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Confirmatory experiments for nuclear emissions during acoustic cavitation

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Abstract

Confirmatory experiments were conducted to assess the potential for nuclear fusion related emissions of neutrons and tritium during neutron-seeded acoustic cavitation of deuterated acetone. Corresponding control experiments were conducted with normal acetone. Statistically significant (5–11S.D. increased) emissions of 2.45 MeV neutrons and tritium were measured during cavitation experiments with chilled deuterated acetone. Control experiments with normal acetone and irradiation alone did not result in tritium activity or neutron emissions. Insights from imaging studies of bubble clusters and shock trace signals relating to bubble nuclear fusion are discussed.
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1. Introduction

It is well-known (Gross, 1984) that the thermonuclear fusion of deuterium (D) atoms requires high pressures, high temperatures and sufficient length of confinement time. The intense implosive collapse of bubbles, including acoustic cavitation bubbles, can lead to extremely high compressions and temperatures, and to the generation of light flashes attributed to sonoluminescence and involves energy focusing of $\sim 10^{11}$ (Crum and Matula, 1997; Camara et al., 2004). The possibility of using the phenomenon of sonoluminescence for attaining thermonuclear fusion in collapsing gas–vapor cavities has been predicted theoretically as a possibility if appropriate techniques and methodologies were discovered and developed to lead to intense-enough compressions and heating (Moss et al., 1996; Nigmatulin et al., 2004; Taleyarkhan et al., 2004b). Taleyarkhan et al. (2002, 2004a) provided experimental evidence of such nuclear emissions using the novel experimental technique and approaches they developed. In this methodology, neutrons are used (much like in a conventional fission reactor where neutrons inter-

Abbreviations: DPM, disintegrations per minute; PNG, pulse neutron generator; PRE, proton recoil edge; PSD, pulse shape discrimination; S.D., standard deviation; SL, sonoluminescence

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act with uranium nuclei and produce more neutrons) to seed nanometer size vapor bubbles in a tensioned organic liquid (acetone) which then grow by factors of ∼100,000 and then intensely implode to produce flashes of sonoluminescence light accompanied with intense localized pressures, and temperatures for the compressed vapor molecules. In a deuterated liquid, the approach resulted in evidence of statistically significant neutron and tritium emissions (Taleyarkhan et al., 2002, 2004a,b).

The aim of the present study and experiments was to confirm if, by following the cited conditions and methodology by Taleyarkhan et al. (2002, 2004a) that nuclear fusion signatures (i.e., statistically significant ≤2.45 MeV neutrons and tritium emissions) can result during neutron-seeded acoustic cavitation of C_3D_6O at ∼0 °C, but not with neutron irradiation alone, nor while conducting corresponding neutron-seeded acoustic cavitation experiments with C_3H_6O since thermonuclear fusion of H-atoms is not possible (Gross, 1984).

2. Experiment set-up

Following the methods and apparatus dimensions reported in the published literature (Taleyarkhan et al., 2002, 2004a), a test cell (∼62 mm in diameter and ∼200 mm in height) made of Pyrex™ driven with a cemented PZT piezoelectric driver ring was constructed. The system was driven with a 40 W PiezoSystems™ linear amplifier and a Agilent™ wave-form generator as shown schematically in Fig. 1. Experiments were conducted to assess if neutrons and/or tritium emissions occur when conducting neutron-seeded acoustic cavitation experiments with deuterated acetone (C_3D_6O, certified 99.92 at% D). Corresponding control experiments were also devised without cavitation (i.e., neutron irradiation alone) as well with neutron-seeded cavitation in normal acetone (C_3H_6O, 100% pure). The negative pressure threshold for bubble nucleation by fast neutrons in acetone is −7 to −8 bar (Hahn, 1961). A pressure map of the chamber was obtained by means of a calibrated hydrophone. The drive voltage corresponding to the onset of cavitation (defined herein as the onset of nucleation and collapse of bubbles within a 10 s observation period) in the presence of neutrons was first determined to get a state point corresponding to ∼±7 bar magnitude, and then doubled (as done by Taleyarkhan et al., 2002) to obtain the approximate drive pressure amplitudes of ±15 bar for conduct of the confirmatory experiments.

Unlike the experiments conducted by Taleyarkhan et al. (2002, 2004a) where precise time-based nucleation was performed with a 14 MeV pulse neutron generator (PNG), such apparatus was not available for the present study. Due to this unavailability seeding of bubbles was conducted using an available isotope neutron source. This is considered reasonable since the present study was not focused on timing of sonoluminescence flashes and time-correlation of emitted neutrons with sonoluminescence, etc., but to investigate if the key nuclear fusion signatures (2.45 MeV neutrons and tritium) are possible to detect in statistically significant quantities with neutron-seeded cavitation of C_3D_6O. The acoustic driving system, filtration (with 1 μm filters), degassing and system pressure (∼10 kPa) were kept similar to that used in the Taleyarkhan et al. (2002, 2004a) experiments. Upon test cell construction, liquid degassing and performance characterization it was confirmed via counting microphone shock trace histories that ∼10–20 bubble clusters could be generated per second with a drive amplitude of ∼±15 bar and a resonance frequency of ∼19.6 kHz for C_3D_6O and about 20.6 kHz for C_3H_6O. Although the bubble cluster activity was not as high as reported (Taleyarkhan et al., 2002, 2004a), this performance was considered adequate for overall confirmatory purposes.

As is well-known, the fusion of D atoms (Gross, 1984) results in the emission of a proton, helium-3, a neutron (of 2.45 MeV energy) and tritium. Protons (in the MeV range) are charged particles which cannot traverse more than ∼1 mm in the liquid before getting absorbed, and therefore, cannot be measured with detectors outside of the apparatus. The same problem holds true for helium-3 atoms which are non-radioactive and difficult to detect in small quantities. Neutrons are uncharged particles which can leak out of the test chamber and can be detected with suitable instrumentation. Also, tritium being a radioactive gas which remains in the test liquid can be counted for beta-decay activity (if a suitable state-of-the-art beta spectrometer is available). Therefore, testing was initiated systematically for monitoring the key signatures consisting of tritium and neutron emissions.