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Energy, Economical, Environmental and Medical Applications of Cold Nuclear Fusion of Hydrogen with Powder and Liquid Forms of Metals

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Abstract

Aim of this paper is to highlight the four major applications of Cold Nuclear fusion (CNF). Considering Google publications, NASA publications, European funding amounts and other important experimental results, we have developed a mechanism for understanding the mystery of energy liberation in CNF associated with fusion of hydrogen with metals. Apart from clean thermal energy liberation, we have identified three important applications of CNF. They are: Preparing Iridium-, Platinum-and Gold-like costly elements from Tungsten-like elements, converting high level nuclear radioactive waste into stable atomic nuclides and preparing radioactive isotopes for medical applications. It may be noted that, we have developed a common, simple and workable theoretical procedure for understanding the above applications and it needs funding for conducting experimental studies. We emphasize the point that, our proposed scientific concept of CNF is practical compared to other theoretical models of cold nuclear fusion.

Keywords: cold nuclear fusion, 4 major applications, energy liberation mechanism, participating atomic nuclide (PAN), need for nuclear experimentation

1. Cold Nuclear Fusion

Since 1989, many scientists and engineers are seriously working on cold nuclear fusion experiments that produce 'excess' heat with no hazardous nuclear radiation (M. Fleischmann and S. Pons, 1989). Here it is very important to emphasize that, energy liberated in cold nuclear fusion is approximately one million times higher than the energy released in burning of ordinary fossil fuels. It clearly indicates the less consumption rate of cold fusion fuel in milligram/sec compared with more consumption of fossil fuels in liter/sec. Point to be noted is that, as the name itself suggests, 'cold nuclear fusion' can be visualized as a peculiar exothermic nuclear physical phenomenon associated with fusion of one heavy atom with one hydrogen atom at low temperatures of the order 2000 degree Kelvin against currently believed fusion of two very light atoms associated with a temperature of the order of million degree Kelvin.

Cold nuclear fusion experiments can be classified into two categories. First one is 'Electrolytic or Alkaline Cold Fusion' associated with 'Electrolysis of Deuterium' (Cohen, J.S., & Davies, J.D., 1989) and second one is 'Hydrated Cold Fusion' associated with 'preheating of hydrated metals in a pressurized reactor' (S. Focardi, V. Gabbani, V. Montalbano, F. Piantelli, and S. Veronesi, 1998). Due to 'failure' of experimental repeatability and 'lack' of proper physical theoretical models, cold nuclear fusion experimental results could not be published in mainstream journals for the past 30 years. As the subject under consideration was associated with clean and green energy, in 2019-20, Google team members published a seminal paper in the prestigious journal 'Nature' and expressed their strong encouragement for conducting future experiments in cold nuclear fusion (Berlinguette, C.P., Chiang, YM., Munday, J.N. et al. 2019; Philip Ball, 2020). In 2020, NASA team developed a mechanism called 'ambient temperature lattice confinement' (Vladimir Pines et al. 2020; Steinetz Bruce M et al., 2020) and working on clean and green energy for space exploration.

In a theoretical perceptive, for any scientist, it is imperative to explain the possibility of low temperature nuclear fusion of atoms against hot fusion and the dominating nuclear Coulombic repulsive forces. Important point to be noted is that, increasing mass number of nucleus can be considered as a representation of increasing strong nuclear attraction. Based on this point, it can be understood as-fusion of two hydrogen ions/atoms at million deg. C seems to be different from fusion of a heavy atom that constitutes (50 to 200) nucleons (having a density of the order of 10^{22} nucleons/cm^3) and one hydrogen atom at 3000 deg. C. Fusing Hydrogen with metals in liquid state seems to be more interesting.

2. Four Major Applications of Cold Nuclear Fusion

Considering 'cold nuclear fusion' as an emerging technology, the following four applications can be fulfilled (Seshavatharam U.V.S, Lakshminarayana S., 2022; Seshavatharam U.V.S, Lakshminarayana S., 2022; Seshavatharam U.V.S, Lakshminarayana S., 2021; Seshavatharam U.V.S, Lakshminarayana S. H. K. Cherop & K.M. Khanna., 2022) with further research and experimentation.

1) Clean and green thermal energy production as per the demand.
2) Production of Iridium, Platinum and Gold-like costly metals via Tungsten-like cheap metals.
3) Conversion of high level nuclear radioactive waste into next stage stable and non-radioactive atomic nuclides.
4) Production of radioactive isotopes required for medical applications.

It may be noted that, in sections 5 to 10, we have developed a technical procedure for understanding the above four applications. It needs funding for conducting experimental studies. We emphasize the point that, our proposed scientific concept of CNF is practical compared to other theoretical models of cold nuclear fusion.

3. Nuclear Binding Energy and Coulombic Repulsions in Cold Nuclear Fusion

It is currently believed that, nuclear Coulombic repulsion phenomenon plays a vital role in stopping or breaking the cold nuclear fusion of hydro-protons with heavy nuclear atomic nuclides. In this context, we would like to appeal that, independent of Coulombic repulsion, and considering strong and electroweak interactions, nuclear binding energy can be understood with the following four term unified relation (Seshavatharam U.V.S, Lakshminarayana S. H. K. Cherop and K.M. Khanna, 2022). For Z= 3 to 118 where $N \geq Z$,

$$BE \cong \left\{ A - \left[1 + \left(0.0008\left(Z^2 + A^2\right)\right)\right] - A^{1/3} - \frac{(A_s - A)^2}{A_s} \right\} (B_0 \cong 10.1 \text{ MeV}) \tag{1}$$

$$\text{where} \begin{cases} 1)\ A = \text{Mass number and } Z = \text{Proton number.} \\ 2)\ \dfrac{\text{Mean mass of Pions}}{\text{Mean mass of Weak bosons}} \cong \dfrac{\sqrt{\left(m_\pi c^2\right)^0 \left(m_\pi c^2\right)^{\pm}}}{\sqrt{\left(m_z c^2\right)^0 \left(m_w c^2\right)^{\pm}}} \cong 0.0016 \\ 3)\ A_s \cong 2Z + 0.0016(2Z)^2 \cong 2Z + 0.0064Z^2 \\ \qquad \cong \text{Estimtaed Mass number close to stability zone.} \\ 4)\ B_0 \cong \dfrac{1}{2}\left[\left(2m_u c^2 + m_d c^2\right) + \left(m_u c^2 + 2m_d c^2\right)\right] \approx 10.1 \text{ MeV} \\ \qquad \text{where } (m_u, m_d) \text{ reprsent Up and Down quark masses.} \end{cases}$$

In this relation,

1) First term can be considered as a consequence of nuclear volume.
2) Second term can be considered as a consequence of non-participating nucleons associated with electroweak interaction and minimum number of non-participating nucleons is defined as 1.
3) Third term can be considered as a consequence of surface and radial effects.
4) Fourth term can be considered as a consequence of asymmetry about the mean stable mass number.

4. Progress and Mega Project Funding on Cold Nuclear Fusion

As the main objective of cold nuclear fusion is to produce clean thermal energy, from 2015 onwards, 'Google' team put lot of efforts in understanding and generating excess heat via all known experimental cold nuclear techniques with advanced and more sophisticated measuring tools (Berlinguette, C.P., Chiang, YM., Munday, J.N. & et al., 2019; Philip Ball, 2020). Another interesting point to be noted is that, right from the beginning, NASA team has shown lot of interest in new cold fusion techniques (Vladimir Pines et al., 2020; Steinetz Bruce M et al., 2020) paving a way for accomplishment of cold nuclear fusion with 'deuterated' Erbium atoms by a new technique called 'lattice confinement'. Following these points and considering the main objective of generating clean energy, in 2020 last quarter, European Union funded 10 million Euros for two cold nuclear fusion projects for a period of 4 years.

5. Basic Mechanism of Hydrated Cold Nuclear Fusion

At fundamental level, concept of 'cold nuclear fusion' (CNF) is highly attractive and mostly speculative. Considering the complicated issues pertaining to hot nuclear fusion associated with million deg. C and understanding the environmental friendly applications of CNF associated with ambient temperatures, many world class scientists and engineers are being attracted towards CNF experiments and theory.

The basic idea of CNF is to observe the generation of excess heat by fusing metals with Hydrogen atoms at room temperature or temperatures around 1000 to 2000 deg. C. Generally, CNF experiments are taking place in the form of Electrolytic equipments having Palladium electrodes and heavy water (Frodl, P., et al. 1990; McKubre MCH., 2015) and Pressurized steel chambers filled with metallic powders and hydrogen (Parkhomov A et al., 2017; Tadahiko Mizuno and Jed Rothwell., 2019; N. M. Evstigneev et al., 2021). As nuclear reactions of CNF assumed to be taking place at low energies compared to hot fusion energies, in most of the cases, CNF can also be called as 'Low energy nuclear reactions' (LENR). For advanced information readers are encouraged to refer (Jean-Paul Biberian., 2020; Freire, Luciano Ondir, and Delvonei Alves de Andrade., 2021). The most confusing point of CNF is—after fusion, whether base metal is in the form of 'Metallic Hydride' or 'heavy isotope of base metal' or 'changed proton number of base metal'. With reference to the current low energy room temperature nuclear reactions, 'isotopic shift' seems to be a notable aspect of CNF (Vladimir Pines et al., 2020; Steinetz Bruce M et al., 2020; Parkhomov A et al., 2017; Norman D. Cook and Andrea Rossi., 2015). In our recent paper (Seshavatharam U.V.S, Lakshminarayana S., 2021), we have proposed a simple explanation for understanding the energy liberation mechanism of CNF with the difference of nuclear binding energy of final and initial metallic nuclides. Considering 'Hydrated cold nuclear fusion' experiments pertaining to Nickel powder, we proposed the following points.

1) Evacuated and sealed reactor is loaded with small quantity of very fine Nickel like powder and large quantity of hydrogen gas under certain pressure.
2) As the reactor is slowly heated by external electric power, reactor temperature and pressure, both, slowly increase and hydrogen atoms start making to and fro forced oscillations in the reactor.
3) At certain controllable temperature and pressure conditions, hydrogen atoms, start entering the nuclear core of the Nickel atoms triggering nuclear fusion reactions.
4) Within the nuclear core of Nickel atom, due to weak nuclear interaction, hydrogen atom immediately transforms to a neutron and by strong attractive nuclear force, new neutron joins with nuclear core and increases Nickel mass by one unit.
5) Due to increasing heaviness in mass and due to weak nuclear force, newly formed neutron transforms to proton, electron and neutrino.
6) Due to strong nuclear attractive force, new proton joins with Nickel's nuclear core and increases the nuclear proton number by one unit.
7) New electron joins with Nickel's electronic orbits and increases Nickel's electron number by one unit.
8) In this way, within the nuclear reactor, as time is progressing, Nickel mass number increases slowly and some times, Nickel transforms to its next level new atoms. This concept can be compared with the observed cold fusion nuclear transmutations.
9) Based on the currently believed nuclear binding energy scheme, maximum binding energy per nucleon is around 8.8 MeV.
10) Considering the fusion of one hydrogen atom in hydrated cold fusion, energy acquired by the final nucleus during the fusion of hydrogen atom seems to be 8.8 MeV. This can be considered as the origin of 'missing energy' or 'excess energy' in cold nuclear fusion.
11) In the absence of increase in internal kinetic energy, there is a scope for liberation of excess energy in the form of safe thermal energy. This can be considered as the basic information missing in mainstream

nuclear physics.

12) Due to Coulombic repulsion, asymmetry effect, pairing effect and other nuclear effects, final atom is forced to choose a little bit of binding energy less than 8.8 MeV and thus it is able to release left over binding energy in the form of internal kinetic energy or external thermal energy. Thus, in hydrated cold fusion, heat release to occur, binding energy difference of final atomic nuclide and base atomic nuclide seems to be less than 8.8 MeV.
13) Qualitatively, energy released during hydrated cold fusion seems to be approximately equal to 8.8 MeV minus the difference of binding energy of final and base atomic nuclides.
14) Based on this idea, under normal conditions, for the case of $_2He^4$, fusion of four protons can liberate (35.2-28.3)=6.9 MeV and it is 3.5 times less than the current estimates.
15) Point to be understood is that, lesser the binding energy of final atomic nuclide, higher is the liberated thermal energy and vice versa.
16) Reactor input charge can be chosen to constitute, less abundant, stable and heavy mass numbers of light Z in large proportion so that, after fusing with hydrogen, output becomes more abundant, light and stable mass numbers of Z+1.Thus difference in binding energy of (Z+1, A+1) and (Z, A) is on lower side and less than 8.8 MeV.
17) Considering $_{28}Ni^{62}$ and $_{29}Cu^{63}$ isotopes, liberated thermal energy can be around {8.8–(550.0–544.4)}= 3.2 MeV.
18) Considering the case of fusion of two Deuterium atoms, liberated thermal energy can be around, {(4*8.8)–[28.3–(2*2.22)]}=11.3 MeV. Clearly speaking, fusion of two deuterium atoms can be considered as a representation of fusion of 4 nucleons. Binding energy of $_2He^4$ is 28.3 MeV and binding energy of deuterium is 2.22 MeV.
19) With a suitable catalyst and sufficient hydrogen under suitable pressure, if reactor's temperature is maintained at (1000 to 1500) ^{0}C, there seems a lot of scope for a chain reaction of cold fusion in which light isotopes transform to their next stage with increased mass number or proton number and liberate safe and clean heat energy continuously.
20) During the reaction, energy released will be roughly (1 to 3) MeV per one atomic nuclide (Giuseppe Levi et al. 2013; Seshavatharam U.V.S, Lakshminarayana S. 2015; Seshavatharam U.V.S, Lakshminarayana S., 2014; M. Lototskyy et al., 2015). Total released energy is proportional to total number of participating atomic nuclides (PAN).
21) Within the nuclear reactor, by increasing the weight or number of participating atomic nuclides, choosing a suitable catalyst and increasing the quantity of hydrogen, it may be possible to increase the output thermal energy. Considering the case of 10^{12} PANs per second, energy released will be around (0.1 to 0.5) joule per second.
22) By arranging 4 to 6 reactors and charging them periodically in tandem, required thermal energy can be produced continuously.
23) For each PAN, energy released in cold nuclear fusion is roughly 100 to 200 times less than the energy released in nuclear fission of one Uranium atom (200 MeV per one fission). Hence it seems safe to study and conduct cold nuclear fusion experiments.
24) In this new direction, by carefully selecting the base isotope and its corresponding catalyst, experiments can be conducted and ground reality of cold fusion can be understood at various temperature and pressure conditions.

6. CNF—The Next Stage of Metallic Hydrides

It is very clear to say that, modern science and technology is aiming in understanding and developing metallic hydrides to store Hydrogen in large quantities at various pressure and temperature conditions. Other notable applications include heat pumps, heat refrigerators and heat storage (Peebles P. J. E., 1968). In this context, considering the basic concept of CNF, we are moving one step further. Clearly speaking, at reasonable pressure and temperature conditions,

1) Process of adding Hydrogen to metals can be called as CNF Hydration.
2) Hydrogen fuses with metals and help in developing heavy isotopes of respective metals.
3) Hydrogen fuses with metals and help in developing next stage metals having a change in proton number.
4) During the above two nuclear reactions, part of nuclear binding energy difference comes out in the

form of safe thermal energy.

Following the above concepts, advancing the current scientific approach and developing new engineering techniques, it is certainly possible to thoroughly study the implications and validation of CNF.

7. Small Scale Production of Gold with CNF Concept

For any country, its national economy and currency value depends on its Gold reserves. Governments are spending lot of money in searching of gold mines and gold mining. It is very important to say that, processing cost of gold ore is higher than the cost of extracted gold. Gold mining process is associated with deforestation, deep mines and hazardous issues of usage of poisonous Mercury and Cyanide in large quantity. Considering the increasing demand of commercial, scientific and technical applications of gold in view, we made an attempt to understand and produce gold via CNF concept in the following way (Seshavatharam U.V.S, Lakshminarayana S., 2022).

1) Selecting any heavy metal whose atomic and metallic properties are closer to gold. It can be called as Base metal of gold (BMG).
2) Expected heavy and cheap BMGs are: Tungsten-74 having stable mass numbers (180 to 186), Rhenium-75 having mass numbers (185,187) and Osmium-76 having mass numbers (187 to 194). See Table-1 for the density, melting point and cost of BMGs.

Table 1. Physical properties and cost of heavy metals starting from Tungsten to Gold

Heavy Atom	Proton Number	Stable Mass numbers	Density (gram/cc)	Melting point Deg. C	Cost Rs/gram
Tungsten (W)	74	182,183,184,186	19.3	3422	120
Rhenium (Re)	75	185,187	21.02	3186	200
Osmium (Os)	76	187,188,189,190,192	22.59	3033	965
Iridium (Ir)	77	191,193	22.56	2446	14500
Platinum (Pt)	78	194,195,196,198	21.45	1768	2310
Gold (Au)	79	197	19.3	1064	4300

3) Filling the cold nuclear heating chamber (CNHC) with pre-weighed BMG powder.
4) Suitable catalyst can also be added to CNHC for a better reaction.
5) Evacuating the CNHC and filling with Hydrogen gas at moderate pressure.
6) Heating the CNHC at moderate temperature and melting the BMG powder.
7) Further heating may help in 100% fusion of hot Hydrogen gas with liquid BMG.
8) Cooling the CNHC to room temperature.
9) Measuring the quantity of exhausted gases while opening the CNHC.
10) Analyzing the nature of exhausted gasses while opening the CNHC.
11) Analyzing and identifying the CNHC metal sample in all possible ways with all available methods.
12) Tabulating the % of BMG hydrides, % of BMG isotopes and % of gold.
13) Repeating the experiment and optimizing and sustaining the production of % of gold.
14) Understanding the pros and cons of the experimental set up and improving it.
15) Selecting and finalizing the best BMG and standardizing the experimental set up and procedure with reference to cost and isotopic abundance of Tungsten, Rhenium and Osmium.
16) If successful, Iridium, Platinum and Gold can be produced in a systematic approach.

8. Operating Mechanism of Cold Nuclear Heating Chamber in Gold Preparation

We present our views in the following way.

1) As the CNHC is completely free from Oxygen and other gases, during heating of CNHC, hot hydrogen gas tries to attack the semi solid BMG to form the respective hydrides.

2) At the time of melting of BMG, super heated hydrogen gas tries to fuse with liquid BMG with ease.
3) It may be noted that, during cosmic evolution, in a cosmological approach, first hydrogen was formed at a temperature of around 3500 K (Ashutosh Goel et al., 2019). It means, hydrogen atom starts dissociating into free proton and free electron above 3500 K.
4) Following the concept of cosmological generation of first Hydrogen atoms, as melting point of BMG approaches 3000 deg C, there is a possibility of hydrogen gas (H_2) to split into hydrogen atoms (H), hydro-protons and hydro-electrons.
5) As the CNHC is completely closed, further heating of liquid and semi gaseous form of BMG and hydrogen atoms (H) and hydro-protons and hydro-electrons, there is 100% scope for fusion of BMG atoms and hydrogen atoms via nuclear fusion.
6) As BMG mass is roughly 180 to 190 times higher than hydrogen, due to strong attractive nature, energetic hydrogen atoms are forced to fuse with BMG atomic nuclides.
7) By means of currently believed nuclear strong interaction, there exit two possibilities. First possibility is BMG nuclide absorbs Hydrogen atom in the form of Neutron. Second possibility is BMG nuclide absorbs Hydro-proton and retains the hydro-electron in its atomic orbit.
8) First possibility can be considered as an increase in mass number of BMG.
9) Second possibility can be considered as an increase in BMG proton number.
10) Repeated cycles of increase in BMG proton number helps in generating Iridium, Platinum and Gold atoms with unstable mass numbers.
11) Further repeated cycles of increase in mass number of unstable Iridium, Platinum and Gold helps in generating stable atomic nuclides.
12) After certain time, heating can be stopped and CNHC can be allowed to cool.
13) CNHC output material can be examined for stable and unstable Iridium, Platinum and Gold atoms in different proportions.

Finally, to the possible extent, stable Iridium, Platinum and Gold atoms can be produced in significant quantities.

9. Processing of High Level Radioactive Waste with Cold Nuclear Fusion

Following the above paragraphs, it seems possible to fuse high level nuclear radioactive nuclides (M. Lototskyy et al., 2015) with hydrogen at moderate pressures and temperatures. In our recently presented and published paper, we have made an attempt to produce Iridium, Platinum and Gold like metals by considering Tungsten-like heavy metals (Seshavatharam U.V.S, Lakshminarayana S., 2022). Key point of study is that, at around 3500 deg. C, Hydrogen transforms to hydro-proton and hydro-electron. Coming to our subject title, we express our views in the following way.

1) See Table 2 for long lived and medium lived high level radioactive nuclides.

Table 2. Long lived and Medium lived HLW nuclides

Long lived HLW nuclides		**Medium lived HLW nuclides**	
HLW nuclide	**Half life in 10^6 Years**	**HLW nuclide**	**Half life in Years**
43-Technetium-99	0.211	63-Europium-155	4.76
50-Tin-126	0.23	36-Kripton-85	10.76
34-Selenium-79	0.33	48-Cadmium-113	14.1
40-Zirconium-93	1.53	38-Strontium-90	28.9
55-Caesium-135	2.3	55-Caesium-137	30.23
46-Palladium-107	6.5	50-Tin-121	43.9
53-Iodine-129	15.7	62-Samerium-151	88.8

2) Fill the evacuated nuclear reactor (NR) with 100 grams of HLW and load the whole volume of nuclear reactor with hydrogen gas to the possible extent.
3) Gradually heat the nuclear reactor and observe for emission of beta and gamma radiations. If there is no

radiation, continue the heating process.

4) As temperature of the nuclear reactor is increasing, hot hydrogen gas starts fusing with liquid radioactive nuclides with increasing kinetic energy.
5) As a result, mass number of the respective radioactive nuclide increases and moves away from the stability line. It may be noted that, as per the proposed binding energy formula, estimated mean stable mass number can be expressed as, $A_s \cong 2Z + 0.0016(2Z)^2 \cong 2Z + 0.0064Z^2$. Based on this relation, mass numbers presented in Table-2 are above the mean stable line.
6) Increased mass number results in addition of extra neutron. As mass number is moving away from stability line, at one stage, by emitting a beta particle, extra neutron transforms to extra proton and the radioactive nuclide transforms to stable non-radioactive atomic nuclide. Emitted beta particle joins with existing electronic orbits.
7) For example, Cs-137 gains one neutron and transforms to stable Ba-138. To confirm this, in an alternative approach, radioactive nuclear waste can be bombarded with free neutrons coming from other nuclear sources.
8) Run the experiment for two to three hours and allow the reactor to cool.
9) Observe and analyze the reactor contents for a possible transformation of radioactive nuclides to non-radioactive stable nuclides.
10) Repeat the process and re-analyze.

10. Preparing Radioactive Isotopes for Medical Applications

Following the above mentioned procedures and selecting the required base nuclide of the medical isotope and continuing the heating procedure, there is a possibility of producing the required medical isotopes. It needs further study and research.

11. Conclusion

Based on the current technological scenario pertaining to fuel oil, gold like costly elements and high level nuclear waste and considering the proposed applications compared to million degree hot nuclear fusion-institutions, organizations and industries can take initiative in conducting experiments in the proposed new direction associated with cold nuclear fusion. In all the cases, the basic requirements are-designing a suitable reactor that can maintain (1000 to 3500) deg. C hydrogen gas without leak and explosion, arranging radiation detecting equipments and other nuclear equipments for identifying the selected and produced atomic nuclides and various energy measuring equipments. It may be noted that, proposed applications are having a lot of impact in current and future economical, industrial, environmental, medical and energy sectors.

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