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Proton and α-particle impact *M*-shell ionization of atoms in binary encounter approximation

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Abstract. *M*-shell ionization cross sections for atoms due to the impact of proton and α-particles have been calculated in the binary encounter approximation. The effects of Coulomb deflection of the incident projectile and increase in binding of the target electron have been investigated. Roothan-Hartree-Fock velocity distribution for the target electrons has been used in the present work. The calculated cross-sections have been compared with experimental results and other theoretical calculations wherever available. The present calculations give a good account of experimental observations.

Keywords. *M*-shell; ionization cross-section; Coulomb deflection; binding energy correlation; Roothan-Hartree-Fock velocity distribution.

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1. Introduction

Investigation of inner-shell ionization of atoms by the impact of heavy charged particles has gained much practical importance, especially, because of the direct use of the particle induced X-ray analysis in many applied fields (Gowda and Powers 1985). *M*-shell studies (theoretical as well as experimental) are scarce in literature (Ishii *et al* 1975; Busch *et al* 1973; Sera *et al* 1980) as compared to the study of *K*- and *L*-shell vacancy production. This is because of the fact that *M*-shell itself is complex in nature (Chen *et al* 1983).

In plane wave Born Approximation (PWBA), Choi (1973) and Johnson *et al* (1979) calculated proton impact inner-shell ionization cross-sections which finally resulted in scaled universal functions for 3*s*, 3*p* and 3*d*. In both the calculations in PWBA, only the effect of Coulomb deflection has been taken into account. Mehta *et al* (1982) have used the PWBA universal function for the direct Coulomb ionization and added to it Oppenheimer Brinkmann Kramers (OBK) results for electron capture by Nikolaev (1967) to calculate *M*-shell X-ray production cross-section. Calculations were also performed by Mehta *et al* (1982) in the perturbed stationary state theory of Brandt and Lapicki (1979). The so-called ECPSSR calculations account for the energy loss and Coulomb deflection of the projectile and the effect of relativistic nature of *M*-shell electron. The ECPSSR calculation goes beyond the first Born approximation which does not include all these effects. Chen *et al* (1983) have scaled their relativistic Dirac-Hartree-Slater calculations of *L*-shell ionization cross-sections to obtain *M*-shell cross-sections.

In recent past, Shrivastava and Roy (1986) have discussed in detail the limitations