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Preliminary observations on possible implications of new Bohr orbits (resulting from electromagnetic spin–spin and spin–orbit coupling) in "cold" quantum mechanical fusion processes appearing in strong "plasma focus" and "capillary fusion" experiments

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The theoretical interpretation of recently observed "excess heat" (i.e. break-even) in low intensity electrolytic and discharge experiments (with both deuterium and hydrogen) as resulting from a new type of non-nuclear quantum phenomena (i.e. spin–spin and spin–orbit couplings added to the usual Coulomb potential in specially structured dense media) leads to the prediction that "fusion ashes" of deuterium (or deuterium compounds now in vanishingly small quantities) will grow with the current intensity input, thus increasing the excess energy output. To test this prediction one can study the dynamic of fusion reactions in simple capacitor bank discharges into deuterated media, both in plasma focus (PF) and capillary fusion (CF) type experiments.

1. Introduction

The discovery in 1989 by Fleischmann and Pons that low intensity electrolytic set-ups using palladium cathodes generated excess energy which could not be explained by usual chemical reactions, has generated a scientific and media commotion, which subsequently receded, for evident theoretical and experimental reasons, and now presently rebounds after the 1992 Nagoya Conference on cold fusion.

The reasons for the first wave of desillusion are clear:

– The process was not reproducible on all palladium samples; so that an apparently unacceptable number of control experiments failed to report any generally acceptable significant results. Some samples worked, some not; and no explanation for this difference has been given to this day.

– The claim suggested by the authors (and widely developed by the media) that the excess heat was somehow related to "cold" nuclear fusion processes was also not acceptable for both experimental and theoretical reasons. In the first place, all the observed "fusion ashes" corresponding to known nuclear fusion reactions were many orders of magnitude (if, and when, detected) too small to explain quantitatively the excess heat (Fleischmann and Pons should have been dead if presently known nuclear fusion processes were responsible for their calorimetric results [#1]) and no alternative satisfying model of possible fusion mechanism was proposed at that time [#2].

Results presented at, and posterior to, the Nagoya Conference have modified the situation.

(a) Low energy input experiments have confirmed the excess heat (break-even) announced by Fleischmann and Pons (see, e.g., refs. [2,3]). It seems that the corresponding energetic reactions last for some time, are associated with bursts, and grow with the intensity input.

(b) Electrolytic and discharge experiments have (with deuterium and heavy water) also confirmed the presence of "nuclear ashes" (neutrons, tritium, helium 3 and 4) but always in insufficient number to explain the energy balance. The number of such fusion ashes has been observed to increase with the growth of the energy input.

(c) Experiments have been presented which show that excess energy is also associated with light water and hydrogen in electrolysis and glow discharge. If confirmed this is a crucial point, since it shows that the excess heat observed has a different origin from fusion processes which are only marginal at low energies.

The aim of the present paper is to present set-ups and preliminary results (devised to test a possible new interpretation of these three sets of facts) presented by one of us (J.P.V.) at the Nagoya Conference [4].

Qualitatively this interpretation rests on three assumptions which can/should be tested experimentally:

(1) The overwhelming part of the excess heat observed at low energies does not result from fusion reactions, but from the intervention of new (hitherto neglected) ion–electron, spin–spin and spin–orbit couplings which appear in special conditions in dense media (such as palladium, titanium, nickel, etc. [5]).

(2) If one accepts the idea that the observed "nuclear fusion ashes" result from the tunneling of associated ions through the Coulomb repulsive potential barrier, this can be trivially explained using the Coulomb potential (along the lines of the cold fusion processes observed with muonic atoms) by an increased "effective" electron mass: since heavier (with respect to electrons) "effective" masses yield new Bohr orbits with smaller radii, which facilitate quantum tunneling. Alternatively the introduction of a supplementary spin–spin and spin–orbit attractive potential (between opposite charges) to the Coulomb potential facilitates tunnelling, since it also implies new Bohr orbits with smaller radii. Since known Bohr orbits associated with ordinary chemical reactions only yield 2 to 3 eV per reaction per atom (compared with MV for nuclear reactions) one needs very tight electron orbits (with orbital energies of 50 kV to explain the observed facts).

(3) One is thus led to add to the Coulomb forces new spin–spin and spin–orbit forces, due to a strong (average) magnetic field generated by the media under certain specific conditions, such as the splitting (bead formation) of currents in capillary structures [6] under the action of Ampère forces.

These new forces, which result from the known interaction of the corresponding antiparallel proton–electron magnetic moments, have been known for a long time (Born–Pauli, Barut, etc., but generally neglected) and yield plausible quantitative predictions [4]: they include, of course, the appearance of soft X-rays in all such reactions (including those with hydrogen and ordinary light water [5]). The new tight Bohr orbits (assumed by us) generate a new exotic quantum chemistry tied to the existence of tightly bound atoms. Since they also help the atomic nuclei to tunnel through the barrier, we explain both heat and a small amount of nuclear products.

The observed appearance of "fusion ashes", when

[#1] As stated by Rabinowitz [1]: "If the energy output claimed calorimetrically is at one level, the energy equivalent for the tritium measurements is five orders of magnitude lower. The energy equivalent for the neutron measurements is some 7 to 8 orders of magnitude down from that. That is about 13 orders of magnitude lower than the calorimetric energy level." No presently known fusion reaction can explain the excess energy recently observed.

[#2] The only known low-energy alternative "cold" fusion mechanisms for deuterium ions (established by Jones) based on quantum tunnelling generated by muons moving on the smaller Bohr orbits, resulting from their mass, was out; and the ion velocity (i.e. the temperature) was much too weak to overcome the Coulomb repulsive barrier. No form of quantum mechanical behaviour could apparently explain the claimed experimental data.

using deuterium and heavy water, can thus also be related with the structure of the metals utilized. Indeed, if one assumes that they contain capillary-type structures in which ionization currents are broken by the longitudinal forces predicted by Ampère [7], it has been observed [4,5] that neutrons appear when the current splits into a string of beads, and are ejected longitudinally: both properties could be explained by the orientation of the magnetic field [4]; excess energy would be maximized if one only conserves the first bump (figs. 7–9). In other terms, if this model is correct, one should distinguish two levels in experiments and future exploitation:

(a) At low energy input, one studies in fact the nature (and fallouts) of the new exotic type of quantum chemistry related with the spin–spin and spin–orbit forces (i.e. work towards a new type of quantum accumulators). In that situation you are not converting mass to energy (i.e. obtain more energy than you put in) but put it in slowly and get it out fast.

(b) At higher energy input, one adds to this basic quantum chemical energy real fusion energy, since tunnelling is increasingly favored by higher input pulses discharged in the plasma: both in plasma focus (PF) and capillary fusion (CF) experiments. (This could yield real fusion reactors.)

This summary explains the nature of our set-ups, evidently tied to the problems (or questions) that we have attempted to explore in these experiments. We shall now successively discuss the experimental method and preliminary results.

The PF and CF experimental facilities are complementary to the experimental facilities for fusion plasma confinement and give possibilities to study processes important for controlled thermonuclear fusion. At the same time, production of hard and soft X-ray radiation, very intense neutron beams and very intense charge particle beams is studied.

We only present here preliminary experimental results on neutron bursts in dense plasmas obtained from discharges in deuterated media. The selection was made considering the different nature and mechanisms of realized fusion reactions.

The production of the neutron burst in dense plasmas obtained from discharges in deuterated media is also presented.

2. Experimental method

2.1. Plasma focus chamber

The plasma focus chamber is of the Mather type and consists of two brass coaxial electrodes (the outer electrode consists of 18 cylindrically positioned brass roads: fig. 1) separated by a glass insulator sleeve at one end, where the breakdown of a gas discharge at an initial density of about 10^{17} cm^{-3} takes place. This chamber has been designed for currents up to 1 MA and 10^{10} neutrons/pulse. Development and acceleration of the plasma focus current sheath have been measured by means of the fiber optic cables that are

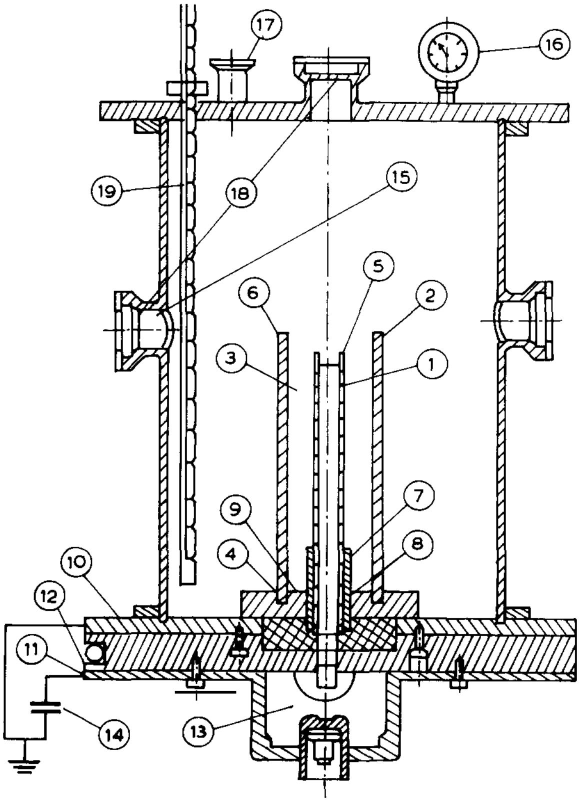

Fig. 1. Schematic sectional view of the plasma focus device. (1) Inner electrode; (2) outer electrode; (3) interelectrode gap; (4) breech wall; (5), (6) muzzle ends; (7) insulator sleeve; (8) field distortion element; (9) cylindrical brass knife edge; (10), (11) breech brass plates; (12) insulator layer; (13) switch; (14) power supply; (15) optical window flanges; (16) pressure control; (17) vacuum pump flange; (18) CR-39 or CA 80-15 with Al pinhole (diameter 1 mm); (19) optic cables, proportion: 1:3.

"looking" at certain spots inside the chamber. Corresponding windows are intended for the laser scattering measurements. Electric circuit parameters (charging voltage, capacitance and external inductance), electrode geometrical dimensions, and gas filling, are chosen in such a way that the radial compression starts near the current maximum. For investigations of a possible influence of different materials on plasma properties, the inner electrode is designed in such a way that we can put on the top different materials (for example Pd foil) in order to study a channel of the D thermonuclear reaction $D^+ \to {}^3T + p$ using β-autoradiography.

The dimensions of our plasma focus chamber are chosen for its optimized operation at an energy up to 40 kJ and a potential up to 40 kV. The working gas in the PF chamber was D with pressure between 1 and 10 mbar.

2.2. "Capillary fusion" chamber

The CF chamber is a modified version of the Uppsala apparatus and a schematic view of it is shown in fig. 2.

The chamber construction ensures that the pressure of nitrogen gas inside the chamber could be ≈ 15 atm. Nitrogen gas is used to prevent sliding discharges along the capillaries surfaces. The dimensions of glass capillary are $l = 22$ mm and $d = 1$ mm.

For "capillary fusion" experiments, the materials used are deuterated compounds (LiOD, $2D_2O$, $K_4Fe(CN)_6 \cdot 3D_2O$, deuterated Pd powder and Pd wire).

2.3. Capacitor bank

For producing a current up to MA and μs electric discharges, a low inductance capacitor bank ($c = 45$

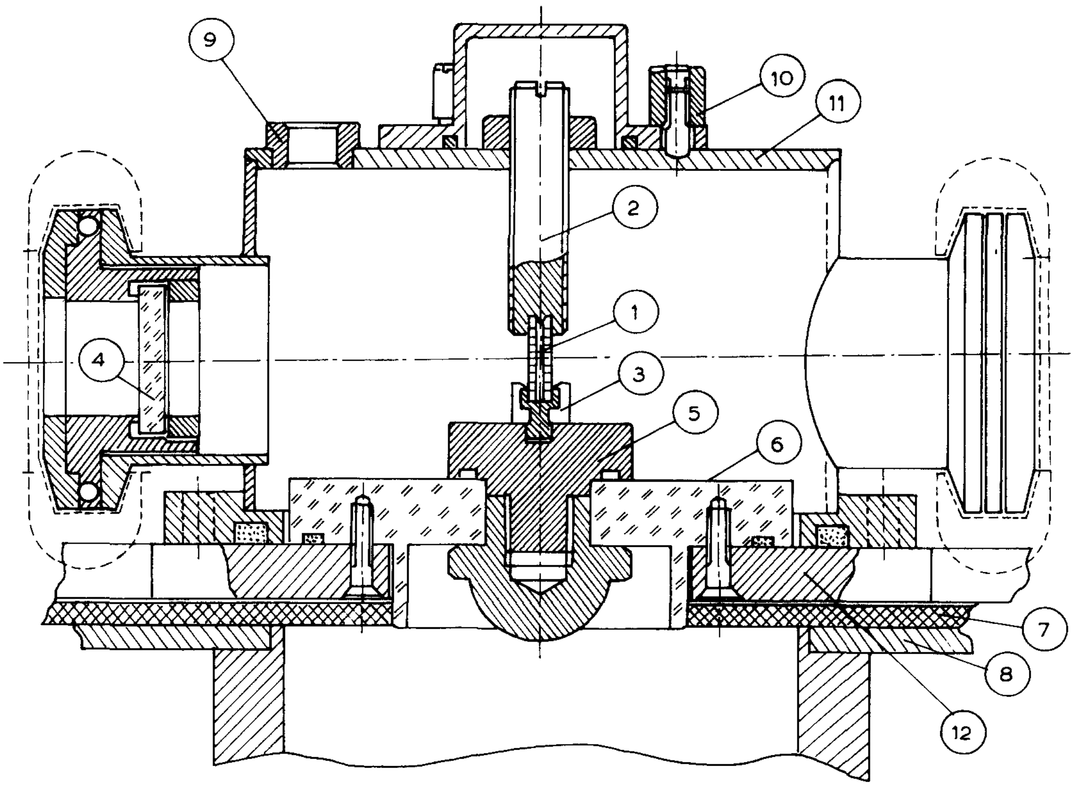

Fig. 2. Schematic sectional view of the capillary fusion device. (1) Capillary; (2), (3) capillary support; (4) quartz window; (5) electrode; (6) insulator G-10; (7) insulator; (8) brass plate; (9) gas inlet; (10) safety valve; (11) chamber; (12) stainless steel plate.

μF, $L=62$ nH, $R=15$ mΩ, $V_{max}=40$ kV, $E_{max}=36$ kJ) with triggered spark gap as a switching device is used as an energy source with a power transmission line between the power supply and two coaxial electrodes.

2.4. Data acquisition system and neutron measurement

At this stage of the experiment development, the main part of the data acquisition system is a digital storage oscilloscope Tektronix 2440 (500 Msamples/s). It allows all voltage and current measurements. This is the most convenient and accurate way of taking data from a neutron detector. A data transfer from the oscilloscope to the personal computer is completed, so all data are available for numerical analysis.

The voltage measurements are taken with high voltage probes. A Rogowski coil between the power transmission plates monitors variations with time of the electrode current.

Because of the sensitivity of our nuclear electronic equipment to electromagnetic interferences (EMI) generated by the discharge of the capacitor bank in the PF and CF chamber, signals from the photomultiplier tubes are mixed and recorded on the os-

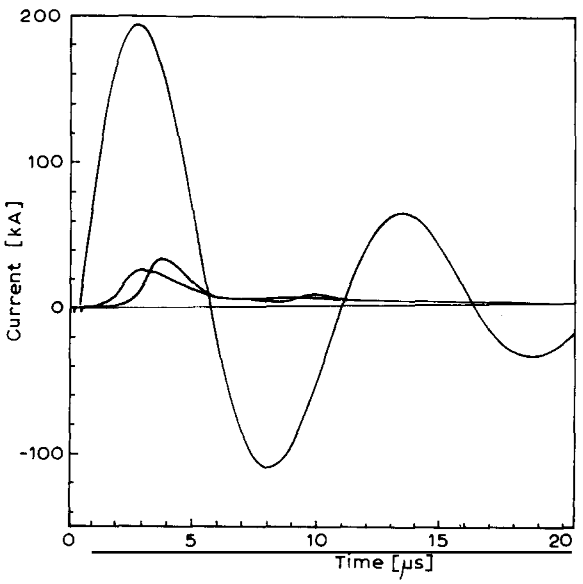

Fig. 3. PF current and photodiode signals (8 and 11 cm signals). $V=9.2$ kV, $P_0=1.3$ mbar, $V_{ex}=2$ cm/μs.

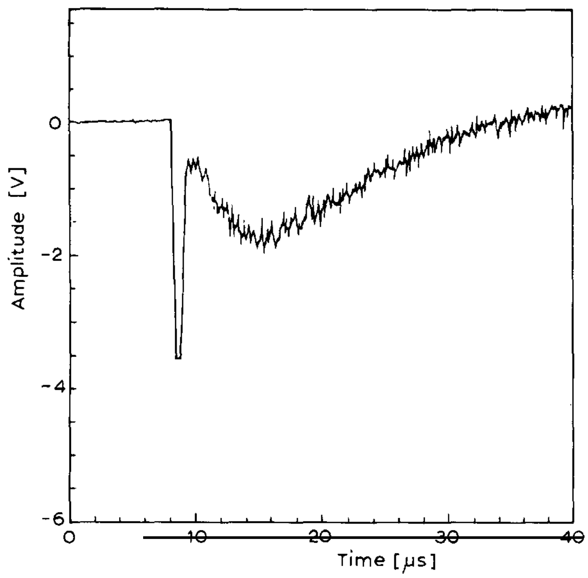

Fig. 4. Neutron flux measurement with NE323. $V=16$ kV, $P=4.5$ Torr, $V_{ex}=4$ cm/μs, $Y_n=10^9$ n/pulse.

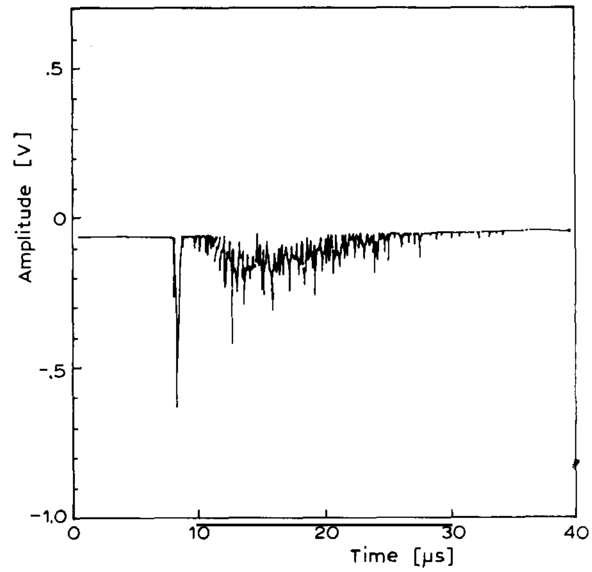

Fig. 5. Neutron flux measurement with NE213. $V=16$ kV, $P=4.5$ Torr, $Y_n=10^9$ n/pulse.

cilloscope, which is excellently protected against EMI. The shapes of the signals are easy to analyze. The possible errors due to EMI on the amplifier discriminator and counting circuitry are avoided.

For a neutron flux measurement, we have selected

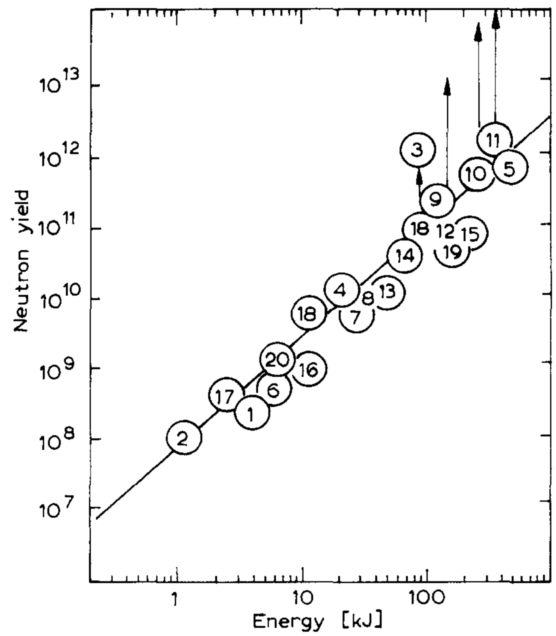

Fig. 6. Our results on international scale. (1) Bucharest; (2) Darmstadt; (3) Düsseldorf; (4) El Sequndo; (5) Frascati; (6) Hoboken; (7) Jülich; (8) Langley; (9) Livermore; (10) Limeil; (11) Los Alamos; (12) Moscow; (13) Osaka; (14) Sandia; (15) Stuttgart; (16) Sukhurni; (17) Tokio; (18) Urbana; (19) Warsaw; (20) Zemun.

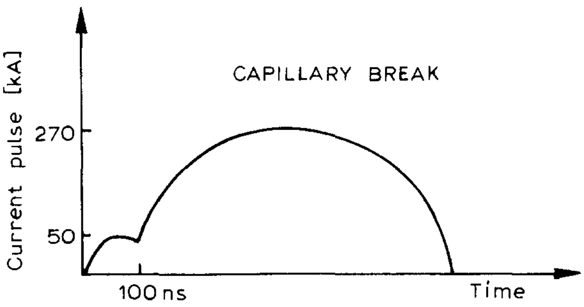

Fig. 7. Current profile in $K_4Fe(CN)_6 \cdot 3D_2O$.

a large volume (600 ℓ) liquid scintillation detector with a gadolinium (NE323) loaded scintillator.

For the time and angular distribution of emitted neutrons were used the NZ213 (proton recoil method) based liquid scintillator detector, because of its excellent time response characteristics.

Our detection system is able to detect 2.45 MV neutrons emitted simultaneously in a broad time interval (about 40 μs) with an efficiency of about 80%.

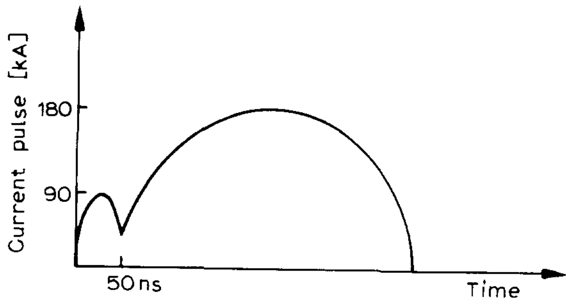

Fig. 8. Current profile in deuterated Pd powder.

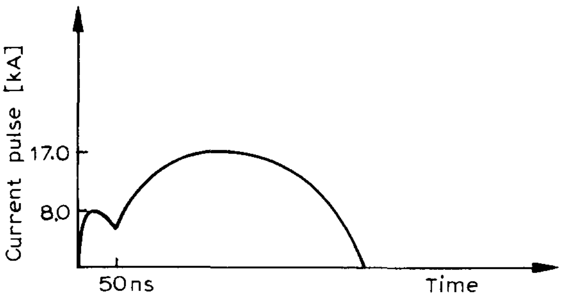

Fig. 9. Current profile in deuterated Pd wire.

It is very important in the case of the PF and CF experiments – since a discharge produces EMI – that these EMI can be avoided by a few μs delay of the start of the neutron counting.

A pin hole camera has been used for determination of positive particle fluxes emitted from the plasma focus (Pd, ^3He).

3. Results and discussion

Until now, we have performed measurements in the case of PF of the following values: (1) capacitor bank voltage; (2) pinch current; (3) neutron yield; (4) fluences and energies of positive ions emitted in the energy range 1–20 kJ, as well as their angular distribution and the axial velocity of the current sheath propagation.

The neutron yield was measured by using a large liquid scintillator (NE232) tank surrounded with 12 photomultipliers which was placed at a distance of 8 m from the PF and CF chamber. For high fluxes ($>10^6$ neutrons/pulse) the integral flux of neutrons was measured by a detector. The treshold of the large detector is 10^3 neutrons/pulse. Typical results for PF are shown in figs. 4 and 5.

For the measurement of the positive particle fluences, a pin hole camera (with CR-39 and CA 85-15 Kodak film) was placed at the optical window position. The maximum yield of positive particle fluxes was obtained in the case when the pin hole camera was placed at the position normal to the PF axes when the neutron yield was maximal in the same discharge.

The comparison of our results with data of other laboratories is shown in fig. 6.

Measurements of the current time development in CF with different deuterated compound show two current peaks similar to the published results [1,4,5]. Typical results for the deuterated compound and deuterated Pd are shown in figs. 7–9.

The neutron yield in these experiments was smaller than 10^3 neutrons/pulse.

As we were finishing the preparation of this Letter for publication one of the authors (J.P.V.) was informed by Professor Hagelstein of MIT of the results by Spence and Vary on the existence of electron–proton [8] and electron–positron [9] resonances at low energy from a relativistic two-body wave equation. They are evidently related with the assumption of this Letter since in the former case the *K*-matrix for electron–protoon scattering can be evaluated in the O^+ channel from 0.5 to 50 eV using a relativistic wave equation derived from QED but different from the approximate equation suggested by one of us [4]. They find very narrow resonances at $E \approx 0.748$, 1.347, 2.095, 3.032 and 4.707 eV. Since these are short range phenomena these resonances may provide a super screening mechanism for fusion reactions: somewhat analogous to muon-catalyzed fusion. No real extensive search for such resonances has been made to our knowledge but they should appear as maxima in electron–proton and electron–hydrogen scattering at low energies and in the uv spectrum of hydrogen under specific conditions. They should also appear in the form of soft X-ray emission in various electrolysis or glow discharge experiments. The existence of new Bohr orbits in the similar electron–positron system is in a better experimental situation since very narrow resonances (called "photonium") were found at energies which compared favorably with electron–positron coincidence data from heavy ion collisions performed at GSI [10]. Indeed the *K*-matrix for electron–positron scattering evaluated in the O^+ channel (for three equations derived from QED) yields very narrow resonance at mass values 1.351, 1.498, 1.659, 1.830, 2.099 and 2.195 MeV. Direct e^+e^- (Bhabha) scattering experiments [9] have shown resonances with masses 1.702, 1.684, 1.832 and 1.662 MeV. A more recent experiment [9] has also shown a peak at 1.51 ± 0.02 MeV close to 1.498 MeV. All experiments agree on the strongest peak at ~ 1.83 MeV and on a secondary peak at 1.65 MeV.

Despite the evidently encouraging evidence of break-even in present-day experiments a considerable amount of work is necessary to understand the real physical nature of the new hydrogen energy and to develop the corresponding technology. We are still discussing on a semi-heuristic level but

(a) on the theoretical level one has still no generally accepted model of the origin of the excess heat observed in low intensity electrolytic and glow discharge experiments. In our opinion the detection of a soft X-ray spectrum would strongly enhance the validity of our "exotic" quantum chemistry interpretation.

(b) on the experimental level one should pass from a low energy to a high energy input. To that effect the our further investigations will be directed towards detailed studies of voltage, energy relationships, conductivity, the input current intensity dependence of the neutron yields, and the lowering tresholds in neutron detection.

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