Electron Clusters and Nuclear Fusion

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ABSTRACT. The way to get nuclear reactions without putting a condensed medium into condition with a large quantity of energy, the scientific community has begun to explore it with changing success since the end of the eighties. No wonder for it, because the people involved in this field had not generally sufficient means to build reproducible and no contestable experiments. And also because there did not exist any clear and largely accepted model of the phenomenon. We propose a model based on "screening" of two colliding nuclei by a transitory electron accumulation, or cluster. This "screening" is obtained in many ways. Whatever the way, it can gives various processes of nuclear reactions, which are often unattended, particularly in fusion.

RESUME. La voie pour obtenir des réactions nucléaires sans mettre le milieu condensé en condition avec une grande quantité d'énergie, la communauté scientifique a commencé à l'explorer avec un succès mitigé, depuis la fin des années 80. Ce n'est pas surprenant, vu que les personnes impliquées dans ce domaine n'avaient pas généralement des moyens suffisants pour monter des expériences reproductibles et non contestables. Mais aussi parce qu'il n'existait pas de modèle du phénomène à la fois clair et faisant l'objet d'un consensus. Nous proposons un modèle fondé sur "l'écrantage" de deux noyaux en collision, par une accumulation d'électrons. Cet "écrantage" est obtenu de diverses façons. Mais, quel que soit le procédé, cela peut produire des processus divers de réaction nucléaire, qui sont souvent inattendus, particulièrement en fusion.

1 Introduction

Since the fifties of the 20th century, one would consider that there is an unique way for obtaining the nuclear fusion between light nuclei, for example, typically, between Deuterium nuclei. It is famed that, according to the thermonuclear explosive scheme, it is necessary to warm up the medium to energies in the range of some Mev per nucleon, and that there are two main channels of reaction, the one producing, an intermediate step a helium3 nucleus, the other a Tritium nucleus. Helium 4 production is thus performed in two steps:

$$D\ (D,\ ^3He\ )\ Neutron$$

$$D\ (D,\ ^3H\ )\ Proton$$

$$^3He\ (D\ ,\ ^4He\ )\ Proton$$

$$^3H\ (D\ ,\ ^4He\ )\ Neutron$$

Our aim is to show that there is an alternative way which leads to make deuterons to react in a cold and dense plasma, i.e. whose temperature is no more than in the keV range, or less, per nucleus. This cold plasma is the result of a good ionization of a condensed medium. It is important to get a plasma as "perfect" as possible. So, one can assume that in the plasma medium there exist only well stripped nuclei and free electrons. At first sight, this point of view can be considered as being too much ideal, but taking into account various experiments, it seems on the contrary to be rather realistic. As it is shown, electrons play a fundamental role in the nuclear process: they are lowering so much the Coulomb barrier that it is practically suppressed. This removal-like of the Coulomb barrier leads also to the possibility of a large number of unusual nuclear reactions, like the straightforward one step Helium 4 production, from two Deuterium nuclei.

2 The non thermonuclear fusion process would occur in various circumstances.

We have to quote some ways of putting the medium into condition, to show how large are the possibilities of such a process and how it leads to a simple and rational modeling. It is important, with this task in mind, to take into account some typical experiments, which have raised a controversies, early during the nineteenth's. Each type of experiment unveil a possibility and a particular aspect of the general process consisting to get nuclear fusion without using thermonuclear temperatures. The first way has consisted, historically, of using an electrolysis cell. The electrolyte is supposed to contain fusible ions. The cathode is made typically of Palladium or Nickel. When fusible ions penetrate into the cathode medium, it is well known that they transform into completely stripped nuclei, and that some "abnormal" phenomena may occur during the ion penetration: abnormal heat quantity, particle production, like neutrons, tritons ^3H, Helium-3, Helium-4. Experiments show that those phenomena would occur preferably when some transitory change of parameter like voltage change does occur. The controversy, at the beginning, was particularly founded on the difficulty to get an evidence about the origin of the abnormal heat quantity [1].

With the electrolysis cell structure, it has been shown that it can exist a correlation between the heat release at the cathode and the rate of nuclear reactions producing directly an Helium-4 nucleus, with 24 Mev of kinetic energy :

$$D + D \Rightarrow He^4 \tag{1}$$

This direct reaction is abnormal inasmuch there is generally no angular momentum preservation. It means that the process is very different from the one of two nuclei collision, which is tempered by the Coulomb barrier. The most important issue of those experiments is probably this direct Helium-4 production, an another way of getting nuclear fusion without using thermonuclear temperatures.

Generally those "abnormal" phenomena have not been robust in function of many parameters. To be successful needs a very good technology. Thus the second aspect of controversy corresponds to the objections about the so called non reproducibility of any process.

But there is at least one device which gives a perfect reproducibility. It is constituted of a vacuum chamber where one use to place a small monocrystal of oxide tungsten bronze (Na_xWO_3), for example, which has been submitted before to an efficient pumping, for hours. A deuterium gas bottle is linked with the vacuum chamber through a lock. A good vacuum is obtained by using a vacuum pump. When one opens the lock, a neutron burst is detected during some minutes: it corresponds to deuterium nuclei penetrating into the chamber. One gets a similar result when one close the lock and the vacuum pump is put into running [2]. This process is perfectly reproducible, but very slow as one has to wait for hours till the piece of palladium is well emptied of its impurities. But this "old" experiment wipes out any reproach of non reproducibility of the process. One has to underline that neutrons are usually detected, because it is the most direct way to detect nuclear reactions, but it is probably, like is discussed further, that Helium-4 nuclei are also produced, in a largely greater number, the produced nuclei number being difficult to detect given the natural Helium-4 noise.

Similar from the reproducibility point of view is the glow discharge device, a reaction chamber being filled with deuterium gas. A continuous voltage of typically some hundred volts, applied between an anode and a cathode, made of palladium makes a low current to flow. One gets a large spectrum of nuclear fusions and fissions, detected with the help of high resolution germanium detector.

Among many experiments which aimed to understand what is going on during collisions of clusters of fusible particles, it is important to quote the ones performed at the Brookhaven National Laboratory by R.J. Beuhler et al. They consisted of making a singly charged cluster of 23 to 1300 D_2O molecules, one time plus charged [5]. Those clusters are accelerated to approximately 300 kev, and are impinging on a TiD target. Deuterons ejected in the collision have a typical energy of 300 eV or a little more, too low for producing directly fusion reactions. Nevertheless, there is evidence for nuclear reactions, 3-Mev protons and 1-Mev Tritons being detected with a silicon detector. Apparently this device had no possibility of detecting Helium 3 and Helium 4, their "signals" being under the noise level. The records of proton yield versus the number of D_2O in the Heavy Water Molecules (HWM) cluster is obtained by adding the counting of a great number of shots: the result of this addition has a maximum approximately in the range of 100-500 HWM per cluster (Figure 1). Our interpretation is that for a low number (inferior or equal to 150 approximately) of HWM, only one deuteron-deuteron collision center is produced by the HWM molecule cluster impinging on the TiD target. For a HWM equal approximately to 150 HVM, it appears randomly a second D-D collision center. But as the available electron's number is limited in the HWM collision, the electron number ν around a D-D collision changes randomly from one collision to another. The result is a cut of the counting, whereas, for HWM number less than 150, it occurs the increase of counting versus the HWM number. It is probable that the counting would increase again for HWM numbers greater approximately than 1500 (Figure 1).

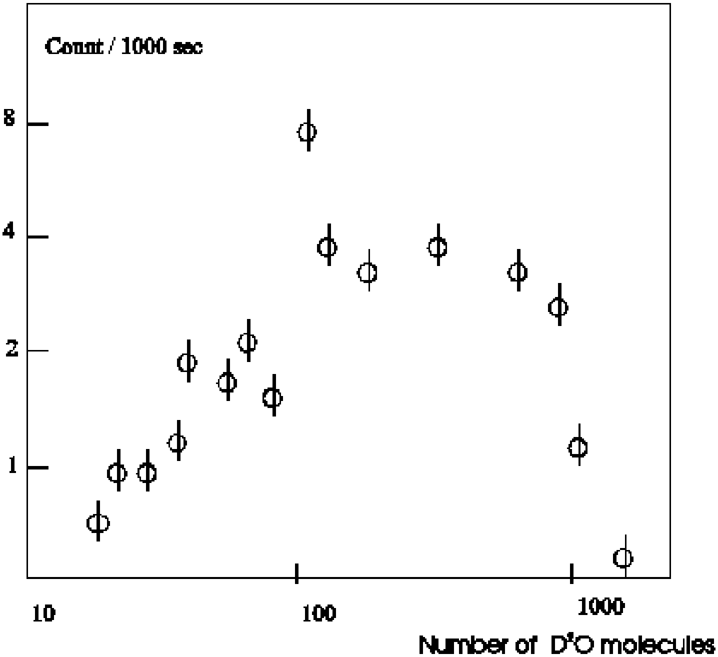

Figure 1 *: Detected proton number vs the D'O molecules number in the cluster, showing the maximum for the counting*

If one remarks that to a definite HWM number, it corresponds another definite number, the ν number of electrons around two colliding nucleons, the figure 2 depicts the variation of counting in function of cluster energy: in logarithmic scale, it is a straight line. It is in agreement with the fundamental point of view, developed further.

But it seems that an electrical current pulse could be the most efficient and straightforward way to get nuclear fusion without warming up the medium to thermonuclear temperatures. In the channel of current pulse, the medium containing nuclei capable of fusion reactions is firstly well ionized, the nuclei being completely stripped from their electron layers when the current apex is reached. Experiments show that nuclear reactions begin to appear in the conducting zone precisely at the current apex. It can be explained by the sudden change of strengths and directions of electromagnetic forces which put the medium into a complex system of resonance which we call, according the Ilya Prigogine theory, a "Large

Poincaré System" [6]. Moreover it does occur, during the current decrease, a plasma instability, which has been sometimes called "sausage instability", the medium being cut into apparent slices. The plasma instability which is an handicap in the thermonuclear scheme, appears as being here a necessary and beneficial characteristic of the condensed medium where the electric current is flowing. During the current decrease, it occurs meetings between two colliding nuclei, typically deuterium nuclei, and an electron accumulation or cluster. And the conditions of two nuclei collision are drastically changed. So begin the description of the "cold" fusion process, in agreement with experiments, as it is shown further. One has to remark that neutrons, and sometimes protons, are generally detected. It would be better if one could detect also $_3$He, $_4$He, $_3$H. But all experimenters have not had, since 1989, at their disposal sufficient means to perform a correct fundamental research in this field, where there are many "things to do".

3 Some elements, which are common to the different ways of getting Cold Fusion.

Firstly the lowering of Coulomb barrier, changing typically from some Mev to some keV or some eV, according the case. This is due to a collective behavior of an electron cluster around two colliding nuclei. This cluster is a fast transitory accumulation of electrons around those fusible nucleons. So, only a low energy is necessary for the nuclei to react.

Secondly, the Large Poincaré System, according the concept of Ilya Prigogine [6]. The N number of particles, involved in interactions in the volume V is great enough for the ratio N/V to be constant, whatever the size of the V volume. It is a "System" because interactions are permanent in the whole V volume. It is "Large" because the mean distance between its constituting parts is low in comparison with its total dimensions. The system is characterized by continuous spectra, owing to a random distribution of the particle parameters (For example: Electrons, Deuterons, Oxygen Nuclei, Deuterons, in the case of initial Heavy Water). This model imply that ions are quasi-free in the 3D space.

Thirdly, a specific dimensional relationship between the basic parameters describing the nuclear fusion process in a low energy condensed medium, which replaces the habitual "Lawson criterion", as being only specific for the thermonuclear hypothesis [7-8 & 13].

The criterion which is suited to process with an electron cluster, is thus:

$$R = (n^2/4)\ (\sigma F \varepsilon/\tau)\ \theta \qquad (2)$$

R : Events number during the time θ
n : Fusible nuclei number, able to be involved in a fusion process
σ : "Geometrical" cross section of a fusible nucleus
ε : Width of the Coulomb barrier between two Deuterons
τ : Barrier crossing duration
θ : Putting into condition duration of the fusible medium
F : Barrier transfer factor, an electron accumulation (cluster) surrounding the two colliding nuclei (Schrödinger calculations)

The electron accumulation, or cluster is a macroscopic entity put into evidence firstly in Russia by G.A.Mesyats [9-11] as early as during the sixties of the twentieth century, which he named "Ecton". Secondly in the United States, during the eighties, by Kenneth Shoulder [15-17] and named by Latin words "Electrum validum" ("Strong Electron"). According specific experiments its shape is spherical and a typical cluster of radius 3µm, contains $2x10^{10}$ electrons [10]. But for performing Coulomb barrier screening, and obtaining nuclear fusions, some 10^3 electrons may be sufficient [7 & 13]. The mean distance between electrons in the cluster is typically in the range of the electron Compton wave length (2.426 10^{-12} m). The most typical way of obtaining electron clusters seems to use rough surfaces of electrodes in the discharge device [9]. For accounting the transitory cohesion of electron clusters, it seems sufficient to take into account the interaction between the spin of electrons, another cause such as the Casimir effect seeming to be ruled out [18].

4 The Quantum point of view leads to a fractal dimension hypothesis.

A simple calculation using the Schrödinger equation leads to a synthetic view on the process. Initially two moving deuterons are supposed to be at a mutual distance which is in the range of the Bohr atom radius ($5.29x10^{-9}$ m). Schrödinger equation gives the wave function of one of the two deuterons, in function of time, approaching the other, in successive slices of time. A typical number of fusible nuclei density ($n = 10^{22}$ /cm^3 for example) has given an important result: in the plane (Log E , Log R), E being the energy of the incident deuteron, the representative points are on a straight line for ν constant [7]. The consequence of Coulomb barrier lowering is firstly to make that nuclei meet together. Practically, only strong interaction remains efficient. Electron cluster favours a symmetrical strong interaction, and it is probably an important remark for understanding why the nuclear reaction between two deuterium nuclei, "screened" by an electron cluster, gives very predominantly Helium4. If one replaces The E energy term by a characteristic dimension of the colliding system i.e. the De Broglie wave length λ, one reads, for ν constant, D being the slope of the straight line .

$$\text{Log } R/R' = D \text{ Log } E/E' = D \text{ Log } \lambda/\lambda' \qquad (3)$$

D is also the fractal dimension of the space [14], where collisions do occur. To verify this hypothesis, one has to adopt a probabilistic point of view.

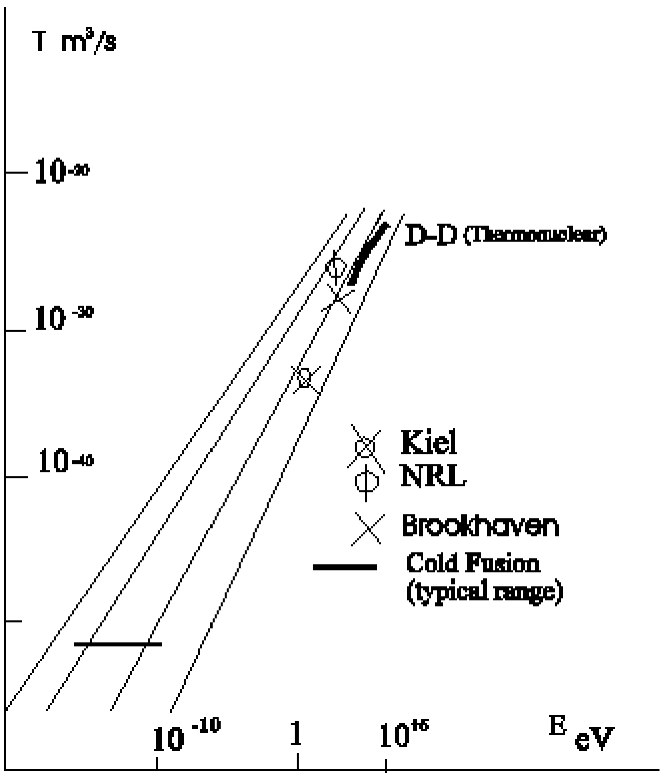

***Figure 2** :*
Estimated position of the Kiel, NRL and Brookhaven resprentative points of experiments. Each straight corresponds to a constant electron number Nu.

5 Probabilistic point of view

Using an important property of a large Poincaré system, the deuterons are supposed quasi-free in this completely ionised medium [6]. Their 3D spatial distribution is supposed to obey the Poisson law. Thus the P_p probability for a micro-volume V, containing p deuterons, μ being the mean number of Deuterons reads:

$$P_p = e^{-\mu} (\mu^p/p!) \tag{4}$$

The probability for the elementary V volume containing two colliding nuclei thus reads:

$$P_2 = e^{-\mu} (\mu^2/2!) \tag{5}$$

And the ratio between the probability of filling a V micro-volume by one unique Deuteron, and the probability of filling it by two Deuterons is equal to the number of electrons ν surrounding two colliding Deuterons (whose distance is inferior to the Bohr atom radius)

$$\nu = 2/\mu \tag{6}$$

Calculations have been carried out with:

$$V = (\text{Bohr radius})^3 = (0.529 \times 10^{-8}\ \text{cm})^3$$

and

$n = 10^{22}$ deutérons/cm^3 $\mu = 10^{-3}$ $\nu = 2 \times 10^3$
$n = 10^{23}$ deutérons/cm^3 $\mu = 2 \times 10^{-3}$ $\nu = 10^3$

There is agreement for the range of ν numbers, between Schrödinger quantum calculations and the probabilistic point of view, grounded on the "Large Poincaré System" hypothesis.

6 Fractal Dimension of collision space

The collision space is made up of the sites of two Deuterons collisions, determined by the dimensions of the cubic elementary V volume
δ : Side of the volume V (supposed cubic)
N_δ : Number of V volumes containing one collision site (per volume unit)
We use the "Box Counting Dimension" algorithm:

$$D = \lim_{\delta \to 0} \frac{\log N_\delta}{\log 1/\delta} \tag{7}$$

But δ is physically finite. One choose a δ value close to the Bohr radius, instead of zero:

$$\delta \# 10^{-9} \text{ cm}, n = 10^{18} - 10^{23}/\text{cm}^3, e^{-\mu} \# 1:$$

With this δ value, different from zero, D is a function of δ and n. One gets this result, by expressing firstly the probability P_1 for a cube of side δ containing one unique deuteron,

$$P_1 = \mu e^{-\mu} = \delta^3 n \tag{8}$$

And the probability P_2 for a cube containing two Deuteron:

$$P_2 = ½ \mu^2 e^{-\mu} = ½ \delta^6 n^2 \tag{9}$$

The number N_δ of cubes containing two Deuterons, in one volume unit, is thus:

$$N_\delta = ½ \delta^6 n^3 \tag{10}$$

And the fractal dimension in function of δ and n:

$$D \# \frac{\log 1/2 \delta^6 n^3}{\log 1/\delta} \tag{11}$$

δ # 10^{-9} cm, n = 10^{18} - 10^{23}/cm^3, $e^{-\mu}$ # 1:

Replacing δ by its expression in function of n and ν,

$$\nu = 2/\mu, \tag{12}$$

$$\delta = (\mu/n)^{1/3} \tag{13}$$

The Fractal Dimension reads:

$$D = \frac{\log 2n/v^2}{1/3 \log nv/2} \tag{14}$$

The slopes of the straight lines for constant ν are very close to the ones of Schrödinger calculation results. For example with n=10^{22}/cm^3, calculations using Schrödinger equation gives D = 1.92, for ν=1.3x10^3 electrons in the cluster whereas the D-formula in function of n et υ gives: D =1.94. The difference is sufficiently low for putting into evidence the agreement between two descriptions of a phenomenon which is drastically different of any "thermonuclear" one.

fIR

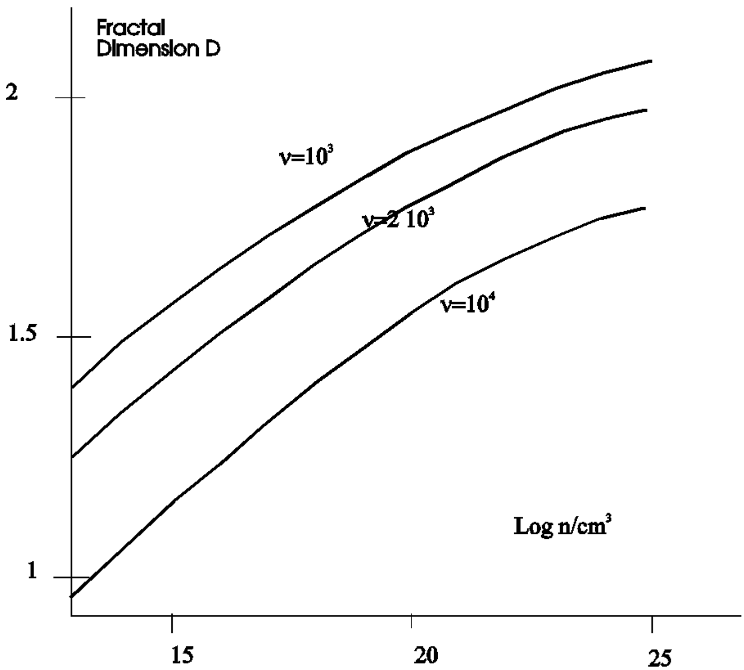

Figure 3 *: Fractal dimension D, in function of fusible medium density, for 3 volumes of the electron number Nu*

The rate R of nuclear reactions is thus ruled by the logarithmic relationship which is linear in logarithmic scale.

$$\text{Log } R'/R = D \text{ Log } (E'/E) \quad (15)$$

E being the energy of the moving deuteron.

7 Experimental evidences

For getting clear evidences, one has to take into account experiments where the realisation probabilities of the above fundamental conditions (LPS, Poisson spatial distributions) may be appreciated as being non-negligible. For example one can consider experiments performed in United States Naval Research Laboratory (NRL) [19]. The quoted experiments consisted of making a current pulse to flow with a peak current between $3x10^5$ Amps to $5x10^5$ Amps and leading and trailing edges of typically 100-120 nanoseconds into a wire of frozen Deuterium (4°K), or into a wire made of a material containing deuterons. The neutron number for one pulse was between two limits, (10^{10}– 10^{12}), for a energy of 2.45 Mev, corresponding to the classical fusion reaction D (D, n) He^3 . One has to notice that the neutrons were detected only during the current decrease, from peak value I_c : this current decrease corresponds apparently to the good functioning of a Large Poincaré System. The number of detected neutrons, is proportional to the 10 power of the current peak I_c^{10} . For accounting of this power with the help of our fractal model", one has to bring out the following remarks:

- Firstly, the mean Deuteron velocity, due to the thermal dissipation during the leading edge, is proportional to the current peak $\sim I_c$
- Secondly, the mean Deuteron velocity, after the current peak, is due to the electrodynamics forces: it is obtained by integrating an expression of the interaction between current elements, which has in factor I_c^2 .

The resulting deuteron velocity is thus proportional to I_c^3 , and its energy is proportional to I_c^6 .

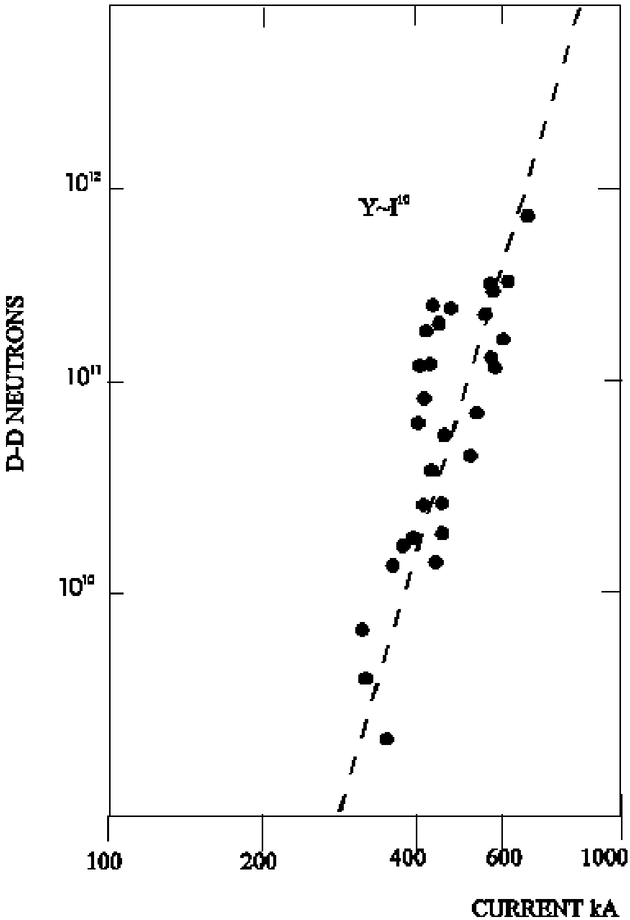

Figure 4 *: Growth of the neutrons burst, coming out during the current decrease, vs the peak current I. The experimenters were claiming a growth proprotinal to* I^{10}

The equation of a straight lines having its slope equal to the fractal dimension D, the rate R of nuclear production is function of the peak current :

$$\mathrm{Log}\ R'/R = 6D\ \mathrm{Log}\ (I'_c/I_c) \qquad (16)$$

One gets a relationship close to I_c^{10} .Given the uncertainties about the parameters, one can speak of agreement between model and experiments. This experiment has been chosen as being demonstrative of the model which is proposed for accounting of nuclear fusion whereas the prerequisites for thermonuclear process are not fulfilled. And also because the pulsed current way seems more promising in the future than simple electrolysis cells.

But one has also to remind the R.J. Beuhler experiments, quoted above, which confirm the electron cluster model from a very different experimental point of view. It shows the pre eminent role of electrons in the collision between a aggregate of some hundred of D^2O molecules with a Titanium target saturated with heavy water [5]. The Proton detection shows clearly that one needs a minimum number of heavy water molecules and thus a minimum number of electrons in the cluster for producing nuclear reactions. Making the D^2O molecules aggregate growing, one gets firstly one unique cluster, but if one makes the aggregate more growing, the Proton number decreases firstly, showing a partition of free electrons between two collision ions sites. As the electrons number is insufficient for two collision sites, their efficiency for screening is insufficient for producing two Protons. If the experimenters had made the D^2O number to grow more, two Protons would be growing again being produced in two aggregates (Figure 1).

8 Generality of the "Electron-Fractal" model.

In the case where there are different kinds of ions in the LPS, everything is approximately going on as if each type of ion would correspond to a specific collision space, the collision sites being rare in comparison with the sites containing only one ion. But one has to emphasize on the fact that the fractal dimension of the collision space of one type of ion is mainly determined by its density per volume unit and by the same ν number of electrons around the two colliding ions, as if there would be only this type of ion in the LPS. From a more general point of view the nuclear reaction one gets depends of the nature of the colliding nuclei, but they can be very different from the habitual ones. For example, according experiments performed in a electrolysis cell [1], the most probable reaction produces with screening, directly ^4He, in the case where the initial medium contains deuterium nuclei. Making a joke One could say: "No Cold Fusion but Electronic Fusion"?

9 Conclusion

The hypothesis of the role of electrons clusters, coupled with the one of LPS, is in agreement with the quantum barrier calculations and with experiments. There is no matter considering the fact that we have mainly considered the case of a condensed medium with deuterium nuclei: it is only an example. For each type of nuclei collision leading to specific nuclear reactions, there does exist a fractal dimension. A very great number of nuclear reactions giving a great variety of new transmutations is possible, as it has been shown recently by experiments performed by L.I.Urutskoev et Al [20]. One can predict a renewal of Nuclear Physics, as much as a new way of retrieving energy.

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