GENERAL INTRODUCTION

Renewed interest in the experimental study of the phenomenon of atomic pair production in the nuclear Coulomb field has been developed recently due to publication of a number of theoretical calculations of the pair production cross-section taking screening of the atomic electrons into account. The basic theoretical treatment of the phenomenon of the atomic pair production is Bethe Heitler's Born approximation calculation (Be-34) which is correct to lowest order in αZ. The validity of this plane wave approximation is restricted by the inequality $\frac{2\pi\alpha ZE}{P} \ll 1$ which must be satisfied for both the formions (where Z is the atomic number, α the fine structure constant, E and P are the energy and momentum of the electrons). Even for high energy this inequality is not valid for high Z elements, accordingly a Coulomb correction i.e. deviation from Born approximation calculation was expected to be considerable

at high energy for high Z elements and even more important for low energy region. By the use of exact coulomb field wave functions Coulomb correction can be calculated at low energy. But this procedure required the wave function and hence the crosssections to be written as partial wave expansions. This turned out to be a formidable task to the theoretical physicists before seventies. But with the advent of computors it has been possible to calculate the cross sections taking coulomb effect and screening of the atomic electrons into account (Øo-67, Ts-71, 72, Øo-79). Many of the previous experimental results are inconsistent with each other (Av-74, Ra-63) and with some of the earlier theoretical results. In view of the new theoretical calculations it is desirable to perform accurate measurements of the pair production cross sections. The aim of the present set of measurements has been primarily to investigate the validity of the recent theoretical calculations of screening effects of atomic electrons on the pair production cross section, considering the inadequacy of the existing experimental results and old theoretical calculations. Experimental verification of theoretical calculations is considered as important as theoretical developments.

The present set of measurements were carried out (a) by making total cross section measurements from which pair production cross section could be extracted using recently published accurate calculation of photo electric cross sections and incoherent and coherent cross sections (b) Direct measurements of pair production yield in comparison to that from a standard. The work done has been organised in the following order.

CHAPTER - I

A summary of the calculations on the theory of atomic pair production is given in this chapter. The development in the calculation of Coulomb correction by Øverbo has been described. Screening correction calculation of Tseng and Pratt and of Øverbo have also been summarised. A critical evaluation of the results of various calculations are presented and discussed.

CHAPTER - 2

All experimental techniques have been described. Many of the experiments overlap in target Z and photon energy. The results of these measurements by these techniques have been compared for an evaluation, (Table- 2.1) and displayed (Fig. 2.1 - 2.3) graphically along with

the old and new theoretical results. The tables and graphs show the inadequacy of the earlier experiments for testing the calculations. It is apparent from the tables that some sort of systematic errors must have been introduced in these experiments resulting in the inconsistancy of the results. This indicates the need for new experiments to test the recent calculations.

CHAPTER - 3

The development of a simple method for pair production experiment is described. The method used in the measurements of pair production cross sections in the sixties used NaI(Tl) detectors in coincidence techniques. The results of these measurements are now found, to be not adequately reliable for a comparison with more refined theoretical calculations taking screening correction to the pair production into account. The experimental method of Avignone et al (Av - 74) using a spherical symmetry of the target and source is dependant on experimental values of the annihilation pair detection efficiency, and total gamma ray absorption coefficient of the target material and is subject to experimental uncertainties. Another disadvantage of the method arises from poor statistics due to lower detection efficiency of Ge (Li) detector. We have developed a method of making measurements relative

to some standard target. Since ratio of pair-counting rates under identical geometry has been taken, the various systematic errors have been eliminated. The results of our measurements have been compared with theoretical calculation and with other experimental results at photon energies (1.332 + 1.173 Mev) and 1.115 MeV on five elements: Copper, Tin, Gold, Thorium and Uranium.

CHAPTER - 4

Attenuation measurements on nine elements at four energies from 1.115 MeV to 1.332 MeV in the range of atomic number 42-82 are presented. Using the new values of cross sections, i.e. incoherent and coherent scattering and photo-electric effect, the pair production cross-section has been extracted and compared with theoretical calculations and also with results of direct measurements. Some of the previous total cross section results have been reanalysed and the pair production cross section extracted with the help of recently calculated cross section for photo-electric effect and scattering.

These extracted cross sections have been compared with the results of direct experiments and theoretical calculations.