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Calculations of Stopping Powerand Rangeof Alpha Particlesfor Several Energiesin Nuclear Emulsion

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Abstract

In this research, the stopping powers due to ionization and excitation for alpha particles moving not only in each element which are composed of nuclear emulsion, but also in nuclear emulsion for the kinetic energies 2-MeV~15-MeV are calculated by using Bethe- Bloch formula. Moreover, the ranges for alpha particles in nuclear emulsion are calculated and compared by using Semi- Empirical formula, SRIM-2006 (Stopping and Range of Ions in Matter) and energy- range program written by Professor Nakazawa based on Barkas literature.

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Introduction

The study of stopping power and range of charged particles in nuclear emulsion is very important for identification of particles, mass, energy and types of reaction. A charged particle moving through a material interacts, primarily, through Coulomb forces, with the negative electrons and the positive nuclei that constitute the atoms of that material. As a result of these interactions, the charged particle loses energy continuously and finally stops after traversing a finite distance, called the range. The energy loss per unit length is called the stopping power (dE/dx). Nuclear emulsion is a good detector which is composed of eight kinds of elements such as hydrogen, carbon, oxygen, nitrogen, sulfur, bromine, iodine and silver with corresponding weight ratio. The stopping power and range of alpha particles in nuclear emulsion, especially for the weight composition of Fuji ET 7C and Fuji ET 7D (KEK E373 experiment), were obtained. A photograph of nuclear emulsion which used in E373 experiment and tracks of alpha particles in nuclear emulsion are shown in Figure (1).

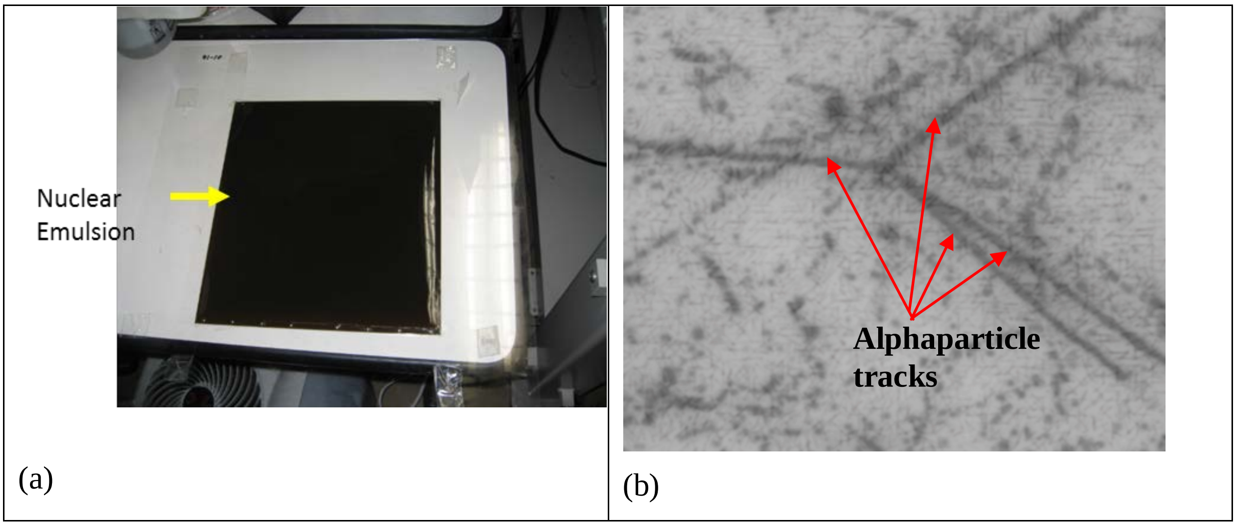

Figure (1) (a) A photograph of nuclear emulsion and (b) alpha particle tracks in nuclear emulsion which can be seen under the microscope.

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Mathematical Calculations for Stopping Power and Range

Calculation of Stopping Power for alpha particle in Nuclear Emulsion

The stopping powers for eight elements which are composed in nuclear emulsion are calculated by using the following Bathe- Bloch equations and Table (1). The weight ratio of Fuji ET 7C and Fuji ET 7D and the corresponding mean excitation potential of each element are shown in Table (1):

$$\frac{dE}{dx}(\mathrm{M}eV/m) = 4\pi r_0{}^2 z^2 \frac{mc^2}{\beta^2} NZ\left[\ln\left(\frac{2mc^2}{I}\beta^2\gamma^2\right)-\beta^2\right] \tag{1}$$

$$\frac{1}{\rho(g/cm^3)}\frac{dE}{dx}(MeV/cm) = \frac{dE}{dx}\left[MeV/(g/cm^2)\right]. \tag{2}$$

For the calculation of stopping power of alpha particles in nuclear emulsion, the weight ratio as expressed in Table (1) and the following stopping power for compound and mixture, equation (3) is used.

$$\left(\frac{1}{\rho}\frac{dE}{dx}\right)_{compound} = \sum_i w_i \frac{1}{\rho_i}\left(\frac{dE}{dx}\right)_i \tag{3}$$

Where, ρ is the density of the compound or mixture. ρ_i is the density of the ith element. w_i is the weight ratio of the ith element in the compound.

Table (1) Mean excitation Potential and weight ratio of the elements in nuclear emulsion of Fuji ET 7C and Fuji ET 7D

Elements	Mean Excitation Potentials I (eV)	Weight Ratio (%)
Iodine(I)	491	0.3
Silver(Ag)	469	45.4
Bromine(Br)	371.5	33.4
Sulfur(S)	190.8	0.2
Oxygen(O)	115.7	6.8
Nitrogen(N)	97.8	3.1
Carbon(C)	73.8	9.3
Hydrogen(H)	20.4	1.5

Calculation of Range of Alpha Particles in Nuclear Emulsion

Firstly, the ranges of alpha particles in air are calculated by using Semi- Empirical formulas as a function of particle kinetic energy. For alpha particles, the range in air at normal temperature and pressure is given by the following equations:

$$R(mm,air) = \exp\left[1.61\sqrt{T(MeV)}\right] \qquad 1 < T \le 4 MeV$$

$$R(mm,air) = \left[0.05T(MeV)+2.85\right]\ T^{\frac{3}{2}}\ (MeV), \qquad 4 < T \le 15 MeV \qquad (4)$$

In above equation T is the kinetic energy of the particle in MeV.

In order to obtain the range of alpha particle in nuclear emulsion, the generated value of range of alpha particles in air by using Equation (4) and the following Equation (5) are used.

$$R(mm) = 0.336\frac{\sqrt{A_{ef}}}{\rho(kg/m^3)}\ R_{air}(mm) \qquad (5)$$

In above Equation (5), $\sqrt{A_{ef}} = \left(\sum_{i-l}^{L}\frac{w_i}{\sqrt{A_i}}\right)^{-1}$,where, L is the number of elements in the compound or mixture, A_i is the atomic weight of the i^{th} element. For this calculation, the above equations are written in FORTRAN programming.

Secondly, the ranges of alpha particles in nuclear emulsion are calculated by using the SRIM (The **S**topping and **R**ange of **I**ron in **M**atter) 2006 software. The image of SRIM main menu is shown in Figure (2).

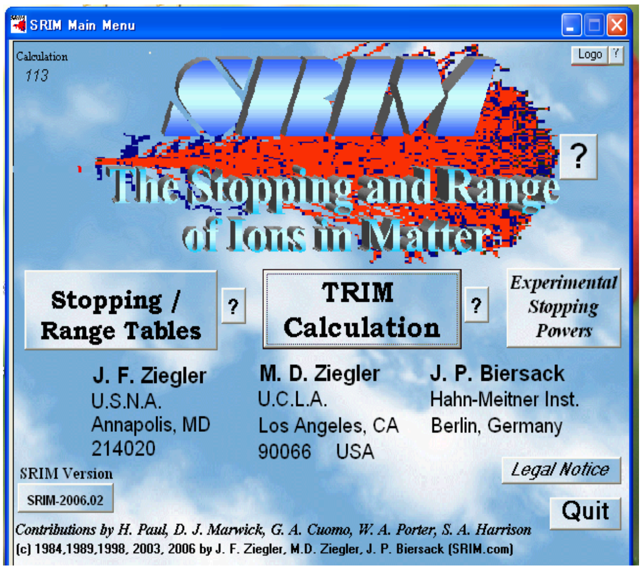

Figure (2) The image of SRIM main menu

Moreover, the ranges of alpha particles in nuclear emulsions are calculated by using energy- range program written by Prof. Nakazawa, Gifu University, Japan.

Calculation of Percentage Difference of Semi - Empirical formula, SRIM-2006 and Energy- Range Program

The percentage error for the range of alpha particles in nuclear emulsion are also calculated by using the following equation.

$$\%\text{error} = \frac{\text{exact value} - \text{approximate value}}{\text{exact value}} \times 100\%$$

Results and Discussions

Results of Stopping Power Calculation

The stopping powers of alpha particles in nuclear emulsion for the kinetic energies (2 - MeV ~ 15 - MeV) are calculated by using equations (1) and (2) for each element. On the other hand, the stopping power of alpha particle in nuclear emulsion is calculated by using Equation (3), Table (1) and the density of nuclear emulsion, ρ = 3.6 g/cm^3. The results are shown in Figure (3) and Figure (4), respectively.

Results of Range Calculation

The ranges of alpha particles in nuclear emulsion for the kinetic energies (2 - MeV ~ 15 - MeV) are calculated by using Semi-Empirical formulas, SRIM- 2006 (Stopping and Range of Ions in Matter) and energy- range program written by professor Nakazawa based on Barkas literature. The results are shown in Table (2) and Figure (5). Moreover, the percentage error for the range is also calculated and presented in Table (3) and Figure (6).

Discussions

From the calculated results of stopping power for alpha particles in each element and nuclear emulsion, it is found that the stopping power decreases as kinetic energy of moving particles increased. It is due to the facts that the stopping power is proportional to charge, velocity, energy of particles and the density of the material.The application of stopping power is important in the area such as radiation protection and nuclear medicine.

The ranges of alpha particles in nuclear emulsion are calculated by using Semi-Empirical formula, SRIM - 2006 and energy- range program. The results of the ranges of the Semi- Empirical equation are compared with the generated values of SRIM - 2006 and energy-range program. The calculated range values were in good agreement with the values obtained from Semi - Empirical formula and SRIM - 2006 since the percentage uncertainty was within 21% and the Semi- Empirical formula and energy- range program generated values had the percentage difference approximately within 12%. From this comparative analysis, it is inferred that the range values obtained from various formulations for nuclear emulsion are very helpful for event analysis in nuclear emulsion.

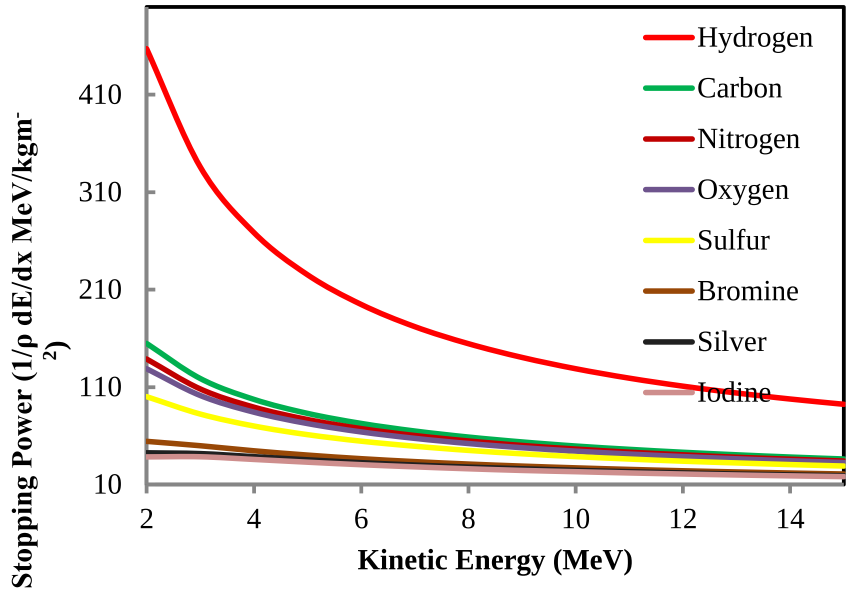

Figure (3) The stopping power of alpha particles for their corresponding energy in each element of nuclear emulsion.

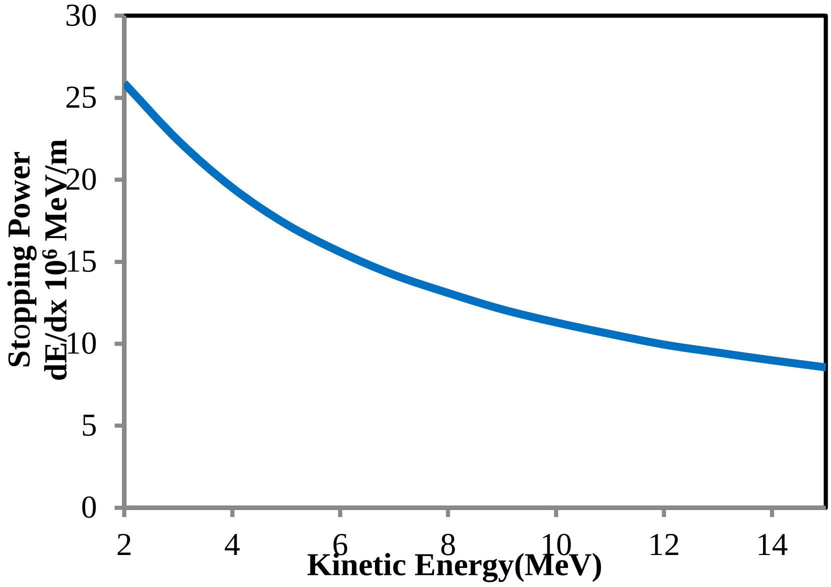

Figure (4) The stopping power of alpha particles for their corresponding energy in nuclear emulsion.

Table (2)The range of alpha particles in nuclear emulsion obtained from Semi-Empirical formula, SRIM - 2006 and energy- range program for several kinetic energies

Kinetic Energy (MeV)	**Range(μm)**		
	Semi- Empirical Formula	**SRIM-2006**	**Energy- range program**
2	6.11	7.45	6.73
3	10.19	12.05	10.78
4	15.69	17.47	15. 69
5	21.73	23.68	21.38
6	29.02	30.64	27.81
7	37.15	38.34	34.69
8	46.10	46.74	42.77
9	55.86	55.83	51.26
10	66.41	65.62	60.38
11	77.76	76.11	70.13
12	89.9	87.23	80.49
13	102.85	98.97	91.45
14	116.58	111.33	103.00
15	131.12	124.30	115.13

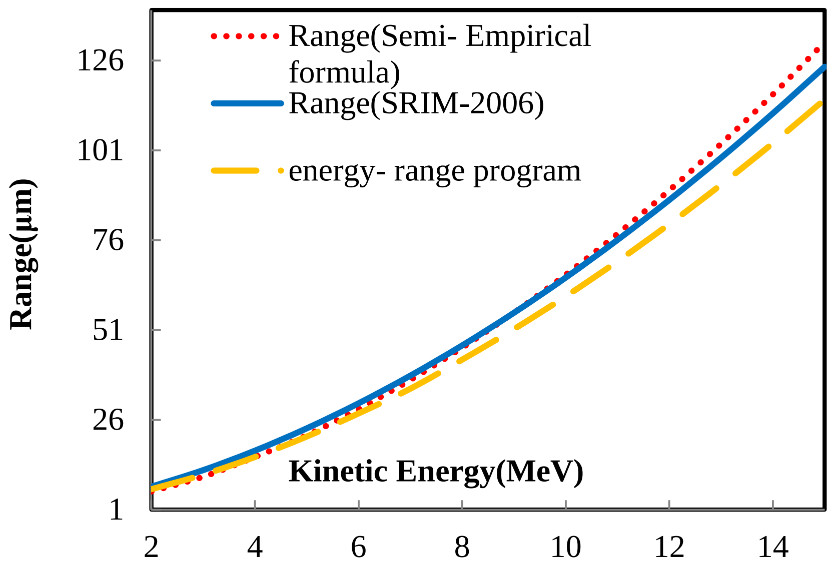

Figure (5) Comparison of range of alpha particles in nuclear emulsion for several kinetic energies.

Table (3) Percentage difference between Semi- Empirical formula and others of the range of alpha particles in nuclear emulsion for several kinetic energies.

Kinetic Energy (MeV)	Error (%)			
	Semi- Empirical Formula and SRIM-2006		Semi- Empirical Formula and Energy- range program	
	Range error%	׀Range error%׀	Range error %	׀Range error%׀
2	-21.93	21.93	-10.14	10.14
3	-18.25	18.25	-5.78	5.78
4	-11.34	11.34	0.00	0.00
5	-8.97	8.97	1.61	1.61
6	-5.58	5.58	4.16	4.16
7	-3.20	3.20	6.62	6.62
8	-1.38	1.38	7.22	7.22
9	0.05	0.05	8.23	8.23
10	1.18	1.18	9.07	9.07
11	2.12	2.12	9.81	9.81
12	2.96	2.96	10.46	10.46
13	3.77	3.77	11.08	11.08
14	4.50	4.50	11.64	11.64
15	5.20	5.20	12.19	12.19

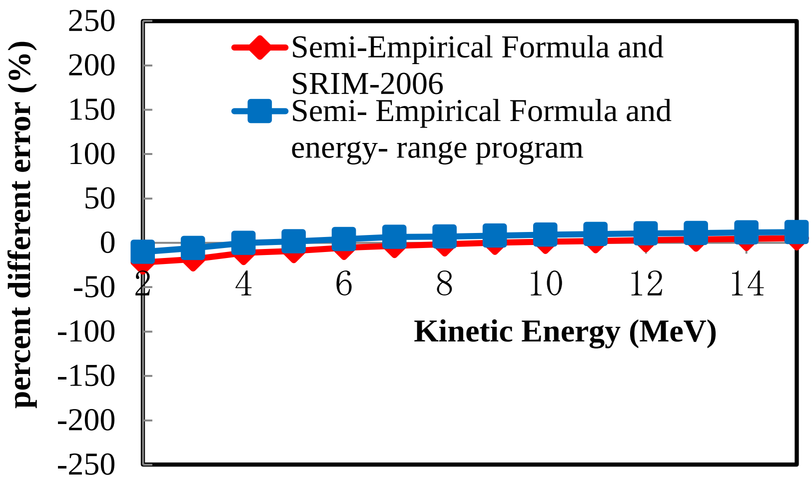

Figure (6) Percent difference (%) between Semi- Empirical formula and others for the range of alpha particles in nuclear emulsion.

Conclusion

Since the event analysis in nuclear emulsion is based on the conservation laws of energy and momentum, range- energy relation is very important. From the range of charge particle, the energy of the particle as well as momentum can be obtained. More experimental research should be conducted for projectiles to enhance the accuracy and estimation of uncertainty in the stopping powers and range values. On the other hand, further work should be conducted to formulate a unified Semi- Empirical relation for the determination of stopping powers and range values.

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References

H. Takahashi, Doctor Thesis, Kyoto University (2003).
http://w ww.srim.org/.
Nicholas T, Measurement and Detection of Radiation, Second Edition, (1979).
R. D. Evens, “The Atomic Nucleus”, Megraw-Hill, New York, (1972).
W. H. Barkas. et al., Nuov. Cim. 8 (1958).