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Computation of time energy gain in D-3He mixture: Energy deposited through deuterium ignition beam

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ABSTRACT

The fast ignition approach to ICF consists in first compressing the fuel to high density by a suitable driver and then creating the hot spot required for ignition by means of a second external pulse. If the ignition beam is composed of deuterons, an additional energy is delivered to the target with increased energy gain. Therefore ,in this innovative suggestion ,we consider deuterium beams for fast ignition in D+^{3}Hemixture and solve the dynamical balance equations under the available physical conditions by considering a new average reactivity formula ,then we compute the energy gain in this mixture .Our computational results show that we can get energy gain value larger than 4 at resonant temperature (200keV)of D+^{3}Hemixture. We select D+^{3}Hefuel, because D+^{3}Hereaction is very attractive from a theoretical point of view since it does not produced neutrons. The D+^{3}Hebenefits include full-lifetime materials, reduced radiation damage, less activation ,absence of tritium breeding blankets ,highly efficient direct energy conversion, easier maintenance, proliferation resistance.

Key words: Fast Ignition, Deuteron Beam, Energy, Dynamics

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INTRODUCTION

There is no doubt that one of the most difficult problems that a peaceful world will face in the 21th century will be to secure an adequate ,safe ,clean and economical source of energy. One of the source of energy is nuclear fusion. Fusion energy which is the energy source that powers the stars, has its origin in nuclear fusion reactions. Inertial confinement fusion (ICF) is the major alternative to magnetic confined fusion. The indirect and direct drive approaches to ICF have been reviewed respectively byLindl et al.(1995 and 2004)and

Bodner (1998). Both rely on implosion of a spherical shell of deuterium –tritium ice with a central core of D+T gas to compress and ignite the fuel at a central hot spot. Fast ignition (FI) is a newer approach to ICF proposed in outline by Basov et al (1992) and in much fuller detail by Tabak et al. (1994). Fuel compression and ignition are separated in FI by using a shell of fuel at solid density which is compressed by long pulse beams, together with short duration localized heating and ignition of the compressed fuel by a short pulse laser beam ,as illustrated schematically in Figure1.

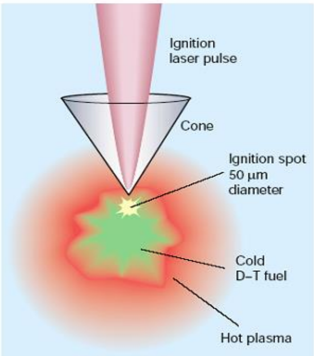


Figure 1. The fast ignition concept using implosion of a spherical shell with an inserted hollow cone to provide a path for the ignition laser pulse to generate electrons close to the compressed D+T plasma

The original concept of Tabak et al. assumed the short pulse laser beam would penetrate close to the dense fuel through a laser formed channel in the plasma and that laser generated relativistic electrons would ignite the fuel. Over the past year, there have been several observations of multi-MeV ion beams generated by high-intensity ultra-short laser pulses in the interaction with solid targets. Light ions, similar to electrons, can be generated due to laser–plasma interaction in a target, while a heavy ion beam must be produced by an external driver and transported to the target. In summary ,the fast ignition (FI) mechanism, in which a pellet containing the thermonuclear fuel is first compressed by a nanosecond laser pulse, and then irradiated by an intense "ignition" beam, initiated by a high power picosecond laser pulse, is one of the promising approaches to the realization of the inertial confinement fusion (ICF). The ignition beam could consist of laser-accelerated electrons, protons, heavier ions, or could consist of the laser beam itself. It had been predicted that the FI mechanism would require much smaller overall laser energies to achieve ignition than the more conventional central hot spot approach, and that it could deliver a much higher fusion gain, due to peculiarities of the pressure and density distributions during the ignition. It is clear, however, that interactions of electrons and ions with plasma, and most importantly the energy deposition mechanisms are essentially different. If the ignition beam is composed of deuterons, an additional energy is delivered to the target and increase target energy gain. Therefore, in thepresent studyas a particularly innovative,due to different advantages of D+^{3}He as already mentioned ,we choose the D+^{3}He fuel with an deuteron ignition beam ,under optimum conditions we compute the total energy deposited in the target and dynamically we determine energy gain. We must notice that D+^{3}Hehas different advantages: they include full-lifetime materials, reduced radiation damage, less activation ,absence of tritium breeding blankets ,highly efficient direct energy conversion ,easier maintenance, proliferation resistance .In this direction,the physics of fusion reactions are described in detail in section II. Investigations of total deposited energy

due to deuteron beam fast ignition in target fuel are described in section III. Balance equations of deuterium-helium3 mixture and interpretation of numerical obtained results are given in section IV. Finally, from the nature of this theoretical work, discussion and conclusionsare performed. در اینجا اعداد سکشنها را به شکل رومی نوشتیم اما شماره گذاری سکشنها در متن به اعداد انگلیسی هست اشکالی نداره؟
در کل متن بعضی جاها که قبلا تصحیح کرده بودید سایز و نوع فونتش با بقیه فرق داشت که من همه را درست کردم و مثل بقیه متن کردم.

PHYSICS OF FUSION REACTIONS

The main fusion reactions are:

$D + T \rightarrow {}^4_2He(3.5MeV) + n(14.1MeV)$ (a)

$D + {}^3_2He \rightarrow {}^4_2He(3.6MeV) + p(14.7MeV)$ (b)

$D + D \rightarrow {}^3_2He(0.82MeV) + n(2.45MeV)$ %50 $(c-1)$

$D + D \rightarrow T(1.01MeV) + p(3.03MeV)$ %50 $(c-2)$

D+^{3}He reaction is very attractive from a theoretical point of view since it does not produced neutrons. A D+^{3}He fueled fusion reactor would also possess substantial safety and environmental advantages over D+T. Efficient D+^{3}He fusion energy would be beneficial to terrestrialelectricity ,space power , and space propulsion. Fusion using D+^{3}He fuel requires significant physics development particularly of plasma confinement in high performance alternate fusion concept. Economically accessible^{3}He on earth exists in sufficient quantities (a few hundred kg ,equivalent to few thousand MW-years of fusion power) for an engineering test. In a D+T and D+^{3}He fuel mixture D+D reaction fusion also occurs. The main difficulties for D+^{3}He reaction are the high temperature conditions and the scarceness of ^{3}He on earth. The formula of fusion cross section for all these fusion reactions is given by:

$$\sigma(E_{lab}) = -16389C_3\left(1+\frac{m_a}{m_b}\right)^2 \times \left[m_a E_{lab}\left[Exp\left(31.40\, Z_1 Z_2\sqrt{\frac{m_a}{E_{lab}}}\right)-1\right]\left\{(C_1 + C_2E_{lab})^2 + \left(C_3 - \frac{2\pi}{\left[Exp\left(31.40Z_1Z_2\sqrt{m_a/E_{lab}}\right)-1\right]}\right)^2\right\}\right]^{-1} \quad (1)$$

with 3 adjustable parameters (C_1, C_2 and C_3) only. In equation (1), m_a and m_b are the mass number for the incident and target nucleus, respectively (e.g. m_a = 2 for incident deuteron);E_{lab} (deuteron energy in lab system)is in units of keV and $\sigma$is in units of barn. The numerical values of C_1, C_2 and C_3 for these reactions are listed in Table.1.

Table 1. Numerical values of C_1, C_2 and C_3 for reactions D+T,D+^{3}He and D+D

	D+T	D+^{3}He	D+D
C_1	−0.5405	−1.1334	−60.2641
C_2	0.005546	0.003039	0.05066
C_3	−0.3909	−0.6702	−54.9932

From this formula ,a schematic diagram of the variations of fusion cross sections for these reactions in terms ofE_{lab} are shown in Figure.2. Also by comparing our calculated numerical values with available experimental results as are shown in,we conclude that this formula is exact.

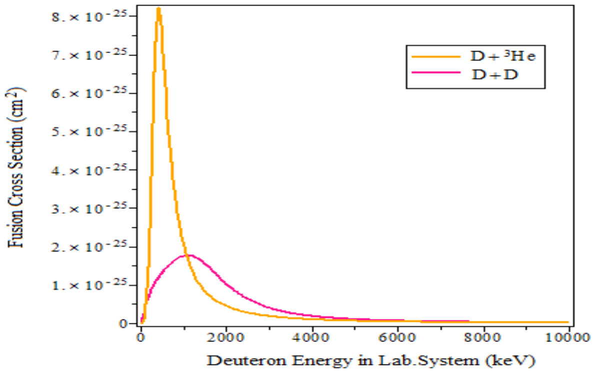


Figure.2.Variations of fusion cross sections versus Deuteron Energy in Lab System (keV) for different fusion reactions of D+^{3}He and D+D.

Another important quantity is the *reactivity*, defined as the probability of reaction per unit time per unit density of target nuclei. In the present simple case, it is just given by the product $< \sigma v >$. We have (Freidberg, 2007):

$$< \sigma v > = \frac{4\pi}{(2\pi m_r)^{\frac{1}{2}}} \frac{1}{(k_B T)^{\frac{3}{2}}} \int_0^\infty \sigma(\varepsilon)\, \varepsilon \exp\left(-\frac{\varepsilon}{k_B T}\right) d\varepsilon \qquad (2)$$

Where m_r is the reduced mass, k_B is Boltzmann constant ,T is the temperature and ε is energyin the center of mass frame. Note that$E_{lab} = \frac{m_a+m_b}{m_b}\varepsilon$ د

Using data in Table. 1 and inserting equation (1) into equation(2)and integrate on it for D+^{3}He and D+D targets,Figure 3 presents plots of averaged reactivity for D+^{3}He and D+D.By way of comparison Figs.2 with 3 we concluded that the cross section and averaged reactivity of D+^{3}He fusion reaction is greater thanD+D reaction, and$< \sigma v >_{D+{}^3He}$ and $< \sigma v >_{D+D}$ are strongly temperature dependent. However, for D+D reaction $< \sigma v >_{D+D}$ isminimized. Notice, however, that the resonance temperature ,is the temperature where the probability for occurring fusion is maximized. In this manner, from Figs 3 , it will therefore be recognize that resonant temperature for both D+^{3}He and D+D fusion reactions are approximately 200 and 300keV ,respectively.

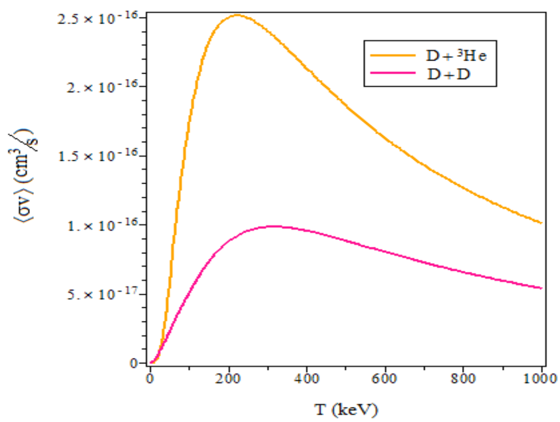


Figure 3:Variations of the averaged reactivity in terms of temperature for $< \sigma v >_{D+{}^3He}$ and $< \sigma v >_{D+D}$

TOTAL DEPOSITED ENERGY DUE TO DEUTERON BEAM FAST IGNITION IN TARGET FUEL

Deuterons have been considered for fast ignition as well. Bychenkov et al., considered an accelerated deuteron beam, but decided that deuterons would have too high an energy (7–8 MeV) to form the desired hot spot .However, the recent proton acceleration experiments suggest that the laser and converter foil parameters can be adjusted to achieve ion beams within the desired range of initial energies and spectra with low$\frac{\Delta E}{E}$ for maximum use of the beam. This reopens the door to a consideration of deuteron driven FI. Deuterons would not only provide proven ballistic focusing, but also fuse with the target fuel (both D and ^{3}He) as they slow down (Bathke etel, 1973) , providing a "bonus" energy gain. Depending on the target plasma conditions, this added fusion gain can provide a significant contribution. We must notice that the idea of a bonusenergy for first time is presented by Xiaoling Yang and et.al at low temperatures (Xiaoling etel, 2011).In this work we elaborate onthis idea, to compute the added energy released as the energetic deuterons interact with the target fuel ions of D+^{3}He in range of temperatures including resonant ones (200keV).This added energy increasesthe total energy gain.We use a modified energy multiplication factor φ to estimate the bonus energy in terms of the added "hot spot" heating by beam-target fusion reaction for D+^{3}He (Bathke etel, 1973) . The deuteron beam energy deposition range and time are also calculated for this reaction. The F value is the ratio between the fusion energy E_f produced and the ion energy input E_I to the plasma and for D+^{3}He reaction is given by (Bathke etel, 1973) :

$$F_{D+\,^3He} = n_{\,^3He} \frac{\int_{E_{th}}^{E_I} S(E)dE}{E_I} \qquad (3)$$

whereE_I and E_{th} are, respectively, the average initial energy and the asymptotic thermalized energy of the injected single ion for this reactions.[18,21,22] .So ,we consider

$$S(E) \equiv \sum_k K_k [< \sigma v(E) >_b]_{Ik} (E_f)_{Ik} / \left(\frac{dE}{dt}\right) \qquad (4)$$

where:

$$\frac{1}{n_{\,^3He}}\left(\frac{dE}{dt}\right) = -\frac{Z_I^2 e^4 m_e^{1/2} E \ln \Lambda_{D+\,^3He}}{3\pi(2\pi)^{1/2}\varepsilon_0^2 m_I (kT_e)^{3/2}}\left[1 + \frac{3\sqrt{\pi} m_I^{3/2}(kT_e)^{3/2}}{4 m_k m_e^{1/2} E^{3/2}}\right] \qquad (5)$$

where m_e is the mass of electron and m_I is the mass of the injected ion, both of which are in atomic mass unit (amu).$< \sigma V >_{Ik}$ is the fusion reactivity for the injected ion I of species k having atomic fraction K_k in the target, $(E_f)_{Ik}$is the corresponding energy released per fusion, and T_e is the target electron temperature. By inserting Eq.(5) inside Eq.(3) we can see that the $n_{\,^3He}$ in Eq. (5) cancel that in Eq.(3), thus $F_{D+\,^3He}$ is nearly independent of the target density ($n_{\,^3He}$). $\ln \Lambda_{D+\,^3He}$ is the Coulomb logarithm for D+^{3}He reaction.

In the D+^{3}He fusion reaction the products are all energetic charged particles (14.7 $MeV\ proton\ and$ 3.6 $MeV\ alpha$) based on the binary collision model, the Coulomb logarithm based slowing down process in the background plasma is usually defined as:

$$\ln \Lambda_{D+\,^3He} = 14.8 - \ln\left(\sqrt{n_e}/T_e\right) \qquad (6)$$

In Fig.4,the two and three dimensional variations of $\ln \Lambda_{D+\,^3He}$ are plotted. From this,we then clearly see thatln $\Lambda_{D+\,^3He}$has a larger value at lower $T_e(keV)$and higher$n_e(cm^{-3})$.

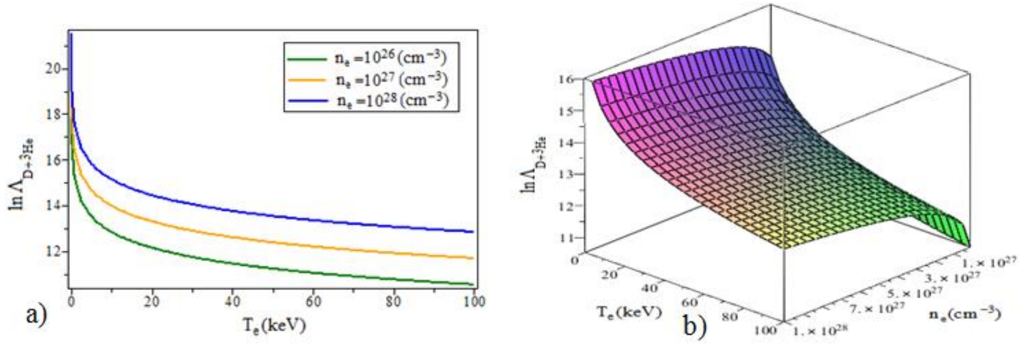


Figure 4: a)The two and b) three dimensional variations of $\ln \Lambda_{D+\,^3He}$ in terms of target density and temperature .

The $(E_f)_{Ik}$ in Eq. (4) gives the energy released in the fusion reaction carried by the produced particles. For, D+^{3}He reaction in the target (see reaction (b)) only 20% of the fusion energy carried by the alphas is applicable for heating while for the D+D reaction about 63% of the total isapplicable (see reaction c) (Xiaoling etel, 2011). Therefore, to prevent confusion, we introduce a new factor φ to represent the energy multiplication factor for the hot spot heating by the charged particles for D+^{3}He fusion reaction. We have $\varphi_{D+\,^3He} = 20\% \, F_{D+\,^3He}$ and for D+D fusion in D+^{3}He mixture $\varphi_{D+D} = 63\% \, F_{D+\,^3He}$. In summary, the total energy that could be deposited into the target due to combined deuteron ion heating and beam-target fusion for D+^{3}He and D+D , respectively becomes:

$$\varepsilon_{D+\,^3He} = E_I \left(1 + \varphi_{D+\,^3He}\right) \qquad (7-1)$$

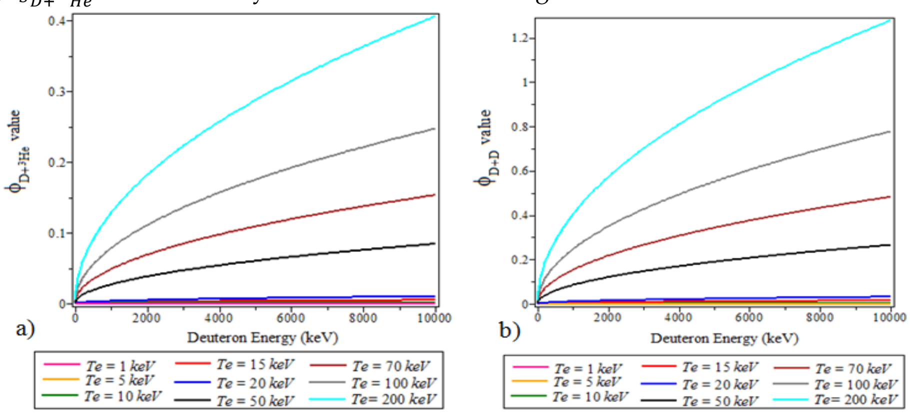
$$\varepsilon_{D+D} = E_I \left(1 + \varphi_{D+D}\right) \qquad (7-2)$$

so it is seen that φplays the role of a"bonus energy" for deuteron driven fast ignition. To avoid confusion, please note that the ε here is the total energy deposited by the ion beam plus any contribution from its beam-target fusion in the hot spot, but not the total input energy to the target which is often cited in energy studies and represents the total laser compression plus fast ignition energy delivered to the total target ,also the deuteron stopping range and stopping time can be calculated by following equations (Xiaoling etel, 2011):

$$R_S = \int_{E_{th}}^{E_I} v_D dE / \left(\frac{dE}{dt}\right) \qquad (8)$$

$$t_S = \int_{E_{th}}^{E_I} dE / \left(\frac{dE}{dt}\right) \qquad (9)$$

Where, $\left(\frac{dE}{dt}\right)$are calculated from Eqs.(5) for D+^{3}He reactions ,the deuteron velocity is $v_D = \sqrt{\frac{2E}{m_D}}$.For calculating the total energy deposited into the target of D+^{3}He mixture at first step we substitute equation (6) into equation (5),then at second step the obtained result is replaced into equation.(4) and at third step the result of second step is inserted into equation (3) and we compute, $F_{D+\,^3He}$ and F_{D+D} in D+^{3}He reaction at step 4 we use these parameters for determining of φ_{D+D} $and \varphi_{D+\,^3He}$.Finally, results are delivered by the last step inserted inEq.(7) and thus we have the numerical values of $\varepsilon_{D+\,^3He}$,ε_{D+D} in D+^{3}He for $10^{26} \le n_e(cm^{-3}) \le 10^{28}$, $0 \le T_e(keV) \le 200$ and deuteron energy E, with range of $0 \le E(MeV) \le 10$. Also under these conditions we can calculate the deuteron stopping range and stopping time by using equations(8) and (9)for D+^{3}He mixture .These parameters are denoted respectively by, $t_{S_{D+\,^3He}}$,$R_{S_{D+\,^3He}}$.The given numerical results are given in Figs.5 to 12. Figure.5 show the results of our calculations of $\varphi_{D+\,^3He}$, φ_{D+D} ,$\varepsilon_{D+\,^3He}$andε_{D+D} in the case of $n_e = 10^{26}(cm^{-3})$. Please note that in order to have a better comparisonof the numerical values of $\varphi_{D+\,^3He}$, φ_{D+D} ,$\varepsilon_{D+\,^3He}$andε_{D+D} in each cases and stressing out theirchanges with temperature and electron densitywe show their maximum values in Table.2. From Figure.5 we see that multiplication factors φ_{D+D} ,$\varphi_{D+\,^3He}$ increase by increasing temperature from 1 to 200keV (resonance temperature of D+^{3}He) The value of total energy deposited in hot spot ($\varepsilon_{D+\,^3He}$and ε_{D+D}) by increasing temperature from 1 to 200keV increases(see Table.2). Also ,the value of total energy deposited by increasing deuteron energy in range of 0 to 10000keV increases(see Figure.5). By increasing electron density from $n_e = 10^{26}$ to $10^{28}\,(cm^{-3})$ the amount of total deposited energy of $\varepsilon_{D+\,^3He}$ and ε_{D+D} and also the amount of multiplication factors$\varphi_{D+\,^3He}$ and φ_{D+D} are decreased(see Table.2). Comparing numerical values of multiplication factors φ_{D+D} and $\varphi_{D+\,^3He}$ we can say that φ_{D+D} is higher than $\varphi_{D+\,^3He}$ .Therefore the total energy deposited ε_{D+D} is higher than $\varepsilon_{D+\,^3He}$ (see Table.2). From Figure.6,we see clearly that the stopping time remarkablyincreases by increasing temperature from 1keV to 200keV , also $t_{S_{D+\,^3He}}$ increases by increasing deuteron energy. We must notice that the values of $t_{S_{D+\,^3He}}$ is reduced by increasing electron density, n_e ,from $10^{26}$to $10^{28}(cm^{-3})$.In the 3 D pictures, the temperature-dependence of$t_{S_{D+\,^3He}}$is manifest. Numerical results of $t_{S_{D+\,^3He}}$ show that stopping time increases with temperature. The effect of helium-3 density ($n_{\,^3He}$) from $10^{22}$to $10^{24}(cm^{-3})$ is important on the value of $t_{S_{D+\,^3He}}$ and in this range this quantity is reduced (by factor O(10) to O(100). In Figs.7-9 show that stopping range ($R_{S_{D+\,^3He}}$) strongly increases with temperature from 1 to 200keVand also deuteron energy is an effective parameter on the stopping power such that by increasing this energy $R_{S_{D+\,^3He}}$ is increased. But the numerical values of $R_{S_{D+\,^3He}}$ are decreased by increasing electron density n_e from 10^{26} to $10^{28}cm^{-3}$. The other parameter affects the numerical values of $R_{S_{D+\,^3He}}$is target density (ρ). If ρ changes from 0.5 to 2.5(mg/cm^3), stopping range is increased. Also, the other effective parameter decreasing stopping range is,$n_{\,^3He}$. Our calculation shows that by changing $n_{\,^3He}$ from $10^{22}$to $10^{24}cm^{-3}$,$R_{S_{D+\,^3He}}$ is decreased by one or two orders of magnitude.



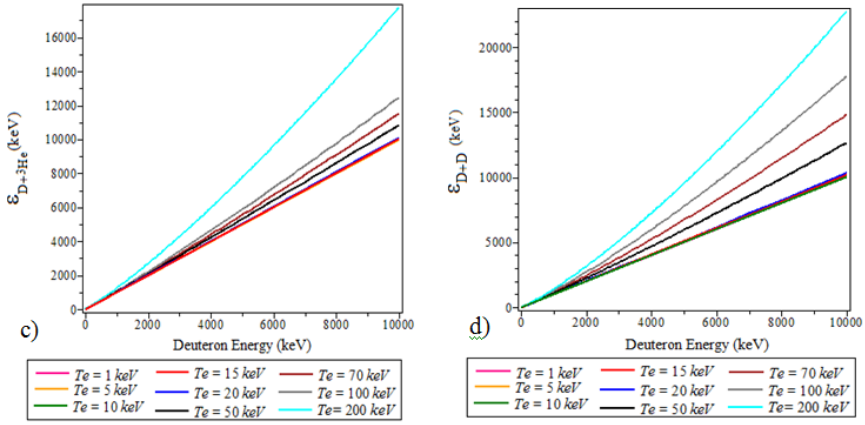
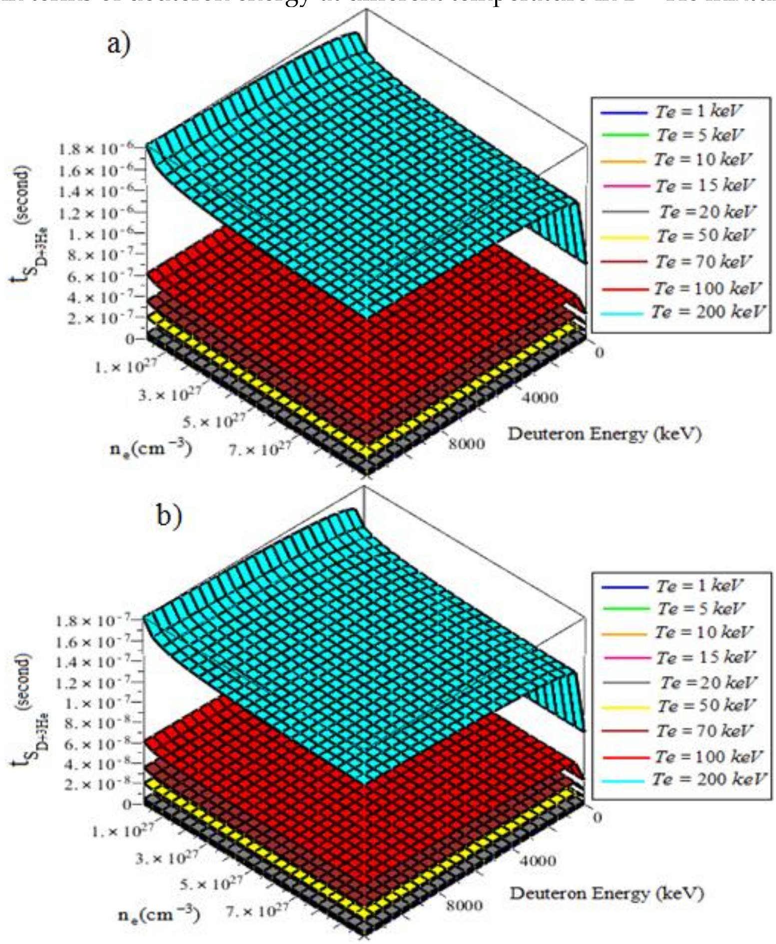


Figure 5: The two dimensional variation of a) $\varphi_{D+{}^3He}$ b) φ_{D+D} c) $\varepsilon_{D+{}^3He}$ d) ε_{D+D} in terms of deuteron energy at different temperature in D+[3]He mixture for $n_e = 10^{26} cm^{-3}$.



c)

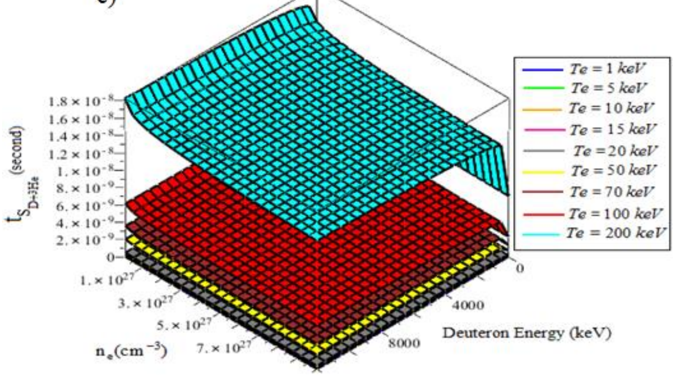
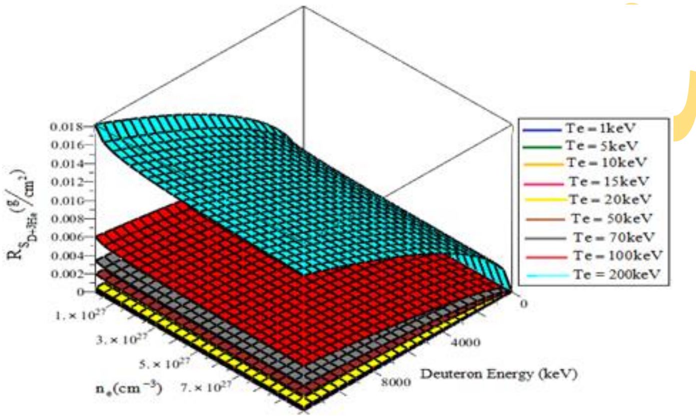
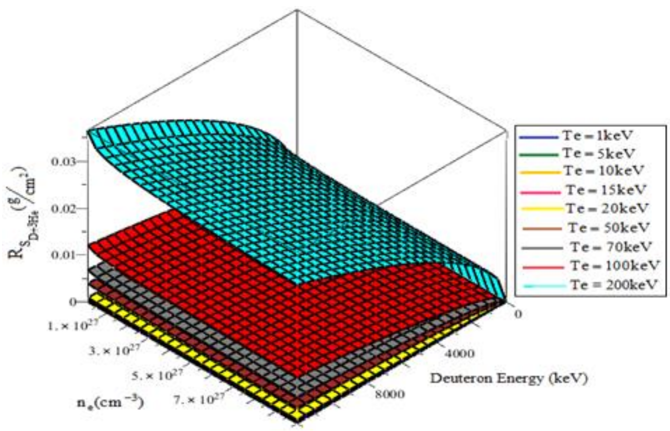


Figure 6: Three dimensional variations of stopping time versus electron density and deuteron energy at different temperatures in different density of ^{3}He a) $n_{^3He} = 10^{22}(cm^{-3})$ b) $n_{^3He} = 10^{23}(cm^{-3})$ c) $n_{^3He} = 10^{24}(cm^{-3})$.

a) $\rho = 0.5\,(mg/cm^3)$ and $n_{^3He} = 10^{22}(cm^{-3})$



b) $\rho = 1\,(mg/cm^3)$ and $n_{^3He} = 10^{22}(cm^{-3})$



c) $\rho = 2.5\ (mg/cm^3)$ and $n_{^3He} = 10^{22}(cm^{-3})$

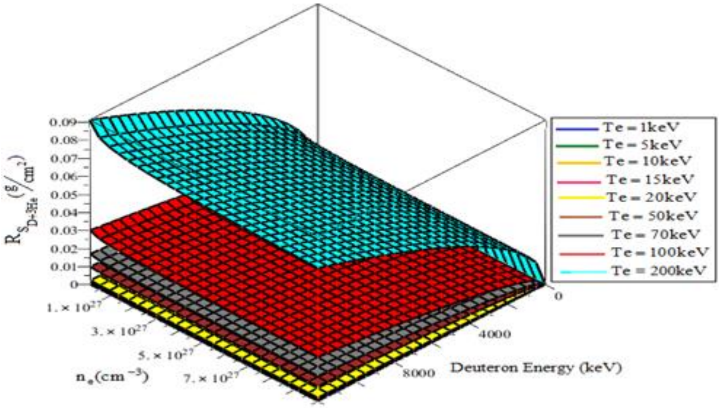
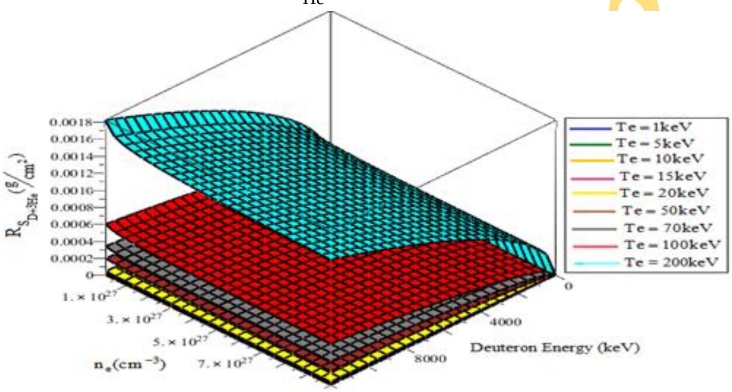
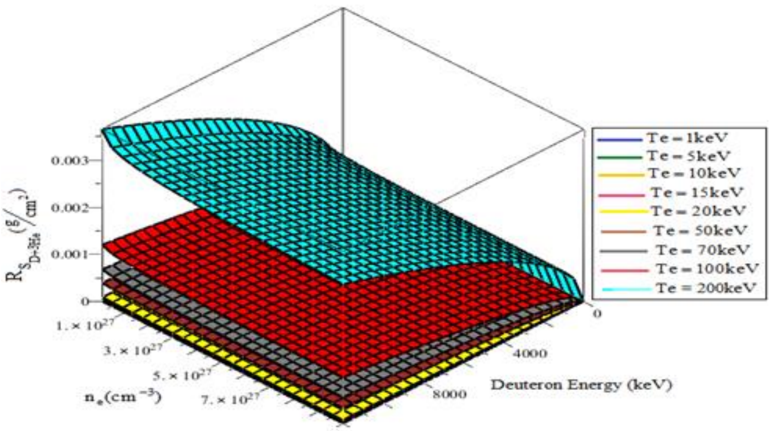


Figure7: The three dimensional variations of stopping range versus electron density and deuteron energy at different temperatures for three cases a) ,b) and c) in D+^{3}He mixture.

a) $\rho = 0.5\ (mg/cm^3)$ and $n_{^3He} = 10^{23}(cm^{-3})$



b) $\rho = 1\ (mg/cm^3)$ and $n_{^3He} = 10^{23}(cm^{-3})$



c) $\rho = 2.5\ (mg/cm^3)$ and $n_{^3He} = 10^{23} (cm^{-3})$

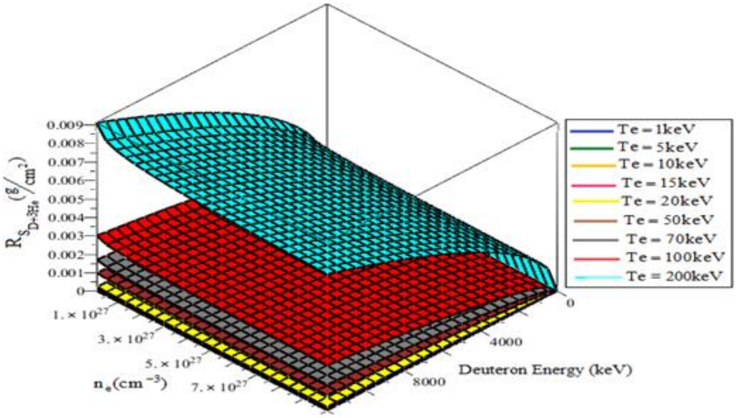
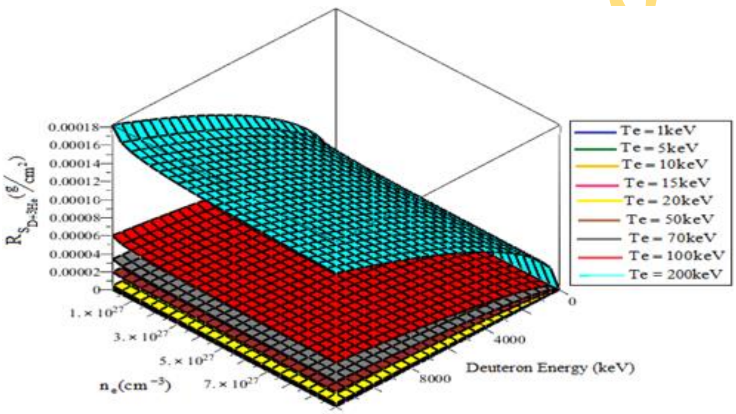
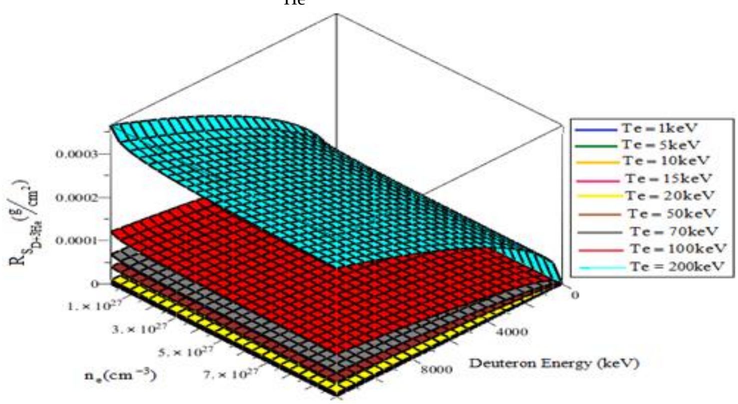


Figure 8: The three dimensional variations of stopping range versus electron density and deuteron energy at different temperatures for three cases a) ,b) and c) in D+[3]He mixture.

a) $\rho = 0.5\ (mg/cm^3)$ and $n_{^3He} = 10^{24} (cm^{-3})$



b) $\rho = 1\ (mg/cm^3)$ and $n_{^3He} = 10^{24} (cm^{-3})$



c) $\rho = 2.5\ (mg/cm^3)$ and $n_{^3He} = 10^{24}(cm^{-3})$

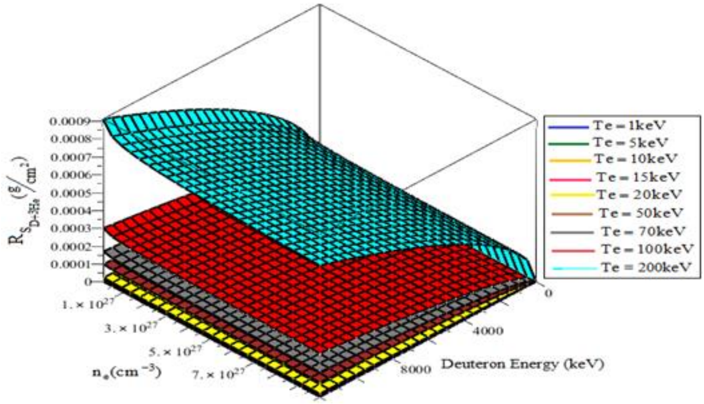


Figure 9: The three dimensional variations of stopping range versus electron density and deuteron energy at different temperatures for three cases a) ,b) and c) in D+^{3}He mixture.

BALANCE EQUATIONS OF DEUTERIUM-HELIUM3 MIXTURE

The following system of equations is used to describe the temporal evolution of plasma parameters averaged over the volume (the density of deuterium ions n_D ,density of helllium-3 ions $n_{^3He}$, density of thermal alpha-particles n_α , plasma energy E), for D+^{3}He nuclear fusion reaction :

$$\frac{dn_D}{dt} = -\frac{n_D}{\tau_P} - n_D n_{^3He}\langle\sigma v\rangle_{D+{^3He}} + S_D \qquad (10-1)$$

$$\frac{dn_{^3He}}{dt} = -\frac{n_{^3He}}{\tau_P} - n_D n_{^3He}\langle\sigma v\rangle_{D+{^3He}} + S_{^3He} \qquad (10-2)$$

$$\frac{dn_\alpha}{dt} = -\frac{n_\alpha}{\tau_\alpha} + n_D n_{^3He}\langle\sigma v\rangle_{D+{^3He}} \qquad (10-3)$$

The energy balance is given by

$$\frac{dE}{dt} = -\frac{E}{\tau_E} + Q_\alpha n_D n_{^3He}\langle\sigma v\rangle_{D+{^3He}} - P_{rad} \qquad (10-4)$$

S_D, *and* $S_{^3He}$ are the source terms which give us the fuel rates; τ_α, τ_P, and τ_E are the lifetimes of thermal alpha-particles, deuterium and helium-3, and the energy confinement time, respectively, also the energy of the alpha particles is: $Q_\alpha = 3.52 MeV = 3.6 \times 10^6 \times 1.6 \times 10^{-19} J$ .The radiation loss P_{rad} is given by:

$$P_{rad} = P_{brem} = A_b Z_{eff} n_e^2 \sqrt{T} \qquad (11)$$

where $A_b = 5.35 \times 10^{-37} \frac{Wm^3}{\sqrt{keV}}$ is the bremsstrahlung radiation coefficients. No explicit evolution equation is provided for the electron density n_e since we can obtain it from the neutrality condition $n_e = n_D + n_{^3He} + 2n_\alpha$, whereas the effective atomic number, the total density and the energy are written as:

$$Z_{eff} = \frac{\sum_i n_i Z_i^2}{n_e} = \frac{n_D + n_{^3He} + 4n_\alpha}{n_e} \qquad (12)$$

where , Z_i is the atomic number of the different ions. The fusion energy gain is defined as : $G(t) = \frac{E_f(t)}{E_{driver}}$, where $E_f(t)$ is equal to the energy due to the number of occurred fusion reactions in target in terms of time and E_{driver} is the required energy for triggering fusion reactions in hot spot and is equal to 4MJ(Pfalzner, 2006). Also the fusion power density for D+^{3}Hereaction is given by$P_{D+{}^3He} = n_D(t) n_{{}^3He}(t) < \sigma v >_{D+{}^3He} Q_{D+{}^3He}$where $Q_{D+{}^3He} =$ 18.3MeV. We solve equations (10-1) , (10-2) , (10-3) and (10-4) in dynamical state (time-dependent density of atoms) with the use of computers (programming, Maple-15) under available physical conditions .Our computational obtained results are given in Figs.10 to 12.From Figs.10 to 12 we see clearly that ,by increasing temperature from 1 keV to 200keV the variations of deuterium and helium-3 density in terms of time $(n_D(t), n_{{}^3He}(t))$ are decreased since by increasing time the consumption rate of $n_D(t)$ and $n_{{}^3He}(t)$ are increased.But the changes of $n_D(t)$ and $n_{{}^3He}(t)$,in all temperature are similar and as we see in Figs.10 to 12 they coincide each other.لطفا چک شودThus, by increasing temperature 1keV to 200keV the variations of alpha density $(n_\alpha(t))$ versus time at first by increasing time is increased and then decreased while the production rate of fusion plasma energy $(E_f(t))$ increases and is maximized at resonant temperature of 200keV,because at this temperature the highest number of D+^{3}He fusion reaction occurs.The numerical values of these quantities $(n_\alpha(t)$ and $E_f(t))$ are decreased at temperature higher than 200keV since temperature 200keV is resonant temperature for D+^{3}He mixture .Also, our calculations show that by increasing the injection rate of deuterium and helium-3 $(S_D and S_{{}^3He})$ from 10^{22} to $10^{24} cm^{-3}$ the rate of variations of $n_D(t)$ and $n_{{}^3He}(t)$ in terms of time are increased while $n_\alpha(t)$ and $E_f(t)$ increase. We expect that at this temperature, energy gain and fusion power density are maximized .Therefore ,for the calculation of theseparameters we use of $S_D = S_{{}^3He} = 10^{24} cm^{-3}$(see Table.3).

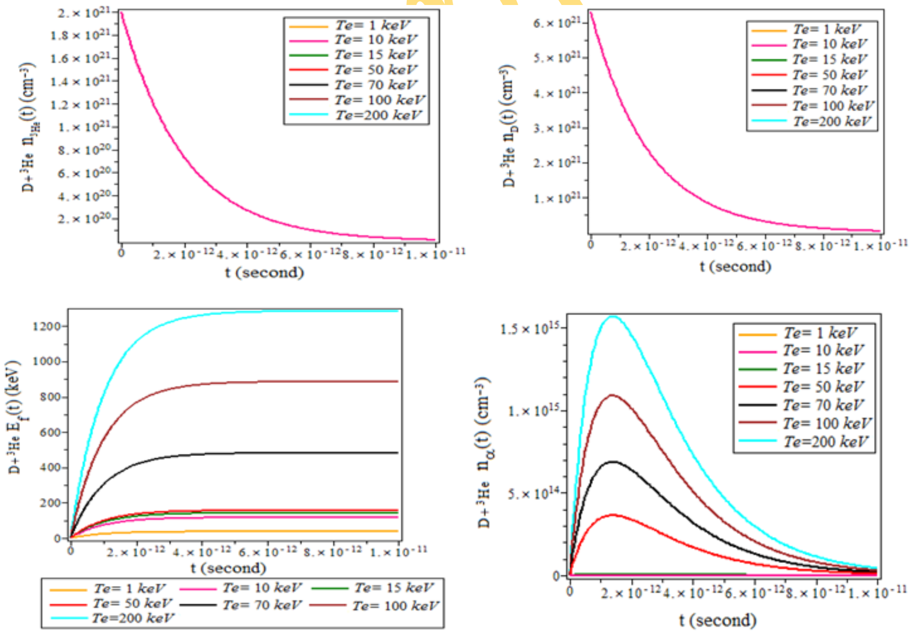


Figure 10: The two dimensional variations of deuterium , helium-3 and alpha particles densities and plasma energy in terms of time at different temperatures for D+^{3}He mixture under choosing $S_{{}^3He} = 0.20 \times 10^{22} (cm^{-3})$ and $S_D = 0.63 \times 10^{22} (cm^{-3})$.

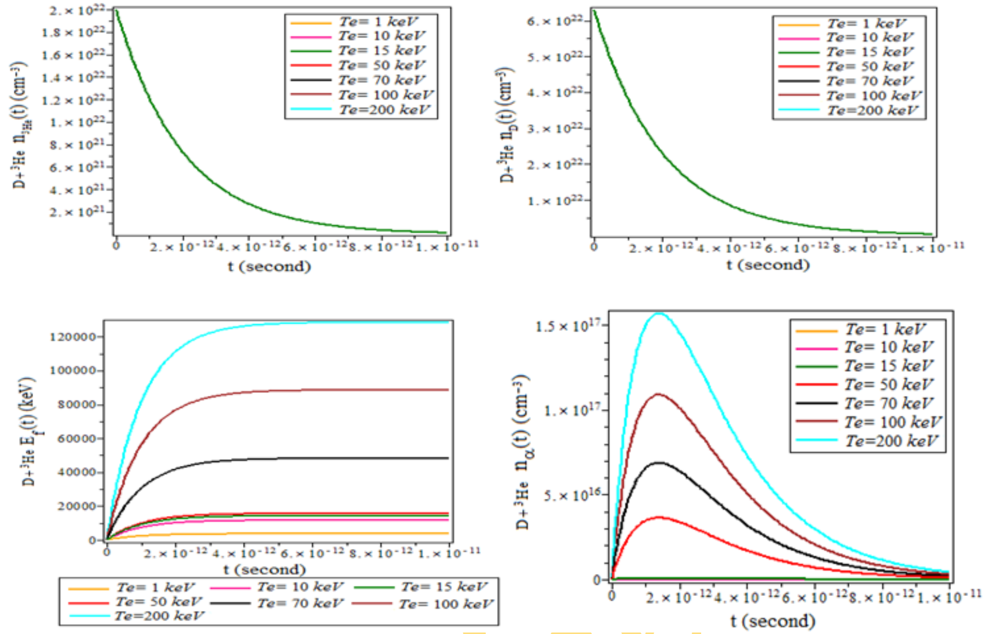


Figure 11: The two dimensional variations of deuterium , helium-3 and alpha particles densities and plasma energy in terms of time at different temperatures for D+[3]He mixture under choosing $S_{^3He} = 0.20 \times 10^{23} (cm^{-3})$ and $S_D = 0.63 \times 10^{23} (cm^{-3})$.

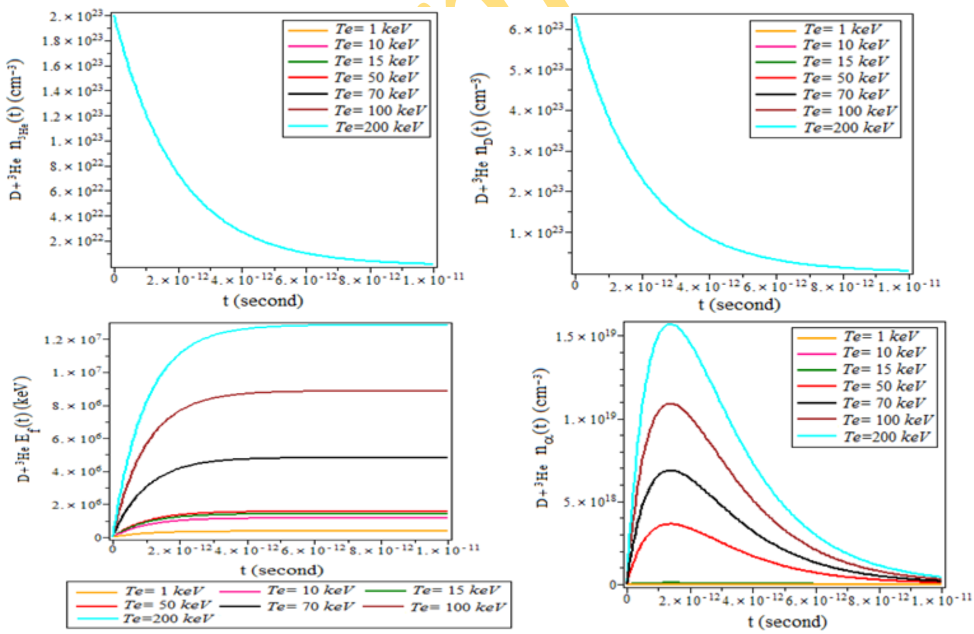


Figure 12: The two dimensional variations of deuterium, helium-3 and alpha particles densities and plasma energy in terms of time at different temperatures for D+[3]He mixture under choosing $S_{^3He} = 0.20 \times 10^{24} (cm^{-3})$ and $S_D = 0.63 \times 10^{24} (cm^{-3})$.

Table.2: Maximum numerical values of total energy deposited in D+^{3}He mixture at different temperature for $10^{26} \leq n_e(cm^{-3}) \leq 10^{28}$.

D+^{3}He					
$n_e(cm^{-3})$	T_e(keV)	$\varepsilon_{D+{}^3He_{max}}$(keV)	$\varepsilon_{D+D_{max}}$ (keV)	$\varphi_{D+{}^3He_{max}}$	$\varphi_{D+D_{max}}$
10^{26}	15	10047.58856	10149.90397	0.0047588563	0.0149903974
10^{26}	50	10840.82266	12648.59138	0.0840822661	0.2648591382
10^{26}	100	12466.83449	17770.52865	0.2466834492	0.7770528649
10^{26}	200	17770.52865	22778.7444	0.4056744253	1.27787444
10^{27}	15	10043.55314	10137.19238	0.0043553138	0.0137192384
10^{27}	50	10762.58435	12402.14071	0.0762584353	0.2402140712
10^{27}	100	12223.67403	17004.5732	0.2223674032	0.7004573201
10^{27}	200	17004.5732	21439.64967	0.3631634817	1.143964967
10^{28}	15	10040.14861	10126.46811	0.0040148607	0.0126468114
10^{28}	50	10697.66667	12197.65001	0.0697666669	0.2197650008
10^{28}	100	12024.14982	16376.07194	0.2024149822	0.637607194
10^{28}	200	16376.07194	20354.58457	0.3287169706	1.035458457

Table.3: Time dependent numerical values of fusion power density and target energy gain.

D+^{3}He $S_D = 0.63 \times 10^{24}(cm^{-3})$, $S_{^3He} = 0.20 \times 10^{24}(cm^{-3})$			
T_e (keV)	t (s)	$P_{D+{}^3He}(t)(\frac{W}{cm^3})$	$G_{D+{}^3He}(t)$
15	10^{-20}	450.12E15	0.0057096E-22
15	10^{-11}	204.35E11	0.57096E-16
15	60	180.05E-8	2.7702E-8
15	110	180.05E-8	0.047945E1
50	10^{-20}	2127.69E16	0.0062723E-22
50	10^{-11}	965.87E12	0.62713E-16
50	60	851.07E-7	3.0428E-8
50	110	851.07E-7	0.052664E1
100	10^{-20}	639.25E17	0.035428E-22
100	10^{-11}	290.13E13	3.5422E-16
100	60	255.73E-6	1.7186E-7
100	110	255.73E-6	0.29745E1
200	10^{-20}	920.77E17	0.051412E-22
200	10^{-11}	417.87E13	0.51397E-15
200	60	368.31E-6	2.4982E-7
200	110	368.31E-6	0.47692E1

CONCLUSION

The advantages of D+^{3}He over D+T appear as full-lifetime materials ,reduced radiation damage ,less activation ,absence of tritium breeding blankets ,highly efficient direct energy conversion ,easier maintenance, proliferation resistance .D+^{3}He reaction is very attractive from a theoretical point of view since it does not produced neutrons. A D+^{3}He fueled fusion reactor would also possess substantial safety and environmental advantages over D+T. Efficient D+^{3}He fusion energy would benefit terrestrial electricity ,space power , and space propulsion. Fusion using D+^{3}He fuel requires significant physics developments particularly for plasma confinement in high performance alternate fusion concept. Economically accessible^{3}He on earth exists in sufficient quantities (a few hundred kg ,equivalent to few thousand MW-years of fusion power) for an engineering test . In a D+^{3}He fuel mixture D+D reaction fusion also occursThe main difficulties for D+^{3}He reaction are the high temperature conditions and the scarceness of ^{3}He on earth. Therefore,from the abovediscussion we select the D+^{3}He mixture and estimate dynamically energy gain by calculating the deuteron beam energy deposited in the fuel target. The deposited energy can reduce laser driver energy. Our calculations show that at200keV (resonant temperature) the maximum number of fusion reactions are obtained. and the energy gain is maximized. The maximum calculated energy gain under optimum conditions $S_D = 0.63 \times 10^{24}(cm^{-3})$, $S_{^3He} = 0.20 \times 10^{24}(cm^{-3})$ and resonant temperature 200keVand t= 110s is approximately equal to 4.77.

REFERENCES

A. Caruso and V. A. Pais, Nucl. Fusion 36, 745 (1996);Phys. Lett. A 243, 319 (1998).
A. Maksimchuk, S. Gu, K. Flippo, D. Umstadter, and V. Y. Bychenkov,Phys. Rev. Lett. 84, 4108 (2000).
A. Maksimchuk, S. Gu, K. Flippo, et al., Phys. Rev. Lett. 84, 4108 (2000).
C. Bathke, H. Towner, and G. H. Miley, Trans. Am. Nucl. Soc. 17,41 (1973).
C.Li and R.D.Petrasso,Phys.Plasmas.Vol.2,No.6,2460 (1995).
D. J. Rose and M. Clark, Jr., Plasmas and Controlled Fusion MIT Press, Cambridge, MA, (1965).
D.Baie-Quan ,Y.gian-Cheng,D.Mei-Gen,P.Li-Lin,Chin. Phys.Lett.Vol.19,No.7,962 (2002).
E. L. Clark, K. Krushelnick, J. R. Davies, et al., Phys. Rev. Lett. 84, 670 (2000).
G. H. Miley, Fusion Energy Conversion American Nuclear Society,Hinsdale, IL, (1976).
H. Schwoerer, S. Pfotenhauer, O. Jackel, K. U. Amthor, Ziegler, R. Sauerbrey, K. W. D. Ledingham, and T. Esirkepov ,Nature London439,445 (2006)
J D LindlPhys Plasmas 2 3933 (1995) and Phys Plasmas 11 339 (2004)
J. R. Rygg, J. A. Frenje, C. K. Li, F. H. Séguin, R. D. Petrasso,J. A. Delettrez, V. Yu. Glebov, V. N. Goncharov, D. D. Meyerhofer,P. B. Radha, S. P. Regan, and T. C. Sangster,PHYSICS OF PLASMAS14,056306(2007).
J.P.Freidberg , "Plasma Physics and Fusion Energy" ,Cambridge University Press ,New York (2007).
K. A. Tanaka, R. Kodama, H. Fujita, et al., Phys. Plas-mas 7, 2014 (2000).
M Tabak et al Phys Plasmas 1 1626 (1994)
M TEMPORAL J Honrubia, S Atzeni. Phys. Plas.9,3102,(2002)
M. L. Shmatov, J. Br. Interplanet. Soc. 57,362(2004).
M. L. Shmatov, J. Br. Interplanet. Soc. 60,180 (2007).
N. Naumova, T. Schlegel, V. T. Tikhonchuk, C. Labaune, I. V. Sokolov,and G. Mourou, Phys. Rev. Lett. 102, 025002 (2009).
N.G. Basov, S.Y. Guskov and L.P. Feokistov, J. Sov. Laser Res. 13, 396 (1992).
S .Pfalzner, "An Introduction to Inertial Confinement Fusion", Published by CRC Press Taylor & Francis Group (2006).
S E Bodner et al. Phys Plasmas 5, 1901 (1998)
S. P. Hatchett, C. G. Brown, T. E. Cowan, et al., Phys. Plasmas 7, 2076 (2000).
V. Bychenkov, W. Rozmus, A. Maksimchuk, D. Umstadter, and C.Capjack, Plasma Phys. Rep. 27, 1017 (2001).
V. T. Tikhonchuk, T. Schlegel, C. Regan, M. Temporal, J.-L. Feugeas, P.Nicolaï, and X. Ribeyre, Nucl. Fusion 50, 045003 (2010).
XiaolingYang,George H. Miley,Kirk A. Flippo, and Heinrich Hora, PHYSICS OF PLASMAS 18, 032703 (2011)
Xing Z. Li, Qing M. Wei and Bin Liu, Nucl. Fusion 48 ,125003 (5pp) (2008).