SYNOPSIS

The work presented in this thesis, describes the measurements of the Z-dependence and the polarization of Rayleigh scattering of gamma rays. The Rayleigh scattering is one of the four important processes through which gamma rays may be elastically scattered, the other three processes are (1) Nuclear Thomson Scattering (2) Delbrück Scattering and (3) Nuclear Resonance Scattering. The last of these processes does not arise under normal laboratory conditions and special techniques have to be used to observe it.

The elastic scattering processes are described in Chapter I. For gamma rays of energy up to 1 MeV, the contribution of Delbrück scattering is negligible, therefore, only Rayleigh and nuclear Thomson scattering contribute to the elastic scattering. Nuclear Thomson scattering can be calculated accurately for gamma rays of various energies and different elements. The study of the elastic scattering of gamma rays of energy below 1 MeV can therefore be used to yield information about Rayleigh scattering. Reliable information, both theoretical as well as experimental, regarding Rayleigh scattering is needed in the analysis of experiments on resonance and Delbrück scattering where Rayleigh and nuclear Thomson scattering provide a background which
cannot be isolated energetically. The exact calculations of Rayleigh scattering are available only for gamma rays of energies 0.32, 0.64, 1.28, 2.56 and 5.12 meV, scattered from the K-shell electrons in mercury at scattering angles from 15° to 150°. These calculations have been extended to tin by means of a modified form factor proposed by Brown and Mayer. However, a number of form factor calculations have been made by various workers using different assumptions and approximations to estimate Rayleigh scattering of gamma rays of various energies from different elements. Each calculation predicts different Z-dependence of scattering intensity. Regarding polarization of Rayleigh scattering, form factor calculations predict that gamma radiation scattered at 90° is 100 per cent plane polarized irrespective of energy of gamma radiation, but the refined calculations show that the scattered radiation is partially plane polarized and that the percentage polarization decreases as the energy of gamma radiation increases. The previous experimental investigations of the Rayleigh scattering of gamma rays are reviewed. It is observed that even though the existing experimental results of various workers on the angular distribution of Rayleigh scattering of gamma rays show
better agreement with the predictions of the refined calculations than those of the form factor calculations, the large experimental errors and the small difference in the predictions of various calculations make the results rather ambiguous especially when the large corrections that have to be applied to the refined calculations to correct for the contributions of L-shell electrons and the different Z-values of the experimental scatterers are taken into account. The available experimental data are found to be too scanty to yield any useful information about the Z-dependence of Rayleigh scattering. It is, therefore, proposed that a systematic investigation of the Z-dependence of the elastic scattering should be useful to confirm the existing superiority of the refined calculations. The experimental data on Z-dependence when combined with the refined calculations for mercury should provide a straightforward semi-empirical method to make a fairly reliable estimate of the scattering from other elements.

The existing measured values of the percentage polarization of the elastic scattering are found to be lower than those predicted by the refined calculations. It is, therefore, proposed to re-examine the polarization of the elastic scattering in order to investigate the reasons for this discrepancy between experiments and the
refined calculations with regard to the polarization.

The measurements of the Z-dependence of the elastic scattering cross-sections of gamma rays were made in two separate experimental arrangements depending upon the angle of scattering. The measurements at small angles are described in Chapter II while those at large angles are discussed in Chapter III. The experimental results show that the index to the power of Z, on which the cross-section depends, increases with the momentum transfer involved in scattering. This clearly contradicts the predictions of form factor calculations of Frans which give \( Z^3 \) dependence for all values of momentum transfer. The experimental values of 'n' are lower than those predicted by Sethe's form factor calculations but agree with those calculated by modified form factor up to momentum transfer of 1 me beyond which the experimental points are lower than the theoretical calculations.

A semi-empirical method for the estimation of elastic scattering cross-sections of gamma rays of any energy from various elements at different scattering angles is described in the Chapter IV. It makes use of the exact calculations of Brown and Mayers for mercury and the experimental data on Z-dependence. The values of cross-sections estimated by semi-empirical method are found to agree well with the available experimental data.
The measurements of polarization of the elastic scattering of 668 KeV gamma rays at various angles are described in Chapter V. The percentage polarization was measured by a gamma ray polarimeter using Compton scattering as the analyzing process. Special care was taken to isolate the elastic scattering from inelastic scattering. The experimental results are found to agree well with the refined calculations of Brown and Mayers and contradict the form factor calculations. The experimental results also indicate that an incomplete isolation of inelastic scattering from the elastic scattering tends to lower measured values of percentage polarization. The present results remove the discrepancy between experiment and theory with regard to polarization of Rayleigh scattering of gamma rays and contradict the earlier assumption that this discrepancy was due to the contribution of L-shell electrons, the exact calculations for which are not available.