ULTRASOUND INDUCED AND LASER ENHANCED COLD FUSION CHEMISTRY

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ABSTRACT

The standard model of sonoluminescence suggests that the Coulomb barrier to deuterium fusion may be overcome by high bubble gas temperatures caused by compression heating if the bubble diameter remains spherical during bubble collapse. However, in the more likely collapse geometry of a pancake shape, the temperature rise in the bubbles is negligible. But the collapsing pancake bubble is found to significantly increase the frequency of the infrared energy available in the vibrational state of the water molecules at ambient temperature. For a collapse to liquid density, ultraviolet radiation at about 10 eV is found. Although the ultraviolet radiation is of a low intensity, higher intensities may be possible if the bubble collapse is enhanced by visible and infrared lasers. Neither hot nor cold fusion is predicted in bubble collapse, but the ultraviolet energy at about 10 eV developed in the bubble is sufficient to provide the basis for a new field of chemistry called ultrasound induced and laser enhanced cold fusion chemistry.

Keywords Cold fusion, Ultrasound, Ultraviolet, Theory

1 INTRODUCTION

In sonoluminescence (SL), gases bubbled through water in an optically transparent flask are found to emit a blue light during ultrasonic cavitation. Based on the emission of blue photons, the apparent magnification of ultrasonic energy in SL was suggested[1] as a possible, yet speculative fusion mechanism. More recently, bubble gas temperatures inferred from black body approximations to the observed optical spectra of bubble gases showed[2,3] temperatures in excess of 50000 K. With expectations[3] of 100000 K in the near future, speculation abounds as to the possibility of hot fusion by ultrasonic cavitation.

Currently, the standard model[4] is used to support SL and the possibility of hot fusion from ultrasound. In the standard model, the rapid collapse of a bubble that remains spherical during collapse compressively heats the bubble gas to high temperatures leading to ionization with the observed spectra produced as the gases recombine. For fusion of deuterium gas, computations[4] of bubble gas temperatures with the standard model give about 10^8 K which is sufficient to overcome the Coulomb barrier and make it possible to achieve hot fusion in a relatively simple manner.

However, the promise of hot fusion by ultrasound may not be fulfilled if the bubbles do not remain spherical during bubble collapse as assumed in the standard model of

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SL. Since bubble collapse occurs along a path of the minimum energy, and since the energy to collapse in a flat pancake shape is significantly less than in a spherical shape, a spherical collapse is the least likely collapse geometry to be observed during ultrasonic cavitation. It is therefore asserted as obvious without proof that a pancake shape collapse is the most likely in ultrasonic cavitation. However, a pancake collapse occurs without a volume change and therefore the temperature increase caused by compression heating is negligible.

The goal of this paper is not to show how hot fusion may be achieved by ultrasonic cavitation with a model that does not rely on a spherical collapse bubble geometry. Instead, a more modest goal of cold fusion chemistry is chosen and differs from the goal of hot fusion where about $\sim$10 keV is required to overcome the Coulomb barrier. Cold fusion chemistry is said to occur if the ultrasound induced cavitation energy is of the order of $\sim$100 eV where nuclear reactions[8] occur but with a non-negligible probability. Alternatively, the goal of this paper is to describe the underlying physics of what may be a new field of chemistry called ultrasound induced and laser enhanced cold fusion chemistry.

2 THEORETICAL BACKGROUND

2.1 Bubble collapse

After bubble expansion, the bubbles are filled with the water vapor in equilibrium with the liquid bubble walls, but also include trace external gases bubbled through the water. Subsequent collapse is an unstable process following a minimum energy path. Since the collapse of a spherical bubble follows a path of maximum energy, a spherical collapse shape is an unlikely event during ultrasonic cavitation. Instead, a pancake shape following a minimum energy path is the likely event as illustrated in Fig.1.

The bubble may be spherical after expansion, but almost immediately after the onset of compression is required to assume a pancake shape characterized by the dimension δ between opposite pancake faces. Since the change in volume of a pancake collapse is negligible, a temperature increase by compression heating of the bubble gases is insignificant. A temperature increase, if any, may only occur over the time the volume changes and the bubble remains in an almost exactly spherical unstable state. Indeed, high bubble gas temperatures do occur in an exactly spherical collapse, but are not realistic because a spherical collapse is an unlikely event. In the SL theory proposed here the most likely temperature increase during bubble collapse is insignificant.

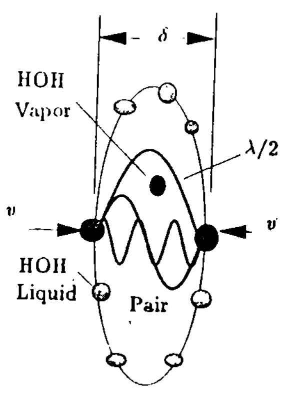

Fig.1 Bubble collapse in ultrasonic cavitation

2.2 Planck energy source

In Planck's theory[6] of electromagnetic radiation within a cavity, the harmonic oscillators lining the cavity walls absorb energy continuously, but emit energy in discrete quanta. The average Planck energy $< E >$ of an oscillator consistent with a continuous absorption and discrete emission is,

$$< E >= \frac{hc}{\lambda}(\frac{1}{2} + \frac{1}{e^{hc/K_b\lambda T} - 1}) \quad (1)$$

where h is Planck's constant, c speed of light, K Boltzmann's constant, T temperature, and λ wavelength.

In the proposed theory of SL, the bubble cavity is treated in the same manner as originally envisioned by Planck except that the liquid water molecules lining the bubble walls are the Planck oscillators. The energy of the Planck oscillators corresponds to the vibrational quantum state of the molecules as contrasted to the electronic and rotational quantum states. Hence, it is the vibrational state of the water molecules lining the bubble walls that directly participates in the increase of Planck energy $< E >$ as the bubble collapses to satisfy half wave boundary conditions for the electromagnetic radiation in the bubble cavity. However, transitions from the vibrational to electronic states may occur. Thus, the proposed SL theory asserts that the water molecules lining the bubble walls act as a pumping mechanism to increase the electromagnetic radiation within the bubble cavity and thereby indirectly excite the bubbled gases to emit photons.

The average Planck energy $< E >$ of a pair of liquid water molecules, one on a liquid wall and the other on the opposite wall, may be conserved with the energy E of the electromagnetic radiation in the space between the pair,

$$E = 2 < E > \approx hc/\lambda \quad (2)$$

Indeed, the conservation of the average Planck energy for the pair of liquid water molecules and the electromagnetic energy E of wavelength λ are required to satisfy the half wave boundary conditions $\delta = \lambda/2$, where the pancake dimension δ is the liquid molecule pair separation distance. Hence, the electromagnetic energy E in the space between the molecular pair is, $E = hc/2\delta$ and consistent with $E = 2 < E >$. This means the decreasing bubble dimension δ during bubble collapse is inextricably linked to an increase in the Planck energy of the liquid molecules lining the pancake walls. At ambient temperature, the thermal contribution to the Plank energy $< E >$ may be neglected for short wavelength λ radiation, say $\lambda < 20\mu$m. From Eq.1,

$$< E > \approx hc/2\lambda \quad (3)$$

Hence, the Planck energy for a liquid water molecule in the wall of pancake bubble reduces to the temperature independent zero point energy. It is noteworthy that the late Nobel laureate Julian Schwinger proposed the zero point energy to explain SL.

2.3 Blue shifted radiation wavelength

The electromagnetic energy E in the space between the pancake bubble walls is quantified by the dimension δ and the wavelength λ. The radiation within the bubble cavity is given by the Richtmyer[6] analogy for the adiabatic compression of blackbody radiation trapped in between a piston and cylinder with perfectly reflecting surfaces.

However, the liquid pancake walls need not be perfectly reflecting as the Planck energy $< E >$ only requires the oscillators in the bubble walls at any instant of time to be in thermal equilibrium with the surroundings.

In the proposed SL theory, only the electromagnetic radiation within the bubble cavity prior to collapse that is in equilibrium with the Planck energy of the water molecules lining the bubble walls may be blue shifted. The Planck energy is to be blue shifted for each independent normal vibrational mode of the bubble wall molecules including the zero point energy and the thermal blackbody energy at the ambient temperature of 20°C, but may be approximated by neglecting the thermal blackbody energy. For the water molecule, the normal modes of vibration are designated by wavelengths λ_0 comprising 6.27μm in bending, and 2.73 and 2.82 μm in the symmetric and asymmetric stretch. The proposed theory of SL requires the blue shifting to be performed independently on each normal mode. This is consistent with the fact that the electromagnetic spectrum may be decomposed into a set of normal modes corresponding to separately distinct oscillators. However, the bubble diameter D_0 after expansion is an important parameter because only wavelengths $\lambda_0 < 2D_0$ are admissible for blue shifting.

Generally, the radiation may fill the bubble cavity with m modes of half wavelength $\lambda_0/2$ where $m \geq 1$. Now, a wavelength changes is negligible for large m where $\delta_0 \gg \lambda_0$. Only for $m = 1$ and specifically for $\delta_0 > \delta > \delta_c$ is the wavelength change significant, i.e., $\delta < \delta_0 = \lambda_0/2$. Now, the bubble collapse provides the required work in compressing the radiation density to achieve the increased energy levels corresponding to the blue shifted wavelengths. During cavitation, the electromagnetic energy density ψ in the bubble wall molecules during collapse is increased from the energy density ψ_0 in the bubble before collapse. The energy densities[6] before E_0 and during collapse E are,

$$E_0 = A_0\delta_0\psi_0 \quad \text{and} \quad E = A\delta\psi \tag{4}$$

where A_0, A are the areas orthogonal to the collapse direction and δ_0, δ are the bubble dimensions. Since the radiation pressure $p = \psi/3$, the work done by the liquid walls to compress the radiation wavelength is $p\mathrm{d}V_{\mathrm{vol}} = -1/3A\psi\mathrm{d}\delta$. For a pancake collapse, $A \approx A_0$ and $A\mathrm{d}(\delta\psi) = A(\psi\mathrm{d}\delta + \delta\mathrm{d}\psi)$. Hence, $\mathrm{d}\psi/\psi = -(4/3)\mathrm{d}\delta/\delta$ and $\psi/\psi_0 = (\delta/\delta_0)^{-4/3}$. Substituting in (4) $E = A\delta\psi_0(\delta/\delta_0)^{-4/3} = E_0A/A_0(\delta/\delta_0)^{-1/3}$. Now, for $A \approx A_0$, $E = E_0(\delta/\delta_0)^{-1/3}$ and since $E_0 = hc/\lambda_0$,

$$E = (hc/\lambda_0)(1/\sqrt[3]{\delta/\delta_0}) = hc/\lambda \tag{5}$$

where λ is the blue shifted wavelength, $\lambda = \sqrt[3]{2\lambda_0^2\delta_c}$.

Of interest is the collapse dimension δ_c in liquid water. At a density of 1000 kg/m^3, the average cubical spacing between water molecules, $\delta_c \approx 0.31$ nm. The blue shifted wavelengths λ in terms of collapse dimension δ_c for admissible wavelengths λ_0 in the bubble cavity are shown in Fig.2.

The blue photon range is from about 390 to 425 nm. In a collapse to liquid density, blue photons are predicted for admissible wavelengths λ_0 of about 10 μm. But, blue photons may also be observed before liquid density is reached if the admissible wavelength λ_0 is about 6.3 μm. The Planck energy $< E >$ corresponding to liquid density collapse as a function of the admissible wavelengths λ_0 is shown in Fig.3.

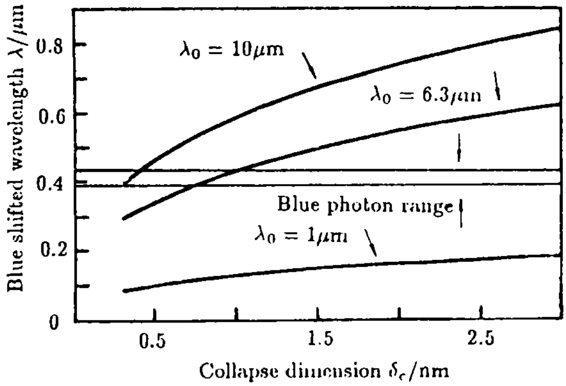

Fig.2 Blue shifted wavelength

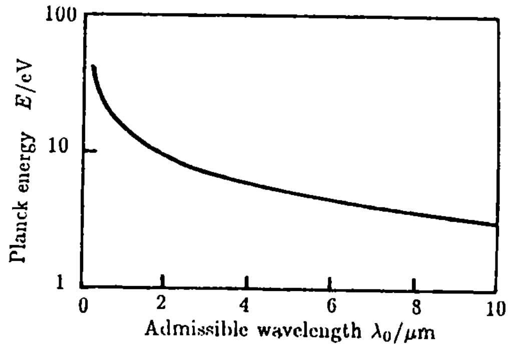

Fig.3. Planck energy at liquid density collapse

For the admissible IR wavelengths λ_0 of the water molecule from 2.73 to 6.27 μm, the Planck energy in a collapse to liquid density is found to be in the 4 to 8 eV range and is sufficient to exceed the 5 eV necessary to emit photons from bubbled gases in SL.

2.4 Bubble collapse quantum number

The proposed theory of SL suggests the average Planck energy $< E >$ of the liquid water wall molecules is not significantly temperature dependent and therefore collapse energy may be expressed in terms of the zero point energy $E_0 = hc/\lambda_0$ and a bubble collapse quantum number $(n-1)$

$$< E > = hc/\lambda_0[(n-1) + \frac{1}{2}] \tag{6}$$

where $n = E/E_0 = \lambda_0/\lambda$ and if $T \approx 20°\text{C}$. This is consistent with the bubble collapse quantum number of the Planck oscillator corresponding to the constant energy level spacings of the harmonic oscillator.

3 SUMMARY AND CONCLUSIONS

The standard model of SL that predicts the Coulomb barrier to hot nuclear fusion may be overcome by high temperatures during bubble collapse is faulted because the bubble collapse is required to be spherical. Spherical bubble collapse is least likely to be observed in ultrasonic cavitation. The most likely pancake collapse occurs without a temperature increase. Hence, hot nuclear fusion is not possible in ultrasonic cavitation.

The proposed theory of SL asserts that the bubble cavity before collapse is filled with normal mode vibrational radiation at the admissible wavelengths λ_0 of the water molecules lining the bubble walls. During bubble collapse, the Planck energy of the wall molecules is increased by the blue shifted λ wavelength required to satisfy half wave boundary conditions. In effect, the water molecules lining the bubble walls pump the bubble cavity with the vibrational energy as the bubble collapses.

The pumping of the radiation within the bubble cavity by the bubble wall water molecules provides the source of excitation to the bubbled gases present. The bubbled gases do not directly participate in the pumping. The proposed theory asserts that in SL, the bubbled gases comprising monoatomic, diatomic, and polyatomic molecules emit photons because of the indirect excitation by the electromagnetic radiation pumped into the bubble cavity by the water molecules lining the bubble walls.

At ambient temperature, only the vibrational normal mode wavelengths of the water molecule are admissible for blue shifting as the thermal contribution to the Planck energy is negligible at ambient temperature.

The Planck energies and bubble collapse quantum numbers are determined from blue shifting the admissible wavelengths λ_0 in the IR vibration spectra for wavelengths $< 20\mu m$ for the water molecule. In a collapse to liquid density, the admissible IR wavelengths $\lambda_0 \approx 6.27$, 2.82 and 2.73 μm are blue shifted to the UV at $\lambda \approx 290$, 170 and 166 nm. The Planck energies in the UV are 4.28, 7.31 and 7.48 eV, and the bubble collapse quantum numbers $n - 1$ are 20, 15 and 15, respectively.

Cold fusion of gases bubbled through the water under ultrasonic cavitation requires at least about 100 eV. However, the Planck energy in a collapse to liquid density is limited to about 7.5 eV and is far less than the 100 eV required for cold fusion.

Consistent with SL, the intensity of the UV from ambient IR is weak and is not sufficient alone to establish a basis for cold fusion chemistry of the bubbled gases. However, the intensity of the Planck energy may be enhanced if the bubbles in the water are filled with VIS and IR photons at the fundamental or the higher excited overtones of the vibrational states of the water molecules lining the bubble walls. For example, the admissible wavelengths λ_0 of the water molecule may be excited with a HF laser at the stretch modes at about 2.7 μm. The conversion of IR laser energy to a UV source within the bubble may be of sufficient intensity to probe the chemistry of the bubbled gases and establish the physical basis for cold fusion chemistry.

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