Can Cold Fusion Be Explained by Quantised Inertia?

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When electrolysis is performed using deuterium and a palladium cathode, more heat can be generated than can be explained by chemical processes, implying that deuterons are fusing but without the typical products of hot fusion (a phenomenon called Low-Energy Nuclear Reactions, LENR, or cold fusion). Fusion between deuterons usually requires temperatures of 100 MK to overcome the repulsive Coulomb forces. Here it is shown that a theory called quantised inertia predicts that in cracks in the metal with diameters less than 28 nm, the temperature is 27,000 K and mutual sheltering by the deuterons can produce an attractive radiation recoil force strong enough to push them together through their Coulomb barriers. This offers a potential explanation for cold fusion or LENR.

1 Introduction

Many attempts are underway to initiate nuclear fusion between atoms such as deuterium, releasing useful energy [1]. The main challenge is to overcome the Coulomb barrier: deuterons have a charge equal to the charge on the proton, and they repel each other with a force given by

$$F_C = \frac{q_P^2}{4\pi\varepsilon_0 d^2} \tag{1}$$

where $q_P = 1.6 \times 10^{-19}$ C is the charge on the proton, $\varepsilon_0 = 8.85 \times 10^{-12}$ m^{-3}kg^{-1}s^{4}A^2 is the permittivity of free space and d is the distance between the deuterons. Overcoming the Coulomb barrier between the two deuterons in this process usually requires a high momentum and therefore temperatures in excess of 100 MK which are thought to only be possible in gravitationally-confined systems such as the Sun or magnetically-confined fusion reactors.

This is why the results of Fleischmann and Pons [2] were so surprising. When they used a palladium cathode to electrolyse heavy water (containing deuterium) they noticed that more heat was given off than was possible from chemical processes, implying that fusion was occuring (so called cold fusion). The expected product of deuterium fusion: helium-4, was also produced, but the nuclear emissions (neutrons and gamma rays) expected from hot fusion were not seen and so cold fusion was dismissed by all but a small minority. However, over the years there have been many successful reproductions of the Pons-Fleischmann effect, or variations of it [3], and many unsuccessful ones as well, and the topic has been renamed LENR (Low-Energy Nuclear Reactions). A good summary is available in [4].

Aoyama [5], Storms [6], [7] and others have noted an intriguing pattern which is that a common feature to the successful experiments are the cracks or defects in the metals, which are on the order of the nanoscale.

McCulloch [8], [9], [10] has shown that a number of dynamical anomalies such as galaxy rotation and cosmic acceleration can be explained by a theory called quantised inertia which assumes that inertial mass is due to Unruh radiation (a radiation seen only by accelerating objects) when this radiation is made non-uniform in space by horizons. These horizons can be caused by acceleration (relativistic horizons) or they can be metal structures or cavities [11].

Another interesting anomaly down at the nuclear scale is that of [12] who showed that when the proton radius is measured with a orbiting muon rather than an electron, an extra unexplained binding energy is present. The muon orbits 200 times closer than the electron, and quantised inertia can explain 55% of this extra binding energy by assuming that the thermal Unruh radiation seen by the muon is blocked (sheltered) from the direction of the proton, leading to a net radiation pressure from outside its orbit, and a new attractive force [13]. Quantised inertia also predicts high temperatures within small horizons, for example in the early universe [14]. This may also apply to small metal cracks and so it may have relevence for LENR.

In this paper it is shown that quantised inertia predicts that cracks or defects in metals of 28 nm diameter or less should be hot enough to cause an attractive radiation recoil force on the deuterons strong enough to overcome their Coulomb repulsion. This suggests a mechanism for cold fusion and LENR.

2 Method & Results

The uncertainty principle of Heisenberg states that the uncertainty in momentum (Δp) times the uncertainty in position (Δx) must be greater than or equal to half the reduced Planck's constant

$$\Delta p \Delta x > \frac{\hbar}{2} \tag{2}$$

so that if the uncertainty in position (Δx) is reduced in a metal cavity of diameter D, then the momentum uncertainty (Δp) should increase. Quantised inertia assumes that this increase in momentum can become real [15], and since $E = pc$ then a new energy becomes available, given by

$$\Delta E > \frac{\hbar c}{2D}. \tag{3}$$

For thermalised energy $E = \frac{3}{2}kT$ we can write an expression for temperature:

$$T > \frac{\hbar c}{3kD}. \tag{4}$$

Eq. 4 predicts that the temperature in tiny volumes is high. Figure 1 shows two deuterons (the black circles) close together inside a defect (the grey area) within a palladium lattice (the mottled area). If the temperature within the defect is as given in Eq. 4 then this radiation will be absorbed by each deuteron only on the side away from the other deuteron, assuming there is a mutual sheltering process (see the white radiation-free area in Figure 1) and so the absorption of this radiation will produce a radiation recoil force (see also [16]) that will push them together. This force is

$$F_R = \frac{P}{c} = \frac{\sigma T^4}{c} \tag{5}$$

where σ is the Stefan-Boltzmann constant and c is the speed of light. In order for this radiative force to cause the deuterons to fuse, it must be larger than the repulsive Coulomb force at the seperation where the attractive strong force can take over and fuse the two deuterons, a distance of $d_s = 1.6 \times 10^{-15}$ m. For this to happen, $F_R > F_C$ at distance d_s, and so using Eqs. 1 and 5, and using Eq. 4 for T we get

$$\frac{\sigma\left(\frac{\hbar c}{3kD}\right)^4}{c} > \frac{q^2}{4\pi\varepsilon_0 d_s^2}. \tag{6}$$

We can now predict the crack size D needed to produce a temperature high enough to cause fusion in this new way:

$$D < (4\pi\varepsilon_0\sigma)^{\frac{1}{4}}\, c^{\frac{3}{4}}\, \frac{\hbar}{3k}\sqrt{\frac{d_s}{q}} = 28 \text{ nm}. \tag{7}$$

Therefore, quantised inertia predicts that deuterons in cracks or defects in palladium of a size less than 28 nm will see temperatures of $\hbar c/3kD \geq 27000$ K and be pushed together by radiation in the crack strongly enough that their Coulomb barrier can be breached, causing fusion. Cracks of this size are present in palladium after being stressed [17].

3 Discussion

Quantised inertia also suggests a way to account for the lack of emitted neutrons in LENR. The inwards force on all particles in the defect may keep them confined, but it does not directly explain the lack of gamma rays.

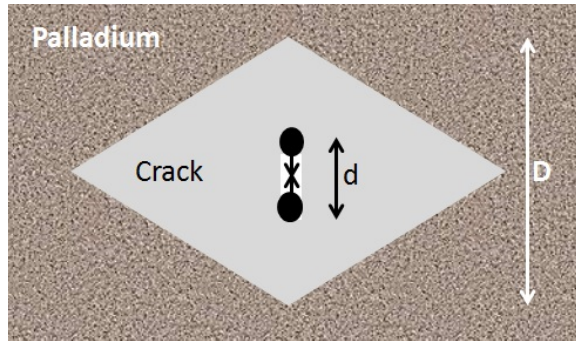

Fig. 1: A schematic showing two deuterons (the black circles) located a distance d apart within a crack/defect of width D (the grey area) in a palladium lattice (the mottled area). The metal radiates, and the mutual sheltering of the deuterons causes the white sheltered zone. The non-uniformity of the thermal radiation then forces the deuterons together (the arrows).

As a test, this theory predicts that metals with cracks or defects of size D should emit radiation of wavelength D. X-rays were indeed seen by [6] and [7] during LENR, with wavelengths in the nanometre range.

This mechanism also suggests a possible reason for sonoluminescence which similarly involves particles being confined to a small region, in this case a bubble collapsing to a size of 0.5 micron and attaining an apparent temperature of between 2300 K to 5100 K, as measured by the radiation given off (see [18]). Eq. 4 predicts a temperature of 1500K.

This application of quantised inertia predicts that a nanometal manufactured to have regular cracks of a size less than 28 nm should show far more uniform LENR.

4 Conclusion

When electrolysis is performed using heavy water (deuterium) and a palladium cathode, unexpected heat and Helium-4 can be generated indicating that nuclear fusion is taking place without the usual products of hot fusion (this is called LENR or cold fusion).

Quantised inertia predicts that deuterons in cracks or defects less than 28 nm in width should heat up enough that, through mutual sheltering, they feel an attractive radiation recoil force that overcomes their Coulomb barrier, allowing fusion. This is a possible explanation for cold fusion.

As a test this model predicts that a metal with cracks should emit radiation of a wavelength similar to the size of its cracks, and that a nanometal manufactured with cracks of size 28 nm or less should produce LENR more uniformly.

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References

1. Clery D. ITER's $12 billion gamble. *Science*, 2006 v. 214, 5797.
2. Fleischmann M., Pons S. and Hawkins M. Elecrochemically induced nuclear fusion of deuterium. *J. Electroanal. Chem.*, 1989, v. 261, 301–308 and errata in v. 263, 187–188.
3. Kitamura A., Takayoshi N., Yu S., Akira T., Akito T., Reiko S., Yushi F. Anomalous effects in charging of Pd powders with high density hydrogen isotopes. *Phys. Letters A*, 2009, v. 373(35), 3109–3112.
4. Storms E.K. How basic behaviour of LENR can guide a search for an explanation. *J. Condensed Matter Nucl. Sci.*, 2016, v. 20, 1–39.
5. Aoyama T. et al. Highly reliable low-level neutron detection using 3He proportional counters. *Radioisotopes*, 1991, v. 40, 188.
6. Storms E.K. and Scanlan B. Detection of radiation emitted from LENR. ICCF-14. Conference on Condensed Matter Nuclear Science, 2008. Washington, DC.
7. Storms E.K. and Scanlan B. Nature of energetic radiation emitted from metal exposed to H2. *J. Condensed Matter Nucl. Sci.*, 2013, v. 11, 142–156.
8. McCulloch M.E. Modelling the Pioneer anomaly as modified inertia. *MNRAS*, 2007, v. 376, 338–342.
9. McCulloch M.E. Testing quantised inertia on galactic scales. *ApSS*, 2012, v. 342(2), 575–578.
10. McCulloch M.E. Galaxy rotations from quantised inerta and visible matter only. *Astrophys. Space Sci.*, 2017, v. 362, 149.
11. McCulloch M.E. Testing quantised inertia on the emdrive. *EPL*, 2015, v. 111, 60005.
12. Pohl R. et al. Laser spectroscopy of muonic deuterium. *Nature*, 2010, v. 466, 213.
13. McCulloch M.E. The proton radius anomaly from the sheltering of Unruh radiation. *Progress in Physics*, 2017, v. 13(2), 100–101.
14. McCulloch M.E. A toy cosmology using a Hubble-scale Casimir effect. *Galaxies*, 2014, v. 2, 81–88.
15. McCulloch, M.E. Quantised inertia from relativity and the uncertainty principle. *EPL*, 2016, v. 115, 69001.
16. Haslinger P., Jaffe M., Xu V., Schwartz O., Sonnleitner M., Ritsch-Marte M., Ritsch H. and Mueller H. Attractive force on atoms due to blackbody radiation. *Nature*, 2017, doi: 10.1038/s41567-017-0004-9.
17. Kim S., Lee H.-S., Jang B. and Cho S. Strain-controlled nanocrack formation in a Pd film on polydimethylsiloxane for the detection of low H2 concentrations. *J. Mater. Sci.*, 2016, v. 51(9), 4530–4537.
18. Brenner M.P., Hilgenfeldt S. and Lohse D. Single-bubble sonoluminescence. *Rev. Mod. Phys.*, 2002, v. 74(2), 425–484.