Triple Differential Cross Sections for Ionization of Metastable 3P-State Hydrogen Atoms by Electrons

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Abstract: Triple differential cross sections (TDCS) for ionization of metastable 3P-state Hydrogen atoms by electrons have been calculated for various kinematic conditions in the asymmetric coplanar geometry using a multiple scattering theory of Das and Seal. The results are compared with the first Born results and existing hydrogenic ground state experimental data and those of other theoretical results. The present results show a good qualitative agreement with the compared results. Yet there is no available theoretical and experimental study for ionization of metastable 3P-state hydrogen atoms by electrons. These offers wider scope for the study of ionization problems of hydrogen atoms in their metastable states.

Keywords: Cross-Section, Electron, Ionization, Scattering, Transition matrix.

I. Introduction

For many atomic systems, ionization by electron impact has been studied with a great interest theoretically and experimentally, which has important challenge in several fields of physics such as plasma physics, astrophysics and irradiation of living matter. Ionization of hydrogen atoms by electrons is the fundamental and simplest ionization problem in this study. In this point of view, the electron-electron coincidence experiments is called (e,2e) experiments, provide a useful description of the kinematics of the collision by giving information about the direction of the scattered and ejected electrons. The quantity measured in this kind of experiment is proportional to the TDCS, which represents the angular distribution of the ejected electron for selected incident and scattered electron momenta.

In the last five decades significant progress has been made in understanding the ionization process both in the ground state [1-10] and metastable states [11-20] of atomic hydrogen. The TDCS for the (e, 2e) techniques were widely studied for the ground state hydrogen atom both experimentally [21-25] and theoretically [26-30].

Jones and Madison [7-9] had studied ionization of atomic hydrogen by electron impact using asymptotically correct two-centre wave functions to describe the scattering system both initially and finally. The theoretical understanding of the (e, 2e) reaction is very satisfactory in the case of the ionization from the ground state atomic hydrogen [10]. Recently the TDCS for the ionization of metastable 2P-state [18] and 2S-state [14] hydrogen atoms by electrons have been calculated following the multiple scattering theory of Das and Seal [4]. Here we use same theory for ionization of hydrogen atoms by electrons for describing the TDCS of metastable 3P-state hydrogen atom by electrons considering at intermediate and high energies.

II. Theory

The single ionization processes of atomic hydrogen by electron of the following type,

$$e^- + H(3\text{P}) \rightarrow H^+ + 2e^-$$

(1)

where the symbol 3P denotes the hydrogenic metastable state and has been obtained in the coplanar geometry by analyzing triple differential cross sections (TDCS) measured in (e,2e) coincidence experiments. The TDCS is a measure of the probability that in an (e,2e) reaction an incident electron of momentum \(\vec{p}_i\) and energy \(E_i\) will produce on collision with the target two electrons having energies \(E_1\) and \(E_2\) and momenta \(\vec{p}_1\) and \(\vec{p}_2\) emitted respectively into the solid angles \(d\Omega_1\) and \(d\Omega_2\) centred about the directions \((\theta_1, \phi_1)\) and \((\theta_2, \phi_2)\).

Triple differential cross section is denoted by

$$\frac{d^3\sigma}{d\Omega_1d\Omega_2dE_1}.$$
The multiple scattering theory of ionization of hydrogen atoms by electrons is described in detail [4,18]. A brief discussion of the theory for the particular case of hydrogenic 3P-state at intermediate and high energies is given here.

The direct transition matrix element for ionization of hydrogen atoms by electrons [4], may be written as,

$$T_\beta = \left\langle \Psi_f (\cdot) | V_i | \Phi_i \right\rangle$$

(2)

The perturbation potential $V_i$ is given by

$$V_i = \frac{1}{r_{12}} - \frac{1}{r_2}$$

and the initial state hydrogenic wave function is given here.

$$\Phi_i = \frac{e^{i\eta_1}}{(2\pi)^{3/2}} \phi_{3p}(\vec{r}_1)$$

Where hydrogenic 3P-state wave function is

$$\phi_{3p}(\vec{r}_1) = \frac{\sqrt{2}}{81 \sqrt{\pi}} (6r_1 - r_1^2) \cos \theta e^{-r_1^2/\lambda}$$

(3)

Here $\lambda = \frac{1}{3}$ and $\Psi_f (\cdot)$ is the final three-particle scattering state wave function [4] and co-ordinates of the ejected and scattered electrons are $\vec{r}_1$ and $\vec{r}_2$ respectively.

Here the approximate scattering state wave function $\Psi_f (\cdot)$ is given by

$$\Psi_f (\cdot) = N(\vec{p}_1, \vec{p}_2) \left[ \phi_f (\vec{r}_1) e^{i\eta_1 \cdot \vec{r}_1} + \phi_f (\vec{r}_2) e^{i\eta_1 \cdot \vec{r}_2} + \phi_f (\vec{r}) e^{i\eta_1 \cdot \vec{r}} - 2e^{i\eta_1 \cdot \vec{r}_1, \vec{r}_2} \right] / (2\pi)^3$$

(4)

Here $N(\vec{p}_1, \vec{p}_2)$ is normalization constant,

$$\vec{r} = \frac{\vec{r}_2 - \vec{r}_1}{2}, \quad \vec{R} = \frac{\vec{r}_1 + \vec{r}_2}{2},$$

$$\vec{p} = (\vec{p}_2 - \vec{p}_1), \quad \vec{P} = \vec{p}_2 + \vec{p}_1$$

and $\phi_f (\cdot)$ is Coulomb wave function.

Now applying equations (3) and (4) in equation (2), we get

$$T_\beta = T_B + T_{B'} + T_i - 2T_{PB}$$

(5)

where

$$T_B = \left\langle \phi_f (\vec{r}_1) e^{i\eta_1 \cdot \vec{r}_1} | V_i | \Phi_i \right\rangle$$

(6)

$$T_{B'} = \left\langle \phi_f (\vec{r}_2) e^{i\eta_1 \cdot \vec{r}_2} | V_i | \Phi_i \right\rangle$$

(7)

$$T_i = \left\langle \phi_f (\vec{r}) e^{i\eta_1 \cdot \vec{r}} | V_i | \Phi_i \right\rangle$$

(8)

$$T_{PB} = \left\langle e^{i\eta_1 \cdot \vec{r}_1, \vec{r}_2} | V_i | \Phi_i \right\rangle$$

(9)

From equation (6), the first Born approximation $T_B$ may be written as
Triple differential cross sections for ionization of metastable 3P-state hydrogen atoms by electrons

\[ T_B = \frac{1}{162\pi^2} \int \phi^{(-\nu)}_p(r_1) e^{-\varphi_{12}} \left( \frac{1}{r_1} - \frac{1}{r_2} \right) e^{\varphi_{12}} (6r_1 - r_2) \cos \theta e^{-\lambda_0 \delta_1} d^3r_1 d^3r_2 \]

\[ T_B = \frac{1}{162\pi^2} \int \phi^{(-\nu)}_p(r_1) e^{-\varphi_{12}} \frac{1}{r_1} e^{\varphi_{12}} 6r_1 \cos \theta e^{-\lambda_0 \delta_1} d^3r_1 d^3r_2 \]

\[ - \frac{1}{162\pi^2} \int \phi^{(-\nu)}_p(r_1) e^{-\varphi_{12}} \frac{1}{r_2} e^{\varphi_{12}} 6r_1 \cos \theta e^{-\lambda_0 \delta_1} d^3r_1 d^3r_2 \]

\[ - \frac{1}{162\pi^2} \int \phi^{(-\nu)}_p(r_1) e^{-\varphi_{12}} \frac{1}{r_2} e^{\varphi_{12}} r_1^2 \cos \theta e^{-\lambda_0 \delta_1} d^3r_1 d^3r_2 \]

\[ + \frac{1}{162\pi^2} \int \phi^{(-\nu)}_p(r_1) e^{-\varphi_{12}} \frac{1}{r_2} e^{\varphi_{12}} r_2 \cos \theta e^{-\lambda_0 \delta_1} d^3r_1 d^3r_2 \]

(10)

For first Born approximation, we calculated the terms of equation (10). Similarly the expression (7), (8) and (9) can be calculated as

\[ T'_B = \frac{1}{162\pi^2} \int \phi^{(-\nu)}_p(r_2) e^{-\varphi_{12}} \left( \frac{1}{r_1} - \frac{1}{r_2} \right) e^{\varphi_{12}} (6r_1 - r_2) \cos \theta e^{-\lambda_0 \delta_1} d^3r_1 d^3r_2 \]

\[ T'_B = \frac{1}{162\pi^2} \int \phi^{(-\nu)}_p(r_2) e^{-\varphi_{12}} \frac{1}{r_1} e^{\varphi_{12}} 6r_1 \cos \theta e^{-\lambda_0 \delta_1} d^3r_1 d^3r_2 \]

\[ - \frac{1}{162\pi^2} \int \phi^{(-\nu)}_p(r_2) e^{-\varphi_{12}} \frac{1}{r_2} e^{\varphi_{12}} 6r_1 \cos \theta e^{-\lambda_0 \delta_1} d^3r_1 d^3r_2 \]

\[ + \frac{1}{162\pi^2} \int \phi^{(-\nu)}_p(r_2) e^{-\varphi_{12}} \frac{1}{r_2} e^{\varphi_{12}} r_1^2 \cos \theta e^{-\lambda_0 \delta_1} d^3r_1 d^3r_2 \]

\[ - \frac{1}{162\pi^2} \int \phi^{(-\nu)}_p(r_2) e^{-\varphi_{12}} \frac{1}{r_2} e^{\varphi_{12}} r_2 \cos \theta e^{-\lambda_0 \delta_1} d^3r_1 d^3r_2 \]

(11)

\[ T_i = \frac{1}{162\pi^2} \int \phi^{(-\nu)}_i(r) e^{-\varphi_{12}} \left( \frac{1}{r_1} - \frac{1}{r_2} \right) (6r_1 - r_2) \cos \theta e^{\varphi_{12}} e^{-\lambda_0 \delta_1} d^3r_1 d^3r_2 \]

\[ = \frac{1}{162\pi^2} \int \phi^{(-\nu)}_i(r) e^{-\varphi_{12}} \frac{1}{r_1} e^{\varphi_{12}} 6r_1 \cos \theta e^{\varphi_{12}} e^{-\lambda_0 \delta_1} d^3r_1 d^3r_2 \]

\[ - \frac{1}{162\pi^2} \int \phi^{(-\nu)}_i(r) e^{-\varphi_{12}} \frac{1}{r_2} e^{\varphi_{12}} 6r_1 \cos \theta e^{\varphi_{12}} e^{-\lambda_0 \delta_1} d^3r_1 d^3r_2 \]

\[ - \frac{1}{162\pi^2} \int \phi^{(-\nu)}_i(r) e^{-\varphi_{12}} \frac{1}{r_2} e^{\varphi_{12}} r_1^2 \cos \theta e^{\varphi_{12}} e^{-\lambda_0 \delta_1} d^3r_1 d^3r_2 \]

\[ + \frac{1}{162\pi^2} \int \phi^{(-\nu)}_i(r) e^{-\varphi_{12}} \frac{1}{r_2} e^{\varphi_{12}} r_2 \cos \theta e^{\varphi_{12}} e^{-\lambda_0 \delta_1} d^3r_1 d^3r_2 \]

(12)

and

\[ T_{PB} = \frac{1}{162\pi^2} \int e^{i\varphi_{12}} e^{-i\varphi_{12}} \left( \frac{1}{r_1} - \frac{1}{r_2} \right) (6r_1 - r_2) \cos \theta e^{i\varphi_{12}} e^{-\lambda_0 \delta_1} d^3r_1 d^3r_2 \]

\[ T_{PB} = \frac{1}{162\pi^2} \int e^{i\varphi_{12}} e^{-i\varphi_{12}} \frac{1}{r_1} e^{i\varphi_{12}} 6r_1 \cos \theta e^{i\varphi_{12}} e^{-\lambda_0 \delta_1} d^3r_1 d^3r_2 \]

\[ - \frac{1}{162\pi^2} \int e^{i\varphi_{12}} e^{-i\varphi_{12}} \frac{1}{r_2} e^{i\varphi_{12}} 6r_1 \cos \theta e^{i\varphi_{12}} e^{-\lambda_0 \delta_1} d^3r_1 d^3r_2 \]

\[ + \frac{1}{162\pi^2} \int e^{i\varphi_{12}} e^{-i\varphi_{12}} \frac{1}{r_2} e^{i\varphi_{12}} r_1^2 \cos \theta e^{i\varphi_{12}} e^{-\lambda_0 \delta_1} d^3r_1 d^3r_2 \]

\[ - \frac{1}{162\pi^2} \int e^{i\varphi_{12}} e^{-i\varphi_{12}} \frac{1}{r_2} e^{i\varphi_{12}} r_2 \cos \theta e^{i\varphi_{12}} e^{-\lambda_0 \delta_1} d^3r_1 d^3r_2 \]
The final transition matrix element [4] is written as

\[
\frac{d^3\sigma}{d\Omega_1 d\Omega_2 dE_i} = \frac{P_1 P_2}{p_i} |T_\beta|^2
\]

(14)

where \( E_i \) is the energy of the incident electron.

Using the Lewis integral [31], we have calculated \( T_\beta \) analytically and then computed numerically for TDCS.

### III. Results And Discussions

The triple differential cross sections (TDCS) for ionization of metastable 3P-state hydrogen atoms by electrons are presented here for scattering in a plane. Ionization of hydrogen atoms by electrons from the ground state theoretical results of Dal et al. [12], the BBK model of Brauner et al. [27] and the absolute data [24] are included here for comparison. Also the previous works on hydrogenic 2S-state [14] and 2P-state [18] ionization results is noted here for comparison. In the present calculation we have considered the TDCS for the ionization of metastable 3P-state hydrogen atoms by electrons for the incident electron energy \( E_i = 250 \text{eV} \), the ejected electron energies \( E_i = 5 \text{eV} \) and 50eV and the different scattering angles

- \( \theta_1 = 3^0 \) (Fig.1), \( \theta_2 = 15^0 \) (Fig.2), \( \theta_2 = 25^0 \) (Fig.3), \( \theta_2 = 5^0 \) (Fig.4), \( \theta_2 = 7^0 \) (Fig.5), \( \theta_2 = 9^0 \) (Fig.6), \( \theta_2 = 11^0 \) (Fig.7), \( \theta_2 = 15^0 \) (Fig.8), \( \theta_2 = 20^0 \) (Fig.9). In all figures the region for \( \theta_1(0^0 - 150^0) \) and \( \phi = 0^0 \), refers to the recoil region, while \( \theta_1(150^0 - 360^0) \) and \( \phi = 180^0 \) refers to the binary region. We have considered here \( \theta \) varies from \( 0^0 \) to \( 360^0 \).

**Fig. 1.** Triple-differential cross sections (TDCS) for ionization of atomic hydrogen by 250 eV electron impact for \( \theta_2 = 3^0 \) vary against the ejected electron \( \theta_1 \) relative to the incident electron direction. The ejected electron energy is \( E_i = 5 \text{eV} \). Theory: full curve (red): present results; dash curve (black): present first Born results; dash curve (green): hydrogenic 2P-state results [18]; short dash curve (blue):hydrogenic ground state 2nd Born results [12]; dash-dotted curve (magenta): hydrogenic ground state BBK model [27] and square: hydrogenic ground state experiments [24] (multiplied by 0.88).

In **Fig. 1** a qualitative comparison among the present results with the hydrogenic ground state results of the BBK model [27], the earlier works on hydrogenic 2P-state result [18], the hydrogenic ground state experimental data [24] and first born results are shown. The peak values of the present results and first born results show good...
qualitative agreement with those of the compared results in the recoil region but show somewhat disagreement in the binary region. This may be happened because of change of the hydrogenic metastable states by electrons. Here in the recoil region the peak values of present and first born and 2P-state [18] results are about double results of the other compared results. The binary peak height of the present results shifted somewhat left from the other compared result.

**Fig. 2.** Triple-differential cross sections (TDCS) for ionization of atomic hydrogen by 250 eV electron impact for $\theta_2 = 15^0$ vary against the ejected electron angle $\theta_1$ relative to the incident electron direction. The ejected electron energy is $E_e = 50eV$. Theory: full curve(red): present results; dash curve(black): present first Born results; dash curve(green): hydrogenic 2P-state results [18]; short dash curve(blue): hydrogenic ground state 2nd Born results [12]; dash-dotted curve(magenta): hydrogenic ground state BBK model [27] and square: hydrogenic ground state experiments [24] (multiplied by 0.00224).

In **Fig. 2** the peak value of present and first born results are lower than the hydrogenic ground state experimental results [24] and hydrogenic metastable 2P state [18]. Also the present peak values shifted slightly to the higher ejected angle near about $\theta_1 = 72^0$. The peak pattern of the present result shows exactly similar behavior as the BBK model [27] with slight shift.

**Fig. 3.** Triple-differential cross sections (TDCS) for ionization of atomic hydrogen by 250eV electron impact for $\theta_2 = 25^0$ vary against the ejected electron angle $\theta_1$ relative to the incident electron direction. The ejected electron energy is $E_e = 50eV$. Theory: full curve(red): present results; dash curve(black): present first Born results; dash curve (green): hydrogenic 2P-state results [18]; short dash curve (blue): hydrogenic ground state 2nd Born results [12]; dash-dotted curve (magenta): hydrogenic ground state BBK model [27] and square: hydrogenic ground state experiments [24] (multiplied by 0.00224).
Fig. 4. Triple-differential cross sections (TDCS) for ionization of atomic hydrogen by 250 eV electron impact for $\theta_2 = 5^0$ vary against the ejected electron angle $\theta_1$ relative to the incident electron direction. The ejected electron energy is $E_1 = 5$ eV. Theory: full curve (red): present results; dash curve (black): present first Born result; dash curve (green): hydrogenic 2P-state results [18]; dash dotted curve (magenta): hydrogenic 2S-state results [14].

Fig. 5. Triple-differential cross sections (TDCS) for ionization of atomic hydrogen by 250 eV electron impact for $\theta_2 = 7^0$ vary against the ejected electron angle $\theta_1$ relative to the incident electron direction. The ejected electron energy is $E_1 = 5$ eV. Theory: full curve (red): present results; dash curve (black): present first Born result; dash curve (green): hydrogenic 2P-state results [18]; dash dotted curve (magenta): hydrogenic 2S-state results [14].

In Fig. 3 the present peak magnitude is the highest among all other compared results [12,18,24,27] representing almost similar peak position as Fig 2.

For $\theta_2 = 5^0$ and $\theta_2 = 7^0$ (Figs. 4 and 5) the recoil peak values show qualitative agreement with 2S [14] and 2P-state [18] of hydrogen atoms from electron impact, whereas there arise somewhat opposite binary peaks.
Triple differential cross sections for ionization of metastable $3P$-state hydrogen atoms by electrons

Fig. 6. Triple-differential cross sections (TDCS) for ionization of atomic hydrogen by 250eV electron impact for $\theta_2 = 9^\circ$ vary against the ejected electron angle $\theta_1$ relative to the incident electron direction. The ejected electron energy is $E_1 = 5eV$. Theory: full curve (red): present results; dash curve (black): present first Born result; dash curve (green): hydrogenic $2P$-state results [18]; dash dotted curve (magenta): hydrogenic $2S$-state results [14].

![Graph 1](image1.png)

Fig. 7. Triple-differential cross sections (TDCS) for ionization of atomic hydrogen by 250eV electron impact for $\theta_2 = 11^\circ$ vary against the ejected electron angle $\theta_1$ relative to the incident electron direction. The ejected electron energy is $E_1 = 5eV$. Theory: full curve (red): present results; dash curve (black): present first Born result; dash curve (green): hydrogenic $2P$-state results [18]; dash dotted curve (magenta): hydrogenic $2S$-state results [14].

![Graph 2](image2.png)

Fig. 8. Triple-differential cross sections (TDCS) for ionization of atomic hydrogen by 250eV electron impact for $\theta_2 = 15^\circ$ vary against the ejected electron angle $\theta_1$ relative to the incident electron direction. The ejected electron energy is $E_1 = 5eV$. Theory: full curve (red): present results; dash curve (black): present first Born result; dash curve (green): hydrogenic $2P$-state results [18]; dash dotted curve (magenta): hydrogenic $2S$-state results [14].

![Graph 3](image3.png)

Fig. 9. Triple-differential cross sections (TDCS) for ionization of atomic hydrogen by 250eV electron impact for $\theta_2 = 20^\circ$ vary against the ejected electron angle $\theta_1$ relative to the incident electron direction. The ejected electron energy is $E_1 = 5eV$. Theory: full curve (red): present results; dash curve (black): present first Born result; dash curve (green): hydrogenic $2P$-state results [18]; dash dotted curve (magenta): hydrogenic $2S$-state results [14].

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Fig. 6 exhibits a deep lobed structure in recoil region almost at \( \theta_1 = 36^\circ \) whereas the present result form a short lobed structure in the same region with same ejection of the hydrogenic electron. But in the binary region, the present and first born results represent distinct peak pattern comparing with the 2S-state [14] and 2P-state [18] hydrogenic results.

We note that the present and present first born results (Fig. 7) appear with greater peak magnitude than the compared results [12,18,24,27], both in recoil and binary regions. Fig. 8 shows that the peak values of the present result remain almost same in magnitude as the hydrogenic 2S-state[14] and 2P-state results[18], whereas the first born result is increased simultaneously with the increase of the scattering angles (\( \theta_2 \)).

In Fig. 9 the present and first born results provide exactly similar behavior as the 2P-state[18] results but show a gross difference with the results of 2S-state [14] both in recoil and binary region. Finally a scattering mechanism for the ionization of metastable 3P-state collision of 250eV electron energy is given here. The first Born term of equation (4), i.e., \( \phi^{(-)}_{Pi}(\vec{r}_1) e^{i\vec{p} \cdot \vec{r}_2} \) are defined by a plane wave whereas the ejected electrons are defined by a Coulomb wave. For the second term, i.e., \( \phi^{(-)}_{Pi}(\vec{r}_2) e^{i\vec{p} \cdot \vec{r}_1} \), the scattered electrons are defined by a Coulomb wave while the ejected electrons are defined by a plane wave. In third term, i.e., \( \phi^{(-)}_{Pi}(\vec{r}) e^{i\vec{p} \cdot \vec{r}} \), the projectile electron interaction shows almost similar behavior in the final channel in which the center of mass goes as a plane wave. The fourth term, i.e., \( e^{i\vec{p} \cdot \vec{r} + i\vec{\pi} \cdot \vec{r}_2} \), represents two plane waves for the ejected and scattered particles. All these results offer good scope for the experimental investigation of these problems and offer a new test for different theories of ionization.

A table of comparison results for ionization of hydrogenic 2S-state, 2P-state and 3P-state atoms by electron is given here.

Table 1. Triple differential cross sections (TDCS) for ionization of atomic hydrogen atoms by electron impact at metastable 3P-state are obtained by using equation (14). The incident energy is 250eV, the scattering angle is \( \theta_2 = 9^\circ \) and the ejected electron energy is \( E_1 = 5eV \). In the given table we present 3P-state results and compared 2P-state and 2S-state results.

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IV. Conclusion

In the present study are have calculated the triple differential cross sections (TDCS) for ionization of hydrogen atoms by 250eV energy in the metastable 3P state following a multiple scattering theory of Das and Seal [4]. We interestingly notice that the implementation of the final state wave function \( \psi_f^{(i)} \) of Das and Seal yields good qualitative agreement with hydrogenic ground state as well as metastable 2S and 2P states [14, 18] result for qualitative enhancement, the present computational findings are encouraging for the future experiments which may play a vital role to provide more interesting and significant results in this area of research. There are wide scopes for improving the wave function of Das and Seal and for applying it to various ionization problems.

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References


[18.] S Dhar and N Nahar, Electron impact ionization of metastable 2p-state hydrogen atoms in the coplanar geometry, Results in Physics, 5, 2015, 3-8.


