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Research Article

Anomalous Heat Energy Released through Cavitation-Coulombic Repulsion Oscillations Following Sodium Metal Dissolution in a Dilute Epsom Solution – Plausible Mechanisms

Arunachalam Lakshmanan *

Saveetha Engineering College, Chennai 602105, India

Abstract

Plausible mechanisms are discussed for explaining the sudden burst of energy released from 0.85 M Epsom ($MgSO_4 \cdot 7H_2O$) aqueous solution following sodium metal dissolution which led to the vaporization of the entire system including the glass beaker. Exothermic reactions lead to micro/nano-metastable crystal formation due to steam cavitation. $H_2{}^+$ molecular ions trapped at Mg^{2+} ion lattice sites in cavitation-induced metastable crystals were considered as precursors for energy release. In principle, for charge compensation, two protons should occupy one Mg^{2+} lattice site in these crystals. Therefore, cavitation crystal formation brings in the two protons in molecular ions closer. This process is, however, opposed by Coulombic repulsion between the two protons which results in the collapse of the nanocrystal containing hydrogen. This leads to the release of hydrogen ions into the solution resulting in the release of hydration energy during the formation of H_3O^+, hydronium ions and in local heating. Stirring distributes the heat energy uniformly in the solution. Local heating, however, leads to the promotion of cavitation – this time with more vigor since additional energy input has occurred. Thus reformation of the crystal takes place quickly and the hydrogen ions are brought together more closer than during the previous occasion which increases the electrostatic repulsive force. As a result, the crystal collapses faster leading to the release of more hydration energy. This is how cavitation gains energy from repulsion. The above cavitation Coulombic repulsion oscillation (CCRO) cycle continues leading to an exponential build-up of the pressure and oscillation speed of the precursors and a decrease in inter-proton separation leading to their collision. Finally a sudden burst of energy witnessed occurs due to cavitation collapse. *It remains to be ascertained if the energy release is a consequence of p–p fusion, or other mechanisms proposed which include volume casimir effect, miniature black holes and lattice phonon amplification. The fact that increase in the oscillation speed of the two protons in the proposed $H_2{}^+$ species is exponential without an upper limit till the end-point is reached should determine the logistics of the underlying mechanism causing the energy release.* The p–p fusion should, however, be accompanied by positron emission whose presence could be verified by its annihilation gamma rays or with 5.5 MeV gamma rays produced from HD fusion reactions if energetic deuterium is formed from p–p fusion in amounts commensurate with the energy produced but this fusion process is mediated by weak interaction process and hence is less probable. No other proposal explains burst of energy observed better than the collapse of miniature black holes.
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of energy, Lattice phonon amplification, Miniature black holes, p–p fusion, Volume casimir effect

1. Introduction

A consideration of present and future energy scenario related to nuclear technology indicates that nuclear fission suffer from issues related to radioactive waste, fuel (uranium) shortage and nuclear security related to proliferation of radioactive materials and other nuclear devices into unauthorized personnel. The feasibility of harnessing nuclear fusion technology in the near future seems to be doubtful since it involves high-energy input resulting in low production efficiency (energy output/energy input) meaning high cost. Another major technological issue related to fusion is hot plasma containment. However, the present work will show for the first time that a pulsed heat energy source can be achieved relatively easily by internal accumulation of phonon energy through cavitation-Coulombic repulsion oscillation (CCRO) in condensed matter following sodium metal dissolution in a dilute Epsom ($MgSO_4 \cdot 7H_2O$) solution. The advantages with the proposed system are: (i) production of green energy – only heat release, no radioactive or radiation release or carbon pollution, (ii) infinite amount of fuel in the form of hydrogen in water, (iii) feasible technology with better understanding and finally (iv) the high-efficiency (energy output/energy input) of proposed system.

It has been shown in part I of this paper [1] that in concentrated aqueous Epsom solution, Na dissolution proceeds peacefully through cation exchange process in cavitation-induced crystals and the Na–H_2O reaction rate is slowed down by the above cavitation process and the hydrogen production rate is controlled with controlled release of Mg atoms from the crystals by $2Na \Leftrightarrow Mg$ exchange reaction. Intermediate salt concentrations (0.7–1.3 M) offer challenging possibilities of hydrogen production by Na–H_2O as well as Mg–H_2O reactions and the trapping of hydrogen produced at a critical Epsom salt concentration in cavitation-induced metastable nanocrystals which is the subject matter of the present study.

2. Sodium Dissolution in 0.85 M Epsom Solution

When a reactor scientist suggested to cut down the salt concentration to save cost, we tried to dissolve Na in 0.85 M Epsom solution. For Epsom concentrations >1.2 M, Na dissolves into Epsom crystals peacefully by $2Na^+ - Mg^{2+}$ exchange reaction. Below <0.6 M, Na–H_2O reaction dominates and solution explodes instantly on Na addition. In 0.6–1.2 M range both these reactions occur. Specifically, an intense explosion accompanied with a shock wave and vaporization of Borosil glass beaker containing salt solution was witnessed in 0.85 M Epsom solution on the completion of sodium dissolution, i.e., nearly 25 s after Na addition. There was Na aerosol everywhere in the room. No trace of the glass beaker was seen. Subsequent search, however, revealed that the bottom of the beaker, which was in contact with the wooden stool on which it was placed did not evaporate but broke into pieces. This was understood on the basis that for reaching plasma like conditions a container free condition is essential. Such a condition could be reached only on the sidewalls of the glass beaker. The intense explosion brought safety personnel from far away rooms in the building to book a complaint against us stating that we are doing unsafe experiment while we were still amazed at the turn of the events. At 0.85 M Epsom concentration, both the reactions mentioned above are shown to take place with equal probability. Glass vaporizes at temperatures $>1000^\circ$C. This fact indicated that a very high temperature has indeed been reached in this experiment. During the explosion, ultra thin molten glass needles flew all around. One such glass needle scratched the finger of the author, who stood at a distance of about 4 m from the beaker. Due to this injury blood oozed out of the author's finger and the scratching mark is visible even now. The glass needles also pierced invisible holes in two plastic water bottles kept around (2–3 m away from the explosion site) after which they could not

*E-mail: arunachalamlakshmanan@yahoo.com

pump out water on squeezing. Despite intense explosion, the stirrer blade made of stainless steel did not get damaged and continued to rotate which indicated that the energy is released outwardly. The fact that no radiation related injury occurred indicates that no nuclear reaction involving fission, fusion or transmutation occurred in the above case. But the involvement of nucleus occurs indirectly in CCRO, since it is the oscillation involving protons in H_2^+ions which lead to the accumulation of hydration energy.

Sodium dissolution in water or in very dilute Epsom solutions ($\ll 0.6$ M) leads to Na–H_2O reaction and the hydrogen released mix with atmospheric oxygen to cause hydrogen explosion resulting in breaking of the glass beaker rather than its vaporization. Additionally, the above explosion occurs within 5 s after Na addition. However, in the above experiment involving 0.85 M Epsom solution, the explosion occurs 25 s after Na addition. Both these factors clearly indicated that the explosion is not a result of detonation of hydrogen in the presence of oxygen.

The intensity and timing of the explosion witnessed above clearly indicated that the hydrogen released during Na–H_2O and Mg–H_2O reactions in 0.85 M Epsom solution somehow got trapped *in situ* in the cavitation-induced Epsom crystals. It is a case where a cage meant for trapping a massive elephant (Na^+ ions), instead, trapping more efficiently the elusive panthers (H^+ ions). The reactions involved are described below.

3. Hydrogen Production and Hydrogen Trapping Mechanisms

If we assume that hydrogen released from Na–H_2O reaction escapes, then the crystalline structure that remain on sodium dissolution in the explosive solution should be considerably unstable and may not even be formed as it assumes one sulphate anion vacancy for every Mg^{2+} ion present [2,3]. In this case it is assumed that 50% of sodium dissolved reacts with water while the remaining 50% get dissolved into Epsom crystal. Alternately, if the NaOH formed from Na–H_2O reaction converts the remaining $MgSO_4$ to $Mg(OH)_2$, then hydrogen trapping would not have been possible and no intense explosion would have resulted. Therefore, hydrogen trapping in the cavitation-induced crystals takes place as per the reactions described below.

The 2Na atoms get into the $MgSO_4$ crystal while one Mg atom is expelled into the solution as a result of cation exchange. The Mg atoms released react with water to produce hydrogen:

- $2Na \leftrightarrow Mg$
- Na donates electrons to a Mg^{2+} ion
- $2Na^+$ will replace a Mg^{2+} ion

$$Mg + 2H_2O \rightarrow Mg(OH)_2 + H_2 \tag{1}$$

- 50% Na added simultaneously reacts with water:

$$2Na + 2H_2O \rightarrow 2NaOH + H_2 \ \text{(to produce more hydrogen)} \tag{2}$$

- Hydrogen donates electrons to a Mg^{2+} ion

$$H_2 + Mg^{2+} \rightarrow {H_2}^{2+} + Mg^0 \tag{3}$$

(Due to ion exchange reaction between hydrogen and Mg, ${H_2}^{2+}$gets into the crystal while Mg is released into the solution).

- Reactions (1) and (2) are primary reactions taking place simultaneously with equal probability.

$$Mg^0 + 2H_2O \rightarrow Mg(OH)_2 + H_2 \tag{4}$$

Mg atoms released through reaction (3) react with water to produce MgOH, a confirmed by product which could be visually seen as a white precipitate from a distance and release further hydrogen which again get trapped in the precursor as hydrogen molecules as shown in Fig. 1a since there are no more Mg left in the crystal. This is a secondary reaction and temporally delayed when compared to the $H_2{}^{2+}$ incorporation through reaction (3).

Calculations reveal that the nanocrystal now contains only Na^+, $SO_4{}^{2-}$ and $H_2{}^{2+}$ ions bonded to the water molecules [3]. This necessitates the creation of $SO_4{}^{2-}$ anion vacancies for charge compensation in which H_2O molecules sit as shown in Fig. 1(a). Electrons donated by nearby water molecules stabilize the two hydrogen ions near a Mg^{2+} cation lattice site.

Additional trapping of hydrogen atoms/molecules near oxygen atom in the water molecule as shown in Fig.1(a) will compensate for the electron density loss created by the pulling of the electronic cloud towards the hydrogen ions needed for their co-existence near Mg^{2+} ion lattice site.

4. $(H_4O)^{2+}$ and $(H_6O)^{2+}$ Species

The formation of a divalent species, like H_4O^{2+} shown in Fig.1(a), would be normally energetically not favored in water because two positive charges are being pushed together on the same water molecule. But in the above case the water molecules act as a carrier of two hydrogen ions with the help of two independent dative bonds formed between the two lone pair electrons in the oxygen and the two hydrogen ions. The divalent crystal lattice energy demands the positioning of two protons at a single Mg^{2+} ion lattice site and hence the energy needed to overcome the electrostatic repulsion of the two protons is provided by the ionic crystal lattice energy. The existence of H_4O^{2+} ions in other systems such as sulfolane solution is known [4]. During oscillatory reactions, a hydrogen ion has to be separated from one of the hydronium ion in the solution and attached with another hydronium ion so as to form the H_4O^{2+}species shown in the crystalline nanoprecursor. The energy required for both the above reactions should come basically from cavitation. Apart from crystallization, dissociation of chemical species in liquids due to cavitation is well known.

Since equal probability of Na–H_2O reaction and Mg–H_2O reaction is proposed, the number of hydrogen atoms generated by the latter reaction would be exactly equal to the number of hydrogen atoms released by the former reaction and so the additional hydrogen generated could get trapped in a structure shown in Fig. 1(a). The hydrogen budget is thus accounted for. Adsorption of hydrogen atoms in such systems is well known. As a result, the structure shown in Fig. 1(a) forms which can be represented as $[H_6O]^{2+}$ with an overall +2 charge as that required at a Mg^{2+} site.

5. Oscillator/Substance (O/S) Theory and Molecular Hydrogen Ion

The O/S theory proposed by Dean Sinclair postulates that the formation of molecular monocation (H_2^+) is more likely rather than hydrogen molecular di-cation ($H_2{}^{2+}$) [5]. Without making any other change, this idea can be fused into the mechanism proposed above. In the alternate proposal shown in Fig.1(b), two $H_2{}^+$ ions replace one $H_2{}^{2+}$ion. The exchange reactions in this case may be described as follows:

$$2H_2 + Mg^{2+} \rightarrow 2H_2{}^+ + Mg^0 \tag{5}$$

Due to exchange reaction between hydrogen and Mg, H_2^+ions gets into the crystal while one Mg atom is released into the solution

$$2Mg^0 + 2H_2O \rightarrow 2MgOH + H_2 \tag{6}$$

Mg released reacts with water to produce MgOH, a confirmed by product

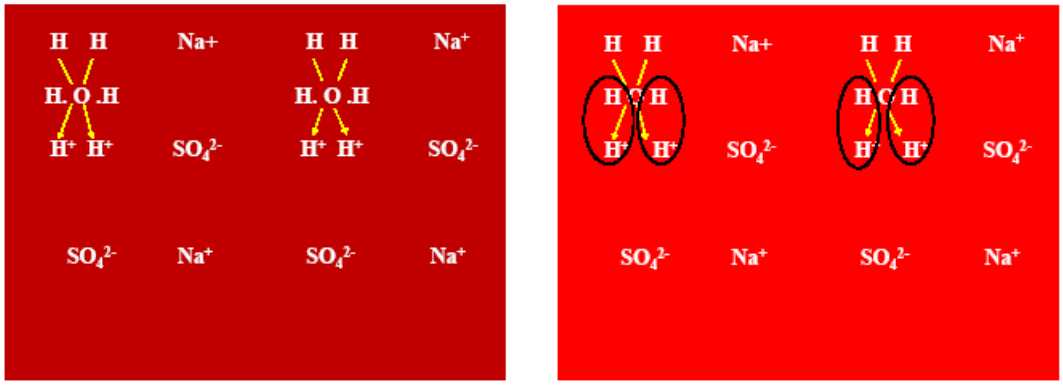

Figure 1. *Original proposal* – Precursor state of the explosive solution after the sodium dissolution. In (a) the electrons are donated to hydrogen ions by water molecules. But in (b), the electrons are part and parcel of the molecular monocation H_2^+. *Alternate proposal* – O/S (oscillator/substance) theory presumes the formation molecular monocation (H_2^+) shown within the oblong circles rather than hydrogen molecular Di-cation (H^+H^+) shown in (a) as more likely. Figure (a) could well be the precursor of (b). See text for more details of the two figures.

On cavitation collapse, $2H_2^+$ ions are released into the solution:

$$2H_2^+ \rightarrow 2H^+ + H_2 \tag{7}$$

$$2H^+ + 2H_2O \rightarrow 2H_3O^+ \quad \text{(Hydration energy release)} \tag{8}$$

Figures 1(a) and (b) are essentially same. Only the concepts differ. Except for the replacement of two H_2^+ ions in the place of one H_2^{2+}ion, both concepts invoke cavitation collapse under high pressures.

6. Cavitation-Coulombic Repulsion Oscillation (CCRO)

In principle, for charge compensation, two protons should occupy one Mg^{2+} lattice site. Therefore, cavitation crystal formation brings in the two protons (and the two electrons attached to them) closer. This process is, however, opposed by Coulombic repulsion between the two protons which results in the collapse of the nanocrystal containing hydrogen.

Hydration energy is released during the formation of $2H_3O^+$, hydronium ions (Fig. 2). This once again leads to the promotion of cavitation – this time with more vigor since additional energy input has occurred. Thus reformation of the crystal takes place quickly and the hydrogen ions are brought together more closer than during the previous occasion which increases the electrostatic repulsive force. As a result, the crystal collapses faster leading to the release of more hydration energy. The above cycle continues leading to increasing oscillation speed with time and pressure build-up on the p–e–p species. The oscillation of the p–e–p species can be compared to a spring action as depicted in Fig. 3. The more the spring is squeezed, the faster it recoils. The beauty with the Cavitation-Coulombic Repulsion Oscillation (CCRO) process lies in the fact that the oscillation can continue indefinitely unhindered (perpetual oscillations!) till the end point is reached. There is no upper limit to the number of oscillations. This means the kinetic energies of protons can reach to very high levels (TeV?) leading to their head-on collisions through exponential accumulation of internally

released chemical energy! The forced end point in this case is of course the vaporization of the system. But for the vaporization, the CCRO would have continued further. The crucial question before us is what causes the vaporization?

In the CCRO process, the electrostatic repulsive force between protons which has been a stumbling block so far in bringing together protons is turned in its favor. Martial art uses this principle by deflecting cleverly the energy possessed by the opponent against the enemy himself. Indian Epic "Ramayana" also describes a character Vanara Vali who possess the power of capturing 50% of the power of the opponent facing him so he could defeat the enemy. It is due to the repulsive electrostatic force, the crystal collapses and it is due this collapse hydration energy is released. This is how cavitation gains energy from repulsion. Eventually the cavitation force wins over the electrostatic repulsive force by increasing the oscillation speed and bringing in the two protons to closer distances by deriving energy from the coulombian repulsion itself. Despite this fact, p–p fusion is unlikely to be the cause of the massive energy release witnessed in the above experiment since nuclear fusion involving protons is mediated by weak nuclear force as one of the proton has to be converted to neutron. This is the reason why Sun is burning very slowly. The reason for it being so sluggish is because its force carriers, intermediate vector bosons, W^+, W^- and Z_0 are so massive (about 80 times higher than that of protons) that the probability of a virtual one arising is extremely small. As per Heisenberg's uncertainty principle (HUP), in view of the short range of such massive particles, during p–p (or p–e–p) nuclear fusion the protons have to approach each other to much closer distances than is the case with deuterons in D–D/D–T fusion which invoke strong nuclear force involving mesons. One must therefore look elsewhere for the cause of the excess energy release in this experiment.

As per the O/S theory, once HH^+, hydrogen molecular cation is formed, it could coalesce into deuterium ion rapidly under suitable orientations in high-pressure conditions inside an ionic solid. This theory predicts that the HH^+ ion rotate down to a proper orientation losing motion (vibrational motion) to the milieu (environment) while condensing (spinning down) into a more symmetric unit when the two protons and electron come closer and closer to a rotating circular array corresponding to a Deuterium ion, eventually coalescing into that form. As per the O/S theory, coalesion (fusion) of para-hydrogen (nuclei with opposing spins) unit HH^+ into D^+ by rotation is more likely than the coalesion of di-protonated hydronium ions or p^+p^+ species. This has been presumed to occur when the rotations of both units are aligned on the same vector, in exactly opposite senses such that the two rotations will cancel before collision occurs as shown in Fig. 4. There would be good deal of usable energy release during this process as it would not be a sudden transform but a succession of transforms which would release energy. O/S theory presumes that very high temperatures

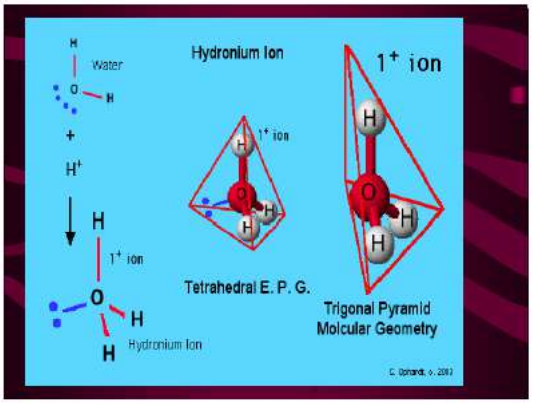

Figure 2. Formation of hydronium ion (H_3O^+) in the aqueous solution releases hydration energy. The exponential accumulation of this energy through repeated cavitation constitutes the energy input in the proposed system.

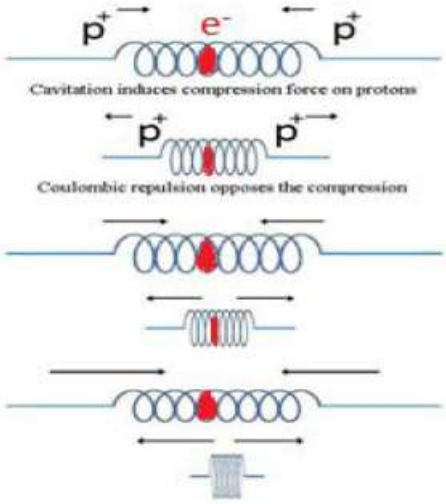

Figure 3. A simplied picture of the Cavitation-Coulombic Repulsion Oscillations of the p–e–p (H_2^+) species. Spring like action takes place due to two strong opposing forces – cavitation force and Coulombic repulsion. Note with increasing number of oscillations, the speed of oscillations increases exponentially and the distance between the protons decrease. Eventually collision of protons can occur. The crystal collapses due to Coulombic repulsion. Each time the crystal dissolves, hydration energy is released during the formation of H_3O^+, hydronium ions (Fig. 2). This once again leads to the promotion of cavitation – this time with more vigor since additional energy input has occurred. Thus reformation of the crystal takes place quickly and the hydrogen ions are brought together more closer than during the previous occasion which increases the electrostatic repulsive force. As a result, the crystal collapses faster leading to the release of more hydration energy. The above cycle continues leading to increasing oscillation speed with time and pressure build-up on the p–e–p species. The oscillation of the p–e–p species can be compared to a spring action as depicted above**.** The more the spring is squeezed, the faster it recoils.

will tear apart the HH^+ species.But high pressures can keep them intact. The situation of reaction within a solid has also the definite advantage of a lattice having many possible energy states to absorb the necessary motion, which must be removed as the entities fuse. This is harder to consider happening easily in a liquid or gas. O/S theory predicts that the formation of para-hydrogen is a necessary pre-requisite for the two hydrogen ions to come closer and that can happen only in H_2^+ molecular mono cation shown in Fig. 1(b) and not in H_2^{2+} shown in Fig.1(a) which is an unknown species. Figure 1(a) shows that there is an additional electron attached to each of the hydrogen ion in the H_2^{2+} species. So essentially in H_2^{2+} species two electrons are attached while in H_2^+ ion only one electron is attached. In both the hydrogen ion species, the attached electrons stabilize the two protons near a divalent cation site. However,the symmetric para-hydrogen depicted in Figs. 4 and 5(c) is favored because in this species the electron density states get automatically squeezed in as they lie in between the two protons and the proposed CCRO basically squeezes the two protons together. *The lone pair electron donated by a nearby water molecule would convert H_2^+ ion into H_2 molecule like species thereby lending further stability to it.* The predicative values of pressure and temperature surrounding the precursors are shown in Fig. 6. Since the solution actually explodes at the end of sodium dissolution process, actual values of these two quantities are not exactly known. The merits of the arguments in O/S theory that the H_2^+ rather than $2H^+$ species could lead to the observed energy release are clear.

Dean Sinclair is of the view that the generation of the initial HH^+ unit to initiate the chain reaction may be the very slowest, least probable, step of the whole process. He is of the view that in our system there may be a film of H_2 molecules on the surface of the glass which goes into a fusion chain reaction once an initial HH^+ unit is generated.

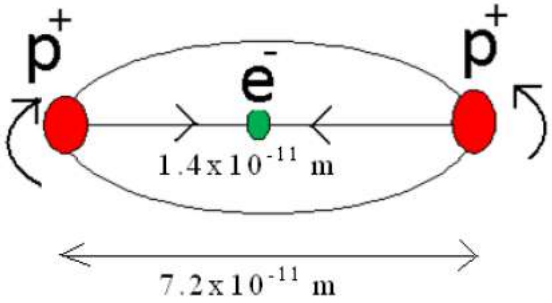

Figure 4. A symmetric para hydrogen in H_2^+ molecular cation.

Thus the arguments in favor of H_2^+ taking part in energy production are quite acceptable but it will be seen that the exact process seems to be connected to the exponential build–up of phonon energy and/or collapse of miniature black holes rather than to nuclear fusion unlike our earlier prediction [6].

7. Volume Casimir Effect

Hawking like radiation can be created in a crystal lattice through dynamic or volume casimir effect. Wilson et al. [7] have reported that a mirror moving at quarter of velocity of light prises virtual photons (always produced in pairs) apart so that instead of rapidly annihilating, the virtual photons are free to remain as real photons. The emitted photon frequency is about half that of the mirror's oscillation frequency. The reason why real photons appear in the experiment is that they lack mass. Relatively little energy is therefore required in order to excite them out of their virtual state. In

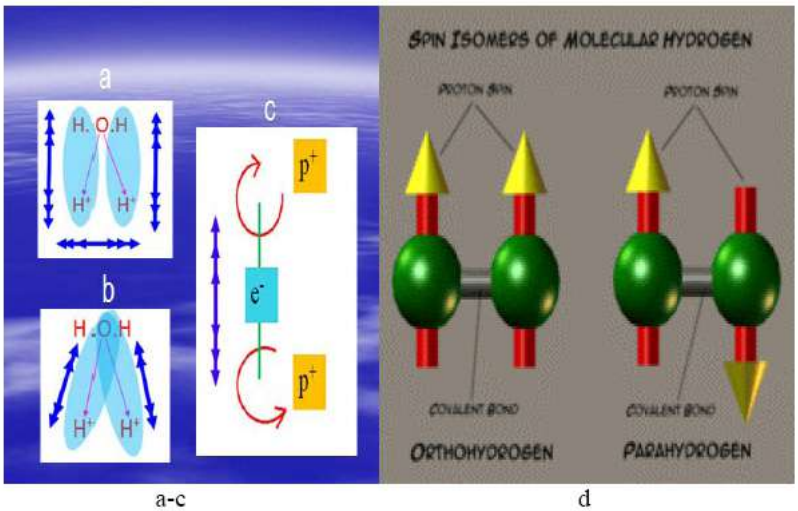

Figure 5. (a-c, *left*). The oscillation of different hydrogen ion species during CCRO process. (d, *right*) Ortho (parallel nuclear spin) and para hydrogen (antiparallel nuclear spin).

principle, one could also create other particles from vacuum, such as electrons or protons, but that would require a lot more energy. In this case, a number of virtual photons from the vacuum are reportedly converted into a pair of real photons produced in opposite direction in the microwave region ("Casimir radiation"), while the moving metal surface loses some of its kinetic energy.

It is known that in principle high electric field generated by fast moving electrons accelerated by high-energy accelerators or high power (terra watt) lasers can prise virtual particles into real ones. But it requires enormous energy input similar to that required in hot fusion devices and therefore no practical device has been produced so far.

This work has, however, shown that in principle it is possible to accelerate/vibrate electrons to relativistic speeds through internal accumulation of energy. Through CCRO, collision of protons at high velocities trapped in cavities in ionic crystals has also been shown to be possible but whether to TeV energy range as envisaged by theorists of black hole production remains to be tested. In condensed matter the energy production mechanism requires elaborate description.

In order to prevent the scattering of electrons by gas molecules, normally electrons are accelerated in vacuum. However, electrons in stationary orbits of atoms do not face this problem. Intense energy source of real photons useful for heat production can be easily created by prising high-energy virtual photons exchanged between protons and electrons near the nucleus of an atom or ion! An added advantage with such an approach is that such electrons do not radiate energy through bremstrahlung process even at high speeds as long as they are bound to the so-called stationary orbits of the atom/ion. When the electric field build-up by the p–e–p in H_2^+ molecular ion oscillations continue unhindered and reaches a critical value extremely rapidly, high-energy virtual photons exchanged between protons and electrons at close distances will be prised to pairs of real photons and emitted as a burst. Accelerating electrons to a KE $>$ 1.02 MeV to prise virtual photons into e^-/e^+ pair requires enormous energy input – roughly million times hydration energy which is unlikely. However, creation to a pair of real photons around 15 keV at relativistic electron speeds is feasible since their rest mass energy is zero. It is roughly only 6000 times the hydration energy released. In principle a 30 keV virtual photon could get converted into two 15 keV real photons. It appears that the kinetic energy of protons as well as electrons seem to be used up in creating the real photons in this case. Therefore, only photons

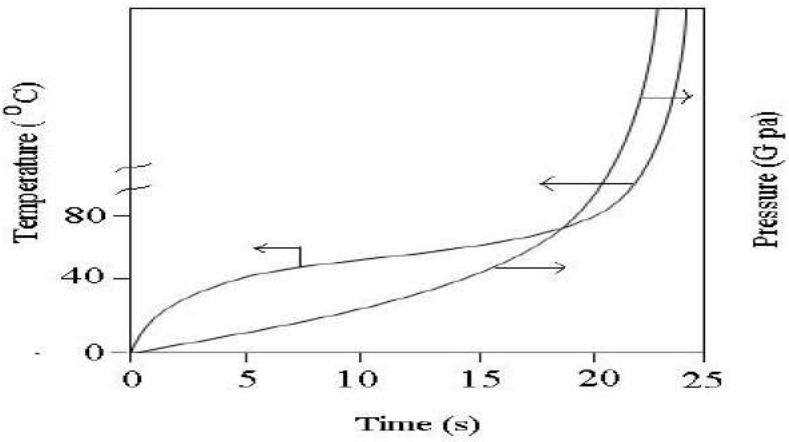

Figure 6. Solution temperature and pressure (predicative) on the hydrogen atoms/ions (HH^+ or $2H_2^+$) trapped in the metastable nanocrystal during sodium metal dissolution in a dilute aqueous Epsom solution (0.85 M). These are predicative values since the solution actually explodes at the end of sodium dissolution process. The figure depicts the scenario during the final moments of cavitation collapse in which the pressures and temperatures shoot up exponentially resulting in the burst of energy as a result of exponential increase in the release of hydration energy.

(in the keV region) appear in the experiment as a burst of energy as their rest mass is zero. The photon frequency is half of electron's oscillation frequency. No radioactivity is produced. The energy that would have otherwise remained dormant is released once the required input energies are reached internally. Since the energy is accumulated internally, the figure of merit of such devices would be very high and therefore a practical energy source is very well possible.

8. Phonon Amplification

Solids with more than one type of atom – either with different masses or bonding strengths – in the smallest unit cell, exhibit two types of phonons: acoustic phonons and optical phonons. Acoustic phonons are coherent movements of atoms of the lattice out of their equilibrium positions. Optical phonons are out of phase movement of the atoms in the lattice, one atom moving to the left, and its neighbor to the right. This occurs if the lattice is made of atoms of different charge or mass. They are called *optical* because in ionic crystals, such as sodium chloride, they are excited by infrared radiation. The electric field of the light will move every positive sodium ion in the direction of the field, and every negative chloride ion in the other direction, sending the crystal vibrating.

The possibility of phonon amplification in connection with a phonon laser was recognized in the early 1960s. Over the years people have built phonon lasers, which amplify phonons. This has been demonstrated from the MHz region up to the THz region. While low-frequency sound in the range that humans can hear (up to 20 kHz) is easy to produce in either a random or orderly fashion, things get more difficult at the terahertz (trillions of hertz) frequencies that are the regime of potential phonon laser applications. Instead of resulting in orderly, coherent phonon lasers, miniscule structures that can produce terahertz sound tend to emit phonons randomly. As an electron hops from one quantum well to the next, it produces a phonon. High-frequency phonons play an important role in thermal energy transport [8,9]. Phonon gain can cause amplification of the vibrations resulting and the build-up of CCRO can be accomplished consistent with the laws of physics *as suggested by an anonymous reviewer of this paper.*

In recent gas loading experiments in NiH, excess heat generation has been reported [10]. H or D flux in metals is expected to create high-frequency phonon excitation. Changes in pressure can lead to sudden violent energy release associated with high-frequency vibrations. CCRO mechanism would provide a route for amplification of high-frequency vibrations.

9. Miniature Black Holes

According to general relativity, a black hole should form whenever some mass is squeezed into a very small region of space. Collisions of protons with other protons at high energies (some observations show energies of hundreds of TeV which is much larger than the collision energies in particle collider experiments) should result in the formation of miniature black holes through quark interaction. However, there are models on the market suggesting that the strength of gravity could become significantly larger at very small distances, up to 10^{38} times stronger. If this is true then the Schwarzschild radius of two colliding partons becomes large enough that, at the LHC center-of-mass energy, two partons passing each other at their Schwarzschild radius is not so unlikely anymore. So, we may be able to produce microscopic black holes after all. During head-on collision of protons, a sufficiently high concentration of mass would result, and a *mini-black hole* would form. Black holes with a mass that is extremely small are extremely hot and unstable. They would evaporate nearly as soon as they are created ($\iota \sim 10^{-25}$ s) with the emission of *Hawking radiation*. Their decay would result in a sudden blast of a few energetic particles. And while such collision events with very high energy are exceedingly rare in particle accelerators, this type of collision has been going on for literally billions of years in the earth's atmosphere by the collision of Ultra High-Energy Cosmic Rays (UHECRs) with nuclei of oxygen, carbon, nitrogen and other elements present in the atmosphere., so an inordinate number of mini black holes would have formed. Since the earth has not (yet!) disappeared into one of these black holes, the much less massive man-made mini black

holes should be quite safe. As stated earlier, it is unique that there is no upper limit to the number of proton oscillations in the proposed CCRO process. This means the oscillation speed of protons and hence their kinetic energies can increase exponentially with oscillations due to phonon amplification to any desired extent with minimal energy input.

Thus the achievement proton energies of hundreds of TeV is very well possible within a very short interval of time. The distance between the protons decrease with the number of oscillations (Fig. 3). At some point, this will result in the their collision. In addition, the protons in the H_2^+ species (Fig. 4) are confined in space which increases their head-on collision probability at high energies unlike the random collisions at the particle accelerators. These two factors put together mean that the formation of miniature black holes is very well possible in the proposed system in laboratory conditions when the proton energies reach a critical point. The observed burst of energy at the conclusion of the CCRO lend further support to this hypothesis since the decay of such mini black holes is expected to result in a sudden blast of energy. No other proposal explains burst of energy observed better than the collapse of miniature black holes.

10. Energy Budget

Let us consider all possibilities of energy production in the above experiment.

10.1. Energy input

To start with the input energy to the bulk of the solution comes from the 40 W electrical stirrer (∼40 J/s) giving rise to an energy input of about 1.2 kJ in 30 s, the approximate time taken for the explosive energy release since sodium addition, which of course is extremely small compared to the energy released eventually (2 MJ).

Na–H_2O exothermic reaction ($Na + H_2O \rightarrow NaOH + 0.5\ H_2 \uparrow$) produces nearly 148 kJ/mol. Sodium added in this case (3.92 g = 0.17 mol) would then produce only about 25.2 kJ which is also quite small compared to 2 MJ.

10.2. Simple hydration

Preliminary calculation reveal that the number of hydronium-like ions formed during a single collapse of the nanoprecursor crystal in the explosive solution = 0.04 mol (2.4×10^{22} ions). Hence each time the above crystal dissolves in the solution an energy equivalent to 18.44 kJ (= 461.1 kJ/mol × 0.04 mol) is released into the solution, *which is less than the energy needed to vaporize the salt solution.* Let us assume that the solution used in the explosive mixture is equivalent to 100 cm^3 of water. Energy needed to vaporize it $\sim 100 \times 1 \times 80 \times 4.1855 + 100 \times 540 \times 4.1855 = 260$ kJ. Energy required to vaporize the glass beaker is $\sim 200 \times 1 \times 1000 \times 4.185 = 837$ kJ. Let us assume that the amount of energy vented out in the form explosion ∼1000 kJ. Then together about 2000 kJ (=2 MJ) of energy is released. The estimation of energy released, especially the amount of energy vented out in explosion is of course very crude.

10.3. Chemical combustion

As 2.4×10^{22} hydrogen ions (0.04 mol) are involved in the present case, the burning of hydrogen would release an energy of 9.57 kJ (240 kJ/mol), *which is also less than the energy needed to vaporize the salt solution.*

10.4. The p–p nuclear fusion

The first step involves the fusion of two nuclei (protons) into deuterium, releasing a positron and a neutrino as one proton changes into a neutron. It is a two-stage process; first, two protons fuse to form a diproton: $^1H_1 + {}^1H_1 \rightarrow {}^2He_2$ followed by the beta-plus decay of the diproton to deuterium: $^2He_2 \rightarrow {}^2D_1 + e^+ + \text{neutrino} + 0.42$ MeV. This first step

is extremely slow, because the beta-plus decay of the diproton to deuterium is extremely rare (the vast majority of the time, it decays back into hydrogen-1 through proton emission). The positron immediately annihilates with an electron, and their mass energy, as well as their kinetic energy, is carried off by two gamma ray photons: $e^- + e^+ \rightarrow 2\gamma$ + 1.02 MeV.

After this, the deuterium produced in the first stage can fuse with another proton to produce a light isotope of helium, ^{3}He: $^2D_1 + {}^1H_1 \rightarrow {}^3He_2 + \gamma$ + 5.5 MeV.

The fusion reaction involving hydrogen releases an energy of 6.945×10^7 kJ/g. The number of hydrogen ions incorporated in the solid solution = 0.239×10^{23}. 1 g of hydrogen will have $6.022 \times 10^{23}/2 = 3.011 \times 10^{23}$number of $H_2{}^{2+}$ ions. Fusion of these ions will release an energy of 6.945×10^7 kJ. Therefore, fusion of 0.239×10^{23} $H_2{}^{2+}$ ions in the solid solution will release an energy of 0.552×10^7 kJ (5.52×10^3 MJ). Thus the energy released during the thermo-nuclear explosion is nearly 5520 times [= (5.52 / 1) × 10^3] more than the energy required to vaporize the system. So it is no wonder that the excess energy has been vented out in the form of a massive explosion! This means that the collapse of the nanocrystals and their reformation should go on many ($\gg$ 100) times in an unhindered manner. This is less likely, since the vaporization of the system occurs after nearly 100 oscillations. Moreover, *p–p fusion invokes weak nuclear interaction and hence is extremely slow even in Sun as pointed out earlier whereas the present experiment which resulted in a massive burst of energy seems to be a result of a fast reaction.*

In any case, one way of testing it would be to look for the reaction products such as deuterium or positron (through their annihilation gammas) expected from such a fusion process or with 5.5 MeV gamma rays produced from HD fusion reactions if energetic deuterium is formed from p–p fusion in amounts commensurate with the energy produced. *Gamma ray spectra have been taken in the Piantelli NiH experiment, and there are not annihilation gammas present in amounts commensurate with the energy produced.*

10.5. The p–e–p nuclear fusion

Deuterium can also be produced by the rare pep (proton–electron–proton) reaction (electron capture): $^1H_1 + e^- + {}^1H_1 \rightarrow {}^2D_1$ + neutrino + 1.44 MeV. In the Sun, the frequency ratio of the pep reaction versus the pp reaction is 1:400. In p–p fusion most of the energy is carried away by positrons whose absorption releases heat but in p–e–p fusion, in the absence of charged particle emission, the neutrinos carry most of the energy released during fusion in a benign way. Hence p–e–p fusion in its present form cannot produce significant heat *(Ref: Proton–proton chain reaction. From Wikipedia, the free encyclopedia).*

10.6. Hawking-like radiation

Basically as per dynamical Casimir effect, the photon frequency is half of the electron oscillation frequency, say in the H_2^+ molecular ion. Let us assume that the inter-ionic (p–p) distance in it = 72 pm similar to the H_2 molecule. The frequency of a 15 keV photon = 3.5×10^{18}/s. Therefore, the electron oscillation frequency = 7×10^{18} vib/s. Let us assume that the electron travels at $1/3^{rd}$ velocity of light at the time of energy release. Therefore $v = 10^8$ m/s. Distance traveled by the electron in one oscillation = 1.4×10^{-11} m, which is about 1/5th of inter-ionic distance. Once the oscillation frequency of the electron bound to the H_2^+ molecular ion reaches the value of 7×10^{18} (electron speed = $c/3$), by the build-up of CCRO a burst of a pair 15 keV real photons will be emitted. Higher electron oscillation frequencies, would, of course result in higher photon energies. An experimental measurement of the photon spectrum would confirm this prediction.

In the above case, intense energy production occurs as a burst instead of the constant low-level energy release reported by others. Of course the systems used by others are quite different than that used by us.

Therefore, it is appropriate that modes of energy production other than fusion must be looked into while explaining heat production in CMNS.

10.7. Phonon amplification

Hydration energy is not released once but is released repeatedly with exponentially increasing rate with time since the rate of collapse of the precursor crystal should increase with increasing force of Coulombic repulsion as the two protons approach closer and closer. This means that the collapse of the nanocrystals and their reformation should go on many (nearly 100 or more) times in an unhindered manner till the pressures required for initiating the accumulated energy release through hydration process is achieved. In fact, the CCRO mechanism proposed envisages unlimited number of oscillations and hence unlimited amount of energy release through internal accumulation of energy without any major energy input. Only limitation occurs due to the limited capacity of the system to withstand the heat energy released due to phonon amplification.

Here comes the interesting question if heat energy is released due to the accumulation of hydration energy or due to phonon amplification. It is like the question which came first? Chicken or egg? Since heat dissipation occurs during stirring, heat accumulation can be discarded in favor of phonon accumulation. Moreover, heat energy transfer from lower temperature to higher temperature would invoke violation of second law of thermodynamics though in principle in small systems in short intervals of time such violation has been known to occur. Pressure build-up can lead to sudden violent energy release associated with high-frequency vibrations. CCRO mechanism would provide a route for amplification of such high-frequency vibrations from the MHz region up to the THz region.

10.8. Miniature black holes

Energy released from miniaturized black holes should be massive. The exact estimate of energy released depends on their number which remains uncertain since head-on probability of two protons in the proposed species is unknown and plasma like conditions seems to have been reached in the experiment only on the sidewalls of the glass beaker. Therefore, only a fraction of protons trapped in condensed matter seemed to have reached the desired head-on collision conditions needed for such an energy release. More detailed studies are therefore needed to verify this claim.

11. Summary

(1) Pressure build-up through accumulation of chemical energy can lead to sudden violent energy release associated with high-frequency vibrations. CCRO mechanism would provide a route for amplification of such high-frequency vibrations from the MHz region up to the THz region. Burst of energy release could occur during cavitation collapse when the build-up of pressure in the Epsom solution surrounding the nanocrystalline precursors by the unhindered p–e–p oscillations reaches a critical value extremely rapidly. Underlying mechanisms causing the explosion are, however, still speculative. A consensus, however, seems to be emerging in the sense that many of the proposed mechanisms of energy production in CMNS predict production of low-energy photons (or particles constituting Hawking radiation!) as the source of heat through high (relativistic) speed oscillations/collisions of charged particles trapped in crystal cavities. Similar views invoking cracks have been proposed to provide nuclear active environments.by Edmond Storms [11] in metal lattices. Burst of energy released from miniature black holes created in laboratory conditions due to collision of protons trapped in ionic crystal cavities appears to be quite an interesting possibility and merit serious consideration.

(2) Energy released in the experiment is nearly 200 times higher than the hydrogen combustion energy and nearly 100 times higher than the energy released by simple hydration. It is large enough to cause the observed explosion but is, however, much less (by nearly 2760 times) than the energy released by p–p nuclear fusion reactions. The p–p nuclear fusion proposal is highly speculative and is considered less probable. It could, however, be proven or disproven by the observation of 5.5 MeV gammas from secondary reactions.

Proposed experiments and challenges involved

(1) Reproduction of the explosive experiment – no other material nearby to curtail plasma.
(2) Effect of container material – should it be made of glass or other thin material?
(3) Should the container hang and not placed on a stool so plasma like condition can be reached even at its bottom?
(4) It is a pulsed energy release. This means for connecting to power grid we need to recharge a number of such fuel cells but each explosion should not disturb the other. How to achieve this?
(5) It is necessary to perform a series of successive experiments done at various Epsom concentration (1.9 M, 1.8 M, etc.) and to see if an increase in energy release along the way prior to where the system explodes. If so, then this might be important in that it could provide a "safe" version of the experiment which begins to show anomalous behavior.
(6) A still better approach would be to develop a fuel cell with a continuous flow of Epsom solution having appropriate salt concentration with continuous addition of appropriate quantity of molten Na metal to produce continuous excess heat energy similar to the heat production in Ni–H systems reported by Focardi et al. [11]. Currently there is enormous interest in the Ni–H experiments.
(7) The absence of any radiation injury suggests that heat energy release occurred without any radiation release. But measurement of radiations released, if any (0.51 MeV annihilation gammas or 5.5 MeV gamma rays produced from HD fusion) using a NaI:Tl detector would confirm or disprove the p–p nuclear fusion process. Once the reproduction is confirmed, technologists can take it over to a commercial electrical power grid level.

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