Incoherent scattering cross sections of gamma rays in lead in the energy region 279-1330 kev

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At first sight such a high probability of dissociation coupled with the comparatively low mass would appear to be inconsistent with the very low upper limit to the frequency of quarks at ground level. However, it is only necessary to invoke a strong interaction with matter for the quark to remove this objection.

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Abstract. The effect of electron binding on the incoherent scattering cross sections of gamma rays in lead in the energy region 279–1330 kev is studied by subtracting theoretical values of all other partial cross sections from the total experimental cross sections. It is concluded that the Thomas–Fermi model underestimates the effect of electron binding in reducing this cross section in the energy region 279–662 kev.

To study the effect of electron binding on the incoherent scattering of gamma rays a simple procedure is followed. From total experimental gamma-ray cross sections, the contributions due to theoretically computed partial cross sections (except the incoherent scattering cross section) are subtracted. The ratio of the remainder to the theoretical free-electron scattering cross section is taken as a measure of the effect of electron binding on the incoherent scattering of gamma rays. The existing investigations utilizing this procedure by Ramana Rao *et al.* (1965) and Parthasaradi and Visveswara Rao (1967) are available in low and medium atomic weight elements only. To extend these investigations to heavy elements very accurate theoretical photoelectric cross-section estimates are necessary because the contribution due to photoelectric cross sections to the total gamma-ray cross sections will be dominating for these elements. Recently very accurate theoretical photoelectric cross-section estimates are reported by Schmickley (1966, see also Schmickley and Pratt 1968) within an accuracy of less than 0·5% in most elements. With

the availability of such accurate theoretical photoelectric cross-section estimates it is of real interest to extend the investigations in a high atomic number element like lead in a wide region of energy, so that the effect of electron binding on the incoherent scattering and its variation with energy can be studied. With this end in view the present investigations are taken up in lead and the region of energy selected is 279–1330 kev.

In the present investigations calculated photoelectric cross sections of Schmickley (1966), coherent scattering cross sections based on the Thomas–Fermi model reported by Brown (1966 a, b) and experimental total gamma-ray cross sections of Colgate (1952) and Wyard (1952, 1953) are used. The pair cross-section contribution was taken from the reported data by Hubbell and Berger (1967), utilizing a semi-empirical relation near threshold.

The experimental incoherent scattering cross sections obtained in this way were divided by the free-electron scattering cross sections (Grodstein 1957) to give the experimental ratios in table 1. Theoretical bound-electron incoherent scattering cross sections, based on the Thomas–Fermi model and reported by Brown (1966 a, b), were used to give the theoretical ratios in table 1. The errors quoted are maximum errors rather than probable errors.

Table 1. Ratios of bound- to free-electron scattering cross sections

(1)	(2)	(3)	(4)	(5)	(6)	(7)
279	156·21 ±2·3	132·11 ±0·71	24·10 ±3·01	28·5	0·81 ±0·10	0·96
320	115·3 ±0·7	92·10 ±0·51	23·20 ±1·21	27·3	0·82 ±0·04	0·97
411	73·39 ±0·1	50·05 ±0·28	23·34 ±0·38	25·1	0·91 ±0·02	0·98
662	36·88 ±0·07	16·76 ±0·1	20·12 ±0·17	20·8	0·96 ±0·01	0·99
1076	22·173 ±0·13	5·96[a] ±0·04	16·213 ±0·17	16·5	0·98 ±0·01	~1·00
1330	19·03 ±0·04	4·26[a] ±0·03	14·77 ±0·07	14·8	1·00 ±0·01	1·00

(1) Energy (kev); (2) total gamma-ray cross sections; (3) photoelectric + coherent scattering cross sections; (4) experimental bound-electron scattering cross sections $(\sigma_b)_{expt1}$; (5) theoretical bound-electron scattering cross sections $(\sigma_b)_{theor}$; (6) $(\sigma_b/\sigma_f)_{expt1}$, where σ_f is the free-electron scattering cross section; (7) $(\sigma_b/\sigma_f)_{theor}$.

a, also includes pair cross-section contribution.

It can be seen from the table that the theoretical values of the ratios are higher than the experimental values at all energies except for 1330 kev, but that the difference is not significant at 1076 kev. In the region 279–662 kev, however, the Thomas–Fermi predictions for the incoherent scattering cross section in lead are overestimations.

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