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Scattering of Electron and Photon from Excited Metastable He (2^3S) Atoms and Study of Energy Variation of Inelastic TCS

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***Abstract:** Scattering cross sections may be defined as in nuclear, atomic and particle physics for collisions of one type of particle with targets; either stationary or moving. The probability for any given reaction to occur is in proportion to its cross section. Thus to find the cross section for a given reaction is a proxy for stating the probability that a given scattering process will occur. The total cross section (TCS) is among the most important measurable quantities and it can reveal a great amount of information about the internal structure of target particle. Exotic He (2^3S) atoms have been considered as a target for theoretical study of electrons as well as photon scattering under various approximate conditions. Evaluation of TCS (total cross section) for electron scattering by these atoms at low and intermediate energies. Results show that good compatibility and analogy with limited experimental data available. For the photon scattering, from this target the isotropic Atomic Compton Profiles J(Q) have also been calculated. For this scattering enough comparable data are not existed in literature.*

***Keywords:** Total cross section (TCS), electron scattering, photon scattering, Atomic Compton Profile.*

I. INTRODUCTION

Excited metastable atoms like Hydrogen in the 2s state or Helium in the n=2, ^3S or ^1S state are well known exotic atomic systems. It is difficult to study them in laboratory, due to various reasons. The He atom in the (2^3S) state, to be abbreviated here as He (2TS), has an electron each in the 1s and 2s state, making it highly polarizable. We present here our theoretical studies of electron as well as photon scattering from He (2TS). Studies of this kind done so far are much inadequate compared to a vast literature available on the ground state He (n=1, ^1S).

The basic input in the present work is the atomic electron charge density ρ(r) obtained from the accurate wave function of He (2TS) as given by Bransden and Joachain (1983). Calculated presently are the various total cross sections (σtot.) for electron scattering, using the complex potential approach, vis-à-vis the preliminary estimate in the Born approximation. Towards photon (or X-ray) scattering from He (2TS), we have calculated the isotropic Atomic Compton Profiles (ACP) for this atom, in the impulse approximation. As for the corresponding experimental data, only few measurements have been reported for electron scattering at low energies. No other work, theoretical and experimental, appears to have been reported for the photon scattering from this atom.

II. THEORETICAL MODELS AND METHODS

To explore reason First of all we used the wave function of the He (2TS) atom to obtain the charge density ρ(r) in the form,

$$\rho(r) = \frac{N^2}{2\pi}\left[4Ƶ_i^3 e^{-2Ƶ_i r} + \frac{Ƶ_0^3}{2}\left(1 - Ƶ_0 r + \frac{Ƶ_0^2 r^2}{4}\right)e^{-Ƶ_0} + C_1\left(-1 + \frac{Ƶ_0 r}{2}\right)e^{-ar}\right] \quad \text{—— (1)}$$

$with\ a = Ƶ_i + \frac{Ƶ_0}{2}$. Here, r= the distance from the nucleus and N, $Ƶ_i$, $Ƶ_0$, and $C_1$are parameters involved in the wave function.

Now, consider an electron of energy E_i and momentum k incident on the He (2TS) atom. In the high energy Born approximation, we calculate the static scattering amplitude $f_{st}(r)$ through the atomic factor F (q), where q=2ksinθ/2 is the elastic momentum transfer, at scattering angle θ. Further, let f_p(q) denote the Born-amplitude for the polarization potential.

$$V_{d\rho} = -\left(\alpha_d . r^2 / 2(r^2 + r_0^2)^3\right) \quad \text{—— (2)}$$

With r_0=0.375k/Δ.

Here α_d is the dipole polarizability and Δ is the effective excitation energy of the atom. We write the total Born scattering amplitude as

$f_B(q) = f_{st}(q) + f_p(q)$ —— (3)

It was used to obtain the total differential cross sections and hence the integrated cross section σ_b (k) through numerical integrations. The Born-Static polarization approximation outlined above, will be abbreviated as BSP. More accurately, we represent our e-atom system by a complex optical potential,

$V_{opt}(r, E_i) = V_R(r, E_i) + iV_i(r, E_i)$ —— (4)

Where; real part= the sum of the static, exchange and polarization potential and imaginary part = an absorption potential. The details for the exchange and absorption model-potentials are given by Joshipura and Patel (1933). The polarization potential given very recently by Gianturco (1994) has been adopted in equation (4). Standard procedures have been used to determine the phase-shifts and total cross section (TCS).

If ($Q_{T.}$) is the total collision cross section, Q_{el} (E_i) is the elastic TCS and Q_{inel} (E_i) is the inelastic TCS, then we have, at a given energy, then we have, at a given energy

$Q_{tot.} = Q_{el} + Q_{inel}$ —— (5)

For the purpose of model study, we also calculated purely elastic TCS under the real potential only, (i.e. V_i=0, from (4)).

Moreover, the study of the compton profile provides useful information for investigating the electronic structure of atoms, molecules and solids. The contributions to the compton profile in atoms or molecules come from all completely or partially filled electronic orbitals. The study of the electronic structure of solid constitutes mainly the study of conduction or valance electrons. The accuracy of various quantum-mechanical models for these electrons can conveniently be tested provided. We have a knowledge of their contribution to the experimental compton profile. The calculations of the compton profile for atoms are usually carried out within the framework of the impulse approximation. The first extensive calculation of the compton profile in atoms and molecules was made by Duncanson and Coulson (1945).

Consider next the scattering of a PHOTON from He (2TS). Following Biggs et al. (1975) the Atomic Compton Profile for an atomic electron in the subshell is defined as,

$J_{nl}(Q) = \frac{1}{2}\int_Q^\infty |X_{nl}(p)|^2 p\,dp$ With, Q= -**K**.p/K —— (6)

Where; p=initial momentum of the target electron, and K=the momentum transfer in the process. X_{nl} (p) is the momentum Fourier transform of the radial wave function of the electron (see Biggs et al. 1975). The quantity J_{nl} (Q) is normalised to 1per electron. Q has the dimensions of momentum and J_n (Q) has that of inverse momentum. The total ACP J (Q) is the sum of the J_{nl} (Q) from all the atomic electrons (Z=2 presently). All the integrals involved in our calculations of J (Q) are evaluated analytically.

III. Results, Discussion And Conclusions

ELECTRON SCATTERING: The cross sections of e-He (2TS) scattering calculated by us in different approximations are exhibited in Table-:1 and *Figure 1*.

Table-1: Energy Variation of inelastic TCS in e-He (2TS) scattering

E_i(eV)	Q_{inel}(in 10^{-16} cm^2)
16	10.4 (experimentally 13.1±4.59)
30	14.2
50	15.3
80	14.3(19)*
100	12.6 (15.1)*
300	5.5

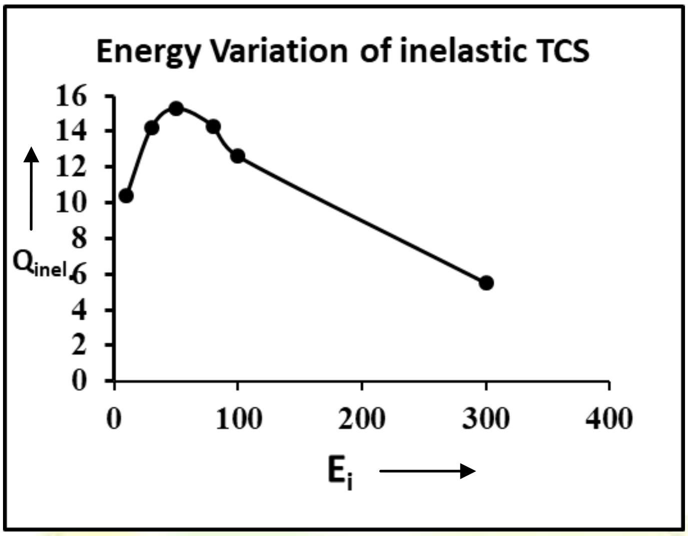

Figure 1Energy Variation of inelastic TCS

The quantity $Q_{inel.}$ Representing overall effects of inelastic scattering on elastic scattering; is shown as a function of energy in table-1. Rall et al. (1989) measured indirect TCS for excitation from (2^3S) states to several important final states, at 16 eV. Our theoretical $Q_{inel.}$ Matches well with the sum of these measured TCS, entered in Table 1. Our $Q_{inel.}$ Exhibit a broad maximum near 50 eV and fall off slowly with E_i. At 80 and 100 eV, $Q_{inel.}$ are also calculated using the polarized charge density in the high energy method developed by us (Joshipura et al. 1994) The polarized part of the charge density is insignificant at large E_i. Also at high energies $Q_{inel.}$ is a good estimate of the total ionization cross-section.

PHOTON SCATTERING: This is perhaps the first ever report on the Compton profile for He (2TS) atom. The ACP J_{1S} (Q), J_{2S} (Q) and their sums J (Q) are shown in Table-:2 and *figure 2*.

Table-2: Atomic Compton profiles for He (2^3S) (in a.u.) Here a-b=a x10^{-b}

Q	J_{1S}(Q)	J_{2S}(Q)	J(Q)
0	0.42	1.77	2.19
0.2	0.41	1.07	1.48
0.4	0.376	0.267	0.643
1	0.217	4.9×10^{-2}	0.266
2	5.36×10^{-2}	6.05×10^{-3}	5.96×10^{-2}
3	1.25×10^{-2}	8.34×10^{-4}	1.33×10^{-2}
5	1.13×10^{-3}	4.95×10^{-5}	1.18×10^{-3}
10	2.47×10^{-5}	8.59×10^{-7}	2.55×10^{-5}

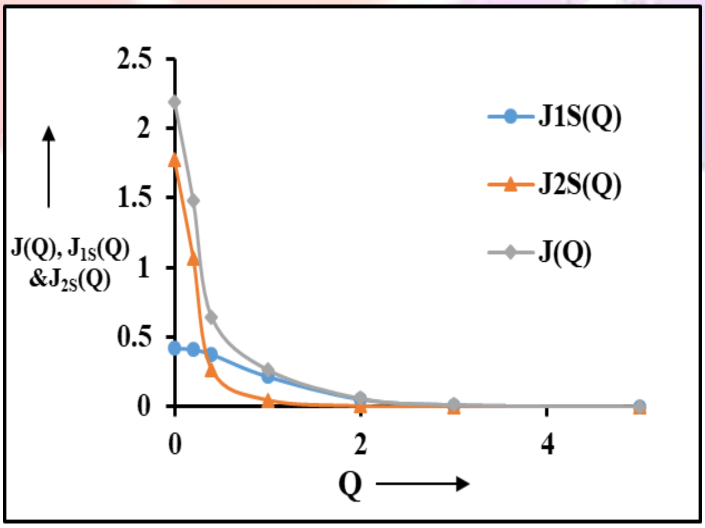

Figure 2 The nature ACP J_{1S} (Q), J_{2S} (Q) & sum of ACP J (Q) vs. Q

We have chosen the sample values of Q to indicate the variation in the ACP with Q. We find from Table-2 that at Q=0 and nearby; the 2S electron of the atom dominates the 1S electron, but for higher Q, the latter overtakes. The total J (Q) of He (2TS) are quite different from that of the normal He in the ground state, due to difference in their electron-momentum distribution. The accuracy of the present result can be judged if the quantity J (Q) is determined experimentally. Thus the calculations presented here seek to understand the behavior of various parameters of electron as well as photon scattering on He (2TS). The electronic cross sections are much larger than those of the ground state He. The electronic configuration of He (2TS) makes it highly polarizable and active (somewhat like Li atom!).We wish to extend our theoretical work on this exotic atom, for which photon scattering and momentum-space properties also need further studies.

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