IFM - 9/89
May 1989

Three-body effects in cold fusion

S. M. Eleutério
R. Vilela Mendes

GTAE - Grupo Teórico de Altas Energias
Av. Gama Pinto, 2 , P-1699 Lisboa Codex, Portugal

Abstract

It is pointed that, whenever the conditions for ergodic motion of deuterons in a lattice are realized, three-body scattering events should be taken into account and make an important contribution to cold fusion processes.

To overcome the Coulomb barrier in DD or DT reactions a large kinetic energy is required. The emphasis on these two-body processes is due to the relative low density (the plasma) or high temperatures (the stars) of the medium where fusion is supposed to take place. In fact there are other many-body processes where the Coulomb barrier may be overcome at low energies, which however are not usually considered because they are much less probable, in the usual environments.

Bound states have been considered and this is the basis for μ-catalyzed fusion, wherein a deuteron muon-molecule is formed and the fact that the μ mass is 200 times that of the electron, causes the molecule to be small enough for fusion by tunneling to occur. It has been suggested that, because the effective mass of an electron in a lattice may be much higher than the free mass, they might form deuteron molecules with properties similar to the μ-deuteron molecules. It is however difficult to understand how an electron, when it ceases to be a collective quasi-particle effect and becomes individually bound in a deuteron molecule, might retain its collective properties.

The situation is however different in a scattering process. Not only may the deuteron be considered to scatter from the quasi-particle but furthermore, electron shielding of the deuteron positive charge as seen by the other deuteron is much less effective in a bound state than in certain configurations of the DeD scattering process. Consider DeD scattering in the electron rest frame. When the two deuterons approach the negative scatterer from opposite sides, their charges are effectively shielded by the negative charge, for velocity directions in a relatively large cone. Furthermore the balance of forces exerted on a deuteron by the negative scatterer and the other deuteron is such that, for some kinematical configurations, it is pushed towards the interior of the shielding cone. In this context, the probability for two deuterons to fuse depends therefore on the likelihood of reaching the neighborhood of the negative scatterer at about the same time. I. e., this type of cold fusion hinges on the possibility of enhancing the three body scattering process and not so much in having enough kinetic energy to overcome the Coulomb barrier.

For the three-body effect to play an important role one should have a high probability to find the DeD configuration in a small neighborhood. Imagining a lattice of negative scattterers, this means that the density should be, at least, of the order of two deuterons per unit cell.

If the deuterons are not strongly stabilized near relatively fixed positions in the absorbing material lattice, the non-integrability of the n-body problem, consisting of quasi-free deuterons interacting through Coulomb forces with the negative scatterers, makes the motion ergodic for initial conditions in a set of very large measure. In first approximation we may therefore use statistical considerations based on available phase space volume for each class of configurations. We will use a reasoning of this kind to estimate a lower bound for the three body contribution under ergodicity conditions.

In the n-body problem consider a volume cell V for which the probability of containing 2 deuterons and a negative scatterer is high. It is here that the deuteron density ρ_D enters because it defines the size of the cell. The radius R_D of the cell is of order $\left(\frac{1}{2\rho_D}\right)^{1/3}$.

We assume the total energy E_0 of the DeD subsystem to be very low ($E_0 \sim 0$). In the center of mass of the three body system one has

$$E_o = T_1 + T_2 + T_e - \frac{e^2}{\rho_1} - \frac{e^2}{\rho_2} + \frac{e^2}{\sqrt{\rho_1^2+\rho_2^2 - 2\rho_1\rho_2\cos\theta}} \quad (1)$$

where $\rho_1=|\vec{r_1}|$ and $\rho_2=|\vec{r_2}|$ are the deuteron scalar distances to the negative scatterer, θ the angle between $\vec{r_1}$ and $\vec{r_2}$ and T_1 ,T_2 ,T_e the kinetic energies.

From $E_o\sim 0$ one obtains

$$\frac{1}{\sqrt{\rho_1^2+\rho_2^2 - 2\rho_1\rho_2\cos\theta}} - \frac{1}{\rho_1} - \frac{1}{\rho_2} \leq 0 \quad (2)$$

as a constraint for the allowed configurations in the reduced configuration space (ρ_1,ρ_2,θ) . This implies

$$\frac{\rho_1}{\rho_2} + \frac{\rho_2}{\rho_1} \geq g(\theta) = \sqrt{(\cos\theta+1)^2 + 1} \quad - \quad (1-\cos\theta) \quad (3)$$

for $g(\theta)<2$ any (ρ_1,ρ_2) pair is allowed and for $g(\theta)>2$ the allowed regions in the (ρ_1,ρ_2)-plane are bound by two straight lines

$$\frac{\rho_1}{\rho_2} \geq \frac{g(\theta)}{2} + \sqrt{\frac{g(\theta)^2}{4} - 1} \qquad \frac{\rho_1}{\rho_2} \leq \frac{g(\theta)}{2} - \sqrt{\frac{g(\theta)^2}{4} - 1}$$

The important point to retain is that in all cases the regions extend to simultaneous low values of the (ρ_1,ρ_2) pair.

Let as define as r_F the radius below which the deuterons fuse, i. e. the situation where

$$\rho_1^2+\rho_2^2 - 2\rho_1\rho_2\cos\theta < r_F^2 \quad (4)$$

This defines the region

$$\rho_2 \cos\theta - \sqrt{r_F^2 - \rho_2^2 \sin^2\theta} \leq \rho_1 \leq \rho_2\cos\theta + \sqrt{r_F^2 - \rho_2^2 \sin^2\theta}$$

The area of the intersection of the regions defined by (3) and (4) varies in the range $(3 - 0.5)r_F^2$, i. e. is always of order r_F^2 for all θ.

Under the ergodicity hypothesis, we assume a uniform probability density in the phase space of the three body problem. The projected measure in the reduced phase space (ρ_1,ρ_2,θ) is

$$d\mu = 8\,\pi^2\,\rho_1^2\,\rho_2^2\,d\rho_1\,d\rho_2\,d(\cos\theta)\;dv$$

where

$$dv = \delta(E_o)\,d^3x_e\,d^9v$$

E_o being the $T_1,T_2,T_e,\rho_1,\rho_2,\theta$-function defined by Eq.(1) , x_e the coordinates of the negative scatterer and v the velocities. If we assume that the weight of the dv measure in the region defined by the intersection of (3) and (4) is not very different from its average weight over all phase space, then the relative probability of a fusion event is of order $\left(\frac{r_F}{R_D}\right)^6 = r_F^6\,(2\,\rho_D)^2$. If the deuterons were forced to move along preferential directions in the lattice, one would have an effective dimension reduction of the problem and the exponent 6 in the above ratio should be replaced by $6-\varepsilon$.

To obtain the number of fusions per unit time one has to consider the dynamics of the reduced phase, namely the average speed of the probability flow. For a mean kinetic energy of the deuterons of order $\frac{e^2}{R_D}$, one estimates a characteristic time, associated to the cell of radius r_F , of order $\frac{r_F}{e}(M_D R_D)^{1/2}$, M_D being the deuteron mass. Finally, for the number of fusions per unit time this leads to an order of magnitude estimate of

$$K\left(\frac{r_F}{R_D}\right)^{6-\varepsilon}\quad e\,r_F^{-1}\,(M_D R_D)^{-1/2}$$

We have not assumed any special rigidity of the negative scatterers. In the limit of fixed scatterers the characteristic time of the phase space flow in the neighborhood of the r_F region is smaller and an enhancement factor K of up to $K=(\frac{r_F}{R_D})^{-1/2}$ may be obtained.

If we now consider a density of two 2 deuterons in a cell of radius 2 Å and, in line with our purpose of obtaining a lower bound estimate, take $r_F=5.\ 10^{-13}$ cm , K=1 and $\varepsilon=0$ we obtain an estimate on the order of 10^3-10^4 fusions/(second . cm^3).

The lower bound estimates in this note are based on uniformity assumptions about the projected phase space of the many-body process which should be checked by detailed computation. Nevertheless, the message to retain at this stage is that, even for very low total energies, there are, in the three body scattering process, phase space regions of close proximity which are not particularly suppressed by the Coulomb barrier.

A more rigorous calculation is in progress and will be reported elsewhere.

We end up by listing the conditions for three-body enhanced cold fusion :

1. Material affinity for hydrogen to create a high density of deuterons in the lattice.
2. Weak bounds of the absorbed hydrogen in the lattice to enhance quasi free motion and scattering processes.
3. Existence of effective negative charge scatterers in the lattice, relative to which the deuteron motion is quasi-ergodic.

Remark : For the favorable three-body effects to occur, the deuterons should be able to explore freely the phase space of the n-body process. This ergodicity condition will be inhibited if the absorbed deuterons are localized in more or less fixed places in the lattice or, in general, if the nature or defects of the lattice are such as to inhibit quasi-free motion.

It may occur that the breaking of ergodicity may be countered by choosing an appropriate working temperature, imposing an energy flow through the system, or absorbing another substance which competes with the deuterons for the stable lattice positions.

If quasi-free motion cannot take place in the steady-state, the three body effect may still be seen in situations of forced rupture of the equilibrium, for example when charging and discharging the absorbed deuterons from the lattice.