Exothermic reaction induced by high density current in metals – Possible nuclear origin

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1 The low energy nuclear reaction (LENR) dilemmas

Experimenters working in the field of LENR face two dilemmas.

1. The experimental dilemma: on one hand, an unexplained exothermic reaction that seems to occur in a rather complex system and on the other hand, the necessity of an irrefutable experimental proof which requires simple and well-proven devices.

2. The theoretical dilemma: if we trust the experiments, the magnitude of the exothermic reactions observed rules out most of the explanations (chemical reactions, thermo-electrical effects...) The only known phenomenon to explain these high exothermic phenomenon is nuclear reactions. Then on one hand, nuclear reactions seems to occur during the experiments and on the other hand, no radiation (or almost no radiation) are observed!

Experimental part

Strategy

The first step is to define a working hypothesis then an experimental device is designed in order to test this hypothesis. The objective being to achieve a correct energy and mass balance, thus enabling to asses the validity of the working hypothesis and at least enabling to establish the veracity of low energy nuclear phenomenon. Several authors had worked in the field of low energy nuclear reaction using various working hypothesis:

- collective behavior of deuterium in palladium lattice (Fleishmann and Pons [1])
- spin/spin interaction in hydrogen atom (Barut / Vigier [2-5])
- virtual neutron (Russel [6], Dufour [7], Kozima [8])
- hydrino (Mills)
- hydrex (Dufour [9])
- magnetic monopole (Ouroutskoiev / Lochak)
- charged clusters (Shoulders, Rambaut)
- ...

They also used various experimental devices:
- electrolysis (Fleishmann and Pons [1] and many others)
- focused plasma (Vigier)
- sparks (Dufour [7])
- plasma electrolysis (Mizuno [10], Naudin...)
- current thru metals (Ouroutskoiev, Dufour [9, 11-13], Miley [14]...)
- current thru proton conductors (Biberian)
- hydrogen diffusion thru palladium
- ...

According to most of these authors several "ingredients" or experimental conditions seems to be required for LENR to happen:
- hydrogen and / or its isotopes needs to be in the system
- a metal and especially an hydride forming metal need to be used in the system
- diffusion of electrical charges in the metal (diffusion of proton, current) is also required
- a magnetic field is almost always present.

Several hypothesis were used in the laboratory: virtual neutron, spin/spin interaction and now hydrex. The hydrex is an hypothetical metastable state of hydrogen predicted by quantum electrodynamic calculation [15]. We assume the existence of this specie. Different experimental devices were built using from sparks to currents thru a metal with or without a magnetic field. The main results indicate that an exothermal reaction occurs. Its energy goes up to 10% of the energy input in the system [16]. New elements at ppm level were also observed. [9, 12, 16].

For example, the sample 3H06 was a palladium wire used as electrode in an ozonizer type reactor filled with hydrogen and was thus submitted to the action of partial discharges breaking thru the hydrogen gap. This partial discharges were in contact only with the Pyrex tube used as dielectric and with the palladium. We can compare the composition of a Pyrex glass (Table 1) with the analysis of the sample before and after experiment (Table 2,

Table 3). The variation of Al can be explained by a transport of these elements from the Pyrex to the electrode by the discharge but it's more difficult to explain the origin of Zn or Cu and even the large variation of Mg.

Oxyde	**%**
SiO_2	80.6
B_2O_3	12.6
Al_2O_3	2.2
Na_2O	4.2
C_aO	0.1
M_gO	0.05
Fe_2O_3	0.05

Table 1: Pyrex typical composition

Element	**3H06 (ppm)**	**Blank (ppm)**
H	43 ± 7	28 ± 10
Li	0.05 ± 0.02	= 0.01
Be	= 0.01	= 0.01
B	= 0.08	= 0.08
Na	nm	nm
Mg	85 ± 9	7.3 ± 0.8
Al	27 ± 3	= 1
Si	nm	nm
P	nm	nm
K	nm	nm
Ca	nm	nm
Ti	= 0.1	= 0.1
V	= 0.2	= 0.2
Cr	7.9 ± 0.8	0.9 ± 0.3
Mn	0.3 ± 0.1	= 0.2
Fe	22 ± 10	= 10
Co	= 0.05	= 0.05
Cd	0.7 ± 0.2	0.7 ± 0.2
Sn	nm	nm

Element	3H06 (ppm)	Blank (ppm)
Sb	nm	nm
Te	nm	nm
Cs	= 0.05	= 0.05
Ba	= 0.07	= 0.07
La	= 0.15	= 0.15
Ce	nm	nm
Pr	= 0.07	= 0.07
Nd	nm	nm
Sm	= 0.4	= 0.4
Eu	= 0.01	= 0.01
Gd	= 0.1	= 0.1
Tb	= 0.02	= 0.02
Dy	= 0.08	= 0.08
Ho	nm	nm
Er	= 0.05	= 0.05
Ni	2.7 ± 9	= 2
Cu	4.1 ± 0.4	1.6 ± 0.2
Zn	43 ± 5	4.3 ± 1.5
Ga	= 0.05	= 0.05
Ge	= 0.7	= 0.7
As	nm	nm
Se	= 8	= 8
Rb	= 0.15	= 0.15
Sr	= 0.15	= 0.15
Y	= 0.05	= 0.05
Zr	= 0.1	= 0.1
Nb	= 0.1	= 0.1
Mo	= 0.6	= 0.6
Ru	= 80	= 80
Rh	= 10	= 10
Pd	bulk	bulk

Element	3H06 (ppm)	Blank (ppm)
Ag	= 20	= 20
Tm	= 0.01	= 0.01
Yb	= 0.08	= 0.08
Lu	0.05 ± 0.02	0.02 ± 0.01
Hf	= 0.15	= 0.15
Ta	= 2	= 2
W	= 0.15	= 0.15
Re	= 0.1	= 0.1
Ir	0.6 ± 0.2	0.5 ± 0.2
Pt	0.8 ± 0.1	1.4 ± 0.2
Au	0.8 ± 0.1	1.1 ± 0.1
Hg	0.4 ± 0.1	0.4 ± 0.1
Tl	= 0.04	= 0.04
Pb	= 0.08	= 0.08
Bi	= 0.05	= 0.05
Th	= 0.15	= 0.15
U	= 0.05	= 0.05

Table 2: sample 3H06 analysis (ppm wt) / nm : not measured

Elements	3H06 (atom)	Blank (atom)	3H06 – Blank (atom)
Li	$5.2x10^{14}$	$1.0x10^{14}$	$4.2x10^{14}$
Mg	$2.5x10^{17}$	$2.2x10^{16}$	$2.3x10^{17}$
Al	$7.2x10^{16}$	$2.7x10^{15}$	$7.0x10^{16}$
Cr	$1.1x10^{16}$	$1.3x10^{15}$	$0.97x10^{16}$
Mn	$3.9x10^{14}$	$2.6x10^{14}$	$1.3x10^{14}$
Fe	$2.8x10^{16}$	$1.3x10^{16}$	$1.6x10^{16}$
Ni	$3.3x10^{15}$	$2.5x10^{15}$	$0.9x10^{15}$
Cu	$4.7x10^{15}$	$1.8x10^{15}$	$2.9x10^{15}$
Zn	$4.8x10^{16}$	$4.8x10^{15}$	$4.3x10^{16}$
Ir	$2.3x10^{14}$	$1.9x10^{14}$	$3.8x10^{13}$
Pt	$3.0x10^{14}$	$5.2x10^{14}$	$- 2.2x10^{14}$
Au	$2.9x10^{14}$	$4.0x10^{14}$	$- 1.1x10^{14}$

Table 3: sample 3H06 analysis (number of atom in 1/4 of the sample)

The hydrex working hypothesis

We assume the existence of a non proven metastable state of hydrogen predicted by the calculation [15]. We call this state hydrex. It has the following properties:

- a nuclear size (some fm to some tens of fm)
- an energy of formation from 0.7 to 4 eV (available in the lattice)
- a life time from hundredths of second to seconds (far greater than the time of a nuclear reaction)
- a magnetic moment (spin magnetic moment of the electron).

We can imagine the formation of a cluster (Figure 1: a nucleous of the lattice surrounded by n hydrex). The nucleus of the lattice undergoes a fission like reaction. Excess neutrons and hydrex form helium. As it is a multi-body reaction no γ-ray is necessary: the reaction energy can be transform in kinetic energy of the products. We can also imagine that this hydrex could react with a proton yielding deuterium and a neutrino. In this case also, no γ-ray is necessary. This hypothesis solve the second dilemma: no neutron and no γ-ray observed.

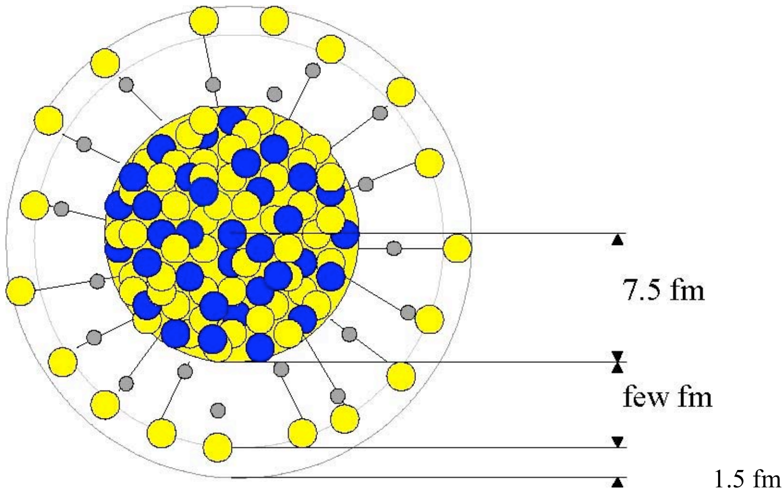

Figure 1: an artist view of the cluster

The calorimetric device in use

Experimental set-up

The goal is to measure the thermal energy generated in the sample under study by using a device as simple as possible. Unfortunately an ice calorimeter is not adapted for a long duration experiment. An other phase-change calorimeter would be a steam calorimeter but it is not reliable because steam can carry along water droplets and the separation of these droplets from the steam is not a trivial problem. Thus, a water mass flow calorimeter was designed (Figure 2, Figure 3). The water conductivity is between 0.8 and 1μScm^{-1}. It is possible to test various condition (nature of the metal: palladium, tungsten,...; different current shape : AC, DC, pulse...; hydrogen loading: in situ electrolysis, presence of permanent magnet to modify the magnetic field...)

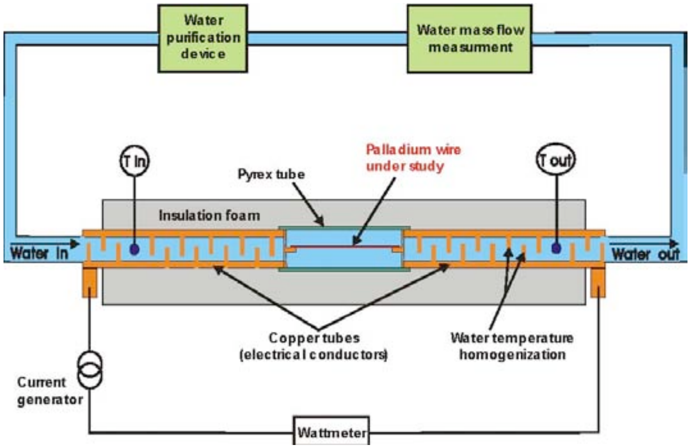

Figure 2: The experiment cell

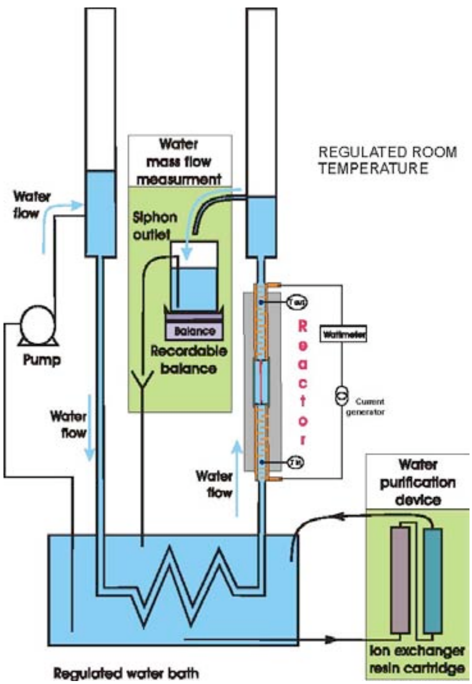

Figure 3: The calorimeter set-up

Energy balance

$$P_{in} = P_m + P_e + P_w \tag{1}$$

$$P_{out} = f(T_{out}C_p(T_{out}) - T_{in}C_p(T_{in}) + L \tag{2}$$

$$L = L_r + L_a \tag{3}$$

- P_m is the main current power
- P_e is the electrolysis current power
- P_w is the power due to the water pressure drop (measured by the difference of water level)
- F is the water mass flow
- $C_p(T)$ is the water heat capacity
- L_r are the radial losses
- L_a are the axial losses.

If no reaction occurs, then $P_{out} - P_{in} = 0$ but if an exothermic reaction occurs in the sample then $P_{out} - P_{in} = W_r > 0$.

Losses

The wire under experiment exchanges heat with the water by convection (70-80%) and with the copper of the reactor by conduction (20-30%). After the heat exchanger, the axial losses are about 0 to 1.5% of the total heat generated in the experiment.

The radial losses thru the insulation are proportional to the temperature difference between the room air temperature and the water temperature. We assume that the axial losses are proportional to P_{out} thus:

$$L_r = K\left(\frac{T_{out} + T_{in}}{2} - T_{room}\right) \tag{4}$$

$$L_a = K'(T_{out} - T_{in}) \tag{5}$$

using (3), (4) and (5) we can write

$$L = K\left[\left(\frac{T_{out}+T_{in}}{2} - T_{room}\right) + \frac{K'}{K}(T_{out} - T_{in})\right] \tag{6}$$

For a given experiment K and K' are constants. We can then measure the losses by varying T_{in} and T_{room} when $P_{in}=0$ and when $P_{in}\neq 0$.

K is typically from 0.3 to 0.4 WK^{-1} and K' from 0 to 0.2 WK^{-1}.

Trueness of the measure

Experiments using a commercial carbon resistor where performed in order to check that we have no systematic errors.

These experiments yield to $|P_{out} - P_{in}|$ inferior to the greater value between 0.3W and $0.004P_{in}$

Precision of the measure

The three thermal sensors are calibrated together. This yield to a relative temperature precision better than 0.01K.

The precision of the wattmeter is typically 1% The precision of the balance used for the mass flow measurement is 0.2g.

For one set of measurements, the dispersion on the energy balance, when no exothermic reaction occurs, $|P_{out} - P_{in}|$ is typically inferior to the greater value between 0.3W and $0.02P_{in}$

Confidence interval on the mean value

For one set of operating condition i.e. 400 to 500 sets of measurements, the confidence interval for the averages values of P_{in} and P_{out} are typically

$$\left\{P_{in}\right\}_{true} = (1 \pm 0.0001)\left\{P_{in}\right\}_{average} \tag{7}$$

$$\left\{P_{out}\right\}_{true} = (1 \pm 0.0003)\left\{P_{out}\right\}_{average} \tag{8}$$

Main results

A blank experiment was perform using a commercial carbon resistance of 5Ω (Figure 4). Whatever is the current in the resistance $\{P_{out}\}_{average}$ - $\{P_{in}\}_{average} = 0 \pm 0.004W$

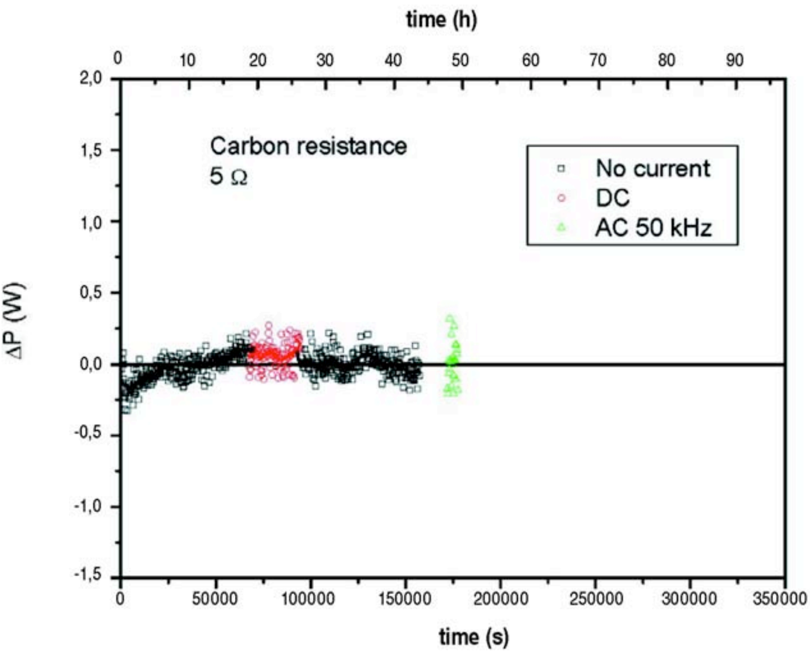

Figure 4 : carbon resistance

The firsts experiments were on palladium. The samples were 100µm diameter, 6cm long palladium wires. An hydrogen processed sample reference 031107 (200°C - 2MPa H_2 - 1 hour) tested with a direct current and near a magnet leads to an exothermal reaction (Figure 5). The mean reaction power is 0.731±0.036W.

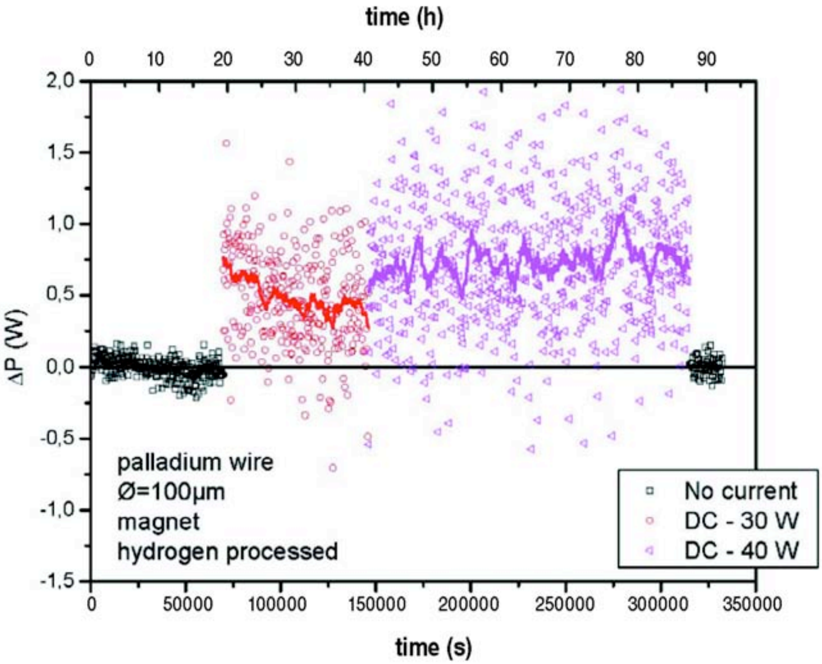

Figure 5 : experiment 031107

Discussion

In this experiment, the sample weight was 6mg which represent $3.2x10^{19}$ palladium atom or $5.3x10^{-5}$ mol. The total energy produced by the exothermic reaction is 125kJ or $2.3x10^{9}$J per palladium mole. This value overrule any known chemical reaction. If we assume that the reaction has a nuclear origin we can expect about $1.6x10^{16}$ heteroatom which represent a composition variation of 480ppm. We need to design a special experimental set-up to perform correct sample analysis. Our calorimeter is built with commercial materials thus we can't perform any correct analysis with the sample used. No γ-ray was observed which is consistent with the hydrex hypothesis.

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