

Electrostatic Force of Repulsion Assists *p-p* Nuclear Fusion

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Abstract

Trapping of hydrogen ions released during sodium metal dissolution in a dilute aqueous Epsom solution in cavitation induced nanocrystals could bring about an easy path to controlled nuclear fusion. This type of fusion envisioning has the advantage of keeping the two protons and the electrons in the same vicinity, bonded in the same unit throughout the fusion process unlike the case in Sun. The electrostatic repulsive force between protons which has been a stumbling block so far in achieving a controlled fusion is now turned in its favor by exploiting the fascinating properties of water.

Keywords: Nuclear Fusion, Cavitation, Sodium Metal Dissolution, Aqueous Epsom Solution, Hydrogen Trapping, Spatial Confinement, Electrostatic Repulsion, Hydrinos

1. Introduction

Any fuel used for power production should not only be eco friendly and economical but also should last longer than the life of universe. Only water qualifies these requirements. The prospect of successful proton-proton (*p-p*) nuclear fusion technology with ordinary water as the fuel, promises virtually unlimited energy. Nuclear energy through fission, has been well understood, and cost-effective in many countries, though it is not without its problems, chief among them being the radiation safety, storage of nuclear waste and limited fuel availability. Thermonuclear fusion, thought to be the process that powers the sun and the stars has not worked so far as a source of energy [1]. Cold fusion process in palladium metal lattice [2] has met with several objections, chiefly on the source from where the required energy for nuclear fusion would come from in room-temperature matter and to the non observance of the reaction products [3]. The claim that the pressures and temperatures inside the collapsing cavitation bubbles could be high enough to initiate nuclear reactions [4] is questioned since the bubble collapse is strongly cushioned and energy being dissipated by several factors may prevent the temperature from approaching levels required for detectable nuclear fusion [5-7]. We are of the opinion that there exists an easy path to achieve controlled nuclear fusion as highlighted below.

2. Methods

In order to develop a method of non-violent dissolution of sodium metal in which the reaction products are non-corrosive and non-hazardous unlike that of caustic process employing NaOH, sodium dissolution was carried out in different aqueous salt solutions [8]. Once sodium metal is dropped into the Epsom solution under stirring, it reacts with water quickly and melts. Without stirring sodium metal floats in aqueous solutions which makes peaceful dissolution impossible. A series of experiments with different concentrations of Epsom salt ($\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$) revealed that in a concentrated (but slightly under-saturated) aqueous solution of Epsom salt, sodium dissolves peacefully without any violent reactions. An ion-exchange reaction involving Na and Mg was found to explain this phenomenon. However, as the Epsom concentrations were lowered, Na- H_2O reaction becomes dominant. High pure (Ranbaxy make, Laboratory reagent) Epsom salt was used in this experiment. The rise in solution temperature was continuously monitored with the help of a thermocouple wire inserted into the solution. An X-Y recorder was used to plot the temperature of the solution as a function of time since the sodium drop. The effects of water content, salt content, quantity of solution as well as the quantity of sodium on the solution temperature were studied. To reduce solid waste, the effect of repeated dissolution of sodium on the

same solution was also studied. However when the mass of sodium was higher than 5 g, additional air ventilation was found essential to dilute the hydrogen concentration and to prevent the fire. A comparison of the above Epsom process with the caustic process has been made under identical experimental conditions.

3. Results

Text book chemistry states that sodium metal in an aqueous solution will react with water only in any condition and that the salt added merely reduces the thermodynamic activity of water. However, experiments carried out by us showed that this theory hold only with NaOH solution in which the salt exists as ions at all concentrations even under stirring conditions. Detailed studies with Epsom ($\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$) solution indicate a new dissolution mechanism of sodium metal based on cavitation induced *meta stable* crystals. Results showed two major differences between sodium dissolution in the above two salt solutions. These were: 1) Na dissolution time decreases in NaOH solution as water content *increases* indicating that Na mainly reacts with water. However, no such dependence was seen with Epsom solution. and 2) With NaOH solution, sodium solubility was found to *decrease* with increasing salt content since Na reacts mainly with water. However, the amount of sodium that could be dissolved peacefully in Epsom solution was found to *increase* with Epsom salt content. These results clearly indicated that that sodium is dissolved mainly in the Epsom salt by ion exchange rather than in water. Sodium is known to have a high solubility in alkaline earth sulphate crystals [9]. Mg atoms released slowly by ion exchange react with water and due to this process the Na dissolution proceeds peacefully in concentrated Epsom solution. Results showed that Na addition increases the temperature of NaOH as well as Epsom solutions since both Na- H_2O and Mg- H_2O reactions are highly exothermic.

For Epsom concentrations > 1.2 M, Na dissolves into Epsom crystals peacefully by $2\text{Na}^+ - \text{Mg}^{2+}$ 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. At this Epsom concentration both the reactions mentioned above are shown to take place with equal probability [10]. Glass vaporizes at temperatures $> 1000^\circ\text{C}$. 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. 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.

4. Discussion

4.1. Vaporous Cavitation

The application of Bernoulli's equation has shown that cavitation occurs in the Epsom solution not because of stirring but due to exothermicity arising during sodium metal dissolution and distribution of these local boiling spots occurs during stirring. A recent study shows that if a steam bubble is introduced in a cold water pool, due to a fast condensation of the steam from the surface of this bubble a phenomena similar to the cavitation collapse of the bubble occurs. The steam bubble cavitation process was more efficient compared to conventional processes because of the elimination intermediate energy-interchange process [11]. The crystal formation due to cavitation has been attributed to a number of factors such as, 1) local temperature increase, 2) pressure changes leading to rapid cooling rates ($10^7 - 10^{10} \text{ k}\cdot\text{s}^{-1}$), 3) concomitant shockwaves, which will overcome energy barriers to nucleation and promote crystal nucleation and its growth even at a modest super saturation level [12]. We extend this fact for the first time to explain the formation of meta stable crystalloids due to exothermicity arising during sodium metal dissolution in concentrated but slightly under-saturated aqueous Epsom salt solutions used for peaceful sodium metal dissolution. The process of generation, subsequent growth and collapse of the cavitation bubbles results in high energy densities, resulting in high temperatures and pressures at the surface of the bubbles but only for a very short time. *Per se* it should, however, be emphasized that the principle of cavitation is used in this work primarily only in the formation of metastable crystals and not in the production of high temperatures directly.

4.2. Possible Causes of Explosion

Preliminary calculations reveal that energy needed to vaporize the system used in the above experiment is about 2.60×10^2 kJ, whereas the energy released by chemical reaction as a result of combustion of hydrogen gas in air is 9.57 kJ. This shows that the observed explosion is not caused by the combustion of hydrogen in the presence of oxygen. In contrast, the energy released during the hydrogen fusion is about 0.276×10^7 kJ which is nearly 10,000 times more than the energy required to vaporize the solution. So it is no wonder that the excess

energy has been vented out in the form of vaporizing the glass beaker with its contents and a massive explosion!

Similarities of the observed explosion in 0.85 M Epsom solution and that of inertial confined fusion are obvious. In the latter case, the fuel is compressed by the rocket-like blow off of the hot surface material. During the final part of the capsule implosion, the fuel core reaches 20 times the density of lead and ignites at 100,000,000°C. Finally, thermonuclear burn spreads rapidly outward through the compressed fuel, yielding many times the input energy. In the present case energy is regenerated from within the system in a metastable ionic crystal lattice surrounded by water and the proposed *p-p* fusion is lattice assisted and hence follows different set of rules.

4.3. Proposed Model Based on *p-p* Fusion Process

The intensity and timing of the explosion witnessed above clearly indicated that the hydrogen released during Na-H₂O and Mg-H₂O reactions in 0.85 M Epsom solution somehow got trapped *in situ* in the cavitation induced Epsom crystals. The reaction may be described as follows:

2 Na atoms get into the MgSO₄ 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:

- $2\text{Na} \leftrightarrow \text{Mg}$
 - Na donates electrons to a Mg²⁺ ion
 - 2Na^+ will replace a Mg²⁺ ion
- $$\text{Mg} + 2\text{H}_2\text{O} \rightarrow \text{Mg}(\text{OH})_2 + \text{H}_2 \quad (1)$$

- 50% Na added simultaneously reacts with water:
- $$2\text{Na} + 2\text{H}_2\text{O} \rightarrow 2\text{NaOH} + \text{H}_2 \quad (2)$$

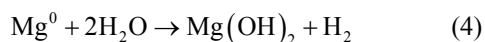
to produce more hydrogen

- Hydrogen donates electrons to a Mg²⁺ ion
- $$\text{H}_2 + \text{Mg}^{2+} \rightarrow \text{H}_2^{2+} + \text{Mg}^0 \quad (3)$$

(Due to ion exchange reaction between hydrogen and Mg, H₂²⁺ gets into the crystal while Mg is released into the solution).

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

Calculations reveal that the crystal now contains only Na⁺, SO₄²⁻ and H₂²⁺ ions bonded to the water molecules [10]. This necessitates the creation of SO₄²⁻ anion vacancies for charge compensation in which H₂O molecules sit as shown in **Figure 1(a)**.



(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 **Figure 1(a)** since there are no more Mg left in the crystal. This is a secondary reaction and temporally delayed when compared to the H₂²⁺ incorporation through reaction (3). Trapping of hydrogen atoms/molecules near oxygen atom in the water molecule 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 Mg²⁺ ion lattice site. The crystal structure shown in **Figure 1(a)** which utilizes several fascinating properties of water represents the precursor state of the explosive solution after Na dissolution. *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 electrostatic force of repulsion between the two hydrogen ions would however prevent them from coming together thereby making it a highly unstable structure. It would hence tend to break the moment it is formed, at a much faster rate than the normal dissolution process of cavitation induced crystals. However, cavitation induced by repeated release of hydration energy will reform these crystals quickly with more vigor and thus an oscillatory reaction sets in. The situation is akin to a mechanical spring being pushed inward by an external force. The more the force that is applied (due to cavitation) the more is its recoil force (due to electrostatic repulsion). In other words, the electrostatic repulsive force between protons which has been a stumbling block so far in achieving a controlled fusion is now turned in its favor. Basically the above repulsive force helps in the regeneration of nanocrystals rapidly which helps in building-up the hydration energy exponentially. The two strong opposing forces mentioned above would never allow the crystals to grow to larger dimensions. This is the premise for assuming the proposed fusion process in *nanocrystals*. It is known that the energy input for inetically confined nuclear fusion decreases with decreasing sample size. The oscillatory chemical reactions, however, repeatedly release hydrogen ions into the aqueous solution. Because the hydrogen ion is so tiny, a large amount of charge is concentrated in a very small area and the polar water molecules are strongly attracted to it thereby forming the H₃O⁺ ions. This “hydration” of the hydrogen ion involves not only in the formation of a coordinate covalent bond to one of the water molecule but a large number of strong hydrogen bonds, so it is a strongly exothermic process (H₃O⁺ ΔS_G hydration energy = 461.1 kJ/mol). However, stirring distributes uniformly the heat energy released from local hot spots. Therefore,

the rise in bulk solution temperature in the beaker is visualized to be not more than 60°C - 70°C until the fusion reaction commences. The re-generation of nanocrystals, however, helps in building-up the pressure on the hydrogen ion species trapped inside the crystal. Since the two hydrogen ions are positioned on either side of the divalent cation site, the pressure exerted on them (*i.e.* H_2^{2+} species) will increase exponentially and is anticipated to be very high, perhaps in the range of Gpa prior to fusion since the charge neutrality demands the positioning of two monovalent hydrogen ions at a single lattice site. However, coulombic repulsion between the hydrogen ions will oppose the crystallization process. The above oscillatory reactions will continue until the phase change (liquid to solid) is complete *i.e.*, crystallization process of Na_2SO_4 in which the two hydrogen ions come together and occupy a single cation site that is vacated by a Mg^{2+} ion which results in the nuclear fusion of hydrogen ions. Thus eventually the cavitation force wins over the electrostatic repulsive force. This is the story of controlled nuclear fusion in a glass beaker. At this point of time (*i.e.* about 20 to 25 s after Na addition) due to a chain fusion reaction, the temperatures and pressures should shoot up instantly. Solution temperature is likely to shoot up at the end of Na dissolution due to the energy released by chain fusion reaction. Therefore even before the crystal lattice disintegrates/vaporizes, fusion chain reaction commences. Fusion occurs once the exponential growth of hydration energy reach a critical point which makes the crystallization process complete. Since fusion is crystal lattice assisted, it is basically a low energy nuclear reaction (LENR). The CCRO (Cavitation-Coulombian Repulsion Oscillation) theory envisions nuclear fusion in a crystal lattice at moderate temperatures but at high pressures.

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

The formation of a divalent species like H_4O^{2+} shown in **Figure 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 [13]. During oscillatory reactions, a hydrogen ion has to be separated from one of the hydronium ion in the solution and attached with an-

other hydronium ion so as to form the H_4O^{2+} species shown in the precursor. 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 [14,15].

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 **Figure 1(a)**. The hydrogen budget is thus accounted for. Adsorption of hydrogen atoms in such systems is well known. If two hydrogen atoms sit beside oxygen atom in the water molecule as shown in **Figure 1(a)** then some sort of covalent bond can be formed between the two hydrogen atoms and the electrons attached with the oxygen. This will compensate for the electron density loss created by the pulling of the electronic cloud towards the hydrogen ions. As a result, the structure shown in **Figure 1(a)** forms which can be represented as $[H_6O]^{2+}$ with an overall +2 charge as that required at a Mg^{2+} site.

4.5. Energy Released in Hydration and Energy Needed for Fusion

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 1200 J 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. Preliminary calculation reveal that the number of hydronium ions formed during a single collapse of the nano-precursor crystal in the explosive solution = 0.04 mol. Hence each time the above crystal dissolves in the solution an energy equivalent to 18.44 kJ (= 461.1 kJ/mol \times 0.04 mol) is released into the solution. However, the energy released in the fusion process in the above case is about 0.28×10^7 kJ. The energy really needed to achieve the fusion depends on the efficiency of the system. Let us assume that the energy needed to achieve the fusion is a factor of 100 times (this number is immaterial—what is important is the collapse of the nano crystals and their reformation as many times that are needed in an unhindered manner till the energy required for initiating the *p-p* or *p-e-p* nuclear fusion is released through hydration process!) lower than the fusion energy released. Even then, the energy required for initiating the fusion would be of the order of 1520 (= 28000/18.44) times larger than the hydration energy stated above. *Here comes the trick.* Hydration energy is not released once but is released repeatedly with 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.

4.6. Exothermic Reaction is Exponential in Nature

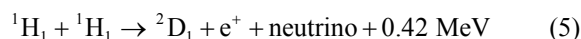
All exponential curves can be represented by the function $y = a.b^x$, where a and b are constants, while x (time) and y (pressure) are the two variables. They all have same basically the same shape—for values of $b > 1$ and positive values of a , the value of y rises slowly first but then begins to rise more and more rapidly, until *finally* y shoots almost straight up. It is the latter property which is very useful for high pressure generation in a short time. x refers to the time since the precursor is formed while y refers to the pressure on the hydrogen ion species. Since the explosion occurred at about 20 to 25 s after sodium addition, the oscillations appeared to have continued for a few seconds prior to explosion. Exothermic chemical reaction is a classical example of producing exponential growth; the more of the reaction rate that is happening, the more heat is produced, which in turn causes the reaction to produce faster, which in turn produces more heat and so on. In the above example, the premise is that the hydration energy (in the kJ range) accumulated repeatedly within a very short period exponentially in the vicinity of nanocrystals can result in the build up-of pressure (MPa range required in plasma state) needed for a nuclear reaction in condensed matter. The time scale is very important here. Only after the fusion reaction takes place within those nano-crystalline region, the p - p fusion energy released is spread out evenly outward in all directions which results in the vaporization of Borosil glass beaker along with its contents. Before the hydration energy released is dissipated into the bulk of the solution, further build-up of hydration energy should take place or else there is a chance of energy dissipation from the nano crystal to the bulk of the solution which would slow down the reformation of crystal and the conditions required for fusion would not have been achieved. The extent of the regeneration suggested is important in this context. Regeneration of a small crystal over a sufficiently small time scale could, in principle, occur. The opposite limit of a large crystal being destroyed and it being regenerated, after a long period of time, involves a significant reduction in entropy in a situation associated with explosion which simply cannot occur. Therefore, details, involving the crystal size, time scale, and the mechanism for creating the nanocrystal regeneration effect are all important so laws of thermodynamics are not violated.

Practically known examples of exponential growth are

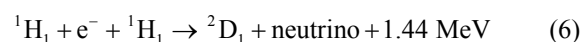
in the end limited by the sample size (*i.e.* the species causing the growth) e.g., the number of microorganisms in a culture will grow exponentially until an essential nutrient is exhausted. Typically the first organism splits into two daughter organisms, which then each split to form four, which split to form eight, and so on. Similarly, an uncontrolled polymerization process can cause exponential release in heat energy until the monomer is exhausted. These are not regenerative systems. What is being considered here is a regenerative system in which there is no limitation of fuel size. The energy will get regenerated as long as it is required to cause the final end point—in this case energy required to cause p - p fusion.

4.7. Fusion in Free State and Fusion in Condensed Matter

It is claimed that in free state p - p fusion reaction is a weak interaction since it requires a conversion of proton $^1\text{H}_1$ to neutron which is associated with a positron e^+ decay. This reaction is described below:



Deuterium can also be produced by the rare pep (proton–electron–proton) reaction (electron capture):



In the Sun, the frequency ratio of the pep reaction versus the pp reaction is 1:400. In p - p fusion in the Sun, 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 cannot produce significant heat [16].

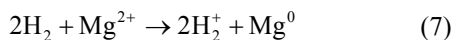
Hot plasma physicists argue that even at temperatures of 10^{10} K that exist in the sun it would take millions of years to produce the number of reactions required. Hence the argument is put forward that p - p fusion can be ruled as a mechanism in the experiment proposed. It is true that with free particles the p - p bound state cannot be formed because of energy conservation but in crystal lattice, the lattice can take up the excess energy and hence a bound state of p - p is very well possible. In **Figure 1(a)**, a water molecule donates two electrons to two hydrogen ions by two independent dative bonds through the two lone pair electrons in the oxygen. *Such a confinement of electrons with hydrogen ions could bring about a new mode of fusion process based on deflated hydrogen discussed below.*

Analogy for differences in the experimental results observed in free state and in crystals can be seen elsewhere too. It was originally thought impossible for nuclei

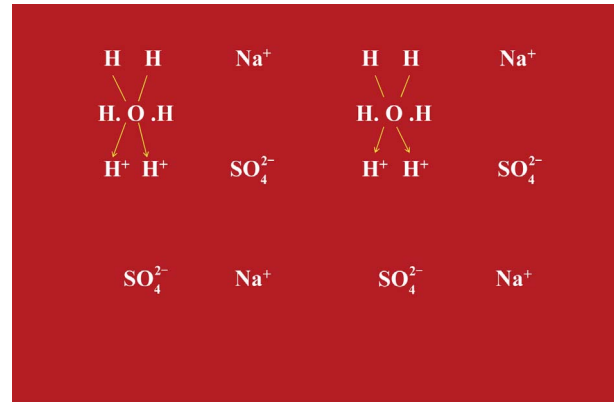
to absorb and emit gamma rays resonantly. It was believed that due to conservation of momentum, the emitting and absorbing nuclei would lose some of the gamma ray energy by recoiling, therefore eliminating any chance of the gamma ray being absorbed again by another nucleus - this due to the very narrow line width of some nuclear energy levels (due to their long lifetime—the uncertainty principle!). Mossbauer, however, showed that if the absorber and emitting atoms are embedded in a lattice, the recoil due to the gamma ray may in fact be taken up by the entire solid, making the energy loss negligible. This is in fact the very essence of Mossbauer Spectroscopy: the discovery of recoil-free nuclear resonance emission and absorption. Yet another instance concerns the rules of luminescence in crystals which are quite different from those governing gases. For example, the luminescence in gases is governed by the rules of atomic spectroscopy which result in line absorption and line emission. In contrast the luminescence in crystals is governed by a different set of rules. Transitions which are forbidden by selection rules in gases become allowed in crystals through the influence of crystal field, sometimes with a very strong probability eg., ligand to metal or metal to ligand charge transfer (CT) transitions or intense thermostimulated luminescence (TL) from $4f-4f$ forbidden transitions in lanthanide doped crystals. Host mediation through phonon interaction removes the degeneracy of lanthanides in the later case. Furthermore, the emission in crystals occur on long wavelength side of absorption due to Stokes shift occurring because of crystal field. Emission and absorption show as bands in crystals [17].

4.8. Oscillator/Substance (O/S) Theory and an Alternate Fusion Process

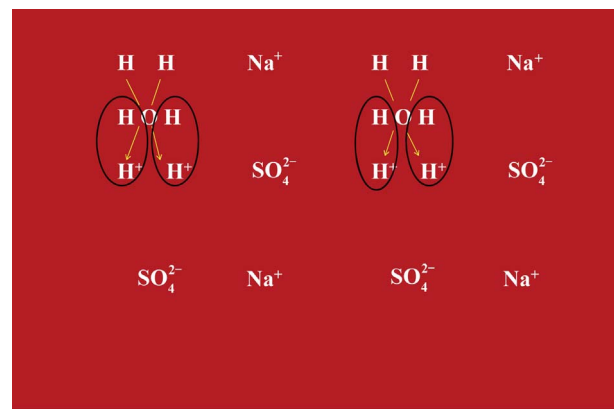
O/S theory proposed by Sinclair [18] postulates that the formation of molecular monocation (H_2^+) is more likely rather than hydrogen molecular Di-cation (H_2^{2+}). As per the O/S theory, coalesion (fusion) of para hydrogen (nuclei with opposing spins) unit HH^+ into D^+ by rotation is more likely than the fusion of di-protonated hydronium ions or p^+p^+ species. Without making any other change, this idea can be fused into the mechanism proposed above. In the alternate proposal shown in **Figure 1(b)**, two H_2^+ ions replace one H_2^{2+} ion. The exchange reactions may be described as follows:



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



(a)

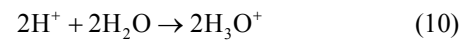


(b)

Figure 1. (a) Original proposal—Precursor state of the explosive solution after the sodium dissolution. (b) 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_2^{2+}) shown in (a) as more likely. See text for more details of the two figures.

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

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



(Hydration energy release)

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 and ably assisted by LENR as the cause for $p-p/p-e-p$ fusion.

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 con-

ditions inside an ionic solid. The W/S 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. 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. 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. This is in resonance with the O/S theory which presumes that *very high temperatures will tear apart the HH^+ species*. 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. The entire fusion process is envisaged to occur in this approach in a very elegant manner at molecular level without the release of high energy photons or high energy neutrinos unlike the random collision approach in hot fusion. Basically low energy photon continuum results when the molecular cations (H_2^+ for $p-p$ fusion and D_2^+ for $d-d$ fusion) are subjected to high pressures in an ionic crystal. The lattice mostly absorbs this photon continuum leading to heat release. O/S theory predicts that the formation of para hydrogen is a must for the fusion and that can happen only in H_2^+ molecular ion and not in H_2^{2+} species which is unknown. In the CCRO model (see **Figure 1(b)**), there is an additional electron attached to one of the H in H_2^+ ion. So essentially both H_2^{2+} and H_2^+ ions have two hydrogen ions to which two electrons are attached. So both the species are essentially same. What is important here is what is happening is perhaps the H_2^+ molecular ion initiates $p-p$ fusion. The electrons surrounding the hydrogen atom/ion species appear to facilitate the fusion process by some mechanism.

This view is similar, in some ways to Mill's Hydrino work [19]. Mill's idea of "electron energy levels lower than ground state" has relevance to hydrogen atoms as well as hydrogen molecular ions. The idea of electron compression into orbits deeper than ground state during CCRO could lead to a large amount of usable energy even without involving $p-p$ fusion. A rough estimate of energy released by hydrinos in the above experiment was found to be = 57.6 MJ which is large compared to the chemical burning of hydrogen (9.57 kJ), but less than that by nuclear fusion reactions (2800 MJ). Previous estimation has shown that the energy needed to vaporize

the salt solution is 260 kJ. Thus the energy released during hydrinos is more than 200 ($\sim 57600/260$) times the energy required to vaporize the solution. So energy released by Hydrinos formed under compression during CCRO can also explain the excess energy that has been vented out in the form of melting the glass container and a massive explosion. The formation of a super-tight molecule with a very deep-electron orbit (nought-orbit electron) that has a very-high fusion probability cross-section is being considered in this regard [20]. If the nought-orbit concept bears fruit, then LENR may be taken out of the unfriendly nuclear-physics community sights and placed in the more-accepting chemistry environment. Yet another of cold fusion proposes a deflated state of hydrogen which is made probable in situations where the probability of an electron in the nucleus is high [21]. This can happen due to molecular or lattice structure producing spin zero orbitals, by compressing an electron cloud around a hydrogen nucleus so as to only allow partial orbitals around the nucleus. Neutron creation via $e + p$ combination requires an energy of about 0.78 MeV. This is energetically not favored from the two body event, because a neutron has more energy than an $e + p$, and also because neutron creation is a weak force interaction and hence require a long exposure time to become probable. It is the wave function collapse to a three body state that creates hydrogen based fusion in LENR. For this to happen, not only must the deflated state be common enough, but it must also be in an environment where the third body is present, or comes and goes, at a useful distance with high probability. This only happens in condensed matter. Typically in deflation fusion the wave functions of an electron and two hydrogen nuclei momentarily collapse into a small volume, their centers of mass being co-located, to create an intermediate state weak and/or strong nuclear reactions may occur in this intermediate state. Because deflated state hydrogen has no net charge, the probability of deflated state hydrogen tunneling long distances is greatly enhanced due to a lack of tunneling barrier. The deflated hydrogen state is explicitly stated to exist for attosecond order durations, but, where LENR occurs to any observable degree, the state is repeated with a high frequency so as to make the state sufficiently probable, and the lattice half life of the hydrogen appropriate. Wave function collapse occurs in electron capture reactions when energetically favorable even though it involves weak force interaction. The deflated state is a degenerate state of the hydrogen within its environment. The fusion tunneling probability is raised in Mill's theory by the reduced hydrogen atom radius. The fusion probability in deflation fusion is raised by the vastly increased *combined* ensemble tunneling probability of the hydrogen-nucleus-electron pair, which

retains at all times a low binding energy.

4.9. Cold Fusion and Uncertainty Principle

Uncertainty principle between momentum (p) and space (x) states that if the particles are confined, *i.e.*, if their position becomes definite, their momentum increases tremendously. *i.e.*,

$$\Delta p \cdot \Delta x \sim h \quad (11)$$

An application of this principle in nuclear fusion implies that when two protons (or deuterons) come close together *i.e.* if they are confined in space (*i.e.*, minimized Δx), their uncertainty in momentum (Δp) becomes exceedingly large—so large that no crystal lattice (metallic or ionic!) can hold it. Protons or Deuterons with large momentum (p) associated with large uncertainty in it (Δp) can exist only in hot plasma state. Hence the argument that fusion is possible only in plasma state where the protons having high momentum collide with each other to overcome the electrostatic barrier prior to nuclear fusion. We shall see that it is possible to achieve the fusion through simpler routes without violating the principles of quantum mechanics.

In this regard, a question which remains to be answered is “how the particle energy in cold fusion should satisfy the Heisenberg Uncertainty Principle (HUP). The relevant relation is:

$$\Delta E \cdot \Delta T \sim h/2\pi \quad (12)$$

It has been reported that in cold fusion involving deuterium, $d-d$ approaches closer through coupled phonon interactions combined with Jahn-Teller displacements [22]. All of the plasma (hot fusion) pathways have the emission of a high energy photon. In contrast, in cold fusion, the excited state alpha energy is internally converted to lattice through optical phonons. Electric dipole transitions are forbidden when there is no parity change but crystal field can lift parity prohibition partly even at RT. Hence some gamma emission could result even in cold fusion but this is not observed. HUP will allow the 24 MeV photon energy to be transferred virtually to the lattice *i.e.* without gamma emission provided it happens in less than 10^{-23} s. However since atoms are typically spaced about 10^{-8} cm apart and $c = 3 \times 10^{10}$ cm/s, this transfer energy can happen only at speeds tens of thousands of times the speed of light, which is impossible according to Einstein’s theory of Relativity. More likely the high energy photon is not emitted in a single step but as a continuum by a totally different process as in hydrino theory as applicable to molecular cations. Therefore lattice absorbs the low energy photons (typically in the eV to keV range) effectively leading to heat release.

In fact the O/S theory also predicts the loss of energy (vibrational motion) to the environment 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. These facts imply that in fusion involving LENR, the emission of high energy photons or high energy neutrinos does not take place.

The CCRO theory explains another HUP relation also elegantly. Since oscillations of protons around the divalent cation site precede fusion, with speed of oscillations increasing exponentially first and in the final stages (preceding fusion) instantaneously shooting-up, the protons undergo a very large momentum (p) associated with a large Δp leading to a low value of uncertainty in its position, *i.e.* Δx , thereby satisfying the relation $\Delta p \cdot \Delta x \sim h/2\pi$. This concept is novel and is visualized only in CCRO theory. In other CMNS theories this conundrum proved to be quite formidable to tackle.

5. Conclusions

Detailed studies with Epsom ($\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$) solution indicate a new dissolution mechanism of sodium metal based on Na-Mg ion exchange in cavitation induced meta stable crystals. Cavitation occurs in the aqueous Epsom solution due to exothermicity arising during sodium metal dissolution and distribution of these local boiling spots occurs during stirring. The intense explosion accompanied with a shock wave and vaporization of borosil glass beaker containing salt solution witnessed in 0.85 M Epsom solution on the completion of sodium dissolution is attributed to fusion of hydrogen nuclei extracted from ordinary water.

The intensity and timing of the explosion witnessed clearly indicated that the hydrogen released during Na-H₂O and Mg-H₂O reactions in the Epsom solution got trapped in situ in the cavitation induced Epsom crystals. Charge neutrality demands the positioning of two H⁺ ions at a Mg²⁺ cation site as the system would then go into more stable state with less potential energy. This factor is the prime reason for promoting nuclear fusion in this system. The electrostatic force of repulsion between the two hydrogen ions would however prevent them from coming together thereby making it a highly unstable structure. It would hence tend to break the moment it is formed which results in the release of hydration energy due to the reaction of hydrogen ions with water molecules. However, cavitation induced by repeated release of hydration energy will reform these crystals quickly with more vigor and thus an oscillatory reaction sets in. The more the force that is applied (due to cavitation) the more is its recoil force (due to electrostatic repulsion). In other words, the electrostatic repulsive force between

protons which has been a stumbling block so far in achieving a controlled fusion is now turned in its favor.

Hydration energy is not released once but is released repeatedly with 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. Once the exponential growth of hydration energy reaches a critical point, the cavitation force overcomes the coulombic repulsion to fuse the hydrogen nuclei and complete the crystallization process. The observed explosion is a consequence of a chain fusion reaction following the crystallization. Since fusion is crystal lattice assisted, it is basically a low energy nuclear reaction (LENR). The fact that a chain reaction does occur is by itself an evidence of the proposed theory.

A confinement of electrons with hydrogen ions could bring about a new mode of fusion process based on deflated hydrogen. However, proton fusion demands the conversion of protons to neutrons and the creation of positrons and both these processes require a very high external energy input and such input can come only from an external event. The deflation fusion concept might assist the process as mentioned above but by itself cannot cause it. So there are more than one factor that leads to fusion in LENR. Alternately, Mill's idea of hydrinos formed under compression during CCRO could lead to a large amount of usable energy without involving p-p fusion.

What is now needed is: 1) the demonstration of the reproducibility of the proposed system, 2) precise measurement of energy released to show that it is consistent with nuclear and not chemical events and finally 3) the measurement of the reaction products—annihilation gammas from positrons and/or deuterons (the two by-products of proton fusion) or the low energy photon continuum predicted by Mill's hydrino theory which is being planned in the near future.

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