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SHRINKING OF HYDROGEN ATOMS IN HOST METALS BY DIELECTRIC EFFECTS AND INGLIS-TELLER DEPRESSION OF IONZATION POTENTIALS

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ABSTRACT

Conversion of deuterium to tritium in palladium has been clearly confirmed by the Arata-Zhang experiments. Endothermic element synthesis in Pd. and/or Ni layers due to high proton concentration, in analogy to stellar synthesis can be seen from the generation of very rare elements such as terbium. A convincing explanation is necessary. It was concluded phenomenologically that the reaction of the protons or deuterons by fusion or with the nuclei of the host metal occurs at a distance of about picometers with a reaction time of about megaseconds. It was noted that the Bohr radius r_B of hydrogen atoms in a dielectric with refractive index **n** is changed to $r_B\mathbf{n}^2$. such that with the electron concentration of the host metals a plasma refractive index of 0.076 results in a value of 3pm. In order to understand the subsequent dielectric modification of the ionization energy, we apply the model of depression of this energy by the Inglis-Teller effect for which a model with the best agreement with plasma experiments was presented before. For our model of the dielectrically shrunk picometer hydrogen atoms, the low ionization energies result in a reasonable relation between dielectric properties and the effective Debye length. Preference of the reaction at surfaces or interfaces between different host metals are due to the same reduction of the dielectric response as observed with surface plasmons. For the swimming electron layer theory, the spreading of the double layer for metal interfaces was discussed.

1. INTRODUCTION

As will be shown in more details at this conference, the confirmation of nuclear reactions of hydrogen isotopes in host metals is based at least on the following experiments. The Arata-type electrolysis of palladium black under extremely clean conditions[1] convincingly showed the generation of large amounts of tririum[2], partially decaying into He^3. The reaction of protons in palladium/nickel layers[3] for generation elements from the whole periodic table had been proved by the fact that some rarest of rare earth elements (terbium) were peoduced[4,5]. Heat production at these experiments was demonstrated by measuring the heat radiation using sensitive image converters where areas of more and less heat production can be distinguished[6]. This clear demonstration of heat production was necessary because calorimetric measurements of heat production were not always convincing. The MITI-supported NHE Institute in Sapporo bought 20 Fleischmann-Pons cells from the French IMRA laboratory where heat production was claimed. S. Pons worked several weeks with these cells and could not demonstrate any he at production in the NHE laboratory in Japan[7].

The fact that no significant gamma emission was detected (apart from soft x-radiation) may be understood from the fact that the initially suggested signals[1] of high He^4 production could not be confirmed[2]. On the other hand, the very high tritium production from D-D reactions and the near absence of neutron production can be understood from the theory of Li et al.[8] –the very first theory for the DT cross sections despite the long history of hot fusion! -that reactions at large separations are characterized by bouncing of the neutrons in the SchrÖdinger potential with the imaginary part of the nuclei leading to no neutron emission. Most convincing is the fully reproducible detection of alpha particles by CR-39 traces[9] similar to earlier measurements by Li et al.[8].

2. SETTLED PHENOMENOLGICAL THEORY

In order to contribute some views on the theoretical understanding of low energy nuclear reactions (LENR) between hydrogen isotopes, as well as their reactions with larger nuclei, we first shall mention some agreed results, remembering that there are "twenty theories" and numerous exotic models known. Indeed this is a challenge with the basic problem that we trained for treating models in classical physics while quantum mechanics is of a basically different (statistical) nature. When Edward Teller asked Niels Bohr whether one should better teach physics from the beginning in terms of quantum mechanics and get the classical picture as a consequence, Bohr preferred to stay with the usual way to think classically and apply these pictures to understand quantum physics[10]. In the mean time we learnt not only how to see the statistical nature of the decay of a radioactive nucleus, the discussion of Bell's theorem led to the visible clarification of nonlocality, e.g. that a neutron does undergo interference within an apparatus with another one which has not yet been emitted from an uranium nucleus[11]. These results are of importance also for the quantum modulation of electron beams[12] or for the consequence that if a physics with fractions of quantization would be designed[13] that then energy conservation breaks down[13].

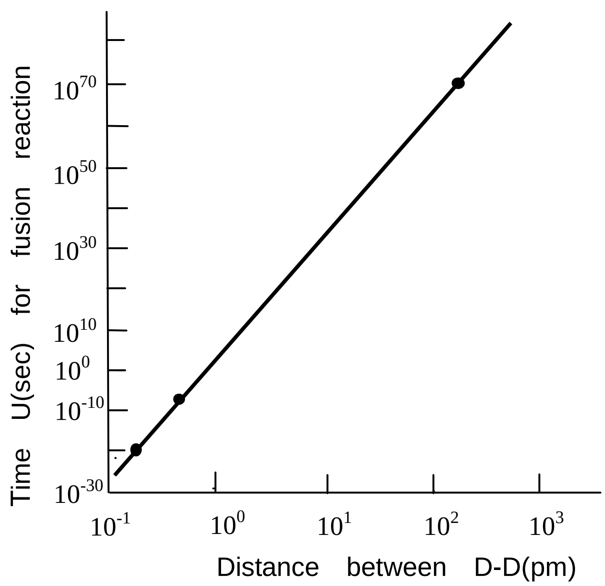

Fig.1. Measured reactions times U and nuclear distance d in picometers (points from the left) for hot fusion, for muonic fusion and calculated for fusion of nuclei in a D_2 molecule. The semi-empirical line indicates the picometer-Megasecond reaction fitting some serious experiments on LENR with some similarity to time and distances (Bohr radius) of the K-shell inverse beta decay [15].

In connection with cold fusion, Scott Chubb et al.[14] underlined the problem of the distance between that of the nuclear size and that of atomic size. This is just the problem with hot fusion, where exceptionally the reaction occurs at distances of more than 100 nuclear radii[15] at energies below 10 keV while all the usual nuclear reactions occur at MeV energies only at femtometer distance. This arrives at the key result (Fig. 1) of the nuclear distance d derived phenomenologically from the experiments of hot fusion, of muonic fusion and the calculated reaction time U in the 10^{80} s range for the reaction between two deuterons in a D_2 molecule of [15]

$$U = 8.1\times10^{4} d^{34.8} \text{s}, \qquad \text{with d in picometer (pm)} \qquad (1)$$

Using the few non-electrolytic measured reproducible reactions of that time, it was derived that LENR happens roughly speaking at distances d of picometer within times U of megaseconds. These Ms-pm nuclear reactions are not unknown since K-shell electron capture is of the same time and length scales though this differs as a process of weak interaction.

From the result of Eq. (1) it was concluded[15] by comparison with experiments that if the hydrogen atoms are ionized in the host metal and the protons or deuterons are like a Maxwellian plasma within the lattice, that these can approach to distances of pm if there would be a Coulomb screening of a factor 13. In high temperature plasma, a screening of up to 5 is well known[16] and in order to achieve a factor 13 in the metal, it was assumed that the swimming electron layer of the degenerate electron gas at the metal surface provides the necessary screening. This model was successful to reproduce the work function and the measured surface tension[17] of metals. The swimming electron layer between metals of different Fermi energy works in the same way for screening and the fact that multi-layers of Ni/Pd increased cold fusion[3] may have proved this effect. Furthermore it was measured by Rutherford backscattering that the reaction of protons with the nuclei of the host metals resulted in generated nuclei whose concentration decreased with distance from the surface[3].

3. CONSISTENCY OF THEORIES

While the phenomenological semi-empirical theory described in the preceding chapter seems to be solidly based, there are further indications of theoretical consistency with measurements. The first significant result of the multi-maxima distribution of the atomic number Z-dependence of the generated elements[3] by LENR turned out to be fully similar to the standard abundance distribution, SAD, of elements in the universe[18,19]. The exponential decay of the maxima in Z had a similar increment of 10. It was most remarkable that from the measured ratios of these endothermic generation probabilities of elements in the universe or in the host metals by LENR, the sequence n = 1,2,3..of Bagge's nuclear magic unmbers[20] could be derived[18,21] as 3^n where the necessary jump from one sequence to the other could immediately be concluded for which the well known reason is given by spin and spin-orbit properties of nuclei from the theory of Jensen and Maria Göppert-Mayer.

Additionally, this theory permitted the calculation of higher magic numbers 180 and 246 than these derived before. The new numbers are in better agreement with measurements and with the relatively stable $^{306}126$ nucleus from the theory of Greiner[22] or in extension[19] of the specially measured Seaborgium[23].

Apart from the maxima of the Z-distribution of the LENR-produced nuclei, also the minima were unique since these showed a small local maximum[24]. at A = 153. It should be mentioned that a similar local maximum was not found initially in the generation distribution of fission products in the main minimum. Only after the local maximum was deduced theoretically from the different fission processes[25] it was measured at A = 119 for ^{238}U fission. In a similar way, the local maximum was not known to Miley before the meadurements[26]. The LENR-result again indicated the probability that the nucleus $^{386}126$ may have been an intermediary state for reactions of the protons in the palladium host metal for n endothermic compound nucleus process in order to finally arrive at nualei which directly could have been produced only by an endothermic process[24].

4. HYPOTHESIS FOR PICOMETER REACTION DISTANCE BY SHRINKING OF HYDROGEN ATOMS

After the pm-Ms reaction for LENR may be sufficiently clarified, the ionized plasma state of the hydrogen or deuterium in the host metal needed the strong Coulomb screening as discussed by the swimming electron layer at surfaces or intermetallic interfaces. We had discussed this also on the basis of the Debye-Milner[27] theory that the degenerate electron gas in the host metal may provide Debye spheres of 3 pm diameter[15,19]. The swimming electron layer theory was discussed in view of spread double layers at metal interfaces for the degenerate electrons.

Alternatively to the ionized state of the hydrogen or deuterium in the host metal, we consider hypothetically what properties will be given if the atoms are not ionized but are affected by the dielectric (metallic) plasma properties in the host metal. First we have to realize that the conduction electrons of the metal show a curious difference in behaving optically or thermodynamically. For optics, the electron gas responds like a plasma fluid of the given density of the electrons n_e. This can be seen that the optical constants are exactly the same as in plasmas with a plasma frequency $\omega_p = (4\pi e^2 n_e/m)^{1/2}$ using the charge e and the mass m of the electron. Also the electron ion collision frequency ν acts for the absorption exactly as in the metal to produce the identical metal optical constants. The refractive index **n** at an optical radiation of radian frequency ω is[28]

$$n^2 = 1 - \frac{\omega_p{}^2}{\omega^2(1 - \frac{i\nu}{\omega})} \qquad (2)$$

These plasma-optical properties for explaining metal optics were used in a textbook[29] following a suggestion by Nikolaas Bloembergen.

On the other hand, the energy states of the electrons in the metal are determined by Feimi-Dirac statistics as seen from the thermal capacity and other properties. Though the electrons have an energy corresponding to few ten thousand degrees only the small amount of energy above this Fermi energy defines the thermal properties of the plasma. For the Debye length 1_D the room temperature T of 0.03 eV of the metal has to be taken (and not the Fermi energy for determining the swimming electron layer[17]) such that for the density $n_e = 1.2\times10^{23}$cm^{-3} of conduction electrons of palladium the metal, the Debye length in cm is[28]

$$\lambda_D = 743(\frac{T}{n_e})^{\frac{1}{2}} = 3.7\,pm \qquad (3)$$

This would be sufficient to explain the screening of ionized hydrogen or deuteron ions in the host metal within the Debye sphere with this radius to understand their interaction without Coulomb repulsion within this pm distance.

But gong back to the hypothesis that the hydrogen or deuterium are not-ionized neutral atoms, this could be understood in the following way. A hydrogen atom within a dielectric environment of refractive index **n** can be described similar to the excess electron of a V-element (e.g. As) in the diamond lattice of silicon. The refractive index is about 4 and the Bohr radius $r_B = h^2/(4\pi^2 m^* m e^2)$ using the effective mass m*(see Appendix A of Ref.[28]) is increased to

$$r = r_B \mathbf{n}^2. \qquad (4)$$

This increased electron radius can be seen from scattering experiments and result in the well known reduction of the ionization energy

$$E_i = \frac{h^2}{8\pi^2 m^* m r^2} \qquad (5)$$

of a few meV as observed.

In metals and plasmas the dielectric constant **n** is less than unity (ignoring here the collisions or absorption for simplification) For the hydrogen or deuterium in the host metals-with the question what optical frequency w has to be adjusted – the refractive index can be e.g. **n** = 0.076 resulting in a Bohr radius of 3 pm. In this case, the ionization energy would go up to very high values due to the square of r in the denominator. This is well known from of the magnetic rotation theory of Vigier for cold fusion[30].

In our plasma model, however we have to take into account the Inglis-Teller effect of the decrease of the electron levels of an atom if located within a plasma, leading to the polarization shift of ions and the decrease of the ionization energy. A special quantum model of an atom taking into account the electrostatic Coulomb energy and its modification by the background field of a surrounding plasma[31] (see Section 2.3 of Ref.[28]) reproduces the measured polarization shift of hydrogen atoms in plasmas better than a semiclassical model or that of approximating the SchrÖdinger equation. The reduction of the electrostatic energy ε by the plasma background is given by

$$\varepsilon = \frac{e^2}{2r^2} - \frac{e^2}{\lambda_D} \qquad (6)$$

Since our plasma conditions resulted in a Debye length λ_D in the pm range and r is by optical conditions of a similar value, we may conclude that the appropriate reduction of the ionization energy to values in the eV range is not impossible.

The hydrogen or deuterium atoms shrunk down to the pm size could then interact with each other or with the nuclei in the host metal or even in clusters of semi-molecular bindings, such that the pm-Ms reactions are possible either in the ionized stage (Section 2) or in the unionized stage as shown now. The favorable modification of the plasma frequency and the Debye length by factors $2^{-1/2}$ for the two dimensional geometry at the surface or interface of metals will increase the reaction probabilities such that the experience for using multi layers[3] to increase LENR events could be understood.

5. CONCLUSIONS

The few serious experimental results of LENR taken from the whole stream of reports during the last years are convincing. The process seems to be the pm-MS mechanisms as following [15] from Fig. 1 in agreement with serious experimental results and in agreement with Li's theory both for hot and cold fusion [8]. A further confirmation decay as the standard abundance distribution of elements in the universe shows the same exponential decay as the measured endothermic element generation by LENR leading to a new relation of the magic numbers of nuclei. While realizing from the experiments [3] that surfaces or interfaces favor LENR, the question whether the pm-MJ process is for ionized hydrogen states with inclusion of the swimming electron layer for the necessary Coulomb screening or is for an unionized state with shrunk atoms may be open. Both models will need more detailed exploration after the basic LENR process has been clarified.

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