Tritium Evidence in Acoustic Cavitation Nuclear Emission Experiments

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Abstract

Tritium measurements conducted in controlled experiments to investigate nuclear emissions during acoustic cavitation of the organic deuterated fluid – reported by Taleyarkhan, *et. al*., in *Science*, 8 March 2002 [1] – provide positive evidence for excess tritium produced (and attributed to D-D nuclear fusion). Tritium data was obtained for both deuterated and normal acetone subjected to cavitation and acoustic oscillation. Samples from pre-cavitation and post-cavitation deuterated acetone were measured for tritium content with a Packard scintillation detector. The experiments were performed using isotropic neutron sources for initiating cavitation in properly degassed deuterated acetone. The results point to statistically **observable** tritium increases in post-cavitation deuterated acetone samples, suggesting the possibility of D-D fusion taking place. Samples of normal acetone and deuterated acetone not subjected to cavitation do not show statistically **observable** changes in tritium.

Introduction

In 2002, Taleyarkhan *et al* claimed evidence for D-D nuclear fusion achieved in what is essentially a table top experiment [1]. Deuterium nuclei present in liquid deuterated acetone are thought to fuse in the implosion of bubbles generated after bombarding with neutrons the liquid which is under tension and subjected to oscillation driven by a piezoelectric element. Taleyarkhan's experiments significantly extends previous attempts to achieve high temperatures and pressures in sonoluminesence, a phenomenon where light emissions follow the collapse of bubbles excited by sound waves. Whereas previous sonoluminesence experiments (typically using water as the oscillating liquid) reach temperatures about 10,000 °K, Taleyarkhan *et al* claim to have achieved thermonuclear range of temperatures, that is, about 100,000,000 °K.

The D-D nuclear reaction proceeds in thermonuclear conditions as follows:

$$D + D \rightarrow \begin{cases} p + T \\ n \quad (2.5 \quad Mev) \quad + \quad He^3 \end{cases}$$

where D stands for a deuteron nucleus, p for proton, T for a triton, n for neutron and He^3 is the nucleus of a helium-three atom. The two branches of the reaction are almost equiprobable and each provides a unique signature for the occurrence of the reaction: tritium in the first branch

and a 2.4 MeV neutron in the second branch. Taleyarkhan *et al* reported evidence for both signatures.

In the work presented we check for tritium production in properly designed deuterated acetone controlled experiments under conditions similar to those reported in [1]. The main objective was to investigate whether or not excess tritium can be observed in a statistically significant manner and whether there was repeatability in the experiment. No effort was made to improve upon the original experiment, or to arrive at any theories explaining the results even though much work should be done in this area.

Achieving the reported conditions of the experiment involves a myriad of factors, not the least of which are, good design of the resonating cavity, careful glass work, and fine tuning of the electronic circuitry. Subsequent to each run (typically seven hours long) we measured for tritium production after preparing a proper scintillation cocktail and performing a scintillation counting procedure. All samples were treated in as close to identical conditions as possible with the operating fluids (normal and deuterated acetone) counted for tritium before and after processing. The results have been analyzed for statistical significance and compared with those published in the original work by Taleyarkhan *et al*, [1].

Theoretical Considerations

Ultrasonic Conditions for Thermonuclear Fusion (TJevremovic to add Ref)

Liquids like solids can be placed in a state of tension. Liquids fracture at negative pressures through a process called *cavitation*. Cavitation means that cavities (bubbles) are generated in a liquid when its pressure is lowered to the point where liquid starts to boil into vapor (liquids boil when temperature is increased or pressure becomes too low). Cavities collapse when they pass into regions of higher pressure.

Cavities can be generated in many different ways; they can be initiated hydronamically, through lasers, or using neutrons. Once a cavity is generated in a fluid it can be driven into high amplitude pulsation by strong ultrasonic waves. In certain organic fluids like acetone, driven by ultrasonic pressure, cavities may grow from an initial size in the order of a nanometer to a millimeter range diameter (a volume change of nearly twelve orders of magnitude) before collapsing, [1].

The low acoustic energy transferred to a fluid converts into high energy light emitted at the moment of bubble collapse. The phenomenon, conversion of sound into light through transient cavitation bubbles' clusters, called *sonoluminescence* (SL), was first discovered in 1934. In 1988 the effect became more interesting when single bubble sonoluminescence (SBSL) was produced [Ref??]. In SBSL a single bubble in a fluid medium (usually water) is trapped in a standing acoustic wave and emits light with each pulsation. The effect is reproducible under highly controllable conditions and with the enormous brightness of the light signal that makes SBSL a unique physical system suitable for investigating fundamental aspects of sonochemistry including, but not limited to, energy conversion, cavitation formation and light emission.

A crucial parameter in determining the conditions for bubble implosion is the maximum expansion of the bubble or cluster of bubbles, defined as the ratio of initial to maximum radius

attained by the bubble. On the basis of experimental observations and theoretical analysis it is expected that the energetics of bubble growth and collapse is a direct function of a magnitude of this ratio. In common SBSL experiments the maximum expansion is in order of 10 (bubble grow from usually 5 μm to 50 μm), [Ref??]. Once a bubble is created in the fluid and acoustically levitated the sound waves cause the bubble to oscillate. The bubble expands and contracts in phase with the oscillating sound field. During the expansion phase a bubble grows under the influence of low pressure (negative or tensile) and the potential energy is increased as a function of the bubble size and the ambient pressure. Once a bubble grows to its maximum size, the surrounding higher pressure region enforces its catastrophic collapse from 50μm to a size of less than 1μm. The process is accompanied with the emission of light. A large number of experiments performed in the regime of SBSL led to the prediction that at the moment of collapse the interior of a bubble vapor condenses under the formation of shock waves emitting light in the range of visible to ultraviolet. The light spectrum compared to a black body radiation indicates the temperature of a bubble reaching over 10,000 °K, [Ref??]. Such high temperatures achieved in SBSL point to the possibility of generating conditions for thermonuclear fusion in a system that would produce a more violent change in bubble size (drastically increasing the expansion ratio well over 10).

Taleyarkhan *et al* [1] designed an experiment to achieve such conditions by using deuterated acetone (C_3D_6O) as the fluid medium, well degassed and exposed to acoustic pressure amplitudes of the order of ±15 bar (the pressure amplitude in standard SBSL experiments with ordinary water is in the range of 1 – 1.35 bar), [Ref??]. To initiate the acoustic cavitation, the very well degassed fluid is exposed to high energy neutrons (in the majority of experiments a pulsed neutron generator (PNG) producing 14 MeV neutrons is used). The bubbles are formed as clusters and the overall expansion ratio is estimated to reach the value of 10^5 (although no direct proof is provided). From the above considerations, it is expected that such dramatic expansion from nanometer to millimeter bubble diameter and its collapse to a small but finite size, may produce temperatures in the thermonuclear range (as high as at the center of Sun) to induce fusion of deuterons.

The history of bubble events that may lead to fusion can be theoretically speculated as a complex chain of interrelated events. When a bubble starts to be compressed the first light emitted is in the red spectrum. As time progress, light of higher energy is emitted reaching the ultraviolet region. At some point a collapsing bubble launches a shock wave that compresses the interior vapor of the bubble in a manner analogous to the compression occurring in a hydrogen bomb. During the early phase of implosive collapse some electromagnetic phenomena are likely to exist and light of harder frequencies is expected to be detected. As the shock wave propagates, however, the size of a bubble decreases dramatically producing a great increase in density, pressures and temperatures at the center of bubble. Although the temperature increases rapidly, the increase is limited by the emission of energy (otherwise the temperature will become infinite). When light is no more emitted, the bubble is speculated to reach the state of thermonuclear plasma and fusion events to be taking the place. The collapse of the bubble and thus the duration of the fusion events are limited by the fact that bubble compression is finite in size due to the repulsive coulomb forces that act between fermions. These forces generate

pressure that act in the opposite direction from the implosion direction, and shock propagates from the interior of bubble outward.

Josh did some MCNP modeling/ Josh would that be proper to add here? We may comment/justify here on the expectations of small quantities of T formed…I would suggest if you could summarize here the model and results. Thanks!!

Dynamics and Modeling of Bubble Grow and Collapse

To be added by MBertodano and JWalters and SRevankar……..

Experimental Set-up

Chamber Design

The chambers used for the cavitation experiments were close to the design described in [2]. Figure 1. shows the schematic of a chambers built at Purdue University. Table 1 summarizes the technical characteristics. The chamber is made of a borosilicate glass cylinder surrounded with the piezoelectric ring, PZT. Two, hollow glass pistons, one at the top and one at the bottom, act as free surfaces. These free surfaces should give a point at which an acoustic node will form and minimize the absorption of acoustic power. Upon filling the chamber with acetone, a silicone rubber tube is connected to the glass tube on the chamber lid. The silicone rubber tube is connected to a hand vacuum pump, with a ball valve between the pump and chamber rated to 29" Hg. The internal part of the chamber and the bottom piston are vacuumized during the experiment. At the operating condition of 0 ºC, the vacuum pressure is kept at 27" Hg. The cavitation fluid used in all experiments consisted of normal spectral grade acetone, and 99.92 a/o deuterated acetone.

Cavitation Source

Two types of isotopic neutron sources were used for initiating cavitation in normal and deuterated acetone: 1 Ci Plutonium-Beryllium (PuBe) source and 10 Ci Americium-Beryllium (AmBe) source.

Experiment Control and Monitoring Equipment

The chamber wall was oscillated by supplying an alternating current to the piezoelectric ring. The piezoelectric ring changes its internal diameter proportionally to the applied voltage. A signal of a specific frequency and amplitude is sent from the wave form generator to the linear acoustic amplifier. The amplifier drives the piezoelectric ring through a set of adjustable inductor coils. The driving voltage and microphone output are measured and displayed on an oscilloscope. The microphone is also a piezoelectric device, which outputs the response of the chamber based on the chamber wall displacement. The microphone was placed onto the wall of

the chamber with epoxy, at a distance of 40 mm above the piezoelectric ring. A schematic of the system is shown in Fig. 2.

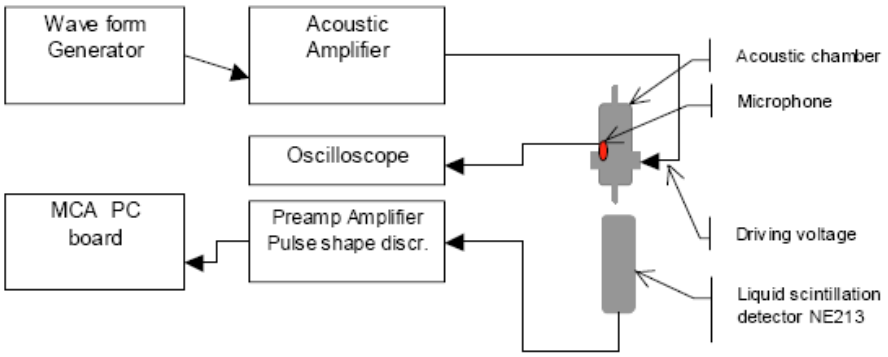

Figure 2 Schematic of experiment signal generation and monitoring

Acoustic Pressure Profiles in the Chamber

Previous experiments [1] have shown that the acoustic pressure to power ratio in a chamber is linear. We performed tests to determine how the chambers behave with respect to operational sound frequency and power level. Measurements to determine such characteristics were performed in axial and radial direction. An axial profile is obtained with the probe submerged into an open chamber (filled with acetone, without lid and top piston). Pressure measurements were taken at a given power for various depths below the free surface of the acetone. The probe gives a voltage output that is proportional to the pressure at the tip of the probe.

The dependence of the pressure on the driving voltage applied to the PZT was also determined. To perform this test, the pressure probe is placed in the center of the chamber, both axially and radially, and the power is increased slowly. This test is performed at the resonance frequency in order to maximize the pressure and the result is depicted in Figure 3. This test was performed at room temperature and at the frequency of 24.57 kHz. Measurements confirmed that there is definitely a linear dependence between the voltage applied to the PZT ring, and the pressure developed within the chamber. Since, voltage is proportional to displacement in PZT systems, the linear relationship is true for any PZT ring thickness provided that the driving signal is undistorted.

The specific axial pressure distribution was required to insure chamber operation in the fundamental mode (first harmonic resonance). To perform such test, the chamber was held at a constant power, and the probe was placed at different depths within the acetone. The result of such test is shown in Figure 4. The 0 mm point refers to the surface of the acetone, and the 80 mm point represents the space just above the bottom piston. The measurements show that the pressure profile developed in the chamber is closely approximated by a sinusoid.

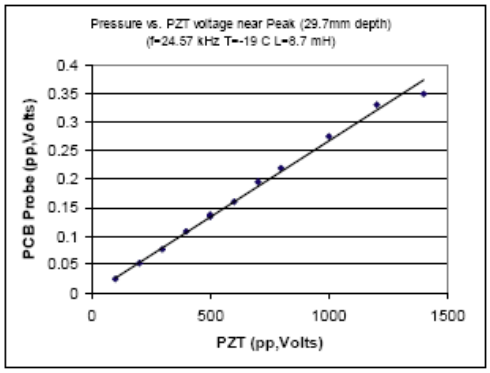

Figure 3: The dependence of pressure on driving voltage

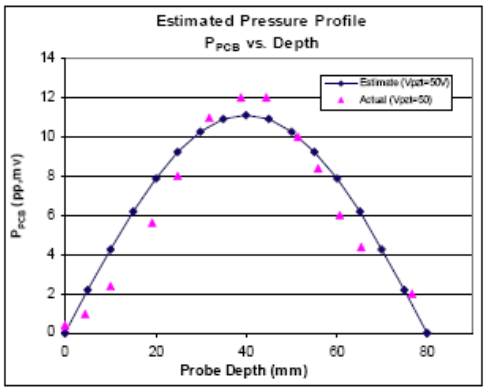

Figure 4 Measured chamber profile plotted with a theoretical sinusoidal profile.

Description of the Experiment

Degassing Stage

Each experimental test began by degassing the fluid. During this process, gasses that are dissolved into the fluid due to normal atmospheric conditions are removed. This ensures that when cavities form, they are composed of acetone vapor and not air. Degassing begins by placing the acetone into the chamber, and lowering the pressure via the external hand pump that is attached to the lower piston and the stem at the top of the chamber. The vacuum pressure is

maintained at the vapor pressure, which is constant for a given chamber temperature. Once a vacuum is drawn at room temperature, the chamber is placed into the freezer, where temperature is kept nearly constant at 0° C. The resonance frequency is determined by sweeping the frequency from 16-22 kHz and finding the peak voltage output from the pill microphone. Once the first harmonic resonance (first mode) is found, power is slowly increased until bubbles form throughout the volume of the chamber. This visually looks similar to a carbonated beverage that was just poured into a glass. The vacuum is increased gradually so that the 'soda style' degassing is continuously facilitated. Excess pumping, however, will lead to system boiling.

Within 10-20 minutes, the 'soda style' degassing will cease and the chamber will become static. At this point, the neutron source is placed by the chamber. At or near the resonance frequency, cavitation will begin to occur. At this stage of degassing, continuous cavitation, events that look like 'comets', are prevalent and individual cavitations are hard to observe. Comets visually appear as a series of bubbles that originate at a single point and then travel to the wall of the chamber. The bubbles that form the comets move rapidly from the center and cannot be distinguished from one another, thus creating a tail. The comets, also known in the literature as streamers, are the result of insufficient degassing or overpowering [3]. Degassing is continued by finding a power and frequency that results in the formation of gas bubbles that form (mostly from comets) and reach the surface of the chamber. After 30–60 minutes, the power is lowered so that all bubbles will travel to the surface. Power is then increased until the onset of cavitation is observed, which corresponds to ~7 bar for acetone. The cavitation will appear as a single bubble that forms in the center of the chamber and travels outward. Power is then increased to reach the ±15 bar operational pressure. If comets still exist at this operational pressure, then degassing should be continued. After a thorough degassing, cavitations will occur and travel from the center of the chamber to the outer edges of the chamber. If the fluid is degassed well, residual bubbles from the cavitation will not be observable.

Runs

The predetermined duration for the cavitation process was 7 hours. To begin the experiment, the operational power at the resonance frequency was determined. This was done by slowly raising the power until single cavitation events occur. This point is referred to as the onset of cavitation, which occurs at 7 bars at 0 °C for acetone. Since the amplification system is linear, the onset of cavitation is used to determine what drive amplitude setting is needed for an acoustic pressure of 15 bars. Once 15 bars was reached, the experiment time began. Throughout the experiment, the frequency is monitored and the cavitation rate is estimated. Frequency tends to drift higher with falling temperatures, and drift lower with higher temperatures. Although the temperature could vary slightly, the effort was made to keep the temperature at or slightly below 0 °C.

For all runs, we could observe that the quality of cavitation tended to degrade after ~4 hours of cavitation. Degradation was characterized by the formation of steamers or non-collapsing bubbles. Once degradation begins to occur, lowering the power slightly or shifting the frequency by a few Hz can lead to partial cavitation recovery, without the streamers. It is important to note that although the degraded system appears similar to late stages of degassing, it

is likely due to impurities, and not loss of vacuum. The formation of impurities is discussed in later sections.

Sampling

Before beginning an experiment, a 5 cc sample of the acetone was removed from the top of the chamber. Upon completion of the experiment, another 5 cc sample was removed from top of the chamber. These samples were called Pre-Processed and Post-Processed samples, respectively. After the post-processed sample was taken, both samples were delivered to the measurement facility immediately for preparation of the scintillation cocktails. The cocktails were prepared by mixing 1 cc of acetone with 15 mL of Ultima Gold™ scintillation cocktail. Two identical cocktails were created from the pre-processed sample, and two identical cocktails were made from the post-processed samples. Weights of the scintillation vials both before and after the addition of acetone gave an accurate measure of the exact quantity of acetone that was added to the cocktail. The process of delivery of the samples and cocktail preparation was on the order of 30 minutes. The samples were counted using a scintillation detector within five to ten minutes of preparation.

The numerical analysis of the measured counts was performed by averaging the counts for the same sample over the different counting cycles, normalizing to sample mass, and then comparing the difference between the pre and post processed samples. The statistical values stem from both the error due to the randomness of nuclear counting and the error added by the detector during the measurement process.

Tritium Counting

Detector Output

Tritium measurements were performed using a Packard 1900 TR scintillation detector. The detector measured each of the samples for one hour in the order of pre-post, pre-post. After these four vials were counted, a vial containing only Ultima Gold™ was counted to determine the background, and a vial containing a NIST standard was also counted. Once one cycle had been completed, the same cycle was repeated several times to improve the statistics.

The Packard scintillation counter gives output in the form of CPM (counts per minute) and DPM (disintegrations per minute). CPM is the actual number of interactions occurring within the detector averaged over a time. DPM is the number of disintegrations in the sample, and is calculated by the Packard scintillation detector taking into account the geometry and detector efficiency. Efficiency is effected by the quench (the chemical effect of the chemicals added to the Ultima Gold® cocktail). Prior to measuring every sample, the Packard counter places a Ba-10 source next to the cocktail vial. The counter then compares the Ba-10 spectrum to a spectrum of standard cocktails with a known amount of quench.

Chemical Quenching

During the interpretation of the results, it was found that the mass of acetone added to the cocktail could have large effects on the tritium counting. A mass correction approach was used to ameliorate these differences

To be added by ABugaev and JWalters and FClikeman……..

(INCLUDE MASS CORRECTION ALGORITH USED BY FRANK – IN SUMMARY FORM)

Results

Run performance and description

To be added by MBertodano and JWalters and SRevankar……..

Raw data/description

To be added by MBertodano and JWalters ……..

Tritium Data Analysis

Several tests were performed including, 10 D-acetone tests, 3 N-acetone tests (N stands for "normal"), and one non-cavitation D-acetone test. In the case of the non-cavitation test, un-cavitated D-acetone was measured as if a cavitation test had been performed. The results are summarized in Figure 5.

(DISCUSSION/OBSERVATIONS ABOUT INDIVIDUAL RUNS HERE CLERIFY THE EXP REGARDING NEUTRON SOURCE INTENSITY)

To be added by ABugaev MBertodano JWalters and FClikeman……..

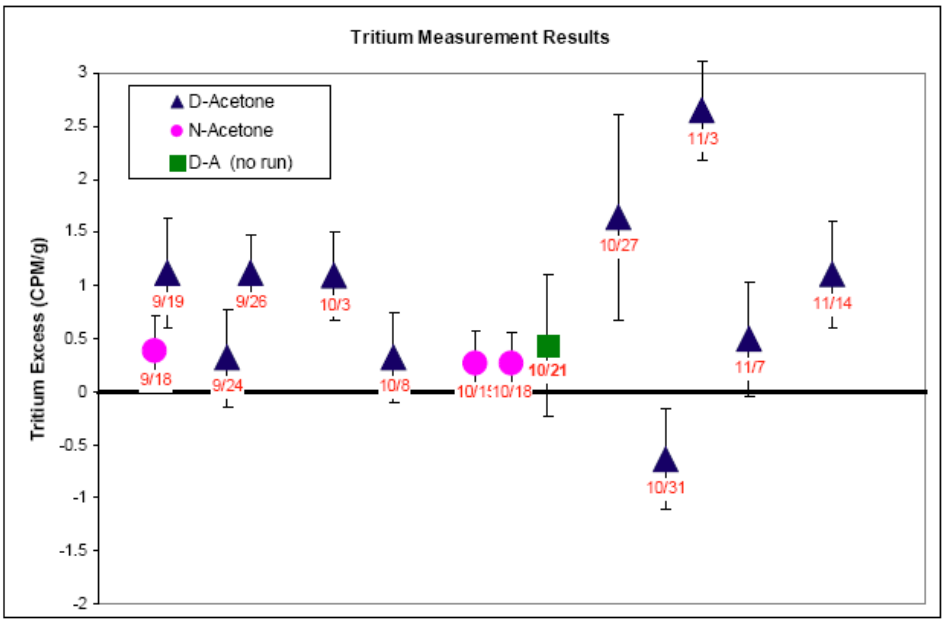

Figure 5: Measurement of excess tritium per gram of acetone in sample /CPM per gram/

Accoring to Fig. 5 the test performed on 11/3 shows the largest CPM excess of tritium counts. This run and the subsequent measurement process were thoroughly analyzed. At that point, a large mass difference (~17%, due to strong acetone evaporation while dispensing) between the amount of pre- and post- processed acetone added to the scintillation cocktails was observed. Figure 6 shows the measured CPM/g *vs* ratio of acetone mass to cocktail and vial mass for all samples. The 11/03 run is the outlier of the pre- and post- processed samples. These samples were obtained from a single batch of D-acetone. Figure 6 shows that samples with less acetone can result in higher counts, which is counter intuitive.

Initialy CPMs were to be used to quantify the tritium count excess in the experiment with D-acetone versus a control experiment with N-acetone. In the original experiment reported by Taleyarkhan, comparisons using count per minute rates rather than disintegration per minute rates were made. Quantification of absolute activity of the sample was not formulated as an objective of the tritium counting process. However, the experimental results suggested that a strong dependence of the tritium counting depends on the mass of acetone introduced into scintillation cocktail.

Normally, the quench correction is performed by the tritium counting machine based on the pre-installed quench curves by estimating **tsi-e parameter** **(NEEDS TO BE EXPLAINED)**. For non-aqueous organic samples a custom quench curve should be built. The quench correction

The results, including corrections **what type?????????**, are shown in Table 2. In the second column we show net counts per minute obtained from the Packard machine. Column three has the results after a mass correction was applied. Column four has the most relevant results obtained after quenching was applied and disintegrations per minute were calculated. Here we see that the aggregate tritium count is nearly eighteen standard deviations above zero.

(DISCUSSION OF INDIVIDUAL RUNS AND COLUMNS HERE)

Table 2 Data Analysis Summary

	Raw data	With Mass Correction	With Quenching	Error Estimate.
	Net Counts	Net Counts	Net Counts	Gaussian
	cpm/gm	CPM/gm	(dpm/gm)	+/- σ
D-Acetone Runs				
D-Acetone 7 hr run 9/19/03	1.11	0.63	1.78	0.49
D-Acetone 7 hr run 9/24/03	0.33	0.32	1.27	0.44
D-Acetone 7 hr run 9/26/03	1.18	0.22	1.14	0.35
D-Acetone 7 hr run 10/3/03	1.08	-0.08	1.75	0.41
D-Acetone 7 hr Run 10/8/03	0.34	0.21	1.18	0.42
D-Acetone 7 hr run 10/27/03	-0.18	-0.21	0.57	0.42
D-Acetone 7 hr run 10/31/03	-0.63	0.07	-0.28	0.46
D-Acetone 7 hr run 11/3/03	2.48	0.10	4.33	0.35
D-Acetone 7 hr run 11/7/03				
Mixed used D-A from runs 11/3 and 10/31 (IS THIS COUNTED IN THE AGGREGATE?)	0.49	0.15	1.06	0.54
D-Acetone 7 hr Run 11/14/03	1.1	0.72	3.11	0.50
Aggregate of D-Acetone Results	***0.72***	***0.25***	***2.65***	***0.14***
N-Acetone Runs				
N-Acetone 7 hr run 9/18/03	0.38		0.89	?
N-Acetone 7 hr run 10/15/03	0.27		1.32	?
N-Acetone 7 hr run 10/18/03	0.27		0.9	?
Aggregate of N-Acetone Runs				

D-Acetone No-Runs				
D-Acetone no run 10/21/03			0.68	?
D-Acetone no run 12/19/03			-0.91	?
Aggregate of D-Acetone No-Runs				

Discussion

Statistical Significance

To be added by ABugaev and JWalters and FClikeman……..

Tritium Counting Issues (net positives)

To be added by ABugaev and JWalters and FClikeman……..

Improved Experiment (suggestions)

To be added by ABugaev and JWalters and MBertodano and SRevankar……..

Mapping out the Ultrasonic Conditions for Fusion

Photons do not suffer interactions with nuclear matter due to their weak electromagnetic coupling with hadrons (neutrons, protons). Produced photons of different wavelengths (*i.e.* energies) can be used to map out the thermodynamical evolution of nuclear matter. The vapor in a bubble that starts imploding becomes ionized gas with free electrons. These electrons have a distribution of energies with the average energy proportional to the temperature of the medium. With the collapse of bubble, the density of bubble increases decreasing the mean separation between the constituent particles. When separation between the electrons become comparable to the de Broglie wavelength of the electrons, the electron gas becomes *degenerate*. (The de Broglie wavelength of the ions is much smaller than that of the electrons, so the ion gas remains non-degenerate.) A degenerate electron gas exerts a substantial pressure, because the Pauli Exclusion Principle forbids the separation between them to become significantly smaller than the corresponding de Broglie wavelengths. This represents one of the reasons why the collapsed bubble has a finite size.

Photons emitted from the vapor have energies equal to the change in electron energy during the collision events. Therefore, the distribution of the photon energies reflects the

distribution of the electron energies having the average value proportional to the temperature. Throughout the sequences of bubble implosion the spectrum of emitted light will show the change of temperature in the bubble interior, density and pressure, and help understand the state of matter, *i.e.* the degree of ionization of the vapor, formation of degenrate Fermi electron gas and other. However, during the light emission, energy is lost from the bubble, and it is expected that the vapor will cool down (or will have balanced change of temperature). This is to be understood yet.

Measuring the time duration of the light emission and the light spectrum (since certain interactions take more time than others) may help to understand better the actual physical conditions in the bubble. On the other hand, knowing whether on not the emitted spectrum is composed of different light colors or even X-rays, would produce a better understanding of the type of interactions responsible for the detected photons; and improve understanding of the state of matter in the bubble during the implosion process. Different colors of light may be due to different speeds at which free electrons jiggle in the field of ions. The electrons accelerate in the field of positive ions, and the process is called *thermal bremsstrahlung*. This is also the current explanation of the standard SL phenomenon observed in a SBSL experiments.

Speculation on Series of Nuclear Events in Imploding Bubble – T Jevremovic (add more, ref, ...)

As bubble becomes denser during the implosion phase, the electrons escape the individual atoms forming most likely a degenerate electron gas. A similar process happens in metals where free electrons move along various trajectories. Fermions /electrons, protons, neutrons/ are particles of half-integral spin that obey Pauli exclusion principle /no two fermions can exist in the same quantum state/. Thus, the number of electrons moving along a given trajectory with a given velocity is limited. Free electrons will fill different energy states according to exclusion principle, unlike the social bosons that can occupy only one quantum state. Bosons /deuteron, helium atom, photon,…/ are particles of zero or integral spin that do not obey Pauli exclusion principle.

In the dense bubble, there are not enough free trajectories available for all of the electrons since they are closely packed together. The similar conditions exist in white dwarf stars, [9]. These electrons must therefore move with different velocities along a trajectory to avoid violating the exclusion principle. The different velocities cause the electrons to move away from each other and the bubble to reach its limitted finite size since the exclusion principle keeps the electrons in different quantum states.

A compression of the bubble interior may eventually lead to nuclear reation between electrons and protons. This process will reduce a number of electrons but increase a number of neutrons. The bubble is electrically neutral such that every free electron is accompined with the proton. Free neutrons decay by beta decay with the decay half life of 12 min, producing beta particle and antineutrions. In the subpico second events most likely is that neutron will scatter and escape a small geometry of the chamber before it decays. However, the decay would contribute to the energy spectrum of the electron gas in the bubble and add the energy to a system.

5. Guderley, G., Luftfahrtforsch, 19, 302 (1942); see also Landau, L. D. and Lifshitz, Fluid Mechanics, 2nd ed., Pergamon Press, New York, 1987
6. Putterman, S. J.,"Sonoluminescense: Sound into Light," Scientific American, 46-51, February 1995
7. West C. and R. Howlett, "Some experiments on ultrasonic cavitation using a pulsed neutron source," Brit. J. Applied Physics (J. Phys. D), ser.2, vol. 1, pp 247-257, 1968.
8. Wu, C. C. and Roberts, P. H., "Shock-Wave Propagation in Sonoluminescing Gas Bubble," Physics Review Letters, Vol. 70, Number 22, 1993
9. http://www.mtsu.edu/~jnm2b/Exclusion.html
10.

HAVE SOMEMORE IDEAS…… BUT NOT SURE THIS PART WILL STAY IN THE PAPER…….. WILL DISCUSS IT. T Jevremovic

Nuclear vs Chemical and Nuclear Many Body Model – LHT

Conclusions

Tritium measurements in deuterated acetone subjected to acoustic processing as reported by Taleyarkhan et al [6] point to positive evidence for increased tritium production. Several runs were made under nearly identical conditions to establish repeatability. Most (but not all) involving deuterated acetone point to a net growth in tritium counts. Several observations need to be mentioned regarding these runs.

INCLUDE A SUMMARY DISCUSSION OF INDIVIDUAL RUNS AND OBSERVATIONS

Tritium data from normal acetone subjected to cavitation and acoustic oscillation does not point to any statistically significant growth.

SUMMARY DISCUSSION of THESE RUNS

References – to be fixed

1. Taleyarkhan, R. P., C. D. West, J. S. Cho, R. T. Lahey, Jr., R. I. Nigmatulin, R. C. Block, "Evidence of Nuclear Emissions During Acoustic Cavitation," *Science*, 295, 1868-1873, 2002
2. West, C. Cavitation Nucleation by Energetic Particles, United Kingdom Atomic Energy Authority: Electronics and Applied Physics Division. Harwell, Berkshire. 1967
3. Leighton, T. G. Acoustic Bubble, Harcourt Publishers Ltd, 1996
4. Frenzel, H. and Schultes, Z, Phys. Chem., B 27, 421, 1934.

5. Guderley, G., Luftfahrtforsch, 19, 302 (1942); see also Landau, L. D. and Lifshitz, Fluid Mechanics, 2nd ed., Pergamon Press, New York, 1987
6. Putterman, S. J.,"Sonoluminescense: Sound into Light," Scientific American, 46-51, February 1995
7. West C. and R. Howlett, "Some experiments on ultrasonic cavitation using a pulsed neutron source," Brit. J. Applied Physics (J. Phys. D), ser.2, vol. 1, pp 247-257, 1968.
8. Wu, C. C. and Roberts, P. H., "Shock-Wave Propagation in Sonoluminescing Gas Bubble," Physics Review Letters, Vol. 70, Number 22, 1993
9. http://www.mtsu.edu/~jnm2b/Exclusion.html
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