Simulation of Palladium Transmutation Products

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Abstract. The build-up procedure for the Palladium isotopes is known from the independent-particle model and implies specific 3D structures for these isotopes in the nuclear lattice model [1]. Using those lattice structures, the favorable modes of fission have been simulated and the fission fragments compared with the transmutation products, as reported by Mizuno [2]. It is shown that (i) the changes in relative abundance of the Pd isotopes, and (ii) the main transmutation products in Mizuno-style LENR studies are consistent with the idea that the bulk of the energy released in such experiments is due to the fission of Palladium isotopes.

1. Introduction

The low-energy transmutation of nuclear species was discovered in 1938 and soon put to military and peaceful uses. Despite remarkable experimental and technological advances, nuclear theory has been ***unable*** to explain the asymmetrical (3:2) masses of the fragments produced by the fission of the actinides. After 7 decades of theorizing, most specialists on fission frankly agree with Moreau & Heyde [3] that "the theoretical description of the fission process is the *oldest problem* in nuclear physics, [but] it appears that a consistent description is still very far away."

A second form of relatively low-energy transmutation of nuclei has been reported in the "cold fusion" literature – specifically, the transmutation of Palladium isotopes (A=102~110) into a variety of small nuclei (A=30~80) subsequent to electrolysis in deuterated solutions. Theoretical controversy continues with regard to the inducing mechanism that leads to the generation of excess heat, but the measured changes in the ratio of Palladium isotopes and the deposition of many small nuclei on the surface of pure Palladium electrodes are strong indication of the fission of the Palladium nuclei. It therefore appears that there are at least two distinct stages in the "cold fusion" reaction: (i) the tunneling of deuterons into the Palladium nucleus, and (ii) the break-up of the Palladium nuclei themselves. The mechanisms of stage (i) remain controversial, but the nuclear transmutation data of stage (ii) have been replicated several times, and have remained essentially unexplained. In computer simulations, we have studied questions concerning the isotopic changes of the Pd electrode themselves [4] and found the Mizuno data [2], in particular, to be self-consistent and indicative of nuclear transmutation. In the present study, we have again made a comparison of simulation results with the experimental data on the Palladium fission products.

2. Simulation of the Fission of Uranium

We have previously reported that a lattice model of nuclear structure [1, 5, 6] – essentially, a "frozen" liquid-drop that is mathematically identical to the standard "independent-particle model" (IPM) – predicts the *asymmetrical* fission fragments produced by the thermal fission of the actinides [5, 7] *without* using any "adjustable parameters" to produce the asymmetry (Figure 1). The basic effect is a consequence of the fact that scission along oblique lattice planes of the somewhat oblate FCC structures for the actinide nuclei requires breaking fewer nearest-neighbor nucleon-nucleon "bonds" than vertical or horizontal slices through the same structures. Because of the large excess of neutrons that give the actinides an oblate shape, the oblique slices through the lattice structures show a 3:2 mass ratio. That result can be verified using the *Nuclear Visualization Software*, available at: http://www.res.kutc.kansai-u.ac.jp/~cook. Similarly, the fission of Palladium (Section 3) can be easily simulated using the same software, and shows that the ***symmetrical*** fission of the approximately spherical Palladium isotopes is energetically favored.

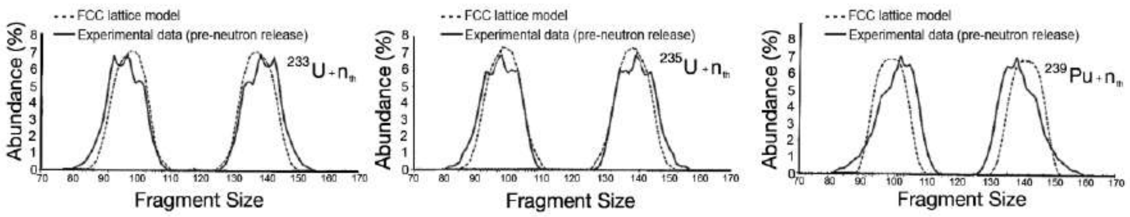


Fig. 1 - The prediction of asymmetrical fragments in the thermal fission of the actinides [5, 7] using a model that employs no parameters to produce the fission phenomena.

3. Simulation of the Fission of Palladium

Here, we apply the *same* lattice technique to the fission of the six stable Palladium isotopes. In a preliminary study, we calculated the total binding energy across each scission plane minus the Coulomb repulsion between the fragments. The lowest energy fission events in each of 6,000 randomizations were then collected (Figure 2). Most fragments were stable or led to rapid β^--decay, with a predominance of ^{24}Cr final products and little ^{23}V, qualitatively similar to the spectrum of deposits on Pd, as reported by Mizuno [2] (Figure 2b, c).

The qualitative agreement between the experimental data and the simulation using the lattice model were encouraging (Figure 2c), but far from definitive. In a recent simulation, we have used a quantitative calculation of the magnetic force between nucleons that is both spin- and isospin-dependent, in order to obtain more precise predictions about the transmutation products. Details of the force are provided in a separate contribution to this Volume [8]. The simulation procedure was similar to that described in [5] and [7], but was done using the magnetic force between nucleons. Specifically, the previous nuclear force was a phenomenological estimate of the mean nearest-neighbor binding among nucleons in the lattice model (i.e., 2.78 MeV). That level of nucleon-nucleon binding among nearest-neighbors has been shown to reproduce the approximate nuclear binding-energy curve of all but the smallest nuclei, but had no dynamical basis. In the present study, we used the spin-, isospin- and distance-dependent magnetic nuclear force described in [8] to calculate the likelihood of scission along various lattice planes. For the purposes of the simulation, it was sufficient to use fixed values for various spin- and isospin-combinations for nearest-neighbors.

The simulation procedure was as follows:

Each of the six stable isotopes of Palladium was individually constructed in the NVS software following the known (IPM) nucleon build-up sequence. By default, this leads to relatively compact lattice structures, but there are necessarily a large number of alternative surface positions for both protons and neutrons that give similar numbers of total nucleon-nucleon bonds and similar total Coulomb effects for the same Z and N. For simulation of fission fragments, each isotope underwent surface randomization 1000 times and a

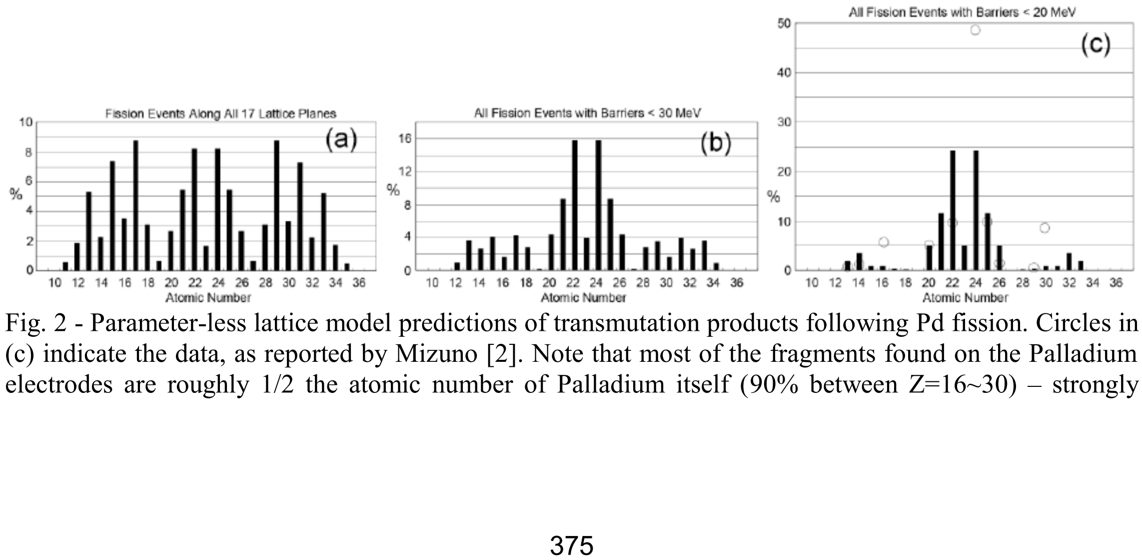
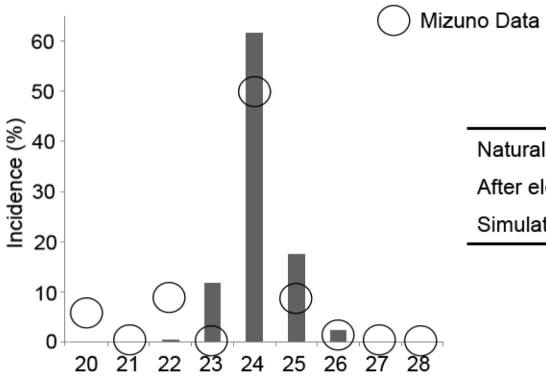


Fig. 2 - Parameter-less lattice model predictions of transmutation products following Pd fission. Circles in (c) indicate the data, as reported by Mizuno [2]. Note that most of the fragments found on the Palladium electrodes are roughly 1/2 the atomic number of Palladium itself (90% between Z=16~30) – strongly

indicating that they are indeed fission fragments and ***not*** transmutations built from the repeated addition of neutrons, etc.
small number (arbitrarily set to 9) showing the greatest nuclear binding were retained. These relatively stable structures were then scissioned along 17 lattice planes passing through or near to the center of the lattice. For each isotope undergoing such scission, the lowest energy scission plane was chosen, and the proton and neutron numbers of the fragments were saved for statistical analysis. A total of 46.2% of the Palladium fission products were stable nuclei, 53.8% were unstable. For all unstable fission fragments, the stable end-products were then calculated (without exception a stable isotope was obtained by one or two β^--decay conversions of neutrons into protons). Half-lives ranged from 33 seconds to 5.8 minutes, with a small number leading to exotic decays. Finally, the percentages of such fragments were adjusted in light of the different natural abundance of the six Palladium isotopes (Pd^{102} 1.02%, Pd^{104} 11.14%, Pd^{105} 22.33%, Pd^{106} 27.33%, Pd^{108} 26.46% and Pd^{110} 11.72%).

The results of the simulation in comparison with the Mizuno data [2] are shown in Figure 3(a). The large excess of Chromium isotopes found experimentally was well-reproduced, but other aspects of the results indicate that a wider spectrum of simulated Palladium structures should have been sampled (arbitrarily set to the 9 most stable nuclei – i.e., specifically restricted to the most stable, most compact Palladium structures to avoid the production of the fission products from highly unstable Palladium isotopes). Specifically, fragments with relatively large and small atomic numbers (12, 14, 16, 20, 29 and 30) were not found in the simulation, but would have been obtained if less-compact lattice structures were retained for the simulation of fission (as in Figure 2). By restricting the simulation to the nine most stable lattice structures, the primary fission fragments from each of the Palladium isotopes was Chromium. Relatively strong contributions of Vanadium (Z=23) and Manganese (Z=25) were found in the simulation but not found in the Mizuno data.

Mizuno also reported the abundances of Chromium isotopes before and after the deuterated electrolysis experiments [2, Plate 15]. Specifically, he found that, although the natural abundances of the four principal isotopes (Cr^{50}, Cr^{52}, Cr^{53} and Cr^{54}) are known to be 4.3%, 83.8%, 9.5% and 2.4%, respectively, they were found at abundances of 14.3%, 50.9%, 23.8% and 10.9% in the experimental "ash" following the presumed fission of Palladium. These numbers are of interest primarily because an explanation due to "contamination" with Chromium is extremely unlikely: even if Chromium from the experimental apparatus had somehow appeared on the Palladium electrodes, they should appear at the natural abundances, whereas quite "unnatural" abundances were obtained. In our simulation, the abundances of these isotopes were 0.0%, 7.9%, 76.8% and 15.3%. Clearly, the simulation exaggerated the isotope shifts, but in the right directions for three of the four Chromium isotopes: a significant decrease in Cr^{52} and significant increases in Cr^{53} and Cr^{54} (Figure 3(b)).
The results of computer simulations of all kinds are highly-dependent on the underlying theoretical model and the choice of parameters used. The present simulations are no exception, so that the theoretical results must be considered in full light of the theoretical input. In this regard, it is relevant to note that the FCC



(a)

	Cr^{50}	Cr^{52}	Cr^{53}	Cr^{54}
Natural abundance	4.3%	83.8%	9.5%	2.4%
After electrolysis (expt)	14.3%	50.9%	23.8%	10.9%
Simulation	0.0%	7.9%	76.8%	15.3%

(b)

Fig. 3 - (a) A comparison of simulation results (bar graph) and the data from Mizuno [2], indicated by the open circles. (b) A comparison of the changes in the natural abundances of the four main Chromium isotopes following electrolysis with the simulation results.

lattice model that has been used so simulate the fission of both the actinides (A>230) and Palladium (A~106) was devised, first and foremost, to explain how the long-standing, mutually-contradictory nuclear models in nuclear structure theory can be viewed in a self-consistent manner [1, 4-6]. For that purpose, the lattice model requires both isospin and orthogonal spin layering of nucleons; those are assumptions that must be made to "make the model work" – specifically, to reproduce the known IPM nucleon texture in the lattice. Only much later after the development of the basic model was it realized [7] that scission of the lattice along lattice planes allows for an explanation of the "anomalous" asymmetry of the fission fragments of Uranium. No changes in the model itself and no *post hoc* addition of "asymmetry" parameters were needed to obtain specifically the 3:2 mass asymmetry of the fragments (Figure 1). On the contrary, it is inherent to the lattice build-up procedure that oblique slices through the lattice for oblate structures such as Uranium will produce asymmetrical fragments. In contrast, similar slices through the more spherical (x=y=z) structures of medium-sized nuclei, such as Palladium, lead to nearly symmetrical fragments. In other words, the predictions of both symmetrical and asymmetrical fission for Palladium and Uranium, respectively, are a consequence of the lattice geometry itself – and not a consequence of manipulation of the basic model.

4. Conclusions

Low-energy nuclear reactions continue to pose fundamental questions that conventional nuclear theory cannot answer. With regard to the fission of Uranium and all of the other technologically important actinides, the *asymmetry* of the fission products is regarded as "the perennial puzzle" of nuclear physics [9]. As noted by Vandenbosch and Huizenga [10], "no theoretical model … has been sufficiently free of parameter fitting to be generally accepted." Without a profusion of adjustable parameters, the LDM predicts *symmetrical* fission products and the shell model predicts fragments with "magic" numbers of protons and neutrons. Neither prediction is correct (despite what the textbooks assert), and has led to the development of hybrid models containing parameters that can be adjusted to fit the data. The most comprehensive modern study of asymmetrical fission is that of Möller and colleagues. In a computational *tour de force*, they concluded that "all of the observed fission phenomena [including the asymmetrical fragments] can be understood in terms of nuclear potential-energy surfaces calculated with five appropriately chosen nuclear shape degrees of freedom" in a 2.6-million parameter space. The inconclusive nature of such modeling, however, is apparent from the fact that the "appropriate" *post hoc* selection of parameters must be made in light of the experimental results [11]. Asymmetrical fission is *not predicted*, but rather *reproduced* by cherry-picking model parameters that give the desired results.

In contrast, we have shown that the FCC lattice model does not require any additional parameters to explain the *asymmetry* of Uranium fission fragments. The asymmetry is inherent to the scission of large, oblate nuclei along fission planes with the fewest "bonds" connecting the fragments. Similarly, we find that the *symmetrical* pattern of experimentally-known nuclear "ash" in Mizuno-style cold fusion studies is obtained from the same lattice-scission technique. We therefore conclude that the substructure provided by the nucleon lattice is a necessary addition to conventional nuclear structure theory and allows for an explanation of the masses of the fragments produced by both the thermal fission of Uranium and the nuclear transmutations detected in "cold fusion" experiments.

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