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

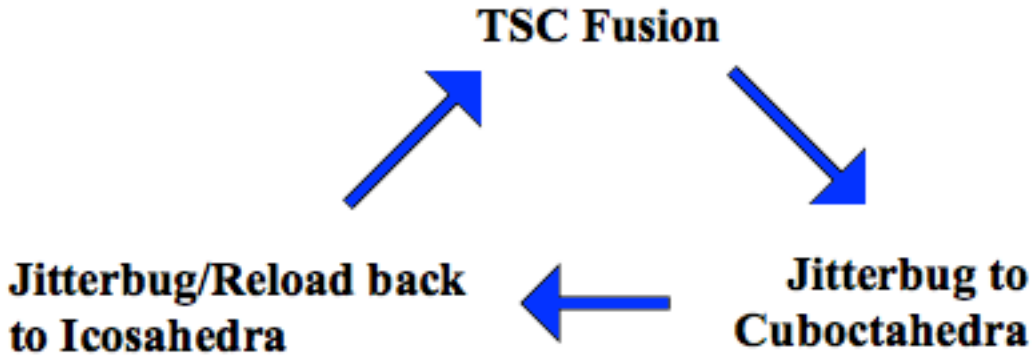
Cuboctahedral with Octahedral absorption sites

3 - Tetrahedral Symmetric Condensation (TSC) in 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:



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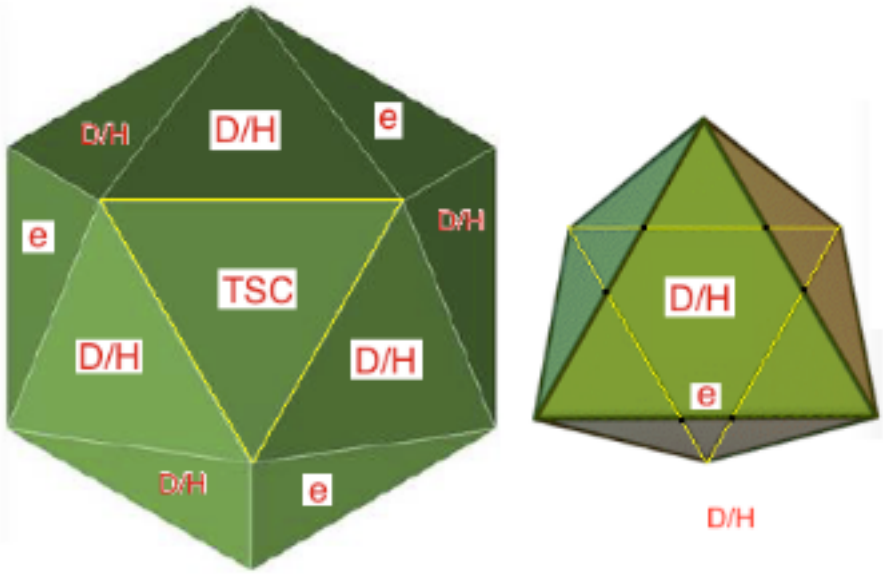
NOTE - Most of the detailed quantitive discussion in this paper is for Pd / D Fusion
but Nickel / Hydrogen is very similar to Palladium / Deuterium
so some of the mutually applicable images etc also indicate Ni / H Fusion.

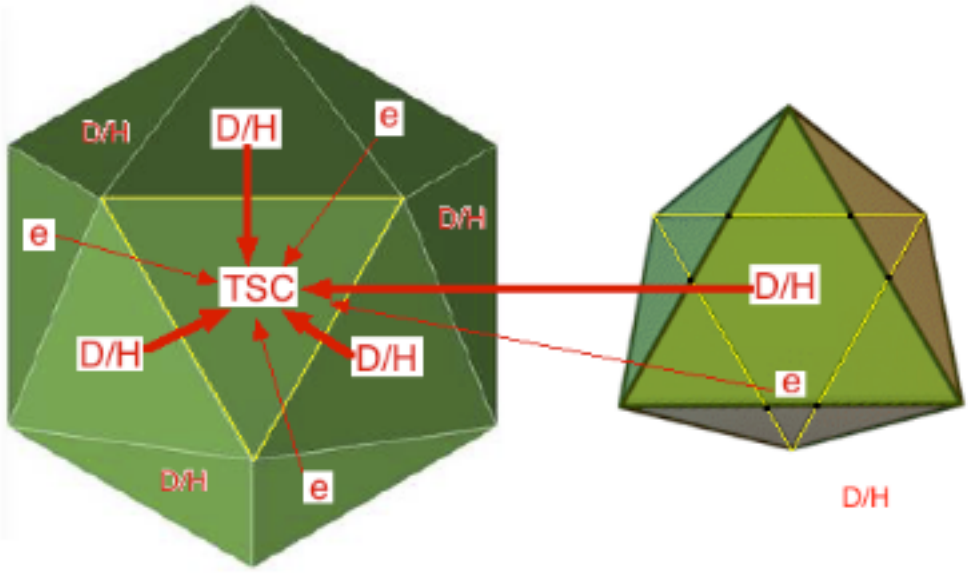
Akito Takahashi has developed a Tetrahedral Symmetric Condensate (TSC) model for fusion D+D+D+D -> 8Be and H+H+H+H -> 4 He in Pd and Ni atomic clusters. This paper describes the geometry of Pd/Ni atomic clusters and how it enables TSC fusion of D/H within the Pd/Ni clusters.
The icosahedral state at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

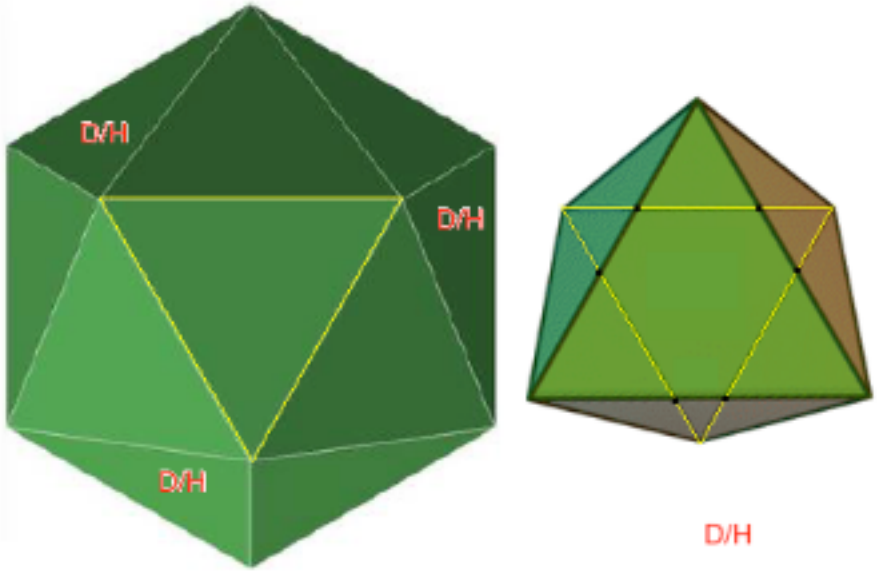


The octahedral cell marked D/H e (large type) is located in the atomic cluster directly above the TSC cell such that the TSC top face coincides with the bottom face of the octahedron. It contains the 4th of the 4 D/H nuclei for TSC fusion and its electron.The D/H (small type) outside the octahedral cell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

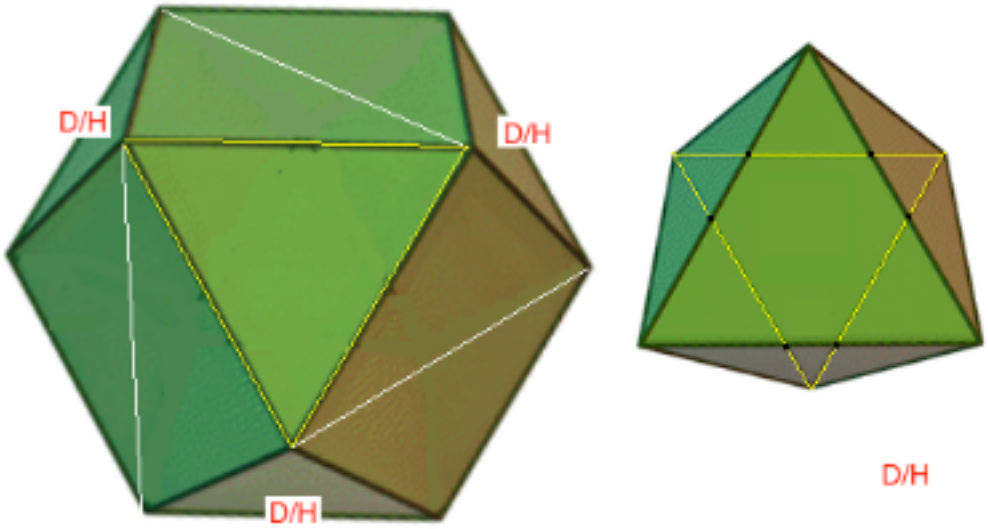
In TSC fusion the 4 D/H nuclei, Coulomb-shielded by their electron clouds, condense at the center of the TSC cell where their fusion produces 8 Be / 4 He.



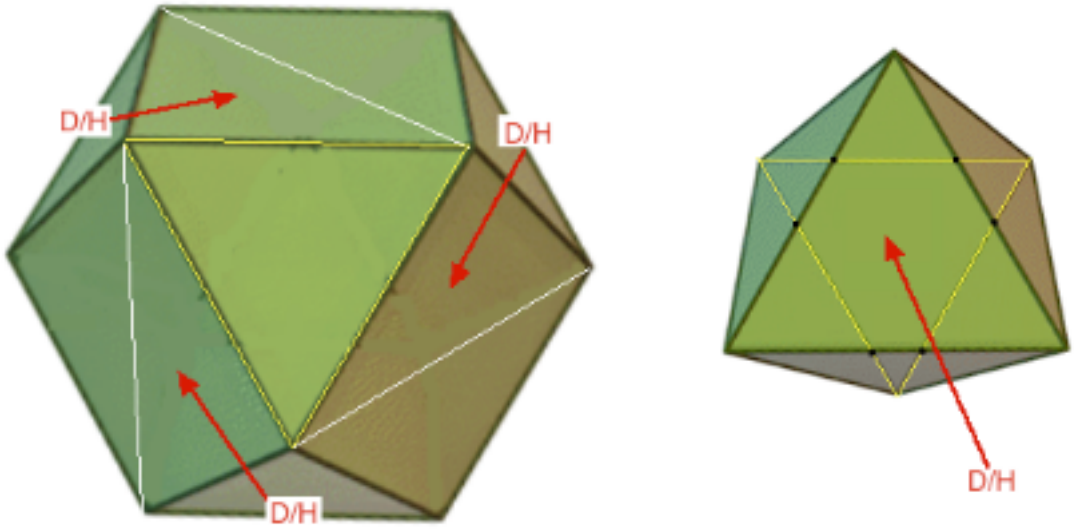
Immediately after TSC fusion



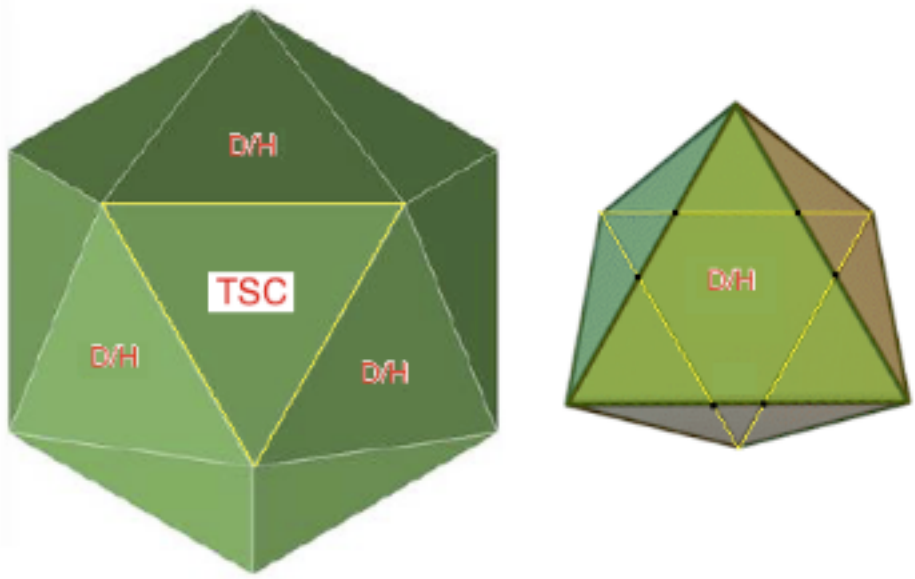
the TSC fusion cell and the D/H fuel cells and their associated e cells are empty but the D/H (small type) reloading cells contain the D/H for Jitterbug reloading. The TSC fusion energy released drives the Pd/Ni cluster state by a Jitterbug transformation to an expanded cuboctahedral state.



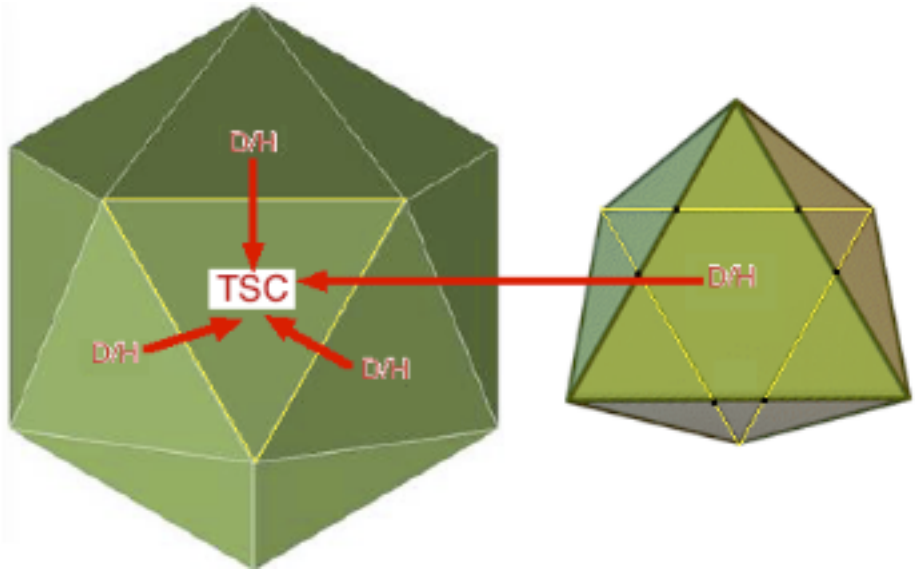
As Buckminster Fuller showed (Synergetics Macmillan 1975, 1982) a cuboctahedron is made up of 8 tetrahedral and 6 half-octahedral cells. 2 of the icosahedral tetrahedra correspond by Jitterbug to one of the cuboctahedral half-octahedra.
The Jitterbug expansion having produced large empty octahedra-type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

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

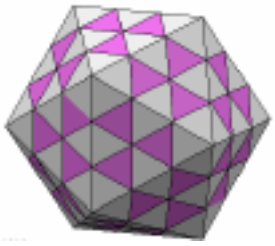
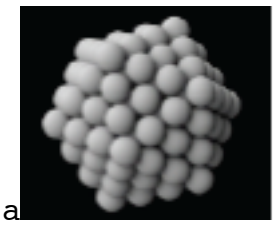
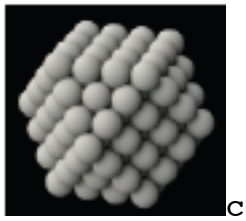

cuboctahedral

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)		

(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.)

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 Site.

The 55-atom Pd/Ni cluster has a full icosahedron (two half-icosahedra) and two octahedra to form 2 TSC Fusion Site.

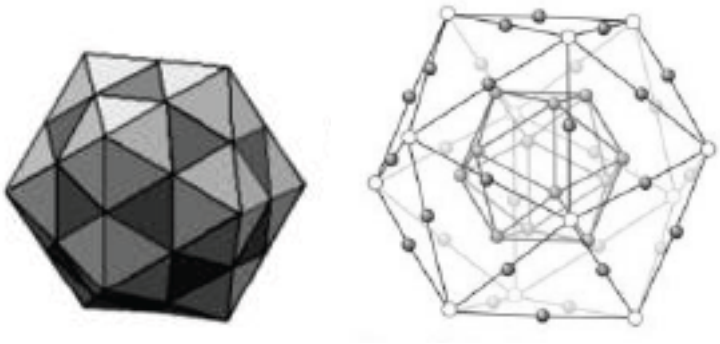
The 147-atom Pd/Ni cluster has the 2 TSC Fusion Sites of the 55-atom TSC cluster plus 12 more half-icosahedra in its outer shells along with octahedra for each, so it has 14 TSC Fusion Sites.

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

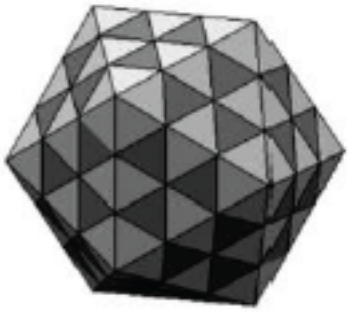
be filled by five-rings of tetrahedra [42 + 12 = 54 vertices]...



... 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**]...".

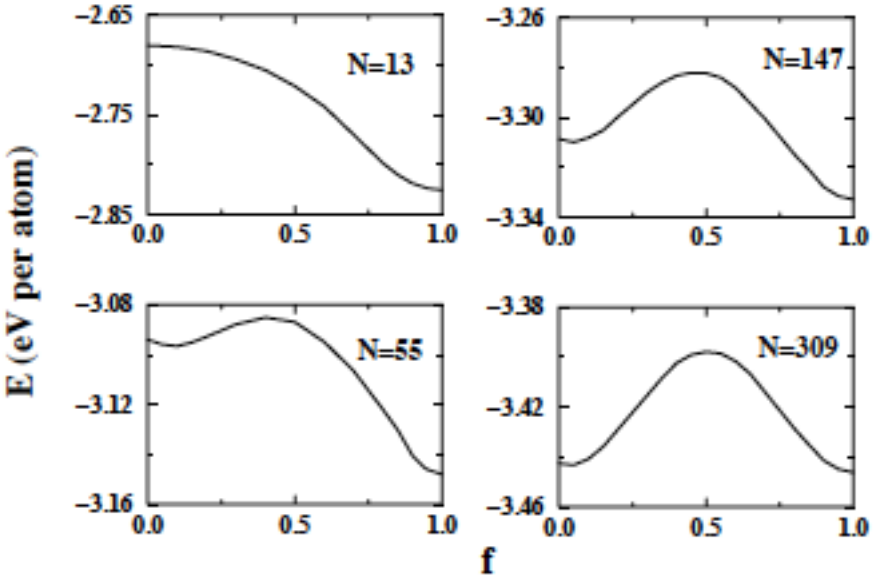
Lord et al use 12, 54, and 146 atoms for Mackay clusters
while Liang uses 13, 55, and 147 atoms.
The difference is whether or not the center vertex is counted, that is,
not so much a real physical difference but a difference in math convention.

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 Jitterbug and TSC Fusion.
The next Mackay cluster beyond 147 atoms has 147+162 = 309 atoms.

Barretau, Desjonqueres, and Spanjaard in Eur. Phys. J. D. 11 (2000) 395-402 say:
"... the icosahedron is the preferred structure at small sizes, and the critical size at which the relative stability becomes favorable to cuboctahedrons is N = 561 for PdN clusters ...[for which]... For N = 13 the cuboctahedron is ... unstable.

For N = 55, 147, and 309 atoms the cuboctahedron is metastable and slightly distorted. Its transformation to a perfect icosahedral structure needs an activation energy of 12 meV for N = 55, 28 meV for N = 147 and 45 meV for N = 309. The activation energies involved in the inverse transformation are 61 meV for N = 55, 51 meV for N = 147 and 48 meV for N = 309.
...[compare 47.6 MeV for each TSC Fusion event]...



... The evolution of the potential energy profile of homogeneously relaxed ... PdN clusters during the Mackay [Jitterbug] transformation for increasing values of N. f is a fraction of the displacements ... f = 0 and 1 correspond to the ... cuboctahedron and icosahedron, respectively ...".

N = 309 is disfavored for TSC-Jitterbug Fusion with respect to N = 147 for two reasons:

energy levels are too close for rapid Jitterbug cubocta to icosa transition

N = 309 Pd Cluster is too large (2 nm) to fit through 1.5 nm expanded Sodium Zeolite Y pore

It seems that **147 atoms is optimal for TSC fusion**.

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.

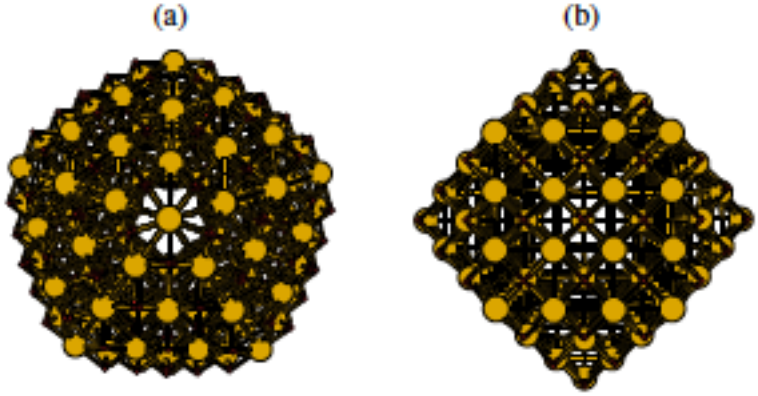


Figure 1. Palladium clusters fully loaded with hydrogen.
(a) $Pd_{147}H_{200}$, I_h symmetry; (b) $Pd_{147}H_{164}$, O_h symmetry.

..."

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 long does it take Deuterium to load into Palladium ?

Wang, Hara, and Watanabe in Materials Transactions, Vol. 48, No. 3 (2007) pp. 560 to 565 say:
"... Pure Pd, Pd-4 at%Pt and Pd-8 at%Pt ... powders smaller than 200 mesh (**<**74 **m**m) were prepared ... hydrogen absorption ...[by Pd-4 at%Pt]... was extremely fast and attained to equilibrium within tens of seconds. Hydrogen absorption by Pd and Pd-8 at%Pt was also very fast ...".

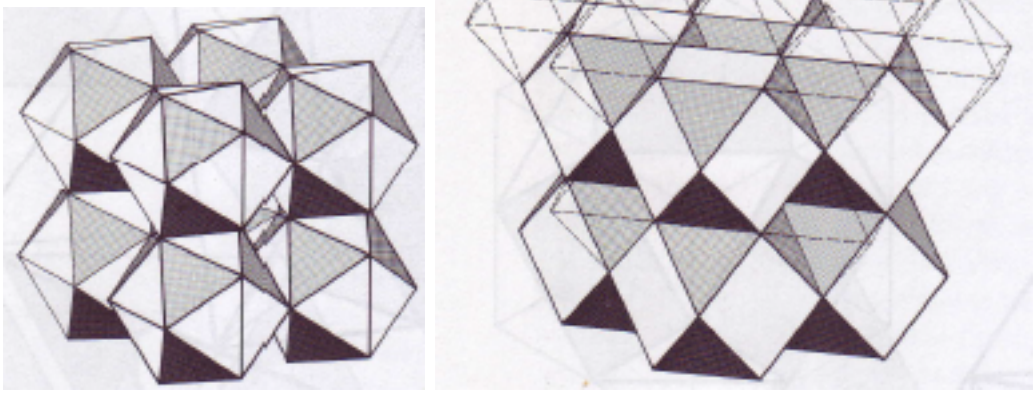
Tens of seconds is much longer than the times for TSC Fusion and for Jitterbug so it determines the time duration of one TSC-Jitterbug Fusion Cycle
and
for the purpose of rough calculations it seems reasonable to take

36 seconds = 1/100 hour = time duration of one TSC-Jitterbug Fusion Cycle.

This time is much shorter than the usual loading time for old-type Cold Fusion experiments using Palladium rods, discs, much-larger-than 1.5 nm powder, etc because there are only 3 layers of Pd atoms in 1.5 nm 147-atom Pd clusters.

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))

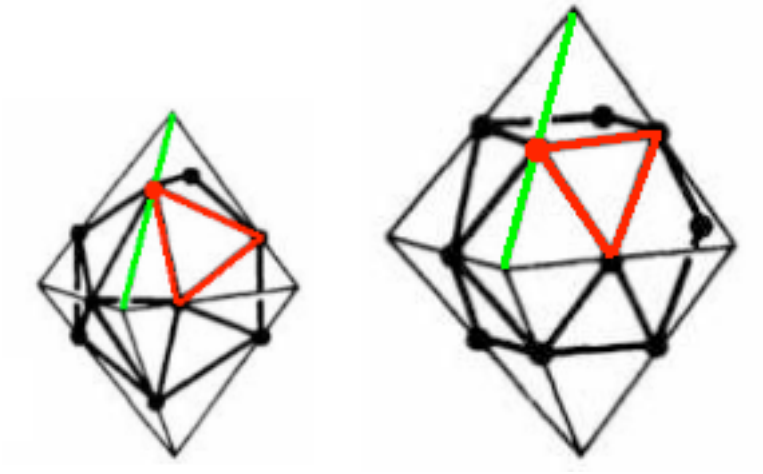
To make Cuboctahedra (unit edge length) from Icosahedra (unit edge length) choose 6 pairs of Icosahedra triangle faces (white in the above images) and lengthen the common edge of each pair by a factor of sqrt(2). That expansion flattens each of the triangle pairs to produce 6 square faces of the Cuboctahedron. 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:

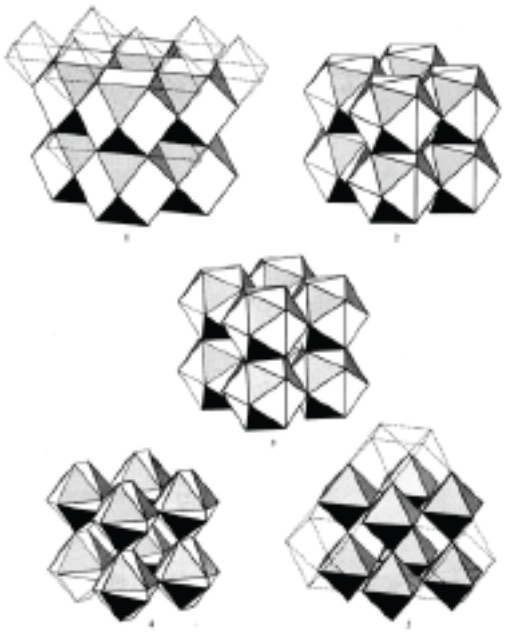
Icosahedron volume = (5/12) (3 + sqrt(5)) = 2.18169499
Cuboctahedron volume = (5/3) sqrt(2) = 2.3570226

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,

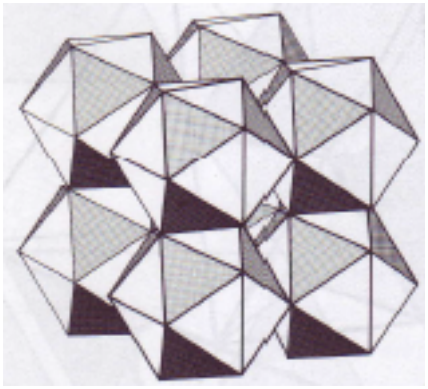
the D/H fusion fuel nuclei are moved from cell to cell
by the Jitterbug transformations

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]

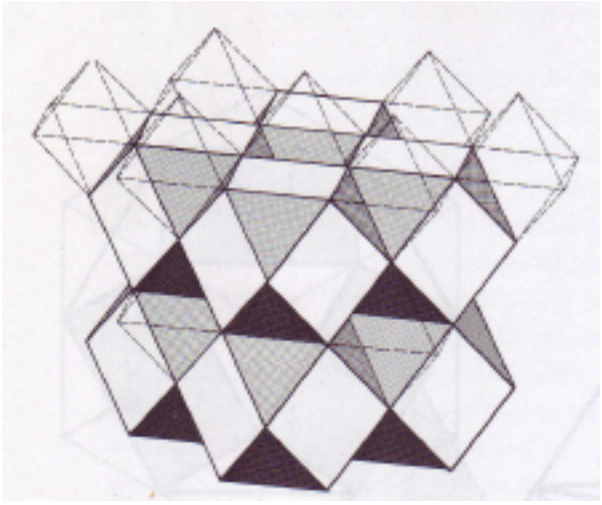
3. The barrel stops, but the unlocked [slide] continues to move to the rear, ejecting the empty shell and compressing the recoil spring.

[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.

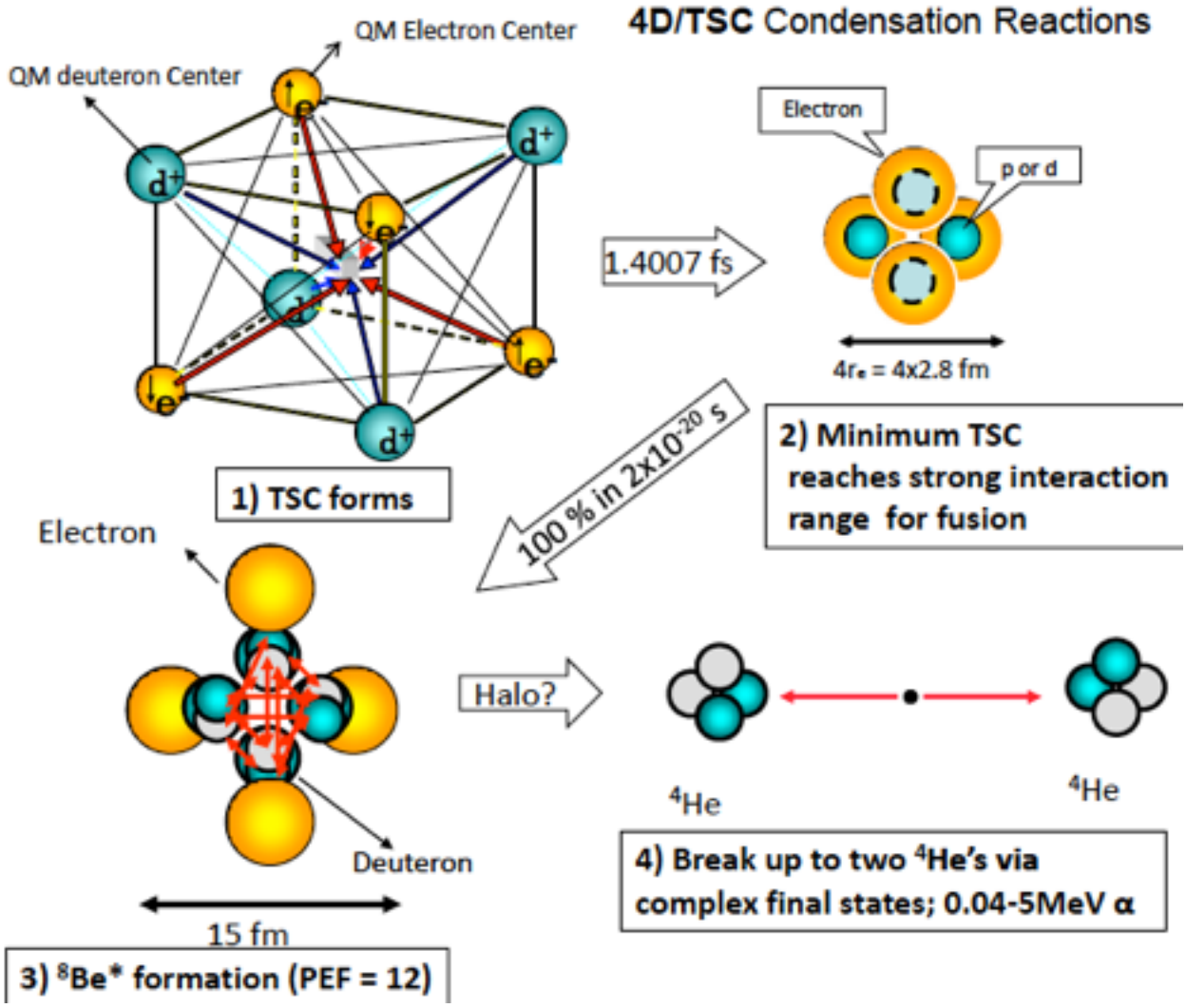


... The very first short-recoil-operated firearm was also the first machine gun, the Maxim gun. ... Vladimirov also used the short recoil principle in the Soviet KPV-14.5 heavy machine gun. ..."

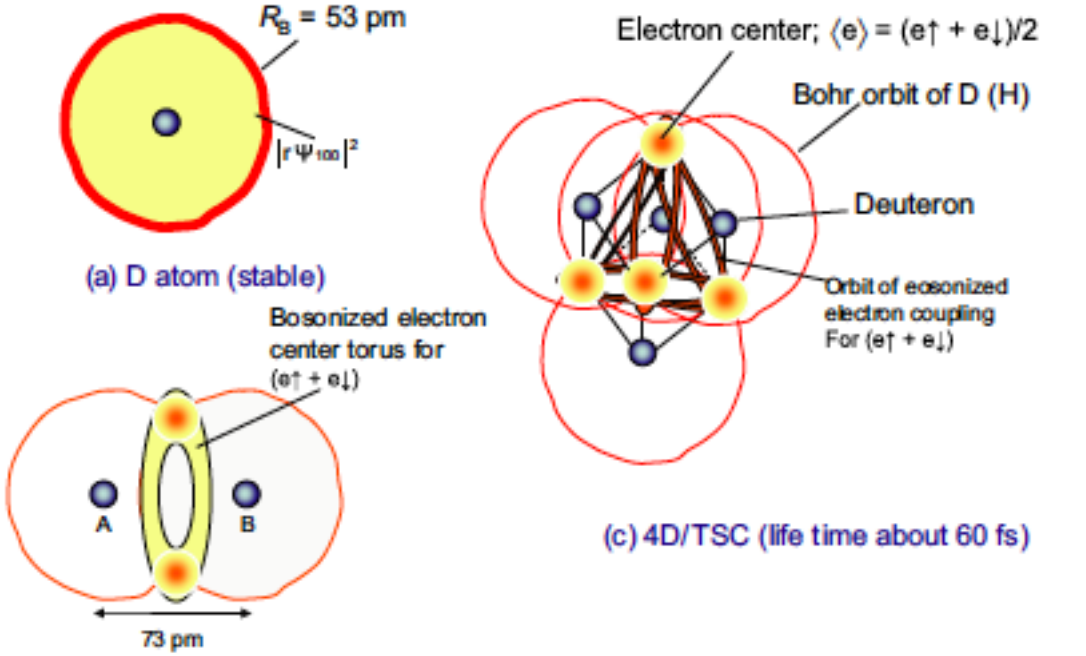
(quote from Wikipedia entries on M1911 pistol and on Recoil operation)

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 ...



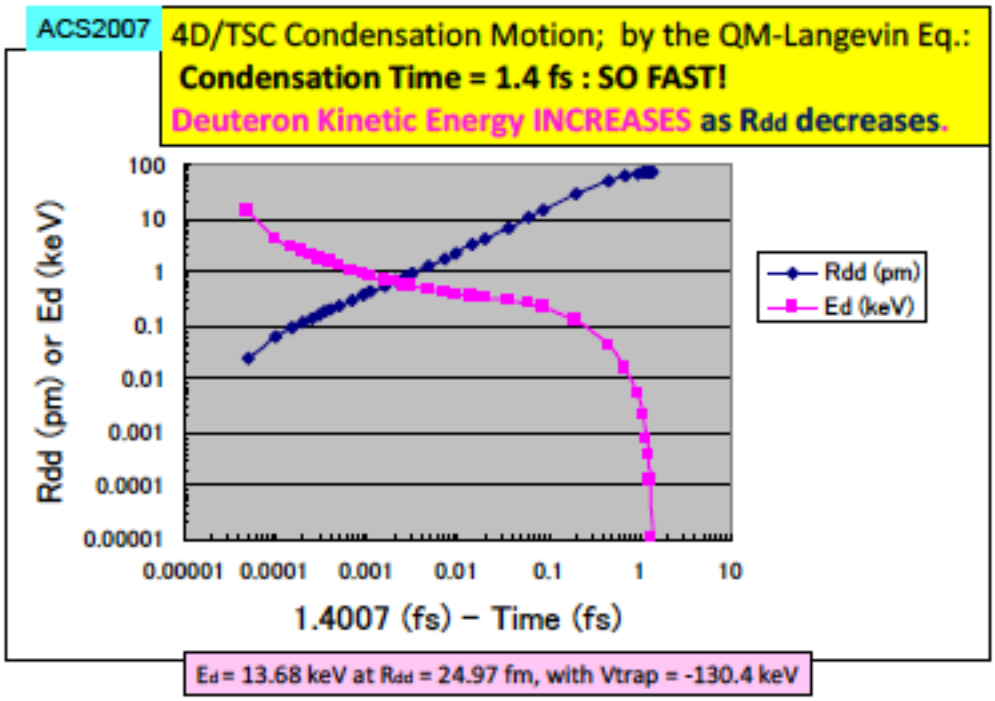
[**Note that the TSC process is spontaneous not requiring initial stimulus**.]
... Classical squeezing motion ends when four deuterons get into the strong force range (5 fm) and/or when four electrons get to the Pauli's limit (about 5.6 fm for e-e distance). Here for Pauli's limit, we used the classical 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 ...[with energy released of about 47.6 MeV, mostly as photons of a few keV energy each] ... 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 ...



... 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 ...".

Where does the 47.6 MeV Energy from a TSC-Jitterbug Fusion Event go ?

As Takahashi said "... 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 . ..."

There are at least 3 possibilities for energy release from 8Be* (Ex = 47.6 MeV):

1 - Each of the **two 4He alpha particles carry away about 23.8 MeV**.
Experiments by Roussetski indicate that this does not occur.

2 - **Takahashi's Nucleon-Halo BOLEP (burst of low energy photons) process**
producing 1 - 10 keV soft X-rays.
This is described on the next page.
Further experiments are needed to show whether or not this is what really happens.

3 - **Schwinger Coherent Electron process**:
Julian Schwinger in 1990 lecture at Universite de Bourgogne 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 ...".
That is the basic idea of Takahashi's TSC process.
At the time of 8Be* formation by TSC,
instead of the "... four electrons ... go[ing] outside ..."
the four electrons should remain part of Schwinger's "coherent ... single state"
and
some of the 47.6 MeV should go to the four electrons.
If the 47.6 MeV were to be shared equally by the two 4He and the four electrons,
then each 4He alpha particle and each electron would carry about 8 MeV.
After decoherence of the TSC Fusion state,
the 4He alpha particles would remain as measurable Fusion Products
and the electrons would join the Pd metal electrons, thus heating the Pd Cluster.

If the Pd Clusters were embedded in Zeolite Cages,
heat from the Pd Cluster would be transferred to the Zeolite,
from which it could be extracted by the Zeolite-Water process.

Further experiments are needed to show whether or not this is what really happens.

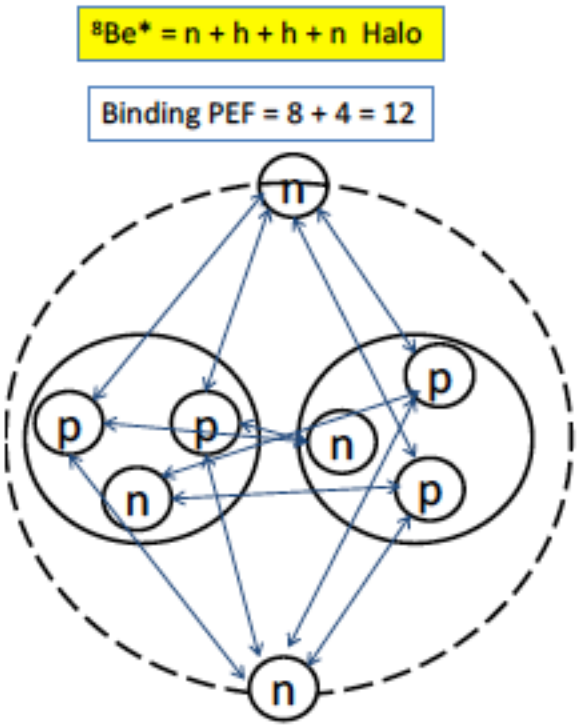
Takahashi's Nucleon-Halo BOLEP (burst of low energy photons) process:

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 ...".

Iraj Parchamazad Experiments show 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 and whose size is large enough to contain several TSC Fusion Cluster sites, which are a half-icosahedron plus an octahedron.

The 13-atom Pd/Ni cluster (0.70 nm) has a full icosahedron (two half-icosahedra) but does not have the necessary octahedron, so it is too small to contain a TSC Fusion Cluster site.

The 2-shell 55-atom Pd/Ni cluster (1.13 nm) has a full icosahedron (two half-icosahedra) and two octahedra for only 2 TSC Fusion Cluster sites.

Clusters of between 56 and 147 atoms contain from 2 to 14 TSC Fusion Cluster sites by partially fillng the 3rd shell of atoms.

The 3-shell 147-atom Pd/Ni cluster (1.56 nm) has the 2 TSC Fusion Cluster sites of the 55-atom Pd/Ni cluster plus 12 more half-icosahedra in its outer shells along with octahedra for each, so it contains 14 TSC Fusion Cluster sites.

Clusters of between147 and 309 atoms contain at least 14 TSC Fusion Cluster sites
The 4-shell 309-atom Pd/Ni cluster is 2.00 nm in size, so it is disfavored with respect to the 3-shell 147-atom cluster for use with Sodium Zeolite Y whose pore size is 0.74 nm expandable to 1.5 nm.

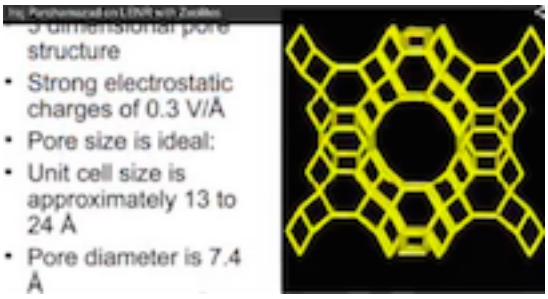
Iraj Parchamazad has experimented with Palladium embedded in Zeolites, getting reproducible heat production in amounts consistent with TSC-Jitterbug Pd-D Fusion:

47.6 MeV x 14 TSC Sites / 147-atom Pd Cluster x 4.45 x 10^(-17) Watt-Hours / MeV =
= **2.965 x 10^(-14) Watt-Hours / 147-atom Pd Cluster for each Jitterbug Cycle**

Mass of 147-atom Pd Cluster 147 x 106 x 1.66 x 10^(-21) = 2.587 x 10^(-17) milligrams
so **a milligram of 147-atom Pd Clusters gives about 1 KiloWatt-Hour each Cycle**

Iraj Parchamazad uses **Sodium Zeolite Y**
also known as faujasite. The Wikipedia page for faujasite says:
"... The faujasite framework consists of sodalite cages which
are connected through hexagonal prisms.
The pores are arranged perpendicular to each other.
The pore, which is formed by a 12-membered ring,
has a relatively large diameter of 7.4 Å [0.74 nm]
The inner cavity has a diameter of 12 Å [1.2 nm]
and is surrounded by 10 sodalite cages. ...".

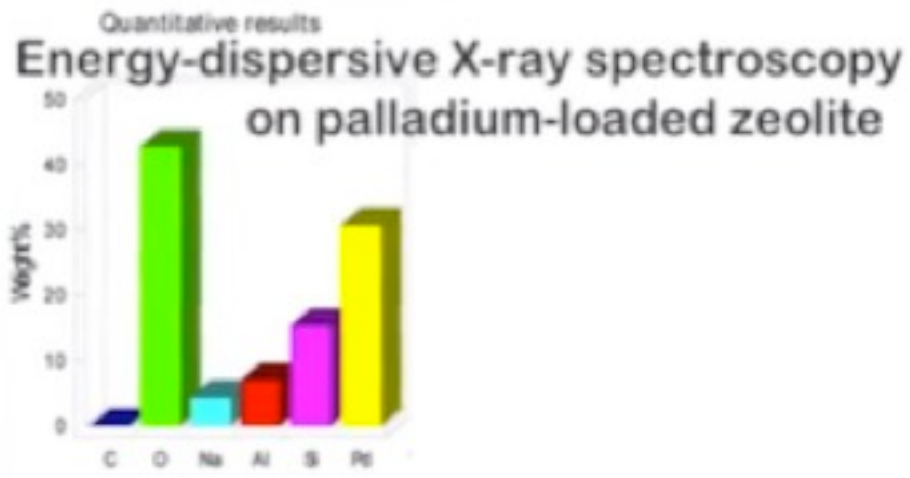
Ruby Carat and Melvin Miles interviewed Iraj Parchamazad of University of La Verne in 2012. In that video interview Iraj Parchamazad said that the Zeolite cavity size can oscillate and vary, enlarging up to about 2.4 nm.



A corresponding enlargement of pore size is to about 1.5 nm
which would permit a 3-shell 147-atom Palladium cluster to enter the Zeolite Cavity.

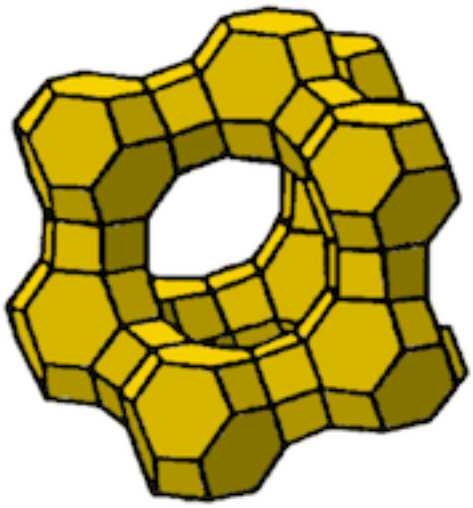
Iraj Parchamazad did not use Sandia's 1.5 nm Palladium clusters in his Zeolite
but
used an organometallic solution containing Palladium atoms.
After putting that into the Zeolite he heated the Zeolite
to burn off Carbon, Hydrogen, and Oxide
leaving a Zeolite and some Palladium.
Then he exposed the Zeolite/Palladium to Deuterium,
and got excess heat 10 out of 10 times, indicating fusion.

As to how much Palladium was put into the Zeolite, he found



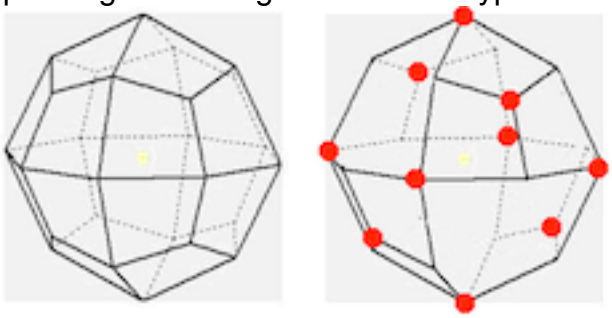
To use those results to see how many Palladium atoms were in each Zeolite Cavity, look at the detailed structure of Sodium Zeolite Y.

Each Zeolite Cavity is surrounded by 10 sodalite cages which are arranged in a 3-dimensional Diamond network as shown in this image



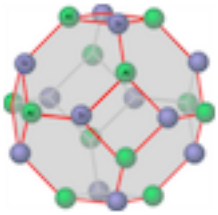
from
http://www.vurup.sk/sites/vurup.sk/archivedsite/www.vurup.sk/english/products/molek/slovsit1/english.html

The Zeolite Cavity has geometric symmetry related to an isometric trapezoid
with the 4 holes corresponding to deleting 4 octahedral-type 3-face groups



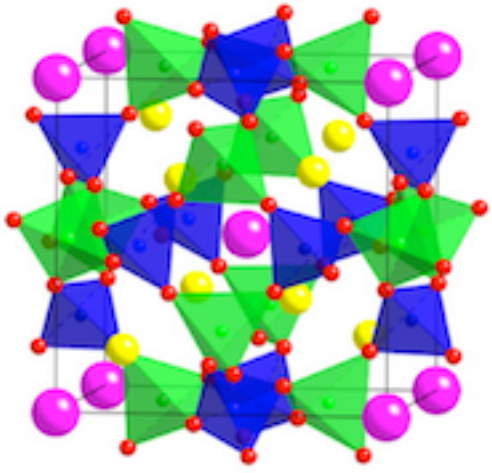
The 10 red dots correspond to the 10 sodalite cages.

Each sodalite cage is a 24-vertex truncated octahedron as in this image from Wikipedia



A more detailed view of a sodalite cage from
http://som.web.cmu.edu/structures/S099-sodalite.html

has red dots for Oxygen and pink spheres for OH and yellow spheres for Sodium
and blue tetrahedra for Silicon and green tetrahedra for Aluminum



It shows that of the 24 vertices of the sodalite cage,
12 are Aluminum and 12 are Silicon
so
each Zeolite Cavity has 10 x 12 = 120 Aluminum atoms.

To see the number of Aluminum atoms in each Zeolite Cavity
look at Iraj Parchamazad's graph of the weights of Aluminum and Palladium
and consider that their Atomic Weights are 27 for Aluminum and 106 for Palladium.
Looking at the graph,
it appears that the weights are about 7 for Aluminum and 32for Palladium
so **the number of Palladium atoms in each Zeolite Cavity** is about

Npd/z = 120 x (32 / 7) x (27 / 106) = 140 atoms

which is roughly equal to the number of atoms (147) in a 3-shell Pd atomic cluster

The 3-shell 147-atom icosahedral Palladium atomic nanocluster
contains 14 TSC Fusion Sites
and each TSC Fusion event produces 47.t6 MeV

47.6 MeV x 14 TSC Sites / 147-atom Pd Cluster x 4.45 x 10^(-17) Watt-Hours / MeV =
= **2.965 x 10^(-14) Watt-Hours / 147-atom Pd Cluster for each Jitterbug Cycle**

Mass of 147-atom Pd Cluster 147 x 106 x 1.66 x 10^(-21) = 2.587 x 10^(-17) milligrams

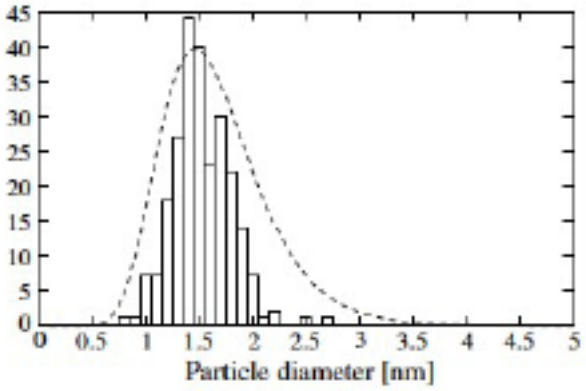
so that **a milligram of 147-atom Pd Clusters**
can produce roughly 1 KiloWatt-Hour
in each TSC-Jitterbug Fusion Cycle

If 36 seconds = 1/100 hour is taken as the Cycle time
then

a TSC-Jitterbug Fusion device with 1 milligram of Palladium
in the form of 147-atom Pd clusters with D-Loading
should produce 100 KiloWatt-Hours in an hour.

147-atom Pd clusters have diameter about 1.5 nanometers.
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 showing

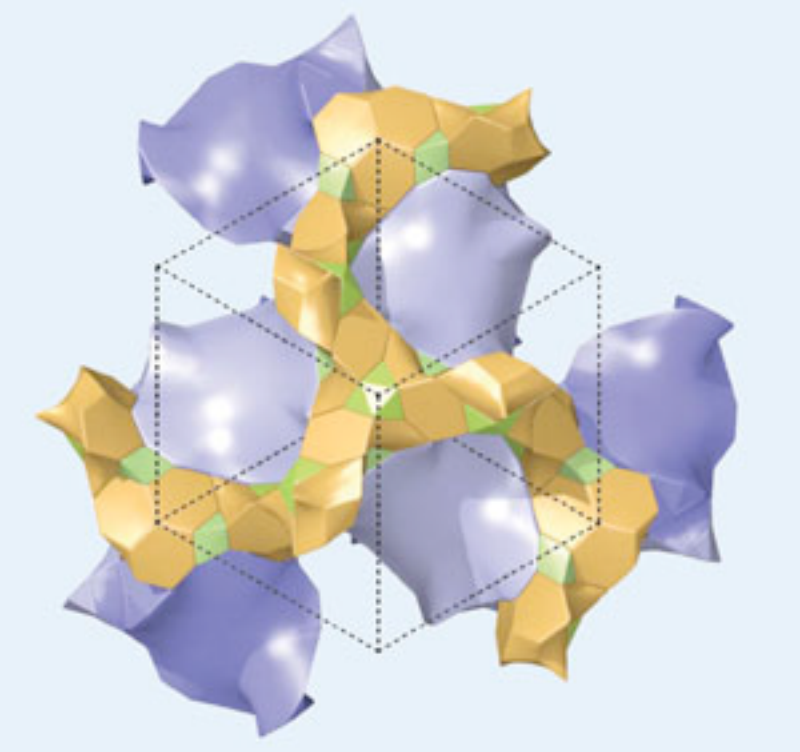


"... ...".

Tim Boyle said in email October 2014:
"... We easily remade the Pd NP just need to get TEM to see what size they are.
If they come out good, we can go ahead and make some for you.
Couple of things.
This is very easy and ya'll may want to do it yourselves
(esp after the next couple of comments).
Simply dissolve Pd-acetate in MeOH and stir for 5 min,
let grow for 20 more and should have your size.
The problem is these will continue to grow and plate out onto the sides of the container,
unless you use a substrate.
Would you want these on a substrate, then that'll need to be supplied.
If we make it, we'd have to send it as a solution ...
could you handle this and could you use it?
It won't be a powder, which I think is what you want.
We can dry it down to a powder but not sure what size that will be
or how they'd cluster and how they'd redisperse or in what solvent.
we can try to deposit the materials on a number of surfaces and just let it dry.
Again, not sure how the clustering of these particles will occur.
A gram will take about 2.5 g of Pd(Oac)2 which we have but will need replaced. ...".

I would like to see experiments
with Zeolite directly using Sandia 1.5 nm Palladium NanoClusters.

If there is difficulty with getting the Sandia Clusters
to fit into the Sodium Zeolite Y
then
I would like to see experiments
with Zeolite ITQ-37



which has pore size about 2 nanometers.
(Royal Society of Chemistry, 29 April 2009 and Sun et al, Nature 2009)

After Palladium TSC - Jitterbug Zeolite fusion has been established the next step is production of useful amounts of energy.

Most of the TSC fusion energy is in photons of a few keV energy

which energy can be used as **Heat**

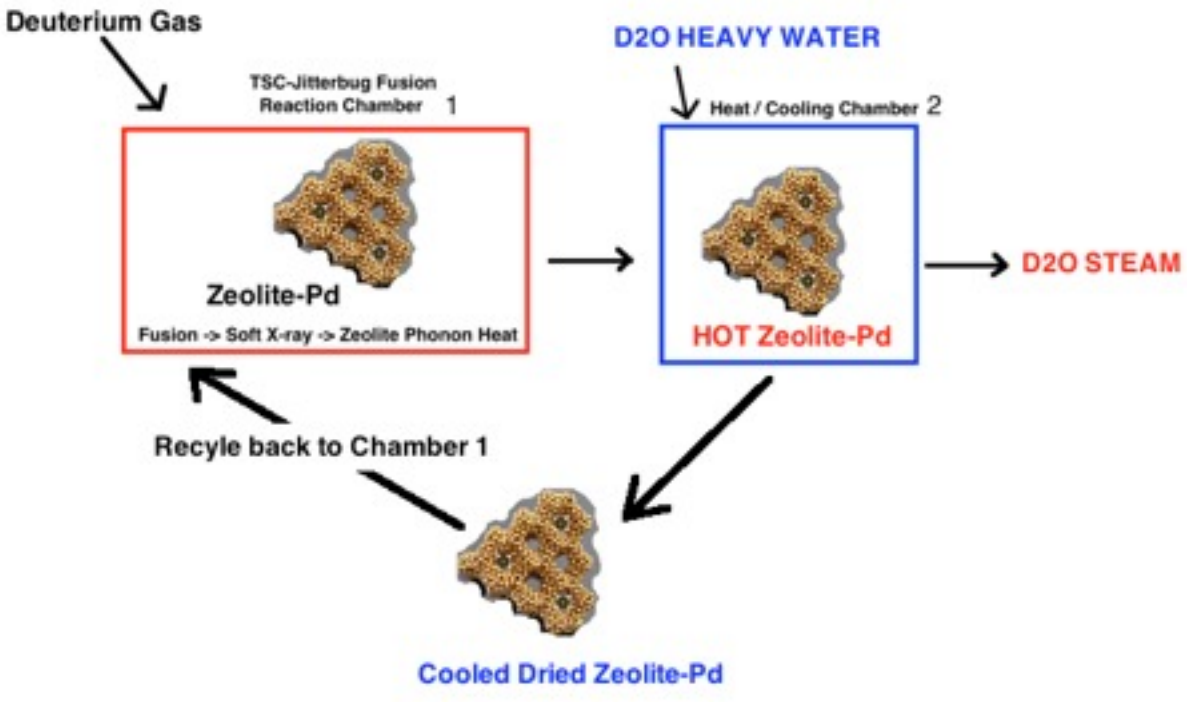
or

as charge of an **UltraCapacito**r:

Heat

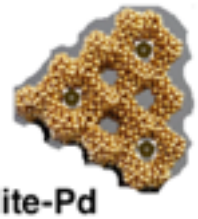
According to a 7 June 2012 techthefuture.com web article by Tessel Renzenbrink:
"... Zeolite is a mineral that can store up to four times more heat than water ...
zeolite retains a hundred percent of the heat for an unlimited amount of time ...
When water comes into contact with zeolite it is bound to its surface by means of a chemical reaction which generates heat. Reversely, when heat is applied the water is removed from the surface, generating large amounts of steam.
The transference of heat to the material does not cause its temperature to rise. Instead, the energy is stored as a potential to adsorb water. The ...[German Fraunhofer Institute]... scientists used these particular properties to turn zeolite into a thermal storage system. They created a storage device and filled it with zeolite pellets.
To charge the pellets, they exposed them to heat.
To retrieve the energy they simply added water. ...".

Here is my design for a TSC-Jitterbug Zeolite Pd-D fusion heat engine:



(Zeolite-Pd images adapted from
Calvo amd Carre in Nanotechnology 17 (2006) 1292-1299 and from
http://gwenbeads.blogspot.com/2014/04/infinite-skew-polyhedron-faujasite-4446.html)

D2O Heavy Water is used to take heat from the Zeolite to make steam so that Hydrogen from H2O does not poison the TSC-Jitterbug process by replacing Deuterium in the Palladium nanoclusters, a possible problem pointed out by Melvin Miles.
D20 heavy water from Fisher Scientific costs about $1,000 per liter for 99.8 atom % D.



Preparation of Zeolite-Pd

Sodium Zeolite Y has unit cell size about 2.5 nanometers
which corresponds to the edge-length per cavity of its overall tetrahedral structure.

According to http://www.google.com/patents/US20040047803
"... Synthesis and stabliisation of nanoscale zeolite particles ...
Zeolite Y is of great interest … Zeolite crystals prepared under conventional synthesis conditionsnfrequently have a mean particle size of between 1 and 5 μm. … it would ... be useful if the zeolite particles were sufficiently small to form a colloidal suspension … Mono- or di-saccharides can be used to keep the crystal size of faujasite (zeolite X and Y) small
… Sucrose, dextrose or other saccharides are added to a conventional aluminium silicate reaction mixture obtained by mixing aqueous alkali metal silicate and alkali metal aluminate solutions at low temperatures, followed by ageing and hydrothermal synthesis. Crystal sizes of between about 30 and 40 nm are claimed …".

According to a Journal of Catalysis article by Patrick D. Burton, Timothy J. Boyle, and Abhaya K. Datye "Facile, surfactant-free synthesis of Pd nanoparticles for heterogeneous catalysts"
"... room temperature reduction of Pd(OAc)2 in MeOH is slow enough to produce a suspension of ... metal-phase ... Pd NPs. ...
A Pd-NP/C catalyst was prepared by mixing the carbon support into the suspension of Pd NPs and evaporating the solvent. Aggregate formation was a concern, as there were no capping agents to prevent particle growth. Therefore, the nanoparticles were collected quickly before substantial aggregation could occur. ... this technique is general and can be extended to other powder supports. ...".

An "other powder support" that would be useful for TSC-Jitterbug fusion energy would be 30-40 nanometer Zeolite Y Crystals in colloidal suspension.

As the Pd nanoclusters "... grow for 20 ... min ..." up to size 1.56 nm for the 147 atom size that is optimal for TSC-Jitterbug fusion,
they are small enough to fit into the Exterior Cavities of the Zeolite Y Crystals
(which are have average pore opening 0.74 nm and cavity size 1.2 nm
but which sizes can oscillate to be up to about twice those sizes)
Due to the open structure of the Zeolite Y Crystals, growth up to the 147 atom size can continue inside the Exterior Cavities of the Zeolite Y Crystals.

As soon as the Pd nanoclusters have grown to the 147 atom size the solvent can be evaporated and the powder of 30-40 nm Zeolite Y Crystals loaded with Palladium can be collected and placed in the TSC-Jitterbug Fusion Reaction Chamber for exposure to Deuterium gas and heating the Zeolite Y Crystals by fusion energy.

As to how many of the 30 nanometer Zeolite Y Crystal Cavities are Exterior
(and therefore easily accessible to the Pd nanoclusters in colloidal suspension)
the Zeolite Y Crystal has tetrahedral structure and each unit cell with 1 Cavity is 2.5 nanometers so a 30 nm Zeolite Y Crystal would have 30 / 2.5 = 12 cavities per edge and its tetrahedral structure would have 12 triangular layers

and a total of 1+3+6+10+15+21+28+36+45+55+66+78 = 364 Cavities
of which 1+3+6+10+15+21+28+36 = 120 would be Interior Cavities (purple dots)
and 364 - 120 = 244 would be Exterior Cavities (orange dots)
so 244 / 364 = 67 % of the Cavities of the 30 nm Zeolite Y Crystals would be Exterior and therefore relatively easily accessible to the Pd nanoclusters in the colloidal suspension.

A 40 nm Zeolite Y Crystal would have 40 / 2.5 = 16 cavities per edge with 16 triangular layers
and 1+3+6+10+15+21+28+36+45+55+66+78+91+105+120+136 = 816 Cavities
of which 1+3+6+10+15+21+28+36+45+55+66+78 = 364 would be Interior Cavities
and 816 - 364 = 452 would be Exterior Cavities
so 452 / 816 = 55 % of the Cavities of the 40 nm Zeolite Y Crystals would be Exterior.

As to how much Zeolite Y Crystal should be mixed in colloidal suspension
with Palladium nanoclusters that grow to 147-atom size:

The atomic mass of a Zeolite Y unit cell is
(from nptel.ac.in Introduction to Catalysis Lecture 36 Zeolites)
(56x23 Na + 56x59 AlO2 + 136x60 SiO2 + 264x18 H2O) = 17,504
for actual mass = 17504 x 1.66 x 10^(-21) = 2.906 x 10^(-17) milligrams

The atomic mass of a 147-atom Pd nanocluster is
147x106 = 15,582
for actual mass = 15,582 x 1.66 x 10^(-21) = 2.587 x 10^(-17) milligrams

so if all the Cavities of Zeolite Y Crystal were External
equal masses of Palladium and Zeolite Y Crystal would be optimal
but
for 30-40 nm Zeolite Y Crystals only about 2/3 to 1/2 of their Cavities are External
so
it may be optimal to use Zeolite Y Crystal mass = 2 x Palladium mass in the colloid.

Pd D Zeolite Y Fusion

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

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

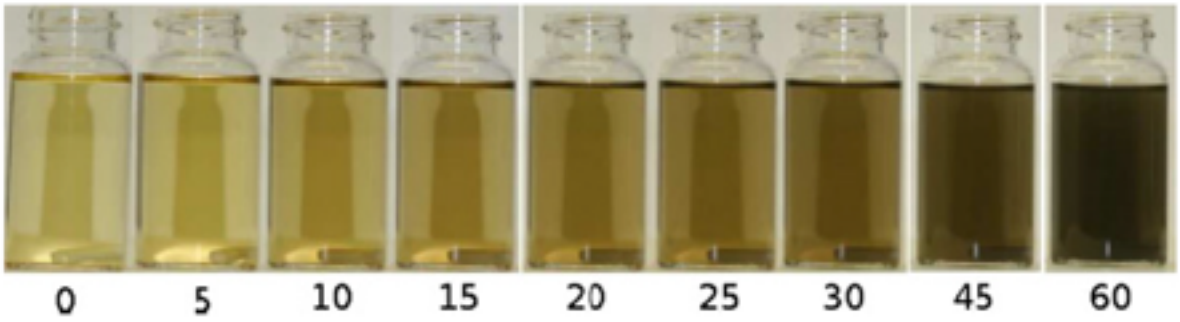
3 - Reduce the Pd(OAc)2 by MeOH to Pd atoms
by stirring for 5 minutes with unobstructed exposure to room lighting.

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

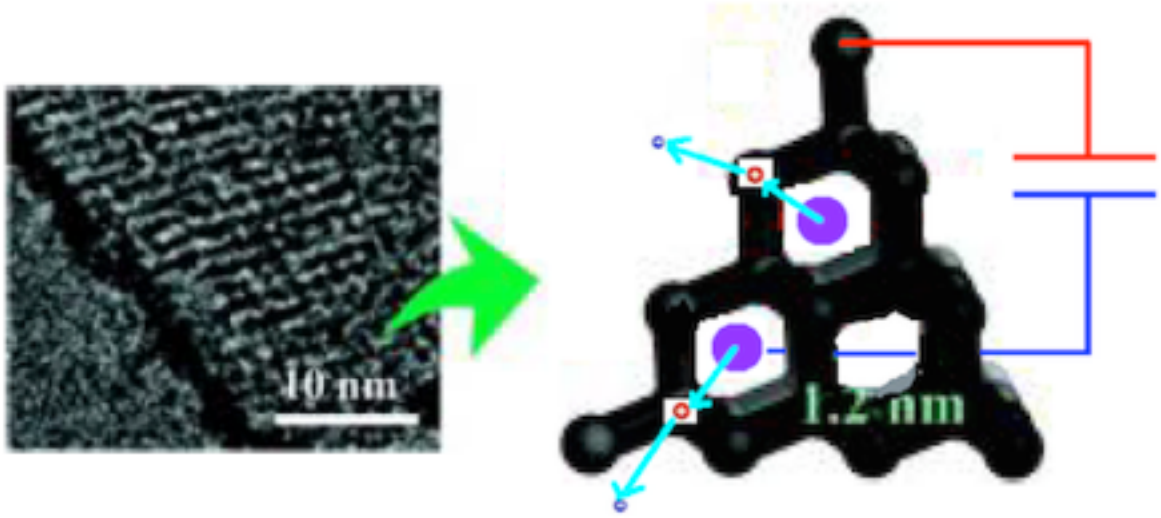


6 - At 20 minutes Pd-loaded Zeolite (and any remnant Pd still in colloidal suspension)
are removed and the Pd-loaded Zeolite is dried

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

UltraCapacitor

According to a 26 January 2011 PhysOrg.com article by Lisa Zyga:
"... The unique 3D array of nanopores in zeolite-templated carbon ...



(image modified to show
Zeolite-Templated Carbon framework as Black, Palladium NanoClusters as Purple,
Ambient Fluid with Deuterium for TSC-Jitterbug Reloading as White,
Soft X-Rays from TSC-Jitterbug Fusion as Cyan arrows
that ionize parts of the Zeolite, ejecting electrons (Blue) into the Ambient Fluid
and leaving positive ions (Red) in the Zeolite-Templated Carbon
thus building up a Capacitance Voltage
between the Zeolite-Templated Carbon and the Ambient Fluid)

... enables it to be used as an electrode for high-performance supercapacitors that have a high capacitance and quick charge time ... The zeolite-templated carbon consists of nanopores that are 1.2 nm in diameter ... and that have a very ordered structure ...".

Synthesis of Zeolite-Templated Carbon is described in the 2013 Caltech Ph.D. Thesis of Nicholas Stadie
"... Zeolite-templated carbon (ZTC) materials were prepared ... by ... established methods ...

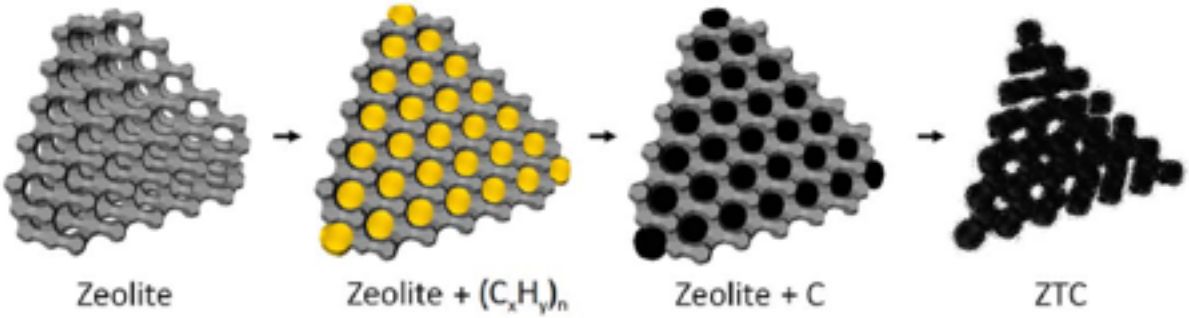


Figure 4.1. A schematic of template-carbonization in a porous zeolite framework, to produce zeolite-templated carbon (ZTC).

...".

The ZTC capacitor process converts TSC-Jitterbug fusion energy directly to electricity.
Since it does not require the Zeolite-heat-water-steam chemical structure
only the Zeolite Y Crystal geometric configuration is needed
so all the Zeolite Y can be converted to ZTC carbon configurations
attached to a single base carbon substrate that acts as a Capacitor Electrode.
(It would be difficult to use separated Zeolite Y Crystals as an electrode.)

However,
the ZTC has fewer Exterior Cavities than the colloidal free-floating Zeolite Y Crystals because
each tetahedral structure is attached to the carbon substrate by a base face,
thus eliminating 1/4 of the Exterior Cavities so that for ZTC Capacitor fusion energy:

a 30 nm ZTC structure would have 30 / 2.5 = 12 cavities per edge
and its tetrahedral structure would have 12 triangular layers
and a total of 1+3+6+10+15+21+28+36+45+55+66+78 = 364 Cavities
of which 1+3+6+10+15+21+28+36+78 = 198 would be Interior Cavities
and 364 - 198 = 166 would be Exterior Cavities (orange dots)
so 166 / 364 = 46 % of the Cavities of the 30 nm ZTC structures would be Exterior
and thus relatively easily accessible to the Pd nanoclusters in the colloidal suspension.

A 40 nm ZTC structure would have 40 / 2.5 = 16 cavities per edge
with 16 triangular layers
and 1+3+6+10+15+21+28+36+45+55+66+78+91+105+120+136 = 816 Cavities
of which 1+3+6+10+15+21+28+36+45+55+66+78+136 = 500 would be Interior Cavities
and 816 - 500 = 316 would be Exterior Cavities
so 316 / 816 = 39 % of the Cavities of the 40 nm ZTC structures would be Exterior.

Therefore
for 30-40 nm ZTC structures only about 1/2 to 1/3 of their Cavities are External
so it may be optimal
for the number of ZTC Cavities to be 3 x the number of Pd 147-atom nanoclusters.

Can TSC-Jitterbug-Zeolite Fusion produce Abundant Cheap Energy
so that Expensive Competition for geologically concentrated Cheap Oil

will become unnecessary ?

Using total Earth Energy Reserves in Terawatt-years, according to M. Taube, in his book Evolution of Matter and Energy on a Cosmic and Planetary Scale (Springer-Verlag 1985), the number of years that 10^10 people could consume energy at the present USA per capita rate, a consumption rate of about 1,000 Terawatt-years/year, is:

	Reserves (Terawatt-years)	Duration (years)
Oil	850	1
Gas	550	1
Methane	1,500	2
Coal	7,000	7
Uranium	1.9 X 10^9 (1/1000 of Earth supply)	2,000,000
Thorium	7.9 x 10^9 (1/1000 of Earth supply)	8,000,000
Deuterium	1.9 x 10^9 (1/1000 of ocean supply)	2,000,000
Lithium	1.9 x 10^9 (source of tritium)	2,000,000

As to solar energy, the total solar energy received by Earth is about 109,000 Terawatt-years/year so that 10^10 people could consume energy at the present USA per capita rate by using about 1% (one percent) of the solar energy received by Earth. This could be done, for example, by building a lot of orbiting solar energy collection dishes and beaming the energy to Earth.

The total geothermal heat flux is about 66 Terawatt-years/year, and the total tidal energy is about 3 Terawatt-years/year, so that those sources would be inadequate to support 10^10 people consuming energy at the present USA per capita rate.

For Everybody on Earth to be Happy, the Abundant Cheap Energy must provide a high Standard of Living (current USA standard) for a lot of people (10 billion), and:

last for a long time (more than decades) - rules out Oil, Gas, Methane, and Coal;

have no serious radioactive waste - rules out Uranium, Thorium, and Tritium (Lithium);

have realistically scalable capital cost - rules out Solar which would require Satellite collectors with area 1% of pi x 6,000^2 = 1,000,000 km^2 = (1,000 km)^2
or cloud-free collectors on Earth surface with the same area. Less than 100% efficiency would require correspondingly larger area of collectors.

That leaves one possible source of Abundant Cheap Energy for 10 billion people:

	Reserves (Terawatt-years)	Duration years)
Deuterium	**1.9 x 10^9 (1/1000 of ocean supply)**	**2,000,000**

Since a gram of properly structured Palladium gives TSC-Jitterbug Pd-D Cold Fusion Energy on the scale of Megawatts:

1 milligram of Palladium gives a 1 kiloWatt Machine,
useful for “electric motors, tools, machines and heaters” (Wikipedia)
Such small energy machines could use the ZTC Electric Capacitor technology.

1 gram of Palladium gives a 1 MegaWatt = 1340 HorsePower Machine,
useful for “large electric motors; large warships such as aircraft carriers, cruisers, and submarines; large server farms or data centers; and some scientific research equipment such as supercolliders, and the output pulses of very large lasers. A large residential or commercial building may use several megawatts in electric power and heat. ...
railway... electric locomotives ... typically have a peak power output of 5 or 6 MW, although ... Eurostar ... uses more than 12 MW,
while heavy diesel-electric locomotives typically produce/use 3 to 5 MW ...” (Wikipedia)
C-130 aircraft have 4 engines each with 4300 HorsePower (globalsecurity.org)
so would need a 4 x 4300 / 1340 = 13 grams of Pd
Such mid-sized energy machines could use, depending on portability and site requirements, either Zeolite Steam or ZTC Electric Capacitor technology.

1 kg of Palladium gives a 1 GigaWatt Machine,
useful for “large power plants ... HVDC converters have been built with power ratings up to 2 GW” (Wikipedia)
Such machines could use either Zeolite Steam or ZTC Electric Capacitor technology, using HVDC converters up to 2 GW to convert the ZTC Electric Capacitor DC into AC.

1,000 kg = 1 ton of Palladium gives 1 TeraWatt.
The total power used by Humans in 2006 was 16 TW.
The average lightning strike peaks at 1 TW, but lasts only 30 microseconds.
Powerful 20th century lasers produce TW, but only for nanoseconds. (Wikipedia)

1,000 tons of Palladium gives 1 PetaWatt.
The Lawrence Livermore Nova laser has power of 1.25 PW in a 5x10^(-13) sec pulse.
The total power of sunlight hitting the Earth is about 174 PW. (Wikipedia)

222 tons of Palladium were mined world-wide (based on 2006 and 2007 data, Wikipedia):

Russia produced 98 tons
South Africa produced 89 tons
Canada produced 13 tons
USA produced 11 tons
the rest of the world produced 11 tons