Nuclear fusion using a table-top sonoluminescence device

Fusion reaction, as a possible source of unlimited energy in the future, has motivated research over several decades now. Every possible way the reaction can be achieved prompts one in this search. This short note deals with one such recent effort.

When liquids are subjected to acoustic vibrations using, say, piezoelectric transducers and if conditions are conducive for occurrence of bubbles in the liquid, one notices that the acoustic field makes the bubbles expand (in the tensile phase of the acoustic wave) and contract (in the compressive phase of the acoustic wave). Studies have earlier been undertaken in relation to light emission from such bubbles and the phenomenon is referred to as 'sonoluminescence'. The cause of sonoluminescence is not known, but it is believed that the shock waves generated during collapse of the bubbles generate high temperatures and pressures in the bubble's gas, which releases a burst of energy. One can trap single bubbles within a sound wave, causing them to swell and shrink and emit light in a regular fashion[1]. Continued research on sonoluminescence over the past three decades has established that 'intense impulsive collapse of gas or vapour bubbles, including acoustically forced cavitation bubbles (cavitation is the formation of bubbles in a liquid when it is 'stretched') can lead to ultra high compression and temperatures'[2].

Taleyarkhan *et al.*[2] from Oakridge National Laboratory, USA (ORNL) aimed at the study of this phenomenon of growth and implosive collapse of bubbles nucleated by means of fast neutrons in liquids containing deuterium.

The reactions:

$$\mathrm{D} + \mathrm{D} \rightarrow {}^{1}\mathrm{H} + {}^{3}\mathrm{H} \text{ (tritium)},$$
$$\mathrm{D} + \mathrm{D} \rightarrow n \text{ (kinetic energy } 2.5\text{ MeV)} + {}^{3}\mathrm{He},$$

are the well-known fusion reactions involving deuterium. The two reactions can occur with equal probability if the deuterium nuclei can coalesce or fuse by overcoming coulombic repulsion between two deuterium nuclei. One notices from these reactions that the tell-tale signatures, when the reactions actually take place, lie in the observation of tritium and the 2.5 MeV neutrons.

In single-bubble sonoluminescence experiments, maximum radius R_m reached by bubbles in relation to the initial radius R_o, that is the R_m/R_o ratio, is only ~ 10 (10 to 100 μm). On the other hand, in the neutron-induced nucleation technique, the corresponding ratio turns out to be much larger, about ~ 10^5 (10–100 nm to ~ 1 mm). This large R_m/R_o ratio happens to be 'a key part for producing very high pressures and temperatures'. Hence the researchers expected that when such a bubble collapses, the vast energy release during implosion may give rise to peak temperatures within the bubbles that may 'possibly lead to fusion and detectable levels of nuclear particle emission in suitable liquids'. Using degassed organic liquids, normal acetone (C_3H_6O) and deuterated acetone (C_3D_6O) at nearly 0°C, the nucleation of vapour bubbles was initiated by fast neutrons using a radioactive neutron source or a pulsed neutron generator. The liquid was also subjected to acoustic pressure field. The light, neutron and γ signals were detected by using a photomultiplier tube and a plastic or liquid scintillation detector with associated electronics. Under the combined neutron and acoustic fields, Taleyarkhan and colleagues detected higher levels of tritium and the 2.5 MeV neutrons in their experiments with deuterated acetone, during bubble implosion, compared to those in control experiments in normal acetone.

Exploitation of the results of these experiments to provide sustained energy production would demand demonstration of net energy gain as well a means of chain reaction without constant input from a neutron source.

The publication of these results by Taleyarkhan in *Science* was not without hiccups. The editors of *Science* had to negotiate a compromise between the authors and their administrators, who rescinded permission that had been given earlier for publication of the paper. Details of what went on can be found in the editorial 'To Publish or Not to [3] by Donald Kennedy. He stated, 'Our mission is to put interesting, potentially important science into public view after ensuring its quality as best as we possibly can. After that, efforts at repetition and reinterpretation can take place out in the open. . . . It goes without saying that we cannot publish papers with guarantee that every result is right . . .'. The publication is plagued by controversies. Criticism has come from other ORNL scientists; others like William Happer of Princeton University joined in the on-going debate. Charles Seife[4] has noted that until people reproduce the experiment 'confusion, not fusion is likely to reign'!

1. Credit: American Association for the Advancement of Science; link: http://www.sciencedaily.com/releases/2002/03/020305074203.htm
2. Taleyarkhan, R. P., West, C. D., Cho, J. S., Lahey, Jr. R. T., Nigmatulin, R. I. and Block, R. C., *Science*, 2002, **295**, 1868–1873.
3. Kennedy, D., *ibid*, 2002, **295**, 1793.
4. Seife, C., *ibid*, 2002, **295**, 1808–1809.

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