Republic of Iraq
Ministry of Higher Education and Scientific Research
University of Baghdad
College of Education for Pure Science
(Ibn Al-Haitham)
Physics Department

Studying to Deduce the Energy Distribution Function for Proton-Triton Fusion Reaction

A Thesis Submitted To

The Council of the College of Education for Pure Science Ibn Al - Haitham / University of Baghdad as a Partial Fulfillment of the Requirements for the Degree of Master in Physics

By

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B.Sc. in Physics / College of Education for Pure Science / Ibn Al-Haitham / University of Baghdad, 2012

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2019 A D 1441 A H

بسم الله الرحمن الرحيم

﴿ وَعَلَّمَكَ مَا لَمْ تكُنْ تَعْلَمُ وكَانَ
فَضْلُ اللَّهِ عَلَيْكَ عَظِيماً ﴾

صدق الله العلي العظيم

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Dedications

To the spirit of my Father and brother martyr Mohammed

To the most precious human beings my dear mother

I would like to thank my dearest people (my wife and my children) have been the greatest role in supporting me to accomplish this work with their continuous encouragement and prayers.

To those who have demonstrated to me what is the most beautiful on the life, my brothers and my sisters

Finally, my enduring gratitude goes to my friends for their unfailing encouragement, support in my endeavors and study.

I dedicate you this humble work...

Acknowledgment

In the beginning, praise is to Allah for helping me in everything. I would like to express my deepest gratitude to everyone who has given me the support, I needed to complete this thesis.

I would like to express deep extend my thanks and my appreciation and gratitude to Dr. **Mustafa Kamel Jassim** for his invaluable help and his attention.

To Prof. Dr. **Raad Hameed Majeed**, my supervisor, I am grateful for the trust deposited in my work and for the motivation demonstrated along this arduous course. His support was without a doubt crucial in my dedication to this investigation.

I would like also to express my thank to Dr. **Enas Ahamed Jawad** for her support.

In the end, I would like to thank all who taught me a letter and illuminated the way to me and saved me from the darkness of ignorance.

Ali

Abstract

We conducted a theoretical study of the effect of changing the temperature (T) of the medium (plasma) on the form of energy depended distribution function (EDDF).

The interaction between the protons resulting from the acceleration Ion Cyclotron Radio Frequency (ICRF) and the thermal tritons in the nuclear-endothermic reaction in the magnetically fusion plasma associated can be represent a source of neutrons which have a multipurpose application. The threshold of the fast proton reaction with thermal triton is about (1MeV) and a peak cross-section at about (3MeV).

The (EDDF) for the particles that plays as a reactant their physical profile depends strongly on the fuel temperature and subsequently can by completely describe by a program model contains all the physical equations control the (EDDF) behavior. That means the (EDDF) may by reach a common form call it (steady state), and finally we can select the more suitable temperature. In general, it is necessary to explain the energy distribution function on which any nuclear fusion interaction is based before deducing or determining the characteristic parameters of a particular reaction The steady state in the behavior of the distribution function give a horizon fact that we have reached a suitable or compatible case and therefore we can be dealing with such fusion parameters

In this study, multiple and variable values of mean temperature with (plasma) was used. The strong dependence of the energy distribution function of the incident protons has been shown on plasma temperature. The best case of the energy distribution function is achieved when the mean temperature was in range ($700 \leq T \leq 800$) keV and this range corresponds to the experimental results.

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Abbreviations and Acronyms

Symbol	Description	unit
Q	Released energy	MeV
T	Temperature	K
Q_{υ}	The neutrino energy	eV
S	Astrophysical factor	MeV. barn
ϵ_G	Gamow Energy	$keV^{1/2}$
D-D	Deuterium- Deuterium fusion reaction	--
D-T	Deuterium- Tritium fusion reaction	--
T-T	Tritium - Tritium fusion reaction	--
P-T	proton - Triton fusion reaction	--
D-^{3}He	Deuterium - Helium-3 fusion reaction	--
Q_{DT}	Released energy Deuterium- Triton fusion reaction	MeV
E_{pCM}	Incidence proton energy in center-of-mass frame	MeV
$E_{th,lab}$	Incidence Proton energy in laboratory frame	eV
E_p	Proton Energy	eV
JET	Joint European Torus	--
ICRF	Ion Cyclotron Radio Frequency	--
E_n	Neutron Energy	MeV
MCF	Magnetic Confinement Fusion	--
RF	Radio-frequency	Hz
ECRF	Electron Cyclotron Radio Frequency	--
CM frame	Centre-of-mass frame	--
σ	Cross Section	barn
EDF	Energy Distribution Function	eV^{-1}
N_p	Protons density	m^{-3}
N_T	Tritons density	m^{-3}

Ȥ	Position vector	m
E	Energy	MeV
F (Ȥ, E)	Distribution function	--
T_T	Tritons temperature	K
U_{pt}	Proton triton reaction rate	--
R	Proton velocity	m/sec
N_p(Ȥ)F (Ȥ, E) R(E)	local fast proton flux	--
σ_{pt}	Cross-Section Proton - Tritium Fusion Reaction	barn
K_{pt}	Total proton triton reaction rate	--
V	Plasma volume	m^3
K.E	Kinetic energy	MeV
F_T (E)	Simple form distribution function	--
T_p (Ȥ)	local fast ion temperature	K
H(Ȥ)	local fast proton energy density	ev /cm^3
$Q_{pt}(T)$	The reaction rate depends on the temperature only	--
h_{Fast}	Total energy in fast ions	MeV
T_{Fast}	Fast ion temperature	K
$Ȥ_0$	Position vector around the peak	--
T_0	Peak temperature	K
A	Half-width peak	MeV
$f_{par}(E)$	A spatially averaged distribution function	--
B	Bessel function	--
$< E >$	The average particle energy	keV
$Q_{pt,par}(T_0)$	The equivalent reaction rate depends on the temperature	--
f_{par}	Equivalent distribution function	--
$E_{\|\|}$	Parallel energy	keV

$T_{\parallel}$	Parallel temperature	K
$T_{\perp}$	Vertical temperature	K
$E_{\perp}$	Vertical energy	keV
$F_{\parallel}(E_{\parallel})$	Parallel energy distribution function	--
$F_{\perp}(E_{\perp})$	Vertical energy distribution function	--
$F(E_{\parallel}, T_{\parallel})$	Parallel and vertical energy distribution function	--
erf	Error function	--
n	Particle Density	m^{-3}
B	Magnetic field	Tesla
^{1}H	Proton	--
^{2}H ,D	Deuterium	--
^{3}H,T	Triton	--
W	The number of reactions per unit time per nucleus.	--
I	The number of incident particles per unit time per unit area	--

Chapter One

INTRODUCTION

GENERAL INTRODUCTION

(1.1) Nuclear Reaction

When a collision occurs between two nuclear particles, the first (projectile) and the second can be fixed (target), nuclear reaction products subject to the laws of the conservation [1]. In the case of two nuclear objects approaching each other at very close distance (10^{-15}m). This process is called (nuclear reaction) and includes the redistribution of energy and momentum [2]. The nuclear reaction can be represented in a form similar to the chemical reactions that must balance the mass on both sides of the equation [3][4].

$$a + X \rightarrow b + Y \qquad (1-1)$$

where a = incident particle

X = target

b = light reaction product

Y = heavy reaction product

Nuclear reactions can be classified into three models. These models are used to describe the interaction of (incident) particles with a nucleus (target), where a new nucleus is formed [5]. First Model (Compound nucleic reactions). In this First Model, the nuclear reaction is divided into two parts. The first, the incident particle, remains in the nucleus for a relatively long time (10^{-14} s). The energy of the incident particle is distributed throughout the nucleus [5]. In this case, it cannot be distinguished from the other nucleus in the composite nucleus. In the second model of this model, the kinetic energy of the incident particle to the nuclear bonding energy can equal the excitation energy of the composite nucleus. Energy in this process is distributed statistically among the nucleons. There is a change in the nucleons because they collide rapidly [5][6]. Sometimes the final nucleus resulting from this interaction is itself the composite nucleus. [7]. In the second model (Pre compound reaction), If the energy of the incident particle (above 10MeV).

A particle emission can occur before the power distribution between the nucleus within the nucleus is carried out. A collision occurs between the nucleus with each other, and energy changes due to collisions [5]. In the third model (direct interaction) the particle incident spent less time in the vicinity of the nucleus (target) (10^{-22}s) In this case a nuclear interaction can occur between the incident particle and the target near the surface of the nucleus [6].

(1.2) Principles of Nuclear Fusion

For fusion nuclear reactions, the main principle is that two lighter nuclei merge to form a heavier and more stable nucleus, this will result in nuclear rearrangement resulting in a decrease in total mass. This will result in the release of energy in the form of kinetic energy divided into reaction products. The best way to supply energy is to heat the fuel to a high enough temperature so that the nuclei 'thermal velocities are high enough for fusion. This is the process that is going on constantly in the sun and the stars. In the heart of the sun at temperatures ranging between (10-15) million degrees Celsius, in this process is converted hydrogen to helium, this will provide sufficient energy to not collapse due to gravity forces. In order to achieve and maintain the reaction for a substantial period of time, temperatures of the order of ($100\ x10^{6}\ C^{0}$ (10^{4} eV)) and a density of about ($10^{20}m^{-3}$) are required. Under these conditions, the fuel changes its state from gas to plasma, in which the electrons are separated from the atoms; these atoms would become charged ions [8].

(1.3) Plasma

The word plasma comes from Greek and means "molded thing". It was first applied by Tonks and Langmuir, in 1929, to describe the inner region, away from the boundary, for ionized gas occurring by electrostatic discharge in a tube, and ionizing gas as a complete non-electrically neutral. Plasma is found in local dynamic thermal balance in many places in nature, as in astrophysical plasma, it is not common in the laboratory. There are many different ways to create plasma in vitro, which may be a high or low density, high or low temperature, it may be steady state or transient, stable or unstable, depending on how they are configured, and so on. Plasma is produced by raising the temperature of the material until a reasonable partial ionization is obtained. Under conditions of thermodynamic equilibrium, there is a relationship related to the degree of ionization and temperature of the electron by the equation of Saha, which explained this correlation. Plasma can also be generated by ionizing processes that raise ionization far above the value of its thermal balance. One of the methods of plasma photoionization production is ionization occurs by absorbing the photons whose energy is equal to, or greater than, the ionization and the potential of absorbed atoms. The excess energy of the photons is transformed into kinetic energy from the pair of ionizing electrons. Ionization can be produced by X-rays or gamma rays, another way to produce the plasma through the gas discharge process is when an electric field is applied through the ionized gas, this will increase the speed of the free electrons to a higher energy that may be sufficient to ionize other atoms by collisions, one of the advantages of this process is that the electric field applied will transport energy more efficiently to light electrons compared to relatively heavy ions. This will result in an electron temperature in the discharge of gas normally higher than the temperature of ions, because the transfer of thermal energy from electrons to heavy ion is very slow [9]. The word plasma is used in physics to designate the high temperature between the charged particles and waves as the temperature of a material is raised, its state changes from solid to liquid and then to gas. If the temperature is elevated further, an appreciable number of the gas atoms are ionized and become the high temperature gaseous state in which the charge numbers of ions and electrons are almost the same and charge neutrality is a macroscopic scale. When the ions and electrons move collectively, these charged particles interact with coulomb force which is long range force and decays only in inverse square of the distance between the charged particles. The resultant current owes due to the motion of the charged particles and Lorentz interaction takes place. Therefore, many charged particles interact with each other by long range forces and various collective movements occur in the gaseous state. The typical cases are many kinds of instabilities and wave phenomena [10]. Plasmas are often called a fourth state of matter. If the temperature is further increased, then the atoms decompose into freely moving charged particles (electrons and positive ions), and the substance enters the plasma state [11]. It can be said that plasma is a group of charged particles that are neutral over a small size if we want to comparing their dimensions. Although the plasma is apparently neutral, it is not neutral at the microscopic scale [12]. Plasma is formed under the condition that the average kinetic energy of an electron substantially exceeds the average need for an ion to bind the electron [13].

(1.3.1) The Criteria That Distinguish Plasma

Plasma has some properties [14].

1- The particle density n (measured in particles per cubic meter).

2- The Temperature T of each species (measured in eV, where 1eV=11.605K).

3 - The steady state magnetic field B (measured in Tesla).

In the middle and late 21st century some countries were taken fusion energy that is a potential source of energy production, fusion reaction occurs within the plasma composed of light nuclei. In order to confinement plasma and facilitate the fusion process, magnetic or inertial means which affect the method of integrative confinement affect the types of radiation and fuel materials that must be controlled by the health physicists. A commercial power plant has been used for this purpose [15].

(1.4) Nuclear Fusion Reaction

One of the most famous examples of nuclear fusion reactions are those stars and sun that were burned for billions of years. In contrast to nuclear fission, heavy nuclei, such as the release of Uranium and energy, begin to merge into light elements and synthesize them so that they can be combined to form heavier elements. The resulting elements of this reaction have a somewhat less mass of components starting to interact and this mass difference leads to the release of energy [16]. The best example of a nuclear fusion is that it is produced in the stars or the sun. The first isotope is used for hydrogen (H), which is called (^{1}H) Protium. The fusion process occurs because of very high temperature and high pressure, which leads to the separation of the nucleons and then returns to form another type of new nuclei. The minimum required for the heat of this process is approximately 40 trillion degrees [17]. Nuclear fusion reactions are combined reactions from light nuclei to heavier. When the total nuclei after nuclear fusion are smaller than the total before the reaction, we call it a major defect. According to the theory of relativity, the amount of energy is released by nuclear fusion. Nuclear reactions in favor of fusion reactors [10]. Interactions between light nuclei require two conditions, very high temperatures and very high pressure to fuse the reacting nuclei. The material that provides these conditions named as plasma it contains of photon, neutral atoms, positive ions and electrons [18] [19].

Table (1.1) Some important fusion reactions and parameters of the cross-section factorization [20]

Fusion Reaction	Q (MeV)	$\langle Q_v \rangle$ (MeV)	S (0) (keV. barn)	$\epsilon_G^{1/2}$ (keV$^{1/2}$)
Main controlled fusion fuels				
$D+T \longrightarrow {}^4He + n$	17.59		1.2×10^4	34.38
$D + D \longrightarrow \{ T+P$	4.04		56	31.40
${}^3He + n$	3.27		54	31.40
${}^4He + \gamma$	23.85		4.2×10^{-3}	31.40
$T + T \longrightarrow {}^4He + 2n$	11.33		138	38.45
Advanced fusion fuels				
$D + {}^3He \longrightarrow {}^4He + p$	18.35		5.9×10^3	68.75
$p + {}^6Li \longrightarrow {}^4He + {}^3He$	4.02		5.5×10^3	87.20
$p + {}^7Li \longrightarrow 2\,{}^4He$	17.35		80	88.11
$p + {}^{11}B \longrightarrow 3\,{}^4He$	8.68		2×10^5	150.3
the p-p cycle				
$p + p \longrightarrow D + e^+ + \upsilon$	1.44	0.27	4.0×10^{-22}	22.20
$D + p \longrightarrow {}^3He + \gamma$	5.49		2.5×10^{-4}	25.64
${}^3He + {}^3He \longrightarrow {}^4He + 2p$	12.86		5.4×10^3	153.8
CNO cycle				
$p + {}^{12}C \longrightarrow {}^{13}N + \gamma$	1.94		1.34	181.0
$[\,{}^{13}N \longrightarrow {}^{13}C + e^+ + \upsilon + \gamma]$	2.22	0.71	_	_
$p + {}^{13}C \longrightarrow {}^{14}N + \gamma$	7.55		7.6	181.5
$p + {}^{14}N \longrightarrow {}^{15}O + \gamma$	7.29		3.5	212.3
$[\,{}^{15}O \longrightarrow {}^{15}N + e^+ + \upsilon + \gamma]$	2.76	1.00	—	_
$p + {}^{15}N \longrightarrow {}^{12}C + {}^4He$	4.97		6.75×10^4	212.8
Carbon burn				
${}^{12}C + C^{12} \longrightarrow \{ {}^{23}Na + p$	2.24		8.83×10^{19}	2769
${}^{20}Na + {}^4He$	4.62			
${}^{24}Mg + \gamma$	13.93			

(1.5) Hydrogen Isotopes Fusion Reactions

Hydrogen(H) is the first and smallest element in the periodic table (Mendeleev's Table), which is widely found in nature and has an atomic weight (1.0078amu). Hydrogen possesses three natural isotopes. [^{1}H,^{2}H,^{3}H], Isotopes are characterized by hydrogen (^{1}H) Protium and the second (^{2}H) deuterium as stable as opposed to the third counterpart (^{3}H) Triton [21]. shown in Fig. (1-1), The hydrogen isotope, the first, simplest and most common, neutron-free is sometimes (scientifically) called "Protium". Its ion (nucleus) is called Proton (isotope = Protium; ion = Proton). The second isotope of hydrogen for Deuterium, symbol D or ^{2}H, if we remove it one electron one obtains its ion (nucleus) called Deuteron (isotope = Deuterium; ion = Deuteron). The third isotope of hydrogen Tritium, symbol T or ^{3}H, if remove one electron it obtains its ion (nucleus) called Triton (isotope = Tritium; ion = Triton). First two isotopes of hydrogen, Protium and Deuterium are stable and the third is unstable is with a half-life of 12.32 years. All other heavier hydrogen isotopes that are known today are synthetic and have a half-life of fewer than 10 seconds (10-21 seconds). Of these, ^{5}H is the most stable and ^{7}H is the smallest [22]. The development of thermonuclear fusion for use as a never-ceasing power source is a challenging field of research. Over 50 years of fusion studies have led to a variety of reactor concepts and significant progress in the fields of plasma physics and nuclear engineering. There is an enormous potential for a fusion-powered reactor. Fuel can be taken from the sea and would last for thousands of years with no radioactive fuel waste produced. The advantages of nuclear fusion relate to the type of fuel chosen. Hydrogen isotopes, deuterium and tritium, are used as reactants. T is an artificial isotope bred from lithium (Li) isotopes, abundantly available on earth, as is D (about 30 ppm in earth's water) [23]. Tritium (having the symbol T or ^{3}H because it is also known as hydrogen-3) is a radioactive isotope of hydrogen. The tritium nucleus, i.e. tritium ion (called Triton) contains a proton and two neutrons. Natural tritium is rarely found on Earth, where the amount of traces is formed by the interaction of the atmosphere with the cosmic rays. It can be produced by irradiating lithium ceramic pearls or metal lithium in a nuclear reactor. Tritium is sometimes used as a radioactive marker in radio luminescent light sources for instruments and watches and together with deuterium is used as a nuclear fuel for nuclear fusion reactions with applications in nuclear power generation as well as nuclear weapons. The name is derived from the Greek third (trítos), i.e. "the third" [17] [24].

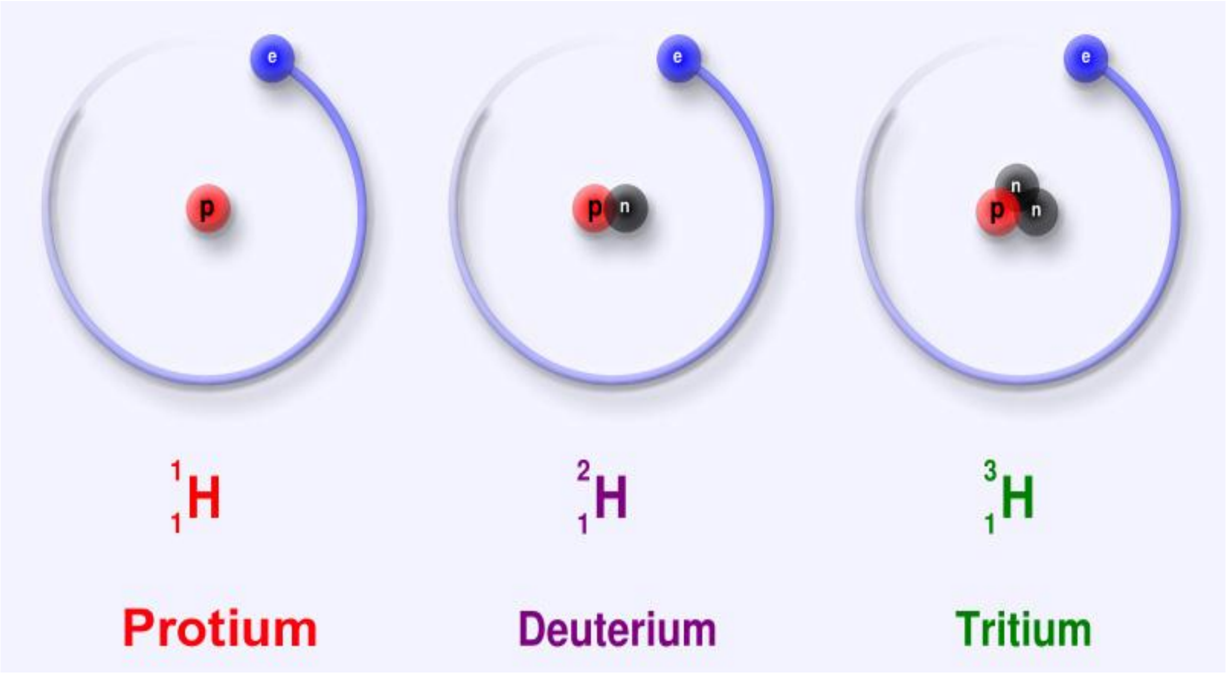

Fig. (1-1) Isotopes of the three hydrogen [24].

(1.6) Production Methods Tritium

Tritium is produced in nuclear reactors by neutron activation of lithium-6. This is possible with neutrons of any energy and is an exothermic reaction yielding 4.7 MeV, shown in Table (1.2).

$${}_{3}^{6}\mathrm{Li} + \mathrm{n} \rightarrow {}_{2}^{4}\mathrm{He} + 2.05\ \mathrm{MeV} + {}_{1}^{3}\mathrm{T} + 2.75\ \mathrm{MeV} = {}_{2}^{4}\mathrm{He} + {}_{1}^{3}\mathrm{T} + 4.748\ \mathrm{MeV} \qquad (1\text{-}2)$$

High-energy neutrons can also produce tritium from lithium-7 in an endothermic (a net heat consuming reaction) reaction, consuming 2.466 MeV. This was discovered when the 1954 Castle Bravo nuclear test produced an unexpectedly high yield. Virtually a high energy neutron is introduced and is obtained another one of low energy [25].

$${}_{3}^{7}\mathrm{Li} + \mathrm{n} + 2.466\ \mathrm{MeV} \rightarrow {}_{2}^{4}\mathrm{He} + {}_{1}^{3}\mathrm{T} + \mathrm{n} \qquad (1\text{-}3)$$

Using high energy neutrons to irradiate boron 10, occasionally tritium and helium can be obtained [25].

$${}_{5}^{10}\mathrm{B} + \mathrm{n} \rightarrow 2\,{}_{2}^{4}\mathrm{He} + {}_{1}^{3}\mathrm{T} \qquad (1\text{-}4)$$

The interaction of two nuclei of the deuterium can also produce one nucleus of triton with a proton in a fusion reaction with a free energy [26], shown in Table (1.2)

$${}_{1}^{2}\mathrm{D} + {}_{1}^{2}\mathrm{D} \rightarrow {}_{1}^{3}\mathrm{T} + {}_{1}^{1}\mathrm{H} + 4.03\ \mathrm{MeV} \qquad (1\text{-}5)$$

(1.6.1) Production Methods Proton

The first isotopes of hydrogen can be produced by deuterium reaction with the helium isotopes shown in Table (1-2), [27].

$${}_{1}^{2}\mathrm{D} + {}_{2}^{3}\mathrm{He} \rightarrow {}_{2}^{4}\mathrm{He} + {}_{1}^{1}\mathrm{H} + 18.3\ \mathrm{MeV} \qquad (1 - 6)$$

Or through helium isotopes interacting with each other to produce a pair of proton nuclei with energy (12.9MeV), [27].

$$ {}_{2}^{3}\mathrm{He} + {}_{2}^{3}\mathrm{He} \rightarrow {}_{2}^{4}\mathrm{He} + 2\,{}_{1}^{1}\mathrm{H} + 12.9\ \mathrm{MeV} \qquad (1-7) $$

And by a nuclear reaction between deuterium and the lithium isotopes

$$ {}_{1}^{2}\mathrm{D} + {}_{3}^{6}\mathrm{Li} \rightarrow {}_{3}^{7}\mathrm{Li} + {}_{1}^{1}\mathrm{H} + 5.0\ \mathrm{MeV} \qquad (1-8) $$

And by Fusion the nucleus of the lithium isotopes with the helium isotopes to produce the proton [27].

$$ {}_{2}^{3}\mathrm{He} + {}_{3}^{6}\mathrm{Li} \rightarrow 2\,{}_{2}^{4}\mathrm{He} + {}_{1}^{1}\mathrm{H} + 16.9\ \mathrm{MeV} \qquad (1-9) $$

(1.7) Some Important Fusion Reactions

In comparison to chemical reactions, where the released energies are in the range of a few eV, fusion operates in the MeV range. That is why a rather small amount of fusion fuel produces a huge amount of energy, a million times more than in simple fuel combustion [28].

Nuclear fusion energy is the energy source of our universe. It is the origin of energy in our sun and in the stars. shown in Table (1-1), [29].

$$ {}_{1}^{1}\mathrm{H} + {}_{1}^{1}\mathrm{H} \rightarrow {}_{1}^{2}\mathrm{H} + e^{+} + \upsilon_{e} + 1.44\ \mathrm{MeV} \qquad (1-10) $$

$$ {}_{1}^{1}\mathrm{H} + {}_{1}^{2}\mathrm{H} \rightarrow {}^{3}\mathrm{He} + \gamma + 5.5\ \mathrm{MeV} \qquad (1-11) $$

$$ {}^{3}\mathrm{He} + {}^{3}\mathrm{He} \rightarrow \alpha + 2\,{}_{1}^{1}\mathrm{H} + 12.9\ \mathrm{MeV} \rightarrow 4\,{}_{1}^{1}\mathrm{H} \qquad (1-12) $$

$$ \rightarrow \alpha + 2e^{+} + 2\upsilon_{e} + 2\gamma + 26.3\ \mathrm{MeV} $$

where: ${}_{1}^{1}\mathrm{H}$, ${}_{1}^{2}\mathrm{H}$, ${}^{3}\mathrm{He}$, and α are proton, deuterium, helium-3, helium-4 , $e+$, γ, υ_{e} , are the positron, gamma, and neutrino respectively [29]

In 1939, Hans Bethe suggested that the energy source of stars more massive than our sun is obtained by the carbon cycle. This cycle is described by the following nuclear reactions [29]. shown in Table (1-1)

$$ {}_{1}^{1}H + {}^{12}C \rightarrow {}^{13}N \rightarrow {}^{13}C + e^{+} + \nu + \gamma \qquad (1-13) $$

$$ {}_{1}^{1}H + {}^{13}C \rightarrow {}^{14}N + \gamma \qquad (1-14) $$

$$ {}_{1}^{1}H + {}^{14}N \rightarrow {}^{15}O + \gamma \rightarrow {}^{15}N + e^{+} + \nu + \gamma \qquad (1-15) $$

$$ {}_{1}^{1}H + {}^{15}N \rightarrow {}^{12}C + {}^{4}He \qquad (1-16) $$

In the first stage a proton reacts with a ^{12}C nucleus to form nitrogen ^{13}N, which is unstable and decays to ^{13}C. Further stages build up through ^{14}N and ^{15}O to ^{15}N, which then reacts with a proton to form ^{12}C and ^{4}He. At the end of the sequence the ^{12}C has been recycled and can start another chain of reactions, so it acts as a catalyst. Overall four protons have been replaced with a single helium nucleus, so the energy release is the same as for the p-p cycle [29].

Table (1.2): Summary of fusion reactions between some light nuclei and their Q values [30].

No.	Reaction	Q (MeV)
1	$n + {}^{6}Li \rightarrow {}^{4}He + t$	4.7
2	$n + {}^{7}Li \rightarrow {}^{4}He + t + n$	-2.5
3	${}_{1}^{2}D + {}_{1}^{2}D \longrightarrow t + {}_{1}^{1}H$	4.03
4	${}_{1}^{2}D + {}_{2}^{3}He \longrightarrow {}_{2}^{4}He + {}_{1}^{1}H$	18.3
5	${}^{3}He + {}^{3}He \rightarrow {}^{4}He + 2{}_{1}^{1}H$	12.9
6	${}_{1}^{2}D + {}_{3}^{6}Li \longrightarrow {}_{3}^{7}Li + {}_{1}^{1}H$	5.0
7	${}_{2}^{3}He + {}_{3}^{6}Li \longrightarrow 2{}_{2}^{4}He + {}_{1}^{1}H$	16.9
8	$t + p \rightarrow {}^{3}He + n$	- 0.76
9	$D + {}^{3}He \rightarrow {}^{4}He + p$	18.35
10	$D + {}^{3}He \rightarrow {}^{5}Li + \gamma$	16.5
11	$t + {}^{3}He \rightarrow {}^{4}He + p + n$	12.1
12	$t + {}^{3}He \rightarrow {}^{4}He + D$	14.3
13	$D + D \rightarrow {}^{4}He + \gamma$	23.6
14	$D + t \rightarrow {}^{5}He + \gamma$	16.6
15	$t + t \rightarrow {}^{4}He + 2n$	11.3
16	$D + t \rightarrow {}^{4}He + n$	17.59
17	$D + D \rightarrow {}^{3}He + n$	3.27

(1.8) The Important Nuclear Fusion Reaction for Hydrogen Isotopes

(1.8.1) The D-T Reaction

when deuterium and tritium nuclei, are brought together, they fuse and form a helium nucleus and a neutron; the mass difference is liberated as 17.6 MeV of energy. Energy releases in the form of the kinetic energies to produce nuclei [16]. We consider the reactions between the hydrogen isotopes deuterium and tritium, which are most important for controlled fusion research, has the largest cross-section, which reaches its maximum (about 5 barn) (1 barn=10^{-24}cm^{2}) at the relatively energy Approximately of (64 keV) shown in Fig. (1-3). Its Q_{DT} = 17.6 MeV is the largest of this family of reactions [31] [32]. shown in Table (1-2)

$$ {}_{1}^{2}\mathrm{H} + {}_{1}^{3}\mathrm{H} \rightarrow {}_{2}^{4}\mathrm{He} + {}_{0}^{1}\mathrm{n} + 17.6\ \mathrm{MeV} \qquad (1\ \text{-}17) $$

It is possible to say that this reaction, which is easier because of excess neutrons on the nuclei of deuterium and tritium, leads to an increase in volume and thus increases the probability of fusion reaction. It also has the smallest possible positive charge (since hydrogen contains only one proton), making it relatively easy to have the two nuclei overcome their repulsion and fuse together [32].

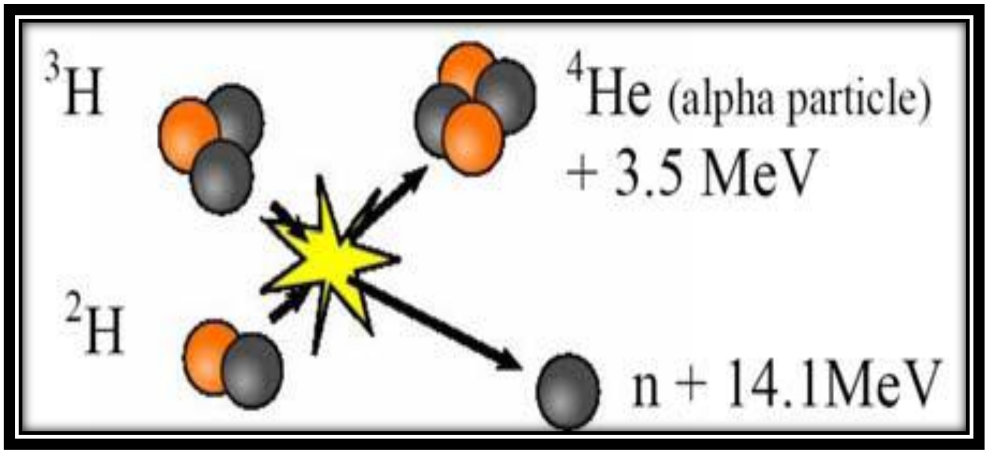

fig. (1-2) D-T reaction [33].

(1.8.2) The T-T Reaction

When this interaction occurs, the outputs are an alpha particle and a pair of neutrons with released energy (11.3 MeV) have cross section comparable to that of D-D. shown in Fig. (1-3). Note that since the interaction has three products, the energies associated with each are not uniquely determined by conservation laws [31].

$$ {}_{1}^{3}\mathrm{H} + {}_{1}^{3}\mathrm{H} \rightarrow {}_{2}^{4}\mathrm{He} + 2\,{}_{0}^{1}\mathrm{n} + 11.3\mathrm{MeV} \qquad (1\text{ -}18) $$

Tritium is only radioactive isotope of hydrogen. The nucleus of a tritium atom consists of a proton and two neutrons. Tritium comprises about 10^{-16} percent of natural hydrogen. Because not little tritium is naturally present, it must be produced artificially for use on a practical scale. Tritium can be made in production nuclear reactors, i.e., reactors design to optimize the generation of tritium and special nuclear materials such as plutonium-239. Tritium is produced by neutron absorption of a lithium-6 atom. The lithium-6 atom with three protons and three neutrons and the absorbed neutron combine to form a lithium-7 atom with three protons and four neutrons which instantaneously splits to form an atom of tritium and an atom of helium – 4 [34].

(1.8.3) The P-T Reaction:

The main nuclear fusion reactions (^{2}H–^{3}H, ^{2}H –^{2}H and ^{2}H –^{3}He) occur in the fusion plasma magnetically confined, and other reactions occur if the plasma contains ionic assemblies with highly supra-thermal energy distribution. Fusion nuclear reaction between the incident proton with triton in the endothermic reaction.

The interaction of nuclear fusion T (p, n)^{3}He and its inverse [^{3}He (n, p) T] is very important in many branches of physics, this interaction has many distinctive characteristics, including the large cross section. In fusion physics, a reaction [T (p, n)^{3}He] is used to produce neutrons. Interaction [^{3}He (n, p) T] is often used in neutron physics to detect neutrons. This interaction provides information about excited (^{3}He) levels that are poorly understood [35,36,37]. In fusion plasma, the thermonuclear reaction between protons and triton is one of the most important sources of neutron production [37]. In this reaction, the proton requires a threshold energy greater than (E_{pCM} =764keV) in the center-of-mass reference frame calculated from [38], and higher than (E_p > 1019keV), its threshold ($E_{th,,lab}$)[39]. Fast protons are produced in the Joint European Torus (JET) Tokamak [40]. The protons are heated by Ion Cyclotron Radio Frequency (ICRF), Neutrons resulting from the interaction of protons with triton possess a wide spectrum of energy because the proton produced by Ion Cyclotron Radio Frequency (ICRF) heated has a large range of energy, the resulting neutron energy was calculated by extracted from [41].

$$E_n = 0.75 \times (E_{pCM} - 764\ \mathrm{keV}) \qquad (1\ \text{-}19)$$

The nuclear interaction between the proton and the triton is characterized by having the highest cross-section in nuclear fusion plasma (hydrogen isotope reactions) If it is a proton energy E_{pCM} > 2MeV [37]. shown in Fig. (1-3) The proton-triton interaction was used to measure the temperature of protons heated by Ion Cyclotron Radio Frequency (ICRF), when no other measurement methods were available such as neutral particle analysis or γ ray spectroscopy [39]. A number of complex magnetic confinement fusion (MCF) machines have been devised to generate a plasma and to provide the necessary electric and magnetic fields to achieve confinement of the discharge. The first successful ring-shaped fusion machine was developed by scientists of the U.S.S.R. around 1960. They called it tokamak, an acronym in Russian for toroid−chamber−magnet−coil. Plasmas of MCF machines must be heated to reach the necessary high temperature. Various methods have been devised to supply the thermal energy. Method uses microwaves in a manner similar to their application for cooking. The energy supply is a radio-frequency (RF) generator. It is connected by a transmission line to an antenna next to the plasma chamber. The waves enter the chamber and die out there, delivering energy to the charges. If the frequency is right, resonant coupling to natural circular motions of electrons or ions can be achieved. The phrases electron (or ion) cyclotron radio-frequency, (ECRF) (or ICRF) the distribution function of ICRF-heated ions becomes strongly anisotropic, with the perpendicular temperature much higher than the parallel temperature, [42]. When studying high-energy nuclear reactions such the p-T reaction, the interaction kinetics are anisotropic The anisotropic in the interaction affects the form of the resulting neutrons spectrum. The proton at the beginning of the reaction has a large energy that will lose a large part of this initial energy to start the Nuclear fusion reaction in the center-of-mass frame, the increase energy residual after the proton with Triton reaction is split according to inverse particle masses, 1/4 for the helium nucleus and 3/4 for the neutron (ICRF) is characterized by its ability to control the accelerated particle and the resulting particle from (ICRF). (proton) is anisotropic in properties the vertical energy is greater than the parallel energy ($E_\perp \gg E_\parallel$) and produces a high-energy neutron [43] [44]. In this study it was assumed that the target (triton) in rest, however, shows that the thermal movement of the target has very little effect. In extreme cases, the thermal movement of triton can affect the threshold of the reaction, When the triton has (10keV) the threshold of the reaction is reduced from (1019 keV) to (905keV), and it can also affect the variation in the emission of neutrons [43].

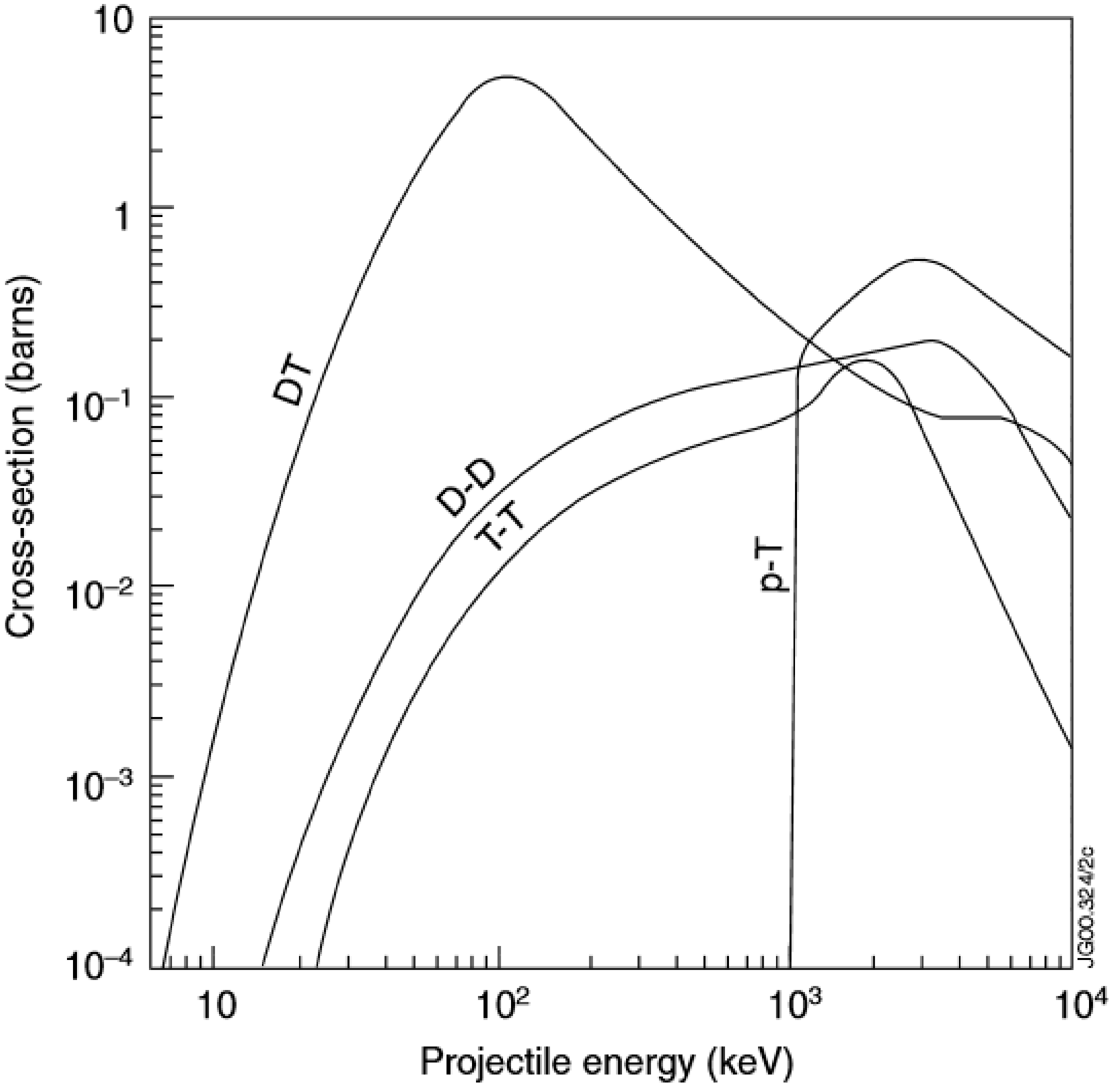

fig (1.3) the cross-section for the fusion reaction involving deuterium, tritium and protons (from [41]). The P-T fusion cross-section is the largest between those typically occurring in fusion plasmas for proton energies (in the center-of-mass frame of reference) above E_{PCM}> 2MeV. [43].

(1.9) Cross Sections of Nuclear Reactions:

To study nuclear reactions in detail, it is necessary to have a quantitative measure of the probability of a given nuclear reaction.

This quantity is one which can be measured experimentally and calculated in such a way that the theoretical and experimental values can be compared readily. The quantity that is most often used for this purpose is the cross section of a nucleus for a particular reaction, usually denoted by(σ) [45]. A most important quantity for the analysis of nuclear reactions is the nuclear cross section, which measures the probability per pair of particles for the occurrence of the reaction [46]. The reaction cross section data provides information of fundamental importance in the study of nuclear systems. The cross section is defined by [47]

$$\sigma = W / I \qquad (1\text{- } 20)$$

where σ is the cross section,

W is the number of reactions per unit time per nucleus.

I is the number of incident particles per unit time per unit area

The concept of a nuclear cross section can be quantified physically in terms of "characteristic area" where a larger area means a larger probability of interaction [48]. A large number of nuclear cross sections are of the order of 10^{-24} cm^2. 1 barn=$10^{-24}cm^2$ or 10^{-28} m^2 [49]. When comparing the cross-section of integrative interactions (D-T, D-D, T-T, P-T). The reaction of D-T contains the largest cross section at (100keV) up to (5 barn). The D-D reaction its cross-section about 100 times smaller than the D-T reaction. In the T-T reaction, the cross section is similar to that of the D-D. Finally, the cross section of the P-T reaction is characterized by having the highest cross-section (reaction of the hydrogen Isotope) if the proton energy is higher than E_{PCM}> 2MeV. [50] [31] [32] [37]. shown in Fig. (1-3).

(1.10) Literature survey

The $p(t,n)^3He$ reaction have been studied since the early days of nuclear physics. These reactions merit continued study for both fundamental and practical reasons. It is sufficient to indicate the several groups, both theoretical and experimental that has devoted their works to study the differential cross sections for p-t reactions. This study begins from 1990's and up to now. So there is a huge number of researches.

S. Cierjacks and Y. Hino and et al in 1990 The fusion materials were selected using a high-energy and high-intensity source and using the interaction of protons with triton as a source for the production of neutrons. The target is a thick hydrogen, but the falling beam is triton (21MeV). A strong neutron produces a continuous card. It features a spectrum (1MeV-14MeV), investigates and discusses the relevant characteristics of this source and its feasibility [51].

C. R. brune and et al in 1999 In this study, the proton interacts with the triton for threshold (4.5MeV). We derived new measurements of the total cross section of this reaction from the proton energy threshold (1.02MeV - 4.5MeV). In this reaction the target was triton. Neutron was produced and detected using a detector (4π), And a resonant structure was observed due to the irritation of the resulting helium nucleus. A new formula was found for the inverse reaction rate of a temperature of less than (10GK). [52]

M.J. Mantsinen and et al in 2001 The interaction of the proton with the triton was studied and the resulting neutron rate was approximately (40%) higher than the neutron rate (14MeV) resulting from the interaction between triton and deuterium minority ions. The interaction of the proton with the triton, the proton, accelerates in (ICRF)pectin. This interaction is explained by the heat-absorbing reactions and the reaction threshold of the proton (1MeV) and the maximum value reached is (3MeV). [53].

M. drosg and et al 2002 The code DROSG-2000 is presented which calculates the kinematic, cross section and yield data of, monoenergetic neutron source reactions based on the following two-body reactions: $^{3}H(p,n)^{3}He$, $^{6}Li(p,n)^{6}Be$, $^{7}Li(p,n)^{7}Be$, $^{9}Be(p,n)^{9}B$. using either the light or the heavy particle of the entrance channel as a projectile. In the (p,n) case the use of the heavy particle as a projectile results in a strong enhancement of the forward neutron yield due to kinematic collimation of the neutrons into a forward cone. In addition, near-threshold neutron production and other more recent trends are discussed [54]

V. M. Bystritsky and at el 2003 A method for measurement of the muon-catalyzed fusion (μCF) parameters in an H–T mixture is proposed. The kinetics of the μ-atomic and μ-molecular processes preceding the pt reaction in the ptμ molecule is described. Analytical expressions are obtained for the yields and time distributions of γ quanta and conversion muons formed in nuclear fusion reactions in p-t μ molecules. It is shown that information on the desired parameters μCF can be found from the joint analysis of the time distributions of γ quanta and conversion muons to be obtained in experiments with the H–T mixture at three (or more) appreciably different atomic concentrations of tritium. The experiments with the H–T mixture at the meson facility PSI (Switzerland) were optimized to gain precise information about the desired μCF parameters [55]

M. I. K. Santala1 and et al 2004 In magnetically confined fusion plasmas, other nuclear reactions can take place in addition to the main D-T, D-D and D-3He fusion reactions. This is especially true, when plasmas contain ion populations with highly supra thermal energy distributions, created e.g. by RF-heating of the plasma ions. p-T fusion is a neutron-producing reaction between tritons and energetic protons with a large cross-section above 1 MeV. it has been observed in JET through excess neutron production in purely RF-heated high-tritium fraction (>90 %) plasmas during the DTE1. We have performed a systematic study of p-T fusion in purely ICRF-heated plasmas with low tritium density typically ($\frac{n_t}{n_e} \sim 1\%$)[56].

D.Testa and et al in 2004 The reaction of triton to the high-energy proton has been studied. This interaction of the heat-absorbing reactions and the reaction product is the neutrons in the tokamak plasma heated by the use of radio frequency waves. We found that the resulting neutron rate in this reaction is constant with the falling proton temperature [57].

G. D. Kim and H. J. Woo, and et al in 2007 the researchers used the interaction of protons with triton to develop a single-energy neutron source. The energies of neutrons and the spread of energy were measured by resonance reactions. The energy used (0.6 MeV- 2.6 MeV) was the energy spread of about (1%) in energy (2.077MeV), indicating that the source of neutrons when information for nuclear reactions is measured through the total cross section [58].

X.J. Xia and W. Ding in 2008, the researchers studied the elasticity of the cross section of the proton pumped from the triton at an angle (165^0) and above. When the proton energy is from (1.4 to 3.4), the increase of the cross section is observed (linear fit). When the energy decreases from 4.5 to 2.3, the resulting data are compared with the available results. There is a difference between the practical results and the available data (2.3%) [59].

M.Cecconello and et al in 2009 A previous investigation of the first measure of the total reaction rate of the proton as a total energy agent was concluded. It was concluded that the rate of neutrons resulting from this study is the result of a previous study of the interaction of the proton with the triton heat-redactor. The result of this reaction is the neutrons in the tokamak plasma heated using radio frequency waves. The reaction is to be increased with proton temperature and total energy content. [60].

R. Lazauskas in 2010 The researcher used the equations of (Faddeev - Yakubovski) to conduct microscopic calculations within the connection area. The elasticity of the low-energy proton in the triton nucleus was derived. Hamilton's nuclear equations were used [61].

A. Deltuva and et al in 2015 Proton's interaction with Triton was studied through elastic scattering and exchange of charge interaction. Consequences were obtained using realistic potential. Differences were found between predictions and obtained data on the ability of proton analysis and polarization of the resulting neutrons. It should be noted that calculations of polarization between proton and neutron are well described [62].

S.B.Dubovichenko and A.V.Dzhazairov-Kakhramanov and et al in 2017 The researchers studied the calculations of the rate of the proton capture reaction on triton when the temperature (0.1-5) obtained by factor (s) at the energies of (1 - 5 keV). This theoretical study contributed to the results when compared with experimental results for agent data (s) in a power field (50 keV – 5 MeV) [63].

L. Girlanda and et al in 2017 The researchers studied (proton scattering with triton) and (neutron with the helium nucleus) in low energies. This study examines the effect of three nucleons. (3NF) In this theory, effective field theory was used

(3NF), using the principle of contrast and harmonic techniques, the results are new with the experimental data obtained. The important conclusion is that the effect of introducing (3NF) is minimal and may lead to variation with experimental data. [64]

R. Lazauskasc and et al in 2018 Some researchers studied proton and neutron at higher energies than helium but below the deuterium-deuterium reaction threshold using three different methods (Alt, Grass Berger and Sand has, Hyper spherical Harmonics, and Faddeev-Yakubovsky). The data obtained from these methods were compared to all elastic exchange processes, a good deal with the three methods can be standard for measurement. [65].

(1.11) The Aims Of This Work:

The fundamental aim for this work is to firstly understanding the physical Behavior of the phenomena controlling the P-T Nuclear fusion reaction.

In turn, we can deal with calculation involving the energy dependences distribution function (EDDF) ،which present the master keys in arriving a more suitable all right case, taken in to account the change of the (EDDF) with different Plasma temperature

Chapter Two

Theory

Theory

(2.1) Reaction Kinematics

A nuclear reaction is the process in which two nuclei, or else a nucleus of an atom and a subatomic particle (such as a proton, neutron, or high energy electron, ...) from outside the atom collide to produce products different from the initial particles. In order to change the number of nucleons in a stable target nucleus, the latter is bombarded with an appropriate projectile-either a charged particle, a neutron or a gamma photon [7]. In different nuclear reactions the condition is to maintain the total energy produced and reactivated. Where the total energy produced, including the remaining mass of the reactants, is equal to the total energy of the blocks of particles produced in the reaction, this means that any increase in kinetic energy of the particles in the reaction is equal to the reduction of the particles interacting particles. The Released energy value of a nuclear reaction may be either positive or negative. If the rest masses of the reactants exceed the rest masses of the products, the Released energy value of the reaction is positive, with the decrease in rest mass being converted into a gain in kinetic energy (K.E) [66]. If Released energy is positive, the reaction is said to be exoergic process, if Released energy is negative, it is endoergic process [67]. These reactions occur only if the required energy is supplied by the (K.E) of the incoming particle [68].

(2.2) Mathematical Modell

The reaction threshold of the proton with triton is higher than (1 MeV). This means that the proton needs much higher energy than the threshold energy to produce neutrons. The rate of the production of neutrons from the proton with Tritons reactions was designed using a simple and general model [69]. As well as by carrying out dedicated simulations with PION code [70].

Protons that have high energy and density $N_p(Ɀ)$, with Triton in the resident state of density $N_T(Ɀ)$, in the plasma. Where the vector of the position Ɀ. And temperature of triton T_t, because Triton in the resident temperature is neglected, the function of the distribution is F (Ɀ, E), the interaction rate of the interaction of the proton with Triton is $U_{pt}(Ɀ)$. The velocity of the protons represents (R), Energy protons represent (E)، and a cross section of the interaction σ_{pt} (E): The rate of reaction can be calculated through folding local fast proton flux is given by [69] $N_p(Ɀ)F(Ɀ, E)\,R(E)$.

$$U_{pt} = \int_0^{\infty} N_p(Ɀ)F(Ɀ, E)R(E)\, N_T(Ɀ)\sigma_{pt}(E)dE \qquad (2\text{-}1)$$

Where $N_P(Ɀ)$ is Protons density, $F(Ɀ, E)$ is Distribution function, $R(E)$ is Proton velocity, $N_T(Ɀ)$ is Tritons density and $\sigma_{pt}(E)$Cross-section proton - tritium fusion reaction.

Of the plasma volume (V), integration of the reaction rate is U_{pt} (Ɀ). We can get the total reaction rate of proton with triton K_{pt}[69].

$$K_{pt} = \int_V N_p(Ɀ)N_T(Ɀ)dⱫ \int_0^{\infty} F(Ɀ, E)R(E)\sigma_{pt}(E)\, dE \qquad (2\text{-}2)$$

Where K_{pt} is the total reaction rate of proton with triton

Equation (2-2) can be simplified, if we assume that the distribution function is in a model 2D-Maxwellian. If the distribution function and other coefficients are known in the equation (2-2), the integration is highly accurate [69].

$$F_T(E) = \frac{1}{T}\exp\left(-\frac{E}{T}\right) \qquad (2\text{-}3)$$

The proton density can be represented in the equation (2-4), if the ion temperature is fast T_p (Ϛ)and the high-energy proton density $H(Ϛ)$ is known in equation (2-4) [69]

$$N_p(Ϛ) = \frac{H(Ϛ)}{T\,(Ϛ)} \qquad (2\text{-}4)$$

The total reaction rate can be expressed in the following formulas (after simplification).

$$K_{pt} = \int_V N_T\,(Ϛ)H(Ϛ)/T(Ϛ)dϚ \int_0^\infty F_t(Ϛ\,, E)R(E)\sigma_{pt}(E)\,dE\,d\,Ϛ \qquad (2\text{-}5)$$

Because of temperature dependence the energy integration is as follows. It can be evaluated independently as in the following equation.

$$Q_{pt}(T)\equiv \frac{1}{T}\int_0^\infty F_t(E)R(E)\sigma_{pt}(E)\,dE \qquad (2\text{ - }6)$$

Where $Q_{pt}(T)$the reaction rate is depends on the temperature only. Eq. (2-6) Represents rate of reaction depends on the temperature only and the reaction rate becomes [69]

$$K_{pt} = \int_V N_T\,(Ϛ)H(Ϛ)Q_{pt}(T(Ϛ))dϚ \qquad (2\text{-}7)$$

An appropriate cross-section (σ_{pt}) and a temperature-dependent reaction rate can be used to compensate for the triton density (N_T) and to find an appropriate value for the total rate of the proton interaction with Triton. Triton density Which spatial dependence is weak if the fast ions are present in the core of the plasma. If the high-energy group of protons is characterized by a single temperature, this will erode spatial dependence A simple model of the interaction of protons with triton is obtained. [69]

$K_{pt} = N_T h_{Fast} Q_{pt}(T)$ (2-8)

Where h_{Fast} is total energy in fast ions.

The predicted rate of nuclear reaction between the proton and triton for total energy in fast ions approximately to 1 MJ and tritons density about 10^{17} m^{-3}.

Where the reaction rate is proportional to (N_T), In plasma fusion conditions the expectation is greater (1000), if the intensity of triton equally to 10^{20} m^{-3}

From Eq. (2-8) the rate of neutrons resulting from the interaction of protons with triton is linearly dependent on both.N_T And h_{Fast} when $T_{Fast}$is kept constant, where (T_{Fast}) is fast ion temperature [69].

From equation (2-8), we note that ($Q_{pt}(T)$), depends largely (linear dependence) on the temperature of the rapid ion. Increasing the temperature of the medium increases the energy of the number of protons that exceed the threshold of the reaction, and when the temperature increases more lead to the largest number of protons at the peak of the cross-section [69].

Note that total energy in fast ions, we need to reconsider to make sure actual proton tail above $E_{th,lab}$. If the spatial temperature described around the peak is accurately described it will result in the use of a simple model T (ζ) around the peak at : $\zeta = \zeta_0$, this will lead us to an equivalent model [69].

where ζ_0 is position vector around the peak and T (ζ) local fast ion temperature

$T(\zeta) = T_0 (1-((\zeta - \zeta_0)/A)^2)$ (2 - 9)

Where A half-width of (T_0) represent peak temperature. Integrating from $\zeta_0 - A$ to $\zeta_0 + A$, one obtains a spatially averaged distribution function f_{par} (E) of the form [69].

$$f_{par}(E) = \frac{B_0}{2T_0}\left(\frac{E}{2T_0}\right)\exp\left(\frac{-E}{2T_0}\right) \qquad (2\text{-}10)$$

Where $f_{par}(E)$ spatially averaged distribution function ,B_0 is the Bessel function.

The following formula is represented the average particle energy $< E > = \frac{2T_0}{3}$ in this distribution [69].

The forms of plasma whose flow is dependent on the same shapes and a common central point can be considered [69].

$Ⱬ_0 - A < Ⱬ < Ⱬ_0 + A$.

Symmetry occurs when $Ⱬ = Ⱬ_0$ is inoperative. This leads unhelpful in the plasma center $Ⱬ_0 < A$.

The shape may be approximated to the equation (2-10). If the energies are too high or ($E > T_0$), the Bessel function is given by [69].

$$B_0(x) \approx \sqrt{\frac{\pi}{2x}}\,\exp(-x) \qquad (2\text{-}11)$$

Where x is Energy (E)

And to compensate for what suits them. It produces us a new situation [69].

$$f_{par}(E) = \sqrt{\frac{\pi}{4T_0E}}\exp\left(\frac{-E}{T_0}\right) \qquad (2\text{-}12)$$

In the interactions of proton fusion with triton, when energies are high. this results in a single Maxwellian distribution. Either at the effective temperatures that are less than T_0. You can specify $Q_{pt,par}(T_0)$, the exact equivalent to Eq(2-6) [69]

$$Q_{pt,par}(T_0) \equiv \frac{3}{2T_0}\int_0^{\infty} f_{Par}(E)R(E)\sigma_{pt}(E)\, dE \qquad (2\text{-}13)$$

Where $Q_{pt,par}(T_0)$ is the equivalent reaction rate depends on the temperature.

The rate of proton interaction with triton is less than for single Maxwellian model.

This is because the average ion temperature is lower in the case of an equivalent distribution if we compare the distribution of a lower temperature [69].

In the proton interaction with triton the important is the hot tail above (1 MeV). The real plasma study does not contain a total distribution of ions the Maxwellian. It is suggested that a more realistic description of the Maxwellian distribution of ionic temperature and density, the proposed model is more accurate because it takes the number of ions peak energy in mind [69].

In the case of differentiated temperatures, the energy distribution function can be derived.

Different distributions of parallel energies ($E_{||}$,$T_{||}$, 1 dimension) and vertical energies can be seen as ($E_\perp$, $T_\perp$, 2 dimensions) [69].

$$F_{||}\left(E_{||}\right)=\frac{1}{\sqrt{\pi\, T_{||}E_{||}}}\exp\left(-\frac{E_{||}}{T_{||}}\right) \qquad (2\text{-}14)$$

$$F_\perp(E_\perp)=\frac{1}{T_\perp}\exp\left(-\frac{E_\perp}{T_\perp}\right) \qquad (2\text{-}15)$$

Because these elements are independent. This leads us to be a common distribution F ($E_{||}$, $E_\perp$)

$$F(E_{\|},E_{\perp}) = F_{\|}(E_{\|}) \, . F_{\perp}(E_{\perp}) \qquad (2\text{-}16)$$

$$F(E_{\|},E_{\perp}) = \frac{1}{\sqrt{\pi\, T_{\|} T_{\perp}^{2} E_{\|}}} \exp\left(-\frac{E_{\|}}{T_{\|}}\right) \exp\left(-\frac{E_{\perp}}{T_{\perp}}\right) \qquad (2\text{-}17)$$

The following formula represents the total energy of vertical and parallel particles $E = E_{\|} + E_{\perp}$. By conducting mathematical processes to determine total energy $E_{\perp} = E - E_{\|}$., integration can be deduced from energy distribution $E_{\|}$: [69].

$$f(E) = \int_{0}^{E} F\,(E_{\|}\,, E - E_{\|}) dE_{\|} \qquad (2\text{-}18)$$

$$f\,(E) = \int_{0}^{E} \frac{1}{\sqrt{\pi\, T_{\|} T_{\perp}^{2} E_{\|}}} \exp\left(-\frac{E_{\|}}{T_{\|}}\right) \exp\left(-\frac{E-E_{\|}}{T_{\perp}}\right) dE_{\|} \qquad (2\text{-}19)$$

$$f\,(E) = \frac{1}{\sqrt{\pi\, T_{\|} T_{\perp}^{2}}} \int_{0}^{E} \frac{1}{\sqrt{E_{\|}}} \exp\left(-\frac{E_{\|}}{T_{\|}} - \frac{E}{T_{\perp}} + \frac{E_{\|}}{T_{\perp}}\right) dE_{\|} \qquad (2\text{-}20)$$

$$f\,(E) = \frac{1}{\sqrt{\pi\, T_{\|} T_{\perp}^{2}}} \exp\left(\frac{-E}{T_{\perp}}\right) \int_{0}^{E} \frac{1}{\sqrt{E_{\|}}} \exp\left(-E_{\|}\left(\frac{1}{T_{\|}} - \frac{1}{T_{\perp}}\right)\right) dE_{\|} \qquad (2\text{-}21)$$

$$f\,(E) = \frac{1}{\sqrt{\pi\, T_{\|} T_{\perp}^{2}}} \exp\left(\frac{-E}{T_{\perp}}\right) \int_{0}^{E} \frac{1}{\sqrt{E_{\|}}} \exp\left(-\frac{E_{\|}}{T^{*}}\right) dE_{\|} \qquad (2\text{-}22)$$

T^{*} can be pointed Using the following formulas

$$\left(\frac{1}{T_{\|}} - \frac{1}{T_{\perp}}\right) = \frac{T_{\perp} - T_{\|}}{T_{\|} T_{\perp}} \equiv \frac{1}{T^{*}} \qquad (2\text{-}23)$$

Using (Mathematica), integration can be found [69].

$$\int \frac{1}{X^{\frac{1}{2}}} \exp\left(-\frac{X}{a}\right) dx = \sqrt{\pi}\ a\ \mathrm{erf}\left(\sqrt{\frac{X}{a}}\right) \qquad (2\text{-}24)$$

Where a is T^{*}

For compensation

$$f\,(E) = \sqrt{\frac{T^*}{T_{\|}T_{\perp}^2}}\exp\ \left(\frac{-E}{T_{\perp}}\right) \mathrm{erf}\left(\sqrt{\frac{E}{T^*}}\right) \qquad (2\text{-}25)$$

where identity erf (0) = 0 has been used. Now

$$\sqrt{\frac{T^*}{T_{\|}T_{\perp}^2}} = \sqrt{\frac{T_{\|}T_{\perp}}{(T_{\perp}-T_{\|})T_{\|}T_{\perp}^2}} = \frac{1}{\sqrt{(T_{\perp}-T_{\|})\,T_{\perp}}} = \frac{1}{T_{\perp}\sqrt{1-T_{\|}/\,T_{\perp}}} \qquad (2\text{-}26)$$

The general distribution function of molecules characterized by having parallel and convective temperatures can be deduced through the use of a definition(T^*)[69].

$$f(E) = \frac{1}{T_{\perp}\sqrt{1-T_{\|}/\,T_{\perp}}}\exp\ \left(\frac{-E}{T_{\perp}}\right)\ \ \mathrm{erf}\left(\sqrt{\frac{E}{T_{\|}}} - \sqrt{\frac{E}{T_{\perp}}}\right) \qquad (2\text{-}27)$$

From equation (2-27), we can develop some special cases.

Through the properties of highly variable temperature conditions where $T_{\perp} \gg T_{\|}$, $(1 - \frac{T_{\|}}{T_{\perp}})^{1/2}$ approaches 1. Likewise, the argument of erf becomes large when $E \gg T_{\|}$, and lim x→∞ erf(x) = 1.

By deriving these estimates, we get a simple Maxwellian form [69].

$$f\,(E) = \frac{1}{T_{\perp}}\exp\ \left(\frac{-E}{T_{\perp}}\right) \qquad (2\text{-}28)$$

In this model, parallel particle motion is not important. For finite ($T_{\|}$) [69].

$E < T_{\|}$ because limx→0 erf(x) = 0.

This proposed model does not contain low energies. Particles are likely to have some parallel energy due to the finite $T_{\|}$ (neglected in Eq. (2-28), This causes the possibility of identifying molecules in low energies. Either in the case of high contrast. can be refined by retaining the factor depending on both $T_\perp$ and $T_\parallel$ f

$$(E) = \frac{1}{T_\perp\sqrt{1-T_{\parallel/}\,T_\perp}} \exp\left(\frac{-E}{T_\perp}\right) \qquad (2\text{-}29)$$

If distributions are slightly different ($T_\parallel \approx T_\perp$), It is possible to be (T^*) large and the argument of erf ($\sqrt{\frac{E}{T_\parallel}}$)in Eq.(2-24) becomes small This leads us to replace the term erf(x) $\approx 2/\sqrt{\pi}$ x and be expressed. Eq (2-25) [69].

$$f(E) = \sqrt{\frac{T^*}{T_\parallel T_\perp^2}} \exp\left(\frac{-E}{T_\perp}\right) \frac{2}{\sqrt{\pi}} \sqrt{\frac{E}{T^*}} \qquad (2\text{-}30)$$

$$f(E) = \frac{2\sqrt{E}}{\sqrt{\pi T_\parallel}\;T_\perp} \exp\left(\frac{-E}{T_\perp}\right) \qquad (2\text{-}31)$$

Eq. (2-30) when parallel temperature and vertical temperature differ only slightly is only valid ($\approx \frac{T_\parallel}{T_\perp} <$ 800keV).

When the properties are complete, $T = T_\parallel = T_\perp$. Can be replaced Eq. (2-31), one obtains [84]

$$f(E) = \frac{2\sqrt{E}}{\sqrt{\pi T^3}} \exp\left(\frac{-E}{T}\right) \qquad (2\text{-}32)$$

Equation (2-31) represents the function of the distribution of kinetic energies of gases. (i. e. isotropic, fully3-dimensional case) [69].

Chapter Three

Calculations and Results

Calculations and Results

(3.1) Energy Distribution Function (EDDF)

Several studies for the nuclear fusion reaction have been done recently, some of these studies are concentrated on cross sections for **P-T** reaction. Other studies are measured the velocity of the outgoing particles from the reactions measuring neutron energies from the reaction of proton with triton. In present work we submit results that concentrated on calculation the Temperature Dependence Energy Distribution Function (TDEDF).

In this work we are using MATLAB program (version R2017b) to Calculate our result.

Our Calculation for the Distribution Function is achieved using Eq. (2-32). The results of calculations of are presented in tables and figures next. Program IGOR.POR. and SCAN IN was used to calculate Cross section

Table (3.1) Calculated distribution function versus incident proton energy for the case (T = 300 keV).

E_p(eV) x10^4	F (E)(eV^{-1}) x10^{-6}	E_p(eV) x10^4	F (E)(eV^{-1}) x10^{-6}	E_p(eV) x10^4	F (E)(eV^{-1}) x10^{-6}
0	0	3400	0.0	6800	0.0
100	0.1556	3500	0.0	6900	0.0
200	0.1577	3600	0.0	7000	0.0
300	0.1384	3700	0.0	7100	0.0
400	0.1145	3800	0.0	7200	0.0
500	0.0917	3900	0.0	7300	0.0
600	0.0720	4000	0.0	7400	0.0
700	0.0557	4100	0.0	7500	0.0
800	0.0427	4200	0.0	7600	0.0
900	0.0324	4300	0.0	7700	0.0
1000	0.0245	4400	0.0	7800	0.0
1100	0.0184	4500	0.0	7900	0.0
1200	0.0138	4600	0.0	8000	0.0
1300	0.0103	4700	0.0	8100	0.0
1400	0.0076	4800	0.0	8200	0.0
1500	0.0057	4900	0.0	8300	0.0
1600	0.0042	5000	0.0	8400	0.0
1700	0.0031	5100	0.0	8500	0.0
1800	0.0023	5200	0.0	8600	0.0
1900	0.0017	5300	0.0	8700	0.0
2000	0.0012	5400	0.0	8800	0.0
2100	0.0009	5500	0.0	8900	0.0
2200	0.0007	5600	0.0	9000	0.0
2300	0.0005	5700	0.0	9100	0.0
2400	0.0004	5800	0.0	9200	0.0
2500	0.0003	5900	0.0	9300	0.0
2600	0.0002	6000	0.0	9400	0.0
2700	0.0001	6100	0.0	9500	0.0
2800	0.0001	6200	0.0	9600	0.0
2900	0.0001	6300	0.0	9700	0.0
3000	0.0001	6400	0.0	9800	0.0
3100	0.000	6500	0.0	9900	0.0
3200	0.0	6600	0.0	10000	0.0
3300	0.0	6700	0.0		

Table (3.2) Calculated distribution function versus incident proton energy for the case (T = 500 keV).

E_p(eV) x10^4	F (E)(eV^{-1}) x10^{-6}	Ep(eV) x10^4	F (E)(eV^{-1}) x10^{-6}	Ep(eV) x10^4	F (E)(eV^{-1}) x10^{-6}
0	0	3400	0.0066	6800	0
100	0.8263	3500	0.0054	6900	0
200	0.9567	3600	0.0045	7000	0
300	0.9594	3700	0.0038	7100	0
400	0.9070	3800	0.0031	7200	0
500	0.8302	3900	0.0026	7300	0
600	0.7446	4000	0.0021	7400	0
700	0.6585	4100	0.0018	7500	0
800	0.5763	4200	0.0015	7600	0
900	0.5005	4300	0.0012	7700	0
1000	0.4319	4400	0.0010	7800	0
1100	0.3709	4500	0.0008	7900	0
1200	0.3172	4600	0.0007	8000	0
1300	0.2703	4700	0.0006	8100	0
1400	0.2296	4800	0.0005	8200	0
1500	0.1946	4900	0.0004	8300	0
1600	0.1646	5000	0.0003	8400	0
1700	0.1389	5100	0.0003	8500	0
1800	0.1170	5200	0.0002	8600	0
1900	0.0984	5300	0.0002	8700	0
2000	0.0827	5400	0.0002	8800	0
2100	0.0694	5500	0.0001	8900	0
2200	0.0581	5600	0.0001	9000	0
2300	0.0487	5700	0.0001	9100	0
2400	0.0407	5800	0.0001	9200	0
2500	0.0340	5900	0.0001	9300	0
2600	0.0284	6000	0	9400	0
2700	0.0237	6100	0	9500	0
2800	0.0197	6200	0	9600	0
2900	0.0165	6300	0	9700	0
3000	0.0137	6400	0	9800	0
3100	0.0114	6500	0	9900	0
3200	0.0095	6600	0	10000	0
3300	0.0079	6700	0		

Table (3.3) Calculated distribution function versus incident proton energy for the case (T = 800 keV).

E_p(eV) x10^4	F (E)(eV^{-1}) x10^{-7}	E_p(eV) x10^4	F (E)(eV^{-1}) x10^{-7}	E_p(eV) x10^4	F (E)(eV^{-1}) x10^{-7}
0	0	3400	0.0415	6800	0.0008
100	0.4401	3500	0.0371	6900	0.0007
200	0.5492	3600	0.0332	7000	0.0007
300	0.5936	3700	0.0297	7100	0.0006
400	0.6049	3800	0.0266	7200	0.0005
500	0.5969	3900	0.0238	7300	0.0005
600	0.5770	4000	0.0213	7400	0.0004
700	0.5500	4100	0.0190	7500	0.0004
800	0.5189	4200	0.0170	7600	0.0003
900	0.4857	4300	0.0151	7700	0.0003
1000	0.4518	4400	0.0135	7800	0.0003
1100	0.4182	4500	0.0121	7900	0.0002
1200	0.3855	4600	0.0108	8000	0.0002
1300	0.3540	4700	0.0096	8100	0.0002
1400	0.3242	4800	0.0086	8200	0.0002
1500	0.2962	4900	0.0076	8300	0.0001
1600	0.2700	5000	0.0068	8400	0.0001
1700	0.2456	5100	0.0061	8500	0.0001
1800	0.2230	5200	0.0054	8600	0.0001
1900	0.2022	5300	0.0048	8700	0.0001
2000	0.1831	5400	0.0043	8800	0.0001
2100	0.1655	5500	0.0038	8900	0.0001
2200	0.1495	5600	0.0034	9000	0.0001
2300	0.1349	5700	0.0030	9100	0.0001
2400	0.1216	5800	0.0027	9200	0
2500	0.1096	5900	0.0024	9300	0
2600	0.0986	6000	0.0021	9400	0
2700	0.0887	6100	0.0019	9500	0
2800	0.0797	6200	0.0017	9600	0
2900	0.0716	6300	0.0015	9700	0
3000	0.0642	6400	0.0013	9800	0
3100	0.0576	6500	0.0012	9900	0
3200	0.0517	6600	0.0011	10000	0
3300	0.0463	6700	0.0009		

Table (3.4) Calculated distribution function versus incident proton energy for the case (T = 1000 keV).

E_p(eV) x10^4	F (E)(eV^{-1}) x10^{-7}	E_p(eV) x10^4	F (E)(eV^{-1}) x10^{-7}	E_p(eV) x10^4	F (E)(eV^{-1}) x10^{-7}
0	0	3400	0.0694	6800	0.0033
100	0.3229	3500	0.0637	6900	0.0030
200	0.4132	3600	0.0585	7000	0.0027
300	0.4579	3700	0.0537	7100	0.0025
400	0.4784	3800	0.0492	7200	0.0023
500	0.4839	3900	0.0451	7300	0.0021
600	0.4797	4000	0.0413	7400	0.0019
700	0.4688	4100	0.0379	7500	0.0017
800	0.4535	4200	0.0347	7600	0.0016
900	0.4352	4300	0.0317	7700	0.0014
1000	0.4151	4400	0.0291	7800	0.0013
1100	0.3939	4500	0.0266	7900	0.0012
1200	0.3723	4600	0.0243	8000	0.0011
1300	0.3506	4700	0.0222	8100	0.0010
1400	0.3292	4800	0.0203	8200	0.0009
1500	0.3084	4900	0.0186	8300	0.0008
1600	0.2882	5000	0.0170	8400	0.0007
1700	0.2688	5100	0.0155	8500	0.0007
1800	0.2502	5200	0.0142	8600	0.0006
1900	0.2326	5300	0.0130	8700	0.0006
2000	0.2160	5400	0.0118	8800	0.0005
2100	0.2002	5500	0.0108	8900	0.0005
2200	0.1854	5600	0.0099	9000	0.0004
2300	0.1716	5700	0.0090	9100	0.0004
2400	0.1586	5800	0.0082	9200	0.0003
2500	0.1464	5900	0.0075	9300	0.0003
2600	0.1351	6000	0.0069	9400	0.0003
2700	0.1246	6100	0.0063	9500	0.0003
2800	0.1148	6200	0.0057	9600	0.0002
2900	0.1057	6300	0.0052	9700	0.0002
3000	0.0973	6400	0.0047	9800	0.0002
3100	0.0895	6500	0.0043	9900	0.0002
3200	0.0823	6600	0.0039	10000	0.0002
3300	0.0756	6700	0.0036		

Table (3.5) Calculated distribution function versus incident proton energy for the case (T = 1250 keV).

E_p(eV) x10^4	F (E)(eV^{-1}) x10^{-7}	E_p(eV) x10^4	F (E)(eV^{-1}) x10^{-7}	E_p(eV) x10^4	F (E)(eV^{-1}) x10^{-7}
0	0	3400	0.0981	6800	0.0091
100	0.2357	3500	0.0919	6900	0.0085
200	0.3077	3600	0.0860	7000	0.0079
300	0.3479	3700	0.0805	7100	0.0073
400	0.3708	3800	0.0753	7200	0.0068
500	0.3827	3900	0.0704	7300	0.0063
600	0.3870	4000	0.0658	7400	0.0059
700	0.3859	4100	0.0615	7500	0.0055
800	0.3808	4200	0.0575	7600	0.0051
900	0.3728	4300	0.0537	7700	0.0047
1000	0.3628	4400	0.0501	7800	0.0044
1100	0.3512	4500	0.0468	7900	0.0041
1200	0.3387	4600	0.0437	8000	0.0038
1300	0.3254	4700	0.0408	8100	0.0035
1400	0.3117	4800	0.0380	8200	0.0033
1500	0.2978	4900	0.0355	8300	0.0030
1600	0.2840	5000	0.0331	8400	0.0028
1700	0.2702	5100	0.0308	8500	0.0026
1800	0.2567	5200	0.0287	8600	0.0024
1900	0.2434	5300	0.0268	8700	0.0023
2000	0.2305	5400	0.0250	8800	0.0021
2100	0.2181	5500	0.0232	8900	0.0019
2200	0.2060	5600	0.0217	9000	0.0018
2300	0.1945	5700	0.0202	9100	0.0017
2400	0.1834	5800	0.0188	9200	0.0016
2500	0.1728	5900	0.0175	9300	0.0014
2600	0.1626	6000	0.0163	9400	0.0013
2700	0.1530	6100	0.0151	9500	0.0012
2800	0.1438	6200	0.0141	9600	0.0012
2900	0.1351	6300	0.0131	9700	0.0011
3000	0.1269	6400	0.0122	9800	0.0010
3100	0.1190	6500	0.0114	9900	0.0009
3200	0.1117	6600	0.0106	10000	0.0009
3300	0.1047	6700	0.0098		

Table (3.6) Calculated distribution function versus incident proton energy for the case (T = 1500 keV).

E_p(eV) x10^4	F (E)(eV^{-1}) x10^{-7}	E_p(eV) x10^4	F (E)(eV^{-1}) x10^{-7}	E_p(eV) x10^4	F (E)(eV^{-1}) x10^{-7}
0	0	3400	0.1174	6800	0.0172
100	0.1817	3500	0.1114	6900	0.0162
200	0.2404	3600	0.1057	7000	0.0153
300	0.2754	3700	0.1003	7100	0.0144
400	0.2975	3800	0.0951	7200	0.0136
500	0.3112	3900	0.0901	7300	0.0128
600	0.3189	4000	0.0854	7400	0.0120
700	0.3223	4100	0.0808	7500	0.0113
800	0.3224	4200	0.0765	7600	0.0107
900	0.3198	4300	0.0725	7700	0.0101
1000	0.3153	4400	0.0686	7800	0.0095
1100	0.3094	4500	0.0649	7900	0.0089
1200	0.3023	4600	0.0614	8000	0.0084
1300	0.2944	4700	0.0580	8100	0.0079
1400	0.2858	4800	0.0549	8200	0.0074
1500	0.2767	4900	0.0518	8300	0.0070
1600	0.2674	5000	0.0490	8400	0.0066
1700	0.2578	5100	0.0463	8500	0.0062
1800	0.2482	5200	0.0437	8600	0.0058
1900	0.2386	5300	0.0413	8700	0.0055
2000	0.2290	5400	0.0390	8800	0.0052
2100	0.2195	5500	0.0368	8900	0.0049
2200	0.2102	5600	0.0348	9000	0.0046
2300	0.2010	5700	0.0328	9100	0.0043
2400	0.1921	5800	0.0310	9200	0.0040
2500	0.1834	5900	0.0292	9300	0.0038
2600	0.1750	6000	0.0276	9400	0.0036
2700	0.1668	6100	0.0260	9500	0.0034
2800	0.1589	6200	0.0245	9600	0.0032
2900	0.1513	6300	0.0231	9700	0.0030
3000	0.1440	6400	0.0218	9800	0.0028
3100	0.1369	6500	0.0206	9900	0.0026
3200	0.1301	6600	0.0194	10000	0.0025
3300	0.1236	6700	0.0183		

Table (3.7) Calculated distribution function versus incident proton energy for the case (T = 1750 keV).

E_p(eV) x10^4	F (E)(eV^{-1}) x10^{-7}	E_p(eV) x10^4	F (E)(eV^{-1}) x10^{-7}	E_p(eV) x10^4	F (E)(eV^{-1}) x10^{-7}
0	0	3400	0.1288	6800	0.0261
100	0.1456	3500	0.1234	6900	0.0248
200	0.1944	3600	0.1182	7000	0.0236
300	0.2249	3700	0.1132	7100	0.0225
400	0.2453	3800	0.1083	7200	0.0214
500	0.2590	3900	0.1037	7300	0.0203
600	0.2680	4000	0.0991	7400	0.0184
700	0.2734	4100	0.0948	7500	0.0175
800	0.2760	4200	0.0906	7600	0.0166
900	0.2765	4300	0.0866	7700	0.0158
1000	0.2753	4400	0.0827	7800	0.0150
1100	0.2727	4500	0.0790	7900	0.0143
1200	0.2690	4600	0.0755	8000	0.0136
1300	0.2644	4700	0.0720	8100	0.0129
1400	0.2591	4800	0.0688	8200	0.0122
1500	0.2533	4900	0.0656	8300	0.0116
1600	0.2471	5000	0.0626	8400	0.0110
1700	0.2406	5100	0.0597	8500	0.0105
1800	0.2338	5200	0.0569	8600	0.0100
1900	0.2269	5300	0.0543	8700	0.0095
2000	0.2198	5400	0.0518	8800	0.0090
2100	0.2127	5500	0.0493	8900	0.0085
2200	0.2057	5600	0.0470	9000	0.0081
2300	0.1986	5700	0.0448	9100	0.0077
2400	0.1916	5800	0.0427	9200	0.0073
2500	0.1847	5900	0.0407	9300	0.0069
2600	0.1779	6000	0.0387	9400	0.0066
2700	0.1712	6100	0.0369	9500	0.0063
2800	0.1647	6200	0.0351	9600	0.0059
2900	0.1583	6300	0.0334	9700	0.0056
3000	0.1520	6400	0.0318	9800	0.0054
3100	0.1460	6500	0.0303	9900	0.0051
3200	0.1401	6600	0.0288	10000	0.0050
3300	0.1343	6700	0.0274		

Table (3.8) Calculated distribution function versus incident proton energy for the case (T = 2000 keV).

E_p(eV) x10^4	F (E)(eV^{-1}) x10^{-7}	E_p(eV) x10^4	F (E)(eV^{-1}) x10^{-7}	E_p(eV) x10^4	F (E)(eV^{-1}) x10^{-7}
0	0	3400	0.1344	6800	0.0347
100	0.1200	3500	0.1297	6900	0.0333
200	0.1614	3600	0.1251	7000	0.0319
300	0.1881	3700	0.1207	7100	0.0305
400	0.2066	3800	0.1163	7200	0.0292
500	0.2197	3900	0.1121	7300	0.0280
600	0.2289	4000	0.1080	7400	0.0268
700	0.2352	4100	0.1040	7500	0.0257
800	0.2392	4200	0.1001	7600	0.0246
900	0.2413	4300	0.0964	7700	0.0236
1000	0.2420	4400	0.0927	7800	0.0226
1100	0.2414	4500	0.0892	7900	0.0216
1200	0.2398	4600	0.0858	8000	0.0207
1300	0.2375	4700	0.0825	8100	0.0198
1400	0.2344	4800	0.0793	8200	0.0189
1500	0.2308	4900	0.0762	8300	0.0181
1600	0.2267	5000	0.0732	8400	0.0173
1700	0.2223	5100	0.0703	8500	0.0166
1800	0.2176	5200	0.0676	8600	0.0159
1900	0.2127	5300	0.0649	8700	0.0152
2000	0.2076	5400	0.0623	8800	0.0145
2100	0.2023	5500	0.0598	8900	0.0139
2200	0.1970	5600	0.0574	9000	0.0133
2300	0.1916	5700	0.0551	9100	0.0127
2400	0.1861	5800	0.0529	9200	0.0122
2500	0.1807	5900	0.0507	9300	0.0116
2600	0.1753	6000	0.0487	9400	0.0111
2700	0.1699	6100	0.0467	9500	0.0106
2800	0.1646	6200	0.0447	9600	0.0102
2900	0.1594	6300	0.0429	9700	0.0097
3000	0.1542	6400	0.0411	9800	0.0093
3100	0.1491	6500	0.0394	9900	0.0089
3200	0.1441	6600	0.0378	10000	0.0085
3300	0.1392	6700	0.0362		

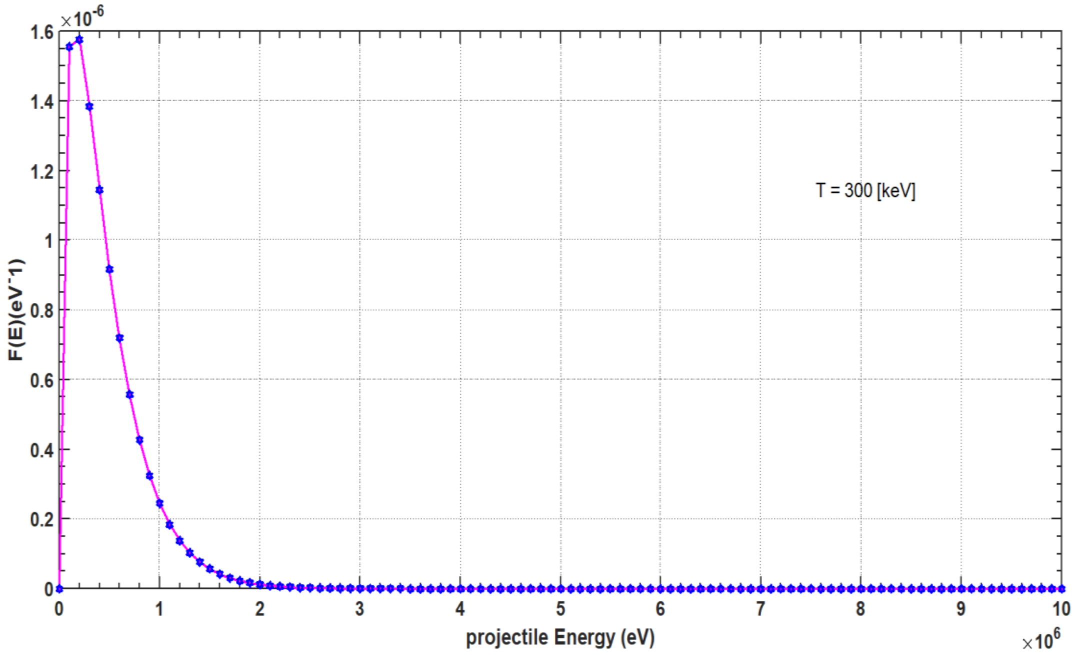

fig. (3- 1): the energy dependence distribution function for p-t fusion reaction for the case (T = 300 keV).

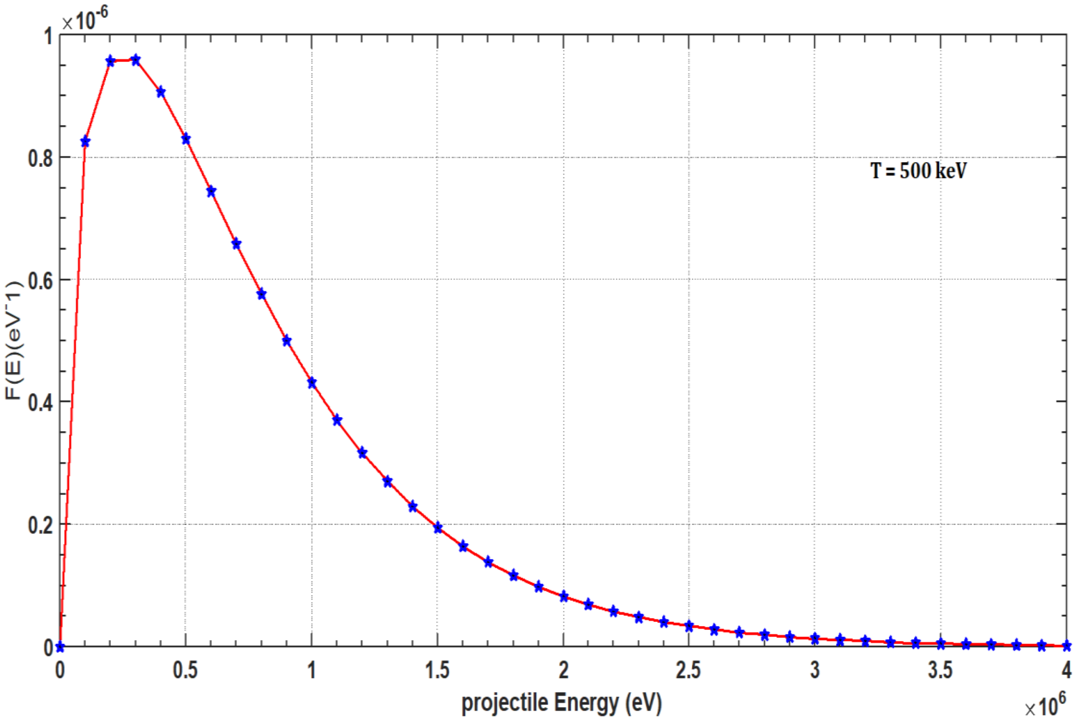

fig. (3- 2): the energy dependence distribution function for p-t fusion reaction for the case (T = 500 keV).

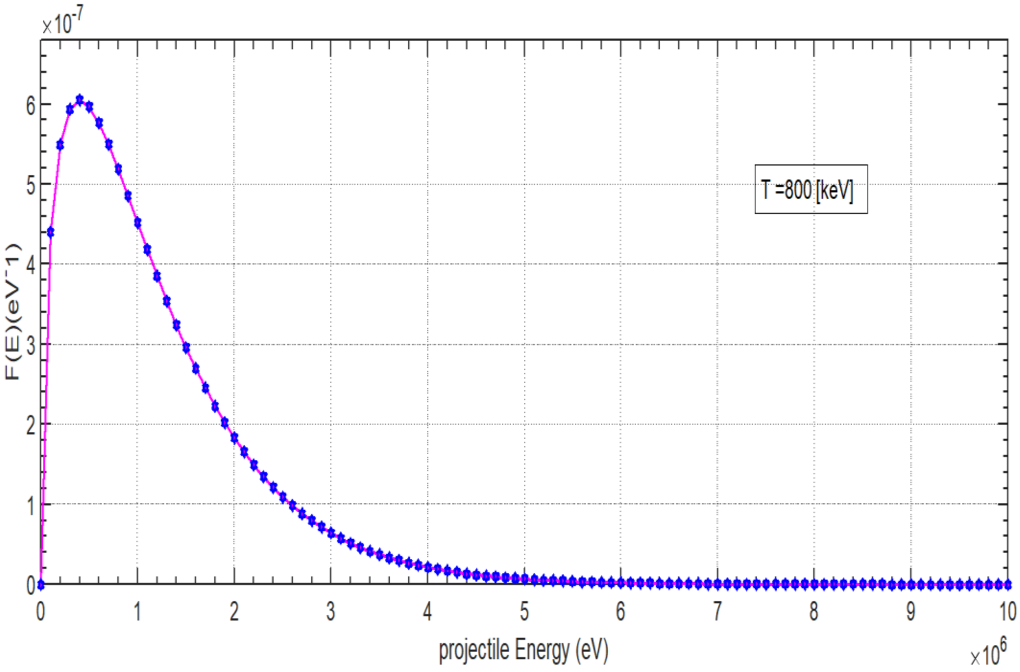

fig. (3- 3): the energy dependence distribution function for p-t fusion reaction for the case (T = 800 keV).

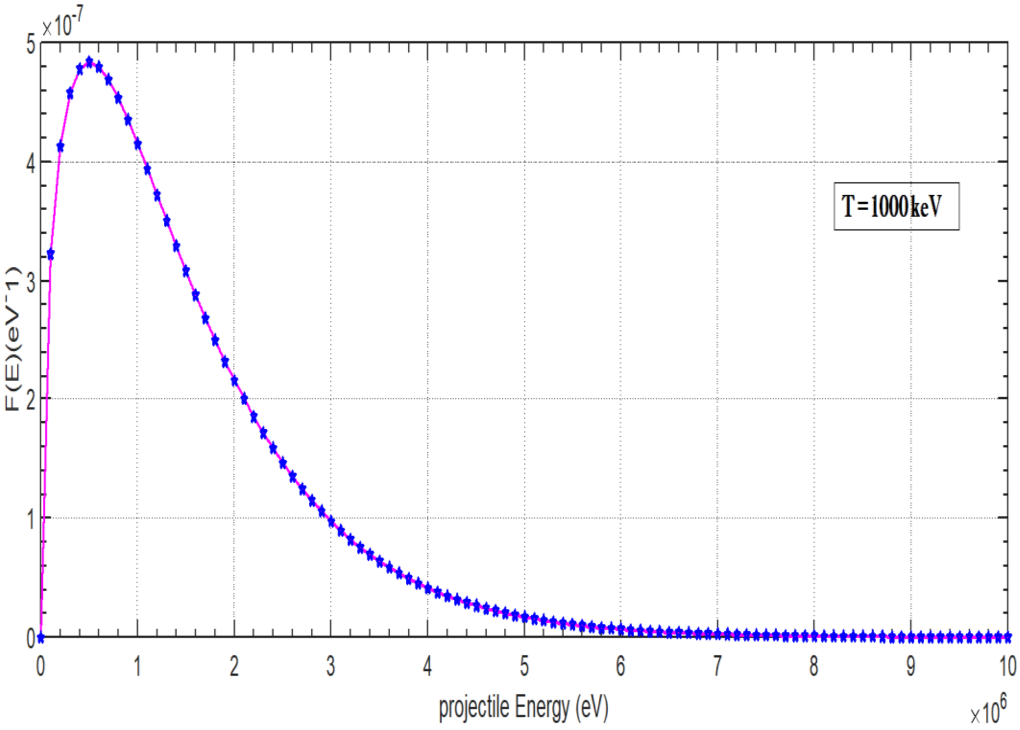

fig (3- 4): the energy dependence distribution function for p-t fusion reaction for the case (T = 1000 keV).

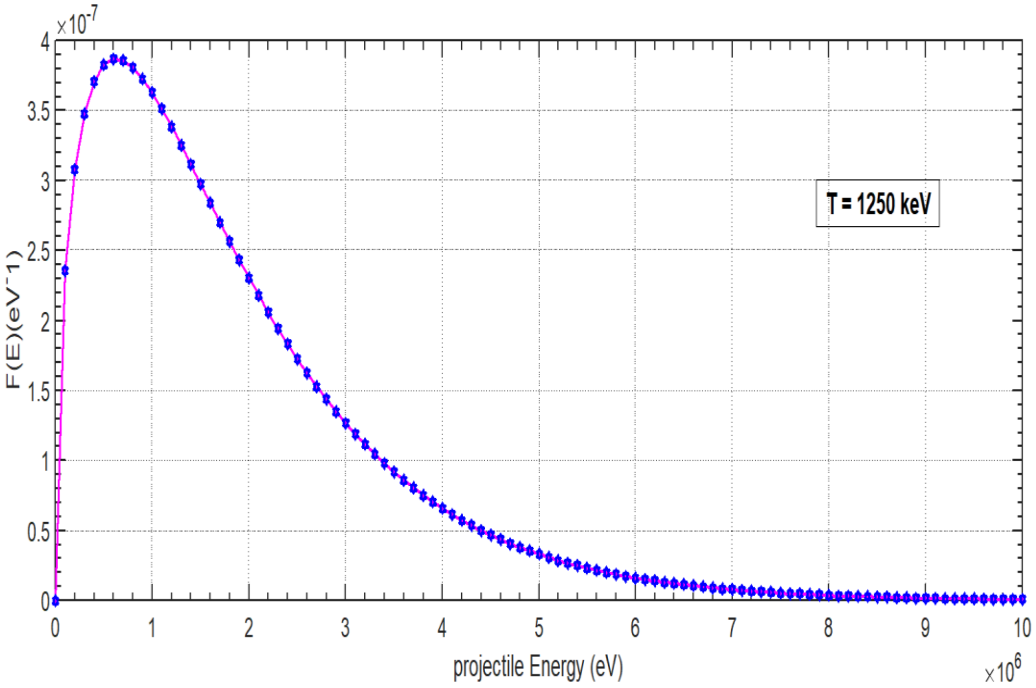

fig. (3- 5): the energy dependence distribution function for p-t fusion reaction for the case (T = 1250 keV).

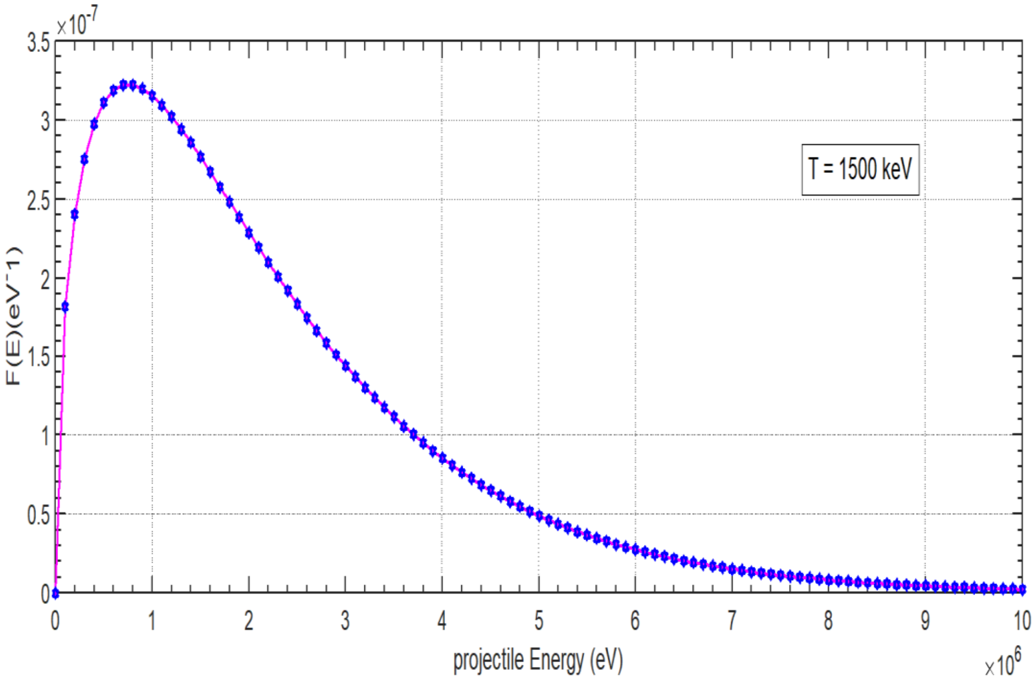

fig. (3- 6): the energy dependence distribution function for p-t fusion reaction for the case (T = 1500 keV).

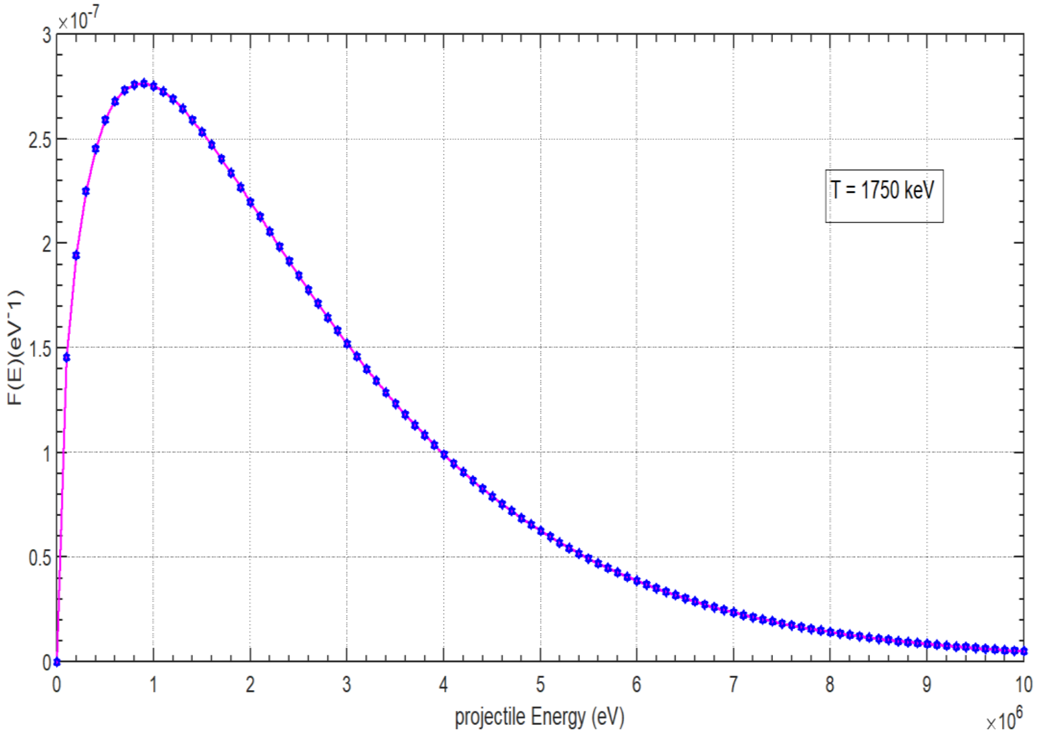

fig. (3- 7): the energy dependence distribution function for p-t fusion reaction for the case (T = 1750 keV).

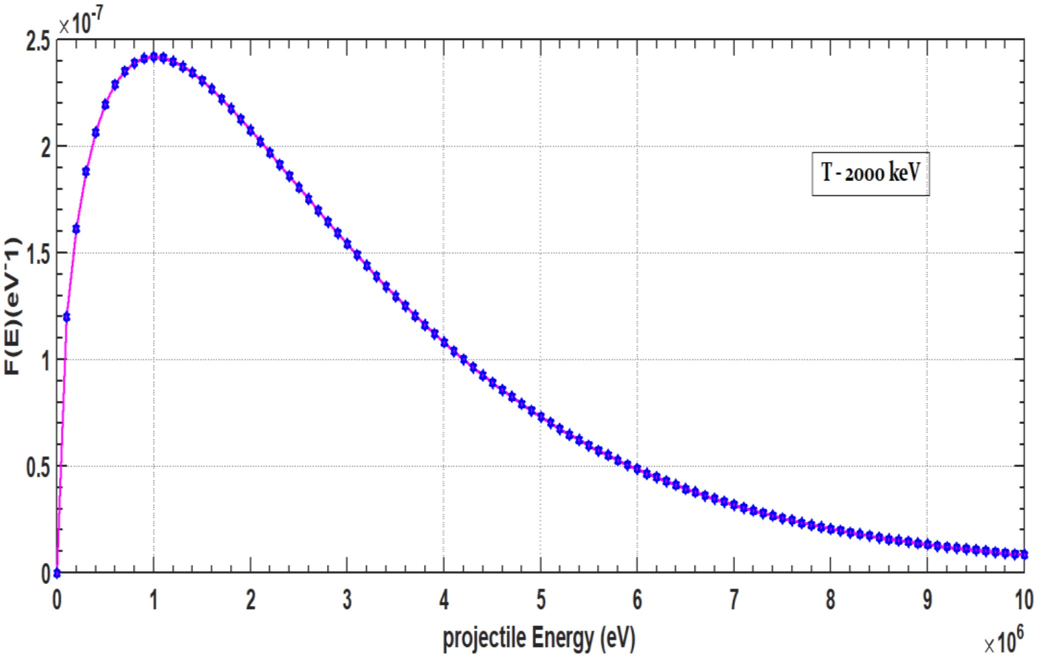

fig. (3- 8): the energy dependence distribution function for p-t fusion reaction for the case (T = 2000 keV).

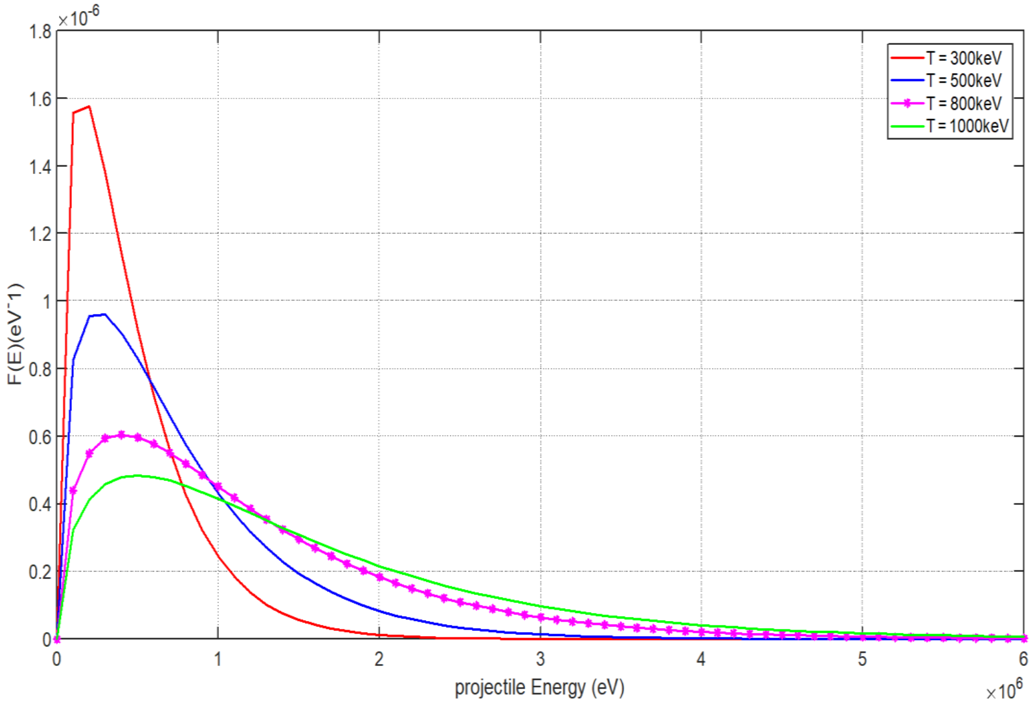

fig. (3- 9): the energy dependence distribution function for p-t fusion reaction for the case (T= 300,500 ,800,1000) keV.

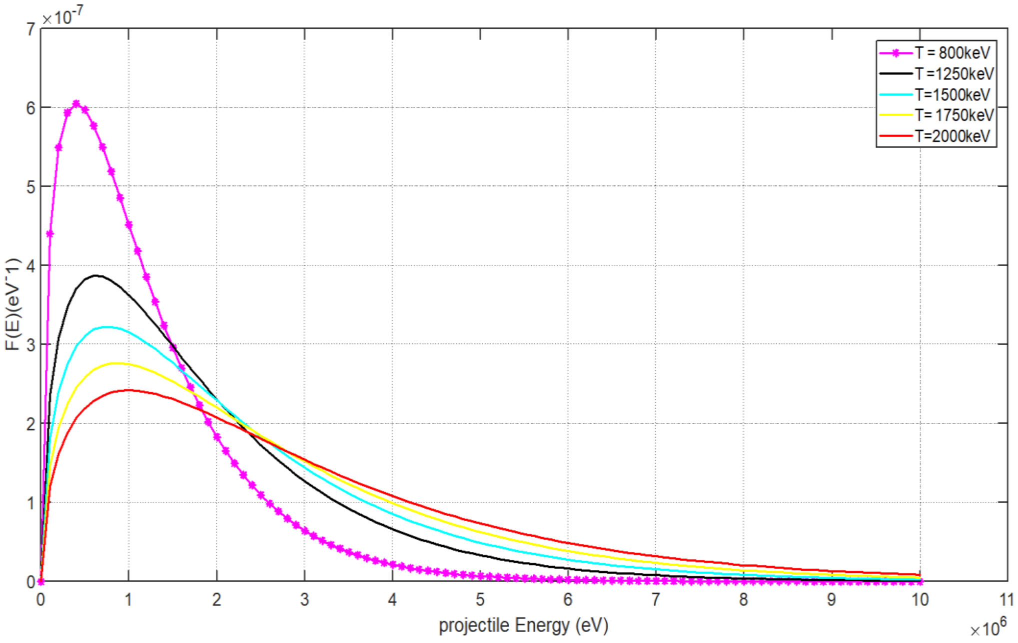

fig. (3- 10): the energy dependence distribution function for p-t fusion reaction for the case (T = 800,1250, 1500,1750,2000) keV

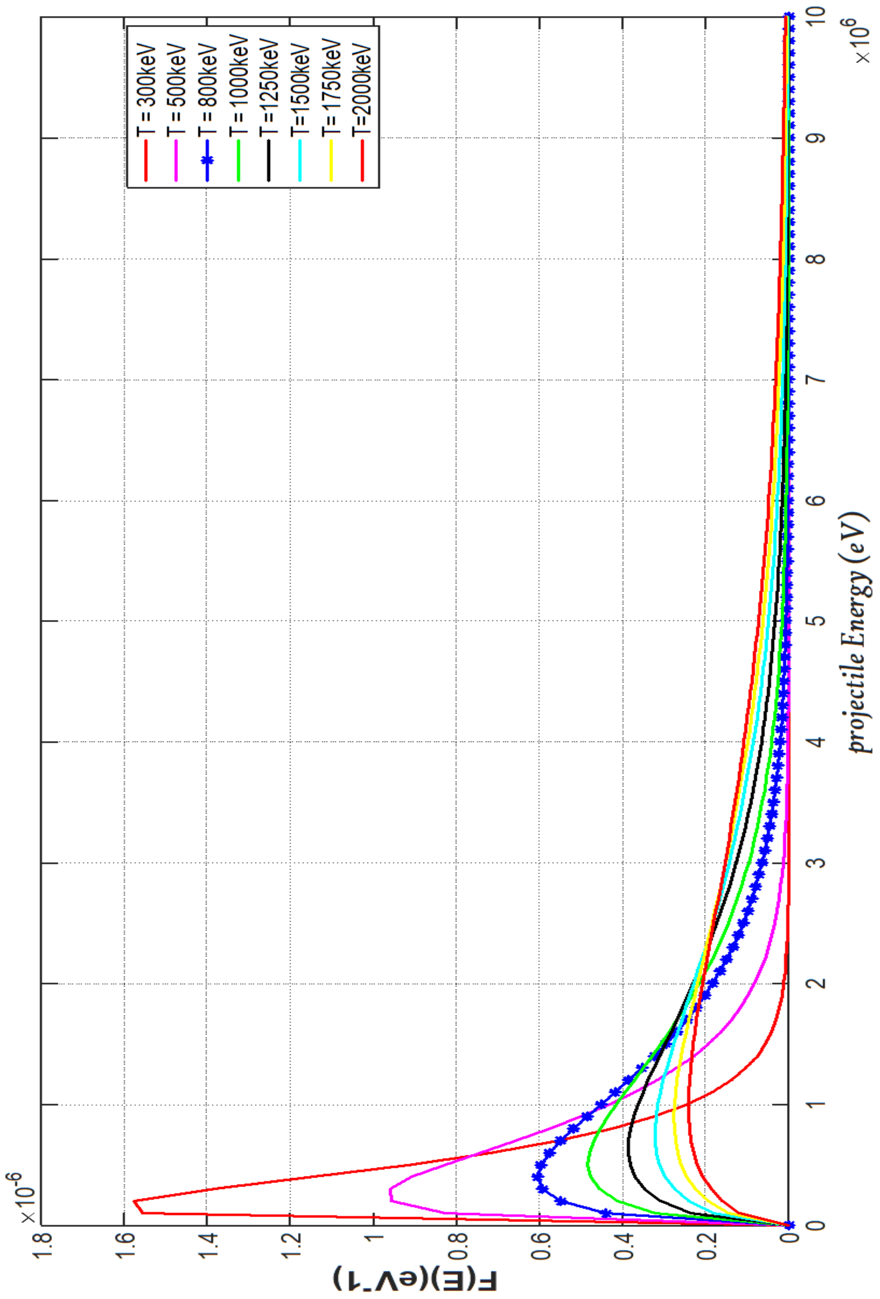

fig. (3- 11): the energy dependence distribution function for p-t fusion reaction for the case (T = 300,500, 800,1000, 1250,1500,1750,2000) keV.

(3.2) Calculate Cross Section of the Proton-Triton Reaction

The nuclear fusion reaction cross section for the following reaction T (p, n)^{3}He may by explain experimental as shown in Figure (3-12) [71].

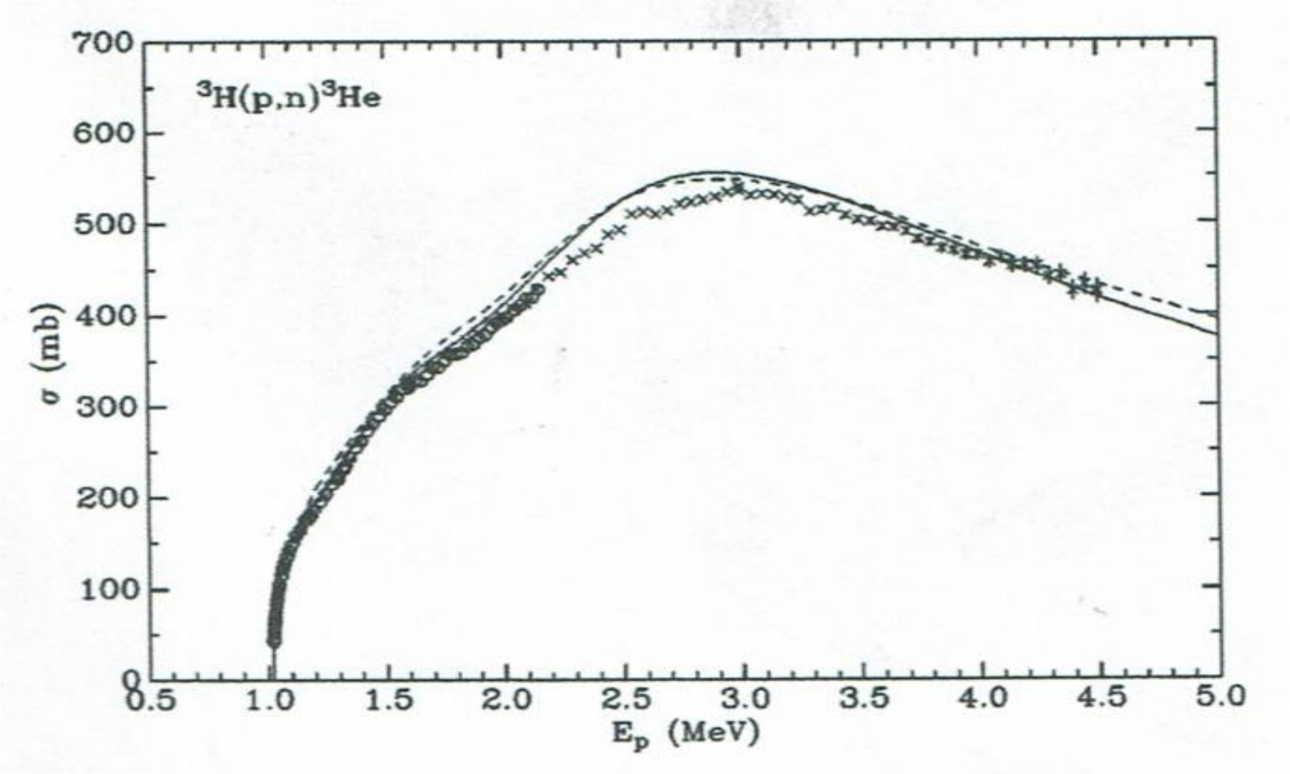

Fig. (3. 12): The recommended ^{3}H (p, n)^{3}He fusion reaction cross section [71].

In our work we arrived to an implement formula for the above fusion cross section since we depended abound a semi experimental published result [71].

By using the fitting concept as a result from the least square fit. our implement result is given by the following formula

$$\sigma(E) = \sigma_0 + A\exp\{ - [\frac{\ln(\frac{E_p}{E_{p_0}})}{\mathrm{Width}}]^2 \} \qquad (3\text{ -}1)$$

Where: σ = fusion reaction cross section(mbarn)

σ_0= fusion reaction cross section = 251.39 ±53.3 (mbarn)

A= constant = 764.98 ± 51.8

E_p = energies for proton(MeV)

E_{p_0} = energies for proton= 2.9891± 0.0178 MeV

Width = energy peak width = 1.1951± 0.0621 MeV

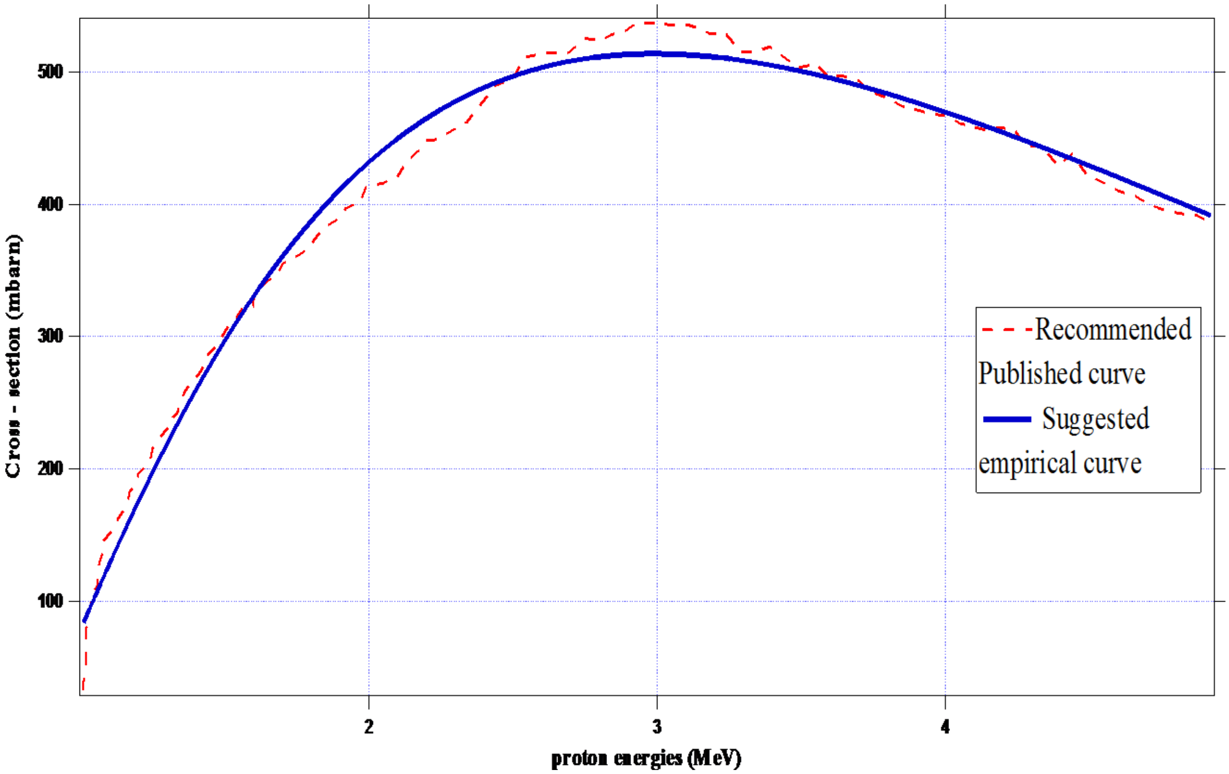

Fig. (3- 13): P-T fusion cross section profile

Chapter Four

Discussion and Conclusion

(4.1) Discussion and Conclusion

Our discussion depends upon calculations and results completely describe in a data values and as physical profiles behaves in table (3-1) to (3-8), and figure (3-1) to (3-8) respectively.

From figure (3-1), one can observe the true physical description for the energy depends distribution function (EDDF). That means we notes the Maxwellin distribution for the number of Particles (density) in which it reaches a steady state form as the energy of the incident proton increased, this result is achieved using the case of the plasma temperature about (T=300keV).

One can observe from figure (3-1) that the energy depended distributions function (EDDF) reach maximum value at approximately (E_p=200keV) and also it is clear that it finishes at approximately, (1.5MeV ≤ Ep ≤ 2MeV).

From figure (3-2) Which shows behavior (EDDF), when the plasma temperatures change (T=500keV), we observe that the behavior (EDDF), is similar to other temperatures. The maximum value can also be noted (EDDF) at approximately (Ep=300keV) and it finish at approximately (3MeV ≤ Ep ≤ 3.5MeV).

From figure (3-3) which explain the same description for the energy depends distribution function (EDDF), but at the case where plasma temperature about (T=800keV), we note that their existence similar behaviors for (EDDF) in which it represents Maxwellian shape and reach the steady state form. Also one can observe that the maximum value for (EDDF) at approximately (Ep=400keV) and it finish at approximately (5MeV ≤ Ep ≤ 6MeV). It is clearing that at this value of plasma temperature, their exist an optimum behaves for the (EDDF) in which their form haves a moderated width and reach the steady state form at a half way range compare with others case

From figure (3-4) Which shows behavior (EDDF), when the plasma temperatures change (T=1000keV), we observe that the behavior(EDDF), is similar to other temperatures. The maximum value can also be noted (EDDF) at approximately (E_p=500keV) and it finish at approximately (6MeV ≤ Ep ≤ 7MeV).

From figure (3-5) note the behavior (EDDF), At plasma temperature (1250 keV), the maximum value reaches (EDDF), at (E_p=600keV) and also it is clear that it finishes at approximately,(7MeV ≤ Ep ≤ 8MeV).

From figure (3-6) which explain the same description for the energy depends distribution function (EDDF), but at the case where plasma temperature about (T=1500keV), we note that their existence similar behaviors for(EDDF) in which it represents maxwellian shape and reach the steady state form. Also one can observe that the maximum value for(EDDF) at approximately (E_p=800keV) and it finish at approximately, (9MeV ≤ Ep ≤ 10MeV).

From figure (3-7) which shows behavior (EDDF), when the plasma temperatures change (T=1750keV), we observe that the behavior(EDDF), is similar to other temperatures. The maximum value can also be noted (EDDF) at approximately (E_p=900keV) and it finish at approximately (10MeV ≤ Ep ≤ 11MeV).

From figure (3-8) Which shows behavior (EDDF), when the plasma temperatures change (T=2000keV), we observe that the behavior (EDDF), is similar to other temperatures. The maximum value can also be noted (EDDF) at approximately (E_p=1000keV) and it finish at approximately (11MeV ≤ Ep ≤ 12MeV).

The empirical formula that involving fusion cross section for P-T reaction in which given by equation (3-1) may be choice as more equivalent formula to describe the theoretical cross section and this result is agree with the published experimental result. finally, we concluded that it is a more convenient to choice the results for the case in which the plasma temperature is about (T ≤ 800keV) as a recommended case where it is a more compatible with the experimental result.

(4.2) Suggestions for Future Works

1- Study and calculation including the all common possible thermonuclear fusion reaction.

2- Extension study contains the other fusion parameter such as reaction rate, reactively and power production.

3-Achieving the similar study depending upon the quantum mechanics experimental.

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الخلاصة

التفاعل بين البروتونات الناتجة من معجل الايونات السايكلتروني بترددات راديوية (ICRF) والترتيونات في التفاعل النووي الماص للحرارة في بلازما الاندماج المغناطيسي يمكن اعتباره مصدراً للنيوترونات التي تستثمر في كثير من التطبيقات .

تم اجراء دراسة نظرية لتأثير تغير درجة الحرارة (T) الوسط (البلازما) على سلوك دالة توزيع الطاقة (EDF) .

دالة توزيع الطاقة (EDF) للجسيمات التي تلعب دور المادة المتفاعلة ، تعتمد بشدة على درجة حرارة الوقود وبالتالي يمكن وصفها بالكامل بواسطة برنامج يحتوي على جميع المعادلات الرياضية التي تتحكم في سلوك دالة توزيع الطاقة . وعن طريق هذا البرنامج يمكن الوصول الى شكل شائع لدالة توزيع الطاقة يدعى (الحالة المستقرة) ، ومنه نستطيع اختيار درجة حرارة الاكثر توافق (ملائمة) . اذ ان من الضروري شرح دالة توزيع الطاقة التي يعتمد عليها اي تفاعل اندماج نووي قبل استنتاج اوتحديد العوامل المميزة لتفاعل معين .

الحالة المستقرة في سلوك دالة توزيع الطاقة تعطي حقيقة مفادها اننا وصلنا الى حالة مناسبة اومتوافقة وبالتالي يمكننا التعامل مع العوامل المعتمدة عليها .

في هذة الدراسة تم استخدام قيم متعددة ومتغيرة لمتوسط درجة حرارة البلازما . وقد تبين ان دالة توزيع طاقة البروتونات تعتمد اعتمادا قوياً على درجة حرارة البلازما . وقد حصلنا على افضل حالة لدالة توزيع طاقة البروتونات عندما كانت درجة حرارة البلازما بحدود ($700 \leq T \leq 800$)، وان هذا المدى يتوافق مع النتائج التجريبية.

جمهورية العراق
وزارة التعليم العالي والبحث العلمي
جامعة بغداد
كلية التربية للعلوم الصرفة / ابن الهيثم
قسم الفيزياء

دراسة لتحديد دالة توزيع الطاقة للتفاعل الاندماجي

بروتون – تريتون

رسالة

مقدمة إلى مجلس كلية التربية للعلوم الصرفة ابن الهيثم / جامعة بغداد كجزء من متطلبات نيل درجة ماجستير في الفيزياء
من قبل

علي جواد سعود

بكالوريوس في الفيزياء / كلية التربية للعلوم الصرفة / ابن الهيثم / جامعة بغداد 2012،

بإشراف

أ. د. رعد حميد مجيد

1441 A H　　2019 A D