Determination of Cross Section for Different Fusion Reactions in Terms of Lattice Effects in Solid State Internal Conversion for Different metallic Crystalline Environments

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Abstract

In thepresent paper, the cross section ofthe D(d,p)T, D(d,γ)^{4}He,T(d,n)^{4}He and D(p,γ)^{3}He fusion reactions in terms of the lattice effect in solid state internal conversion for different structures and different metallic crystalline environments in comparison with palladium environment has been determined. Elements that we used in this article are Ni, Ru, Rh, Pt, Ta, Ti, Zr, which are contained FCC, BCC and HCP lattice structures. Fusionable particles are solved as a sublattice in mentioned crystalline metals.Fusionreactionsare generated by theflux of incoming fusionable particles.We took lattice effect part in our calculations with regard the Bloch functions for the initial and final state of athree body system. Three-body system involved the host lattice, sublattice and incident particles. The cross section to perform each fusion reaction inside different metal is computed using the state of initial and final system. Then our resultsfor cross section of different metal are compared with palladium metal. Finally, the solid state internal conversion coefficient is obtainedbyconsidering the lattice effect.

Key words: *internal conversion, fusion cross section, lattice effect in solid state internal conversion*

1. Introduction

Nowadays using nuclear energy is very important as a clean source of energy. There are two kinds of nuclear reactions, fusion and fission. Since thefusion reaction has less radioactive radiation and the fusion fuels required for these reactions are more sufficiently available in the nature, therefore fusion reactions are important to study.

In 1995, many experimental works are done on gaseous metals for determining screening effect [1]. From 1998 to 2001, these experiments continued on metallic environments [2-4]. In 2000, the electron screening effect onthe cold fusion reaction was studied for D + D in the metallic environment [5]. In 2002, they released a two-volume report, "Thermal and nuclear aspects of the Pd/D$_2$O system," with a plea for funding [6]. In 2002, the enhancement of cold fusion and solid state effect were studied in deuterated metal for D+D [7]. From 2002 to 2004, the screening effect on 50 metals and insulators is checked by aseries of experiments [8-10]. In 2003, the enhancement of deuteron-fusion reactions in metals and experimental implications were studied for electron screening effect [11]. In 2004, the subject of solid state internal conversion came up [12].In 2005, many efforts were cleared to create an apparatus according to the Fleischmann and pons' works; finally, Cold fusion apparatus was made in San Diego Space and Naval Warfare Systems Center. They used other names instead of cold fusion to reduce the effect of previous failures.Often they prefer to name their field **Low Energy Nuclear Reactions** (**LENR**) or **Chemically Assisted Nuclear Reactions** (**CANR**), also**Lattice Assisted Nuclear Reactions**

(**LANR**), **Condensed Matter Nuclear Science** (**CMNS**) and **Lattice Enabled Nuclear Reactions** [13-16].

In 2002, Peter Kalman and Thomas Keszthelyi studied this problem (enhancing cross section) on different metals. They studied many different factors to explain the enhancement of cross section. For example, the electron screening was checked for 29 deuterated metals and 5 deuterated insulators/semiconductors from periodic tables. Among them, metals were most convenient. Some of the other factors that they considered were: stopping power, thermal motion, channeling, diffusion, conductivity, and crystal structure and electron configuration. None of them could explain the observed enhanced cross section [7, 9, 11, 17-19]. In 2004, they found a reason to explain the enhancement of cross section that was called solid state internal conversion [12]. In 2008, screening effect is studied for the first time on metals by considering solid state; actually solid state of metals is expressed in experiments [20]. Finally, in 2009, they considered a metal with its lattice structure and entered the lattice shape of the solid in their internal conversion calculations [21]. Their calculations were just for $D(p,\gamma)^3He$ reaction.

In this paper, different metals are considered. We choose such metals that show the best results in term of screening effect and the density of deuterium [22]. In this article, in order to compare internal conversion(IC)with lattice effect in solid state internal conversion(LEISSIC), we calculate cross section for different seven particles plus palladium for $D(p,\gamma)^3He$, $D(d,p)T$, $D(d,\gamma)^4He$, $T(d,n)^4He$.

The objective of this studyis to determinatefusion cross section (FCS) for above reactions in different metallic environments regarding LEISSICin order to find the reason of enhanced FCS in these metallic media then recommend the best metal. Tocome onthis aim, following steps are studied:First, right after introduction, the aspects of IC, SSIC and LEISSIC are explained. Second, different special lattice such as Face Cubic Centered (FCC), Body Cubic Centered (BCC) and Hexagonal close Packed (HCP)is introduced in details. Third, LEISSIC and other required quantities to determinate FCS and LEISSIC coefficient for Pd environment are computed. Fourth, all calculations in the third step are repeated for Ni, Ru, Rh, Pt, Ta, Ti, Zr. Fifth, microscopic FCS for all elements are determined in different reaction inthe case that these metals are considered asa host particle in lattice. Finally, we can suggest the best kind of lattice, fusion reaction and metallic environment which have high value LEISSIC when cold fusion happening.

2. Internal Conversion (IC) and Solid State Internal Conversion (SSIC)

Internal conversion is a radioactive decay process where an excited nucleus interacts with an electron in one of the lower atomic orbitals, causing the electron to be emitted from the atom. Thus, in an internal conversion process, a high-energy electron is emitted from the radioactive atom, but without beta decay taking place. Since no beta decay takes place in internal conversion, the element atomic number does not change, and thus (as is the case with gamma decay) no transmutation of one element to another is seen. Also, no neutrino is emitted in internal conversion.Most internal conversion electrons come from the K shell (1s state, see electron shell), as these two electrons have the highest probability of being found inside the nucleus. After the electron has been emitted, the atom is left with a vacancy in one of the inner electron shells. This hole will be filled with an electron from one of the higher shells and subsequently a characteristic x-ray or Auger electron will be emitted[23, 24]

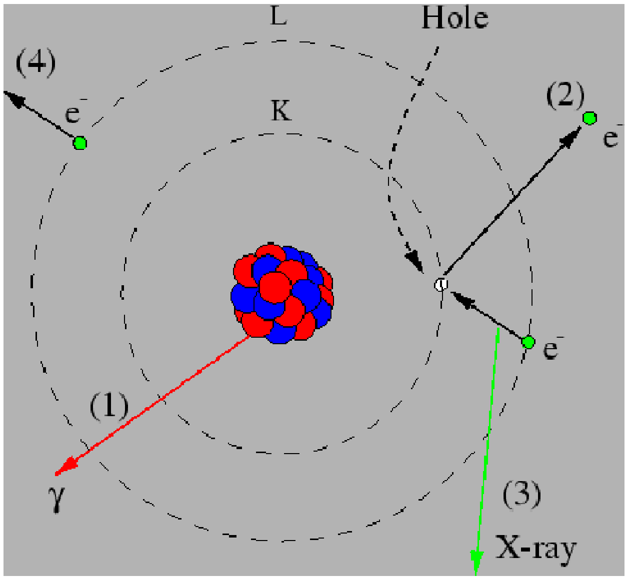


Figure 1: Internal conversion

The enhancement in the fusion rate, which is observed in solid metallic environments, is attributed to the presence of solid state material but up to now the theoretical explanation of the phenomenon is still missing [25-27]. In what follows, we suggest a possible mechanism called solid state internal conversion process that should be considered when trying to understand the extra fusion events. [28].

A similar process to IC can take place on a solid between fusionable nuclei and any charged particle in the crystal. The solid state internal conversion process, e.g.D(p,γ)^{3}He nuclear reaction,can be processes consisting of (a) a bound-free electron transition $p + d + (e) \to {}^3He + e$ and (b) a bound-free deuteron transition $p + d + (d) \to {}^3He + d$.Therefore, an internal conversion happened ina solid environment in addition of electron channel, we have deuterium channel too [12].Increasing absorption is expressed that in a solid material, nuclear fusion reactions(NFR) can happen in solid state internal conversion that creates transit for every charged particle by electromagnetic reaction [12].

3. Describing mentioned latticestructure in this article: FCC, BCC, HCP

In this paper, these elements are studied: Ni, Ru, Rh, Pt, Ta, Ti, Zr. Which, Ni, Pt, Rh have an FCC lattice such as Pd. Ru, Ti, Zr have anHCP lattice and the lattice of Ta is BCC.

After investigating prior experimental work, finally in 2008 solids are considered without their lattice crystal [20]. Then, in 2009, calculations are continued for Pd and with regard the crystalline lattice [21]. Before studyingfor solid state internal conversion the scientists examined screening effect on metals,to find the reasons of the enhancement FCS of metals which was observed[22].In this article chosen elements are significant in screening effect or deuterium density. For example, Ti and Zr showed the most screening potential in the experiments [11]. Ta and Zr had the most solved deuterium density [22]. Whereas having a maximum deuterium density in Ti depends on having high temperature [12].

The most important quantities that change during calculations are unit cell volume and the number of atoms that belongs to each kind of lattice. Those quantities are explained for each lattice that is following.

In each unit cell of FCC and BCC lattice, eight atoms stand on the corner of cubic that arecollaborations between eight other closed cubic (Fig 2, a_1 and a_2),thus, each unit cell has one atom from corners ($8 \times \frac{1}{8} = 1$). For FCC there is one atom which belongs to two closed cubic but for BCC one atom locates in the center of each unit cell. So, FCC and BCC lattice have respectively 3 atoms from all 6 sites ($6 \times \frac{1}{2} = 3$) and one atom from its center. Therefore, FCC and BCC have four($1 + 3 = 4$) and two ($1 + 1 = 2$) atoms in each unit cell respectively.

HCP lattice: In each unit cell of HCP (see fig.2,a_3), there are two atoms at the top and down sides that are shared between two closed unit cells $\left(2 \times \frac{1}{2} = 1\right)$, on the other sides of the unit cell there are six atoms. Each atom belongs, two closed unit cells$\left(6 \times \frac{1}{2} = 3\right)$. There are twelve atoms in the corners that are collaborating between three closed unit cells$\left(12 \times \frac{1}{3} = 4\right)$. Consequently, there are eight atoms that are completely belonged to one unit cell. In this lattice there are two lattice constants: c height of unit cell and a, the face of hexagonal.

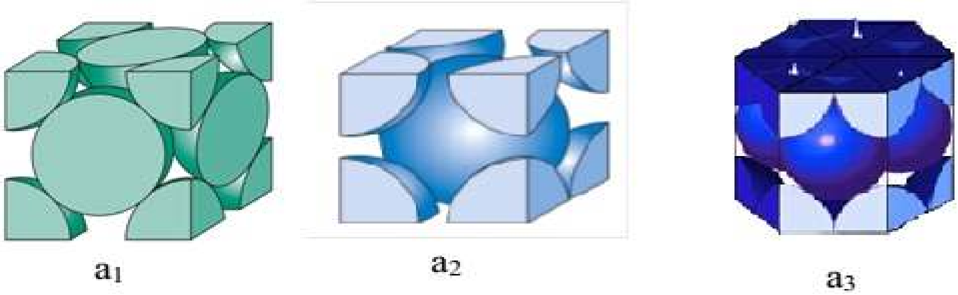


Figure 2: Shape of unit cell; a_1: FCC unit cell, a_2: BCC unit cell, a_3: HCP unit cell.

The volume of unit cell for each lattice is definedby equation 1.

$$v_{cell} = \begin{Bmatrix} \frac{a^3}{4} & FCC \\ \frac{a^3}{2} & BCC \\ \frac{3\sqrt{3}}{16} a^2 c & HCP \end{Bmatrix}, (a, c\text{: lattice constant}) \quad (1)$$

4. Lattice Effect in Solid State Internal Conversion

4.1. Cross section theory of LEISSIC

In this case to insert LEISSIC into the cross section formula, we break through the procedure that is mentioned at ref 20 completely. So, only those important formulas that are really needed here are written.For comparison the fusion cross section with and without LEISSIC we have to determine the macroscopic cross section.

$$\Sigma = N\sigma_2 \qquad (2)$$

In pervious equation, $\sigma_2$the cross section of fusion reaction between host and target fusionable particles is obtained at the following,

$$\sigma_2 = C_0 \frac{\exp(-2\pi\eta)}{E} \qquad (3)$$

E is the energy of incoming particle and C_0 contains all the properties of the lattice that is determined by,

$$C_0 = |F_{Cb}|^2 A_0 k_\mu \left(\frac{\beta_2}{K_Q}\right)^3 \langle |\tilde{\chi}|^2_{K=K_Q} \rangle_{\Omega_K} \qquad (4)$$

All parts of equation 4 and the way that it obtained are presented in ref 20.m_n, nucleons mass, ω_n angular frequency of binding energy are calculated for each reaction separately (table 3).

$$\lambda = \frac{\sqrt{m_n\omega_n}}{\hbar} \qquad (5)$$

$$m_n = m_i + m_{He}\ , i = d\ or\ t \qquad (6)$$

$$\omega_n = \frac{binding\ energy\ of\ He(MeV)}{\hbar} \qquad (7)$$

Here, C_0 is calculated for one d or one Pd. In order to compare C_0 with astrophysical factor (S(0)) in ordinary state , it must be calculated considering the density of these particles. So, we use the Eq.8,

$$NC_0 = A\Delta R_h C_1\ , N(Pd) = V_{eff}/v_{cell}\ and\ N(d) = u\,V_{eff}/v_{cell} \qquad (8)$$

Where $v_{cell} = d^3/4\ , V_{eff} = A\Delta R_h$ and $d = 3.89 \times 10^{-8} cm$ is the lattice constant. In Eq.8, u is the ratio of deuteron to palladium number density. For electron u = 10 which is the number of electron valence in palladium.

4.2. Results of numerical calculations for each reaction

There are two tables for all reactions that can aid in plotting the cross section and compared with the ordinary state. The suppositions of hosts, sublattice and incoming particles are expressed for all reactions in this way: the host particles are Pd,d,e for Palladium. The sublattice isdeuterium for all reactions. The incoming particles are proton (p) in D(p,γ)^{3}He , deuterium (d) in D(d,p)T and D(d,γ)^{4}He and tritium (t) in T(d,n)^{4}He . In order to get to the equation 4and obtain fusion cross section, all our calculation and requirements for all three kinds of host particles are summarized in tables 1, 2 and 3 to according to the formulas in ref 20.

Table 1: our numerical calculation of necessary quantities for obtaining C_0 for all chosen reactions

Type of Reactions	**host particles**	A_0**(MeV)**	**μ(gr)**	K_Q**(cm^{-1})**	$\lvert\widetilde{\chi}\rvert^2_{K=K_Q}$ **(cm^3)**	**ξ**
D(p,γ)3He	**Pd**	175	5.013×10^{-24}	8.91×10^{12}	3.95×10^{-38}	10.755
	d	0.0827	2.005×10^{-24}	5.64×10^{12}	5.13×10^{-38}	0.1477
	e	0.0103	-----------	2.78×10^{11}	6.11×10^{-38}	-560382
D(d,p)T	**Pd**	349	6.686×10^{-24}	8.82×10^{12}	3.15×10^{-38}	14.462
	d	0.165	2.229×10^{-24}	5.09×10^{12}	3.97×10^{-38}	0.181
	e	0.021	-----------	2.05×10^{11}	4.45×10^{-38}	-0.0011
D(d,γ)4He	**Pd**	349	6.686×10^{-24}	7.93×10^{12}	3.69×10^{-38}	16.075
	d	0.165	2.229×10^{-24}	4.58×10^{12}	4.51×10^{-38}	0.202
	e	0.021	-----------	1.65×10^{11}	4.98×10^{-38}	-0.0022
T(d,n)4He	**Pd**	524	8.35×10^{-24}	2.05×10^{13}	2.89×10^{-39}	5.863
	d	0.248	2.387×10^{-24}	1.10×10^{13}	4.24×10^{-39}	0.09
	e	0.031	----------	8.90×10^{11}	4.30×10^{-38}	-4.228

We can calculate the required parameters such as C_0 and C_1 which are important for estimating cross section of the fusion reactions.

Table 2: our numerical calculation C_0 and C_1 for different host particle and different reactions

Type of Reactions	**host particles**	k_μ **(cm^{-1})**	$\lvert F_{Cb}\rvert^2$	C_0 **(MeV b)**	C_1 **(MeV b)**
D(p,γ)3He	**Pd**	1.42×10^{14}	3.14×10^{-28}	4.92×10^{-38}	3.36×10^{-24}
	d	0.57×10^{14}	0.61	2.30×10^{-13}	$u \times 15.6$
	e	-----------	1	9.10×10^{-13}	6.18×10^{2}
D(d,p)T	**Pd**	1.90×10^{14}	3.27×10^{-38}	1.11×10^{-47}	7.53×10^{-34}
	d	0.63×10^{14}	0.5371	1.88×10^{-13}	$u \times 12.78$
	e	-----------	1	2.48×10^{-12}	1.687×10^{3}
D(d,γ)4He	**Pd**	1.90×10^{14}	7.02×10^{-41}	3.83×10^{-50}	0.26×10^{-35}
	d	0.63×10^{14}	0.4964	2.70×10^{-13}	$u \times 18.35$
	e	-----------	1	4.31×10^{-36}	2.93×10^{-21}
T(d,n)4He	**Pd**	2.37×10^{14}	4.44×10^{-15}	2.05×10^{-25}	1.39×10^{-12}
	d	0.68×10^{14}	0.7438	4.45×10^{-15}	$u \times 0.3024$
	e	-----------	1	1.87×10^{-13}	127.1

Since each palladium unit cell has 4 Pd atoms purely and since we suppose that the number of host and sublattice particles are equal, then we have

$$N_{Pd} = \frac{1}{4} \times 4.22 \times 10^{22} \tag{9}$$

Table 3: our obtaining required quantities which are calculated for determination of different fusion

Type of Reactions	λ (cm^{-1})	β_2(cm^{-1})	Q (MeV)	Binding Energy (MeV)
$D(p,\gamma)^3He$	9×10^{12}	4.81×10^{14}	5.49	7.718
D(d,p)T	10×10^{12}	4.81×10^{14}	4.04	8.482
$D(d,\gamma)^4He$	9.63×10^{12}	4.81×10^{14}	3.27	28.3
$T(d,n)^4He$	21.8×10^{12}	4.81×10^{14}	17.59	28.3

4.3. Calculations the solid state internal conversion coefficient for different fusion reactions in Palladium crystal environment

With regarding to definition that exists in Ref.11, we can write$v_{eff} = A\Delta R_h$, where A is the cross section of the beam, ΔR_h is the “differential” range, that is, the distance within which the energy of the incoming particle can be considered unchanged. The $\Delta R_h \ll R_h$ condition helps in an order of magnitude estimate of ΔR_h , where R_h is the stopping range of a proton which is about $8 \times 10^{-2} \mu m$ at $E = 0.01\, MeV$ in Pd [22]. The quantities A and R_h were measured in mm^2 *and* $10^{-3} \mu m$ units. The solid state internal conversion coefficient is introduced as,

$$\alpha_{SSIC} = A\Delta R_h C_1 / S(0) \quad (10)$$

S(0) is the astrophysical factor and the amounts of S(0) were calculated completely in the ref 27. Here since the issue is studied on the low energy (5-30 eV), the amounts of S(0) for each reaction is a constant that are shown in table 4.

Table 4: the amounts of astrophysical S-factor for different reactions in ordinary state in low energy

Reactions / Astrophysical factor	$D(p,\gamma)^3He$	D(d,p)T	$D(d,\gamma)^4He$	$T(d,n)^4He$
S(0) MeV barn	0.2×10^{-6}	0.056	0.054	10

By using the amounts exist in tables 2, 4 and replacing them into Eq.9 the solid state internal conversion coefficient for different reactions can be found. This coefficient indicates the internal conversion rate in different reactions. The result of the calculations summarized in table 5.

Table 5: solid state internal conversion coefficient in different reactions for e, 4d and d channels

Type of reactions	$\alpha_{SSIC,d}\ A\Delta R_h$	$\alpha_{SSIC,e,\mathbf{4d}}\ A\Delta R_h$
$D(p,\gamma)^3He$	$u \times 7.8 \times 10^5$	3.1×10^9
D(d,p)T	$u \times 3.03 \times 10^4$	3.2×10^6
$D(d,\gamma)^4He$	$u \times 3.398 \times 10^2$	5.42×10^{-20}
$T(d,n)^4He$	$u \times 0.03$	12.7

We find out the solid state internal conversion happens in D(p,γ)^{3}HeandD(d,p)T reactions with more rates. All calculations in this part are shown for palladium. In the next part we show the results for other elements in detailed.

5. Calculations of LEISSIC forotherelements

5.1. Tables of Calculation for Different Elements and Reactions

By using all formulas in section 3, such as what we have done for palladium, all required quantities can be computed for mentioning elements. Becauseother host particles (deuterium and electron) don't change in these calculations and the only thing that changes is the first row of the Table.1. Meanwhile, C_1 and C_0which changes only for the elements are respectively shown in Table 6 and 7.

Table 6: Our numerical calculations of C_0 for different elements and reactions with FCC, BCC and HCP lattice

Quantity elements	$C_{0,D(p,\gamma)3He}$ (MeV barn)	$C_{0,D(d,p)T}$ (MeV barn)	$C_{0,D(d,\gamma)4He}$ (MeV barn)	$C_{0,T(d,n)4He}$ (MeV barn)
Pd (FCC)	4.92×10^{-38}	1.11×10^{-47}	3.83×10^{-50}	2.05×10^{-25}
Ni (FCC)	3.44×10^{-27}	6.79×10^{-33}	2.56×10^{-35}	6.98×10^{-23}
Pt (FCC)	1.34×10^{-57}	1.95×10^{-74}	1.21×10^{-81}	1.63×10^{-45}
Rh (FCC)	1.08×10^{-36}	7.43×10^{-47}	6.61×10^{-51}	1.38×10^{-24}
Ru (HCP)	8.49×10^{-37}	5.07×10^{-46}	5.56×10^{-50}	1.21×10^{-30}
Ti (HCP)	1.10×10^{-23}	4.63×10^{-28}	6.49×10^{-30}	1.93×10^{-21}
Zr (HCP)	2.25×10^{-34}	1.01×10^{-42}	2.69×10^{-46}	6.27×10^{-29}
Ta (BCC)	1.30×10^{-54}	3.10×10^{-70}	5.79×10^{-77}	2.64×10^{-43}

Table 7: Our numerical calculations of C_1 for different elements and reactions with FCC, BCC and HCP lattice

qantity elements					
Pd (FCC)	Pd				
	d				
	e				
Ni (FCC)	Ni				
	d				
	e				
Pt (FCC)	Pt				
	d				

	e				
Rh (FCC)	Rh	7	5		
	d				
	e				
Ru (HCP)	Ru	5	3		
	d				
	e				
Ti (HCP)	Ti	5	2		
	d				
	e				
Zr (HCP)	Zr	8	3		
	d				
	e				
Ta (BCC)	Ta	7	1		
	d				
	e				

For comparing C_0, the microscopicFCS of these metallic environments for all elements, numerical values from Table.6 can be useful. For studying the comparison of the C_1 quantity see table 7.

According to table 7, we find out that: wherever elements themselves are considered as host particles, the results of C_1 from large to small values for all reactions are: Ti, Ni, Zr, Ru, Rh, Pd, Ta and Pt. For cases that deuterium and electron are host particles, our comparing values lead to Ru, Ni, Ti, Rh, Pd, Pt, Zr, Ta and Ni, Ru, Pd, Pt, Rh, Ti, Ta, Zr respectively. In case that electron is host the number of electrons in capacity layer is too important indeed whatever the numbers of electrons increases the screening effect is enhanced. Between all reactions, D(p,γ)^{3}He , D(d,p)T and D(d,γ)^{4}He have larger values of C_1 than T(d,n)^{4}He.

(According Table.7 the result of comparing C_1 for different host particles in different metallic environments are: element host particle, $C_{1,Ti} > C_{1,Ni} > C_{1,Zr} > C_{1,Ru} > C_{1,Rh} > C_{1,Pd} > C_{1,Ta} > C_{1,Pt}$; deuterium host particle, $C_{1,Ru} > C_{1,Ni} > C_{1,Ti} > C_{1,Rh} > C_{1,Pd} > C_{1,Pt} > C_{1,Zr} > C_{1,Ta}$; electron host particle, $C_{1,Ni} > C_{1,Ru} > C_{1,Pd} > C_{1,Pt} > C_{1,Rh} > C_{1,Ti} > C_{1,Ta} > C_{1,Zr}$)

Table 8: Our numerical calculations of LEISSIC for all elements in different reactions

quantity elements					
Pd (FCC)	**d**	u	u		
	e				
Ni (FCC)	**d**	u	u		
	e				
Pt (FCC)	**d**	u	u		
	e				
Rh (FCC)	**d**	u	u		

	e				
Ru (HCP)	**d**	u	u		
	e				
Ti (HCP)	**d**	u	u		
	e				
Zr (HCP)	**d**	u	u	u	
	e				
Ta (BCC)	**d**	u	u		
	e				

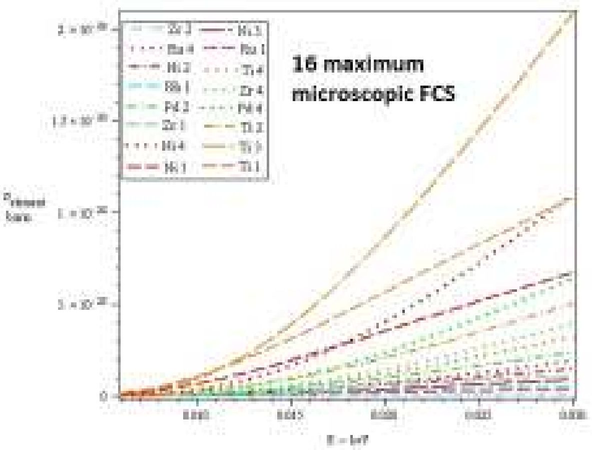
In the each environment, IC coefficient shows internal conversion rate and determined the cross section enhancement in each environment. By studying table 8, we find out that the internal conversion coefficient of deuterium for D(p,γ)^{3}He is the largest one. The IC coefficient for D(p,γ)^{3}He for different reactions from larger to smaller value is: Ru, Ni, Rh, Pt, Zr, Ta, Ti and Pd. As you see in this reaction Pd has the last rank. In D (d,p)T, the arrangement of the elements is: Pd, Ru, Ni, Ti, Rh, Pt, Zr and Ta.

Electronicinternal conversion coefficientarrangementfor different elements is: Ni, Ru, Pd, Rh, Ti, Ta, Zr, Pt. ($\propto_{e,Ni}>\propto_{e,Ru}>\propto_{e,Pd}>\propto_{e,Rh}>\propto_{e,Ti}>\propto_{e,Ta}>\propto_{e,Zr}>\propto_{e,Pt}$)

(According to Table.8, comparing ICC values of deuterium host particle for the two largest reactions D(p,γ)3He and D(d,p)T are respectively: $\propto_{d,Ru}>\propto_{d,Ni}>\propto_{d,Rh}>\propto_{d,Pt}>\propto_{d,Zr}>\propto_{d,Ta}>\propto_{d,Ti}>\propto_{d,Pd}$ *and* $\propto_{d,Pd}>\propto_{d,Ru}>\propto_{d,Ni}>\propto_{d,Ti}>\propto_{d,Rh}>\propto_{d,Pt}>\propto_{d,Zr}>\propto_{d,Ta}$)

6. Microscopic cross section for all elements in different reactions

MicroscopicFCS for all metallic environments when metal considers as a host particle are plotted by replacing numerical values from Table 6 inEq.3. All FCS are divided into two groups in order to show changes clearly: 16 maximum and 16 minimum which are respectively shown in Fig 3. Numbers 1 to 4 besides the name of the elements shows D(p,γ)^{3}He , D(d,p)T , D(d,γ)^{4}He and T(d,n)^{4}He .



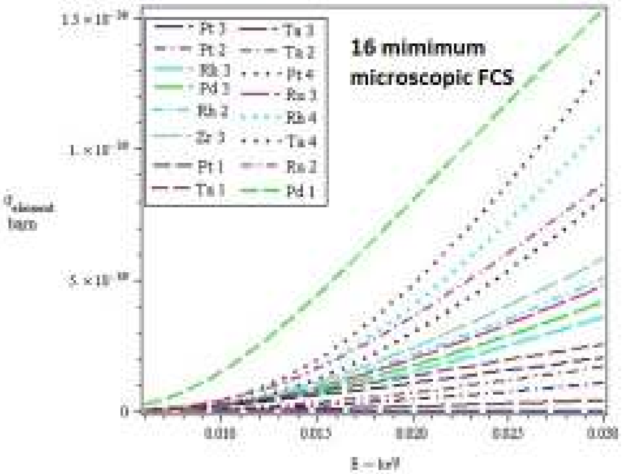


Figure3:16 maximum and minimum measurements of microscopicFCS in terms of incoming energy for all reactions are represented.

In the above graph, different colors shows kinds of elements and the styles of shape introduce kinds of reactions. D(p,γ)^{3}He by “dash”, D(d,p)T by “dashdot”, D(d,γ)^{4}He by “longdash” and T(d,n)^{4}He by “dot” are shown. The color of Pd, Ni, Pt, Rh, Ru, Ti, Zr, and Ta are respectively: Green, red, navy, cyan, dark pink, coral, aquamarine and brown. As you see Ti and Ni have the lager cross section. After them palladium shows up just in the T(d,n)^{4}He reaction.

To realize the best kinds of lattice structure, microscopicFCS related to element host particles are plotted for each fusion reactions separately.Here in these graphs, colors shows kinds of elements and the styles of the graph indicate the kind of the lattice. BCCshows by “dot”, FCC by “long dash” and HCP by “dash dot”.

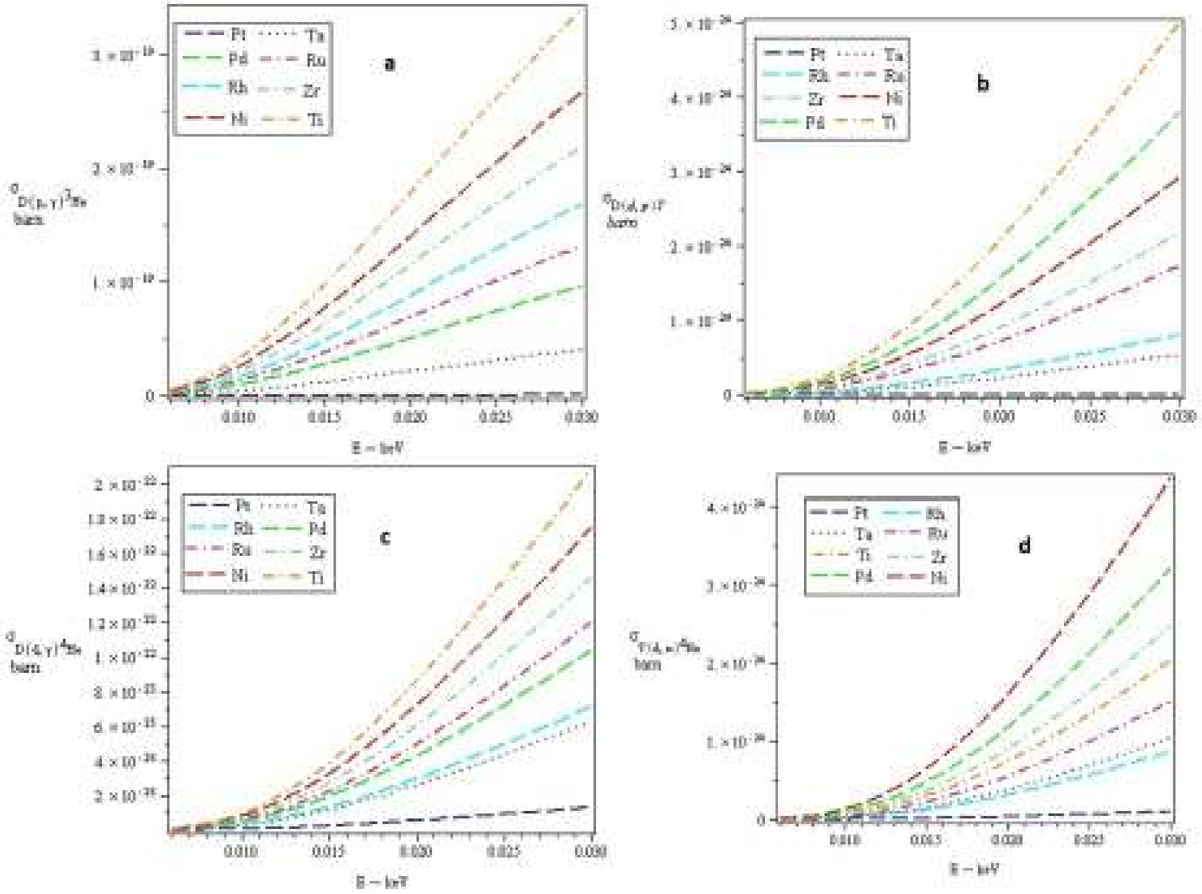


Figure 4:MicroscopicFCS of all elements for different fusion reaction are presented

For D(p,γ)^{3}He , D(d,p)T , D(d,γ)^{4}He (Fig.4), Ti with HCP lattice has the largest microscopicFCS and Pd with FCC lattice is respectively in the sixth, second and fifth place. Ni with FCC lattice is in the first place of microscopicFCS and Pd is the fifth for T(d,n)^{4}He. Now the data that are correspond to figures 3 are summarized in table 9.

Table 9: numerical microscopic cross sectioned values in special energy (0.025MeV) for different elements in different reactions

quantity elements	$D(p,\gamma)^3He$ (MeV)	D(d,p)T (MeV)	$D(d,\gamma)^4He$	$T(d,n)^4He$ (MeV)
Pd (FCC)	1	8	2	8
Ni (FCC)	8	5	1	2
Pt (FCC)	2	1	9	6
Rh (FCC)	2	5	5	5
Ru (HCP)	2	3	4	5
Ti (HCP)	2	3	4	7
Zr (HCP)	5	7	2	2
Ta (BCC)	3	2	4	1

7. Discussion and Conclusion

According to table.7, the result of comparing C_1 for different host particles in different metallic environments are: when the metals are considered as host particle, $C_{1,Ti} > C_{1,Ni} > C_{1,Zr} > C_{1,Ru} > C_{1,Rh} > C_{1,Pd} > C_{1,Ta} > C_{1,Pt}$; whenever deuterium considered a host particle, $C_{1,Ru} > C_{1,Ni} > C_{1,Ti} > C_{1,Rh} > C_{1,Pd} > C_{1,Pt} > C_{1,Zr} > C_{1,Ta}$; electron host particle, $C_{1,Ni} > C_{1,Ru} > C_{1,Pd} > C_{1,Pt} > C_{1,Rh} > C_{1,Ti} > C_{1,Ta} > C_{1,Zr}$.

As you see in table.9 the best cross sections belong to $D(p,\gamma)^3He$ and D (d,p)T reactions. In order to achieve our goals we need to look back to our data about internal conversion coefficient by considering lattice effect.

In table 8, we find out that the internal conversion coefficient of deuterium for $D(p,\gamma)^3He$ is the largest one. The IC coefficient for $D(p,\gamma)^3He$ for different reactions from larger to smaller value is: Ru, Ni, Rh, Pt, Zr, Ta, Ti and Pd. As you see in this reaction Pd has the last ICC. In D (d,p)T, the arrangement of the elements is: Pd, Ru, Ni, Ti, Rh, Pt, Zr and Ta.

Electronic internal conversion coefficient arrangement for different elements is: Ni, Ru, Pd, Rh, Ti, Ta, Zr, Pt. ($\propto_{e,Ni}>\propto_{e,Ru}>\propto_{e,Pd}>\propto_{e,Rh}>\propto_{e,Ti}>\propto_{e,Ta}>\propto_{e,Zr}>\propto_{e,Pt}$)

Accordingto Table.8, comparing ICC values of deuterium host particle for the two largest reactions $D(p,\gamma)^3He$ and D(d,p)T are respectively: $\propto_{d,Ru}>\propto_{d,Ni}>\propto_{d,Rh}>\propto_{d,Pt}>\propto_{d,Zr}>\propto_{d,Ta}>\propto_{d,Ti}>\propto_{d,Pd}$ and $\propto_{d,Pd}>\propto_{d,Ru}>\propto_{d,Ni}>\propto_{d,Ti}>\propto_{d,Rh}>\propto_{d,Pt}>\propto_{d,Zr}>\propto_{d,Ta}$)

As you see Ti and Ni have the lager cross section. After them palladium shows up just in the T(d,n)^{4}He reaction.

Looking at Fig 4, can show that what the best lattice, kinds of environment and kinds of reactions are. Ti with HCP lattice has the largest micFCS and Pd with FCC lattice is respectively in the sixth, second and fifth place. From Fig.4d we can understand that Ni with FCC lattice is in the first place of micFCS and Pd is the fifth. FCC and HCP are the best lattice structures and Ti and Ni are best elements, Ru has a largest ICC In the case that deuterium is the host particle.

By comparing FCS in term of LEISSIC, Ti and Ni show maximum data. By comparing internal conversion coefficient in term of LEISSIC, the best results belong to Ni and Ru. So Ni can be the best option for the next experimental works.

The other investigations show that: FCC and HCP lattice have a much closed results. Palladium shows good results just in the D(p,γ)^{3}He and D(d,γ)^{4}He .

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