Is Sono-Fusion to be a Possible Mechanism for Cold Fusion ?

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ABSTRACT

Phenomena of sono-luminescence now appear before the footlights. Recently direct measurement of the temperature of a hot spot created in a liquid by applying a supersonic field was carried out and very large values, $T \sim 0.5$ eV, were obtained.

It seems, therefore, to be an urgent problem to determine the upper bound for temperatures and densities realizable in the hot spot, in connection with cold fusion. In this paper we calculate it by use of the bubble dynamics so far developed by many authors and estimate the fusion rate per bubble.

1. Introduction

Let us start with a brief description of phenomena of sono-luminescence. A supersonic field applied to a liquid yields vapour- and/or gas-filled cavitations in the liquid, which subsequently expand and contract more or less oscillatorilly in phase with the supersonic field. The temperature and density of an adiabatically compressed bubble is so high that atoms or molecules in it are excited and then irradiate photons in its expansion phase.

Recently Flint and Suslick[1)] succeeded in directly measuring the temperature of hot spots and obtained the value

$$T = 5075 \pm 156\text{K}.$$

The aim of this work is to estimate the upper bound of the temperature and density of the hot spot created in a liquid by a supersonic field.

2. Rayleigh-Plesset Equation

The sono-luminescence has a long history of research more than forty-five years and constitutes a well-established branch of physics. We now have a lot of review works, by which one may easily get familiar with it. (For example, see Reference 2)

FRONTIERS OF COLD FUSION

The motion of a bubble in a liquid with radius R is described by the following Rayleigh-Plesset equation

$$\ddot{R} = -\frac{3}{2R}\dot{R}^2 + \frac{1}{\varrho R}\Big[(P_0 + \frac{2\sigma}{R_0})(\frac{R_0}{R})^{3\kappa} - \frac{2\sigma}{R} - \frac{4\mu\dot{R}}{R} - P_0 - P_A(t)\Big], \tag{1}$$

where P_0 is a hydrostatic pressure of the liquid and R_0 is a radius of the bubble in equilibrium with the pressure P_0. The ϱ, σ and μ are, respectively, the density, surface tension and viscosity coefficient of the liquid. The κ is the polytropic index of the gas (this will vary between the specific heat ratio γ and unity, the limits of adiabatic and isothermal conditions, respectively). It is assumed in (1) that the content of the bubble is an ideal gas, but generalization to a van der Waals gas may be straight-forward. The $P_A(t)$ is the applied supersonic field

$$P_A(t) = -P_A \sin\omega_A t. \tag{2}$$

In deriving (1), several simplification were made. (For details, see Reference 2)

3. <u>An Ideal Gas Case</u>

Let us consider a bubble with radius R_0 and in equilibrium with hydrostatic pressure P_0 at $t = 0$, which will then expand isothermally in the first quarter of a period of the supersonic field (2). If the amplitude P_A of the field is large enough, the radius of the bubble is known to abnormally grow up beyond the Blake radius R_B [2]. Let the maximum value of the radius R be R_{max}. In a subsequent half period, the pressure field increases from $P_0 - P_A$ to $P_0 + P_A$ and the bubble contracts adiabatically with increasing pressure. Let R_{min} be a radius of the minimum bubble, where the gas filling the bubble achieves the maximum temperature T_{max}.

The expansion phase is describable in terms of (1) by putting $\kappa = 1$ (isothermal proccess), since the poccess takes place quasistatically. Neppiras [3] numerically calculated the R_{max} for an air bubble in water, assuming that the air is an ideal gas.

Next turn to the contraction phase. It was numerically ascertained by many authors that the contraction occurs very rapidly around the end of the third quarter of a period of the supersonic field (2), when the pressure field is almost $P_0 + P_A$. We can thereby describe the adiabatic contraction proccess by a couple of following equations

$$(P_0 + P_A)(V_{max} - V_{min}) = -\int_{V_{max}}^{V_{min}} P\,dV, \qquad PV^{\gamma} = \text{constant} \tag{3}$$

in stead of directly solving the differential equation (1).

After integrating (3), we can get the maximum temperature and minimum radius as follows;

$$T_{max} = T_0 Z^{\gamma-1}, \qquad Z \equiv (\frac{R_{max}}{R_{min}})^3 \sim \Big[(\gamma-1)\frac{P_0 + P_A}{P_0 + 2\sigma/R_0}(\frac{R_{max}}{R_0})^3\Big]^{1/(\gamma-1)} \tag{4}$$

if Z is much greater than unity, where T_0 is the initial temperature. Figs. 1(a) and 1(b) depict R_{min} and T_{max} against R_0, where we have used values of R_{max} calculated by Neppiras.

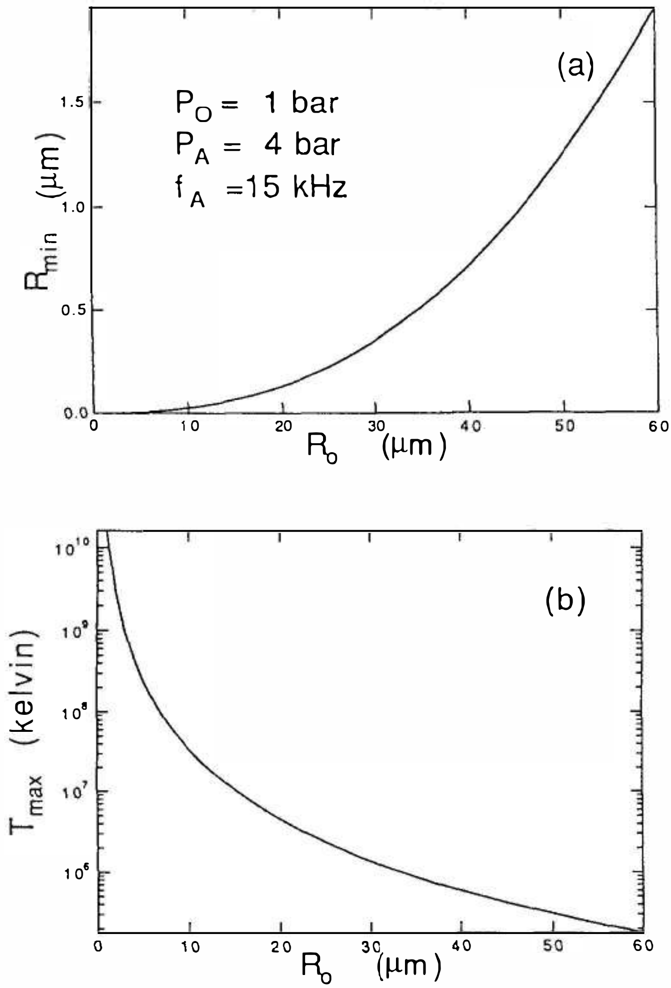

Figure 1

As seen from Fig. 1(b), for initial bubbles of a few microns the maximum temperatures reached are high enough for nuclear fusion to take place. Let the bubble be filled by D_2 gas instead of air. The fusion number per bubble can be calculates as

$$\text{No. of fusions/sec/bubble} = f_\tau (N_e/N)^2 N \varrho v \sigma(E), \tag{5}$$

where f_τ is the fraction of the duration of a minimum bubble to the period of the supersonic field, and N and N_e are the numbers of particles contained in the initial bubble and remaining in the minimum bubble, respectively. The rest of factors on the right hand side of (5)

$$N\varrho v\sigma(E) \tag{6}$$

is a so-called fusion rate per bubble, where ϱ, v and $\sigma(E)$ are the number density of gas in the minimum bubble, averaged relative velocity of gas constituents and fusion cross section, respectively. In (6), $E = (1/2)\mu v^2 = (3/2)k_B T_{max}$, where μ is the reduced mass, k_B the Boltzmann constant. In deriving (5), we postulate that the fusion reaction takes place as in free space, neglecting the dynamical correlation among deuterons, dynamical screening of Coulomb repulsion by electrons etc. We can roughly estimate f_r and the fraction N_e/N as follows. The speed of wall of the bubble in the contraction phase may be close to the sound velocity v_s. The duration of the minimum bubble, therefore, may be roughly estimated as R_{min}/v_s. On the other hand, the speed of diffusion of the gas content to the liquid is much smaller than that of the wall, so that we may put $N_e/N \sim 1$. The fusion rate per bubble (5) are plotted against R_0 in Fig. 2.

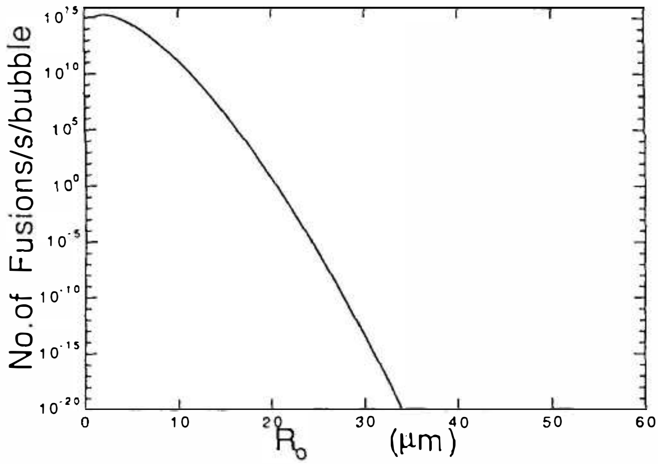

Figure 2

After all, we get a sufficient number of fusions easily detectable in a laboratory.

4. Discussion

Calculations so far made concerns a perfect gas and it is questionable whether such an idealization is valid up to extreme conditions that we are now interested in. To obtain quantitatively acceptable results, we have at least to carrry out calculation similar to the above for a van der Waals gas, and eventually apply molecular dynamics, plasma physics etc. This work only constitutes a preliminary part of the whole task and detailed calculation will appear in another place.

References

1. Flint, E. B. and Suslick, K. S., 1991, Science, 253, 1397.
2. Walton, A. J. and Reynolds, G. T., 1984, Advances in Physics, 33, 595.
3. Neppiras, E. A., 1984, Physics Reports, 61, 159.