

# TSC Pd-D Fusion, Effective Electron Mass, Muon Fusion

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## Abstract

Muon fusion is a known process based on the high muon / electron mass ratio enabling a muon of a Deuterium atom to screen the positive charge of its Deuterium nucleus and allow two Deuterium nuclei to approach one another close enough for fusion  $D + D \rightarrow 4He + 23.8 \text{ MeV}$  to take place.

Julian Schwinger, who said

“... in the very low energy cold fusion, one deals essentially with a single state, described by a single wave function, all parts of which are coherent ...”, encouraged Simons and Walling to propose that Deuterium nuclei and electrons in Palladium could get increased effective mass through Palladium structure quantum processes to screen Deuterium nuclei enough for fusion  $D + D \rightarrow 4He + 23.8 \text{ MeV}$  to take place and for the “heavy electrons” to carry away most of the 23.8 MeV fusion energy into Palladium structure electron system and for the entire process to be “... enhanced ... by high electron density contributed by ... Pd centers” located near the point of fusion.

Akito Takahashi proposed that the structure of Palladium would encourage a tetrahedral configuration of 4 Deuterium nuclei and 4 Deuterium electrons as a coherent quantum Tetrahedral Symmetric Condensate (TSC) that would collapse ( with the 4 electrons screening the 4 D nuclei ) and fuse  $D + D + D + D \rightarrow 8Be + 47.6 \text{ MeV} \rightarrow 4He + 4He + 47.6 \text{ MeV}$ .

Palladium clusters of 147 atoms ( about 1.5 nanometers ) have a ground state icosahedral configuration that encourages TSC fusion and a metastable cuboctahedral configuration that allows reloading of ambient Deuterium into the Palladium cluster by a Jitterbug transformation with, for each TSC configuration, a central Palladium atom to enhance the process.

If each 147-atom Palladium cluster is embedded into a Zeolite cage then the fusion energy can be carried from the Deuterium electrons to the Palladium electrons to the Zeolite electrons, thus heating the Zeolite, which heat can be released as needed by reacting with D2O to form steam.

“... Muon-catalyzed fusion ... is a process allowing nuclear fusion to take place at temperatures significantly lower than the temperatures required for thermonuclear fusion, even at room temperature or lower. It is one of the few known ways of catalyzing nuclear fusion reactions ...

The muon, 207 times more massive than the electron ... form[s] an electrically neutral muonic deuterium atom ... that acts somewhat like a "fat, heavy neutron" due both to its relatively small size ... about 207 times smaller than an electrically neutral electronic deuterium atom ... and to the very effective "shielding" by the muon of the positive charge of the proton in the deuteron ... reduc[ing] the electromagnetic repulsion between two nuclei and draw[ing] them much closer into a covalent bond than an electron can.

Because the nuclei are so close, the strong nuclear force is able to kick in and bind both nuclei together. They fuse ...” ( Wikipedia - Muon-catalyzed fusion )

“... In muon-catalyzed fusion ... the internuclear distances are shortened, potential well depths increased, and turning points moved inward in much the same way as suggested here; the screening caused by the lattice electrons acts much as the muon does, although the fact that only one muon is present per 2H+ pair whereas the 2H+ are surrounded by many electrons may cause the "heavy electrons" and muons to behave differently as far as radiationless relaxation is concerned ...

in the Pd lattice ... enhanced rate of 2H + 2H fusion ... involves a tunneling phenomenon aided by screening of the Coulombic repulsion between the 2H+ ions ... by neighboring "heavy electrons" with mass  $m^* = 10$  electron masses ...

... two D+ nuclei in the presence of ... Pd lattice ... electrons experience an attractive interaction at long range analogous to chemical binding;

this attraction is balanced and eventually exceeded by the screened Coulombic repulsion at smaller bond lengths.

... screening moves the  $E = 0$  turning point inward ( this turning point occurs at approximately 0.5 Å in D2+ ) but does not persist much beyond approximately 0.1 Å; from this point inward,

the bare Coulombic barrier (plus any centrifugal barrier) pushes the D+ nuclei apart.

The  $E = 0$  turning point shifts inward to approximately 0.5 Å /  $m^*$  in a model which attributes screening to "heavy electrons" of mass  $m^*$  times the true electron mass.

Thus, the primary effect of the screening is the reduction of the width of the barrier through which tunneling must occur rather than the height of the barrier. ...

$$[[ ( 0.5 \text{ \AA} = 0.05 \text{ nm} ) / ( m^* = 10 m_e ) = 0.005 \text{ nm} = 5,000 \text{ fm} ]]$$

...

a radiationless relaxation (RR) path ...



... in which energy is transferred to the PdD... lattice, perhaps mediated through the lattice electrons, ... predicts that each fusion event could produce up to 24 MeV of heat, unaccompanied by a large, troublesome neutron flux or by 3H formation ...

For muon-catalyzed fusion, tunneling through the Coulombic-plus-centrifugal barrier is possible even at low temperature because binding by the muon ( $m^* = 207$ ) moves the turning point inward to approximately  $2.5 \times 10^{(-11)}$  cm [ =  $2.5 \times 10^{(-13)}$  m = 250 fm ]

...

Once the  $4\text{He}^*$  is formed ... it must ... undergo relaxation to produce ground-state  $4\text{He}$  ... [such as by] ... internal conversion (IC) in which energy is transferred from the excited  $4\text{He}^*$  nucleus by coupling to neighboring electrons ... IC rates scale as the electron density near the nucleus from which they receive energy as do rates of most radiationless transitions that occur via energy transfer from the excited nucleus through the electrons to the lattice ... this density could be greatly enhanced by the proximity of either Pd electrons or lattice electrons having large "effective masses"

( perhaps  $m^* = 10-12.5$  )

... we estimate the rate of IC for a process in which a single electron carries away all 24 MeV of energy ... [ of ] ...  $4\text{He}^* \Rightarrow 4\text{He} + \text{heat}$

... It is known that IC can eject K-shell, L-shell, and other electrons ...

and that more than one electron may be ejected ..

It may therefore be possible for the excited nucleus to transfer its energy to several electrons, each of which subsequently undergoes thermalizing collisions ...

In the absence of a method for estimating the rate of such many-electron events, we present here the lower bound estimate described above

...

it may be that RR is enhanced ... [also] ... by high electron density contributed by the neighboring Pd centers ( where the density of conventional electrons is even higher than that computed for heavy electrons near  $4\text{He}^*$  nuclei

and where the inner-shell electrons have bohr frequencies of the order of  $10^{19} \text{ s}^{-1}$  ) .

It should be noted that these RR energy-transfer rates are in line with isomer shifts in Mossbauer spectroscopy ( e.g., an isomer shift of 1 mm  $\text{s}^{-1}$  corresponds to a frequency shift of  $4.8 \times 10^{11} \text{ s}^{-1}$  for a 24-MeV photon ) .

Isomer shifts reflect the differential effects on the energies of the ground and excited nuclear states caused by the electron density near the nucleus

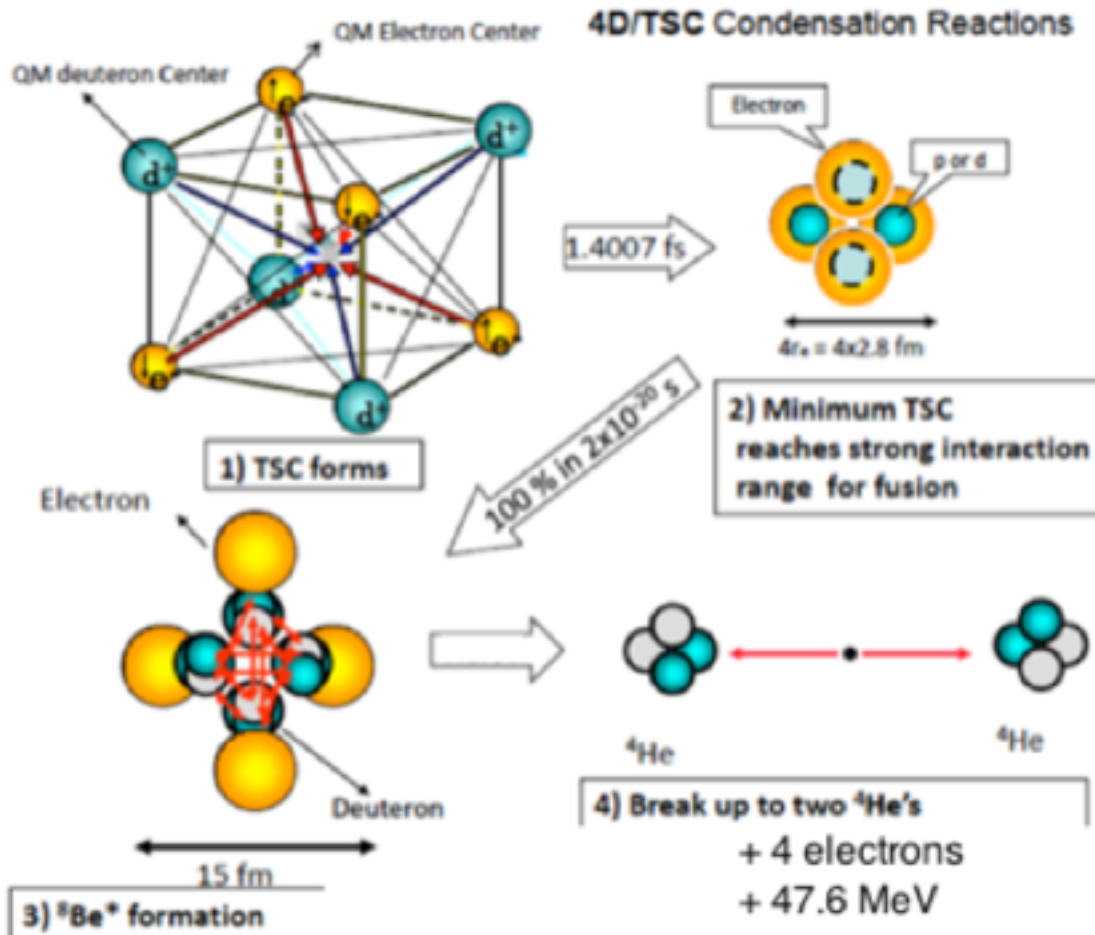
...

It should be stressed that RR rates need only be considerably faster than the rates of fragmentation to either  $3\text{He} + \text{n}$  or  $3\text{H} + 1\text{H}$  for this model to be consistent with the observations. We argue that formation of the odd-parity states of  $4\text{He}^*$  that fragment quickly is suppressed at low energies. Moreover, the even-parity  $(0^+,0)$  state can not fragment to the odd-parity  $3\text{He} + \text{n}$  or  $3\text{H} + 1\text{H}$  products unless the fragments exit with one (or more) unit of collisional angular momentum. Doing so would require these fragments to tunnel outward through their repulsive centrifugal barriers which is certain to slow fragmentation. Clearly, if the  $4\text{He}^*$  fragmentation rates are much less than the RR rate, little neutron or tritium signal will be detected. The model put forth here, which attributes qualitative differences between low- and high-energy fusion to parity, is consistent with ... observations

...

J.S. thanks Prof. Julian Schwinger for very stimulating and encouraging conversations. ...". ( Cheves Walling and Jack Simons, J. Physical Chem. 93 (1989) 4693-4696 )

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## Exceptionality of the 147-atom Pd cluster size is supported by magnetic studies:

“... Bulk palladium has a large susceptibility, but nevertheless it is a paramagnetic material ...

Nevertheless, Pd is close to a ferromagnetic instability.

The magnetic properties of Pd clusters and nanoparticles have been studied a lot in both theoretical and experimental investigations. It was revealed that the low dimension and lower coordination number of these clusters and nanoparticles results in enhancement of their magnetism. ...

ferromagnetism existed in solid solutions of Co in Pd as dilute as 0.1% although the distance between Co atoms was about 10 Å indicating a ferromagnetic interaction between the Co atoms at these long distances. The above mentioned experiments suggested that **the solute atom polarizes the surrounding Pd atoms to form a ‘giant’ magnetic moment.**

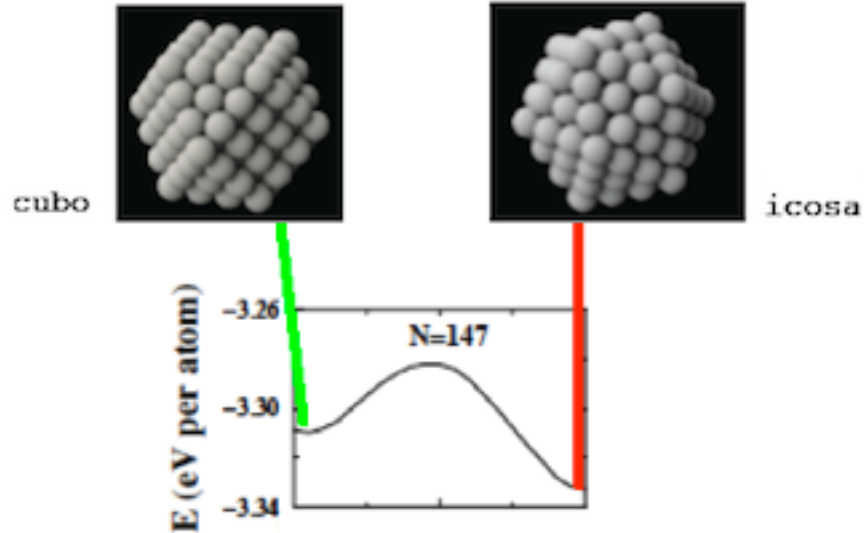
The total magnetic moment of a polarized cloud may be as much as 10  $\mu\text{B}$  with average Pd moments of 0.05–0.4  $\mu\text{B}$  .

Such a polarization cloud may consist of 200 host atoms.

The spatial extent of this cloud ranges from 10 to 50 Å [ = 1 to 5 nanometers ]. ...”  
( Stepanyuk, Ingnatiev, Negulyaev, Saletsky, and Hergert, J. Phys. Condens. Matter 24 (2012) 235301 )

## Geometry of Palladium 147 atom cluster

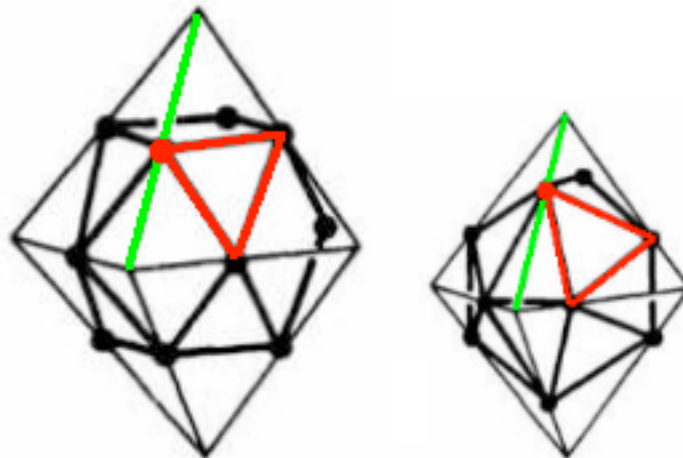
The 147 atom cluster of Palladium atoms has two geometric configurations:



a metastable Cuboctahedral state and an Icosahedral ground state which can transform into each other by a Jitterbug transformation



whereby the 6 cubo square faces correspond to 6 pairs = 12 icosa triangle faces and the 4 - 6 = 8 cubo triangle faces correspond to 20 - 12 = 8 icosa triangle faces

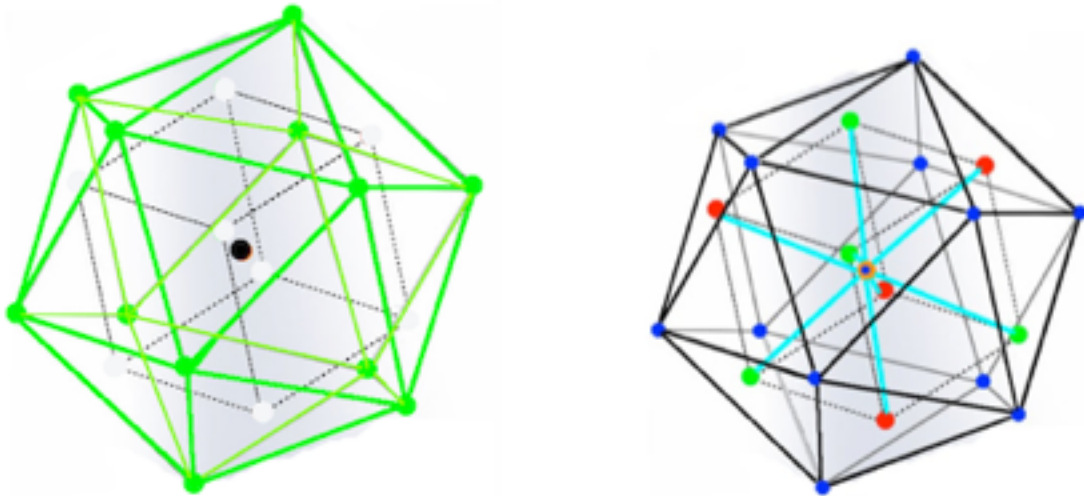


with vertices rotated from a mid-point of an edge of an enclosing Octahedron to a Golden Ratio point on that edge.

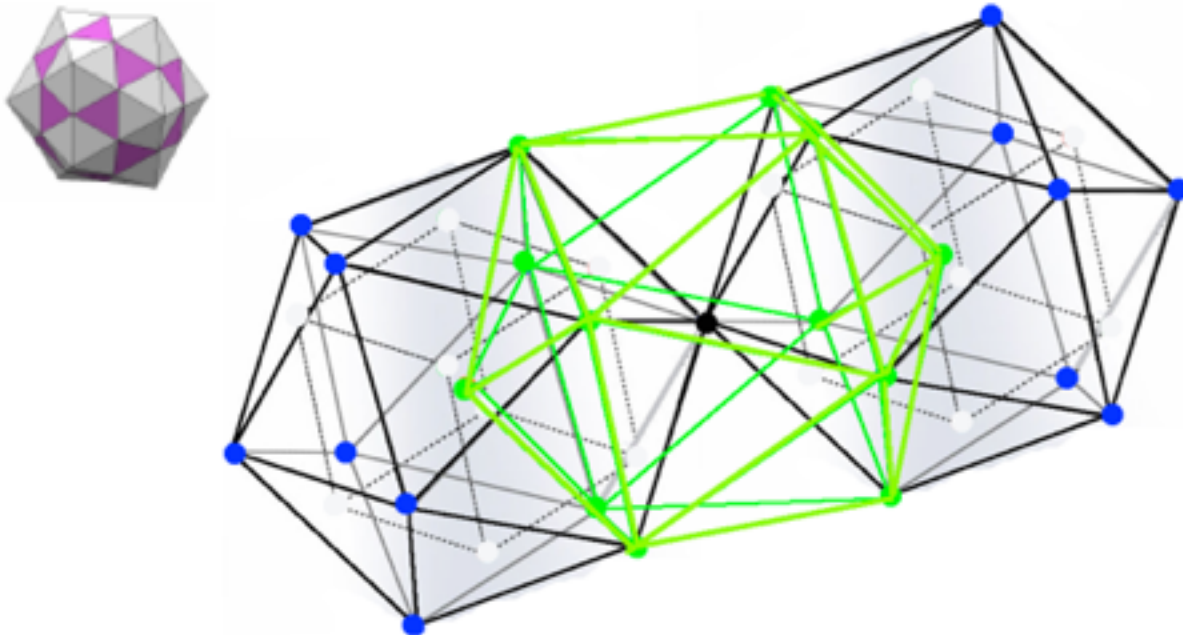
The 147-atom cluster is made up of a single central Palladium atom surrounded by 3 layers of Pd atoms:

Layer 1 = central 1 (black) + 12 icosahedral (green) = 13 vertices and 20 tetrahedral cells

It is a single icosahedron configuration that allows TSC fusion of 4 Deuterium nuclei (red dots) screened by their 4 electrons (green dots) condensing along symmetrical paths (cyan lines) to fusion at the center

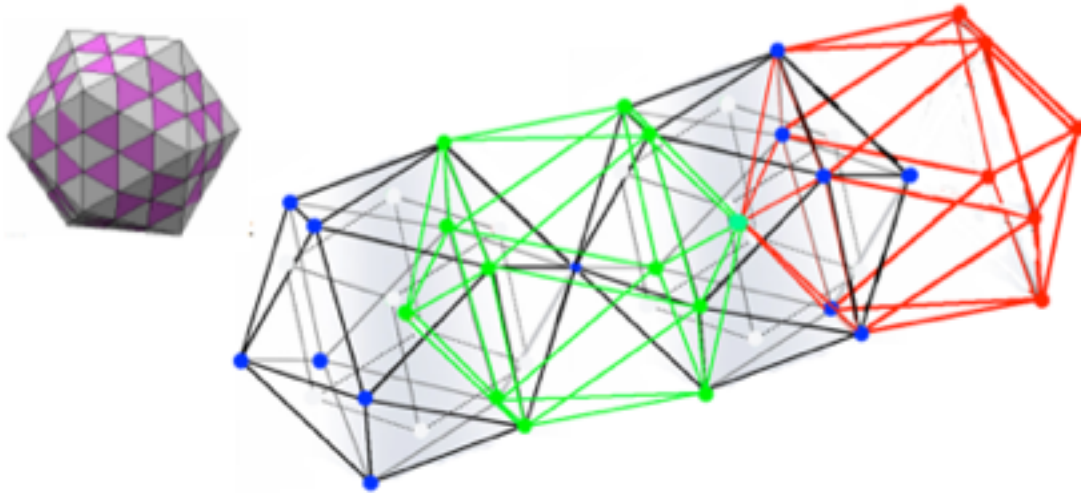


Layer 2 adds 42 vertices (blue) for total of 55 and 60 tetrahedral + 20 cuboctahedral cells for total 80 tetra + 20 cubo = 100

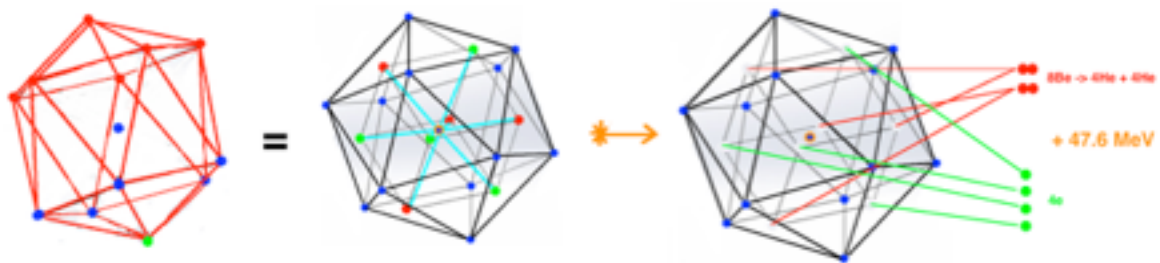


It is a configuration of 2 TSC fusion icosahedra sharing the central vertex with the remaining 55 - (26-1) = 30 vertices in 3 10-vertex bands

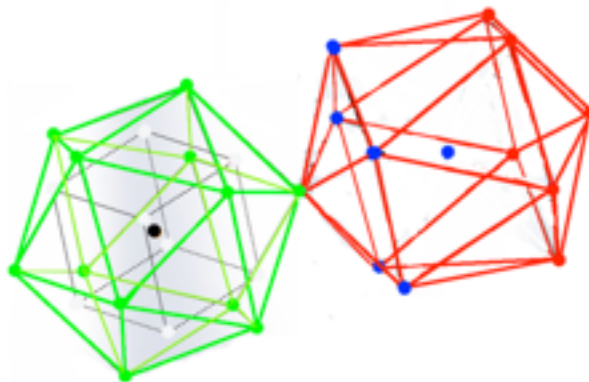
Layer 3 adds 92 vertices (red) for total of 147  
 and 120 tetrahedral + 60 cuboctahedral cells for total 200 tetra + 80 cubo = 280



It is a configuration of 12 TSC fusion icosahedra



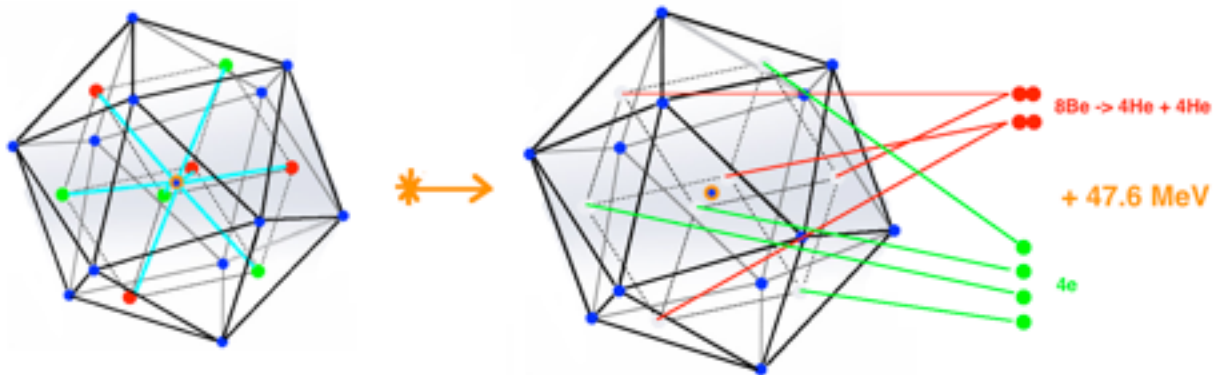
each of which shares a vertex with one of the 12 vertices of the Layer 1 icosahedron.



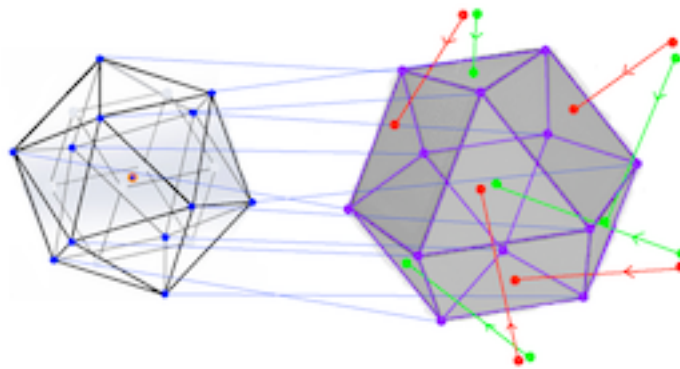
so that the entire 3-layer 147-atom configuration has 13 TSC fusion icosahedra:  
 12 outer icosahedra and 1 central icosahedron.  
 The 13 TSC configurations have  $13 \times 13 = 169$  vertices but  
 24 vertices are shared between an outer and the central TSC  
 and  $5 \times 12 = 60$  vertices are shared between two outer TSC  
 so  $169 - 24/2 - 60/2 = 127$  of the 147 vertices are in the 13 TSC  
 The remaining  $147 - 127 = 20$  vertices outside the 13 TSC are  
 at the centers of the triangle faces of the entire 147-atom icosahedron.



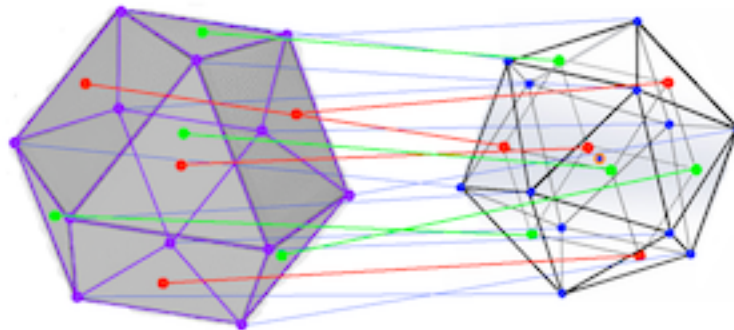
Each of the 13 TSC fusion icosahedra is capable of TSC fusion if it has absorbed 4 Deuterium nuclei + electrons:



The heated Palladium cluster expands by Jitterbug to Cubocta Metastable State  
The Fused Deuterium nuclei can be replaced by ambient Deuterium.  
Replacement is easier for the 12 outer TSC configurations than for the 1 central TSC configuration which is not directly exposed to ambient D gas

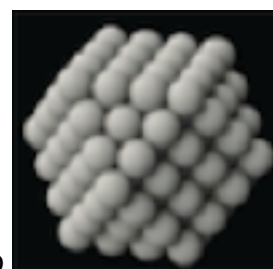


The Cubocta Metastable state, loaded with the new Deuterium, collapses by Jitterbug back to the Icosa Ground State

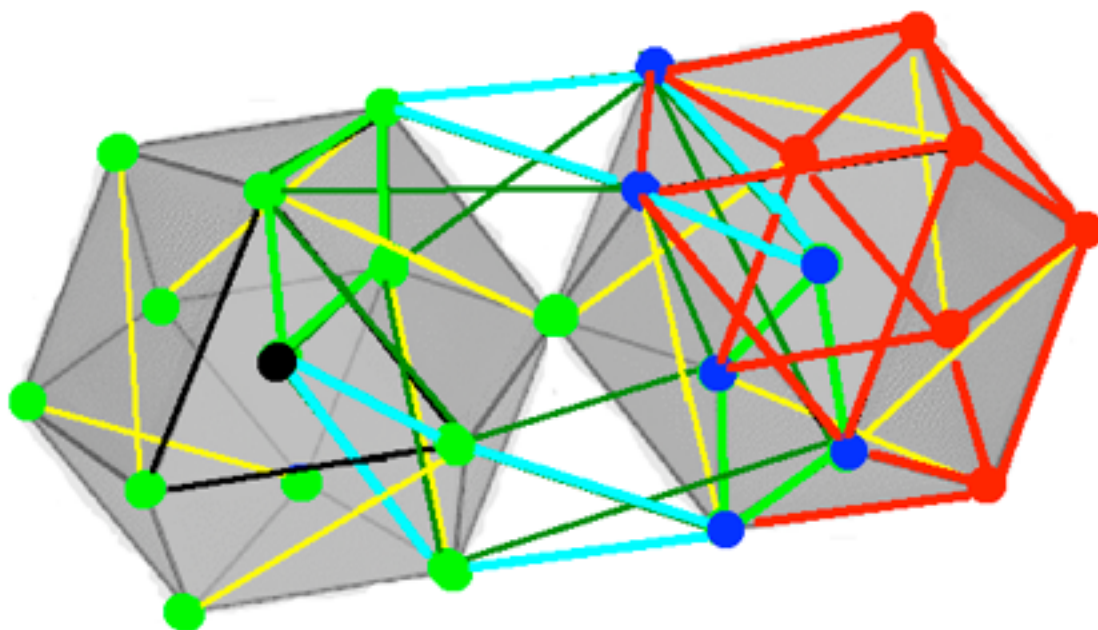


Then a new TSC Fusion occurs and the cycle repeats.

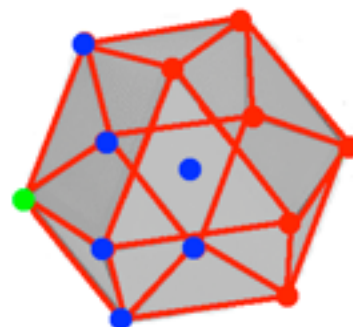
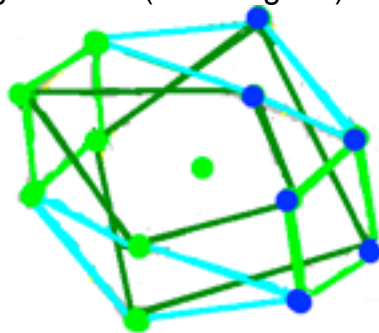
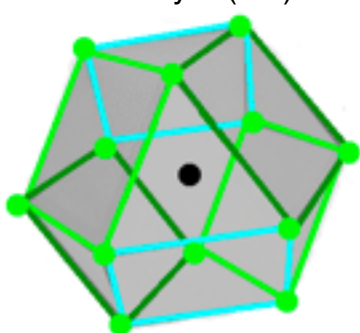
## 147-atom Cuboctahedral Geometry



The 147-atom 3-layer icosah structure goes to a 3-layer cuboctahedral structure by Jitterbug transformation of all 147 atoms.

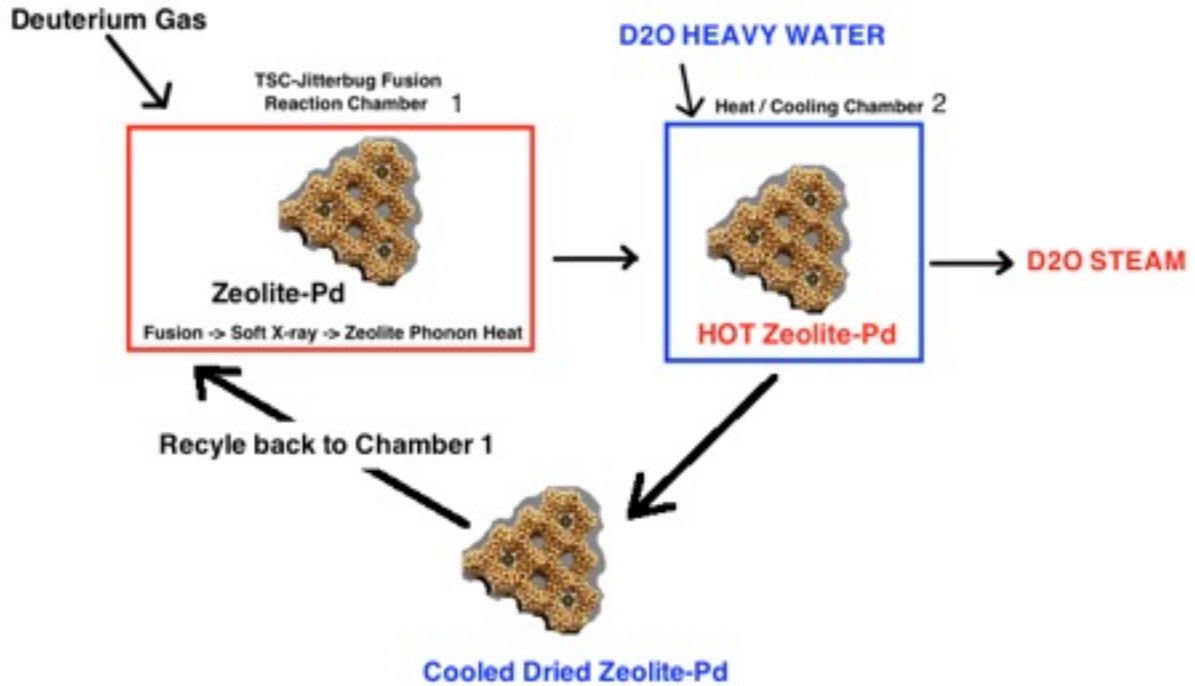


Like the icosah case, in the cubo case there is a central (black) vertex surrounded by 12 (green) cubo-configured vertices and a second layer (blue) forming an intermediate (distorted) cuboctahedron and a third layer (red) forming an outer (more regular) cuboctahedron.



In the cubo case, there are also 12 outer TSC Jitterbug cuboctahedra plus a single central TSC Jitterbug cuboctahedron, so Jitterbug transformation of the entire 147-atom Pd cluster works consistently with individual Jitterbug transformations of the 13 TSC icosahedra and TSC Jitterbug cuboctahedra.

If each 147-atom Palladium cluster is embedded into a Zeolite cage then the fusion energy can be carried from the Deuterium electrons to the Palladium electrons to the Zeolite electrons, thus heating the Zeolite, which heat can be released as needed by reacting with D2O to form steam.



Further details are in my papers at

<http://vixra.org/abs/1501.0234>

<http://vixra.org/abs/1502.0096>

# Pd D Zeolite Y Fusion

1 - 15 ml of methanol ( MeOH ) in a scintillation vial

2 - Add 5 mg palladium acetate ( Pd(OAc)<sub>2</sub> ) whose color is red-orange

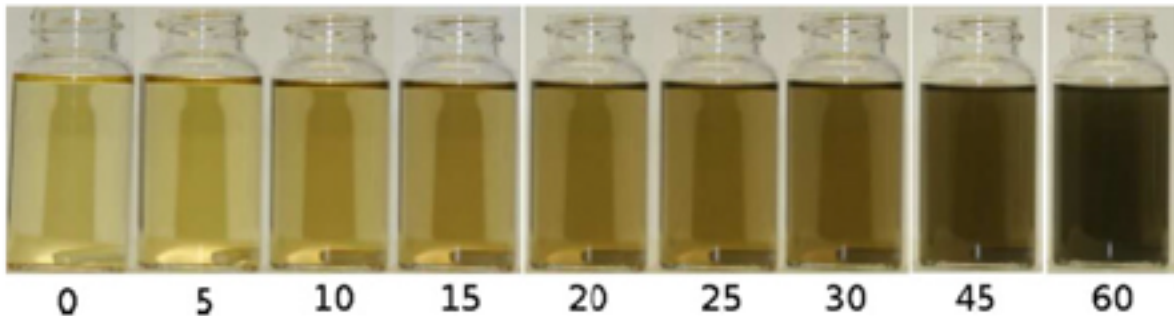
3 - Reduce the Pd(OAc)<sub>2</sub> by MeOH to Pd atoms  
by stirring for 5 minutes with unobstructed exposure to room lighting.

4 - Add 10 mg of 30-40 nm Sodium Zeolite Y Crystals in colloidal suspension  
Each Zeolite Crystal will be Tetrahedral in shape  
At 30-40 nm size each will have about 12 to 16 large Cavities per edge  
About half of the Cavities will be on the Exterior Surface of the Tetrahedral Crystal  
where they will be easily accessible by Pd atom clusters in the colloidal suspension  
( [Microcrystalline synthetic faujasite](#) )  
( ? where can 30-40 nm Zeolite Y be purchased and how much does it cost ? )

5 - Place on elevated stir plate and allow to react undisturbed for 20 minutes.

During 20 minutes the Pd atoms form clusters that grow to size 1.5 nm (147 atoms)

Initially the Pd atom clusters are very small (only a few atoms)  
and will migrate into the large Cavities of the Zeolite Crystals and continue to grow  
to size 1.5 nm (147 atoms) at 20 minutes  
Color of colloidal suspension changes from pale yellow to dark green over the 20 min



6 - At 20 minutes Pd-loaded Zeolite (and any remnant Pd still in colloidal suspension)  
are removed and the Pd-loaded Zeolite is dried

7 - Pd-loaded Zeolite is placed in reaction chamber  
where it is exposed to Deuterium gas from tank  
and  
calorimeter measurements are taken to measure any heat  
that might be produced by TSC-Jitterbug fusion

( analogous to heat produced by Arata and Zhang (replicated by McKubre at SRI)  
with no external power input - only palladium powder + deuterium gas )