

Pd/Ni Clusters for D/H TSC Jitterbug Fusion

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Clusters of Palladium atoms (also clusters of atoms of Nickel and similar elements) have two basic structures:

Icosahedral and Cuboctahedral

1 - Icosahedon <-> Cuboctahedron Jitterbug Transformation

2 - Pd/Ni clusters with absorbed Deuterium or Hydrogen have two states:

Icosahedral with Tetrahedral absorption sites

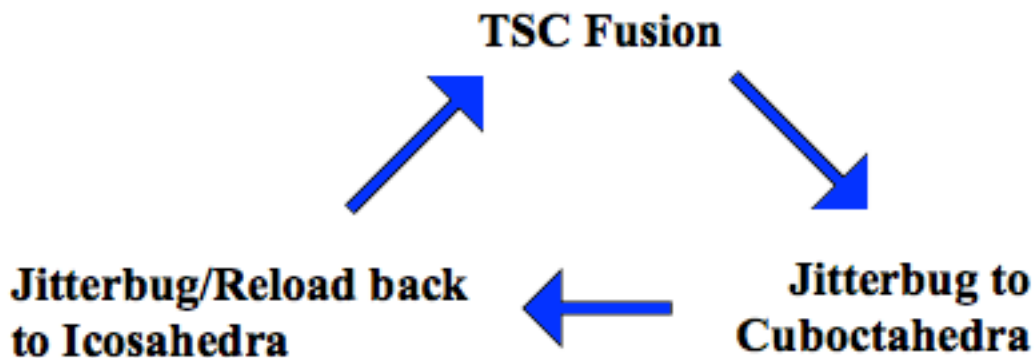
Cuboctahedral with Octahedral absorption sites

3 - Tetrahedral Symmetric Condensation (TSC) in PdD_x produces Fusion.

4 - Icosahedra TSC Fusion Triggers Jitterbug to Cuboctahedra.

5 - Cuboctahedra Jitterbug back to Icosahedra and reload TSC sites.

6 - Repeat the Cycle:



Akito Takahashi has developed a Tetrahedral Symmetric Condensate (TSC) model for fusion $D+D+D+D \rightarrow 8Be$ and $H+H+H+H \rightarrow 4He$ in Pd and Ni atomic clusters. This paper describes the geometry of Pd/Ni atomic clusters and how it enables TSC fusion of D/H within the Pd/Ni clusters.

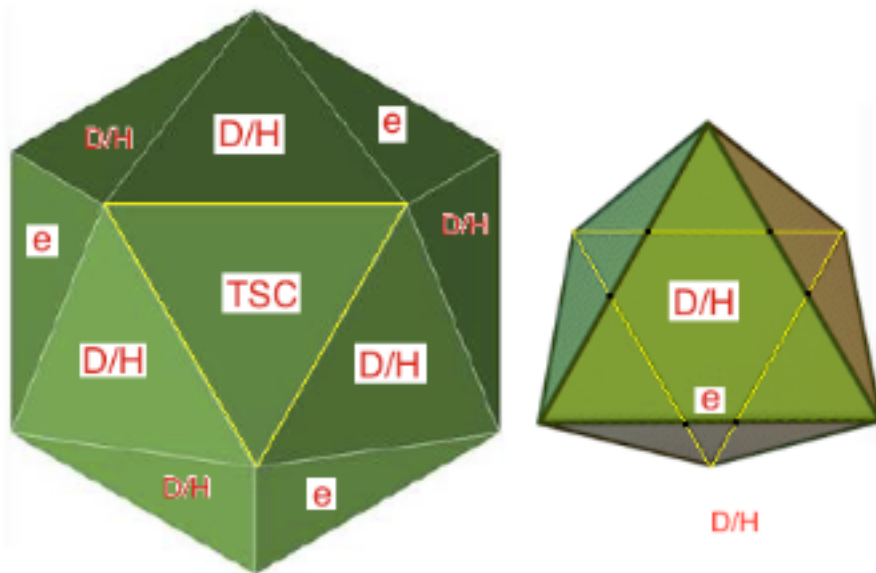
The icosahedral state at the beginning of the TSC process is the stable ground state. The basic TSC structure is a half-icosahedron with 10 approximate tetrahedra and approximate octahedron. The tetrahedra and octahedra are approximate because they do not fit together exactly within Pd/Ni atomic clusters because they must be slightly deformed from exactly regular tetrahedra and octahedra in order to fit together in our physical flat 3-dimensional space.

Details of the deformation are being studied by Klee Irwin and his coworkers Fang Fang, Julio Kovacs, and Garrett Sadler. Discussion with them led to the ideas described in this paper.

The vertices of the half-icosahedron and octahedron are positions of Pd/Ni atoms.

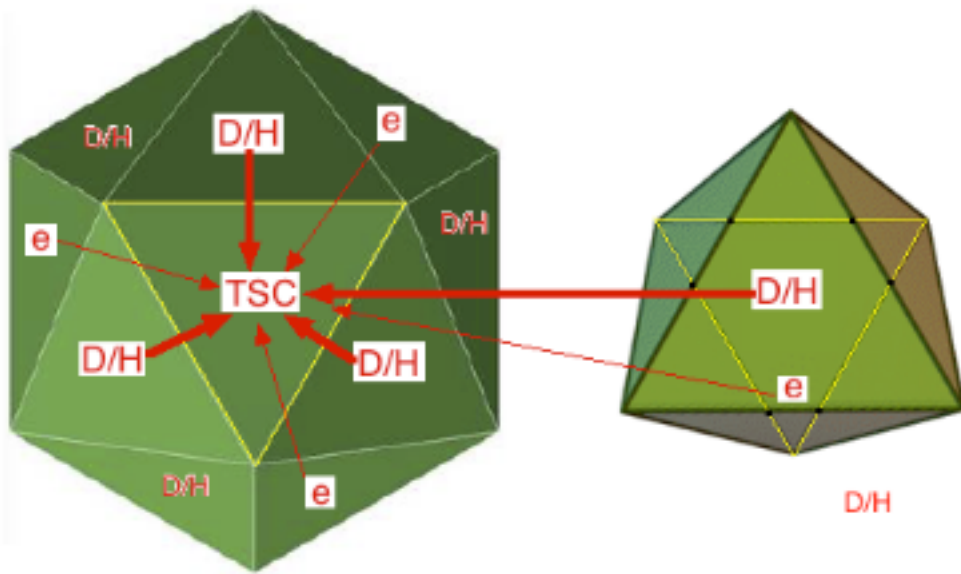
As to the half-icosahedron tetrahedral cells (images adapted from Wikipedia):

The central cell marked TSC is the cell in which the TSC fusion reaction takes place at the end of the TSC process. The 3 cells marked D/H (large type) contain 3 of the 4 D or 4 H nuclei for TSC fusion. The 3 cells marked e contain the electrons for those 3 D/H nuclei. The 3 cells marked D/H (small type) contain 3 D or H nuclei that will be reloaded by the Jitterbug process into TSC fusion position.

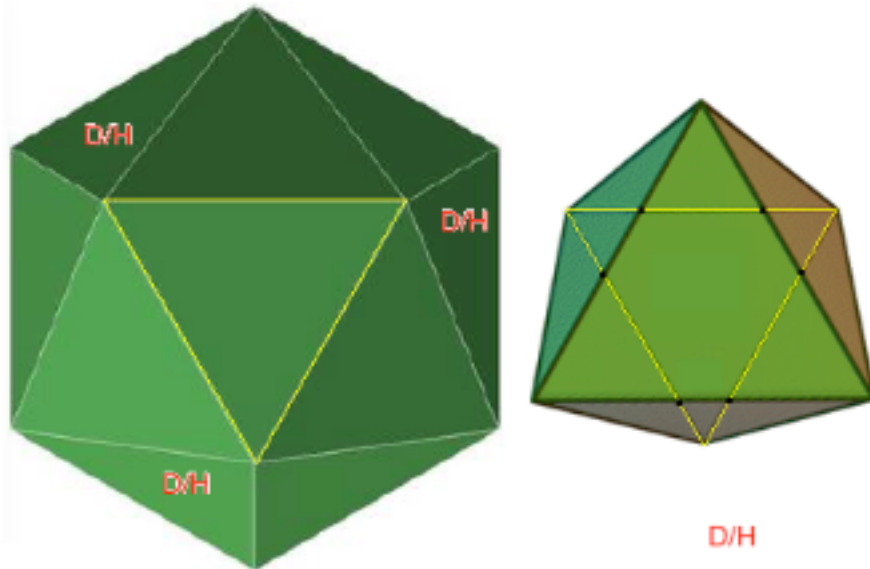


The octahedral cell marked D/H e (large type) is located in the atomic cluster directly above the TSC cell such that the TSC top face coincides with the bottom face of the octahedron. It contains the 4th of the 4 D/H nuclei for TSC fusion and its electron. The D/H (small type) outside the octahedral cell is for reloading.

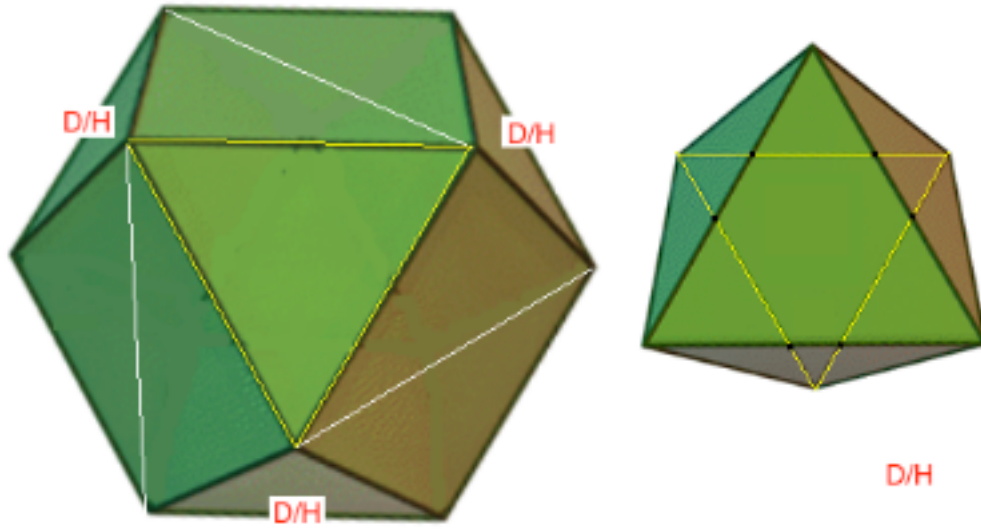
In TSC fusion the 4 D/H nuclei, Coulomb-shielded by their electron clouds, condense at the center of the TSC cell where their fusion produces 8 Be / 4 He.



Immediately after TSC fusion

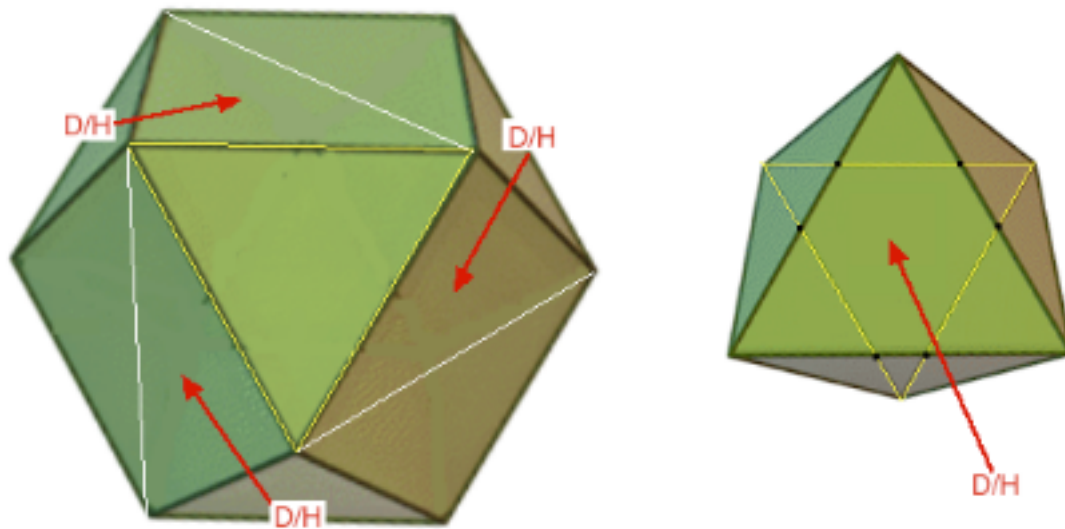


the TSC fusion cell and the D/H fuel cells and their associated e cells are empty but the D/H (small type) reloading cells contain the D/H for Jitterbug reloading. The TSC fusion energy released drives the Pd/Ni cluster state by a Jitterbug transformation to an expanded cuboctahedral state.

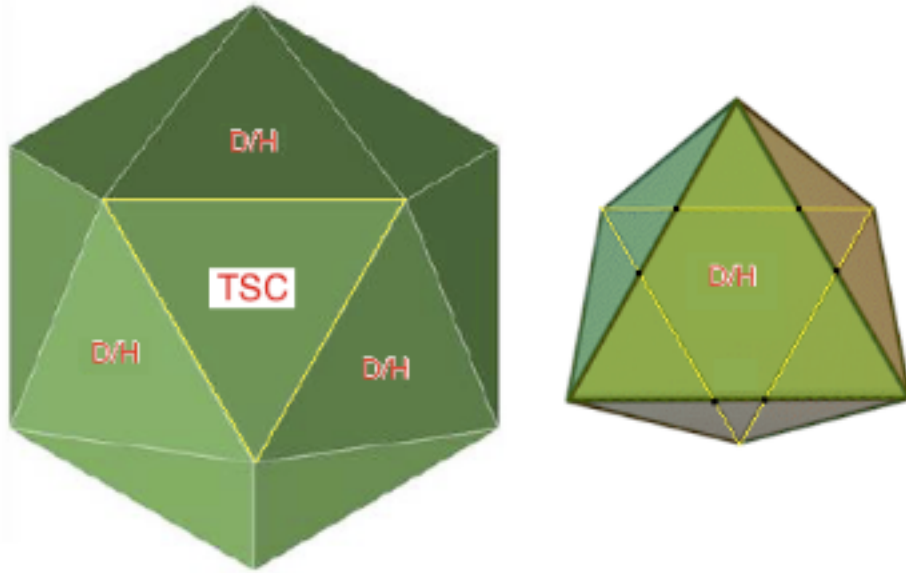


As Buckminster Fuller showed (Synergetics Macmillan 1975, 1982) a cuboctahedron is made up of 8 tetrahedral and 6 half-octahedral cells. 2 of the icosahedral tetrahedra correspond by Jitterbug to one of the cuboctahedral half-octahedra.

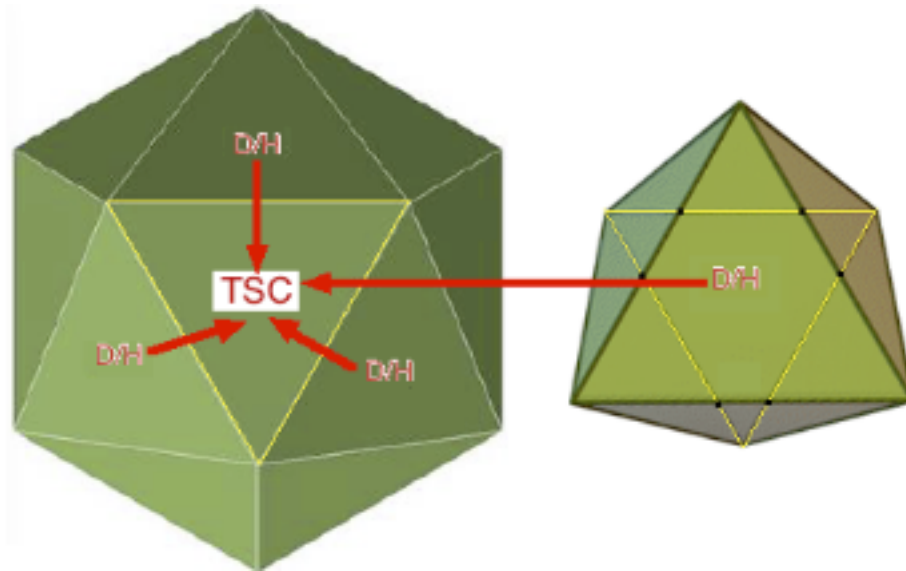
The Jitterbug expansion having produced large empty octahedra-type cells, the D/H (small type) flow from their smaller tetrahedral cells into the larger empty octahedral-type cells



Since the icosahedral cluster state is the stable ground state, the reloaded cuboctahedral state goes by Jitterbug transformation to the reloaded icosahedral state



whereupon a new cycle of TSC fusion begins:



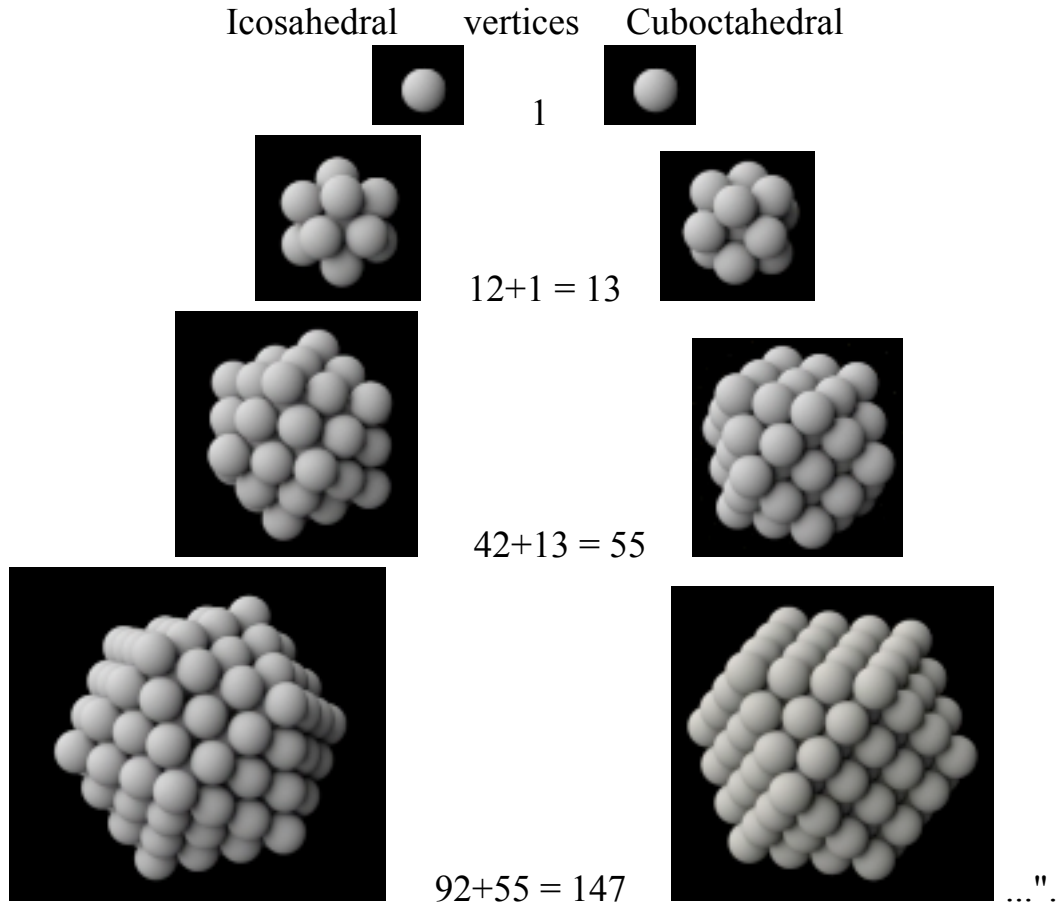
(The images above, adapted from Wikipedia, are somewhat oversimplified such as by not indicating the reloaded electron cells and the next-order reloading D/H reloading cells.)

What is the overall structure of the Pd/Ni clusters ?

There are two basic structures that are Jitterbug Transforms of each other:

Icosahedral and Cuboctahedral

From vimeo.com/27662398 by Yan Liang (L2XY2) August 2011: "...



How many TSC fusion sites are in a Pd/Ni cluster ?

A TSC fusion site has (icosahedral phase) a half-icosahedron plus an octahedron.

The 13-atom Pd/Ni cluster has a full icosahedron (two half-icosahedra) but does not have the necessary octahedron and so is not a TSC Fusion Cluster.

The 55-atom Pd/Ni cluster has a full icosahedron (two half-icosahedra) and two octahedra to form 2 TSC fusion sites, so it is a TSC Fusion Cluster of order 2.

The 147-atom Pd/Ni cluster has the 2 TSC fusion sites of the 55-atom TSC cluster plus 12 more half-icosahedra in its outer shells along with octahedra for each, so it is a TSC Fusion Cluster of order 14.

How do the Icosahedral Clusters grow to 147 atoms ?

Eric A. Lord, Alan L. Mackay, and S. Ranganathan say in

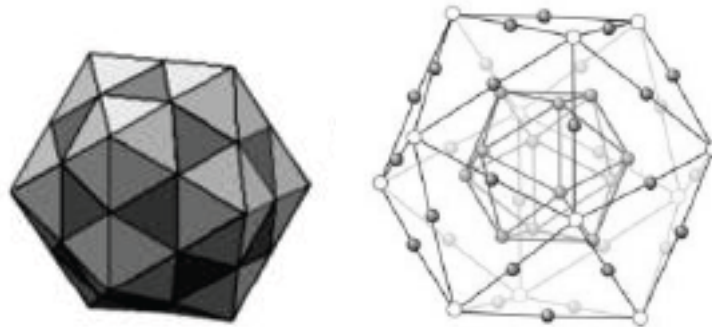
"New Geometries for New Materials" (Cambridge 2006):

"... The Mackay icosahedron is obtained by packing tetrahedra and octahedra around an icosahedron [12 vertices]...

if an octahedron is placed on every face of an icosahedron, the angular gap between neighboring octahedra can be closed by a very small deformation, to bring them into face contact [$12 + 20 \times (6-3)/2 = 42$ vertices]...



... The concave regions of the resulting polyhedron can be filled by five-rings of tetrahedra [$42 + 12 = 54$ vertices]...

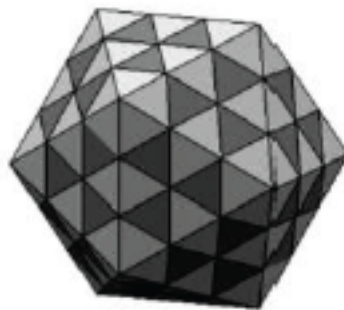


... The 54-atom Mackay cluster ...[triangles: dark = octahedra; light = tetrahedra]...

The process can be continued ...[with octahedra on each of the $12 \times 5 = 60$ outer cell faces of 5-rings thus adding $60 \times (2/2 + 1/3) = 80$ vertices and creating

12 TSC structures similar to half-icosahedra at the 12 vertices of the cluster.

This also creates concave places for 30 pairs of tetrahedra adding no vertices plus 12 tetra-5-rings adding 12 vertices for a total of $54+80+12 = 146$ vertices.



The 146-atom cluster

has $12+2 = 14$ TSC sites]..."

Lord et al use 12, 54, and 146 atoms for Mackay clusters
while Liang uses 13, 55, and 147 atoms.

The difference is whether or not the center vertex is counted, that is,
not so much a real physical difference but a difference in math convention.

What about more than 147 atoms ?

As more layers are added, the deformations of tetrahedra and octahedra accumulate
and eventually destabilize the structures necessary for the TSC fusion process.

The next Mackay cluster beyond 147 atoms has $147+162 = 309$ atoms,
and it is my guess that **147 atoms is optimal for TSC fusion:**

**55 atom clusters have only 2 TSC sites while 147 atom clusters have $2+12 = 14$
and**

309 (and larger) atom clusters may not be sufficiently stable.

Therefore, in a 147-atom Pd/Ni cluster:

each full set of TSC fusion events can consume $14 \times 4 = 56$ D/H nuclei.

How many D/H atoms can live in a 147-atom Pd/Ni cluster ?

F. Calvo and A. Carre say in Nanotechnology 17 (2006) 1292–1299

"Structural transitions and stabilization of palladium nanoparticles upon hydrogenation":

"... Cuboctahedra ...[and]... icosahedra ... contain exactly the same number of
atoms. ... In the case of ... the 147-atom Pd cluster ... the favoured structure in the
pure metal is the three-layer icosahedron.

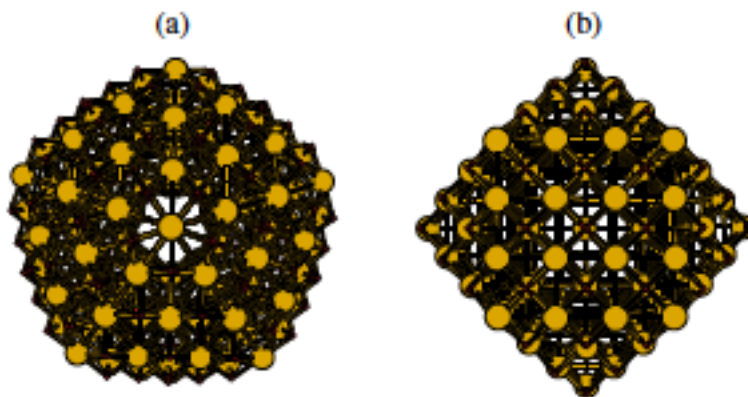


Figure 1. Palladium clusters fully loaded with hydrogen.

(a) $\text{Pd}_{147}\text{H}_{200}$, I_h symmetry; (b) $\text{Pd}_{147}\text{H}_{164}$, O_h symmetry.

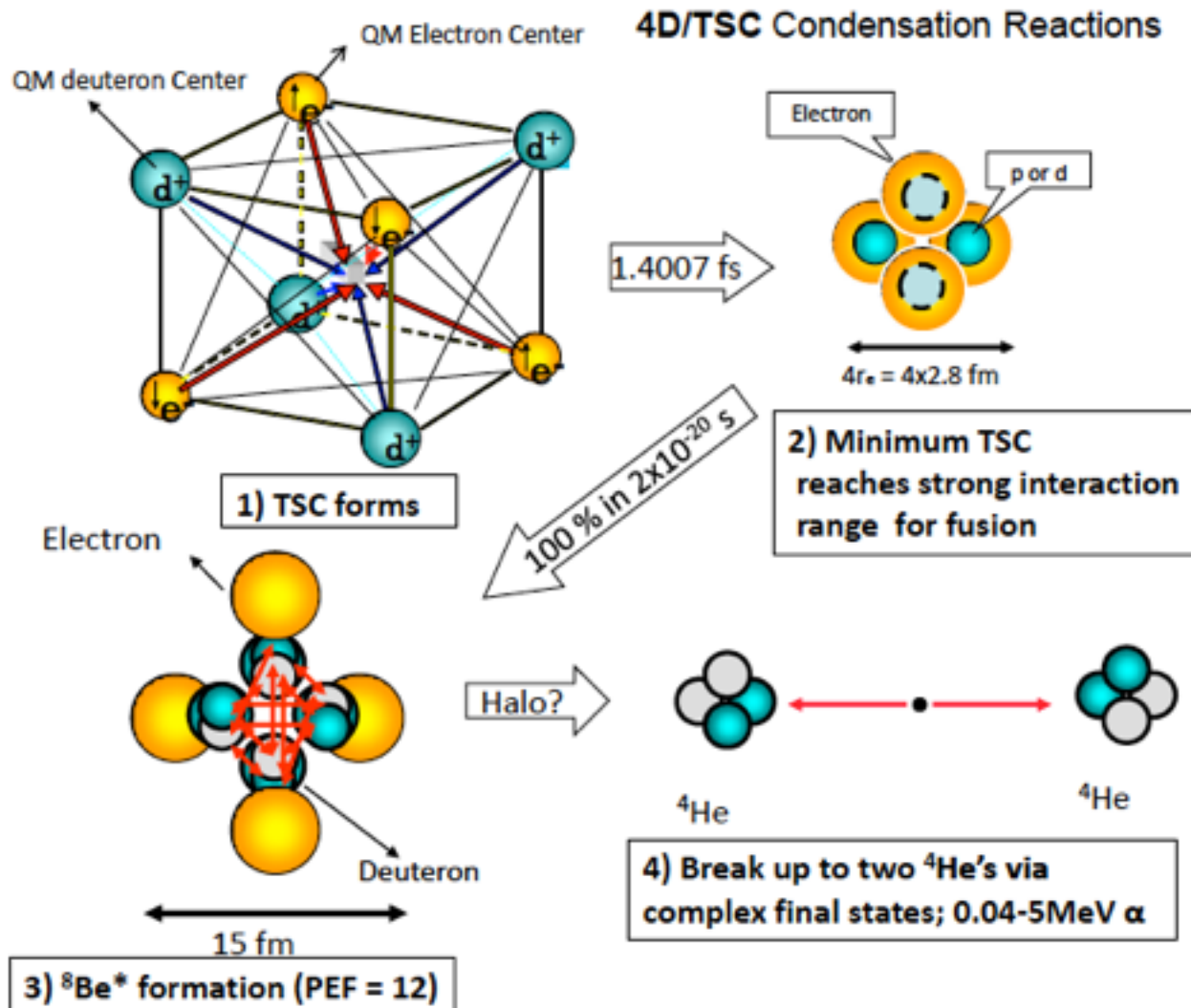
...".

Since the minimum full load for Icosa or Cubocta Pd/Ni 147-atom clusters
is 164 D/H atoms, no more than 3 cycles of full TSC fusion
(each consuming 56 D/H nuclei) can occur without replenishment of D/H from the
surroundings of the clusters (such as immersion of the clusters in D/H gas).

How does TSC Fusion work ?

Akito Takahashi in Physics of Cold Fusion by TSC Theory by Akito Takahashi ICCF17 12-17 August 2012 and J. Condensed Matter Nucl. Sci. 33 (2009) 33-44 and J. Condensed Matter Nucl. Sci. 1 (2007) 129-141 "... proposed ... **deuteron fusion process by ... Tetrahedral Symmetric Condensate (TSC) ...**

Every particle in TSC can make central squeezing motion with same velocity, to keep charge neutrality of total TSC system ... this squeezing motion can be treated as Newtonian mechanics until when four deuterons get into the range (about 5 fm) of strong nuclear interaction. ... TSC starts Newtonian squeezing motion to decrease linearly its size from about 100 pm radius size to ... the minimum size state ... as shown in ... Semi-classical view of squeezing motion of TSC, $\langle e \rangle = (e\downarrow + e\uparrow)/2$ for QM view at four electron centers ...

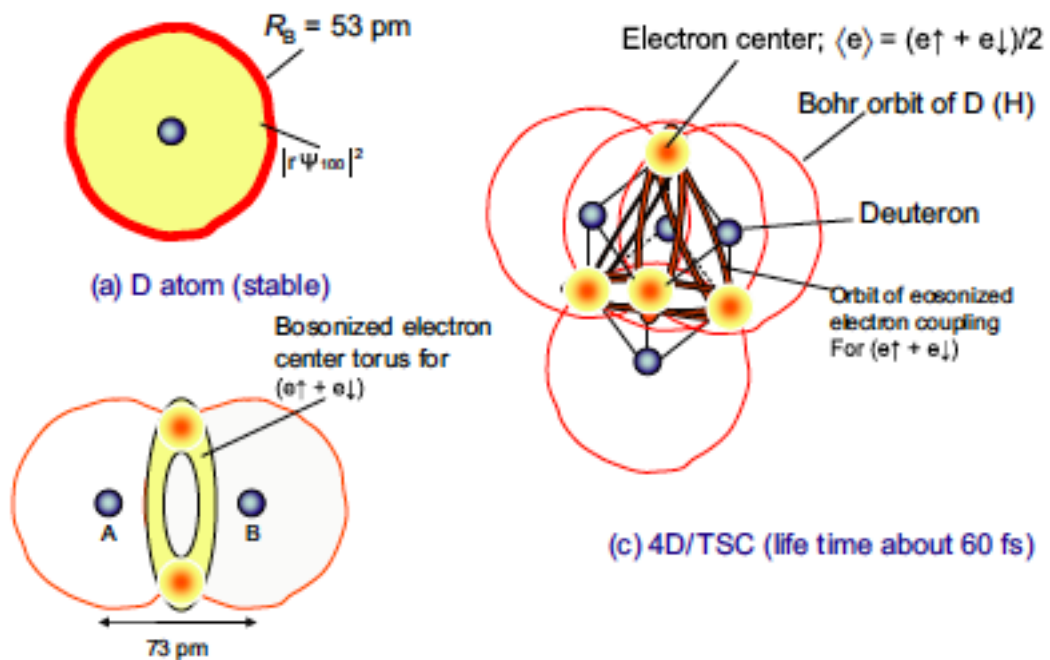


[Note that the TSC process is spontaneous not requiring initial stimulus.]

... Classical squeezing motion ends when four deuterons get into the strong force range (5 fm) and/or when four electrons get to the Pauli's limit (about 5.6 fm for e-e distance). Here for Pauli's limit, we used the classical electron radius of 2.8 fm ... Since the range of strong interaction is comparable to the classical electron diameter (5.6 fm) ... the intermediate nuclear state 8Be^* will be formed just after the minimum size state ...

Immediately at ... 8Be^* formation ... 4d-cluster shrinks to much smaller size (about 2.4 fm radius) of 8Be^* nucleus, and four electrons should go outside due to the Pauli's repulsion for fermions. Shortly in about few fs or less (note; Lifetime of 8Be at ground state is 0.67 fs), 8Be^* will break up into two 4He particles, each of which carries 23.8 MeV kinetic energy ...

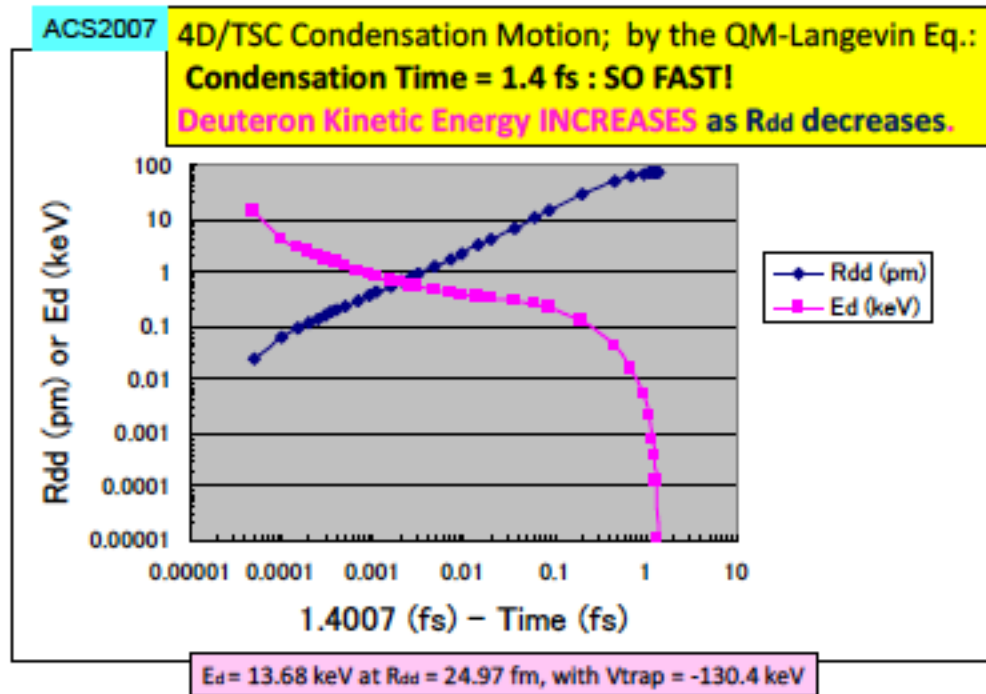
when TSC is just formed ... averaged electron position (electron center of $\langle e \rangle = (e\downarrow + e\uparrow)/2$, Bosonized electron pair ...) ... locates at vertexes of regular cube with tetrahedral combining orbits and outer dilute clouds ...



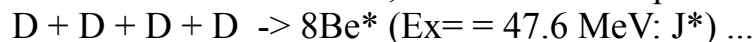
(b) D_2 molecule (stable): $\Psi_{2D} = (2+2\Delta)^{-1/2} [\Psi_{100}(r_{A1}) \Psi_{100}(r_{B2}) + \Psi_{100}(r_{A2}) \Psi_{100}(r_{B1})] X_s(S1, S2)$

... At ... cube ... vertexes ... three Bohr wave functions superpose and electron density is about nine times larger than that of outer dilute cloud. Therefore, the semi-classical treatment of central squeezing motion by Newtonian is approximately fulfilled for "coherent" central averaged momentums for eight particles. ...

As soon as 4D/TSC($t=0$) state with D₂ molecule size ($R_{dd} = 74$ pm) is formed ... the QM-Langevin equation gives numerical solution for time-dependent R_{dd} and mean relative kinetic energy of d-d pair of a face of 6 TSC (d-e-e-d-type) faces, as copied from reference and shown in Fig.10. ...



... The ‘adiabatic’ size of 4D/TSC reaches at a few tens fm size in 1.4 fs, so fast. With adiabatic 4D/TSC size around 20 fm, 4D-fusion takes place by ...



Fusion yield per 4D/TSC generation is calculated by integrating time-dependent fusion rate by the Fermi’s first golden rule ... that was very close to 1.0, namely 100%, during the very small time interval of ca. $2 \times 10^{(-20)}$ s in the final stage of condensation.

Mean relative kinetic energy of neighboring d-d pair of 4D/TSC-minimum is ca. 14 keV, which is accidental resembling value to the hot fusion experimental devices as ITER (DT plasma).

...

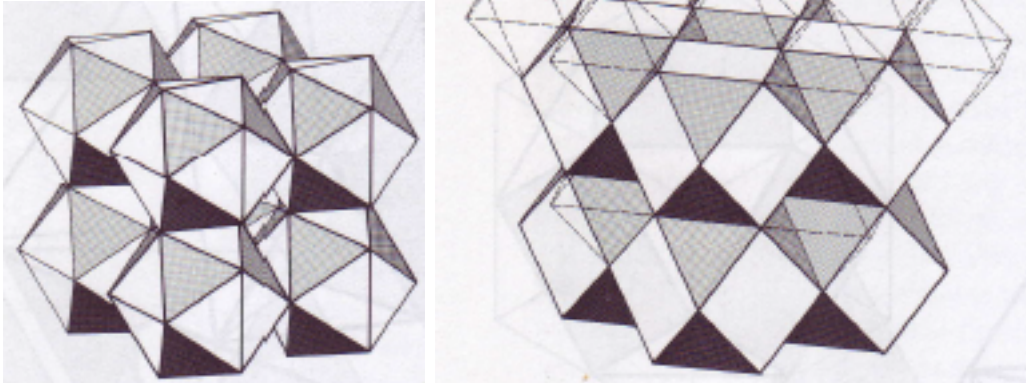
the quantitative study on the **TSC formation probability in D(H)-loaded metal systems is yet to be done** by solving many-body time-dependent problems under organization field of condensed matter. It is challenging work ...".

The answer to that challenge may be

the Icosahedra <-> Cuboctahedra Jitterbug Transformation.

What is the Jitterbug Transformation ?

Icosahedra and Cuboctahedra both have 12 vertices so that it is possible to transform them into each other. Buckminster Fuller called that transformation the Jitterbug



(images from Synergetics by Buckminster Fuller (Macmillan 1975, 1982))

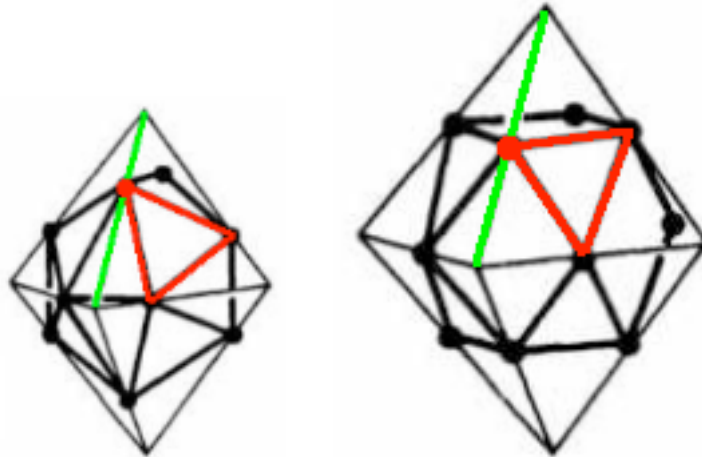
To make Cuboctahedra (unit edge length) from Icosahedra (unit edge length) choose 6 pairs of Icosahedra triangle faces (white in the above images) and lengthen the common edge of each pair by a factor of $\sqrt{2}$. That expansion flattens each of the triangle pairs to produce 6 square faces of the Cuboctahedron. The other Icosahedral $20 - 2 \times 6 = 8$ (shaded) triangle faces are rotated and become the other $14 - 6 = 8$ triangle faces of the Cuboctahedron.

thus increasing the number of faces from $8+6 = 14$ to $8+(6+6) = 20$ while keeping the number of vertices constant at 12.

There are two ways to choose a diagonal of an Icosahedron triangle face pair in the construction, corresponding to the two possible orientations of an Icosahedron.

Choice of diagonal for one Icosahedra triangle face pair forces (by requiring consistency) the choices for all other face pairs of all Icosahedra.

The triangle faces of the Icosahedron/Cuboctahedron are rotated by a Golden Ratio



(images adapted from Geometrical Frustration by Sadoc and Mosseri (Cambridge 2006))

angle defined by
 sliding Icosahedron vertices on the edges of a circumscribing Octahedron
 from points dividing edges into Golden Ratio segments
 to points dividing edges into two equal segments
 so that the Octahedron then circumscribes a Cuboctahedron.
 If the edge lengths of the Icosahedron/Cuboctahedron are kept the same
 then the Octahedron surrounding the Cuboctahedron will be an expansion
 of the Octahedron surrounding the Icosahedron.

Just as in the choice of a Cuboctahedron square diagonal to be compressed,
 there are two ways in which the edge could be divided into Golden Ratio segments,
 corresponding to the two possible orientations of an Icosahedron.

Choice of Golden Ratio segments for one edge forces (by requiring consistency)
 the choices for all other edges.

The volume expansion of the Jitterbug Transformation
 from Icosahedron (unit edge) to Cuboctahedron (unit edge) is:

$$\text{Icosahedron volume} = \frac{5}{12} (3 + \sqrt{5}) = 2.18169499$$

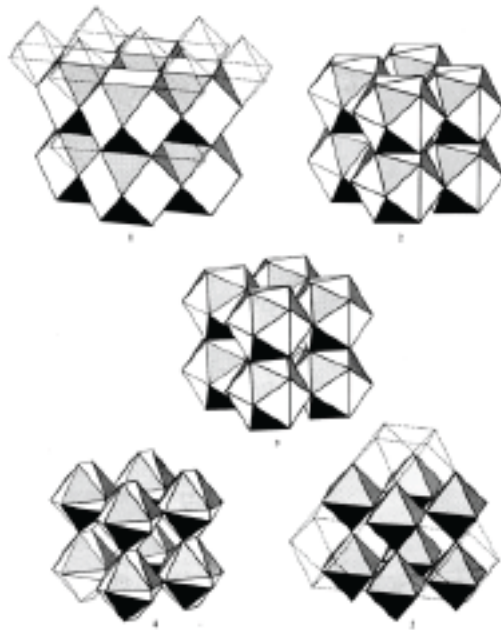
$$\text{Cuboctahedron volume} = \frac{5}{3} \sqrt{2} = 2.3570226$$

$$\text{Icosahedron/Cuboctahedron volume ratio} = 0.9256147947$$

$$\text{Cuboctahedron/Icosahedron volume ratio} = 1.0803630254$$

Why do Jitterbug Transformations move D/H among the cluster cells ?

The Jitterbug Transformation proceeds:
from the cuboctahedral state (top left)
to an intermediate state (top right)
to an icosahedral state (center)
to another intermediate state (bottom left)
to a dual cuboctahedral state (bottom right)



(images from Synergetics by Buckminster Fuller (Macmillan 1975, 1982))

and then back up in reverse order to the original cuboctahedral state.

Since the dual cuboctahedral state interchanges octahedra and cuboctahedra with respect to the original cuboctahedral state,

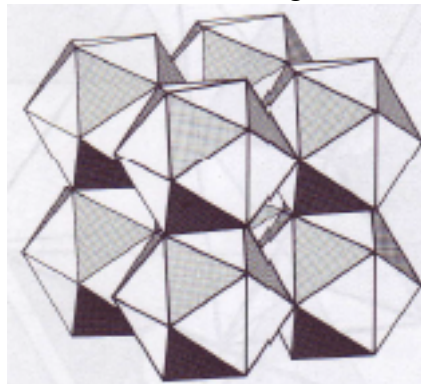
**the D/H fusion fuel nuclei are moved from cell to cell
by the Jitterbug transformations**

thus enabling

reloading of fusion fuel into the TSC fusion cell sites.

Pd/Ni and D/H Fusion from Jitterbug TSC: Mechanical Analogy

(with Colt Series 80 Government 10 mm Delta Elite version of Browning's M1911 semi-auto)



"... The M1911 ... use[s] ... the short recoil ... action ... Cycle ...

1. Ready to fire position. [Slide] is locked to barrel, both are fully forward.

[Icosahedral Pd with D atoms in TSC positions]

2. Upon firing, [slide] and barrel recoil backwards a short distance while locked together. Near the end of the barrel travel, the [slide] and barrel unlock.

[Firing = D-D Fusion]

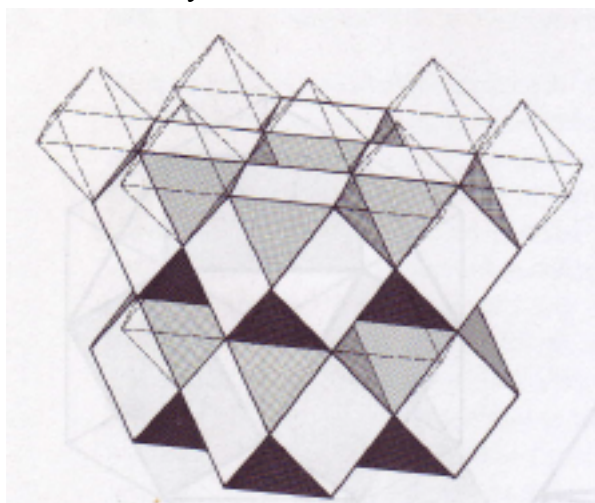
3. The barrel stops, but the unlocked [slide] continues to move to the rear, ejecting the empty shell and compressing the recoil spring.

[Recoil Spring = Icosahedral Stability Phase induces transformation of Cuboctahedra]

4. The [slide] returns forward under spring force, loading a new round into the barrel.

[Loading New Round = Cuboctahedral D atoms moved to Icosahedral TSC positions]

5. [Slide] locks into barrel, and forces barrel to return to battery.



... The very first short-recoil-operated firearm was also the first machine gun, the Maxim gun.

... Vladimirov also used the short recoil principle in the Soviet KPV-14.5 heavy machine gun. ..."

(quote from Wikipedia entries on M1911 pistol and on Recoil operation)

n = number of shells
 N = number of Pd atom vertices
 d = diameter of icosahedral configuration in nm
 C = number of cells in icosahedral phase
 CT = number of tetrahedral cells in icosahedral phase
 CO = number of octahedral cells in icosahedral phase

n N d $C = CT + CO$

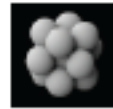
0 1 0.27 $0 = 0 + 0$

icosahedral   cuboctahedral

1 13 0.70 $20 = 20 + 0$



icosahedral



cuboctahedral

2 55 1.13 $100 = 80 + 20$

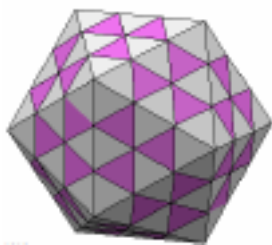


icosa

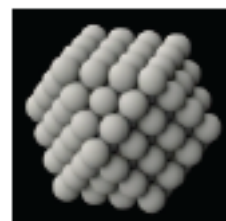
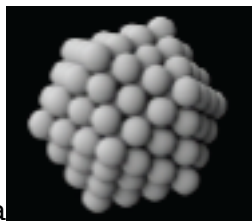


cubo

3 147 1.56 $280 = 200 + 80$



icosa

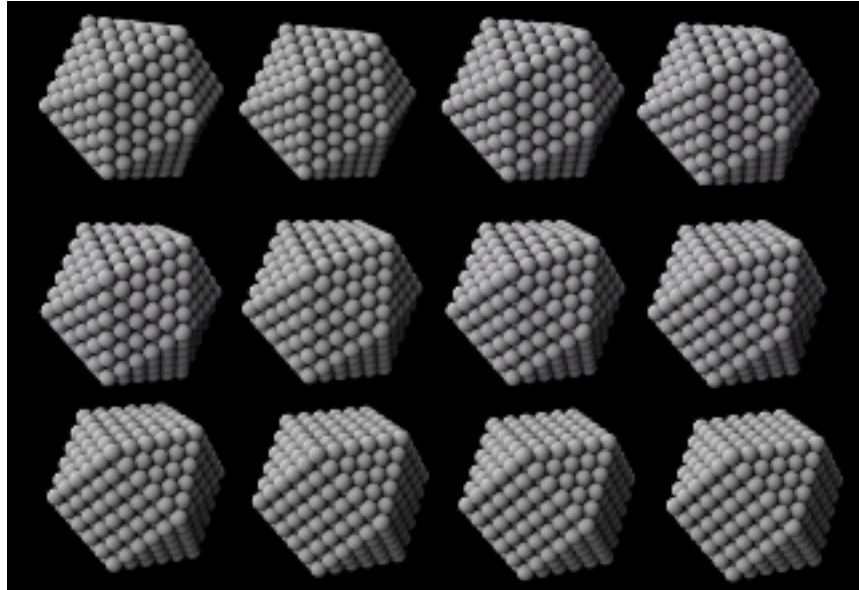


cubo

4 309 2.00 (icosa and cubo images not shown)

n N d(icosahedron)(nm)

5 561 2.44 12 stages of Jitterbug between
icosahedron (top left) and cuboctahedron (bottom right):



At the 5-shell level the Jitterbug transformation is harder to do than at lower levels.

Also, as the shell level and number of atoms increases and the configurations become larger the icosahedral phase becomes less stable.

6	923	2.88
7	1415	3.33
8	2057	3.77
9	2869	4.21
10	3871	4.65
11	5083	5.09
12	6525	5.53

(Images from: Polyhedral Clusters by Lord et al;
Frank and Kasper in Acta Cryst. 11 (1958) 184-190;
Mackay in Acta Cryst. 15 (1962) 1916-1918;
vimeo.com/27662398 by Yan Liang (L2XY2) August 2011.
Data for n, N, and d from Shtaya-Suleiman dissertation Gottingen 2003.)

147-atom Pd clusters have diameter about 1.56 nm according to 2003 Gottingen dissertation of Mohammed A . M. Shtaya-Sulieman at <http://webdoc.sub.gwdg.de/diss/2004/shtaya-suleiman/>

1.5 nm Pd clusters have been produced at Sandia National Laboratories and University of New Mexico Center for Micro-Engineered Materials according to a Journal of Catalysis article "Facile, surfactant-free synthesis of Pd nanoparticles for heterogeneous catalysts" at <http://www.flintbox.com/public/filedownload/2871/2011-038%20Science%20Direct%20Article> by Patrick D. Burton, Timothy J. Boyle, and Abhaya K. Datye.

I would like to see an experiment in which 1.5 nm Pd nanoparticle clusters from Sandia / U. New Mexico are immersed in Deuterium to see whether or not TSC fusion takes place.