JOURNAL OF UNIVERSITY OF THIQAR
vol(8) no.(3) June 2013

Damping Effect on Stopping Power of Dicluster Hydrogen Ions

Saher M. Mutasher   Sana T. Kadhum

Collage of medicine/ Thi-Qar University,

Abstract :

In this search , we study stopping power of dicluster with and with not damping at high and low velocities . we use (Se,Bi,Cs) as targets . this work discuses damping effect on stopping power at dicluster hydrogen ions interaction with solid targets at different velocities and study effect of wigner-sitz radius (density parameter r_s) and internuclear distance (r_{12}) on stopping power. This search give detail studying about stopping power at different adverbs and effect of different parameters .

1. Introduction:

Beams of molecule and cluster ions covering a wide range of energies have become available recently. Such beams are useful tools in fundamental research on the interaction of particles with matter, expanding the number of available degrees of freedom and thus the range of observable phenomena[1,2]. This has implications on ion-beam-induced adsorption [3,4], track formation [5], and inertial confinement fusion [6]Conversely, clusters with energies per atom in the eV regime are of potential use for depositing material because of the highly achievable particle currents that combined with low damage rates [7, 8].when ionized cluster beams are used, the distance between the particles in a given cluster is similar to the interatomic distances in a solid, and therefore the cluster components will interact collectively [5].This can involve simultaneous interactions between several particles in the cluster and the solid. Hence, the use of cluster beams of atomic ions provides a new tool to investigate dynamical interaction processes in matter [5,6].The present search deals with the deposition of electronic energy by slow and swift molecules and clusters in matter (less or greater than Fermi velocity ($\vec{v}_F$) respectively).A central quality characterizing the interaction of clusters projectiles with matter is the mean stopping power per traveled path length, or stopping power. This quality is approximated by the sum of the stopping powers for the constituent atomic ions of cluster [9],

$$\left(-\frac{dE}{dX}\right)_{cluster} \sim \sum_{cluster}\left(-\frac{dE}{dX}\right)_{atom} \qquad \text{….. (1)}$$

2. Stopping power:

When an ion moves inside the material, it collides with the electrons of the material, which can be either bound or free. In metals the electrons are divided into bound core electrons and free conductive electrons. If the ion is moving slowly, it carries all of its electrons with it. If the ion is moving faster than the fastest target electrons, it losses all its electrons and is completely ionized[10]. These cases are the theoretically best understood ones [11]. An ion moving slowly losses energy only to the free electrons of the target due to momentum exchange with them . Due to the forbidden energy levels , this results in a linear dependence of the stopping on velocity [12]. A high velocity ion can be considered to be a point-like charge, which can collide with all electrons in the target. The stopping is then inversely proportional to the square of the ion velocity [13]. When the ion velocity is between these two cases, the ion is partially stripped leading to considerably more complicated description [14], because the ion may lose electrons to and capture them from, the medium. The possible phenomena contributing to the electronic stopping in the velocity region well below the light velocity are [10]:

S1: momentum exchange in a collision between the ion and a free electron in the target material.

S2: ionization of the ion.

S3: the ion captures an electrons.

S4: de-excitation of the ion.

S5: de-excitation of the target atom.

S6: ionization of a target atom.

S7: collective effects such as the polarization or plasmon excitation.

The electronic stopping is also divided into two different terms: stopping during the collisions of the ion and atom and electronic stopping between the ion-atom collisions. The latter electronic stopping refers to the constant slowing force acting on the ion due to the momentum exchange with the electrons in material (S1). The former refers to the electron exchange between the atom and the ion in close collisions (S4, S5). The importance of the different contributions to the total electronic stopping power depend on the ion velocity. Thus the velocity region of the ion is divided into three regions[10].

1. Low-velocity region, where the ion velocity v is below the Bohr velocity $V_o (v_o = \frac{e^2}{\hbar} = 2.19\times10^8 cm/\sec = 1.a.u[11])$ of the target electrons, i.e. the velocity of the fastest electrons in the material (in the electron gas theory the limit is commonly the Fermi velocity v_F). The ion is called slow.

2. High velocity region, where $v > v_o Z_1^{2/3}$ [Z_1 is atomic number of the projectile). The ion is called fast or swift.

3. Intermediate velocity region, which is the intermediate area between the low and high velocities $v_o < v < v_o Z_1^{2/3}$ where $v_o Z_1^{2/3}$ is the mean velocity of the electrons filling the levels of a neutral atom with atomic number Z_1 obtained from the Thomas-Fermi statistical theory[7].

In the low-velocity region, which usually means ions moving with velocity much below the Fermi velocity of the electrons of the target material, the ion cannot be ionized. The electronic stopping power is then calculated taking into account only the effects S1, S4 and S5 from which S1 is the most important[15]. The main reason for the interest of this region is the extensive use of low energy ion implantation in the semiconductor industry[10].

3. The Ionic Clusters

3-1 Small Proton Clusters

The development was stimulated greatly through an early paper by Brandt et al. [17] reporting measurements and estimates on stopping of H_n^+ ions cluster with n=1, 2, 3. In the absence of screening one may envisage such a molecule as a point charge from some distance. To the extent that the stopping power is proportional to the square of the charge, $(dE/dx)_n$ proportion to n^2 while the sum of individual proton stopping powers would proportion to n. Such close collisions dominate at low projectile velocities $\vec{v} < \vec{v}_\circ$, where $\vec{v}_\circ = e^2/\hbar$ is the Bohr velocity. At higher speed, close collisions contribute to up to half the stopping power. A pertinent parameter is the effective range of the Coulomb interaction of a moving point charge, i.e., Bohr's adiabatic radius, $\vec{a}_{ad} = \vec{v}/\omega$ where ω is an effective resonance frequency of the target.

3-2 Large Clusters and Clusters of Heavier Ions

It is well documented that theoretical estimates geared toward small hydrogen clusters do not describe experiments performed with heavier molecular ions like nitrogen and oxygen [18]. A characteristic feature of such measurements is molecular stopping-powers smaller than the sum of atomic stopping powers, [19].

4. Damping Fluctuation

Estimates of the stopping power of slow protons interacting with solids may be made using a free electron-gas model to describe the electronic response of the solid [20]. Earlier calculations for electrons interacting with an electron gas [21] showed that significant changes occur in the mean free paths and stopping powers of low energy electrons when one includes damping in the electron gas, where the electron gas or a plasma oscillation in a metal is a collective longitudinal excitation of the conduction electron gas. A Plasmon (a quantum of a plasma oscillation) may be excited by passing an electron through a thin metallic film or by reflecting an electron or photon from a film. The charge of the electron couples with the electrostatic field fluctuations of the plasma oscillations. The reflected or transmitted electron will show an stopping power equal to integral multiples of the Plasmon energy. In a dielectric the plasma oscillation is physically the same as in metal: the entire valence electron sea oscillates back and forth with respect to the ion cores [21].The increase in stopping power rate (or decrease in mean free path) is due to the possibility of Plasmon excitation for electron energies below the threshold predicted in the absence of damping. A similar situation should be obtained for heavy charged particles and could have important implications for estimates of the energy deposited in.

5. Cluster stopping power

The stopping power due to valence electrons will be discussed here within the framework of the dielectric formalism, and the connection with other methods will be indicated. In the present approach the properties of the target are described by its dielectric function $\in(\vec{k},\omega)$ where *K* and *w* represent the momentum and energy transferred in an inelastic process to the system. This approach has the possibility of describing in a self-consistent way the screening of the intruder ions as well as the excitations of valence electrons in the solid, including both collective and single-particle excitations. the excitation of electrons may be considered decoupled from the relative motion of the ions. Within this scheme, the instantaneous stopping power of a swift molecular ion or cluster of N atomic ions, moving with velocity v; is given by the average of the stopping power for the whole cluster as follows:

$$\left(-\frac{dE}{dx}\right)=\frac{e^2}{2\pi^2 v}\int d^3\vec{k}\,\frac{\vec{k}.\vec{v}}{k^2}\,\mathrm{Im}\left(\frac{-1}{\in(\vec{k},\vec{k}.\vec{v})}\right)\times\left(\sum_i Z_i^2+\sum_{i\neq j} Z_i Z_j\cos(\vec{k}.\vec{r}_{ij})\right) \qquad (2)$$

Where r_{ij} is the internuclear separation of two ions in the cluster. The terms have separated with i=j, which give the stopping power of totally independent charges, and the terms with $i \neq j$, which represent interference effects on the stopping power due to the simultaneous perturbation of the medium by the charges in correlated motion.

6. Calculation & results:

The main electron gas parameters to be used here are the following: Fermi velocity $(\vec{v}_F)$, plasma frequency (ω_p), and Wigner-Seitz radius of the average volume occupied by each electron in units of Bohr radius $a_\circ = \hbar^2 / me^2 = 0.529 A^\circ$. with relations: $\vec{v}_F = 1.919/r_s$, $\omega_p = \sqrt{3/r_s^3}$ in atomic units. All the calculations which have been done depend on the atomic unit (ħ=e=m=l) and for benefit- it is suitable to state that Bohr velocity $\vec{v}_\circ = \frac{e^2}{\hbar} = 2.18\times10^6 m/\sec = 1a.u$ also 1 au=27.

Eq. (2) is a general formula for the stopping power of the dicluster of charges (z_1e) and (z_2e) in correlated motion a structure that may be obtained by the incidence of diatomic molecules with velocity $(\vec{v})$ and internuclear separation $\vec{r}_{12}(\vec{r}_{12} = \vec{r}_1 - \vec{r}_2)$. in a dense medium of valence electrons of solid. then

$$\left(-\frac{dE}{dx}\right) = \frac{e^2}{2\pi^2 v}\int d^3\vec{k}\,\frac{\vec{k}.\vec{v}}{k^2}\,\mathrm{Im}\left(\frac{-1}{\in(\vec{k},\vec{k}.\vec{v})}\right)\times\left[\left(z_1^2 + z_2^2\right) + 2z_1 z_2\cos\left(\vec{k}.\vec{r}_{12}\right)\right] \qquad (3)$$

In Eq. (3) the stopping power is given as a function of the relative orientations of $\vec{r}_{12}$ and $\vec{v}$. Consider the orientations $\vec{r}_{12}$ are randomly distributed and the mean stopping power $\langle -dE/dx\rangle$ corresponding to random orientations of $\vec{r}_{12}$ may be obtained by using the property of $\delta-$function. Eq. (3) becomes,

$$\left\langle -\frac{dE}{dx}\right\rangle = \frac{2e^2}{\pi v^2}\int_0^\infty \frac{d\vec{k}}{\vec{k}}\int_0^{\vec{k}.\vec{v}} \omega d\omega\,\mathrm{Im}\left(\frac{-1}{\in(\vec{k},\omega)}\right)\times\left[\left(z_1^2 + z_2^2\right) + 2z_1 z_2\frac{\sin\left(\vec{k}.\vec{r}_{12}\right)}{\vec{k}.\vec{r}_{12}}\right] \qquad (4)$$

6-1 Low Dicluster Velocity (LV.) $\vec{v} < \vec{v}_F$ with no damping $\gamma \to 0$

The well-known Lindhard function [22] gives in a self-consistent way an exact description of the dielectric function for a non-relativistic free electron gas of high density at zero temperature. In the low frequency limit, within this Random Phase Approximation (RPA) for the dielectric function, the loss function can be written as:

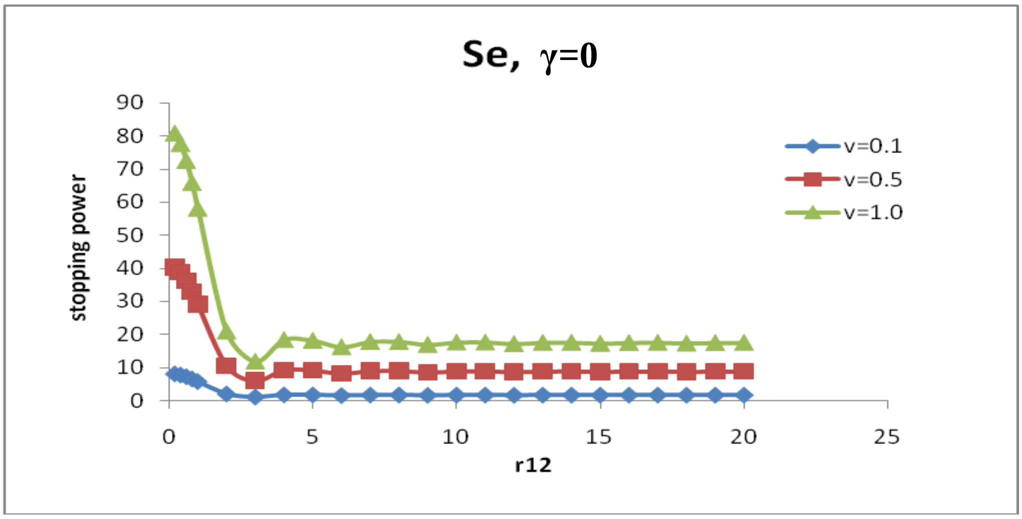
$$\mathrm{Im}\left(\frac{-1}{\in(\vec{k},\omega)}\right) = \frac{\dfrac{4\vec{k}_F}{\pi k^2}\times\dfrac{\pi\omega}{2\vec{k}.\vec{k}_F}}{\left\{\left(\dfrac{4\vec{k}_F}{\pi k^2}\right)\left[\dfrac{1}{2}\left(1+\dfrac{4k_F^2 - k^2}{4\vec{k}.\vec{k}_F}\,\ell n\left|\dfrac{\vec{k}+2\vec{k}_F}{\vec{k}-2\vec{k}_F}\right|\right)\right]+1\right\}^2 + \left[\dfrac{4\vec{k}_F}{\pi k^2}\times\dfrac{\pi\omega}{2\vec{k}.\vec{k}_F}\right]^2} \qquad (5)$$

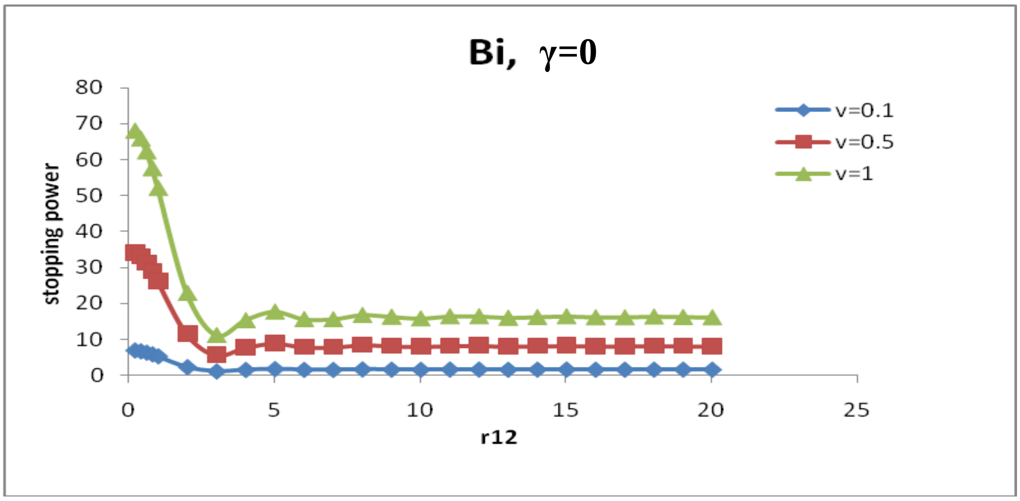
Thus eq.3 becomes

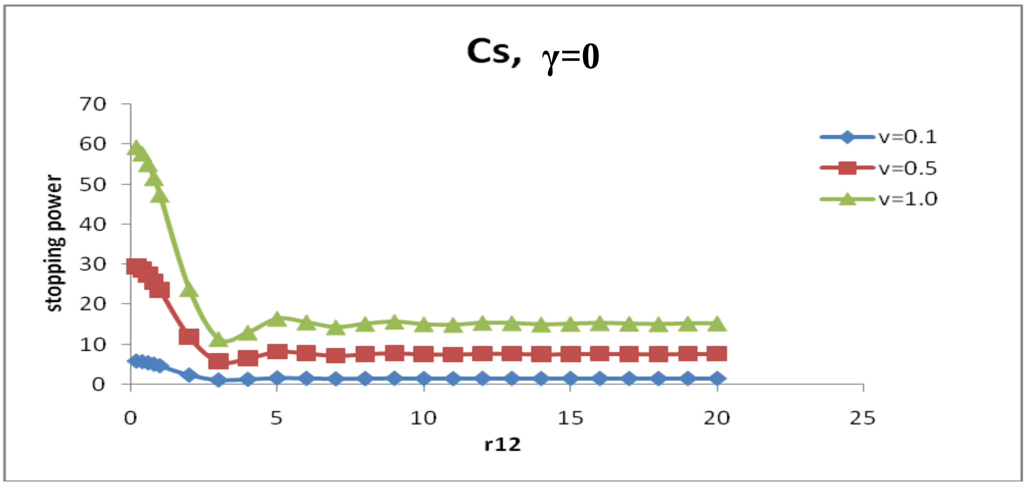
$$\left\langle -\frac{dE}{dx}\right\rangle = \frac{2e^2}{\pi v^2}\int_0^\infty \frac{d\vec{k}}{\vec{k}}\int_0^{\vec{k}.\vec{v}} \omega d\omega \times \frac{\frac{4\vec{k}_F}{\pi k^2}\times\frac{\pi\omega}{2\vec{k}.\vec{k}_F}}{\left\{\left(\frac{4\vec{k}_F}{\pi k^2}\right)\left[\frac{1}{2}\left(1+\frac{4k_F^2-k^2}{4\vec{k}.\vec{k}_F}\ell n\left|\frac{\vec{k}+2\vec{k}_F}{\vec{k}-2\vec{k}_F}\right|\right)\right]+1\right\}^2+\left[\frac{4\vec{k}_F}{\pi k^2}\times\frac{\pi\omega}{2\vec{k}.\vec{k}_F}\right]^2}$$

$$\times\left[\left(z_1^2+z_2^2\right)+2z_1z_2\frac{\sin\left(\vec{k}.\vec{r}_{12}\right)}{\vec{k}.\vec{r}_{12}}\right] \qquad (6)$$

These equations can be solved numerically as the following figure which shows stopping power of dicluster hydrogen ions versus internuclear distance (r12) of targets (Se,Bi,Cs) without damping at low velocities. We notes the maximum value of stopping power when (r12→0) then its begin less after that it's become constant. The value of stopping power increase when velocity decrease. The first target (Se) have bigger value of stopping power while the last target (Cs) have less value .







Fig(1) shows stopping power of dicluster versus (r_{12}) of (Se,Bi,Cs) targets at low velocities without damping.

6-2 High Dicluster Velocity (HV.) $\vec{v} > \vec{v}F$ **with no damping** $\gamma \to 0$

At high velocities, where the projectile can excite Plasmon in the medium, by using the Plasmon Pole Approximation (PPA) of the dielectric function [23].

$$\in(\vec{k},\omega) = 1 + \frac{\omega_p^2}{\omega_g^2 + \beta^2 k^2 + \dfrac{k^4}{4} - \omega(\omega + i\gamma)} \qquad (7)$$

The Plasmon frequency $\omega_p = \dfrac{3^{1/3}}{r_s^{3/2}}$ and the effective band gap frequency in semiconductors and insulators give a collective resonance frequency $\Omega_p = (\omega_p^2 + \omega_g^2)^{1/2}$[13]. Dispersion is included through the term containing $\beta^2 = \dfrac{3}{5}k_F^2$ where $\vec{k}_F = 1.919 r_s^{-1}$. Contributions from single-particle excitations are accounted for through the square of the kinetic energy $k^2/2$ of a free electron of momentum $(\vec{k})$. The small constant γ represents damping processes. It follows that in the limit $\gamma \to 0$,

$$\mathrm{Im}\left(\frac{-1}{\in(\vec{k},\omega)}\right) = \frac{\pi\omega_p^2}{2A}\delta(\omega - A) \qquad (8)$$

Where $A^2 = \Omega_p^2 + \beta^2 k^2 + k^4/4$

The upper and lower integration limits in $\vec{k}$ are the maximum and minimum momentum transfers $\vec{k}_+$ and $\vec{k}_-$ to target electrons.

$$\vec{k}_{\pm} = \left\{ 2(v^2 - \beta^2) \pm 2\left[(v^2 - \beta^2)^2 - \Omega_p^2\right]^{1/2} \right\}^{1/2} \quad \ldots. (9)$$

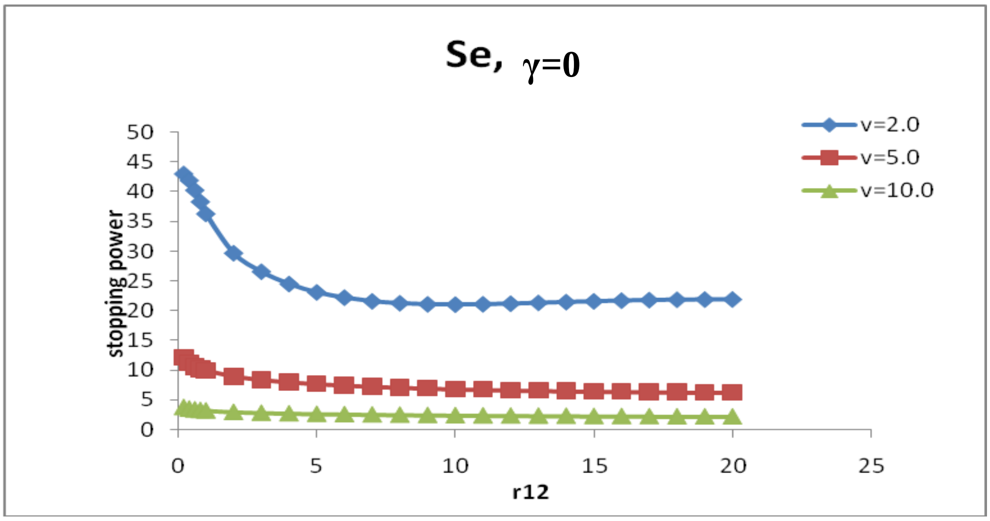
Which gives as threshold for $\vec{v}$,

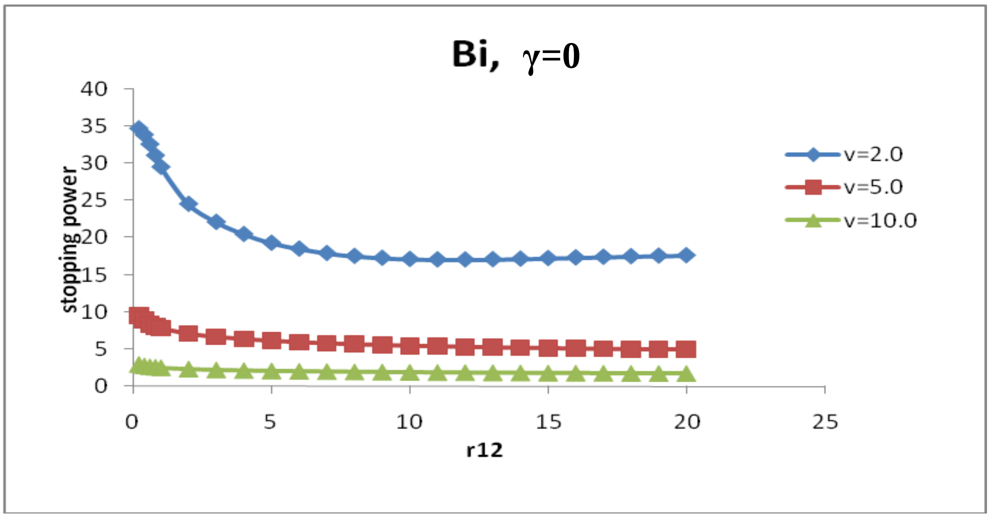
$$\vec{v}_{thr.} = (\beta^2 - \Omega_p^2)^{1/2}$$

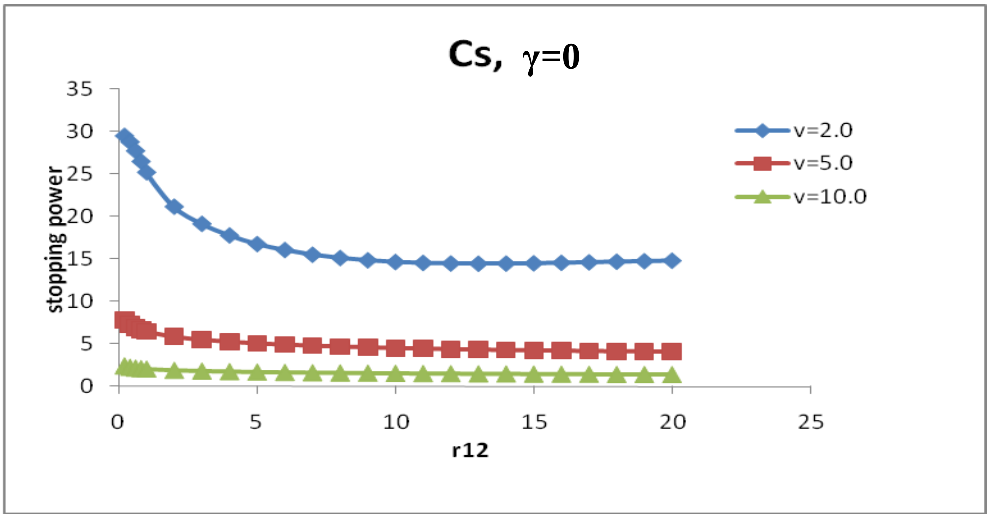
Then by substituting Eq.8 in (3) we can get,

$$\left\langle -\frac{dE}{dx} \right\rangle = \frac{2e^2}{\pi v^2} \int_0^{\infty} \frac{d\vec{k}}{\vec{k}} \int_0^{\vec{k}.\vec{v}} \omega d\omega \times \frac{\pi \omega_p^2}{2A} \delta(\omega - A) \left[\left(z_1^2 + z_2^2\right) + 2z_1 z_2 \frac{\sin\left(\vec{k}.\vec{r}_{12}\right)}{\vec{k}.\vec{r}_{12}} \right] \quad (10)$$

After solve and programming this equation we get the following figures which show the stopping power of dicluster at high velocities of (Se,Bi,Cs) targets without damping .when velocity increase ,stopping power decrease . stopping power begin decreasing with increasing internuclear distance (r_{12}). We can notes that (Se) target have higher value of stopping power and the target (Cs) have less value .







Fig(2) Stopping power of dicluster of (Se,Bi,Cs) targets versus internuclear distance (r_{12}) at high velocities without damping.

6-3 Low Dicluster Velocity (LV.) $\vec{v} < \vec{v}_F$ with damping (γ>0)

For an electron gas described by a complex dielectric function, $\in(\vec{k},\omega)$ the stopping power for a carbon of velocity $\vec{v}$ in the electron gas (or the stopping power of the electron gas) is given by the Eq. (3), and Ferrel et al. [24] have suggested a dielectric function approximation for the case of slow ions. They employ an approximation form for, $\in(\vec{k},\omega)$ the dielectric function of the metal, which is appropriate when energy transfer, ω, is small compared with the Fermi energy of the metal.

The effect of disorder leads to a damping of excitations enters the RPA dielectric function, for a given electron-impurity collision frequency γ [20], through $\in_{RPA}(\vec{k},\omega+i\gamma)$ where γ is used as a model parameter

$$\in_{RPA}(\vec{k},\omega+i\gamma)=$$

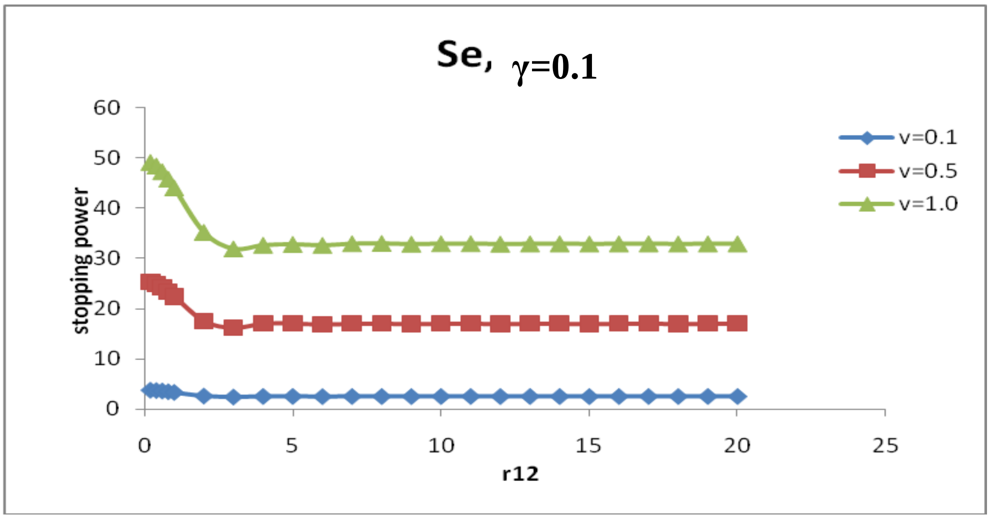
$$1+\omega_p^2 \Big/ \left\{ s^2k^2\left[1-i\pi\theta(2\vec{k}_F-\vec{k})/2\vec{k}.\vec{v}_F\right]-\omega(\omega+i\gamma)\right\} \qquad \text{.... (11)}$$

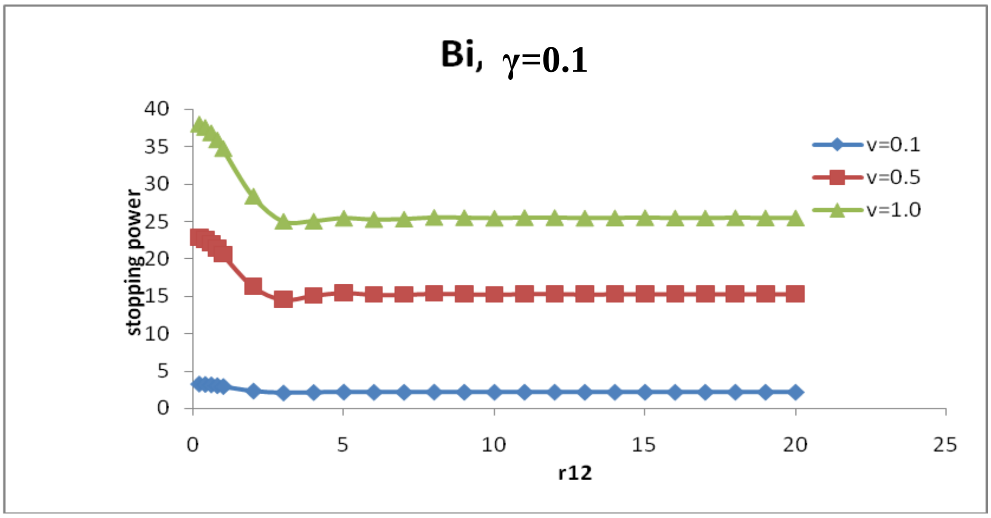
From the hydrodynamic model [19], in which the propagation velocity $s=\vec{v}_F/\sqrt{3}$.

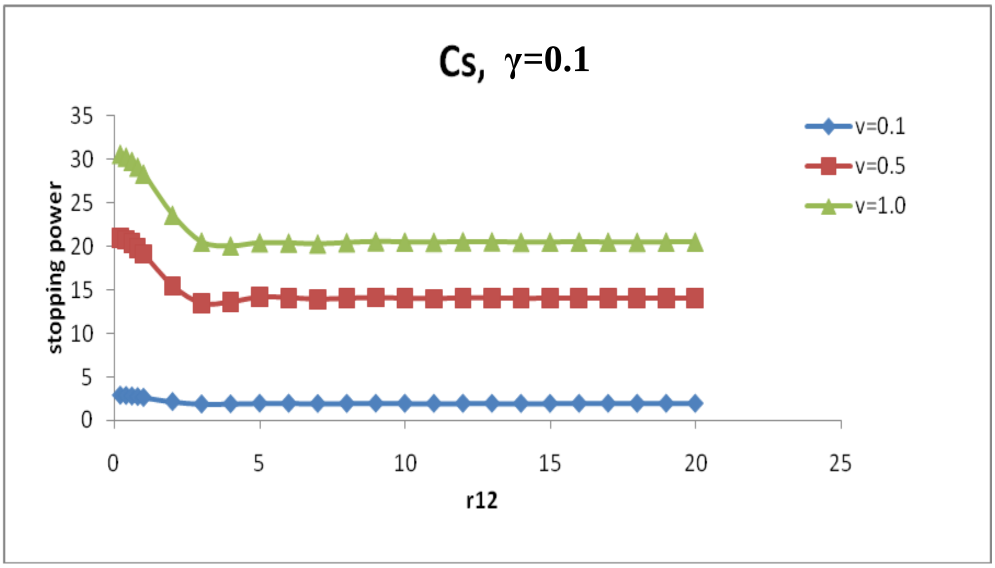
The term proportional to ω multiplying s^2k^2 in the denominator describes damping due to electron hole excitation, $\theta(2\vec{k}_F-\vec{k})$ is the Heaviside unit step function, $\theta(x)=\left(\frac{1}{2}\left(1+\frac{x}{|x|}\right)\right)$.By substituting the imaginary part, $\operatorname{Im}\left(\frac{-1}{\in(\vec{k},\omega)}\right)$ into Eq(3)

$$\left\langle -\frac{dE}{dx}\right\rangle = \frac{2e^2}{\pi v^2}\int_0^\infty \frac{d\vec{k}}{\vec{k}}\int_0^{\vec{k}.\vec{v}} \omega d\omega \times \mathrm{Im}\left[\frac{1}{1+s^2k^2\left[1-i\pi\omega\theta\,(2k_F-k)/2k\upsilon_F\right]-\omega(\omega+i\gamma)/\omega_p{}^2}\right]$$
$$\left[\left(z_1^2+z_2^2\right)+2z_1z_2\frac{\sin\left(\vec{k}.\vec{r}_{12}\right)}{\vec{k}.\vec{r}_{12}}\right] \qquad (12)$$

This equation can programming and we got the following figures which explain stopping power of dicluster of (Se,Bi,Cs) at low velocities with damping we note the stopping power have bigger value when ($r_{12}\rightarrow 0$) and it decrease when velocity decrease.







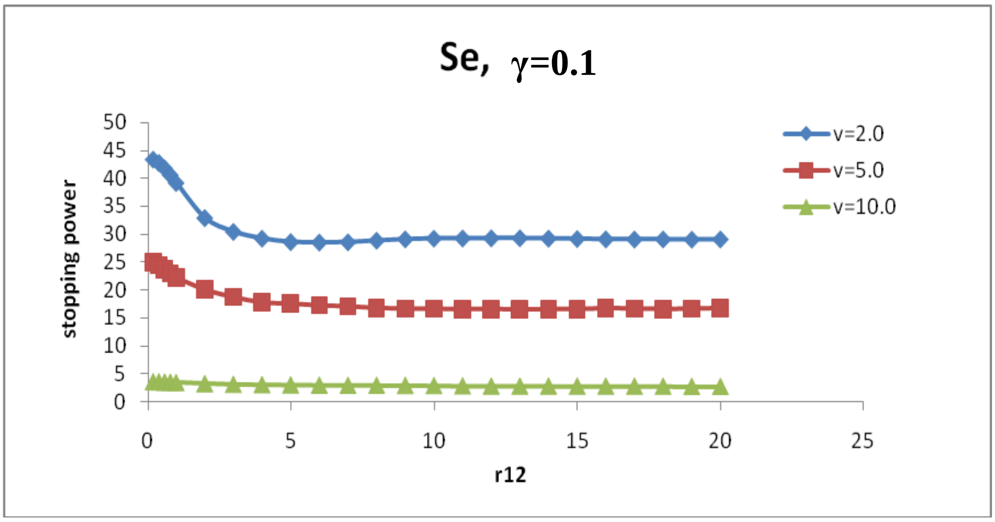
Fig(3) Stopping power of dicluster of (Se,Bi,Cs) targets with damping at low velocities.

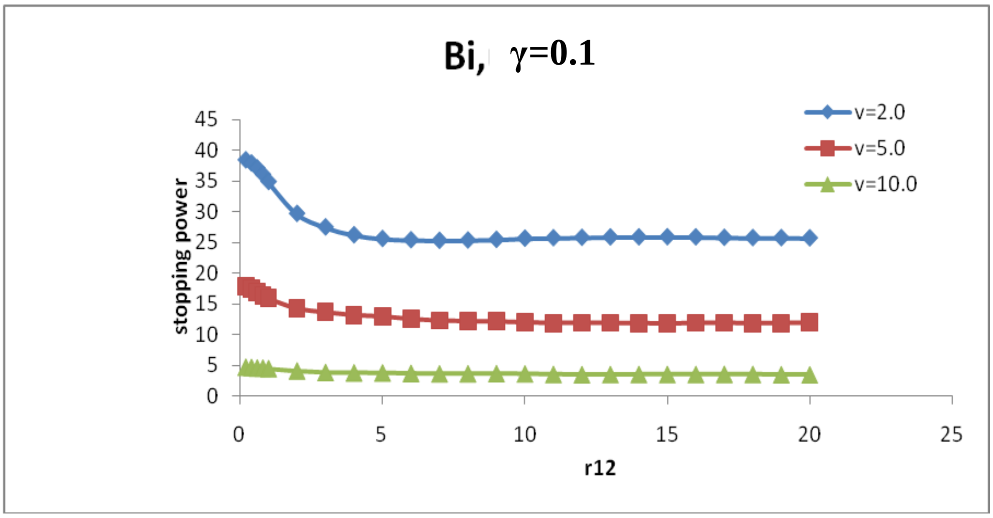
6-4 High Dicluster Velocity (HV.) $\vec{v} > \vec{v}F$ **with damping (γ>0)**

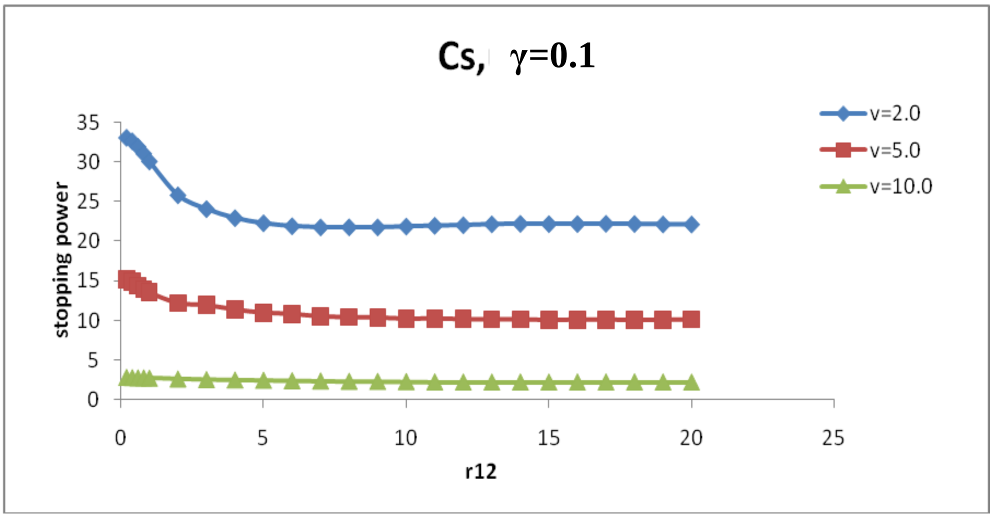
The interaction of fast ions with an electron gas is a problem of continuing interest, specifically, a great deal of theoretical and experimental work has been concerned with the distribution in space and time of perturbation of electron motion in solids caused by the passage of swift heavy charged particles. The explicit expression for the stopping power of pair charged particles was given by Eq. (3), [15]By substituting the imaginary part of $\left(\frac{1}{\in(\vec{k},\omega)}\right)$ for a suitable approximation of the dielectric response $\in(\vec{k},\omega)$ in the limit of damping process in Eq. (3) then we can find

$$\left\langle -\frac{dE}{dx}\right\rangle = \frac{2e^2}{\pi v^2}\int_0^\infty \frac{d\vec{k}}{\vec{k}}\int_0^{\vec{k}.\vec{v}} \omega d\omega \times \left[\frac{\omega\gamma\omega_p^2}{(A^2-\omega^2)^2+\omega^2\gamma^2}\right]\left[\left(z_1^2+z_2^2\right)+2z_1z_2\frac{\sin\left(\vec{k}.\vec{r}_{12}\right)}{\vec{k}.\vec{r}_{12}}\right] \quad (13)$$

After programming this equation we get the following figures which show the stopping power of dicluster at high velocities of (Se,Bi,Cs) targets with damping . when velocity increase ,stopping power decrease . stopping power begin decreasing with increasing internuclear distance (r_{12}). We can notes that (Se) target have higher value of stopping power and the target (Cs) have less value .







Fig(4) Stopping power of dicluster of (Se,Bi,Cs) targets at high velocities with damping.

7. Results and Discussion

The stopping power of a pair of charges in correlated motions through a degenerate electron gas is calculated in the present work, within the linear response approximation of Random Phase Approximation (RPA) and Plasmon Pole Approximation (PPA) to describe collective and single- particle excitations, where the total stopping power incorporates both excitation effects $(-dE/dx)$ while the correlated stopping power represents the correlation effect alone. For sufficiently low velocities the stopping power of correlated charges depends on the relation between the internuclear distance $\vec{r}_{12}$ and the wavelength of the electrons at the Fermi surface λ_F or Wigner Seitz radius r_s where $\vec{k}_F \alpha \frac{1}{r_s}$ and $\vec{k}_F \alpha \frac{1}{\lambda_F}$ [17, 18]. For $\vec{r}_{12} >> \lambda_F$ (or r_s).The Figs. (1-4) show dependant of stopping power on the Wigner Seitz radius (r_s) for different values of internuclear distance $\vec{r}_{12}$ at high and low velocities. The increasing values of r_s leads to decrease $\vec{v}_F$ (Fermi Velocity) of a target and also the density of electrons according to the relation as $\vec{r}_s = \left(\frac{3}{4\pi n_e}\right)^{1/3}$, where r_s is the radius of a sphere contains one electron [19] and n is the density of electrons. The impingement of dicluster in a target of small r_s means that there will be high dense of electrons to screen the projectile and retarding it. In addition, one may expect a short interaction time, therefore each target medium exhibits prevention against the projectile dependant on its density where $Se(r_s = 1.84)$ represents the highest screening and then, $Bi(r_s = 2.17)$ and $C_s(r_s = 5.88)$. We can note the variation of total stopping power according to the internuclear distances of damping targets for different values of projectile velocity. The general behavior shows that the highest stopping power when $\vec{r}_{12}$ approaches to zero (united atom), where as this states the bound electrons of projectile are being the largest number without loss and this matter lets the interaction projectile-target to be very violent specially when the projectile velocity close to Fermi velocity in each target. The overlap of interaction aspects depends on the target medium density. the most important note which shows the difference between the stopping power of dicluster with damping and no damping target medium that the active domain of $\vec{r}_{12}$ in which the vicinage effect being exhibited in the case of no damping target medium is larger than that belongs to the damping medium at high velocity, this results agree with the results which obtained by Nersisyan and Das [25], it is found that the role of damping considerably soften the correlation which effects for cluster of velocity, $\vec{v} > \vec{v}_F$.

The dicluster behavior, which is stated above being gradually unclear with increasing the projectile velocity as, appears obviously in Figs. (3,4) where at very high velocities the dicluster losses its valence electrons which is regarded as interaction tool with the electron .

Reference:

1) Y. Le Beyec,Y.Hopllard,H. Bernas,Nucl.and Methods Phys.Res B88,1(1994)
2) J. P. Thomas, Nuclear Instrum. and Methods Phys. Res. B112 (1996).
3) K. Baudin, A. Brudin, A. Brunelle, S. Della-Negra, D. Jacquet, P. Hakansson, C. Schoppmann, Nucl. Instrum and Methods Pyhs. Res. B112, 59 (1996).
4) Y. Le Beyec, Int. J. Mass Spectrum. Ion Processes 146, 101(1998).
5) H.Dammak,Dunlop,D.Leseur, A. Brunelle,Le Beyec, Phys.Rev. Lett.135 (1995)
6) N. A. Tahir, D. H. Hoffman, J. A. Maruhn. And C. Deutsch, Nucl. Instrum. and Methods Phys. Res. B88, 127 (1994).
7) J. Matsuo, N. Toyoda, and I. Yamada, J. Vac Sci. Technol. B14, 3951 (1996).
8) I. Yamada, in Application of Accelerators in Research and Industry, Proceedings of the 14th Internatural Conference, AIP Conf. Proc. No. 392 AIP,. 479. (1997).
9) P. Sigmund, I.S.Bitensky, Nucl.Instrum. and Methods Phys.Res. B112, (1996).
10) P. Sigmund and A. Schinner, Nucl. Inst. and Meth. Phys. Res. B. 192, 46 (2002).
11) J. Sillanpa, HU-P-D 8484. 1, PhD thesis, University of Helsinki (2000).
12) K. Baudin et al., Nucl. Inst. and Meth., P.94 341 (1994).
13) M. Fritz, K. Kimura, Y. Susuki, and M. Mannami, Phys. Rev. A50 2405 (1994).
14) J. Steinbeck and K. Dettmann, J. Phys. C11 290 (1978).
15) J. Jensen,H. Mikkelsen and P. Sigmund, Nucl. Instrum and Meth. 1388, (1994).
16) Y. N. Wang, and T. C. Ma, Phys. Rev. A50 3192 (1994).
17) . A. Lyrio, H. H. Anderson, and L. G. Feldman, Phys. Rev. A17, 90 (1978).
18) W. Brandt, A. Rat- Kowski, and R. H. Ritchie, Phys. Rev. Lett. 33. 1325 (1974).
19) M. F. Steuer and R. H. Ritchie, Nucl. Inst. and Meth. B33 170; 41 372 (1989).
20) C. Ashly and P. M. Echnique, Phys. Rev. B31, 4655 (1985).
21) M. F. Steuer, D. S. Gammell, E. P. Kenter, E. A. Johnson and J. Zebransky, IEEE Trans. Nucl. Sci. Ns-30 1069 (1983).
22) N. Bohr, Phys. Rev. 59 270 (1941).
23) J. Lindhard, K. Dan. Vidensk. Selsk. Mat. Fys. Medd. 28, 8 (1954).
24) L. Ferrel, P. M. Echenique and R. H. Ritchie, Soli St. Commun. 32, 419 (1979).
25) H. B. Nersisyan, and A. K. Das, Phys. Rev. E. 69, 046404 (2004).

JOURNAL OF UNIVERSITY OF THIQAR
vol(8) no.(3) June 2013

تأثير الاضمحلال على قدرة الإيقاف لايونات عناقيد الهيدروجين الثنائية

سحر مزهر مطشر ، سناء ثامر كاظم ،جامعة ذي قار – كلية الطب

الخلاصة:

في هذا البحث درسنا قدرة الإيقاف العناقيد الهيدروجينية الثنائية بوجود الاضمحلال وبعدم وجوده في السرع العالية والواطئة . تم استخدام (Se,Bi,Cs) كأهداف. هذا البحث يناقش تأثير الاضمحلال على قدرة الإيقاف عند تفاعل العنقود الثنائي مع المواد الصلبة وبسرع مختلفة .كذلك درس هذا البحث تأثير كل من المسافة النووية البينية r_{12} ومؤثر الكثافة r_s . هذا البحث يعطي دراسة تفصيلية لتأثير الاضمحلال على قدرة الإيقاف في ظروف مختلفة.