SEARCHING FOR TRUTH WITH HIGH EXPECTATIONS

--5 Year Studies on Cold Fusion in China --

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ABSTRACT

The "cold fusion" research in China is reviewed for the past five years. Emphasis is focused on the attempt to set up the Chinese-based reproducible experiments and the study on the key parameter which is supposed to control the reproducibility. Theoretical effort in understanding these phenomena is described as well.

INTRODUCTION

The situation of "cold fusion" in China is similar to that in Russia. Since communication was somehow delayed, we started the "cold fusion" research based on our own understanding and the resources available to us[1-14].

After 5 years of studies on "cold fusion", more people in China think that there must be something behind it, and it is worthwhile to seek the truth for the fundamental physics, and for the possible future energy.

Research in China has been conducted in both theory and experiments with more emphasis on experiments. The experiments are in two categories: (1) Attempt to set up a Chinese-based experiment; (2) Study the key parameters which might control the reproducibility of the experiments.

We have three efforts to set up the Chinese-based experiments: (1) The electrical discharge in deuterium gas with palladium electrode; (2) Gas loading experiments with detectors to search the precursor and the energy carrier for the anomalous phenomena in D/Pd systems; (3) Excess heat measurements in D/Pd and D/Ti systems.

Based on international academic exchange, the loading ratio of deuterium in palladium was selected as a key parameter to study. We designed several systems to study the various treatments which might affect the terminal loading ratio and the loading speed. Some factors have been identified which may enhance the loading ratio to pass the resistance peak, and over the threshold (i.e. D/Pd~0.84).

Theory is important, although it is still in an immature stage. Wherever the experiments continued in these 5 hard years, there must be a plausible "theory" to stimulate the investigators. The penetration of the Coulomb barrier has been a persistent subject over 5 years. Bohm's theory has been developed in three aspects: (1) The direction of WKB connection formula, which has been a controversy for more than twenty years; (2) A simplified formalism for WKB method which is particularly useful for a chain of potential barriers and wells; (3) A new explanation of the penetration of potential barrier in quantum mechanics. The recent calculation shows that the split of the Coulomb barrier may be necessary, and some experiments have been suggested to test this idea.

We have started three new sets of experiments:
(1) The electrolysis of pressurized heavy water to study the "excess heat" in high temperature condition, based on our experience with pressurized light water fission reactors. (2) The enhancement of spontaneous fission in uranium due to hydrogen loading. (3) The positron annihilation studies of the surface layer of the palladium sheet during the hydrogen loading.

Electrical Discharge in Deuterium Gas

Five years ago, when the fax copies from the US were disseminated in China, a lot of experiments were tried to reproduce the electrolysis or the gas-loading results. Some of the Chinese scientists decided to do something else.[1-4] The electrical discharge in a deuterium gas tube was one of these pioneer works. Xiong[1] et al. at the Southwestern Institute of Nuclear Physics and Chemistry reported the first observation of neutron bursts in an electrical discharge tube with a palladium cathode and a tungsten anode. The neutron yield was -10^6 per burst. It was too high to convince enough people to continue this experiment in that Lab. However, an elder scientist (Long, H.Q.[3,4]) at the Sichuan Institute of Material Technology continued this electrical discharge experiment under difficult conditions. After three years of silent research, it was found that the "anomalous neutron emission" was reproducible as long as three prerequisites were satisfied i.e. (1) a thin film of palladium was formed on the surface of discharge bulb; (2) the deuterium gas was flowing through the discharge bulb at a low pressure(5~17 Pa.); (3) the A.C. voltage between two electrodes was in certain range (6000~17000 V.).

The neutron emission was reproducible and verified by an activation method which was free of electromagnetic disturbance, and there was no neutron emission in the control run with hydrogen or helium gas. The neutron emission was considered "anomalous" because an unexpected peak was observed in the neutron energy spectrum. The ordinary D-D neutrons were supposed to peak at 2.45 MeV; however, a high energy component appeared with energy greater than 5 MeV. A careful study on this anomalous neutron emission revealed that this "neutron peak" was indeed caused by the overlap of intensive X-ray radiation.[5,6]

However, it is still a puzzle why the low energy radiation is so intensive at this discharge condition. Scientists at the Institute of High Energy Physics [7] were stimulated by this puzzle to redo their early experiment. In 1989, they detected an anomalous low energy radiation with no neutron emission. They stopped their experiment, because four years ago the overwhelming point of view was that neutron emission was the necessary feature of anomalous phenomena. Now more people believe that the neutron is not necessary, but the energy carrier must exist somehow to explain the excess heat. So they returned to their early data again. They have found that in fact there were several peaks in the low energy radiation (< 900 keV). These peaks corresponded to the characteristic lines of spectrum for electrodes: a peak at 425+40 keV which corresponds to the nuclear de-excitation process: 108Pd* → 108Pd + γ (E_γ = 425 keV), and a peak at 870±50 keV which corresponds to $^{56}Fe^* \rightarrow {}^{56}Fe + \gamma$ (E_γ = 854 keV).

The electrical voltage between the electrodes of the discharge tube was 10 kV, which was too low to excite the nuclides for γ-ray emission. There should be some energetic charged particles with several MeV. So this was an indication of nuclear reaction products. The A.C. voltage was in a pulse shape, and the instruments for detection of neutron and γ-ray were set to work only in the intermission period when the pulse was over; hence, it was supposed that there was no electromagnetic disturbance. One might suspect that some induced high voltage could accelerate the deuterons to produce the ordinary D-D fusion reactions, but the neutron detector did not register any neutrons above the background level. Hence it is suggested that there were two stages of reactions: the first stage was the anomalous D+D reaction which produced only proton (3MeV) and tritium without the neutron branches; the second stage was the Coulomb excitation induced by 3 MeV protons. Then the de-excitation gave the characteristic gamma ray.

Calculations show that the gamma yield is about 10^{-6} per 3 MeV proton absorbed in palladium, and this result can be probably explained by the decay of excited Pd* and Fe*. Since tungsten electrode was used also, there should be a de-excitation process: $^{184}W^* \rightarrow {}^{184}W + \gamma$ ($E\gamma$=110 keV). If the low energy spectrum could get rid of the noise, one should have seen the 110 keV gamma-ray as well. Recently an unexpected peak has been seen around 130 keV, which could not be attributed to any Coulomb excitation process. Fortunately, Professor Hagelstein is just looking for a peak around 129.5 keV to explain his neutron transfer reaction.

Gas Loading Experiment

Another early experiment in China was to identify the precursor and the energy carrier for the anomalous nuclear phenomena[8,9]. We proposed that the necessary product of any nuclear process is the energetic charged particle; the neutron is not a necessary product for any nuclear process. The CR-39 plastic track detector was used in a "freeze and thaw cycle" or D/Pd system to detect the energetic charged particles. The CR-39 detector is particularly suitable for this process, because it can be sealed in a high pressure container with direct contact to the palladium surface and is free of any electronic noise. It has the highest sensitivity among all the detectors available to us. It is possible to avoid any cosmic interference by the pre-etching method, and the air-borne radiation background can be deduced by control run with hydrogen. We saw the energetic charged particle in the early experiments with the Russian palladium imported in the early 60's. However, the signal was greatly reduced in the later experiments using other palladium samples or the titanium samples.

In order to reproduce the early experiments, a systematic study[10,11] on the loading ratio (D/Pd) in gas loading experiments was started in 1991 after a visit to Stanford Research Institute. It is clear that the reproducibility depends on the loading process. The annealing in the vacuum, and the multiple-step loading have been identified as two important factors which may affect the terminal loading ratio. Table 1 and Table 2 in Ref. 11 summarize the gas-loading experiments with palladium in hydrogen and in deuterium. It is possible to reach the loading ratio of D/Pd >0.84 by annealing in the vacuum, and multiple-step loading under 30 atm.

Excess Heat Experiments

Calorimetric experimentation is difficult and requires more funds and time, so it is done in only a few laboratories in China. The Institute of Chemistry, Academy of Science, keeps a small group using microcalorimetry[12]; and the Institute of Atomic and Molecular Science at High Temperature and High Pressure, Chengdu University of Science and Technology keeps doing electrolysis of heavy water with titanium cathode and platinum anode[13]. They measured the temperature inside the Ti-rod, and observed the extraordinary ascent of temperature five times among seven experiments. Although the explanation of extraordinary ascent of temperature is unclear yet, they found that if a mixture of H_2O and D_2O was used as the electrolyte, then no extraordinary ascent of temperature was observed. The extraordinary ascent of temperature was about 1.5~24°C dependent on the size of the Ti-rod. The SIMS (secondary ion mass spectrum) analysis showed strangely that the Ti-rod sample above the water level absorbed much more hydrogen than deuterium if there was some H_2O in the electrolyte. However, the Ti-rod sample beneath the water level absorbed both deuterium and hydrogen. The hardness and the metallurgical structure of the Ti-rod were monitored before and after electrolysis.

Theory -- Precursor and Energy Carrier

It is too early to extract any definite theoretical model from these experiments. However, it is essential to have some kind of "plausible" theory to stimulate the effort in experiments. Five years ago when the neutron was taken as the characteristic symbol of the anomaly in D/Pd systems, we proposed that the energetic charged particles might be the necessary signal for any anomalous nuclear reaction. This idea led to a series of studies using CR-39 (plastic track detector). When the sporadic bursts made the experiment unpredictable, we suggested that there had to be some precursors before the anomaly appeared. This idea led to careful studies about the electromagnetic radiation using thermal luminescence detectors.[8,9] When international academic exchange revealed that the excess heat might not be accompanied with nuclear signals, or the amount of excess heat might not be compatible with the weak nuclear signal, we considered that a two-step model[14] might be necessary to reconcile the two facts: (1) More experiments confirmed that there was some excess heat in the closed system[15], and in the open system[16]; (2) The nuclear signals (helium-4[17] or tritium[18]) seemed always very weak, and were compatible only with low level energy release. The two-step model requires a strong electron screening effect to reduce the Coulomb barrier and release enough energy to explain the experiments. Although it is still premature to imagine some theoretical model for this kind of screening, it is possible to deduce some corollaries from this two-step model, which can be tested by experiment. For example, the screening means a region of high electron density which may be detected by positron annihilation technique; the penetration of the Coulomb barrier by resonance tunneling must help both the fusion and fission, which might affect the spontaneous fission of the fissile elements. Both of these experiments are currently under way in China. We have to identify what are the precursors, and what are the energy carriers in this D/Pd system.

The other aspect of theoretical work is just to develop the theory itself to make it compatible with the need to explain the experiments. For example, the WKB method is commonly used in quantum mechanics for calculating barrier penetration. However, the resonance tunneling needs special attention to the direction of the arrow of the WKB connection formula. Even in Bohm's discussion of resonance tunneling, the problem of the direction of the arrow is barely mentioned. The famous Russian theoretical physicist L.D.Landau said quite differently in the 1960's and 1980's[19]. This is still controversial in the textbooks on quantum mechanics today. We investigate this problem, and find that the existing WKB connection formula can be used only in one direction. In order to use the WKB connection formula in resonance tunneling, it should be modified to include some additional parameters. However, the conclusion is that the resonance tunneling is still possible with a little correction. On the other hand, the physical explanation of resonance tunneling is still an open question. Usually, it is explained by a steady state calculation; however, it is essentially a non-steady state phenomenon. A careful study is necessary through both theory and experiments[20].

Another example is the uncertainty principle. If the electron cloud shrinks to form a strong screening effect, an energy level lower than usual ground level is always assumed. The Mills model[21] or the solutions of the relativistic Schrodinger equation and Dirac equation[22] are invoked to find this energy level, but the uncertainty principle is not compatible with it. A multiple body problem in the crystal lattice should be investigated.

CONCLUDING REMARKS

After five years of searching with high expectations, we are still working very hard. As long as the experiments are getting stronger in confirmation, we will keep searching for the truth.

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