A Process for Making Nuclear Fusion Energy

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Abstract: A process is described for producing regular nuclear fusion at room temperature by compressing a deuteride mixed with catalytic material. The reaction is explosive beyond any possible chemical reaction for these materials. An attempt at explaining the nuclear processes in terms of soft X-ray emission has been made by deriving models of a deuteron and α-particle. Future development for commercial energy production is discussed.

Keywords: condensed matter nuclear fusion

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1. Introduction

At the highest level of government in many countries, it is understood that efforts must continue to develop nuclear fusion as an energy source. Consequently, Research Councils UK has established an energy programme for urgent research into fusion, see www.rcuk.ac.uk/research/xrcprogrammes/energy/EnergyResearch/Fusion/ .

Nuclear fusion is the process whereby two light nuclei bind together to form a heavier nucleus, with energy release due to some conversion of mass to energy. Harnessing fusion on earth, via deuterium to helium reactions would be environmentally friendly, safe, clean, and effectively limitless. One such process involves confining hot plasma inside a tokomak reactor: see www.ccfe.ac.uk and www.iter.org . Alternatively, inertial confinement fusion is being tried wherein a pellet of deuterium and tritium fuel is compressed strongly by lasers, or particle beams, or z-pinch wires: see http://dorland.pp.ph.ic.ac.uk/magpie/ and http://www.hiper-laser.org and https://lasers.llnl.gov . World-wide, other experimenters persistently try to produce cold fusion in electrolytic cells: see http://lenr-canr.org/ and www.iscmns.org. All these techniques are now being pursued vigorously in many different laboratories, in an effort to prevent a global warming catastrophe and the riotous consumption of remaining oil and gas supplies. Unfortunately, progress has been depressingly slow and expensive.

The subject of cold fusion has been ridiculed in several unscientific commentaries since it was publicised in 1989 by Martin Fleischmann FRS and Stanley Pons. In contrast, a significant number of trustworthy scientists world-wide have pursued the subject in their own time, discreetly and without proper financial support, [1]. They have published a large number of papers in the proceedings of 18 International Conferences on Condensed Matter Nuclear Science, in order to circumvent impervious referees, [2a,b,c]. However, a problem of comprehension and reproducibility does remain, and the absence of expected fusion products like neutrons and γ-rays has been puzzling. Many interesting experiments indicate that some new phenomenon is operating under specific conditions involving unidentified trace catalysts.

In this paper it will be shown that given an appropriate deuteride and catalyst under compression, one type of nuclear fusion does occur in the solid state, [E.B., private communication]. Repeatability is not a problem, and there should be a way of making this process commercially viable using an inertial confinement technique.

Section 2 will outline our current methods to produce this condensed matter nuclear fusion. Sections 3 and 4 will explain the apparent chemical and nuclear processes involved. Section 5 will propose ways to develop a commercial energy generator.

2. Experimental methods

The techniques involved for demonstrating the reality of nuclear fusion are basic but generate explosions stronger than chemical reactions. Very many experiments have been performed to confirm that the proposed fusion is real.

First of all, a quantity of calcium deuteride was produced by heating small turnings of calcium in a flushed-out closed silica tube containing deuterium supplied by a manometer assembly, see Fig.1. An external blow-torch on the tube was adequate. The used volume of deuterium was measured, in order to estimate the final purity of the calcium deuteride at around $CaD_{1.75}$ as if some CaD was also produced. The lumps of $CaD_{1.75}$ were then ground to a fine powder with mortar and pestle and thoroughly mixed with similar weights of red phosphorus and manganese powders, to yield the ‘’primary fusion fuel”. Typical particle sizes of the powders have been in the range 20 to 75 μm, while the weight proportions of the ingredients have been varied around 1:1:1.

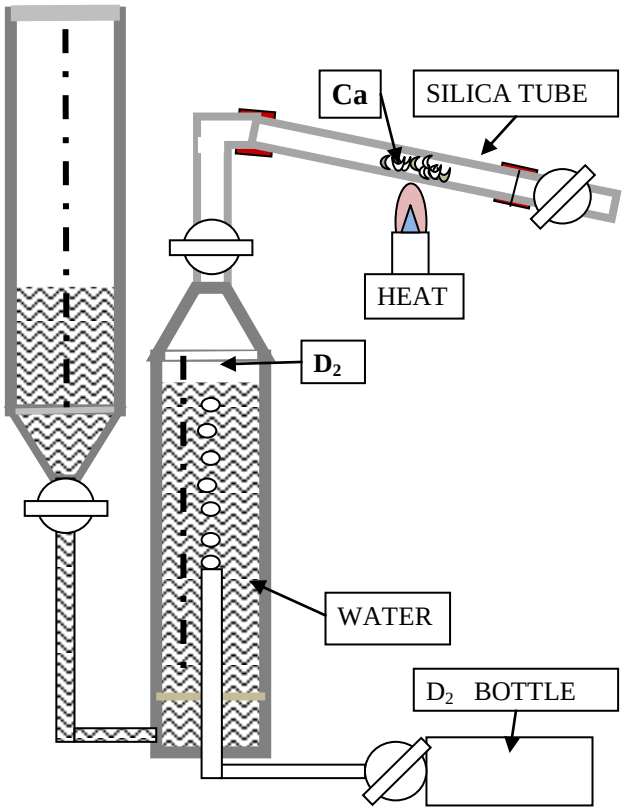

Fig.1. Apparatus for preparation of calcium deuteride from calcium and deuterium.

Subsequent experiments using the deuteride of magnesium, strontium, barium, lithium and sodium in place of calcium deuteride have also provided satisfactory results; so deuterium fixation is a fundamental requirement and the cation must actively participate by combining with the phosphorus exothermically. Likewise, other transition metals have been found to work in place of manganese to some degree. Experiments have confirmed this by mixing the deuteride and phosphorus powders with each one of the following powders: scandium, titanium, vanadium, chromium, manganese, iron, cobalt, nickel, copper, zinc, yttrium, zirconium, niobium, molybdenum and cadmium. It follows that a metallic particle surface with its high electron density and ionic lattice is required.

About 200mg of the primary fuel powder was put in a compression cell which consisted of two EN31 chrome steel roller bearings (12mm x 12mm) in a mild steel sleeve, sealed with a lead/tin solder ring to contain generated gases, see Fig.2a. When this cell was subjected to a vertical force of 30 tons in a press, the compound was formed into a hard solid pellet, but no fusion occurred. The force was then removed so that a thin steel wedge could be placed underneath, before re-applying the force gradually. As a high force level was approached this time, some shear occurred within the fuel pellet such that localised hot-spots [3a] in the shear-plane ignited a chemical exothermic reaction which enabled the fusion process within the enclosed pressurised environment; see Section 3 for a proposed mechanism.

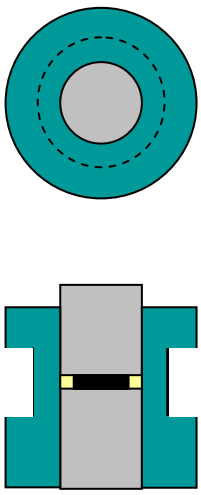

Fig2a. Compression cell consisting of two chrome steel roller bearings in a steel sleeve with solder seal to contain the fuel compound and gases.

Figure 2b illustrates two typical examples, wherein the fusion gas pressure was great enough over a 1mm x 4mm surface area to create a cutting wedge of steel which immediately cleaved the roller bearing into pieces. Often, the bearings were shattered into many pieces within the cell, and the fusion process ceased because the gases were able to escape through the cracks. This means that the fusion process is fail-safe in this configuration and not susceptible to run-away. The explosion sometimes blasted scorched fuel into the debris where it crackled readily if the applied force was continued.

Fig 2b Two typical results of fusion ignition, wherein the local gas pressure has forced a wedge of steel downwards through the lower bearing, splitting it apart.

Many subsequent experiments have employed smaller roller bearings (10mm x 14mm, and 8mm x 8mm) in a dry sintered bronze bush sleeve (10mm x 15mm x 16mm, and 8mm x 11mm x 12mm) because less compression force is necessary. The actual compression and explosion reaction force have been monitored by means of a load-cell placed beneath the fusion cell. Sometimes the reaction impulse is many tons greater than the applied force, see Fig.3a.

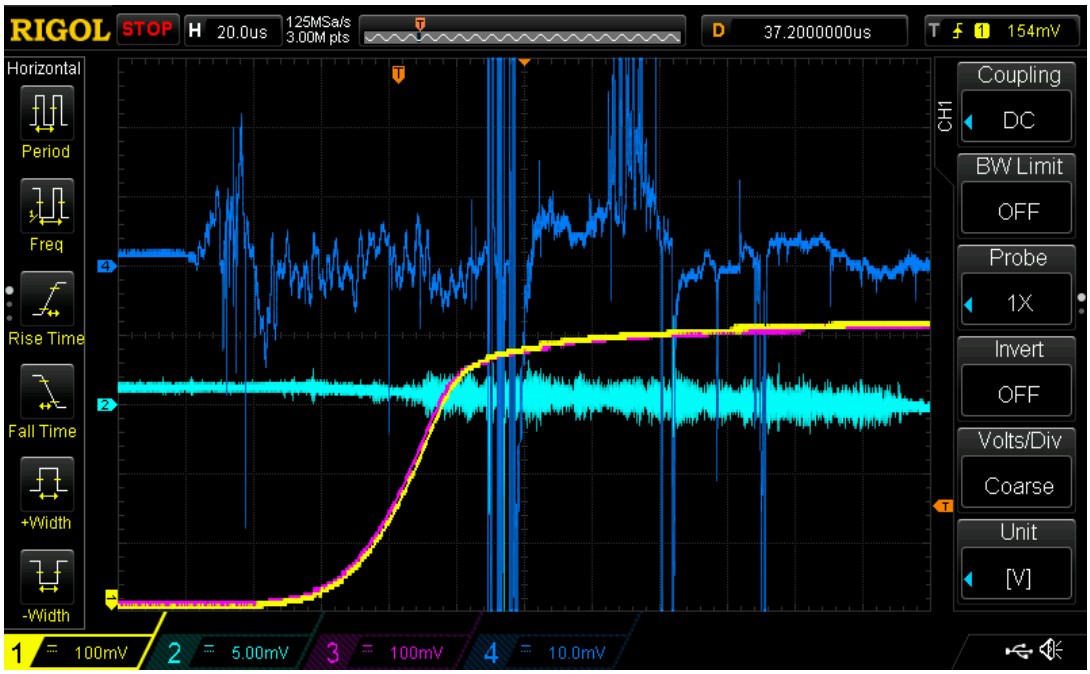

Fig.3a. Typical digital oscilloscope traces for explosion processes. Yellow trace illustrates the direct view photodiode response to the flash. Red is the output from the photodiode with scintillator, a few microseconds ahead of the direct view. Blue trace is the load-cell output showing how the initial load at 20 tons increases rapidly to 100 tons during the explosion, with huge ringing as the lower steel bearing fractures and skids across the load-cell top surface in an effort to escape. The fusion pressure develops for 20μsec within the compressed fuel before it becomes visible to the photodiodes. Turquoise trace is the output from strain-gauges attached to the top of the press to monitor loading; the actual explosion impulse is smoothed out but some high frequency vibration is observed.

The explosion gas pressure usually creates a steel wedge in the bearing surface nearest to the fusion source, which separates and cleaves the bearing. Figure 3a also shows the explosion flash as monitored by unbiased UV-enhanced silicon photodiodes (Centronic OSD35-7XCQ) attached directly to the oscilloscope. The photodiode with the scintillator (BC-408 or Polycarbonate) always detects the flash in advance of the direct view photodiode, so some Extreme-UV or Soft X-rays must be emitted by the fusion process. Figure 3b is a typical video camera snapshot of the flash, which is very bright.

Fig.3b. Video camera snapshot of a typical fusion explosion, as viewed through a 12mm thick shatterproof polycarbonate window. The silicon photodiodes are mounted in the central region to view through a hole in the window, but are protected from flying debris by a stainless steel mesh. Some shaking of the whole enclosure and camera is always evident.

A great effort has been put into the search for any nuclear particles emitted by the fusion explosion, but none have been found for sure. Detectors with stainless steel mesh screening were located at 10cm from the fusion cell and repeatedly subjected to the blast which ultimately ruined a BP4 beta-probe, a ZP1401 GM tube and a ZP1610 proportional counter. In addition, neutron activation was sought many times using indium, lithium, copper, niobium, titanium, aluminium, and vanadium. These materials were placed inside the cell then collected with the debris and tested for radioactivity, but none was detected.

Figure 4a illustrates another type of cell which easily produced the required shearing action. The fuel powder was put around a case-hardened steel piston rod with a shoulder that compressed the powder as it was pushed through a shaped sleeve. Upon applying several tons of force, shear in the powder produced hot-spots wherein ignition of fusion then broke many pieces off the rod shoulder, see Fig.4b. This allowed the local gas pressure to subside and prevented the fusion from progressing.

Clearly, extreme pressure pulses must have been generated to do this amount of damage on hardened steel. Inspection of the mild steel sleeve adjacent to the hot-spots revealed a melted appearance. An accelerometer was incorporated to monitor the series of ignitions on an oscilloscope.

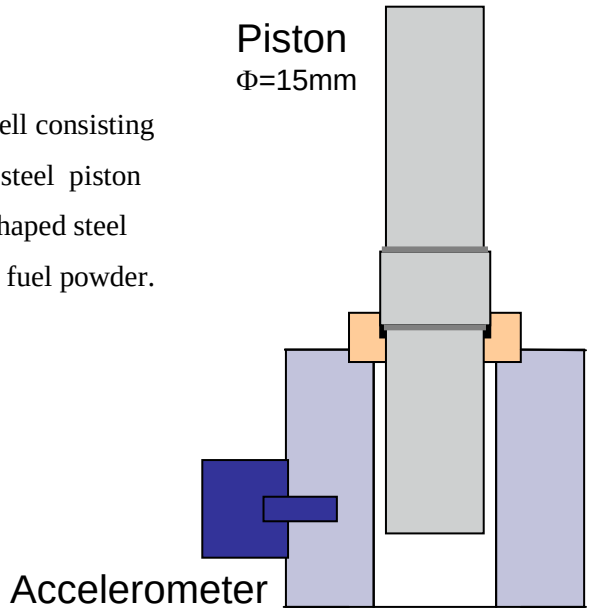

Fig 4a Long shear cell consisting of a case-hardened steel piston with shoulder in a shaped steel sleeve to contain the fuel powder.

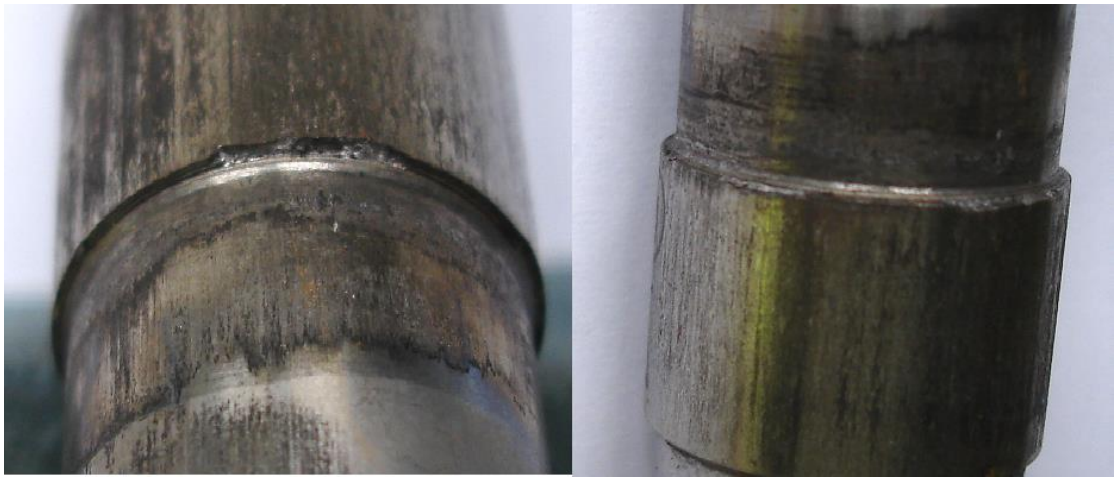

Fig. 4b. Enlarged view of two typical results of fusion ignition wherein the explosion gas pressure has broken pieces off the piston shoulders, in order to escape upwards.

Other methods of inducing fusion with this fuel have been tried, and need further experimentation. For example, externally heating the pressurised cell sleeve caused it to split open and show the burnt interior as a sign of fusion. Therefore, heating the fuel in a container pressurised with deuterium may be one way of producing controlled fusion for small-scale energy generation.

A diesel-engine glow-plug has also been used to heat a cell internally by touching the compressed fuel directly, see Fig.5a.

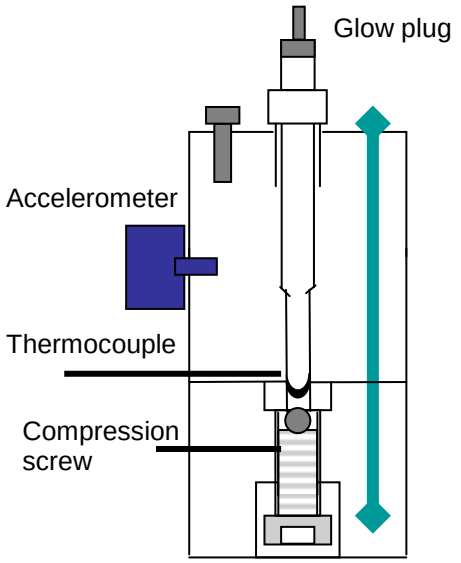

Fig 5a Glow-plug cell, to heat the compressed fuel compound and induce steady fusion.

Alternatively, Fig.5b shows an embodiment wherein the fusion-fuel was compressed by screw and heated directly by a wire carried by ceramic-metal seals.

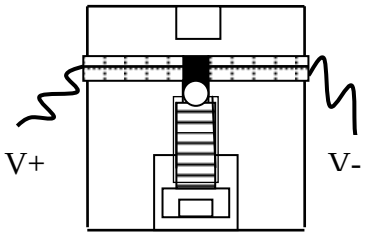

Fig 5b Hot-wire cell, to heat the compressed fuel.

3. Chemical processes

First of all, phosphorus, calcium and manganese compounds are known to have catalytic properties, [3b, c, d, e]. For example, some primary fusion fuel ($CaD_{1.75}$ + P + Mn) was heated in a test tube and found to decompose readily yielding deuterium gas.

Chemical processes occur within the fuel shear-plane hot-spots [3a], which develop into the high pressure plasma regions suitable for fusion ignition. A local hot-spot in bulk material could increase in temperature by 1000^{o}K, for a specific heat of 0.2cal/g^{o}K Thus in the hot-spots, ionised manganese and phosphorus may combine exothermically, yielding 104kJ per mol of MnP [4a]. Nearby calcium deuteride, bound by 180kJ/mol during its production [4b], may now be dissociated by energetic phosphorus ions plus mechanical shearing energy. Deuterium is thereby freed and calcium phosphide formed exothermically at 543kJ/mol [4b], adding further kinetic energy within the hot pressurised plasma now containing deuterium ions and deuterons. This 543kJ/mol from calcium phosphide is equivalent to 5.3eV per molecule or an electron temperature of 60,000^{o}K. For manganese in particular, the low thermal conductivity (7 $Wm^{-1}K^{-1}$) helps to retain the heat.

Now under pressure, freed deuterium atoms will occupy interstitial positions between surface lattice atoms of manganese grains [5] where they are dynamically constrained while being bombarded by energetic deuterons in the plasma. At the same time, bombardment by energetic free electrons adds to the environment of manganese valence and conduction electrons and results in screening of the Coulomb force, thereby enabling fusion of the free and constrained deuterons.

To support this explanation, other metal powders listed earlier also behaved like manganese in producing fusion. Likewise, deuterides other than calcium were successful. However, no fusion could be induced when pre-formed manganese phosphide was substituted for the elemental manganese and red phosphorus powders.

Overall, this is a self-restricting process and there is usually a residue of unconsumed fuel around the hot-spots after the explosion. A smell of impure phosphine is always apparent.

4. Physical processes

A most puzzling feature of cold fusion is the apparent lack of free neutrons and γ-ray emission, as if a new process is operating different from the well understood hot fusion. Given the numerous experiments described above, it is suggested here that the energy released by fusing two deuterons into an alpha particle is emitted as a cascade of low energy X-rays which are absorbed locally to generate heat within the source compound. Some investigators have actually reported measurement of anomalous X-ray emission from various deuteride/hydride-containing systems, [6].

In order to understand how the low energy X-rays could be generated by combining two deuterons, it is helpful to define a model of a deuteron. The measured deuteron spin angular momentum is unity, such that the proton and neutron spins have parallel alignment with zero orbital angular momentum. We shall propose that the proton and neutron are side by side, and vibrate apart, out and back. The low binding energy (2.224566MeV) indicates a large amplitude vibration maintained by elastic hard core repulsion.

A Yukawa-type nuclear field model with hard core repulsion has been derived for the proton potential energy $V_E(r)$, based on pionic-type interactions; see Fig.6, taken from Section 4 of ref [12], that is:

$$V_E(R) = m_p c^2 \left(\left\{ 1 - \left[1 - \left(\frac{1}{R} \right) \exp - \left(\frac{R - R_p}{R_p} \right) \right] \left(\frac{R_p}{R} \right) \exp - \left(R - R_p \right) \right\}^{1/2} - 1 \right), \quad (1a)$$

where radius R has been normalised by the pion radius ($r_\pi = \hbar/m_\pi c = 1.461935$fm), and R_p is the proton radius. The non-relativistic approximation of this potential is given by:

$$V_{NR}(R) = m_p c^2 \left(-\frac{1}{2} \left[1 - \left(\frac{1}{R} \right) \exp - \left(\frac{R - R_p}{R_p} \right) \right] \left(\frac{R_p}{R} \right) \exp - \left(R - R_p \right) \right), \quad (1b)$$

and will be used in the Schrödinger equation to derive a wavefunction comparable with others [7a,b].

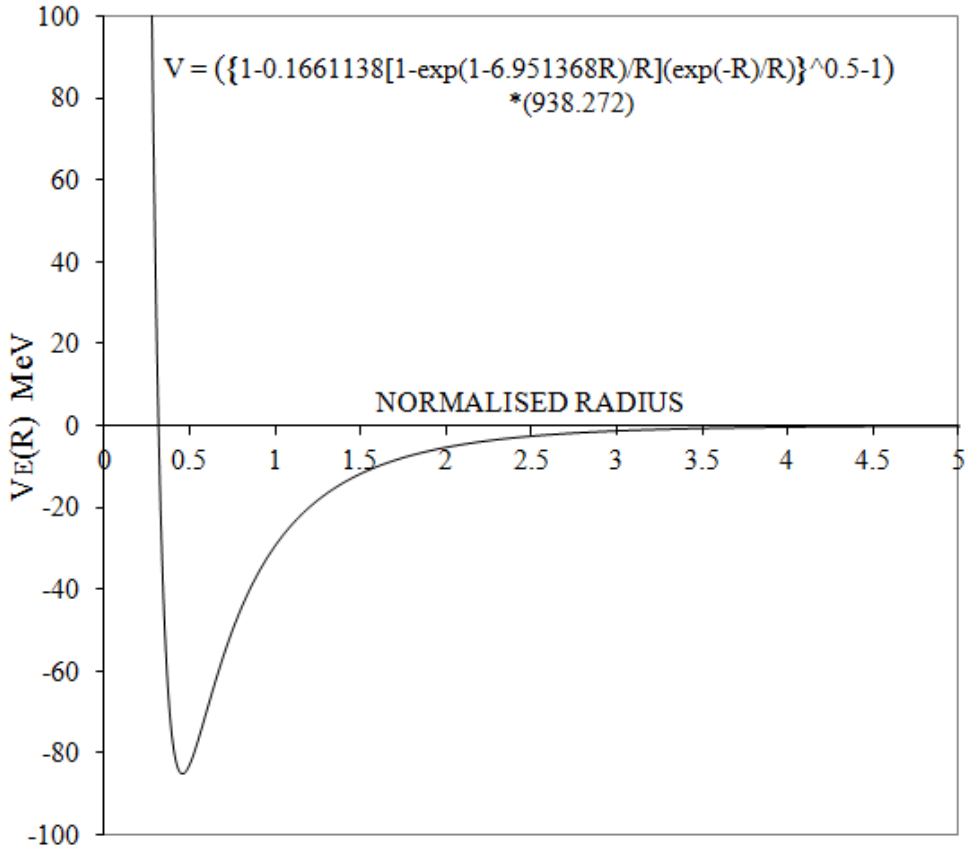

Fig 6. A Yukawa-type potential model of the nucleon field. Radius is expressed in units of the classical pion radius (r_π = 1.461935fm).

The non-relativistic Schrödinger equation will be solved numerically by separating it into known and unknown parts:

$$\frac{1}{u}\frac{d^2u}{dr^2} = \frac{2m}{\hbar^2}\left[E_B + V_{NR}(r)\right], \quad \text{or} \quad \frac{1}{u}\frac{d^2u}{dR^2} = \frac{2m}{(m_\pi c)^2}\left[E_B + V_{NR}(R)\right]. \qquad (2)$$

Here, u is the one-dimensional wavefunction, and m is the reduced mass for a proton-neutron pair [$m = m_p m_n/(m_p + m_n)$ = 469.459134MeV/c^2], and the binding energy is (E_B = 2.224566MeV).

Figure 7 illustrates the known right side f(E) of Eq.(2), overlaid by the derived left side. The approximated wavefunction is then:

$$u = [1/\sqrt{(2a)}]*[1 - (4a)\exp(-4aR) + (9a/b)\exp(-bR)]*\exp(-aR), \qquad (3)$$

where ($a = 0.338593064 = \sqrt{[2mE_B/(m_\pi c)^2]}$) is the asymptotic exponential constant, and factor ($b = 6.9513682 + 0.5$) is based on the potential expression in Fig.6. The weak asymptotic exponential shows that the proton and neutron separate widely due to hard core repulsion. Classical *centre to centre* separation for the binding energy E_B is marked at $R = 2.60r_\pi = 3.80$fm, which is inside the measured *rms charge diameter* of 2 x 2.14fm in [8]. Peak probability lies at a separation $1.41r_\pi = 2.06$fm, which is well inside the E_B position and indicates that a large amount of nuclear field stress energy is involved in the coupling.

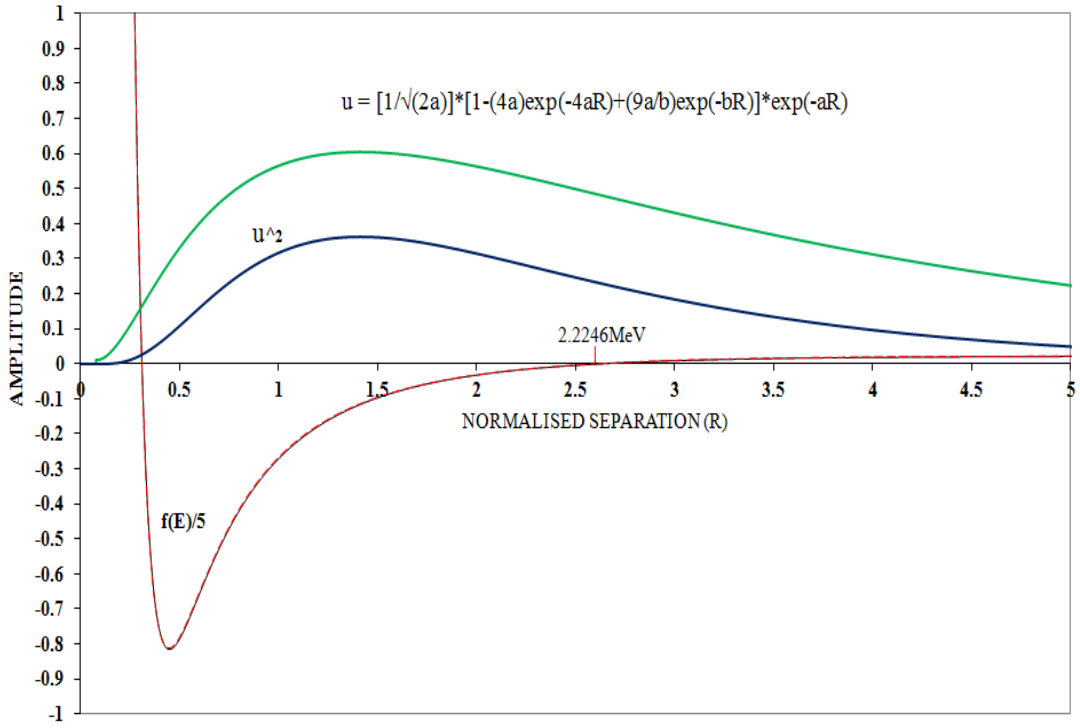

Fig 7 Numerical solution of Equation (2) for the deuteron wavefunction (green, blue), where f(E) is the right-side (black) overlaid by the calculated left side (red-dashes). The centre to centre normalised separation of the neutron and proton is in units of the pion radius.

Given this model of the deuteron, the process for graded formation of an α-particle from two deuterons may be proposed as follows, with reference to Fig.8. After penetrating the repulsive Coulombic field, let the deuterons retain their structure and be situated in the x-z plane, either side of the origin such that both are vibrating internally parallel to the y-axis. Mutual attraction through their nuclear

fields will bring them together towards the origin, where they feel hard core repulsion as they pass across each other in a glancing collision. It is proposed that the deuterons then continue to oscillate back and forth and radiate away 23.846478MeV as low energy X-rays in steps until they reach equilibrium in an α-particle. Thereafter they continue to oscillate across the origin without radiating.

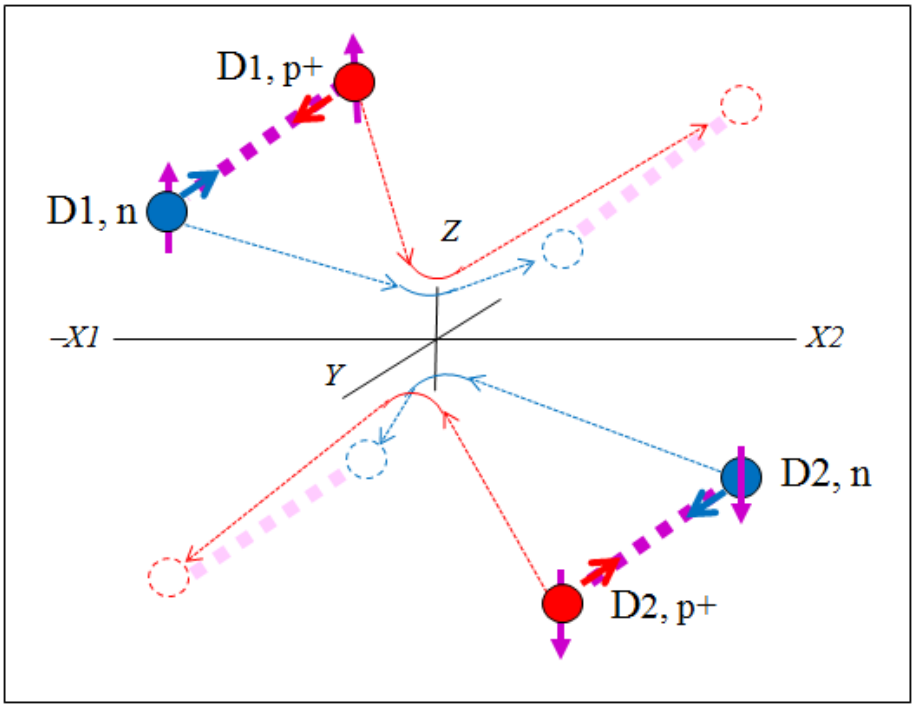

Fig 8 Model of the α-particle consisting of vibrating deuterons D1, D2, colliding diagonally.

To agree with the measured α-particle size, the vibration amplitude in each deuteron must be less than that in the free deuteron; and the oscillation amplitude component along the x and z directions could be similar in size. Spins must be aligned anti-parallel to produce the α-particle's zero spin and magnetic moment. When subjected to electron scattering experiments, this proposed design of α-particle would exhibit a depressed occupancy at the centre [9].

For comparison purposes only, Fig. 9 shows the calculated potential energy for two nucleons separated from two other nucleons on the x-axis, in accordance with Eq.(1a). But for this α-particle model, the proton and neutron of each deuteron vibrate parallel to the y-axis, which reduces the x-component of attraction; and hard core repulsion is limited to a glancing interaction as the deuterons pass across each

other. Let the nucleons have equal amplitude of motion but still act like 2 deuterons, then their total binding energy of 28.29561MeV can be held as 18.86374MeV for deuteron motion towards the origin plus 4.715935MeV for each deuteron internal vibration parallel to the y-axis.

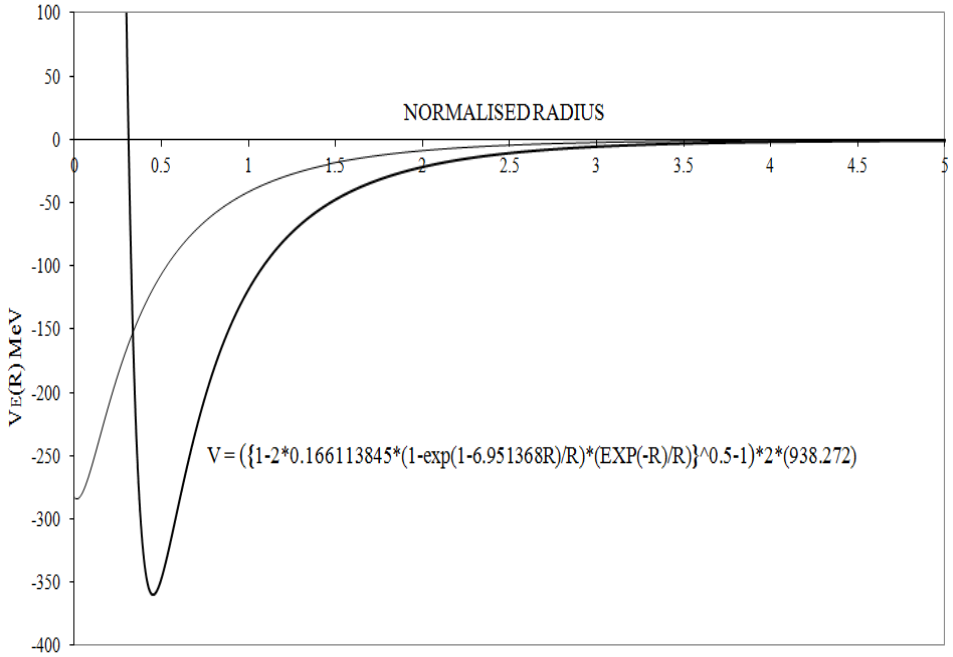

Fig 9 Thick line is the theoretical potential energy (V) for two static nucleons separated from two other nucleons on the axis. Thin line is the estimated potential energy for two separated vibrating deuterons colliding diagonally.

By using Schrödinger's equation again, this reduced energy profile allows calculation of the α-particle wavefunction for deuteron motion, as shown in Fig.10. Here, E_B = 18.86374MeV, 2m equals the deuteron mass 1875.612859MeV/c^2, and asymptotic value (a_α = 1.393564317) has been used. The wavefunction implies that the potential energy converts mainly to stress energy in the nuclear pionic field, rather than the kinetic energy one would get in an atomic electromagnetic field. The shape of the wavefunction is that of harmonic motion at the third (n = 2) energy level; so two lower levels may not be viable, wherein the deuterons cross by straddling each other without experiencing close contact.

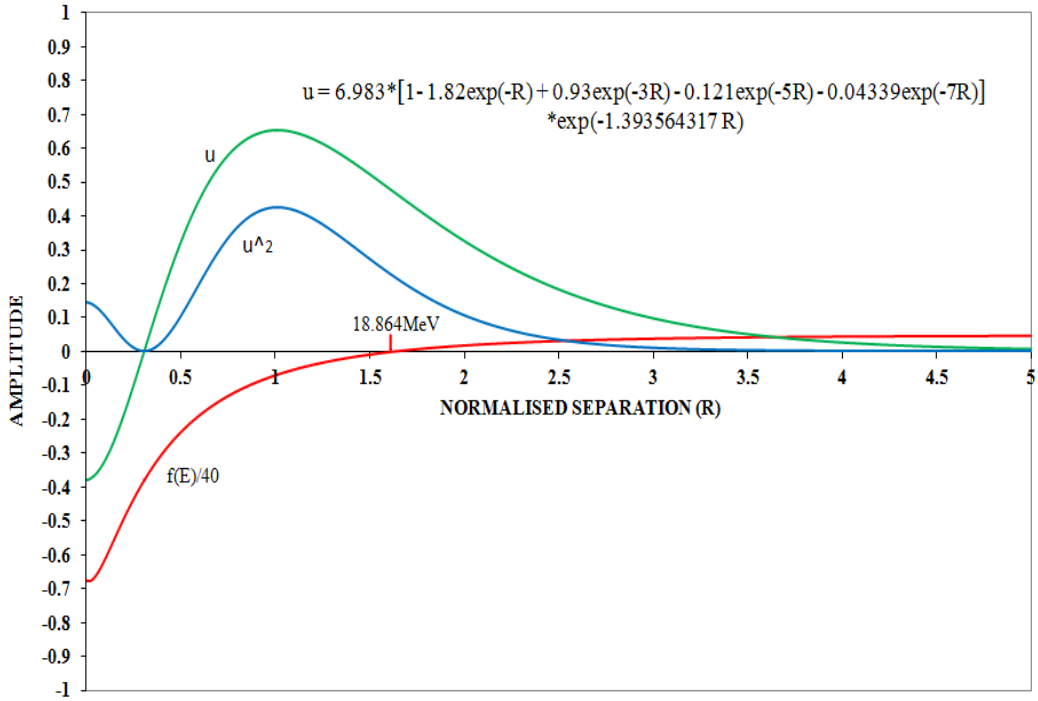

Fig.10 Numerical derivation of the wavefunction for an α-particle comprising deuterons oscillating across the origin; where f(E) is the right-side of Eq.(2). The deuterons contact each other obliquely and cross over the origin.

An estimate of the emitted X-ray energies can be obtained by considering the α-particle creation in a classical sense as follows. Let two free deuterons approach each other and acquire 23.846MeV worth of kinetic energy when they get to a separation of 2.3fm (ie. R ~ 1.6). This represents a velocity of approach equal to 2x $3.4\text{x}10^7$m/s at a position where the accelerating field strength is 16MeV per fermi. The deuterons do not continue to accelerate greatly inside this equilibrium position because the field stress energy grows rather than kinetic energy. From classical electrodynamics theory [10], the power radiated by each deuteron with its electronic charge *e* under acceleration *a* is:

$$P = \frac{2}{3}\frac{e^2a^2}{4\pi\varepsilon_o c^3} = \frac{2}{3}\frac{e^2}{4\pi\varepsilon_o c^3}\left(\frac{\Delta E}{m\Delta R}\right)^2 = 3.4\times10^6\,\text{J/s}, \qquad (4a)$$

where *m* is the deuteron mass 1875.612MeV/c^2, and $\Delta E/\Delta R$ = 16MeV/fm. Therefore, if this acceleration persists over a separation distance of 1fm for deuteron travel time $1.5\text{x}10^{-23}$ sec, then the photon energy radiated per deuteron evaluates to:

$$\delta E = 320\text{eV}. \qquad (4b)$$

This initial photon energy will decrease with vibration amplitude over thousands of oscillations. Such soft X-rays in solids are absorbed within a few millimetres and converted into heat [11]. Hard X-rays, free neutrons and tritium are not generated. A steady X-ray cascade like this does not occur in standard hot fusion processes because conditions there are too violent.

5. Further developments

The experiments performed as described in Section 2 are clearly limited to fusion demonstration only, to prove it is possible in the solid state. For commercial energy generation we need a continuous high energy process like inertial confinement fusion, as already tried by various groups [13]. Our fusion fuel pellet would be compressed and heated by powerful laser beams, or heavy-ion beams, or electron beams, or a Z-pinch cell.

An alternative process for continuous energy generation may be to heat a pressurised fuel pellet of source compound in a carefully controlled manner with pressure limitation valves. An inlaid element of tungsten wire might be hot enough, equivalent to the hot-spots in a shear-cell.

When trying these different techniques, the fuel compound could be varied by substituting other chemical elements in part, to get a controllable reaction. In fact, calcium hydride has already been substituted for the deuteride and produced strong explosions.

6. Conclusion

A large number of fusion experiments have been conducted with powdered material comprising a deuteride and catalyst. The technique for ignition is inherently safe and is understood in terms of the localised hot-spots produced by shearing the compressed fusion material. Then within the high pressure hot-spots, exothermic chemical reactions produce enough Coulombic screening to allow nuclear fusion of deuterons.

Theoretical models of a deuteron and α-particle have been derived in order to explain the anomalous lack of free neutrons and γ-rays from the fusion process. The α-particle creation mechanism generates soft X-ray production which converts to heat in the material. From an engineering point of view, there is nothing to prevent this

invention from being developed immediately for commercial energy production using inertial confinement techniques available.

Caution and safety shielding have been necessary in all fusion experiments with confinement and solid state fuel compounds.

Acknowledgements

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References

1. www.LENR-CANR.org

2a. The international society for condensed matter nuclear science www.iscmns.org

2b. Beaudette, C.G. 2000, Excess Heat 2nd Ed., Oak Grove Press.

2c. Krivit, S.B. & Winocur, N. 2004, The rebirth of cold fusion, Pacific Oaks Press.

3a. Tullis, T.E., Goldsby, D.L., American Geophys Union, Fall 2003.
http://adsabs.harvard.edu/abs/2003AGUFM.S51B..05T

Fialko, Y. and Khazan, Y., J. Geophys. Res., 110, 2005
http://sioviz.ucsd.edu/~fialko/Assets/PDF/fialkoJGR05a.pdf

3b. Sheldon, R.A., & Kochi, J.K., 1981. Metal-Catalysed Oxidations of Organic Compounds. Academic Press, N York

3c. Alyea, E.C. & Meek, D.W., 1982. Catalytic Aspects of Metal Phosphine Complexes. American Chemical Society

3d. Kornfilt, D.J.P. Calcium Compounds In Catalysis.
http://www.scs.illinois.edu/denmark/presentations/2011/gm-2011-3-15.pdf

3e. Brinksma, J. Manganese Catalysts in Homogeneous Oxidation Reactions.
irs.ub.rug.nl/dbi/43789b96d64f9

4a. Myers, C.E., Jung, E.D., Patterson, E.L., 1980. Inorganic Chemistry 19, 532.

4b. CRC Handbook of Chemistry and Physics, 2006 Edition, CRC Press.

5. Ertl, Gerhard. Chemical Processes on Solid Surfaces.
http://www.nobelprize.org/nobel_prizes/chemistry/laureates/2007/advanced-chemistryprize2007.pdf

6. Miley, G.H., et al., 2005. The 12th International Conference on Condensed Matter Nuclear Science. Yokohama, Japan.

7a. Azzam, A.K.A. et al., 2005. Chinese J. Phys. 43, 813.

7b. Righi, S. and Rosa-Clot, M., 1987. Z. Phys. A-Atomic Nuclei 326, 163.

8. Deuteron charge radius. http://physics.nist.gov/constants

9. Willets, L., et al. New approach to ^{4}He charge distribution. http://arxiv.org/pdf/nucl-th/9612060v2.pdf

10. Jackson, J.D., 1975. Classical Electrodynamics 2nd Ed. J.Wiley & Sons, N York.

11. X-ray data. http://www.nist.gov/pml/data/xraycoef/index.cfm

12. Wayte, R., A Model of the Proton, http://vixra.org/abs/1008.0049

13. Basko, M.M., 2005. Nuclear Fusion 45, S38-S47. Summary talk. http://www-naweb.iaea.org/napc/physics/fec/fec2004/papers/s_1-4.pdf