New Neutron State in Transition-Metal Hydrides and Cold Fusion Phenomenon

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INTRODUCTION

The Cold fusion phenomenon (CFP) has been studied for more than 13 years without a consistent explanation based on modern physics. Relying on theories to infer the nature of neutron wave functions at the excited bound levels that are less than 1 eV from zero, we have shown that CFP in transition metal hydrides and deuterides is explained by the formation of neutron valence bands consisting of excited neutron states in metal nuclei mediated by occluded hydrogen (deuterium).[1]

THEORETICAL INVESTIGATION

Two experimental data sets [2,3] show that it is very difficult to measure neutrons with very low energies around several eV due to the large background, low counting rates, uncertainty of the neutron detector efficiency and difficulty in detecting low-energy neutrons (<500 keV). Fortunately, recent work on the parity violation measurements with medium and heavy nuclides have shown the existence of resonance levels down to 10 eV in absorption and transmission spectra of neutrons.[4] From these experimental data sets, it is reasonable to expect the presence of excited levels near zero with a long tail outside the nucleus..

Using two methods, we can determine possible wave functions of neutrons in excited states at and below zero energy (the separation level): wave functions suggested by neutron scattering cross sections [5] and wave packets of neutrons in excited bound levels in a semi-classical model by Weisskopf.[6] The wave function of the neutron with an energy $E = -|\varepsilon|$ is expressed as follows;

$$\chi(r) = C \times \exp(-r\sqrt{(2m|\varepsilon|)}/\hbar) \quad (1)$$

where C is a constant. This shows that a neutron level near zero has a slow damping exponential function extended out into space outside the nucleus.

Therefore, we may extrapolate the density of excited neutron levels determined by the experiment [2] to the energy domain near zero. We assume the existence of excited neutron levels (single particle or wave-packet type) around zero with wave functions extending out of a nucleus into outside space as (1) These decrease exponentially with a decay parameter $\kappa = \sqrt{}(2m \mid \varepsilon \mid)/\hbar$. The value of κ with the neutron mass $m = m_n = 1.67 \times 10^{-27}$ kg for $\mid \varepsilon \mid$ below 100 eV is easily calculated and gives $\kappa = 7$ (A $^{-1}$), the e-folding length $r_{1/e} = 0.14$ A for $\mid \varepsilon \mid = 0.1$ eV.

This value shows that the wave function of the neutron at excited levels near zero down to 0.1 eV extends far into space where proton or deuteron wave functions of occluded hydrogen isotopes overlap with it in transition metal hydrides, e.g. PdH. The lattice constant a = 3.89 A (Pd metal) and the static Pd-H distance is 1.95 A (octahedral) and 1.68 A (tetrahedral sites) using a for Pd.

When these neutrons with energies close to zero have wave functions largely extended out beyond the nuclear domain, they interact with occluded protons (or deuterons) through the nuclear force. The wave functions of the occluded protons (and deuterons) are represented as wave functions localized at interstitial sites [7] or Bloch functions of band states [8]. In either case, the wave functions have the possibility to spread out to lattice points where there are lattice nuclei with neutrons at excited levels near zero described above.

As a result, two neutrons in different adjacent lattice nuclei interact with each other through their interactions with the same proton (or deuteron) of the occluded hydrogen (or deuterium). This interaction results in neutron Bloch waves with a band structure in its energy spectrum.

RESULTS

The states of the neutron Bloch waves at band bottoms have almost the same energy and slightly different wave vectors, in general. Therefore, there appears local coherence [9] of neutron Bloch waves where they are reflected at a boundary (and/or surface) region of the crystal. Then, if there are many neutrons in the band excited from the ground states of lattice nuclei somehow, the density of neutrons in the boundary layer becomes very large. This results in the formation of stable neutron drops [10] composed of many neutrons and a few protons similar to the Coulomb lattice in neutron star matter.[11]

The scenario of the CFP will be described as follows. The background (ambient) thermal neutrons enter into a neutron band above zero (neutron conduction band) when they are trapped in a sample of the transition metal hydrides or deuterides.[12] Their density in the boundary (surface) region of a crystal becomes high due to the local coherence but may not be sufficient to form neutron drops. The neutrons in the neutron conduction band, however, can react with nuclei in the boundary region and the reactions can be called the trigger reactions. The nuclear products of the trigger reactions induce breeding reactions resulting in multiplication of the number of neutrons in the conduction band and also excitation of neutrons in lattice nuclei. This causes the formation of neutron valence bands. The neutron drops thus formed from neutrons in the valence bands in boundary layers effectively induce CFP.

ACKNOWLEDGEMENT

The author would like to express his thanks to John Dash of PSU for correcting the English of this paper. He is also thankful to Motoe Suzuki and Tsuneo Nakagawa of Japan Atomic Energy Research Institute for the information about the paper in reference [4]. This work is supported by a grant from *the New York Community Trust*.

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