Role of Cluster Formation in the LENR Process

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Criteria for Judging a Proposed Mechanism

- The proposed process must be consistent with all correctly observed behaviors of CF. Transmutation and fusion must be explained by the same mechanism.
- The process must be consistent with well-established behavior observed in other fields of science.

1. All spontaneous reactions are exothermic
2. Energy resists going up hill.
3. Energy caused to concentrate enough to initiate a nuclear reaction can be expected to first initiate chemical reactions.
4. After formation by LENR, all isotopes will exhibit their known nuclear behavior.

Questions to be Answered

- Are clusters of d, p, n involved in cold fusion?
- If so:

1. How large are the clusters?
2. What is their role in producing fusion of d to make ^{4}He or to cause transmutation?
3. What are the important characteristics of the NAE that allow their formation?

Evidence for the Role of Clusters

- Transmutation provides the most obvious evidence for cluster involvement in CMNS.
- Additions cannot be made one at a time because:

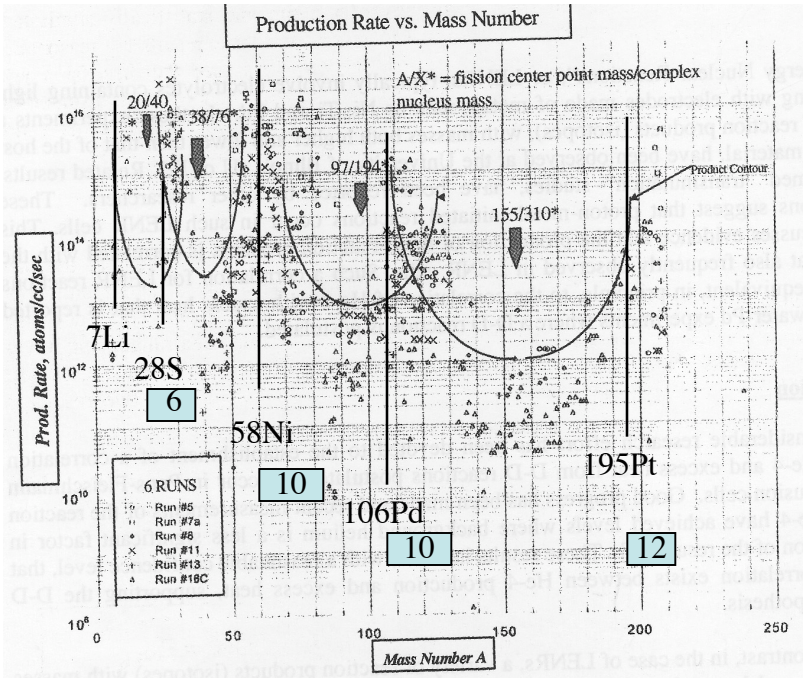
1. The concentration of isotopes resulting from the same target element would drop as an exponential function.
2. The limited number of stable isotopes in some elements limits the available paths to reach observed isotopes.
3. The reaction rate for production of large additions would be small.

IWAMURA et al.

Gas loading of D_2 in Pd with CaO

- Ba + 6d = Sm + ?, Q=67.6 MeV
- Cs + 4d = Pr + ?, Q = 50.5 MeV
- Sr + 4d = Mo + ?, Q=53.4 MeV
- Cs + 2d = La + ?, Q = ~24 MeV

MILEY et al.

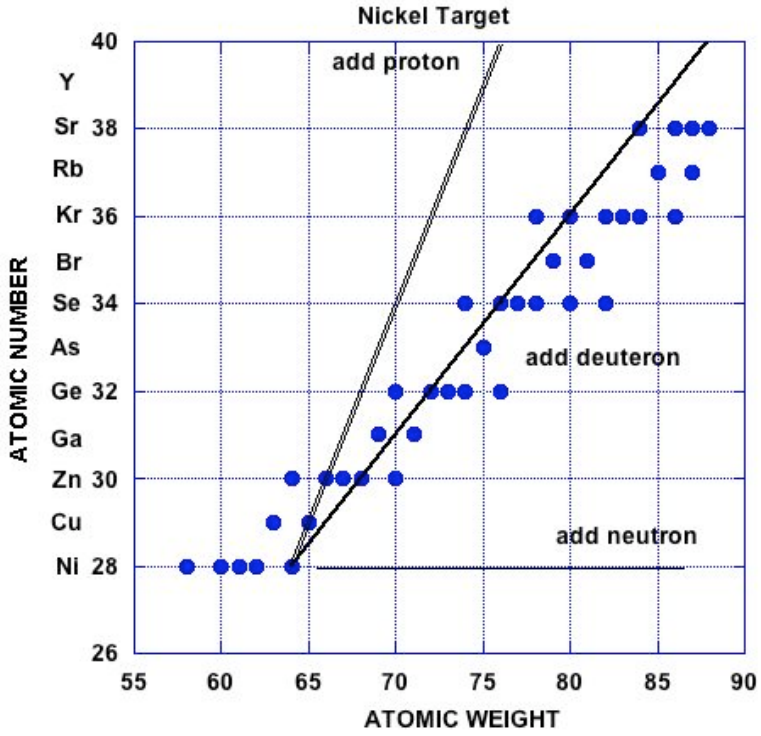


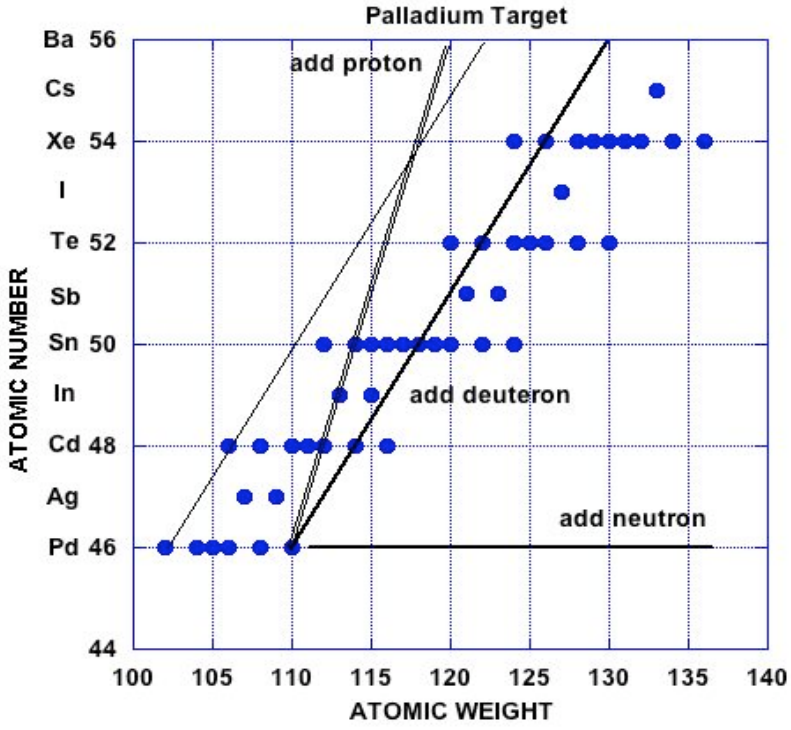
QUESTIONS: What is the target nuclei?
What is the range of cluster sizes? shown
What causes Mass Number below target MN at Ni?
What particles carry away the energy?

Pd+Ni electrolyzed in H_2O containing Li_2SO_4

Conclusion: Large clusters of various sizes are required to reach the upper limit of the transmutation range and to carry away the energy.

Consequence of Transmutation





Conclusions

- Neutrons are not involved in transmutation.
- Protons do not produce the full range of transmutation products.
- At least 10 deuterons can make a cluster and enter the nucleus of palladium or nickel.

Question: What role do clusters play in producing fusion of d to make ^{4}He and where does this reaction occur?

Rate Sensitive to Deuterium Concentration

- Excess Power = $M*(x-x_o)^2*(i-i_o)*\delta x/\delta t$, x_o= critical average D/Pd, i_o= critical average I/cm^2 (McKubre et al. 1995)
- M = n * [nae], where [nae] is the amount of NAE having 'n' efficiency
- Rate is greatest where deuterium content is largest.

  (Surface of F-P cathode, and surface of nanoparticles)
- The concentration of D in the surface of a F-P cathode will change rapidly as the bulk D/Pd approaches unity.
- Role of flux?

Conclusion: Reaction occurs where the *d* concentration is greatest, i.e. the surface, which has a greater D/Pd value than the bulk average.

Logical Consequences

- Because large clusters of deuterons can enter the nucleus of Pd, Ni, and S, the cluster must shield the Coulomb barrier of its members from an external nucleus.
- Therefore, a cluster is able to cause fusion between one of its members and an external deuteron or transmutation with any atom.
- When transmutation or fusion occurs, the members of the cluster not directly involved in the nuclear reaction carry away the nuclear energy and momentum.

Question: Where and how are the clusters formed?

Role of Nanoparticles

- Every successful method has nanoparticles present in some form.
- Nanoparticles of Pd show a surface/interior concentration ratio of H(D) that increases as the particle gets smaller.
- The physical form and size of the nanoparticle may act as a template for formation of clusters.

Proposed Conclusions

- Many theories can be eliminated because they are not consistent with observed behavior of cold fusion or with general behavior.
- Cluster and nanoparticle involvement are consistent with all observations.

- LARGE clusters of *p* or *d* are part of the CF process. These shield the Coulomb barrier and carry away resulting energy from the nuclear reaction as *p* or *d* particles having a variety of energies.
- These clusters form on the surface of certain nanoparticles and complex protein molecules.