Electron clusters – possible deuterium fusion catalyzers

Article · March 1997

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ELECTRON CLUSTERS - POSSIBLE DEUTERIUM FUSION CATALYSERS

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(Paper published in J. New Energy, 1997. 2 (1): p. 37)

Abstract

Simple calculations concerning the behaviour of the deuterons trapped in an electron cluster are presented. The kinetic energy achieved by a deuteron accelerated from the edge to the center of an electron cluster is sufficient for the coulomb barrier to be penetrated in the traditionally known manner. The results are discussed in connection with the published experimental data concerning the impact of the electron clusters on a metal target.

I. Introduction

In a recent paper [1] it is stated that the electron clusters, containing 10^{8} to 10^{13} electrons, named Electrum Validum (EV) can be produced by electric discharges [2] and can contain embedded positive ions, in a concentration of 1 to 10 positive ions to a million electrons [1], capable of producing nuclear reactions, and named Nuclear Electrum Validum (NEV). The acceleration mechanism of the ions transported by the EV, and accelerated at the same velocity as they were having the same mass as the electrons, is presented in [1]. This mechanism and the nuclear reactions produced by the NEV at the impact with a target is not the subject of this paper.

The electron cluster exhibits a large negative electric charge concentration, therefore an intense electric field must be present inside it. A simple model will assume the EV to be a sphere, while a more developed model will consider it to be a toroid, perpendicular on the direction the velocity, stable for certain range of values for it’s parameters, as it is presented and explained in the theory paper [3].

In the next section the electric field and potential distribution inside a EV is presented, considering both the spherical and the toroidal shape for the EV.

II. The electric field and potential distribution

If a spherical shape for an EV is considered, having the radius R=0.5 μm and the total number of electrons of $N=10^{11}$ [4], then the electron concentration n can be calculated as:

$$\frac{4\cdot\pi}{3}\cdot R^3\cdot n=N \qquad (1)$$

and will lead to n=1.9x10^{29} m^{-3}, a value which is higher than the concentration of “free electrons” in palladium, which is 6x10^{28} m^{-3}. This value of 1.9x10^{29} m^{-3} is considered in this article to stand for the concentration of electrons in an EV, for both spherical and toroidal shape.

If a spherical shape is considered, the electric field distribution inside the EV can be easily found using Gauss’ law; E, the electric field intensity, can be described as:

$$E=\frac{\rho\cdot r}{3\cdot\varepsilon_0} \quad where \quad \rho=n\cdot e \qquad (2)$$

The electric potential inside the EV can be found easily as:

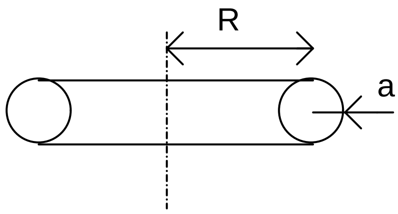
$$\Phi=-\int\overline{E}\cdot d\overline{l}=\frac{\rho\cdot r^2}{6\cdot\varepsilon_0}+C \qquad (3)$$

where C is determined from the border conditions. The electric potential difference between the center and the edge of the EV will be :

$$\Delta\Phi=\frac{\rho\cdot R^2}{6\cdot\varepsilon_0}=\frac{1}{2}\cdot\frac{Q}{4\cdot\pi\cdot\varepsilon_0\cdot R}=142x10^6V \qquad (4)$$

which will accelerate a deuteron from the edge to the center to a kinetic energy of 142 MeV. Q stands for the total electric charge of the cluster, Q=Ne.

If a toroidal shape for an EV is considered, like in [4], and assuming that the electron concentration n has the same value, the external radius R and the total number of electrons N are the same, we can asses the transversal radius a from:



$$2\cdot\pi\cdot R\cdot\pi\cdot a^2\cdot n=N \qquad (5)$$

The electric field distribution inside the EV can be found using Gauss’ law for a cylindrical surface, with the assumption that a << R; E can be estimated as:

$$E=\frac{\rho\cdot r}{2\cdot\varepsilon_0} \qquad (6)$$

The electric potential inside the EV can be found from:

$$\Phi=-\int\overline{E}\cdot d\overline{l}=\frac{\rho\cdot r^2}{4\cdot\varepsilon_0}+C \qquad (7)$$

The electric potential difference between the axis and the edge of the toroidal EV will be :

$$\Delta\Phi=\frac{\rho\cdot a^2}{4\cdot\varepsilon_0}=\frac{1}{2\cdot\pi}\cdot\frac{Q}{4\cdot\pi\cdot\varepsilon_0\cdot R}=45x10^6V \qquad (8)$$

which will accelerate a deuteron from the edge to the center of the tube to a kinetic energy of 45 MeV.

It should be stated here that the total electrostatic potential energy, for a simple spherical shape of the EV, can be calculated as:

$$W_e=\int_0^\infty\frac{1}{2}\cdot E^2=\frac{3}{5}\cdot\frac{Q^2}{4\cdot\pi\cdot\varepsilon_0\cdot R^2}=1,73x10^{19}eV=2,76J \qquad (9)$$

while the kinetic energy of the EV, accelerated at U=1 KV, will be:

$$E_k = Q \cdot U = 10^{14}\, eV = 1.6x10^{-5}\, J \qquad (10)$$

III. The deuterons collected by the EV

The intense electric field outside the cluster will polarise the deuterium atoms in the gas the EV is travelling through and strongly attract them inside, which will lead to a number of deuterons of $N_D = 10^5$, as stated in [4]. Once it crossed the border, the deuteron will be accelerated toward the center by the extremely intense electric field. Will the kinetic energy of the deuteron in the center of the EV be 142 MeV for a spherical shape, or 45 MeV for a toroidal one? It is very unlikely, because on it's way the positive ion will interact via the Coulomb force with a considerable number of electrons, in a manner resembling the passage of a heavy ion through substance, therefore it will loose considerable energy.

An exact calculation of the variation of energy per unit pass dE/dx is not the subject of this paper. Still, it would be interesting to asses the average value of the stopping force the electrons in the EV act against the deuteron. In a metal like aluminium, the average force $F_r = <-dE/dx>$ can be approximated as W/R, where W is the initial energy and R the mean pass. For W=5 MeV R=0.06 mm [5], we can find a value of $1.33x10^{-8}$ N for F_r. As the principal mechanism of interaction of heavy charged particles with the substance is the interaction with the electrons, it is of interest to asses the electron concentration in a metal, e.g. aluminium. It can be assessed as:

$$n_e = \frac{Z \cdot \rho \cdot N_A}{A} = 7.8x10^{29} m^{-3} \qquad (11)$$

where ρ=2,7 g/cm^3 is the density, Z =13 is the atomic number, A=27 is the mass number, and N_A=6.023x10^{23} mole^{-1} is Avogadro's number. The electron concentration in aluminium is about four times larger than in the EV. Besides, the energy loss of an ion when it interacts with the atomic electron is comparable with the ionisation energy of that atom, which makes the electrons belonging to an EV to stop the ion in a more smoother manner, as they are not bound. With these considerations in mind, one can conclude that the average stopping force F_r in an EV is at least a few times lower then in a metal like aluminium.

The electric force which accelerates the deuteron towards the center of the EV is:

$$F = E \cdot e = \frac{\rho \cdot e}{3 \cdot \varepsilon_0} \cdot = \frac{Q \cdot e}{4 \cdot \pi \cdot \varepsilon_0} \cdot r = 2.88 \cdot r \;\; (N) \qquad (12)$$

which is 1.44x10^{-6}N at the edge of the spherical EV and 2.88x10^{-7}N at 0.1 μm from the center, and of a comparable magnitude for a toroidal EV. These computed values for the accelerating force are much higher than the stopping force, so it can be concluded that the deuterons are accelerated towards the center where they will have a large kinetic energy. Even if the kinetic energy of the deuteron will be 10% of the computed values in eq. (4) and (8), it will still be high enough to produce the nuclear fusion of the deuterons trapped inside the EV, by penetrating the Coulomb barrier, which is lower than 0.5 MeV.

The accelerated deuteron will interact in the core of the EV with another deuteron. As the nuclear reaction will carry on in the same way as in the thermonuclear plasma, the most probable to occur reactions will be:

$$d+d=t+p \qquad (4.03\ \mathrm{MeV})$$
$$d+d={}^{3}He+n \qquad (3.27\ \mathrm{MeV})$$

Among them the first seems to be the most probable while the second not, because in most of the experimental studies concerning the loading of palladium or titanium with deuterium there have been reported neutrons in an amount only a few times larger than the background [6], while, statistically, tritium is reported in quantities much in excess than a few times the usual contamination [6]. It should not be completely neglected the possibility that the rich electron environment inside the EV can favour the fusion reaction d+d=He + γ, in a manner unknown to the author. The energy of a few MeV, e.g., 6 MeV, which is about the maximum which can result from a fusion act of two deuterons, could be transmitted not to the γ quantum, but to the whole EV, (which is a strongly coupled plasma as revealed in [3]), which would make only 6MeV/10^{11} electrons = $6*10^{-5}$ eV per electron, energy which would not be dissipated as radiation.

The charged particle produced from the fusion reaction of the deuterons, trapped inside the EV on it's way by the strong electric field, and then accelerated towards it's center, can not be expunged outside the EV, because of the large electric potential they have to escalate from near the center to the edge, having the magnitude of 142 MeV or 45 MeV, but will be released at the impact of the EV with the target.

The total energy produced by the reactions induced by the collected deuterons is not enough to break the equilibrium of the EV. Assuming that other reactions take place inside the EV, starting from deuterons and leading to the most stable isotopes, that is starting from a binding energy of 2.2 MeV/nucleon to about 8 MeV/nucleon, the maximum resulting energy per nucleon is about 6 MeV, or 3 MeV/deuteron. Even if all the 10^5 deuterons inside the EV are collected on it's way, the maximum amount of energy resulting from the fusion of the deuterium inside, in the manner previously described, would be $W_f=3*10^5$MeV$=4.8*10^{-8}$J, which is much lower than the electrostatic energy of the EV which is 2,76 J (9). The electrodynamic forces which compensate the strong coulomb repulsion and keep the EV in conditions close to those of equilibrium, are very likely to be able to compensate the extra small amount W_f

It would be interesting to analyse the possibility that two deuterons initially found inside the EV, not accelerated toward it's center, to go through a nuclear reaction, as a result of the modified coulomb barrier caused by the rich negative environment and as a result of the strong electric field. This will be presented in the next section.

IV. Deuterium Fusion Rate in an EV

The Coulomb barrier of the deuterons trapped in an NEV can be described by a screening potential of the form:

$$V(r) = \frac{e^2}{4 \cdot \pi \cdot \varepsilon \cdot r} \exp\left(-\frac{r}{l}\right) \qquad (13)$$

where the screening length can be considered to be the Debye length:

$$l = \sqrt{\frac{\varepsilon \cdot k \cdot T}{n \cdot e^2}} \qquad (14)$$

like in many papers on this subject, e.g. [7].

For a simple estimation the fusion rate of the deuterons in a NEV can be expressed as in [8]:

$$R = \frac{1}{4} \cdot V \cdot n^2{}_D \cdot v \cdot < \sigma > = \frac{1}{4} \cdot N_D \cdot n_D \cdot v \cdot < \sigma > \qquad (15)$$

where V is the volume of the NEV, n_D is the deuteron concentration, σ is the fusion cross section and v the average velocity of the deuterium.

For the volume, a sphere of the radius equal to 0.5 μm has been considered [3]. The electron concentration n is assumed to be 1.9*10 /cm^3. This value is assumed to be equal to n_D as well, because the deuterons have been dragged to the center by the electric field and formed a neutral plasma in the core of the EV.

The cross section can be estimated like in [7]:

$$\sigma = \sigma_0 \cdot P \qquad (16)$$

where σ_o is a pre exponential factor of 10^{-24} cm^2 and P is the Coulomb barrier penetration probability.

The values of the Debye length, of the velocity and of the incident energy of the deuterons depend of the temperature of the dense plasma inside the EV. It is worth noticing that this temperature is not dependent of the acceleration electric potential but is rather the temperature when the EV was created by the discharge. The kinetic energy of the cluster is transformed in thermal energy only when collided on the target. A temperature consistent to a thermal energy of 50 eV and 5000 eV for the deuterons has been considered for the calculation, which leads to the values of $6.9 \cdot 10^6$ cm/s and $6.9 \cdot 10^7$ cm/s respectively for the deuteron velocity.

The values for P, computed in the frame of the WKB approximation, for the two incident energies mentioned, are $P=10^{-734}$ and $P=10^{-210}$ respectively, which are much larger than for the bare Coulomb barrier [8]. Using the values above mentioned, for the calculation of the reaction fusion rate (in s^{-1}) in an EV we get $R=10^{-724}$ and 10^{-199} s^{-1} per EV, respectively, both values being far too low to be detected.

In spite of the large electron concentration inside the EV the electron screening of Coulomb barrier is not strong enough to lead to a detectable "cold" deuterium fusion rate, for the deuterons which form the neutral strong coupled plasma in the core of the EV.

Still, the EV carries an amount of kinetic energy which will leave traces on the impact with the surface of a metal. In the next section a rough estimation of the size of the crater produced on the metal surface is presented.

V. The Impact Crater

The EV, containing a charge Q, when accelerated by an electric potential U, will have a kinetic energy W=Q*U. Assuming for Q a value of 10^{11} times [3] the charge of an electron and a value of 1 KV for the acceleration electric potential, a value of 10^{14} eV is obtained, which is $W_k=1.6*10^{-5}$ J.

Assuming that a fraction f=1/2 of this kinetic energy is used to melt, evaporate and expel the metal at impact, we can estimate the dimension of the crater as the $V^{1/3}$, where V is the volume of the crater. If we use for the density of the target metal ρ and if we consider a generic value of 10 g/cm^3 for it, for the specific heat c and take a value of 500 J/kg*K, and we consider that in order the crater to be produced a temperature increase ΔT of 10^4 ^oC must be achieved by the metal to be vaporised and expelled, then:

$$f \cdot W_k = \boldsymbol{r} \cdot V \cdot c \cdot \Delta t \qquad (17)$$

which yields for the volume V about $1.6*10^{-16}$ m, which means a crater of a diameter of 5.4 μ m. These results are consistent with some of the figures presented in [4].

VI. Discussions

The high electron concentration in the EV does not offer a strong enough screening for the Coulomb barrier of a deuteron to be penetrated at a sufficient rate, such as "cold nuclear fusion" between the deuterons trapped inside, and forming a neutral plasma in the core of the EV, to occur in the classical manner inside the cluster. Still, the deuterons collected during the short existence of the EV are accelerated toward the center at a high enough velocity to go through a nuclear reaction; the energy will be released at the impact of the EV with the target. If this hypothesis is correct, a larger heat excess will be generated in those hydrogen isotopes loading experiments, where clusters containing initially a small number of hydrogen isotope nuclei are generated and where conditions for a large number of hydrogen isotope nuclei to be collected by the EV are created. The EV acts like a very small fusion reaction catalyser by accelerating the ions from the edge toward the center at a kinetic energy with the magnitude of MeV, even tens of MeV.

This is not the only way the EV acts as a positive ions accelerator. At the impact the positive ions trapped in the NEV will have the same velocity as the cluster, but much larger masses than the electrons, which will make them have kinetic energies of the magnitude of tens of MeV, as stated in

[1], which is high enough for producing nuclear reactions on the target material. The energy resulting from the nuclear reactions on the surface of the target must be added to W_k in (17) and will lead to larger craters, conclusion which is again in good agreement with the figures presented in [4]. Not all the EV-s will produce nuclear reactions. The large number of electrons accompanying the collision and the atomic electrons from the solid state of the target might have an important role in reducing the Coulomb barrier of the ions embedded in the lattice of the target [9]. Another major triggering fact for the nuclear reactions at the impact of the EV to occur might be the loading factor of the host lattice with the hydrogen isotopes.

Aknowledgements

I fully aknowledge Dr. Hal Fox, Dr. Gheorghe Vsaru and Dr. Peter Gluck for the fruitful discussions, for the good advises and straight guidance, for their encouragement.

References

[1] H. Fox, R. W. Baas, S. Jin, "Plasma - Injected Transmutation", Journal of New Energy, vol. 1 no. 3, 1996.

[2] K. R. Shoulders, "Energy Conversion Using High Charge Density", US. patent 5,018,180, May, 1991.

[3] S.X Jin, H. Fox, “Characteristics of High - Density Charge Clusters: A Theoretical Model”, to be published in ....

[4] K. Shoulders, S. Shoulders, “Observations of the Role of Charge Clusters in Nuclear Cluster Reactions”, Journal of New Energy, vol. 1 no. 3, 1996.

[5] Yu.M. Shirokov , N.P.Yudin, “Nuclear Physics” vol. II, MIR Publishers, Moscow, 1982.

[6] Storms Edmund, “Critical review of the “Cold Fusion” Effect, Journal of Scientific Exploration vol. 10, June 1996.

[7] D. Chicea, "Electron Screening And Cold Fusion In Condensed Matter, "Cold Fusion", No. 14, Dec. 1995.

[8] V.I. Goldanskii, F.I. Dalidchick, "On The Possibilities of Cold Enhancement of Nuclear Fusion", Phys. Lett. B vol. 234, No. 4, 1989.

[9] H. Fox, Private communication, January 17, 1997.