Pd/Ni Clusters for D/H TSC Jitterbug Fusion

Frank Dodd (Tony) Smith Jr. - 2012, 2014

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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:

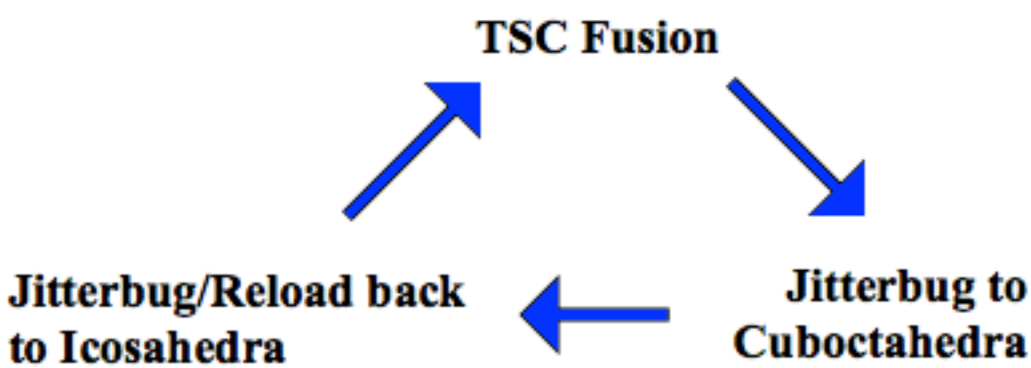
Icosahedral with Tetrahedral absorption sites
Cuboctahedral with Octahedral absorption sites

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

4 - Icosahedra TSC Fusion Triggers Jitterbug to Cuboctahedra.

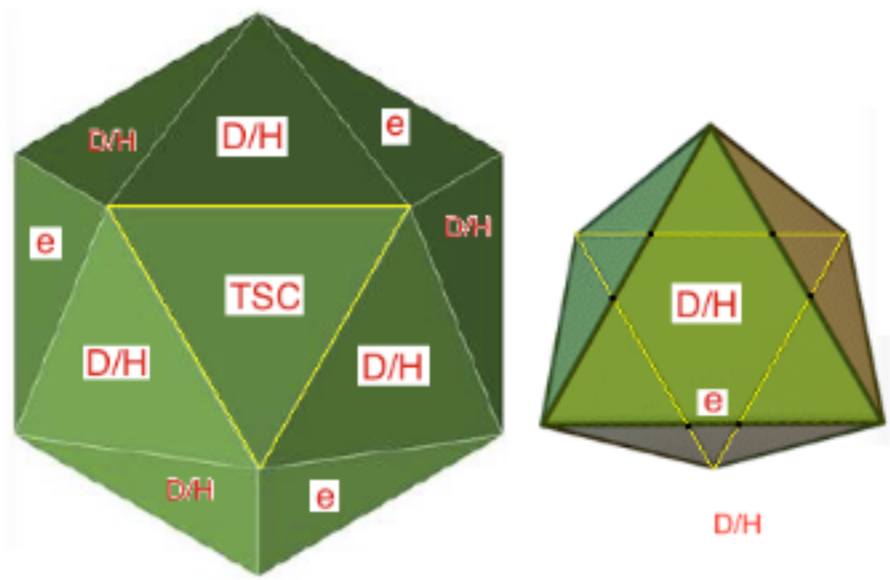
5 - Cuboctahedra Jitterbug back to Icosahedra and reload TSC sites.

6 - Repeat the Cycle:



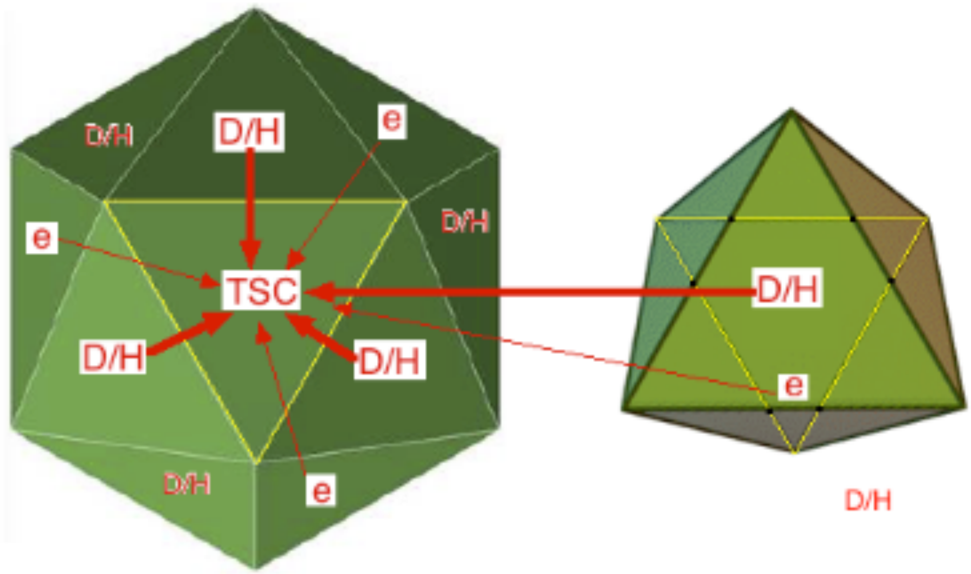
Akito Takahashi has developed a Tetrahedral Symmetric Condensate (TSC) model for fusion D+D+D+D -> 8Be and H+H+H+H -> 4 He in Pd and Ni atomic clusters. This paper describes the geometry of Pd/Ni atomic clusters and how it enables TSC fusion of D/H within the Pd/Ni clusters.
The icosahedral state at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

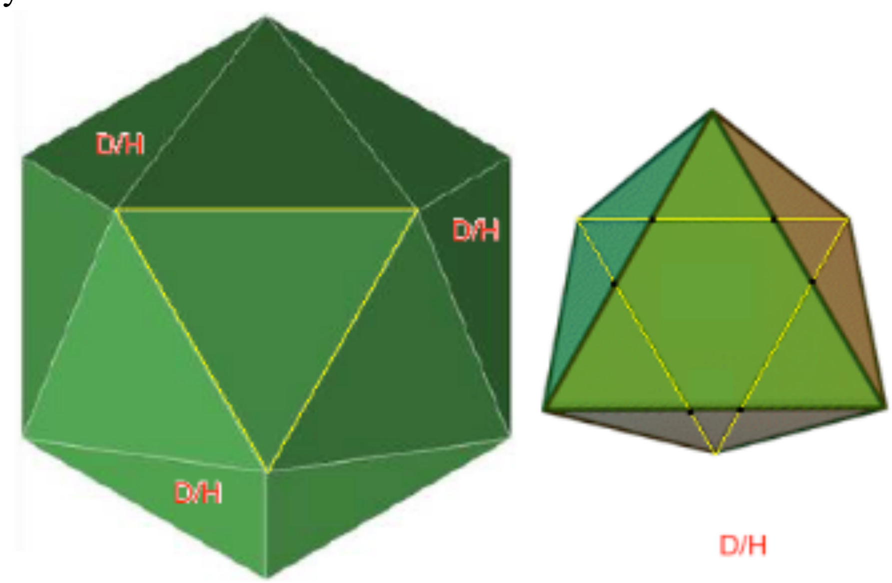


The octahedral cell marked D/H e (large type) is located in the atomic cluster directly above the TSC cell such that the TSC top face coincides with the bottom face of the octahedron. It contains the 4th of the 4 D/H nuclei for TSC fusion and its electron.The D/H (small type) outside the octahedral cell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

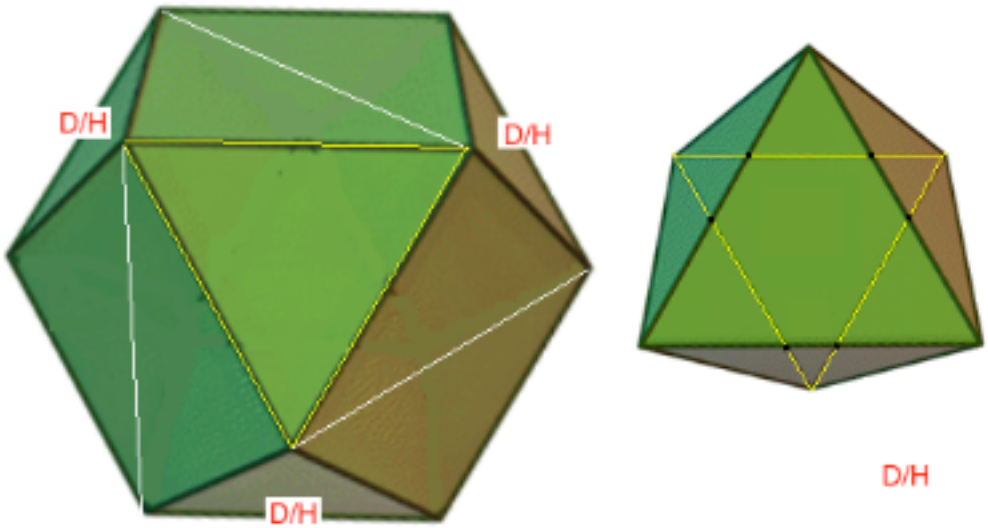
In TSC fusion the 4 D/H nuclei, Coulomb-shielded by their electron clouds, condense at the center of the TSC cell where their fusion produces 8 Be / 4 He.



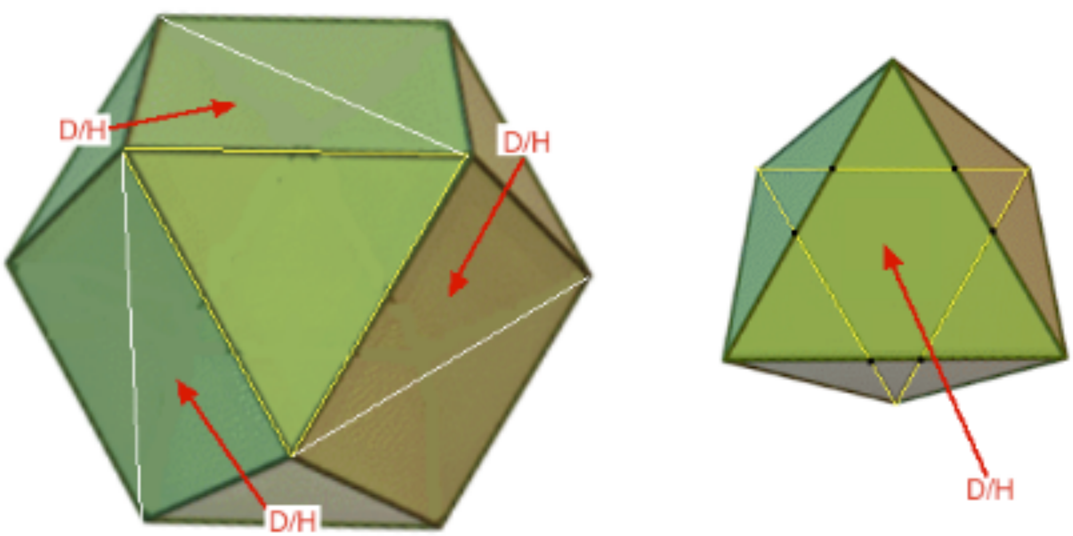
Immediately after TSC fusion



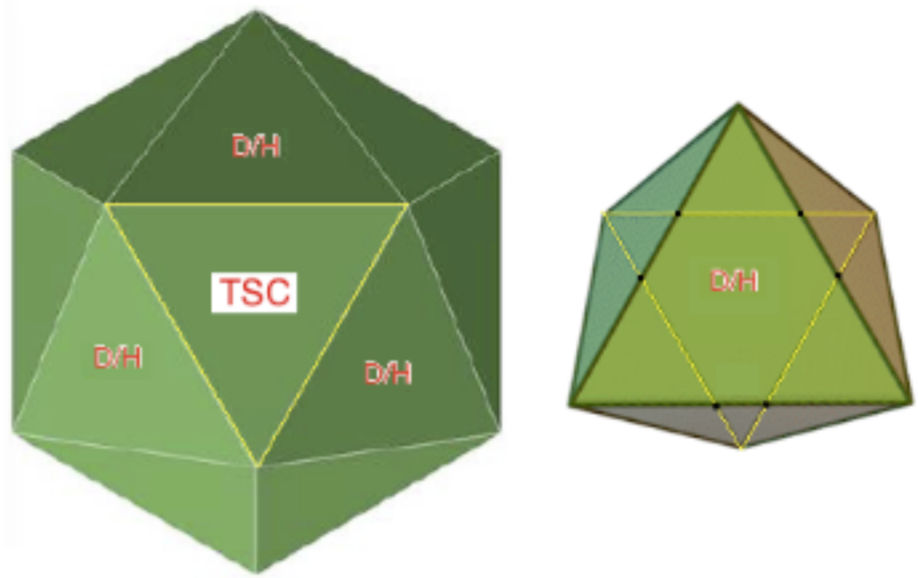
the TSC fusion cell and the D/H fuel cells and their associated e cells are empty but the D/H (small type) reloading cells contain the D/H for Jitterbug reloading. The TSC fusion energy released drives the Pd/Ni cluster state by a Jitterbug transformation to an expanded cuboctahedral state.



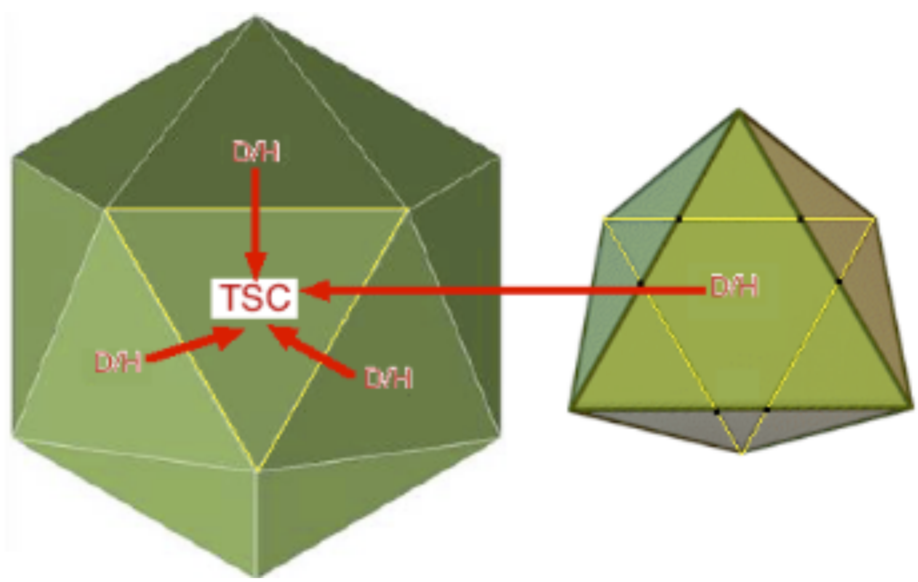
As Buckminster Fuller showed (Synergetics Macmillan 1975, 1982) a cuboctahedron is made up of 8 tetrahedral and 6 half-octahedral cells. 2 of the icosahedral tetrahedra correspond by Jitterbug to one of the cuboctahedral half-octahedra.
The Jitterbug expansion having produced large empty octahedra-type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

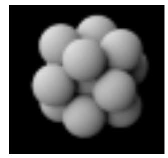
Icosahedral and Cuboctahedral

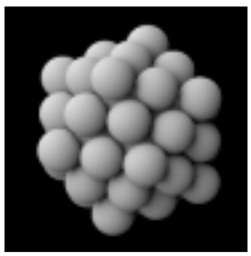
From vimeo.com/27662398 by Yan Liang (L2XY2) August 2011: "...

Icosahedral vertices Cuboctahedral

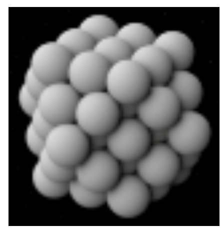
1

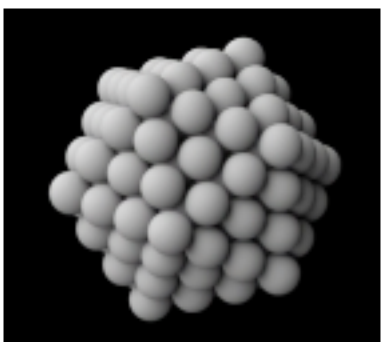
12+1 = 13



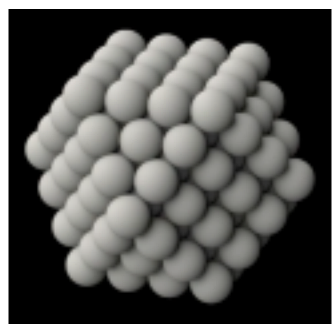


42+13 = 55





92+55 = 147



...".

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.

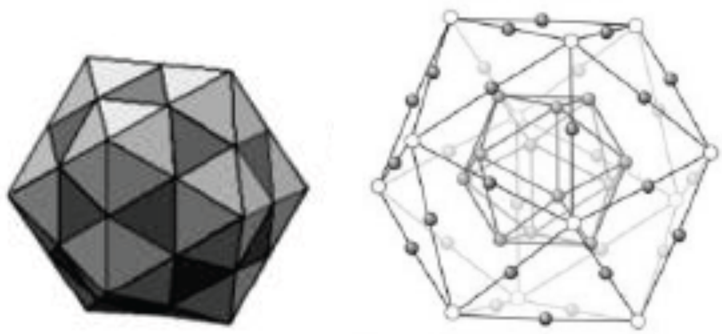
The 147-atom Pd/Ni cluster has the 2 TSC fusion sites of the 55-atom TSC cluster plus 12 more half-icosahedra in its outer shells along with octahedra for each, so it is a TSC Fusion Cluster of order 14.

How do the Icosahedral Clusters grow to 147 atoms ?

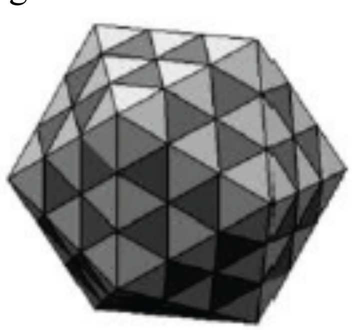
Eric A. Lord, Alan L. Mackay, and S. Ranganathan say in
"New Geometries for New Materials" (Cambridge 2006):

"... 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 x (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 12x5 = 60 outer cell faces of 5-rings thus adding 60 x (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 14x4 = 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.

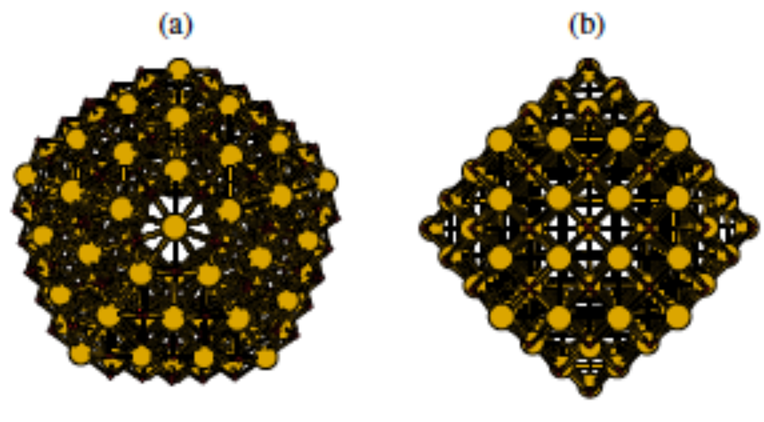
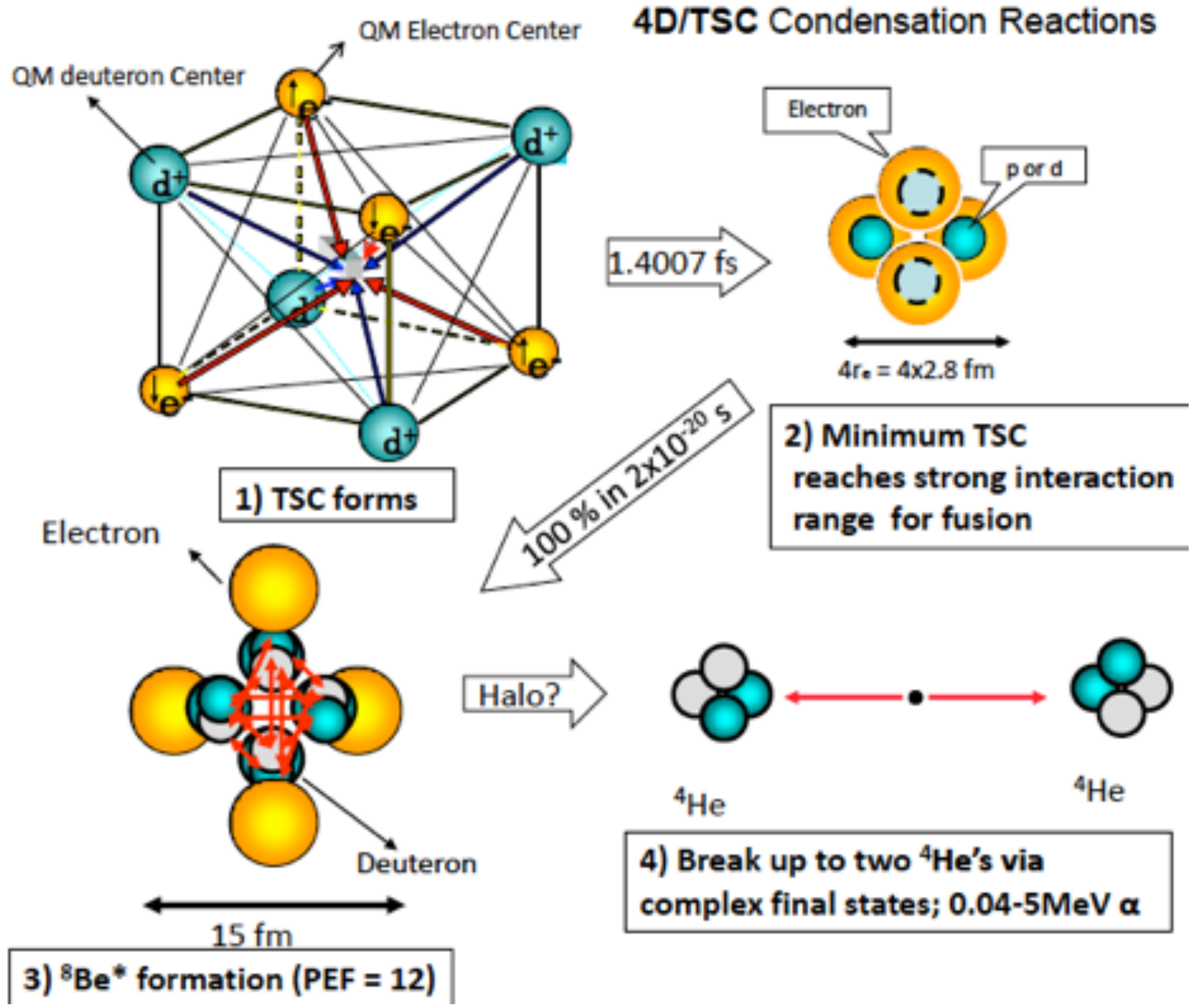


Figure 1. Palladium clusters fully loaded with hydrogen.
(a) $Pd_{147}H_{200}$, I_h symmetry; (b) $Pd_{147}H_{164}$, O_h symmetry. ...".

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,
<e> = (e↓ + e↑)/2 for QM view at four electron centers ...

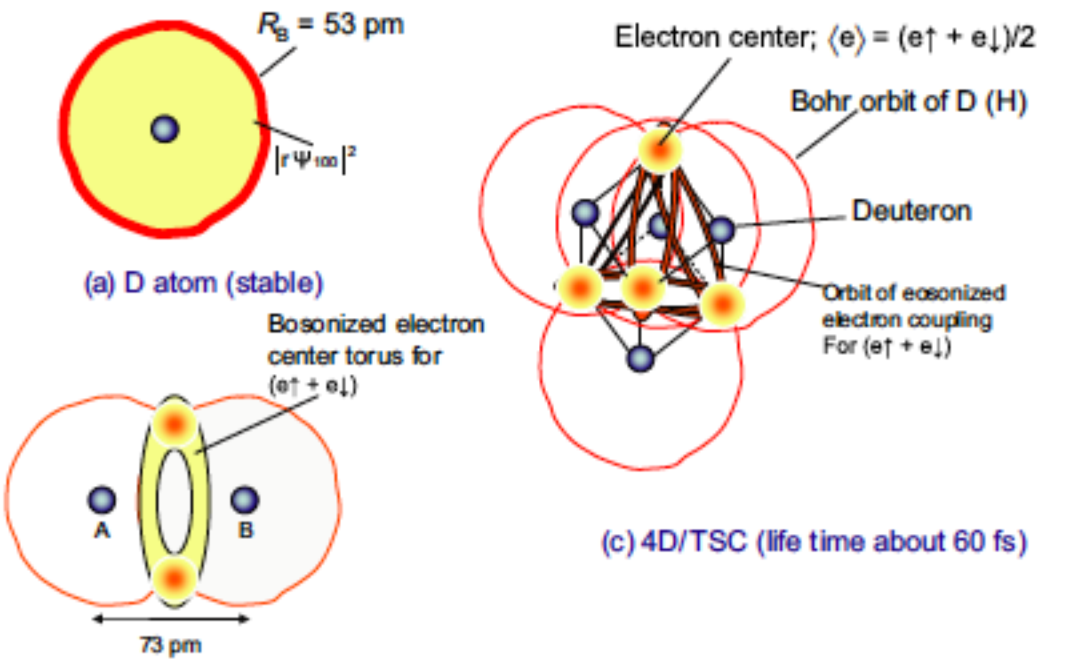


[**Note that the TSC process is spontaneous not requiring initial stimulus**.]

... 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 ...

[**NOTE - Takahashi has revised his 8Be* decay scheme. Now no 23.8 MeV alpha particles are produced - see page 24 of this paper**]

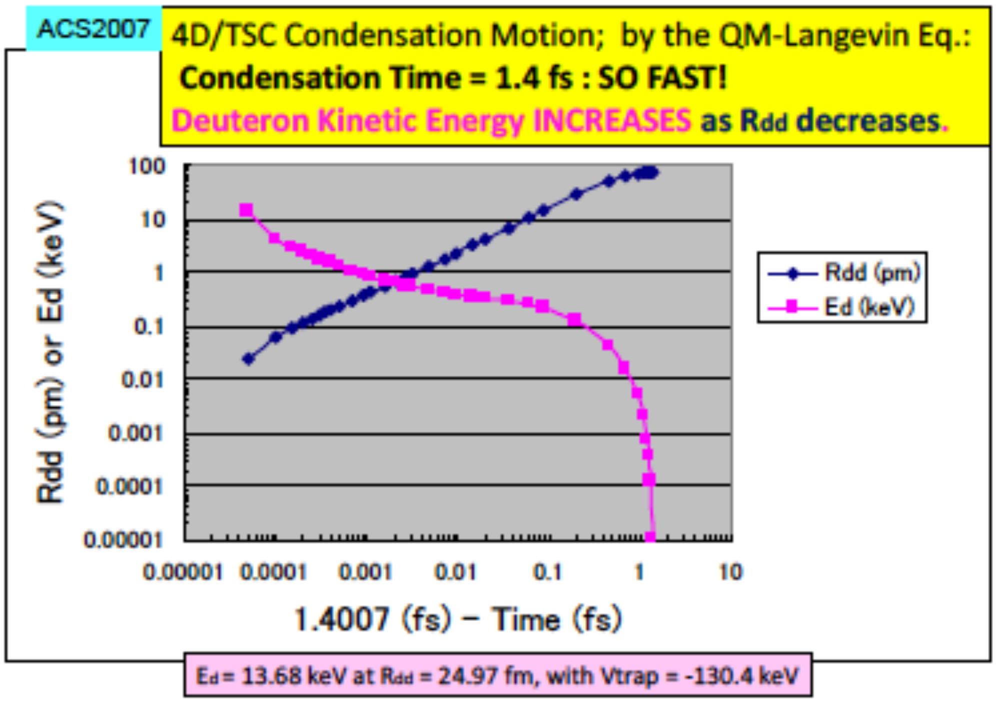
when TSC is just formed ... averaged electron position (electron center of <e> = (e↓ + e↑)/2, Bosonized electron pair ...) ... locates at vertexes of regular cube with tetrahedral combining orbits and outer dilute clouds ...



(b) D2 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 (Rdd = 74 pm) is formed ... the QM-Langevin equation gives numerical solution for time-dependent Rdd 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 ...

D + D + D + D -> 8Be* (Ex= = 47.6 MeV: J*) ...

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 x 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).

...

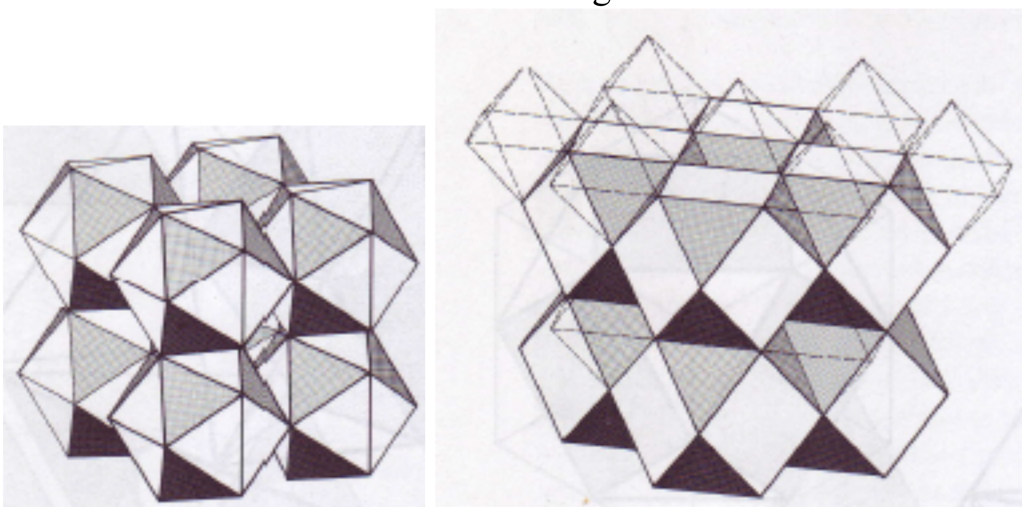
the quantitative study on the **TSC formation probability in D(H)-loaded metal systems is yet to be done** by solving many-body time-dependent problems under organization field of condensed matter. It is challenging work ...".

The answer to that challenge may be

the Icosahedra <-> Cuboctahedra Jitterbug Transformation.

What is the Jitterbug Transformation ?

Icosaahedra 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 - 2x6 = 8 (shaded) triangle faces are rotated and become the other 14 - 6 = 8 triangle faces of the Cuboctahedron.

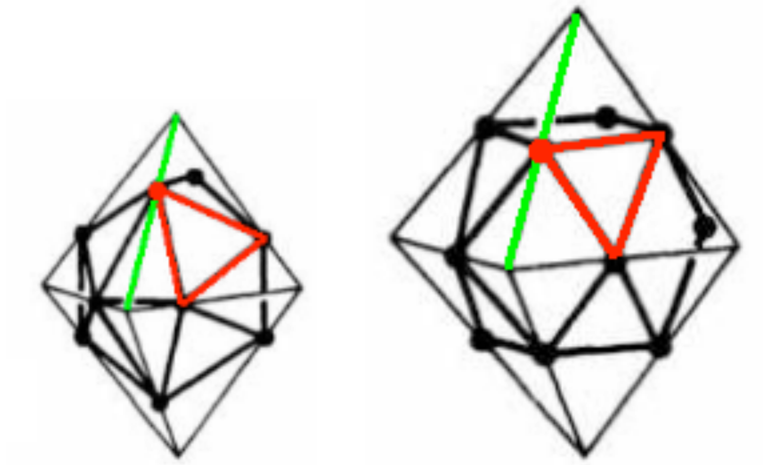
,

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:

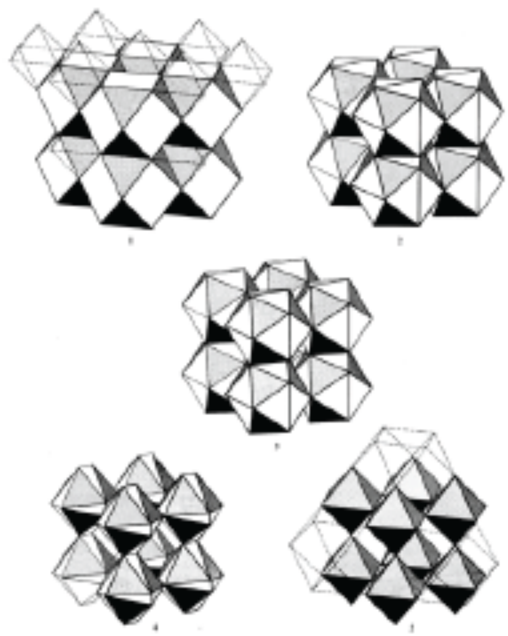
Icosahedron volume = (5/12) (3 + sqrt(5)) = 2.18169499
Cuboctahedron volume = (5/3) sqrt(2) = 2.3570226

Icosahedron/Cuboctahedron volume ratio = 0.9256147947

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]

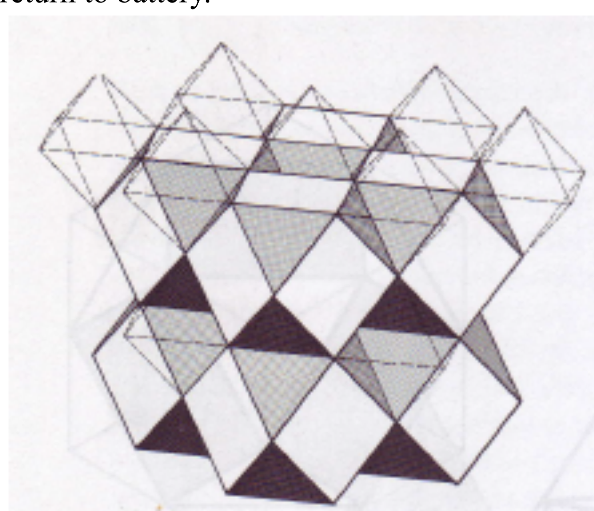
3. The barrel stops, but the unlocked [slide] continues to move to the rear, ejecting the empty shell and compressing the recoil spring.

[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.

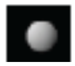
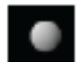


... The very first short-recoil-operated firearm was also the first machine gun, the Maxim gun.
... Vladimirov also used the short recoil principle in the Soviet KPV-14.5 heavy machine gun. ..."

(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

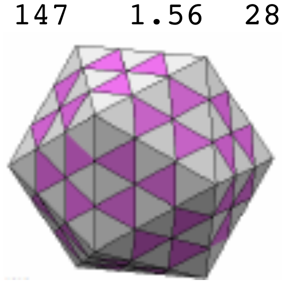
n	N	d	C =	CT + CO
1	13	0.70	20 =	20 + 0

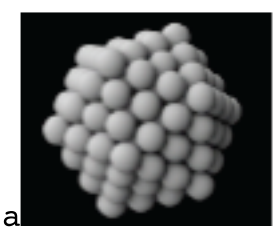
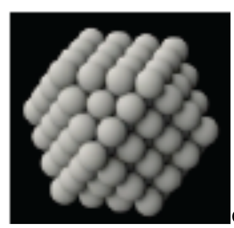
icosahedral   cuboctahedral

n	N	d	C =	CT + CO
2	55	1.13	100 =	80 + 20

icosa   cubo

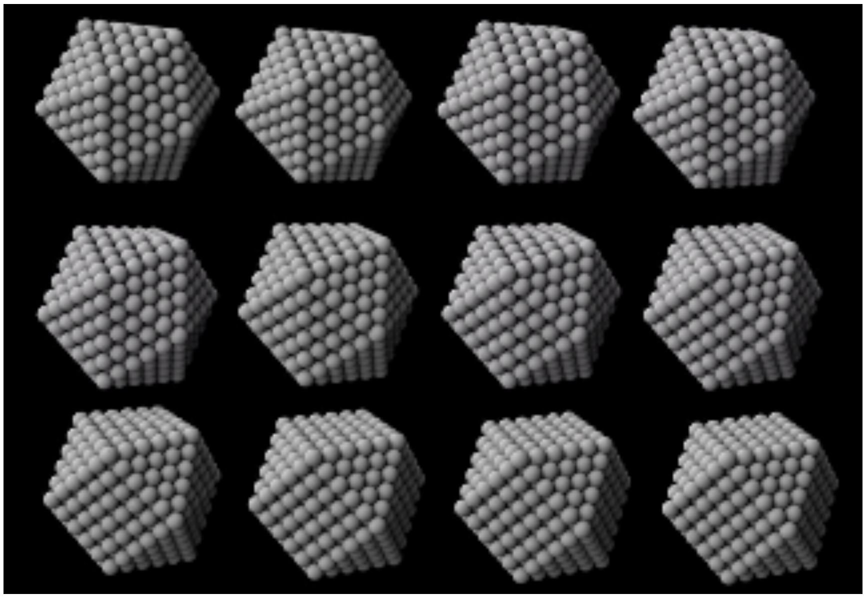
n	N	d	C =	CT + CO
3	147	1.56	280 =	200 + 80



icosa   cubo

4 309 2.00 (icosa and cubo images not shown)

n	N	d(icosa)(nm)	
5	561	2.44	12 stages of Jitterbug between icosa (top left) and cubo (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.

Iraj Parchamazad Experiments: Heat from Pd Clusters of the size required for Jitterbug / TSC Fusion

The size required for Jitterbug / TSC Fusion is a Palladium atomic cluster whose ground state is icosahedral and can easily Jitterbug Transform into a cuboctahedral state. The most useful sizes are

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3-shell cluster with 147 atoms and size 1.56 nanometers
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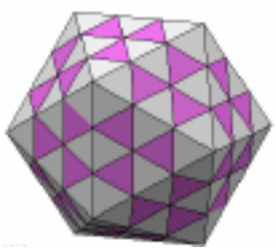
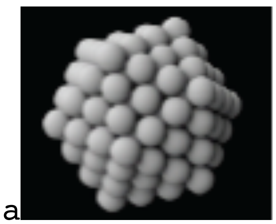
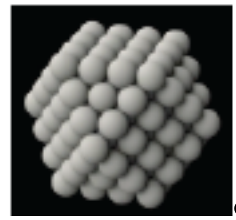
 icosa   cubo

```
and
4-shell cluster with 309 atoms and size 2.00 nanometers
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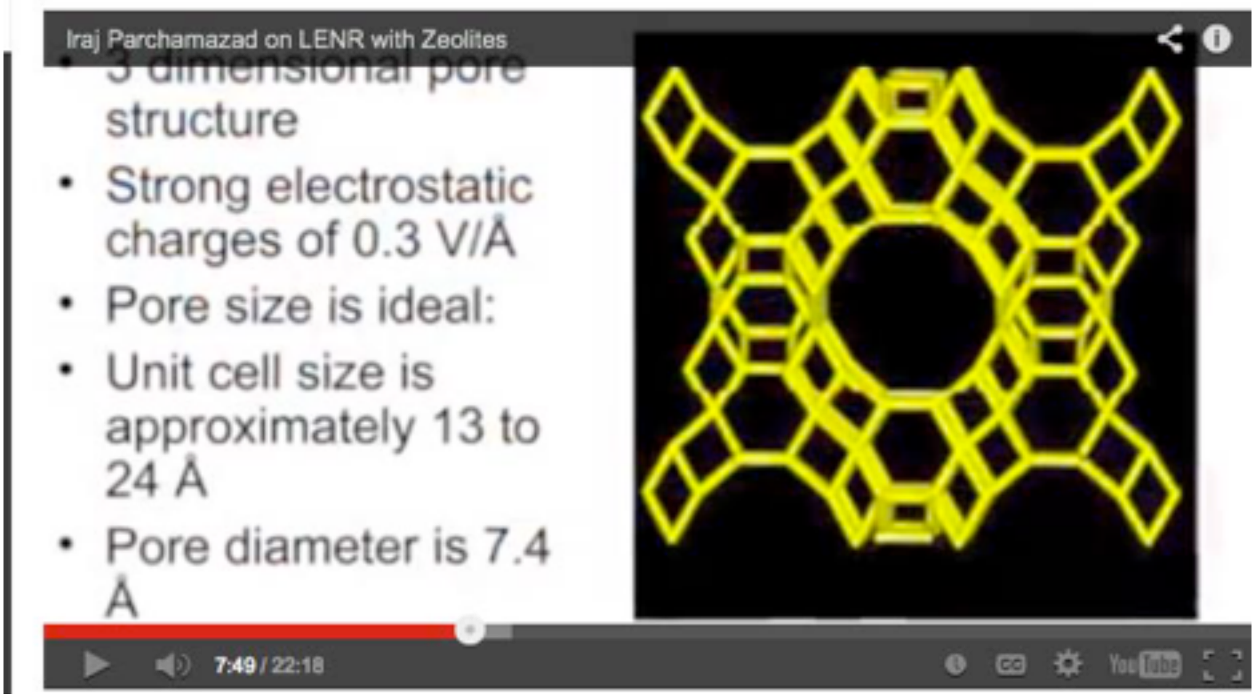
Ruby Carat and Melvin Miles interviewed Iraj Parchamazad of University of LaVerne in 2012. Here are some screen shots from the video interview:

Iraj Parchamazad on LENR with Zeolites

a billiionth-of-a-meter is 1 nanometer



13 to 24 A (Angstroms) = 1.3 to 2.4 nanometer

Palladium 3-shell clusters (147 atoms, 1.56 nanometers)
and 4-shell clusters (309 atoms, 2.00 nanometers)
will fit into the Zeolite Unit Cell (1.3 to 2.4 nanometers)
but
the 5-shell cluster (561 atoms, 2.44 nanometers)
and larger clusters are too big to fit easily
and are less able to have a Jitterbug Transformation.
Smaller clusters (0,1,2 shells) will fit in the Zeolite Cell
but they will not hold as much Deuterium for TSC Fusion.

Iraj Parchamazad on LENR with Zeolites

The 0.74 nanometer (7.4 Angstrom) pore diameter
is smaller than the 1.56 and 2.00 nanometer size
of the 3-shell (147 atoms) and 4-shell (309 atoms) Pd Clusters

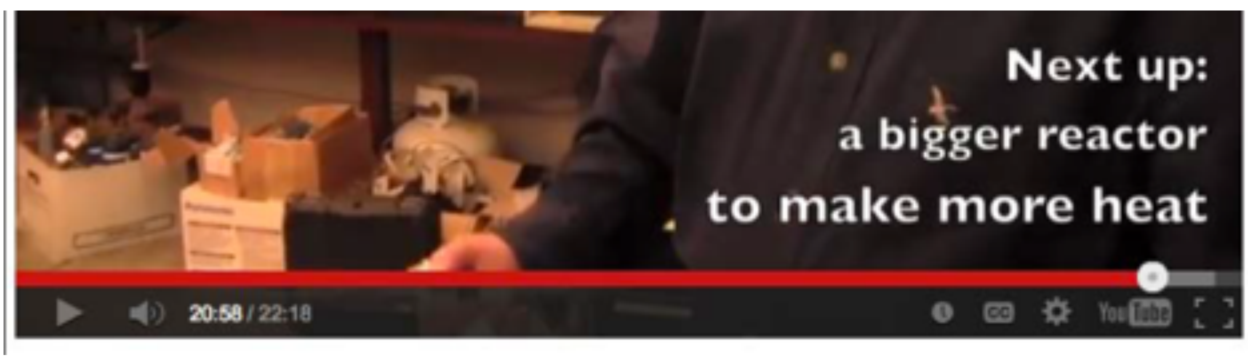
but

the Zeolite Opening can Open Up to let them in:

Iraj Parchamazad on LENR with Zeolites

Iraj Parchamazad on LENR with Zeolites

Iraj Parchamazad on LENR with Zeolites



I hope that a bigger reactor will be built in California
to make and measure more heat
and
to produce a protoype machine producing useful energy.

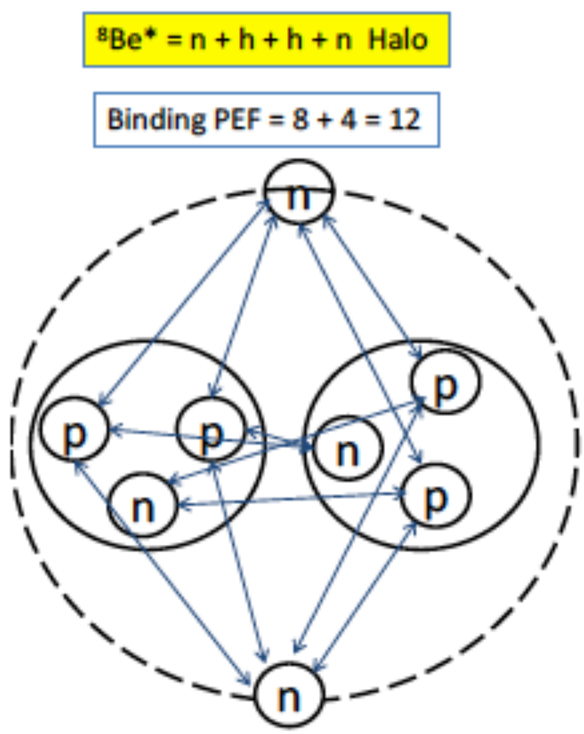
Akito Takahashi has done recent work indicating that TSC Fusion of 2D1 + 2D1 + 2D1 + 2D1 = 4D will NOT form 23.8 MeV alpha particles from the Beryllium excited state 8Be4*

Akito Takahashi said in a September 2014 email message:

"… my recent theory of nucleon-halo model (JCF13, attached) maximum alpha-particle energy from 8Be* by 4D-fusion is 17 MeV … 23.8 MeV alpha particles should not be emitted either by the 4D-fusion or by the DD fusion …".

His paper JCF13 says

"… The 8Be* (Ex = 47.6 MeV) may damp its excited energy by major BOLEP (burst of low energy photons) process from <n-h-h-n> nucleon-helion halo state ...



... to 8Be-ground state …
A complex decay scheme is proposed …

Major decay channel is modeled as an electro-magnetic transition of BOLEP
to the 8Be-ground state which breaks up into two 46 keV alpha-particles ...
BOLEP is modeled as emission of ... stochastic burst events
of ca. 1.5 keV averaged energy photons ...
Minor channels are modeled as BOLEP transitions to lower ... states
(Ex = 34, 27.5, 22.98, 22.0, 20.1, 16.6, 11.4 and 3.04 MeV),
from where two-alpha beak-up channels open ... emit[ting] ... alpha-particles at
17, 13.8, 11.5, 11, 10, 8.3, 6.9, 5.7 and 1.55 MeV
... which meets ... with observed data by Roussetski et al ...
The asymmetric break-up from the EX = 34 MeV state
has a branch to emit 5.2 MeV triton,
which will induce secondary D-t reaction ... to emit 9-19 MeV (En) neutrons ...".

**Due to the complexity of the decay scheme
and the fact that most of the energy will go to photons
rather than charged particles such as alpha**

**I hope that a bigger California reactor
will not expend much effort on measuring decay products
but
will emphasize ways to scale up the Iraj Parchamazad experiments
and
ways to get the fusion energy into useful form efficiently.**