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Neutrons Observations in Cold Fusion Experiments

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Abstract

This report is a review of the most convincing observations of neutrons in Cold Fusion history up to recent experiments in which neutrons were so numerous and long-lasting so as to allow activation of thermal detectors. Lately neutrons were observed also by using natural hydrogen. A more complete review is published elsewhere [1].

1. Introduction

In the experiments conducted with deuterium, the measurement of neutrons, attributed to the reaction

$$D + D = {}^3He + n \qquad (1)$$

and therefore with energy of 2,45 MeV, has presented difficulties since the very first experiments in 1989 due to the scarcity and/or irregularity of the emission.

The fact that the neutron emission is weak even when the excess heat is rather high compels us to suppose that (1) holds true, however, in a minority of reactions; it seems therefore necessary to consider separate the cause of the heat and that of the neutrons.

The reaction could be different from (1) : Takahashi[2] has measured neutron emissions at energy between 3 and 7 MeV; Karabut [3] has obtained neutrons with energy up to 17 MeV from glow discharge in deuterium and, recently, Manduchi/Mengoli[4] have observed neutron emission (of energies > 2.45 MeV) from application of d.c current to Pd deuteride. In the electrolysis of D_2O in presence of tritium Stukan[5] has observed hard neutrons ascribable to the cold fusion T+D.

Although experiments have been reported in which the emission appears constant in time [6-9], irregularity is the most frequent characteristic of neutron production in cold fusion: the neutrons are often grouped in bursts of varied composition and duration.

2. Neutrons 1989-1995

Subsequently to the first communications of 1989 many groups have detected neutron intensities well above the background. We limit ourselves to an exemplification of experiences in which neutron generation is many times the statistical error σ_B on background.

ELECTROLYTIC LOADING

Measurement of reaction neutrons - Neutron spectrometry presents difficulties with this type of loading, because the electrolytic solution and the possible thermostatic bath slow down the neutrons. However, Takahashi[2] in pulsed electrolysis with a heavy water LiOD solution has measured neutron emissions at 2.45 MeV (but also at energy between 3 and 7 MeV).

Measurement of neutrons after thermalization - Sanchez[10], during heavy water electrolysis with a Ti cathode has measured for several hours, with a BF_3 detector, counting rates up to 10^5 n/s. Palibroda[11] has worked in electrolysis with a palladium cathode and a solution with an addition of thiourea; various neutron emissions have been recorded which, after thermalization, reached 300 times the background and lasted up to 12 hours. Fujii[12] has worked with a 0.1 mol/dm^3 LiOD solution in heavy water. Utilizing ^{3}He counters he has found neutron bursts up to 135 σ_B.

GASEOUS LOADING

Measurement of reaction neutrons - Botta/Bressani[13] have applied a time of flight spectrometer to the Ti/D system; neutrons of 2.45 MeV energy have been found in the excess of 5 σ_B compared to the background. Manduchi/Mengoli[14] have utilized the technique of gaseous loading of deuterium on Pd with decreasing temperature from 900°C to 20°C. The neutron measurement was effected with a NE213 (100 cm^3) spectrometer; significant quantities of neutrons have been observed especially in the temperature intervals in which the deuterium was more actively absorbed by the metal. Neutrons also are produced following loading with natural hydrogen.

Measurement of neutrons after thermalization - Manduchi/Mengoli[15] have, among other things, sought confirmation of Scaramuzzi's experiment of 1989, by producing many cycles of deuterium charging and discharging on titanium: for about two weeks they periodically found neutron emission, measured as thermals, for approximately 10 times σ_B.

ELECTRIC DISCHARGES IN DEUTERIUM GAS

This type of experiment, already begun in 1989[16,17], appears efficacious in the production of neutrons, but the reaction rate is not in general sufficient to produce a measurable excess heat. Only in the work of Kucherov[18], favorably characterized also by the maximum neutron emission (with activation of ^{107}Ag and ^{109}Ag) related to the minimum d.d.p. employed (< 500 V) , have 50 W been appreciated.

Long[19] experimented with the glow discharge between Pd-deuterated electrodes, obtaining reactions in the metallic film deposited on the glass of the bulb. The neutrons, measured with a recoil-proton scintillation detector, reached the average rate of several hundred per second. With metals other than Pd the neutrons were more numerous (10^4 n/s) and long-lasting, so much so as allow the radioactivation of indium and iridium.

DIFFERENT TECHNIQUES AND / OR MATERIALS

Lyakhov[20] has found that the combined action of cavitation and electrolysis on a titanium surface determines a reproducible neutron emission (0.6 n/s) with bursts of 10^3 n/ms.

Bittner[21] employs a mixed method, in that it involves electrolytic deuteration of palladium and subsequent degassing through heating; the emission of neutrons (of approximately 2.5 MeV) took place mainly during the degassing phase, at high temperature, for about an hour.

The Piantelli's technique [22,23], which uses natural hydrogen, allows a generation of $>10^6$ n/s (radioactivity was induced in Au,In and Mn) besides of significant anomalous excess heat. Then this "Siena experiment" [24,25,26] is to be considered as the most sure acknowledgement, up to date, of the nuclear cold fusion hypotesis.

Manduchi-Mengoli [4] have founded strong neutron emission (30÷40 n/s) correlated with the migration of deuterium; the energy was > 2.45 MeV for 80% of the total.

Wada[27] reports emission of 2.45 MeV neutron bursts with temperature rise from palladium by means od simple exposure to D_2 gas in a closed glass bulb.

3. Transmutations

The finding of particular nuclides might be an indirect signal that neutron generation has taken place.

Coupland[28] reports that in the superficial layers of Pd electrodes the isotopic ratio $^6Li/^7Li$ appeared very reduced (from 0.08 to less than 0.05) after having been used by Pons and Fleishmann. The anomaly may be interpreted as the consequence of reactions of the ^6Li with thermal neutrons whose cross section (n,α), as is known, is very large (945 barn).

Other nuclides are presumably created by the transmutation of species originally composing the crystalline lattice. Rollison[29], in mass-spectrometric observations of the deuterated Pd, has found an increase (from 27 % to 40 %) in the abundance of the ^{106}Pd isotope (^{105}Pd abundance undergoes a corresponding reduction).

Karabut [3] has measured a γ-ray emission attributed to ^{109m}Pd ($T_{1/2}$= 4.7 min). Recently the production of silver has been observed, in particular by Dash[30], who believes that the $^{108}Pd\ (n,\gamma)^{109}Pd$ capture has taken place followed by decay into stable ^{109}Ag , with half life $T_{1/2}$ = 13.7 h. Obviously also the original impurities (for example Ag, Au and Pt) as well as the Pt of the anode, transferred in part onto the cathode in the course of experiments of electrolytic loading, may undergo transmutations[31]. In particular ^{196}Pt (relative abundance 25.3% in the natural element) through reaction (n,γ) would give place to ^{197}Pt which would become stable ^{197}Au after beta decay.

4. What activates the neutron channel ?

The examination of the works mentioned so far does not seem yet to furnish a final evidence about what could be the modes which activate the neutron channel, but in many cases non-equilibrium conditions appear necessary; the temperature seems important.

Loading ratio - It is known that many experiments indicate for Pd a loading ratio x = 0.85 as the threshold for the production of excess heat; for neutrons some authors have reported as useful decidedly inferior values. Shani[32] sealed the Pd sample destined to emit neutrons when the D/Pd ratio had been brought to a value of .6. In addition Long has indicated the condition x > .3, while from Bittner's graphs[21] neutrons still seem to be emitted when, during degassing, the ratio had been reduced to about .66. Iwamura[33], who with ^{3}He detectors observes neutron emission during degassing, claims to load to the maximum value of x = .66, while Nakada[34] recognizes a requisite value of x=.77 and, lately, Garg[35] has indicated useful x values from 0.4 to 0.7 in a variety of gas loading experiments.

For D/Ti systems Algueró[36] recommends the critical value x=1.95, which is attained in only a thin layer close to surface (few microns) during D_2O electrolysis.

Stratifications - In the Iwamura's and Algueró's experiments the phenomena seem to concentrate on the deposited superficial layer. Other experiments, as well, seem to indicate that the generative processes of neutrons are produced in correspondence to thin stratifications. Nakada[37] has proved that the formation of Pd-Li layers in the surface region favours the anomalous deuterium accumulation, with neutron emission.

Catalytic hypotheses - Some researchers affirm that the stochastic character of the emissions of neutron bursts suggests a catalytic nature, for which such episodes may be induced by neutrons or by other particles of the environmental background. From such a viewpoint the experiment described by Shani[32] seems interesting: in a high-neutron background environment (0.05 counts/s/cm^2) a 2.45 MeV neutron peak was observed, while in a low background environment (0.0002 counts/s/cm^2) there was no peak. The idea of catalysis is sustained also by Gluck [38] and by Kozima[39] who adduces as a clue the fact that the phenomena of cold fusion appear markedly less frequent in heavily shielded environments.

5. Conclusions

Neutrons were observed in many laboratories. The most frequently measured neutron energy is 2.45 MeV of the D+D reaction; reported higher energies need further confirmations. The isotopic shifts would also deserve careful examination.

Experiments seem to support the firm belief that excess heat is generated by principales nuclear events accompanied by less frequent reactions which produce neutrons.

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