Protons Range in some superconductor mediums(Ti, Mo, Sn and W) with Energy (2-10MeV)

(Ti, Mo, Sn and W)مدى البروتونات في بعض الاوساط فائقة التوصيل بطاقة (2-10MeV)

Wafaa.N.Jassim , Rashid. A. Kadhum
Wafaan.jasim@uokufa.edu.iqrashid.alghanimi@uokufa.edu.iq
University of Kufa/College of Education of girls/ Physics Department

Abstract
In this research, a theoretical study for calculation of the range of protons with energy (2-10MeV) when passing in the superconductor media (Ti, Mo, Sn and W). The range of proton were calculated by using A. K. CHAUBEY and H. V. GUPTA equation, SRIM 2012 program ,PASTR programs, and then by using a semi empirical equation we got for calculating least square method . We get a good agreement among these results. As well as that we calculate the maximum difference between the semi empirical calculation and with all results by using the statistical test (kstest2) in Matlab program .
Keyword: Range, stopping power, heavy charged, superconductor, proton.

الخلاصة
تم في هذا البحث دراسة نظرية لحساب مدى البروتونات بطاقة (2-10MeV) عند مرورها في أوساط فائقة التوصيل (Ti, Mo, Sn and W) . تم حساب مدى البروتون باستخدام معادلة توصل إليها A. K. CHAUBEY و H. V. GUPTAوباستخدام برنامج SRIM 2012 و برنامج PASTR وكذلك باستخدام معادلة شبه تجريبية حصلنا عليها باستخدام طريقة المربعات الصغرى (least square method).حصلنا على توافق جيد بين جميع هذه النتائج . بالإضافة إلى ذلك قمنا بحساب أعظم اختلاف بين الحسابات الشبه تجريبية وكل النتائج باستخدام اختبار (kstest2) الإحصائي في برنامج الـMatlab

1-Introduction:

The information of the features of the transmission and absorption of low, intermediary and high energy proton in elemental materials is of great importance for the experimental methods in nuclear and atomic physics. It is also beneficial in thoughtful the several interactions of these particles with matter .The facts of the ranges of this particle in matter has useful uses for the study of biological effects, radiation damage dosage–rates ,structure analysis of solid target by Rutherford backscattering spectroscopy and energy dissipation at a variety of depths of an absorber. It has also useful applications in the design of detection systems, radiation technology, semi-conductor detectors, shielding and choosing the exact thickness of the target[1,2]. If an ion beam penetrates through matter it misses energy due to collisions with electrons and target nuclei [3].The first who calculate of the energy loss of energetic particles was Bohr, while the first quantum mechanical usage was done by Bethe. This later theory of stopping power is particularly exact when the projectile's velocity is adequately high[2]. The range R(T) of a particle of kinetic energy T is the integral of this quantity down to zero energy[4,5,6]:

$$R(T) = \int_0^T \left(-\frac{dE}{dx}\right)^{-1} dE \ldots..(1)$$

which for heavy charged projectiles is approximately the same as the median range *R*, the average pass through absorber thickness, because heavy ions are very little dispersed and transfer nearly on a straight line [5].

2- Theory :

There have been several theoretical and experimental studies of variation of range of protons with energy in several materials. These studies have guide to the development of empirical relations exact for the material under inquiry and within the energy range used in the experiment. Let us have a look at the proton range relations for air. In air the range of protons having energy E_p can be computed from [6]:

$$R_p^{air}[m] = \left[\frac{E_p}{9.3}\right]^{1.8} \text{for } E_p<200 \text{ MeV} \ldots..(2)$$

Ranges of protons and charged particles as an alpha particles and deuterons given energy in absorber elements of atomic number Z > 10 in units of absorber mass thickness can be determined directly by contrast to the proposed range of the same charged particles of the same energy in air as said by [7,8]:

$$\frac{R_z}{R_{air}} = 0.90 + 0.0275Z + (0.06 - 0.0086Z)\log\frac{E}{M} \ldots(3)$$

where R_{z}: is the range of the charged particle in mass thickness units ($mgcm^{-2}$).
R_{air}: is the range of the charged particle in air in the same mass thickness units.
Z: is the atomic number of the absorber element.
E:is the particle energy in MeV.
M: is the mass number of the particle (i.e.,1 for protons, 2 for deuterons, and 4 for alpha particles).

The formulation gave by Eq. (11) is valid to charged particles over a wide range of energies(almost over the range (0.1–1000MeV) and for absorber elements of Z> 10. For lighter absorber elements the term 0.90+0.0275Z is supplanted by the value 1.00 with the exclusion of hydrogen and helium, where the value of 0.30 and 0.82 are used [7,8] . For two heavy charged particles which in the same initial speed β, the ratio between their ranges is [4]:

$$\frac{R_1(\beta)}{R_2(\beta)} = \frac{Z_2^2 M_1}{Z_1^2 M_2} \quad \ldots..(4)$$

where $M1$ and $M2$ are the rest masses for projectile and target respectively and Z_1 and Z_2 are the charges. If particle number 2 is a proton we can write for the range *R* of the other as:

$$R(\beta) = \frac{M}{Z^2} R_P(\beta) \quad \ldots..(5)$$

The range of a charged particle is calculated by numerical integration of the stopping power. The range R in the nonstop slowing down is [10] :

$$R = \int_{E_{min}}^{E_{max}} \left(-\frac{dE}{\rho dx}\right)^{-1} dE + R(E_{min}) \ldots..(6)$$

where R(E_{min}) is the calculated range at energy E_{min} and the stopping power of protons is :

$$-\frac{dE}{\rho dX} = \frac{a}{A} E^{-b} Z^{c \log E + d} \quad \ldots.. \quad (7)$$

Which is empirical relation for the stopping power of protons have attained by A.K. CHAUBEY and H.V.GUPTA[1,10].The suitable values of the constants a,b,c, and d are a = 915.0, b = 0.85, c = 0.145, d = 0.635.ρ,A and Z characterize the density,atomic weight and atomic number of the stopping material while E is the kinetic energy of the particle in MeV/amu .Where R(E_{min}) is the measured range at energy E_{min} which additional to the integral equation(6) and it is a constant for a particular particle and material. Compensate for the value of $-\frac{dE}{\rho dX}$ from eq. (7) into eq. (6) and changing energy units from MeV to MeV/amu it become:

$$R_p = \int_{E_1}^{E} m_p \left[\frac{a}{A} E^{-b} Z^{clogE+d}\right]^{-1} dE + R_1\,(E_1) \quad .....(8)$$

After integration and putting in the rates of the constants it become :

$$R_p = m_p \left[\frac{A}{915 \times 1.85 Z^{0.635\left(1-\frac{0.145logZ}{1.85}\right)}}\right] \times \left[E^{1.85} Z^{-0.145logE} - E_1^{1.85} Z^{-0.145logE_1}\right] + R_1\,(E_1) \quad .....(9)$$

The $R_1\,(E_1)$ is the experimental range of the proton at energy E_1 which negligent varies from the calculation at the like energy E_1. So, the second term in the second bracket of eq. (9) can be joint with $R_1\,(E_1)$ and a correction term F_p to the range if a medium is a specific by:

$$F_p = R_1\,(E_1) - m_p G_p E_1^{1.85} Z^{-0.145logE_1} \quad .....(10)$$

$$G_p = \left[\frac{A}{915 \times 1.85 Z^{0.635\left(1-\frac{0.145logZ}{1.85}\right)}}\right] \quad .....(11)$$

Therefore, eq. (10) reduces to

$$R_p = m_p G_p E^{1.85} Z^{-0.145logE} + F_p \quad .....(12)$$

Which provides the ranges of protons in gm/cm^2 in solid medium in the region of energy (0.7 - 12.0) MeV/amu[1,10].

3-Results and discussion :

Superconducting materials shall have an important part in advancing industrial and scientific usages with chief advances in various regions counting energy, environment, and healthcare [11]. By using the equation (12) we calculate the range of protons with energy (2-10MeV) when passing in the superconductor media (Ti, Mo, Sn and W), for this calculation we have taken E_{min} as 1 MeV. We have arrived at the following semi empirical relation for the range of protons for that four superconductor media by using least square method :

R=aE+b .....(13)

$$a = \frac{10\sum ER_{srim} - \sum E \sum R_{srim}}{10\sum T^2 - (\sum T)^2} \quad ......(14)$$

$$b = \frac{\sum E^2 \sum R_{srim} - \sum E \sum TR_{srim}}{10\sum E^2 - (\sum E)^2} \quad .....(15)$$

Where

Energy	Function	Element	Constant
2-10MeV	R=aE+b	Ti	a = 20.2258 b = -26.5584
		Mo	a = 25.4094 b = -31.4339
		Sn	a = 27.5067 b = -33.6185
		W	a = 33.4659 b = -38.6250

Table(1) the equation which represent the Range of protons in (Ti, Mo, Sn and W)

We programming equation(14) depended on Matlab program . As well as we using the SRIM2012 program to calculate the range of protons in this superconductor mediums[12], the corresponding values obtained from PASTR program on line the internet and the range calculated from equation(12) for the same elements[13]. The figures (1- 4) are plots of the Range versus the incident proton energy from (2 -10Mev) for the elements Ti, Mo, Sn and W by using Matlab Language. These figures represented comparison among the range calculated from equation(12), the corresponding values obtained from SRIM-2012 program , the corresponding values obtained from PASTR program and the range calculated from equation(14) for the same elements. From figures(1,2,3,4) we note the semi empirical formula agree with all results we achieved compare with it. To show The maximum difference between the curves we use the statistical test k (kstest2Two-sample test) by using Matlab program. The maximum difference between the present semi empirical results(equations (14)) and all results for figure (1,2,3,4) which for Ti , Mo ,Si and W gave k = 0.1111.

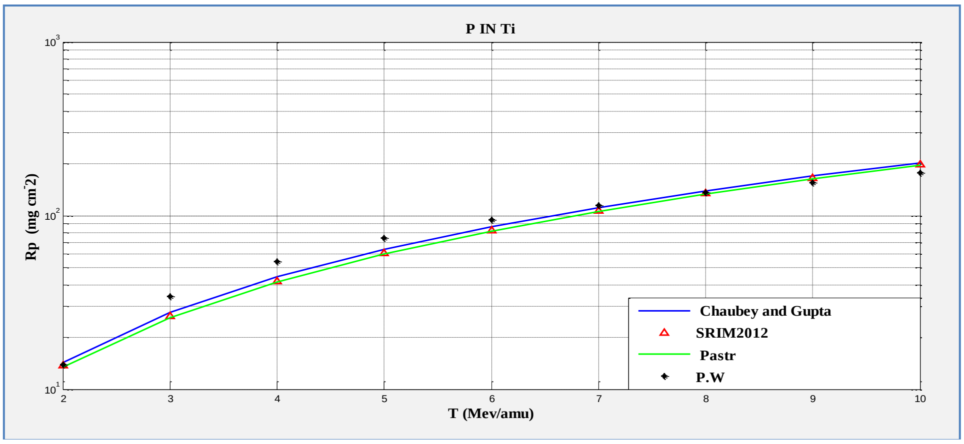

Fig.1Range of proton versus energy in Titanium with others workers value

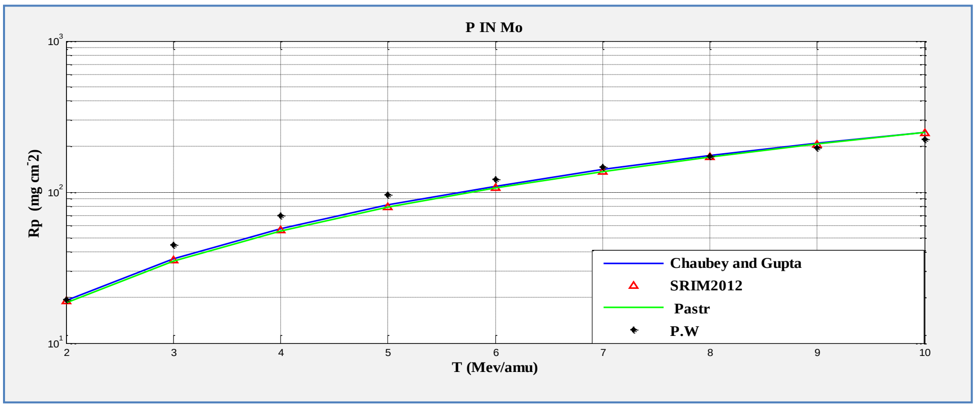

Fig.2 Range of proton versus energy in Molybdenum with others workers value

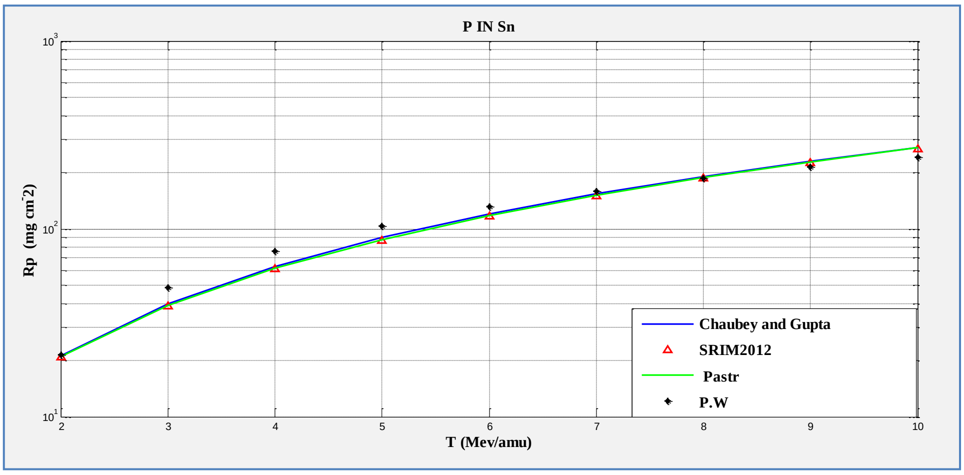

Fig.3 Range of proton versus energy in Tin with others workers value

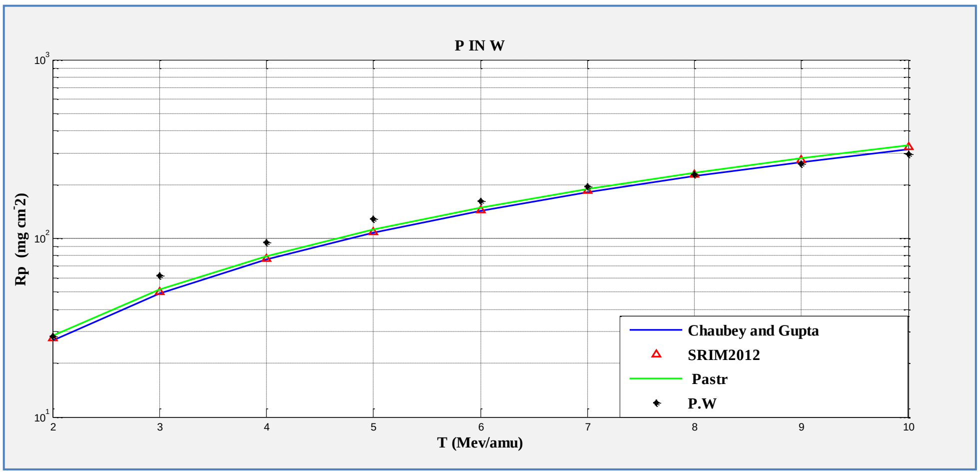

Fig.4 Range of proton versus energy in Tinjasten with others workers value

4- Conclusions:

From this research we get semi empirical equation to calculate the range of protons in some superconductor mediums depend on least square method. The results of this equation were agree with the results which calculate by SRIM-2012 program and PASTR program. By using the test statistic k (kstest2) we get the present semi empirical results have good agreement with the values of all results we compare with it .

References:

[1] A. Getachew, "Stopping Power and Range of Protons of Various Energies in Different Material", M.Sc. Thesis ,University of Addis Ababa, p(1-2), (2007).

[2] M.Tufan, J. Magill and J. Galy "Range And Stopping Power Calculation In Nuclonica "research gate,p(1-6), (2016).

[3] M. Mayer, "Rutherford Backscattering Spectrometry (RBS)", Max-Planck-Institute Plasma physic, Euratom Association, Garching, Germany p(12-13), (2003).

[4] J.Turner's, "Atoms, Radiation , and Radiation Protection" WILEY-VCH Verlag GmbH & Co. KGaA, Weinheim , p(126-127) (2007).

[5] D.Schardt, T.Elsässer and D. Schulz-Ertner,"Heavy-ion tumor therapy: Physical and radiobiological benefits", Reviews of modern physics, Vol.82,No.1, p(383-386), (2010).

[6] S. N. Ahmed," physics and Engineering of Radiation Detection ", University of Queen's ,p(118-120) ,(2007).

[7] F.L.Michael ,"Nuclear Radiation ,Its Interaction With Matter and Radioisotope Decay", The Montague Group, P.O. Box 5033, Oceanside, CA 92052-5033, USA , p(8-14), (2003).

[8] M.M.Al- Qysi," Radio Chemistry" ,University of Baghdad, p(111-115), (1986)

[9] K.E. Holbert, "Chaeged Particle Ionization And Range",EEE460-Handout, p(7-8),(2012).

[10] K. Chaubey and H. V. Gupta, " New empirical relations for stopping power and range of charged particles ", revue de physique appliquée, Vol. 12, p (321-329) , (1977) .

[11]Z.Melhem, "In the future of energy, superconducting materials matter and will make a material difference"Materials UK Preliminary Review, p(2-3), 2011.

[12] see: www.srim.org

[13] see: http://physics.nist.gov/PhysRefData/Star/Text/contents.html