Impact-parameter dependent of moving nuclei target

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Abstract

In order to compute impact-parameter-dependent energy losses, two extensions are needed, the orbital motion of target electrons (shell correction) need to be incorporated before instead of after integration over impact parameter, the spatial distribution of the target electrons needs to be considered. Unless stated otherwise, the term 'shell correction', when applied to impact-parameter-dependent energy losses, implies allowance for both the spatial and the velocity effect [1].

1. *Introduction*

The impact parameter defined as the perpendicular distance between the path of a projectile and the center of the field created by an object that the projectile is approaching, The problem here is that in the absence of binding, the position of the target nucleus does not enter the formalism, the definition of the impact parameter invokes the position of the nucleus. Therefore we need to redefine the impact parameter the interaction with a harmonically bound target electron [1].

2. Theory

2.1 Impact Parameter to the Moving Target

The orbital motion may be characterized by [1].

$$\vec{r}(t) = \vec{r}_e\, e^{i\omega(t-t_0)} \qquad (1)$$

$$\vec{v}(t) = i\omega\, \vec{r}_e e^{i\omega(t-t_0)} \qquad (2)$$

$$= \vec{v}_e\, e^{i\omega(t-t_0)} \qquad (3)$$

With $\vec{v}_e = i\omega\vec{r}_e$. For $t \simeq t_0$ we have approximately a straight-line motion

$$\vec{r}\,(t) \simeq \vec{r}_e + \vec{v}_e(t - t_0) \qquad (4)$$

Where t_0 the time of closest approach between the ion and the target nucleus.
Now we consider an arbitrary orbit, which for $t \simeq t_0$ can be approximated by a straight line, equation (4) with real parameters r_e and v_e. In a reference frame moving with the projectile the electron trajectory then reads

$$\vec{r}\,(t) = \vec{s} + \vec{\omega}(t - t_0) \qquad (5)$$

$$\vec{s} = \vec{r}_e - \vec{p} \qquad (6)$$

$$\vec{\omega} = \vec{v}_e - \vec{v} \qquad (7)$$

Where p is the impact parameter when the nucleus of the target is at rest and v is the projectile velocity.

With this, the ion-electron impact parameter ($\acute{p}$) is found by projection of (s) on the impact plane defined by the ion and the target nucleus [1],

$$\acute{p} = \vec{s} - (\vec{s}.\hat{\omega})\hat{\omega} \qquad (8)$$

With $\hat{\omega} = \vec{\omega}/\omega$; $\quad \hat{\omega}.\hat{\omega} = 1$

$\acute{p}$ is the impact parameter to the moving target.

Having thus defined an impact parameter, we may compute the ion-electron energy transfer T_0 ($\omega,\acute{p}$) in a reference frame in which the target electron is at rest. This is accomplished by classical scattering theory employing the interaction potential as Eq. (9).The transformation from the target frame to the laboratory frame is accomplished by multiplying T_0 by a factor $|v \cdot \omega|\,(-v \cdot \omega)/v^2\omega^2$ according to reference [2]. With this we find the shell-corrected, impact-parameter-dependent energy-loss function.

$$T(v,p) = \int d^3\, v_e \int d^3\, r_e f(v_e\, ,r_e) \times \frac{(-v.\omega)}{v\omega}\left|\frac{(v\cdot\omega)}{v\omega}\right| T_0(\omega,\acute{p}) \qquad (9)$$

Where f ($\boldsymbol{v}_e$, $\boldsymbol{r}_e$) is the distribution in phase space of the target electron under consideration, normalized to 1. Integration over d^2p leads to the well-known relation between the stopping cross section S_0 (v) for a target electron at rest and S (v) for a moving target electron [2, 3].

A final step, T (v, p) needs to be computed for various shells or subshells, characterized by binding energies U and I-values $\hbar\omega$ and weighted by bundled oscillator strengths f as described in reference [4].

2.2 Asymptotic expansion

Since the impact parameter (p) is orthogonal to the projectile velocity(v) it is convenient to split all vectors into their transverse and longitudinal parts, in particular [1].

$$r_e = (\rho_e, z_e)\, ; v_e = (u_e, \eta_e)\, , \qquad (10)$$

Where ρ_e and u_e are two-dimensional vectors perpendicular to v.

From equation (8) we find

$$\acute{p}^2 = \acute{p}.\acute{p} = [s - (s.\hat{\omega})\hat{\omega}].[s - (s.\hat{\omega})\hat{\omega}],$$

$$= \text{s.s-}(s.\hat{\omega})^2 - (s.\hat{\omega})^2 + (s.\hat{\omega})^2\,(\hat{\omega}.\hat{\omega}),$$

$$= s^2 - (s.\vec{\omega})^2 \frac{1}{\omega^2},$$

$$\acute{p}^2 = \frac{1}{\omega^2}\,[\omega^2 s^2 - (s.\vec{\omega})^2]. \qquad (11)$$

And after insertion of the above definitions of (ω) and (s) and expansion in terms of u_e, η_e, ρ_e and z_e one finds [1].

$$\acute{p} = p - \frac{\rho_e . p}{p} + \frac{1}{2p^3}\left(\rho_e^2 p^2 - (\rho_e \cdot p)^2\right) - \frac{(u_e \cdot p)^2}{2v^2 p} - \frac{Z_e u_e \cdot p}{vp} \ldots \quad (12)$$

The trick in this type of Taylor expansion is reduce everything to binomials of the type of

$$(1+X)^{\alpha} = 1+\alpha X + \frac{1}{2}\alpha(\alpha-1)X^2 + \ldots\ldots\ldots \quad (13)$$

For arbitrary α, Eq. (11) can be written as:

$$\frac{\acute{p}^2}{p^2} = \frac{s^2}{p^2} - \left(\frac{\vec{\omega}}{\omega}, \frac{\vec{s}}{p}\right)^2 \quad (14)$$

We can write

$$\frac{s^2}{p^2} = \frac{p^2 - 2\vec{p}\vec{r}_e + r_e^2}{p^2}$$

$$= 1 - 2\frac{\vec{p}\,\vec{r}_e}{p^2} + \frac{r_e^2}{p^2} \quad (15)$$

with

$$\frac{s^2}{p^2} = \frac{\vec{s}}{p} . \frac{\vec{s}}{p}$$

$$\frac{\vec{s}}{p} = -\frac{\vec{p}}{p} + \frac{\vec{r}_e}{p},$$

$$\frac{\vec{\omega}}{\omega} = \left(-\frac{\vec{\upsilon}}{\upsilon} + \frac{\vec{\upsilon}_e}{\upsilon}\right)\left(1 - 2\frac{\vec{\upsilon}}{\upsilon} . \frac{\vec{\upsilon}_e}{\upsilon} + \frac{\upsilon^2{}_e}{\upsilon^2}\right)^{-1/2}$$

$$\vec{\omega} = \frac{\vec{\upsilon} e}{\upsilon} - \frac{\vec{\upsilon}}{\upsilon}$$

$$, |\vec{\omega}| = (\vec{\omega}.\vec{\omega})^{1/2}$$

thus,

$$|\vec{\omega}|^2 = \left(\frac{\vec{v}_e}{v} - \frac{\vec{v}}{v}\right) . \left(\frac{\vec{v}_e}{v} - \frac{\vec{v}}{v}\right)$$

$$= \left(\frac{\vec{v}_e}{v}\right)^2 - 2\left(\frac{\vec{v}_e}{v}\right) . \left(\frac{\vec{v}}{v}\right) + 1$$

According to Eq. (13), the last factor reduce to

$$\left(1 - 2\frac{\vec{\upsilon}}{\upsilon} . \frac{\vec{\upsilon}_e}{\upsilon} + \frac{\upsilon^2{}_e}{\upsilon^2}\right)^{-1/2} = 1 - \frac{1}{2}\left(-2\frac{\vec{\upsilon}}{\upsilon} . \frac{\vec{\upsilon}_e}{\upsilon} + \frac{\upsilon^2{}_e}{\upsilon^2}\right) + \frac{3}{8}\left(-2\frac{\vec{\upsilon}}{\upsilon} . \frac{\vec{\upsilon}_e}{\upsilon} + \frac{\upsilon^2{}_e}{\upsilon^2}\right)^2 + .$$

When done, will get expression of the form

$$\frac{p'^2}{p^2} = 1 + A_1 + A_2 + \ldots.$$

Where A_1 is a term linear in r_e or v_e and A_2 quadratic term. Applying Eq. (12) again will find

$$\frac{p'}{p}=1+\frac{1}{2}(A_1+A_2)-\frac{1}{8}A_1^2+\ldots$$

Where term of higher than second order have been ignored [5].
After insertion into Eq. (9) and expansion including the ω- dependent term we finally get,

$$T_{(v,p)}=\left[1+\frac{\overline{u}_e^2}{v^2}\left(-1+\frac{1}{2}v\frac{\partial}{\partial v}-\frac{1}{4}p\frac{\partial}{\partial p}\right)+\frac{1}{2}\overline{\eta}_{e^2}\frac{\partial^2}{\partial v^2}+\frac{1}{4}\overline{\rho}_e^2\left(\frac{1}{p}\frac{\partial}{\partial p}+\frac{\partial^2}{\partial p^2}\right)\right]T_0(v,p)$$

(16)
Up to the second order and the term containing $\overline{\eta_e\rho_e}$ has been dropped.

2.2.1 Determined the contribution

According to Eq. (16), assume that,

$$T_a=\left[\frac{\overline{u}_e^2}{v^2}\left(-1+\frac{1}{2}v\frac{\partial}{\partial v}-\frac{1}{4}p\frac{\partial}{\partial p}\right)\right]T_0(v,p) \quad (17a)$$

$$T_b=\left[\frac{1}{2}\overline{\eta}_{e^2}\frac{\partial^2}{\partial v^2}\right]T_0(v,p) \quad (17b)$$

$$T_c=\left[\frac{1}{4}\overline{\rho}_e^2\left(\frac{1}{p}\frac{\partial}{\partial p}+\frac{\partial^2}{\partial p^2}\right)\right]T_0(v,p) \quad (17c)$$

A simple formula of $T_0(v,p)$[6].

$$T_0(v,p)=\frac{S_0(v)}{2\pi a^2}e^{-p/a} \quad (18)$$

Where (a) is a parameter determined from the fitted output data of program Caps [7] (Convolution approximate stopping power). $S_0(0)$ Can be either used from Bohr's formula or Bethe's formula with stopping number.
Apply Eq. (18) on Eq. (17), one can all the contribution in Eq. (16) (For details see appendix A). According to contribution in Eq. (17), determined the value of (T_a ,T_b and T_c).
In Bethe formula,

$$S_0(v)=\frac{4\pi Z_1^2Z_2e^4}{mv^2}\ln\frac{2mv^2}{\hbar\omega}$$

$$=\frac{A}{v^2}L$$

$$Let\quad A=\frac{4\pi Z_1^2Z_2e^4}{m},\quad L=\ln\frac{2mv^2}{\hbar\omega}$$

From Eq. (17a) we can take the value of T_a

$$T_a = \left[\frac{\bar{u}_e^2}{v^2}\left(-1 + \frac{1}{2}v\frac{\partial T_0}{\partial v} - \frac{1}{4}p\frac{\partial T_0}{\partial p}\right)\right]$$

Where

$$\frac{\partial T_0}{\partial v} = \frac{-2}{v}T_0(v,p) + \frac{2A}{v^3}\frac{e^{-p/a}}{2\pi a^2}$$

$$\frac{\partial T_0}{\partial p} = T_0(v,p)\left(\frac{-1}{a}\right)$$

Insert the value of $\frac{\partial T_0}{\partial v}$ and $\frac{\partial T_0}{\partial p}$ in Eq. (17a) get on

$$T_a = \left[\frac{\bar{u}_e^2}{v^2}\left(-1 - T_0 + \frac{T_0}{L} + \frac{1}{4}p\frac{T_0}{a}\right)\right]$$

From Eq. (17b) we can take the value of T_b

$$T_b = \left[\frac{1}{2}\bar{\eta}_e{}^2\frac{\partial^2 T_0}{\partial v^2}\right]$$

Where

$$\frac{\partial^2 T_0}{\partial v^2} = \frac{2}{v^2}T_0(v,p) - \frac{2}{v}\frac{\partial T_0}{\partial v} - \frac{6A}{v^4}\frac{e^{-p/a}}{2\pi a^2}$$

Insert the value of $\frac{\partial^2 T_0}{\partial v^2}$ in Eq. (17b) get on

$$T_b = \left[\frac{1}{2}\bar{\eta}_{e^2}\left(\frac{2}{v^2}T_0 + \frac{4}{v^2}T_0 - \frac{4}{v^2}\frac{T_0}{L} - \frac{6}{v^2}\frac{T_0}{L}\right)\right]$$

From Eq. (17c) we can take the value of T_c

$$T_c = \left[\frac{1}{4}\bar{\rho}_e^2\left(\frac{1}{p}\frac{\partial T_0}{\partial p} + \frac{\partial^2 T_0}{\partial p^2}\right)\right]$$

where

$$\frac{\partial T_0}{\partial p} = T_0(v,p)\left(\frac{-1}{a}\right) \qquad \text{and}$$

$$\frac{\partial^2 T_0}{\partial p^2} = \frac{1}{a^2}T_0(v,p)$$

Insert the value of $\frac{\partial T_0}{\partial p}$ and $\frac{\partial^2 T_0}{\partial p^2}$ in Eq. (17c) one can get,

$$T_c = \left[\frac{1}{4}\bar{\rho}_e^2\left(\frac{-1}{\text{p a}}T_0 + \frac{1}{a^2}T_0\right)\right].$$

A program (IshraqT0) has been written in Fortran -90 for numerical calculated using Compaq Visual Fortran 6.6 for compiling and executing program [8].

3. Result and discussion

Figure. (1) Shows comparison between energy loss T_0 as a function of the impact parameter $\omega p/v$ for H in Al at (a) $2mv^2/\hbar\omega$ =10 and at (b) $2mv^2/\hbar\omega$=30.

Figure. (2) Shows the contribution of T_a, T_b and T_c as a function of impact parameter ωp/υ at different values of $2mv^2/\hbar\omega$, i.e., at a velocity where the shell corrections are significant.

At large impact parameter the contribution of shell correction is nearly vanished, also the lateral velocity correction nearly cancels each other in the small impact parameter. The contribution of small correction decrease as the velocity of incident proton increase i.e., $2mv^2/\hbar\omega$. This implies that at large impact parameters the spatial correction dominates.

Figure. (3) Shows the energy loss for the uncorrected term $T_0(v,p)$, uncorrected terms from Bohr and energy loss TCasp as a function with impact parameters, for H in Al at (a) $2mv^2/\hbar\omega = 10$ and (b) $2mv^2/\hbar\omega = 30$.

Assume T_1 is the value of T but ignores the velocity correction, $v_e = 0$, T_2 is:

$T_2 = T_0 + [T(Bohr) - T_0(Bohr)]$

In $T_1(v,p)$ the complete shell–correction (including the velocity correction) is determined for the Bohr Stopping function and added to uncorrected T-value. Finally T_3 is given by the following Eq.:

$T_3 = T_1 + [T(Bohr) - T_0(Bohr)]$

In $T_3(v,p)$ a velocity correction based on the Bohr Stopping function is applied to $T_1(v,p)$ [1].

Figure (4) shows the three values of T (T_1, T_2 *and* T_3) with $\omega p/v$ for H – Al at $2mv^2/\hbar\omega$ =10 and 30.There is a minor difference between them at $\omega p/v > 1$ and a major difference at $\omega p/v \to 0$.this agree with Sigmund 2010[1].

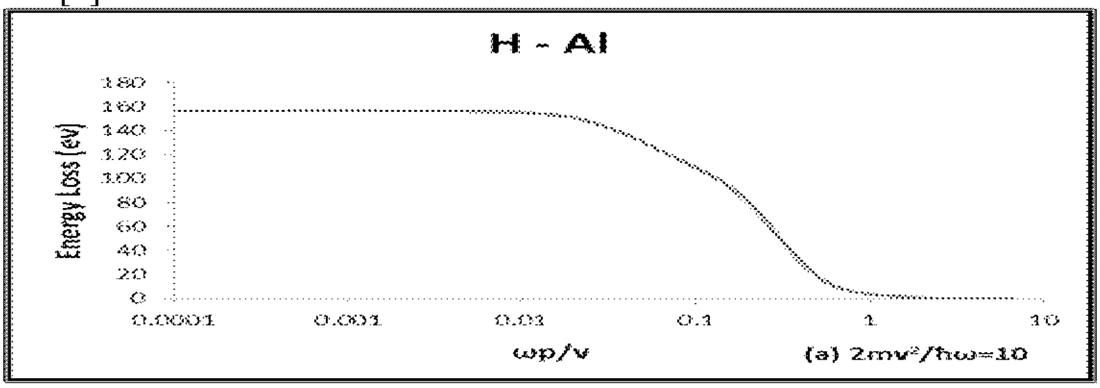


Fig. (1): Comparison between energy losses T_0 as a function of the impact parameter $\omega p/v$ for H in Al.

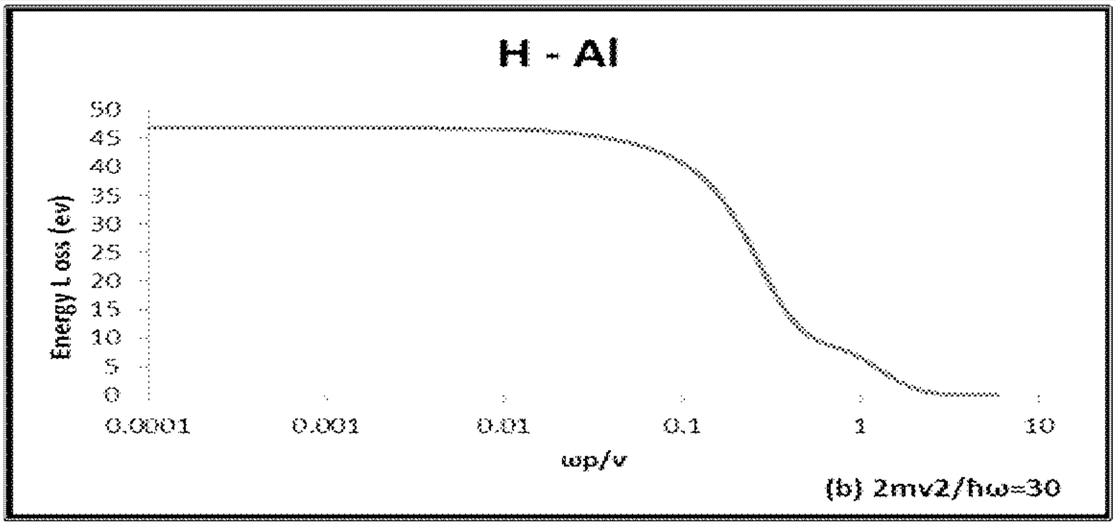


Fig. (1): Comparison between energy losses T_0 as a function of the impact parameter $\omega p/v$ for H in Al.

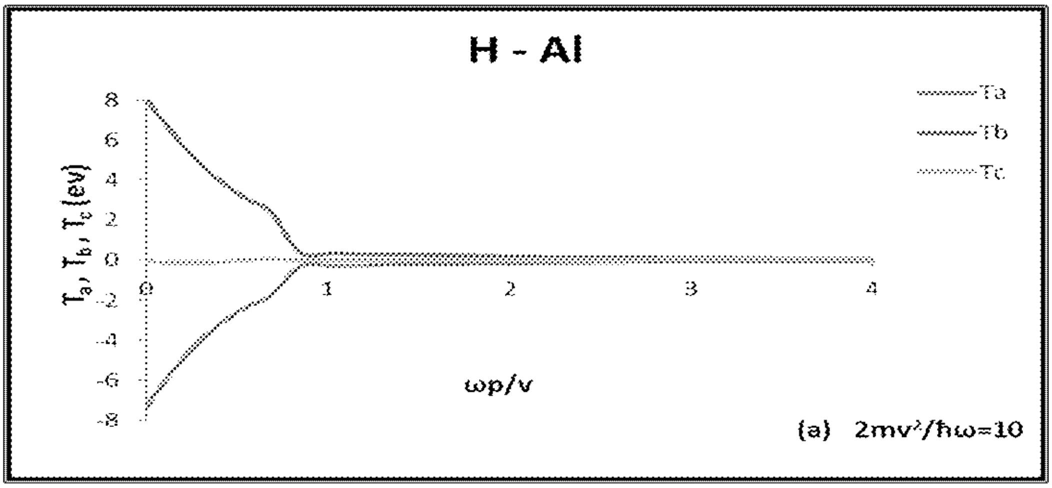


Fig. (2): The contribution of T_a, T_b and T_c as a function of impact parameter ωp/υ forH in Al at different values of $2mv^2/\hbar\omega$.

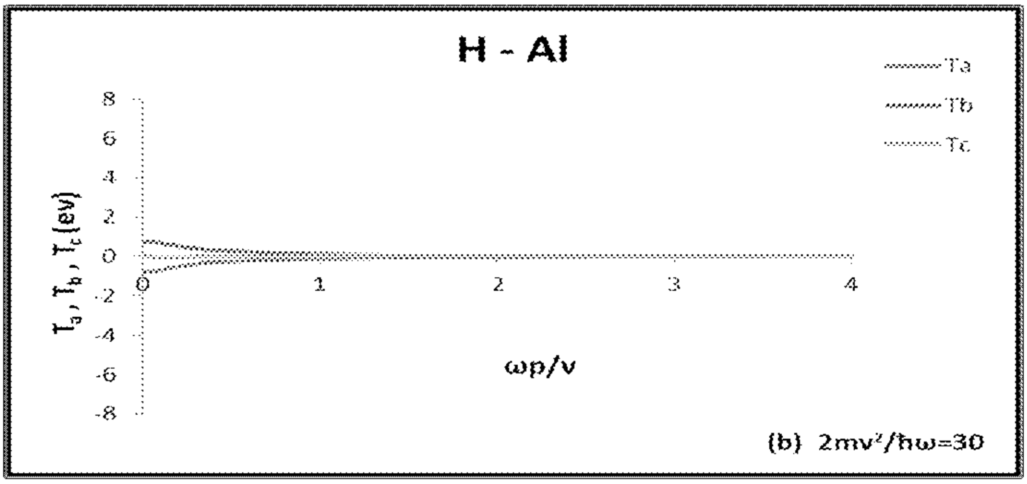


Fig. (2): The contribution of T_a, T_b and T_c as a function of impact parameter ωp/υ forH in Al at different values of $2mv^2/\hbar\omega$.

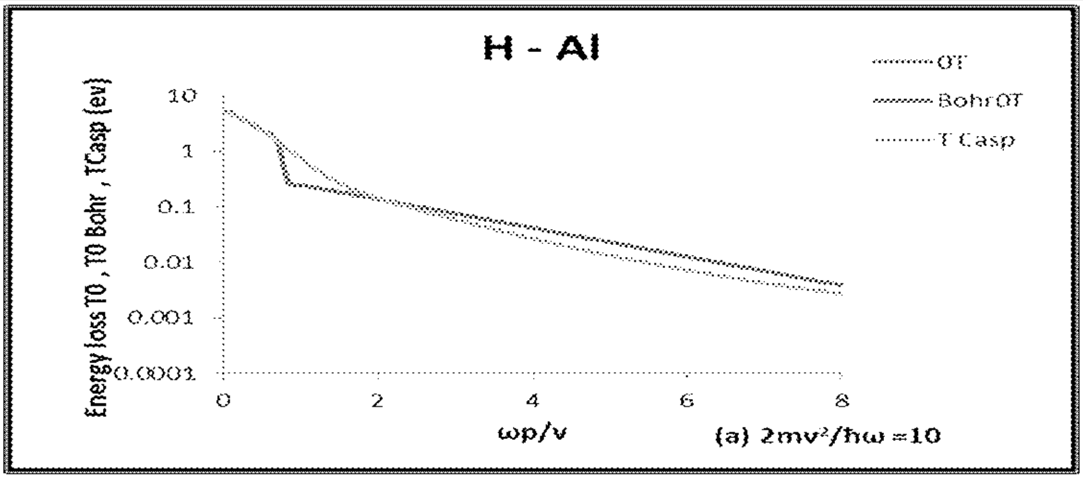
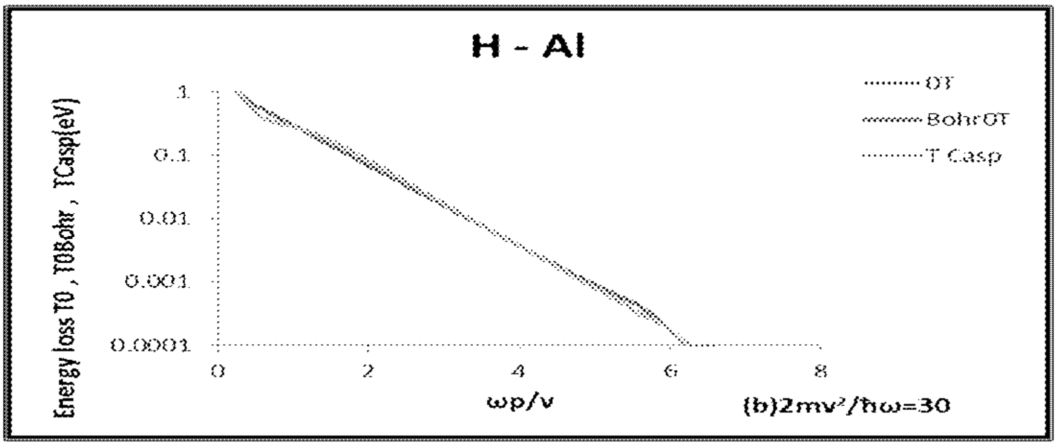


Fig.(3):The energy loss for the uncorrected term $T_0(v,p)$, uncorrected terms from Bohr and energy loss TCasp as a function with impact parameter, for H in Al.



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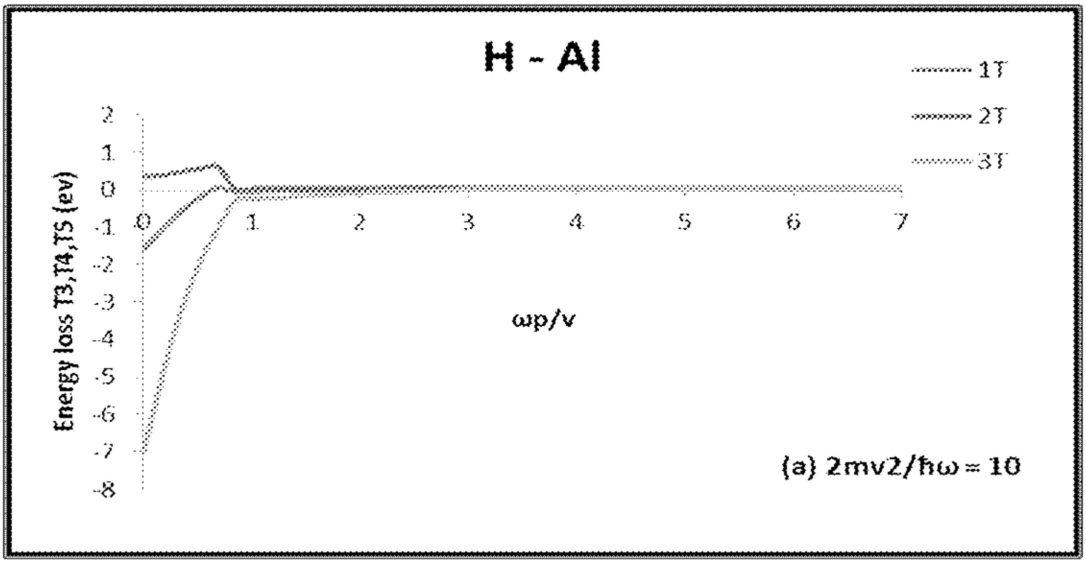

Fig. (4): Shows the energy loss T_1,T_2,T_3 versus with impact parameter for H in Al.

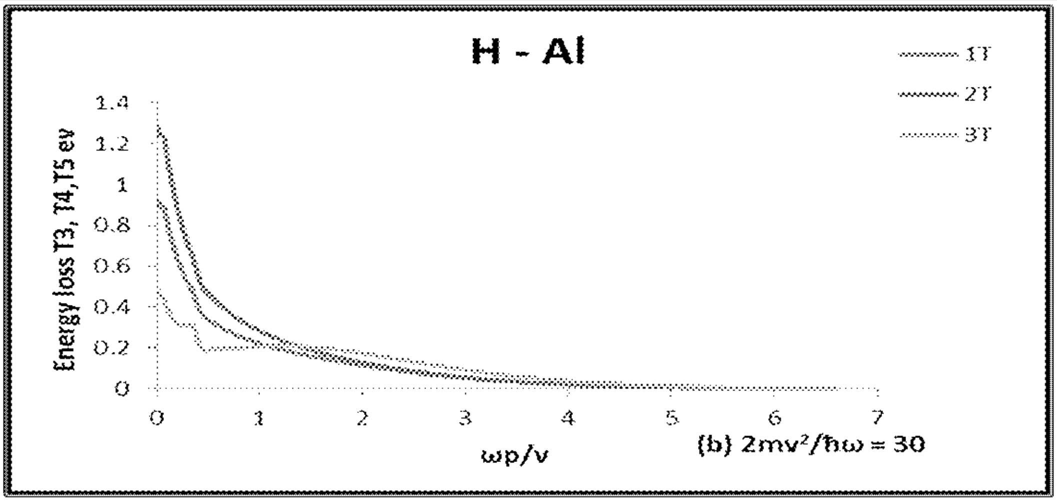

Fig. (4): Shows the energy loss T_1,T_2,T_3 versus with impact parameter for H in Al.

4. Conclusion

1. Equation (16) can be used to calculate the energy loss$T(v,p)$ versus impact parameter of heavy ions for any target at low velocity ($v \ll 2Zv_0$) and high velocity ($v \gg 2Zv_0$).Taking in the consideration moving of target nuclei.
2. Needs to use energy $T\ (p)$ for close and distant collision rather than suggested formula from Schinner [6] which is given in Eq.(18).
3. Studying the effects of charge exchange.
4. More corrections must be taken into consideration like shell correction, Barkas effects.

Reference

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Appendix (A)

Contribution of equation (16)
In Bethe formula

$$S_0(v) = \frac{4\pi Z_1^2 Z_2 e^4}{mv^2} \ln\frac{2mv^2}{\hbar\omega}$$

Let $L = \ln\frac{2mv^2}{\hbar\omega}$, $A = \frac{4\pi Z_1^2 Z_2 e^4}{m}$

$$S_0(v) = \frac{A}{v^2} L$$

$$\frac{dS_0}{dv} = \frac{-2A}{v^3} L + \frac{A}{v^2}\frac{dL}{dv} \qquad \text{(A1)}$$

$$\frac{\partial L}{\partial v} = \frac{2m}{\hbar\omega}\frac{2v}{v^2}\frac{\hbar\omega}{2m} \qquad \text{(A2)}$$

Insert (A2) *in* (A1) *get*

$$\frac{dS_0}{dv} = \frac{-2A}{v^3} L + \frac{A}{v^2}\frac{2m}{\hbar\omega}\frac{2v}{v^2}\frac{\hbar\omega}{2m}$$

$$= \frac{-2A}{v^3} L + \frac{2A}{v^3}$$

$$\frac{dS_0}{dv} = \frac{-2}{v} S_0(v) + \frac{2A}{v^3} \qquad \text{(A3)}$$

$$T_0(v,p) = \frac{S_0(v)}{2\pi a^2} e^{-p/a} \qquad \text{(18)}$$

$$\frac{\partial T_0}{\partial v} = \frac{e^{-p/a}}{2\pi a^2}\frac{dS_0}{dv} \qquad \text{(A4)}$$

Insert (A3) *in* (A4) *get*

$$\frac{\partial T_0}{\partial v} = \frac{e^{-p/a}}{2\pi a^2}\left[\frac{-2}{v} S_0 + \frac{2A}{v^3}\right]$$

$$= \frac{-2}{v}\frac{S_0(v)}{2\pi a^2} e^{-p/a} + \frac{2A}{v^3}\frac{e^{-p/a}}{2\pi a^2},$$

$$= \frac{-2}{v} T_0(v,p) + \frac{2A}{v^3}\frac{e^{-p/a}}{2\pi a^2} \qquad \text{(A5)}$$

And

$$\frac{\partial^2 T_0}{\partial v^2} = \frac{2}{v^2} T_0(v,p) - \frac{2}{v}\frac{\partial T_0}{\partial v} - \frac{6A}{v^4}\frac{e^{-p/a}}{2\pi a^2} \qquad \text{(A6)}$$

$$\frac{\partial T_0}{\partial p} = \frac{S_0(v)}{2\pi a^2} e^{-p/a}\left(\frac{-1}{a}\right)$$

$$\frac{\partial T_0}{\partial p} = T_0(v,p)\left(\frac{-1}{a}\right) \qquad \text{(A7)}$$

$$\frac{\partial^2 T_0}{\partial P^2} = -\frac{1}{a}\frac{\partial T_0}{\partial P} \qquad \text{(A8)}$$

Insert (A7) in (A8) get

$$\frac{\partial^2 T_0}{\partial P^2} = \frac{1}{a^2}\, T_0(v, p) \qquad \text{(A9)}$$

To determined the value of T_a, T_b *and* T_c

$$T_a = \left[\frac{\overline{u}_e^2}{v^2}\left(-T_0 + \frac{1}{2}\, v\frac{\partial T_0}{\partial v} - \frac{1}{4} p\frac{\partial T_0}{\partial p}\right)\right] \qquad \text{(A10)}$$

Insert (A5), (A7) *in* (A10) *get*

$$T_a = \left[\frac{\overline{u}_e^2}{v^2}\left(-T_0 + \frac{1}{2}\, v\left(\frac{-2}{v}T_0 + \frac{2A}{v^3}\frac{e^{-p/a}}{2\pi a^2}\right) - \frac{1}{4}\, p\left(\frac{-T_a}{a}\right)\right)\right]$$

$$= \left[\frac{\overline{u}_e^2}{v^2}\left(-T_0 - T_0 + \frac{A}{v^2}\frac{e^{-p/a}}{2\pi a^2} + \frac{1}{4}\, p\frac{T_0}{a}\right)\right],$$

$$= \left[\frac{\overline{u}_e^2}{v^2}\left(-T_0 - T_0 + \frac{A}{v^2}\frac{T_0}{S_0} + \frac{1}{4}\, p\frac{T_0}{a}\right)\right],$$

$$= \left[\frac{\overline{u}_e^2}{v^2}\left(-T_0 - T_0 + \frac{A}{v^2}\frac{T_0}{\frac{A}{v^2}L} + \frac{1}{4}\, p\frac{T_0}{a}\right)\right],$$

$$T_a = \left[\frac{\overline{u}_e^2}{v^2}\left(-2T_0 + \frac{T_0}{L} + \frac{1}{4}\, p\frac{T_0}{a}\right)\right].$$

To find T_b

$$T_b = \left[\frac{1}{2}\overline{\eta}_e^2\, \frac{\partial^2 T_0}{\partial v^2}\right] \qquad \text{(A11)}$$

Insert (A6) *in* (A11*) get*

$$T_b = \left[\frac{1}{2}\overline{\eta}_{e^2}\left(\frac{2}{v^2}T_0 - \frac{2}{v}\frac{\partial T_0}{\partial v} - \frac{6A}{v^4}\frac{e^{-p/a}}{2\pi a^2}\right)\right],$$

$$= \left[\frac{1}{2}\overline{\eta}_{e^2}\left(\frac{2}{v^2}T_0 - \frac{2}{v}\left(\frac{-2}{v}T_0 + \frac{2A}{v^3}\frac{e^{-p/a}}{2\pi a^2}\right) - \frac{6A}{v^4}\frac{e^{-p/a}}{2\pi a^2}\right)\right],$$

$$= \left[\frac{1}{2}\overline{\eta}_{e^2}\left(\frac{2}{v^2}T_0 - \frac{2}{v}\left(\frac{-2}{v}T_0 + \frac{2A}{v^3}\frac{T_0}{S_0}\right) - \frac{6A}{v^4}\frac{T_0}{S_0}\right)\right],$$

$$= \left[\frac{1}{2}\overline{\eta}_{e^2}\left(\frac{2}{v^2}T_0 - \frac{2}{v}\left(\frac{-2}{v}T_0 + \frac{2A}{v^3}\frac{T_0}{\frac{A}{v^2}L}\right) - \frac{6A}{v^4}\frac{T_0}{\frac{A}{v^2}L}\right)\right],$$

$$= \left[\frac{1}{2}\overline{\eta}_{e}2\left(\frac{2}{v^2}T_0 - \frac{2}{v}\left(\frac{-2}{v}T_0 + \frac{2}{v}\frac{T_0}{L}\right) - \frac{6}{v^2}\frac{T_0}{L}\right)\right],$$

$$T_b = \left[\frac{1}{2}\overline{\eta}_{e}2\left(\frac{2}{v^2}T_0 + \frac{4}{v^2}T_0 - \frac{4}{v^2}\frac{T_0}{L} - \frac{6}{v^2}\frac{T_0}{L}\right)\right].$$

To find T_c

$$T_c = \left[\frac{1}{4}\bar{\rho}_e^2\left(\frac{-1}{p\,a}T_0 + \frac{1}{a^2}T_0\right)\right] \qquad (A12)$$

Insert (A7) *and* (A9) *in* (A12) *get*

$$= \left[\frac{1}{4}\bar{\rho}_e^2\left(\frac{1}{p}T_0\left(\frac{-1}{a}\right) + \frac{1}{a^2}T_0\right)\right],$$

$$T_c = \left[\frac{1}{4}\bar{\rho}_e^2\left(\frac{-T_0}{p\,a} + \frac{T_0}{a^2}\right)\right].$$

معامل التصادم المعتمد على حركة نويات الهدف

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الخلاصة

نحتاج امتدادين من اجل حساب معامل التصادم المعتمد على فقدان الطاقة الأول هو الحركة المدارية لألكترونات الهدف(تصحيح القشرة) يؤخذ عوضاً عن بعد التكامل على معامل التصادم ،والثاني هو التوزيع المكاني لألكترونات الهدف يجب ان تؤخذ بنظر الأعتبار.

وخلاف ذلك تصحيح القشرة عندما يطبق على معامل التصادم المعتمد على الطاقة المفقودة يضمن بالسماح لكل من التوزيع المكاني وتأثير السرعة.