material is not a unique number, since it assumes different values for different interaction processes. However, it has been shown (Parthasaradhi 1968) that the effective atomic number defined for a particular partial process is quite unique and retains its identity over a considerable energy range. Hence, more attention is devoted to the study of these partial effective atomic numbers (Visweswara Rao *et al* 1968, Parthasaradhi *et al* 1969) for various alloys. In these investigations (Parthasaradhi 1968) no discrimination seems to have been made between coherent and incoherent scattering processes, with the hope that the effect due to this indiscrimination in the energy region considered is small on the effective atomic number for total scattering process. Further, no attempt seems to have been made to determine partial effective atomic number for coherent scattering except at 30 keV in water and perspex (Parthasaradhi 1968). It is therefore felt that a detailed study of the effective atomic numbers for coherent and incoherent scattering processes separately in the energy region 0.1 to 1.33 MeV might be interesting. For this purpose two alloys of tin and a heavier element (Pb) and two of tin and a lighter element (Cu) in different proportions are chosen and the results are reported in this note.

As in previous investigations (Parthasaradhi 1968) the incoherent scattering cross-sections for the elements Pb, Sn and Cu are obtained by subtracting the other theoretical partial cross-sections (Plechaty 1968, Schmickely *et al* 1967) including the coherent scattering cross-sections (Plechaty) from the total experimental gamma ray cross-sections reported by McCrary *et al* (1967), Colgate (1952), Wyard (1952) and Parthasaradhi *et al* (1968). From these, the cross-sections in the alloys are determined using the sum rule. Making use of these effective cross-sections, the effective atomic numbers in alloys for incoherent scattering process are determined at the various energies by interpolation from the plots of cross-section *versus* atomic number. Since experimental total coherent scattering cross-sections are not available the effective atomic numbers for this process are determined, in a similar manner as described above, utilizing the theoretical cross-sections reported by Plechaty. The values of the incoherent and coherent scattering cross-sections of the alloys are given in table 1 and the deduced values of the effective atomic numbers are presented in table 2.

TABLE 1. Coherent and incoherent scattering cross-sections in alloys (in barns/atom)

Energy (keV)		Solder Pb 67% Sn 33%	Solder (soft) Pb 40% Sn 60%	Bell metal Sn 25% Cu 75%	Bronze aluminium Sn 10% Cu 90%
100	Incoherent	—	—	15.0	11.8
	Coherent	—	—	6.3	3.69
279	Incoherent	22.5	20.2	11.4	9.2
	Coherent	6.3	4.35	0 84	0.49
412	Incoherent	20.2	17.7	9.4	7.9
	Coherent	2.85	1.97	0.40	0.23
662	Incoherent	16.6	14.7	8.15	6.6
	Coherent	1 08	0.75	0.15	0.09
1332	Incoherent	12.2	10.6	5.8	4.8
	Coherent	0.28	0.19	0.033	0.02

TABLE 2. Effective atomic numbers for incoherent and coherent scattering processes of gamma rays

Energy (keV)		Solder Pb 67% Sn 33%	Solder (soft) Pb 40% Sn 60%	Bell metal Sn 25% Cu 75%	Bronze aluminium Sn 10% Cu 90%
100	Incoherent	—	—	32±1	27±1
	Coherent	–	—	33	27
279	Incoherent	64±2	57±2	32±1	26±1
	Coherent	69	61.5	33.5	27
412	Incoherent	64±2	56±2	31 5±1	26±1
	Coherent	69	61	33	27
662	Incoherent	65±2	58±2	32±1	26±1
	Coherent	69	61	33.5	27
1332	Incoherent	66±1	58±1	32±0 5	26±0.5
	Coherent	69	61	33	27

It can be seen from table 2 that the effective atomic number for each scattering process retains its identity over the energy region considered within the limits of errors. There is a significant difference between the two effective atomic numbers in the two alloys composed of Pb and Sn, while the difference is not discernible in the other two alloys composed of Sn and Cu. It thus appears that in alloys consisting of heavy elements the effective atomic numbers for coherent and in coherent scattering processes have to be treated separately.

Two of the authors (M.S.M. and M.N.S.) are grateful to the Department of Atomic Energy, Government of India, for awarding them Research Fellowships.

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