Chapter 1

INTRODUCTION

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With the increasing use of radio-isotopes in industry, agriculture and medicine, the subject of "radiation physics" has gained great prominence in recent years. As a result, there is a revival of interest in the studies involving gamma ray interaction with matter, which is essential for designing radiation shields. The attenuation of gamma radiation in matter is, in general, complex due to the contributions from different competing processes which depend both on the energy of the radiation and the atomic number of the absorbing material. The main interaction modes have been classified by Fano[1] who also discussed their relative importance in particular cases. For investigations with low energy ($\lesssim$1 Mev) gamma rays, there are three competing partial processes : (i) the photoelectric effect, (ii) the coherent scattering, and (iii) the incoherent scattering.

The photoelectric process involves the complete absorption of an incident photon by the atom resulting in the emission of an electron, preferably from the inner shells. In the coherent scattering, the photon is deflected without any energy loss. However, when the energy of the photon is larger than the binding energy of the electrons, there can be an energy transfer to the electron resulting in its ejection, along with the scattered photon of reduced energy. This is termed "incoherent scattering". For a given element, the photoelectric process predominates over the others at low energies whereas scattering becomes important at intermediate photon energies. At very low energies, coherent scattering is more frequent than incoherent scattering. Although all these processes become more frequent with increasing Z, the photoelectric process exhibits the most rapid increase.

The behaviour of these processes at low photon energies is quite interesting. Whereas the cross-section for coherent scattering shows a rapid decrease with increasing energy, the incoherent scattering cross-section increases at first and then decreases slowly with increasing photon energy clearly exhibiting the influence of bound electrons. However, the total scattering cross-section exhibits a smooth variation with increasing energy. Thus, the decrease in the incoherent scattering cross-section due to electron binding effects is compensated for by the increase of the coherent scattering process. On the other hand, the photoelectric cross-section shows characteristic discontinuities at energies corresponding to the electron binding energies. As a result, investigations on the photoelectric and incoherent scattering cross-sections in the low photon energy region (with energies comparable to the electron binding energies in typical elements), should reveal interesting information about the influence of bound electrons on these processes.

Theoretical studies on these processes have been extensive. As the interaction of a photon with the atom is normally treated as weak, the theoretical framework for all these partial processes is provided in the perturbation approximation. For any of these processes, the common situation is that an electron makes a transition from its initial state to a final state under the influence of the electromagnetic field of the photon. Then, the problem reduces to the evolution of the matrix element for this transition, after choosing appropriate operators and wave functions for the initial and final states of the electron. For an atomic electron, the initial state is bound and the final state is free for all these processes except for coherent scattering where, the initial and final states are identical. However, several factors have to be taken into account for a proper choice of the wave function. Important amongst them are :

(i) The influence of other electrons in the atom and their screening effects;

(ii) the influence of the atomic nucleus on the outgoing electron;

(iii) the effect of the charge distribution inside the atom resulting in coherent effects;

(iv) treating the electrons with higher energies as relativistic particles, and

(iv) considering possible radiation losses and exchange effects.

In the earliest theoretical attempts, a number of simplifying assumptions were made to reduce the complexity of the calculations and to obtain simple analytical expressions for the various partial processes. Later, attempts were made to introduce appropriate (but approximate) correction factors. More recently, with the availability of fast electronic computers, it has become possible to remove all the simplifying assumptions. Even then, the computer time among other things, limits the accuracy and the extent of sophistication attainable. The review articles by Grodstein[2] and by Storm and Israel[3]