

TSC Jitterbug Fusion of D in Pd NanoClusters

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viXra

Abstract:

Graphic Cover summarizes TSC Fusion of D in 147-atom Palladium Clusters; Jitterbug Icosa - Cubocta - Icosa Transformation reloading D into Pd Clusters; and Zeolite Steam Engine utilizing Fusion Energy.

The body of the paper gives details of the Pd - D TSC Jitterbug Fusion Process:

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 clusters with absorbed Deuterium have two states:

Icosahedral ground state
Cuboctahedral metastable state

3 - Tetrahedral Symmetric Condensation (TSC) in Icosahedral Pd-D produces Fusion.

4 - Icosahedra TSC Fusion Triggers Jitterbug to Cuboctahedra.

5 - Cuboctahedra reload TSC sites and Jitterbug back to Icosahedra

6 - Repeat the Cycle:

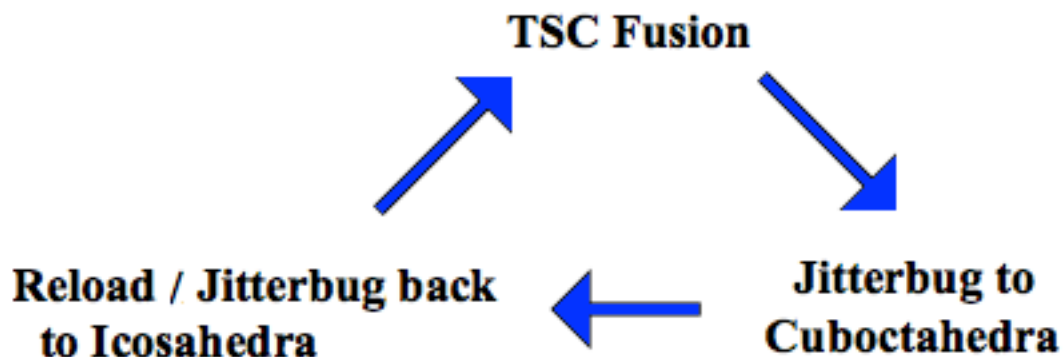


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NOTE - Most of the detailed quantitative discussion in this paper is for Pd / D Fusion but Nickel / Hydrogen is very similar to Palladium / Deuterium so the same processes may hold for Pd / H and Ni / D and Ni / H Fusion.

Introduction:

D = Deuterium = Heavy Hydrogen nucleus has 1 Neutron + 1 Proton

D + D has 2 Neutrons + 2 Protons

He = Helium nucleus also has 2 Neutrons + 2 Protons

BUT

(using Einstein's $E = mc^2$)

D+D is heavier than He by 23.8 MeV

(where 1 MeV of energy = about 2 x mass of electron)

so

Fusion of D+D to He produces Energy

How much Energy ?

Earth's Oceans contain a lot of Water, most of which is H₂O = HHO

where H = Hydrogen nucleus = 1 Proton

but

0.015% = about 1 part per 7,000 of Earth's Ocean Water is D₂O = DDO

D₂O can be extracted by processes such as distillation and chemical exchange.

**If 1 / 1,000 of the Earth Ocean D₂O were used for Fusion of D+D to He
the Energy would be enough to sustain**

**10 billion people consuming energy at the level of 1985 USA
for 2,000,000 years**

How much would it Cost ?

The energy equivalent of a gallon of D₂O is about equal to 300,000 gallons of fuel oil.

You can buy a liter of D₂O for about \$1,000

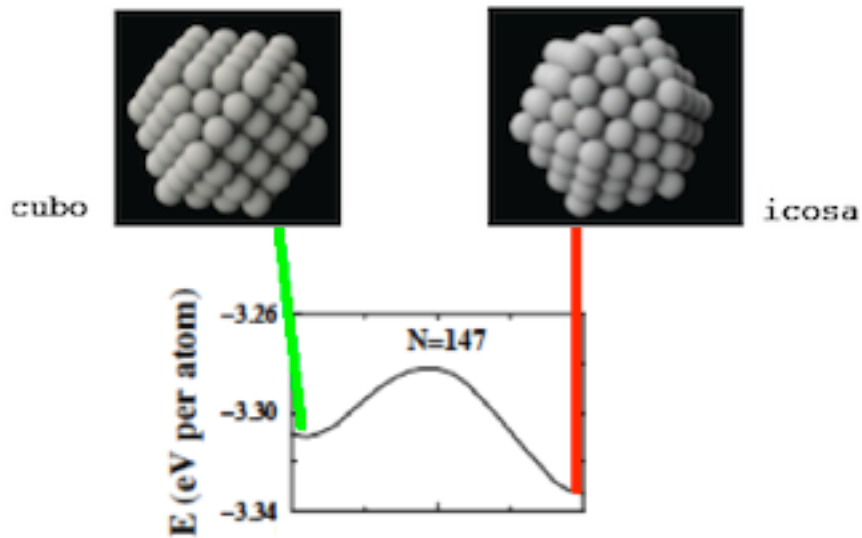
which is about 1 cent per gallon of oil (energy equivalent).

**Can D+D to He Fusion be done
without using the High Energy Input needed by Hot Fusion ?**

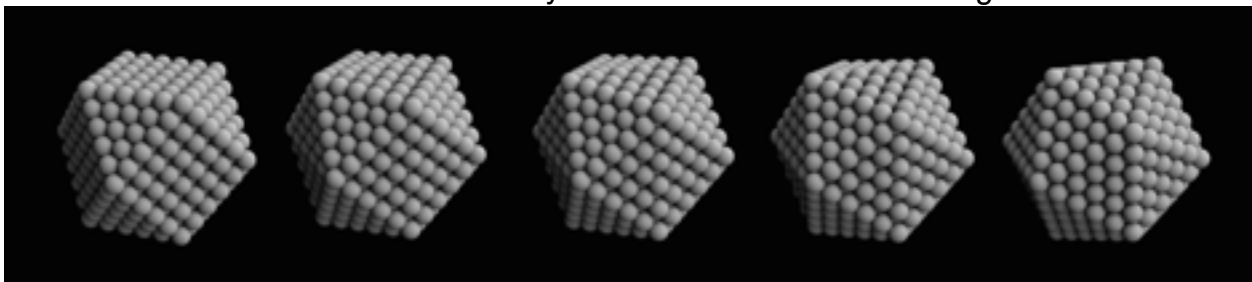
Around 1999 at Osaka University, **Arata and Zhang** filled a tube of Palladium metal with Palladium-black which is **Palladium particles of size about 5 nanometers and injected high-pressure Deuterium gas** producing, **for some batches** of Palladium-black, **Energy and He continuing as long as pressure was maintained.**

Why did only **some batches** produce Energy ?
My guess is that the 5-nanometer average size of Palladium particles is **not** the optimal size for D+D to He Fusion Energy but **some batches** may contain a lot of the optimal size which I think is about 1.5 nanometers.

What is so special about 1.5 nanometers ?
1.5 nanometers is the size of a cluster of 147 Palladium atoms



which has two states,
an Cuboctahedral Metastable State and an Icosahedral Ground State,
that can transform into each other by a Buckminster Fuller Jitterbug Transformation



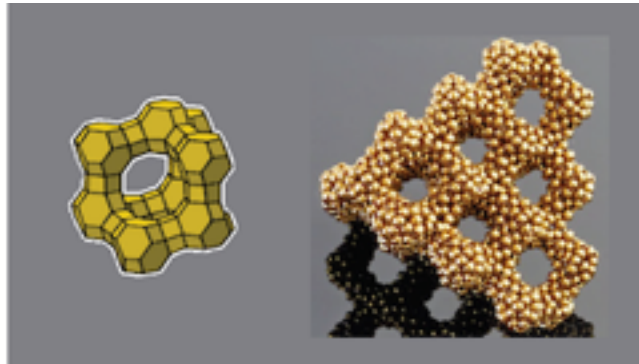
that facilitates the Fusion Energy Process.

Has anyone gotten consistently reproducible results ?

Around 2012 at University of LaVerne, Iraj Parchamazad experimented



with Deuterium gas injected into a chamber containing Palladium embedded in Zeolites



producing heat **Energy in 10 out of 10** runs of the experiment
with Energy produced on the scale of **kiloWatts of power per milligram of Palladium.**

Each Zeolite Cage contains a Palladium atom cluster.

In the Iraj Parchamazad experiments,
the Zeolite cage size is 1.3 to 2.4 nanometers and each Palladium Cluster
contains on the order of the optimal 147 atom = 1.5 nanometer size.

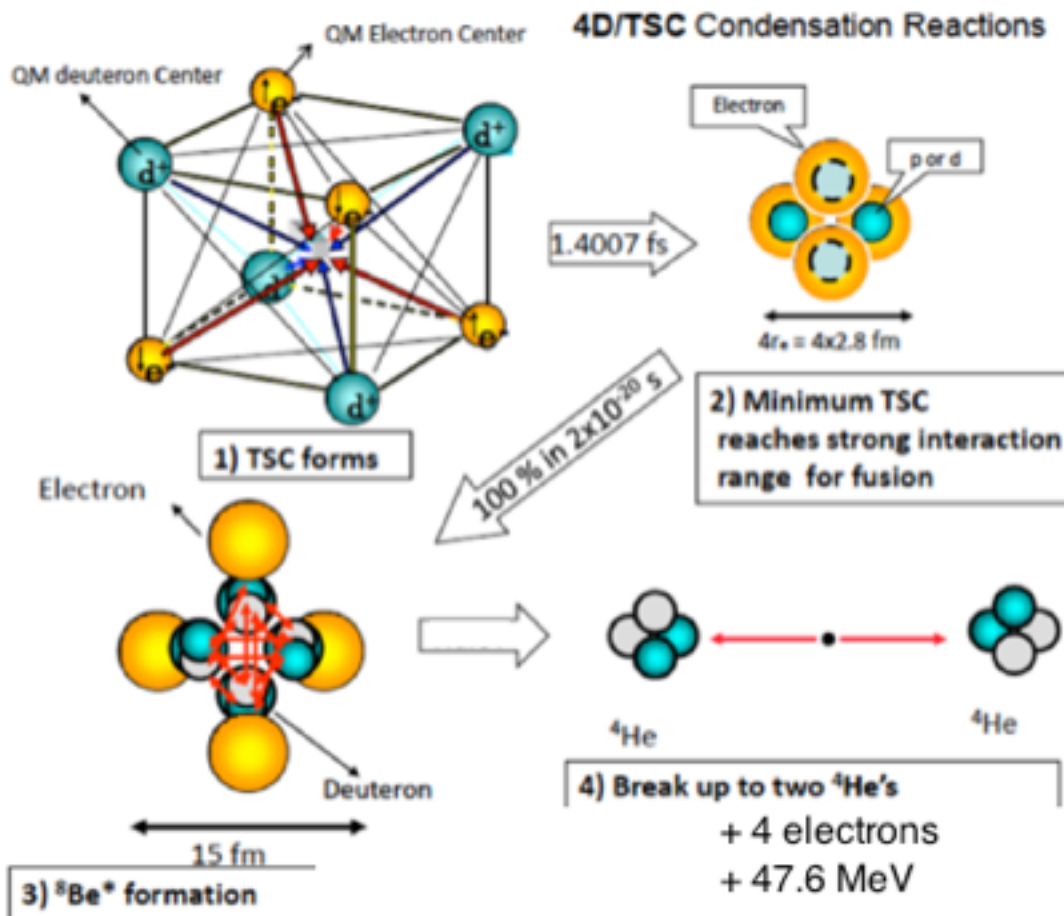
Even though experiments show that D+D to He Fusion works with Palladium Clusters, Hot Fusion needs High Temperature / Energy for two Deuterium nuclei both of which are have Positive Electric Charge = Coulomb Barrier repelling each other
so

How can Deuterium nuclei in Palladium Clusters get close enough for Fusion ?

Julian Schwinger 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 ...”.

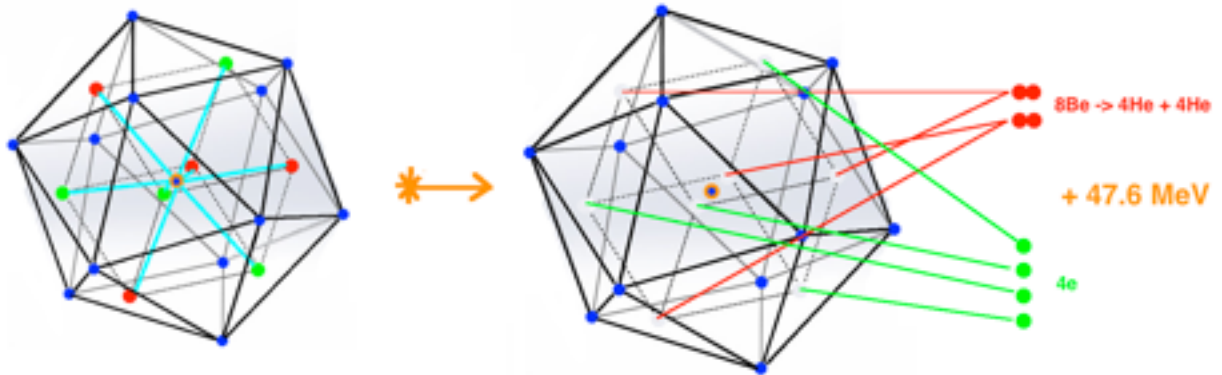
Akito Takahashi uses a **single coherent state of 4 Deuterium nuclei and 4 electrons** within Palladium Cluster structure for a **Tetrahedral Symmetric Condensate** process:



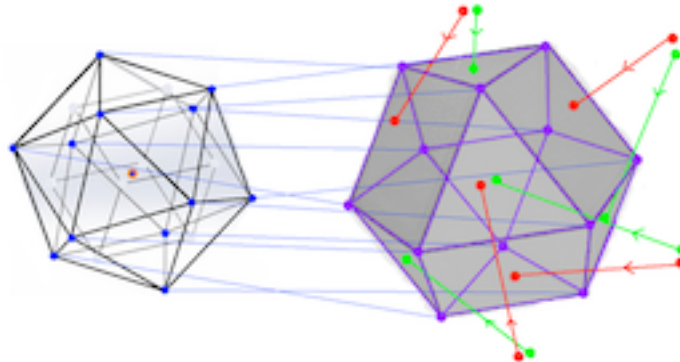
The 4 D = D+D+D+D and 4 electrons are each in Tetrahedral Symmetry. Their single coherent state has net Electric Charge = 0, so there is no Coulomb Barrier to prevent them from Condensing together close enough for the D+D+D+D to Fuse producing an excited Beryllium Be nucleus with 4 protons and 4 neutrons which then splits into two He nuclei plus $2 \times 23.8 = 47.6 \text{ MeV}$ Energy, much of which Energy is carried away by the 4 electrons when they interact with Palladium Cluster electrons and the Zeolite electric field.

How can
Jitterbug Icosa-Cubocta Transformations of 147-atom Palladium Clusters
 facilitate
Tetrahedral Symmetric Condensate D+D+D+D to Be to He+He + Energy Fusion ?

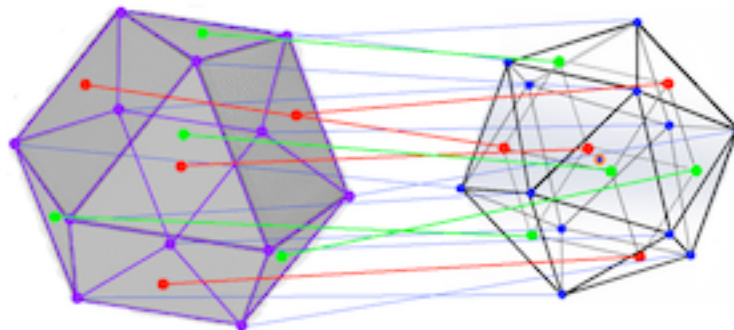
147-atom Palladium Cluster with absorbed Deuterium is in Icosa Ground State and TSC Fusion heats the Palladium cluster and the Zeolite



The heated Palladium cluster expands by Jitterbug to the Cubocta Metastable State and the Fused Deuterium nuclei are replaced by new Deuterium from the gas



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



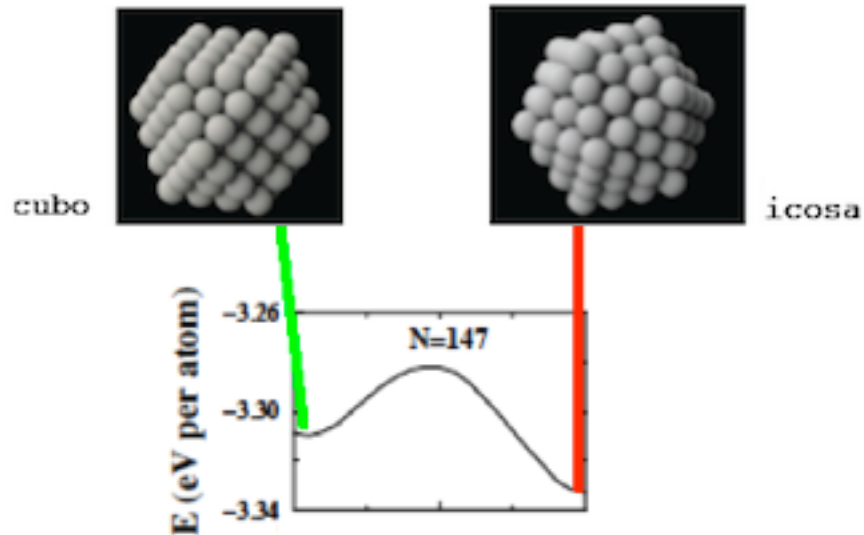
Then a new TSC Fusion occurs,
 and the cycle repeats a long as there is Deuterium "ammunition" to fuel the Fusion.

Geometry of TSC Jitterbug Fusion of Deuterium in Palladium Clusters

Akito Takahashi has developed a Tetrahedral Symmetric Condensate (TSC) model for fusion $D+D+D+D \rightarrow 8Be \rightarrow 4He + 4He + 47.6 \text{ MeV}$ in Pd atomic clusters. The same type of process may occur with Ni instead of Pd and/or H instead of D.

This paper describes the geometry of Pd atomic clusters and how it enables TSC fusion of D within the Pd clusters.

A 147-atom Palladium cluster has two special states:

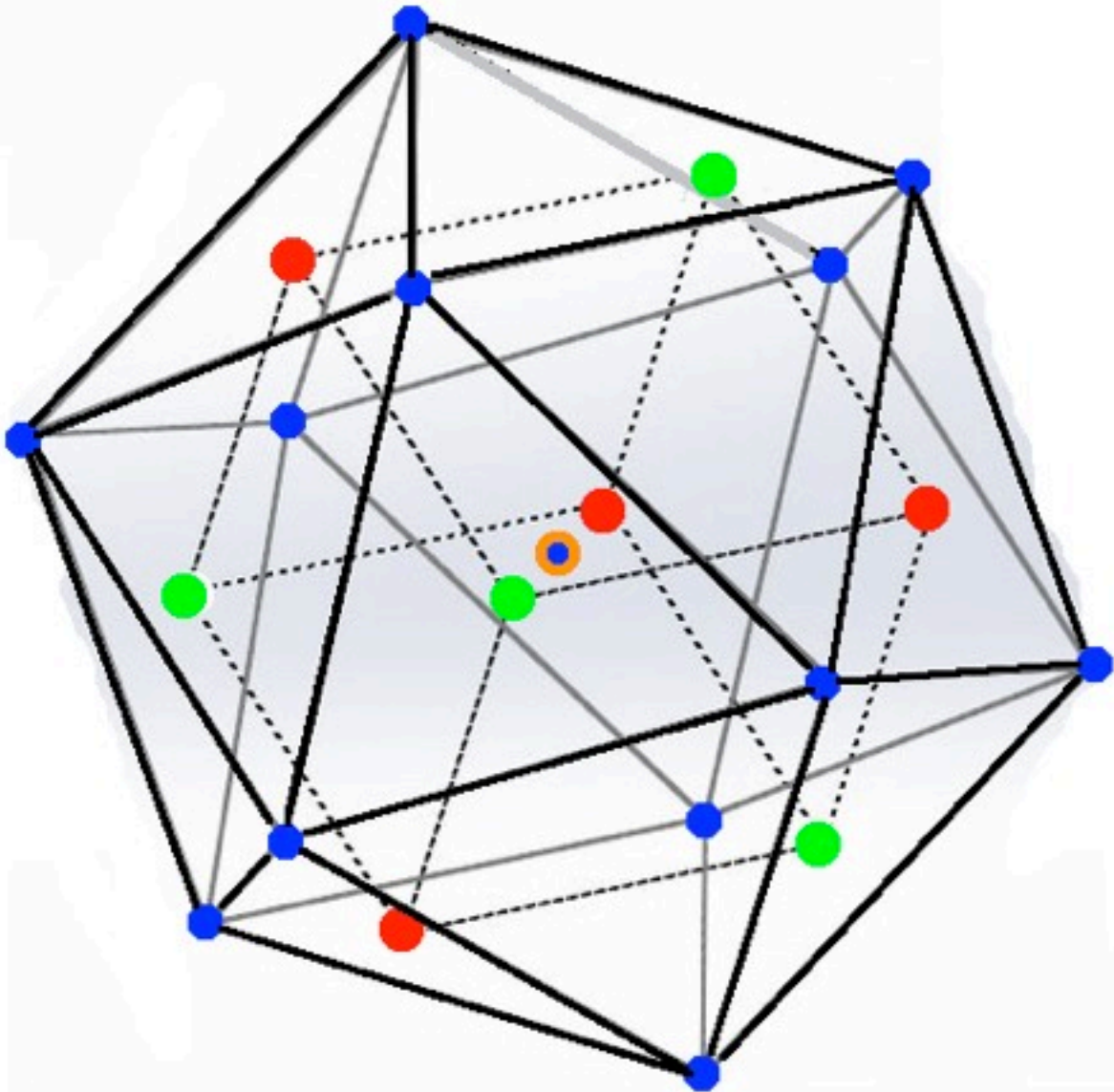


a metastable cuboctahedral state and an icosahedral ground state.

The icosahedral ground state has 12 outermost vertices, each of which is the apex of a simple icosahedral configuration of 12 Palladium nuclei (blue dots) arranged in an icosahedral configuration plus a 13th Palladium nucleus at the center of the configuration.

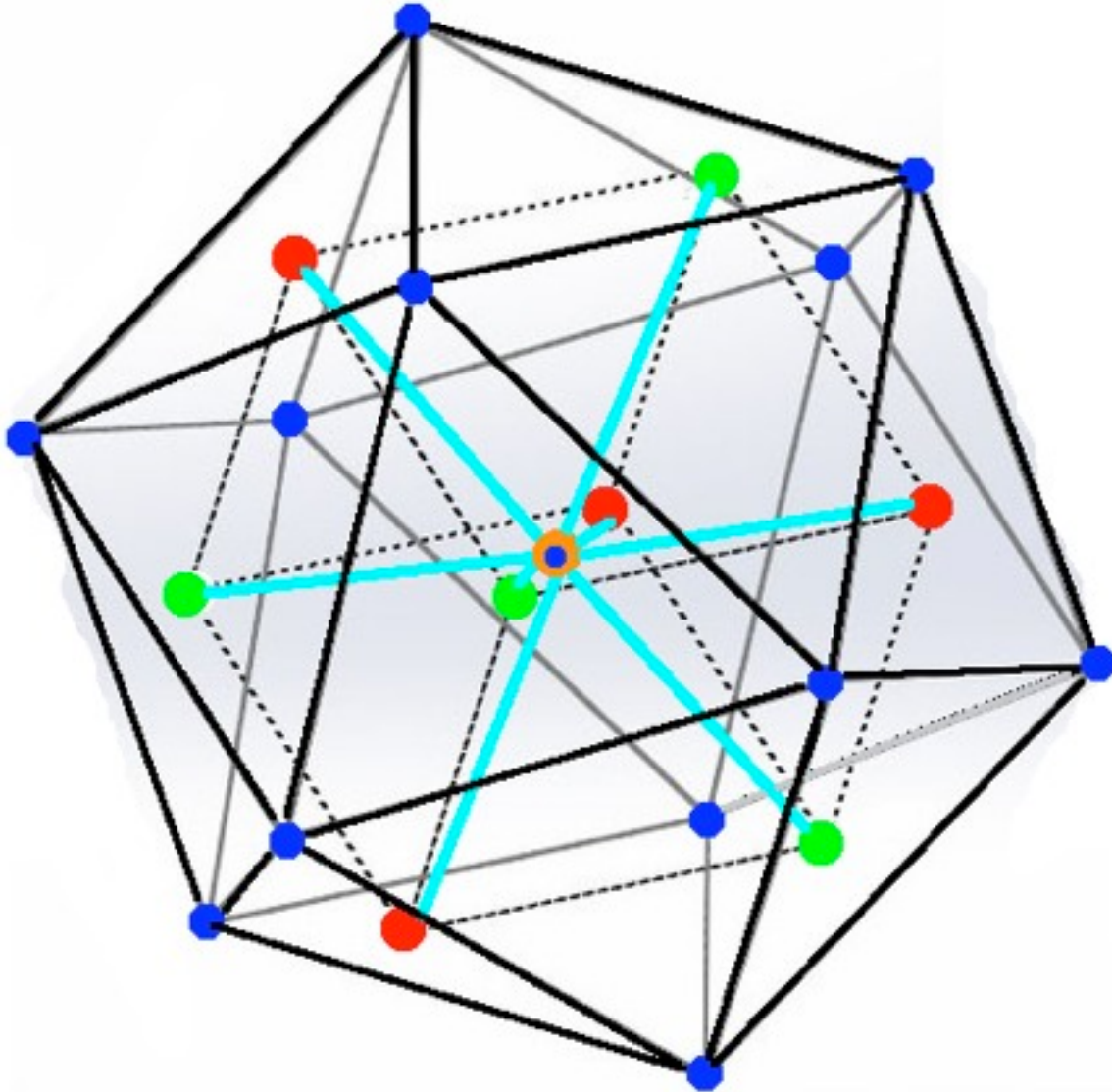
These 12 icosahedral configurations are not totally independent, because (since $12 \times 13 = 156$ is more than 147) a few vertices near the Pd cluster center are shared, but for simplicity as a rough approximation this paper will look at individual 13-vertex icosahedral configurations as being roughly 1/12 of the 147-atom configuration instead of looking in detail at the full 147-atom configuration.

This image (adapted from a Thingiverse web site image) shows



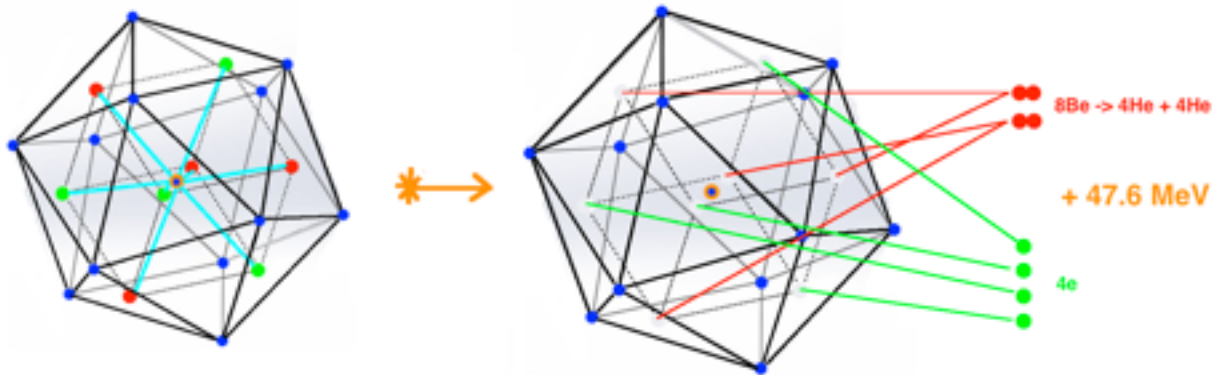
the 12 Palladium nuclei (blue dots) arranged in an icosahedral configuration plus a 13th Palladium nucleus at the center of the configuration that is the TSC fusion site (orange dot fusion site containing blue dot Palladium nucleus). Within the icosahedral configuration the 4 Deuterium nuclei (red dots) and their 4 electrons (green dots) are at the vertices of a cube and are in a single coherent quantum state.

That state then contracts in a symmetric way along the cyan lines going down to the center of the cube at the central Palladium nucleus (blue dot) which acts as a quantum attractor, combining into the Deuterium TSC quantum state to guide the condensation of the quantum state of Deuterium nuclei and electrons.



The $D + D + D + D$ does Fusion at the orange dot to form ${}^8\text{Be}$ which decays to $4\text{He} + 4\text{He} + 47.6 \text{ MeV}$ energy most of which energy is carried away by the $4\text{He}+4\text{He}$ and the $4e$ electrons of the TSC coherent quantum state.

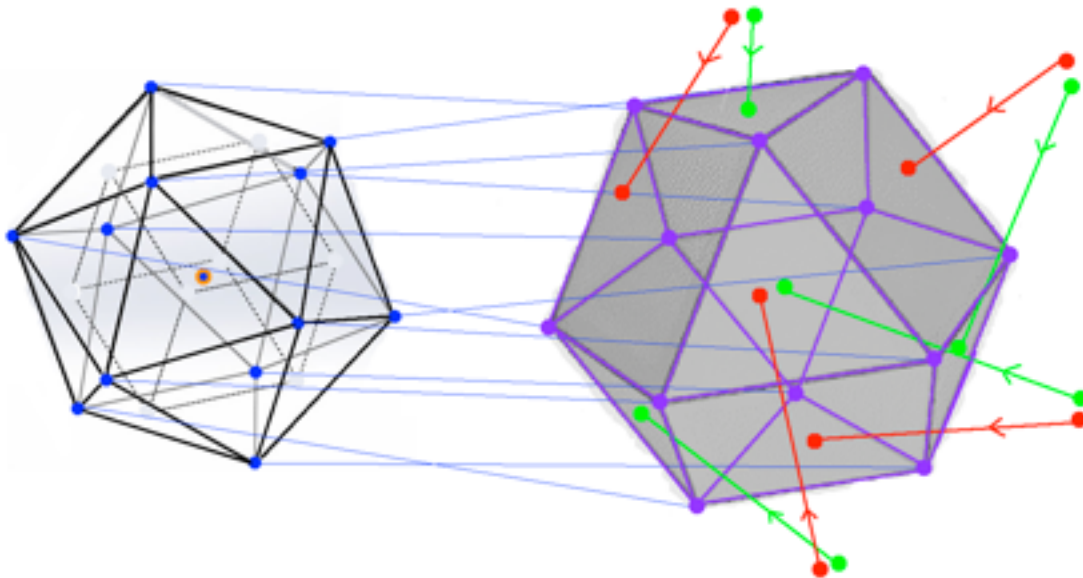
The 4e electrons may carry, by quantum processes, most of the energy to the Palladium cluster electrons and on to the Zeolite in which the Palladium cluster is enclosed.



Some of the energy goes to a Jitterbug transformation

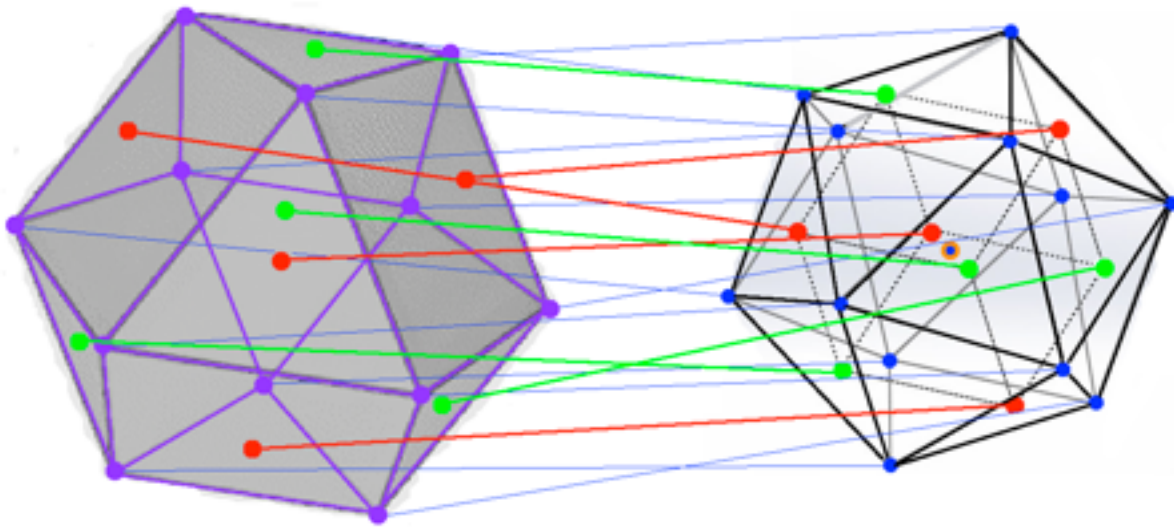


of the icosahedral Palladium, depleted of Deuterium fusion fuel, to a cuboctahedral configuration

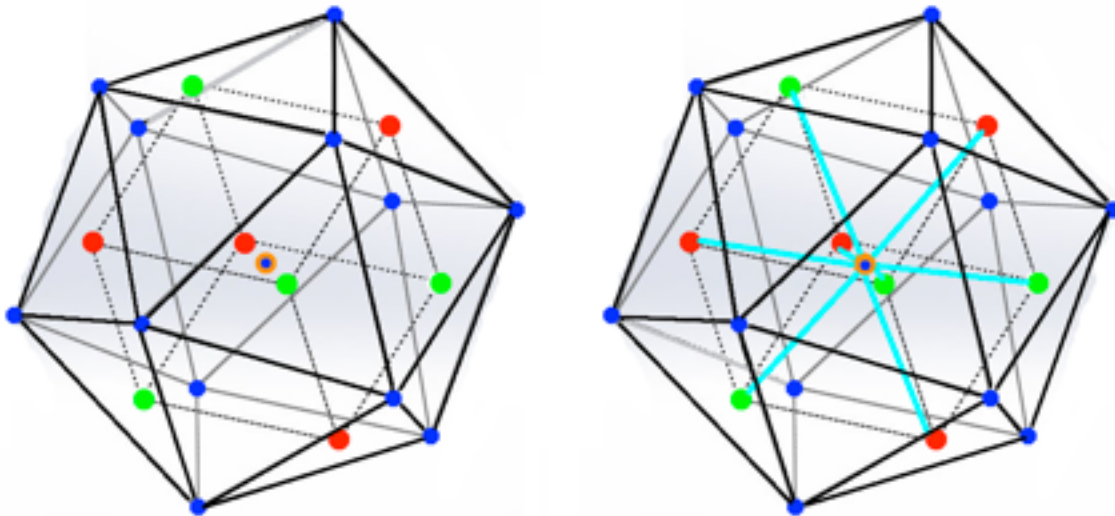


which has 6 large square openings through which ambient Deuterium Fuel can enter the Palladium cluster.

After entering the Palladium cluster the 4 Deuterium nuclei (red dots) and 4 electrons (green dots) form a Tetrahedral Symmetric Coherent Quantum State centered on the 8 triangular faces of the cuboctahedral configuration. Then, since the icosahedral configuration is the Palladium cluster ground state, another Jitterbug transformation



takes the Palladium cluster to an icosahedral configuration with the replenished Deuterium nuclei and electrons ready for another round of TSC fusion



Structure of Palladium 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	$0 = 0 + 0$
1	13	0.70	$20 = 20 + 0$
2	55	1.13	$100 = 80 + 20$
3	147	1.56	$280 = 200 + 80$
4	309	2.00	(icosa and cubo images not shown)

icosahedral   cuboctahedral



icosahedral



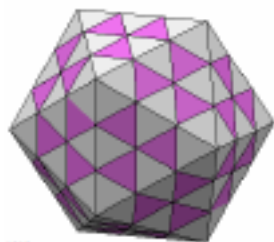
cuboctahedral



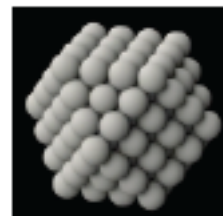
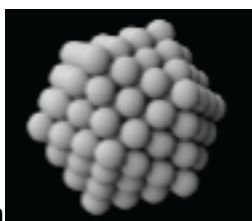
icosa



cubo



icosa

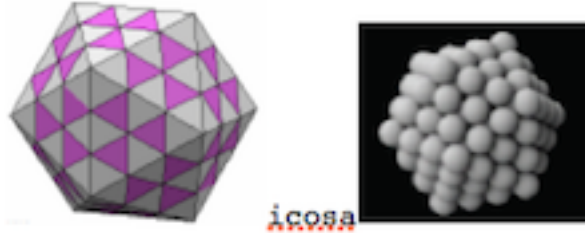


cubo

(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 147-atom Pd cluster ?

The icosahedral ground state has 12 outermost vertices, each of which is the apex of a simple icosahedral configuration of 12 Palladium nuclei arranged in an icosahedral configuration plus a 13th Palladium nucleus at the center of the configuration.



These 12 icosahedral configurations are not totally independent, because (since $12 \times 13 = 156$ is more than 147) a few vertices near the Pd cluster center are shared, but for simplicity as a rough approximation this paper will look at individual 13-vertex icosahedral configurations as being roughly 1/12 of the 147-atom configuration instead of looking in detail at the full 147-atom configuration so, roughly, there are 12 TSC Fusion sites in each 147-atom Pd Cluster.

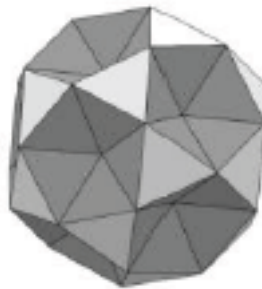
How do the Icosahedral Clusters grow to 147 atoms ?

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

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

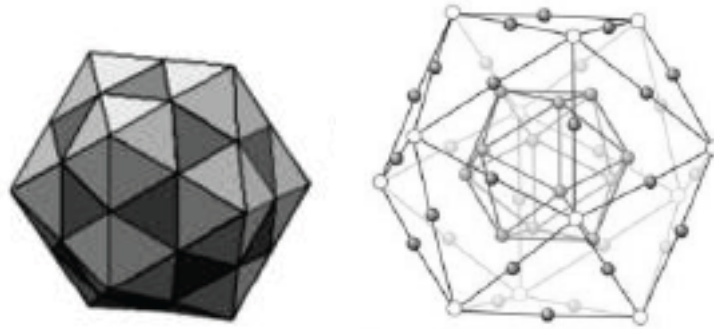
"... The Mackay icosahedron is obtained by packing tetrahedra and octahedra around an icosahedron [12 vertices]...

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

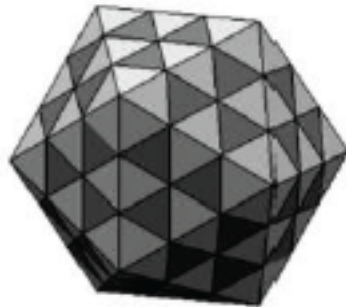
be filled by five-rings of tetrahedra [$42 + 12 = 54$ vertices]...



... 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.

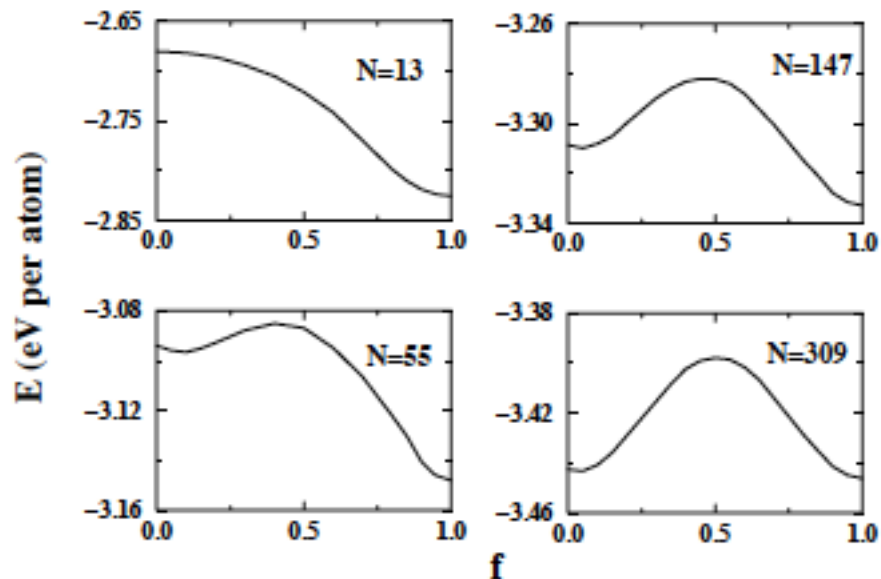
The difference is whether or not the center vertex is counted, that is,
not so much a real physical difference but a difference in math convention.

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 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 icoso 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.

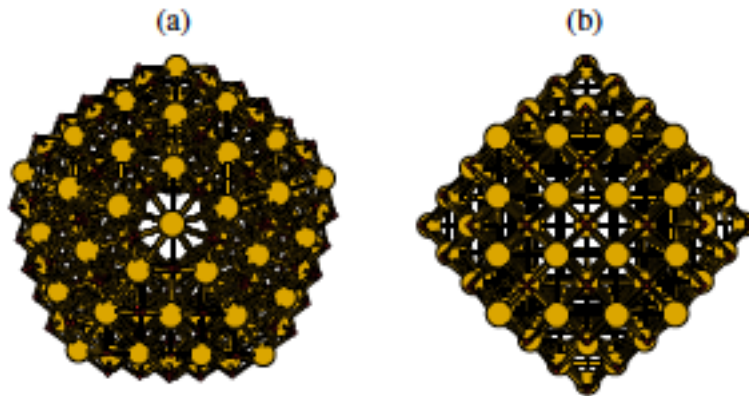


Figure 1. Palladium clusters fully loaded with hydrogen.

(a) $\text{Pd}_{147}\text{H}_{200}$, 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 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 ($<74 \text{ nm}$) 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

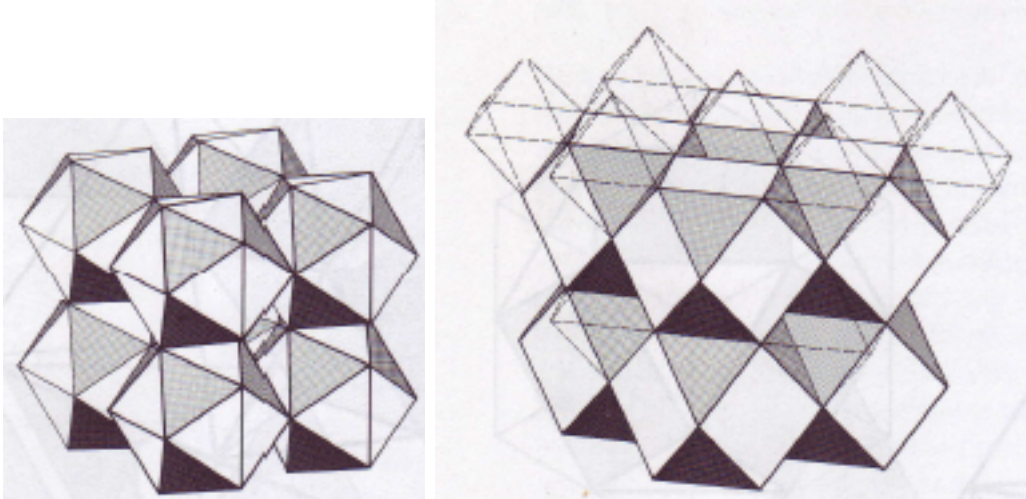
for the purpose of rough calculations it seems reasonable to take

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.

Jitterbug Transformation between Icosahedron and Cuboctahedron

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))

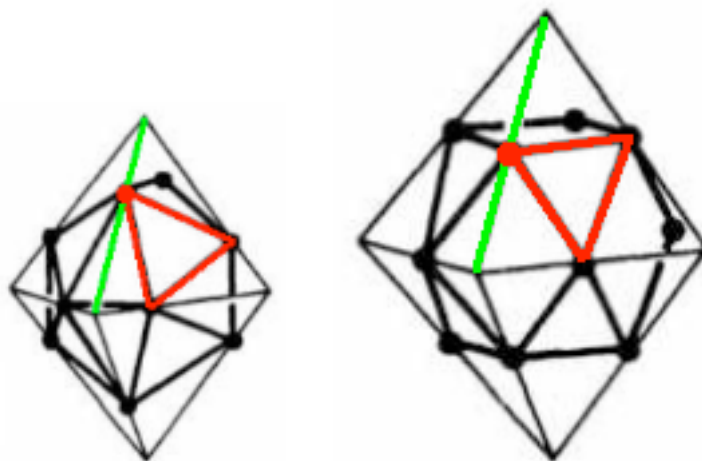
To make Cuboctahedra (unit edge length) from Icosahedra (unit edge length) choose 6 pairs of Icosahedra triangle faces (white in the above images) and lengthen the common edge of each pair by a factor of $\sqrt{2}$. That expansion flattens each of the triangle pairs to produce 6 square faces of the Cuboctahedron. 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 time scale of such a Jitterbug Transformation of a Pd cluster may be on the order of a picosecond (compare Euro. Phys. J. D. 19 (2002) 333-337 by Pundt et al).

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

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

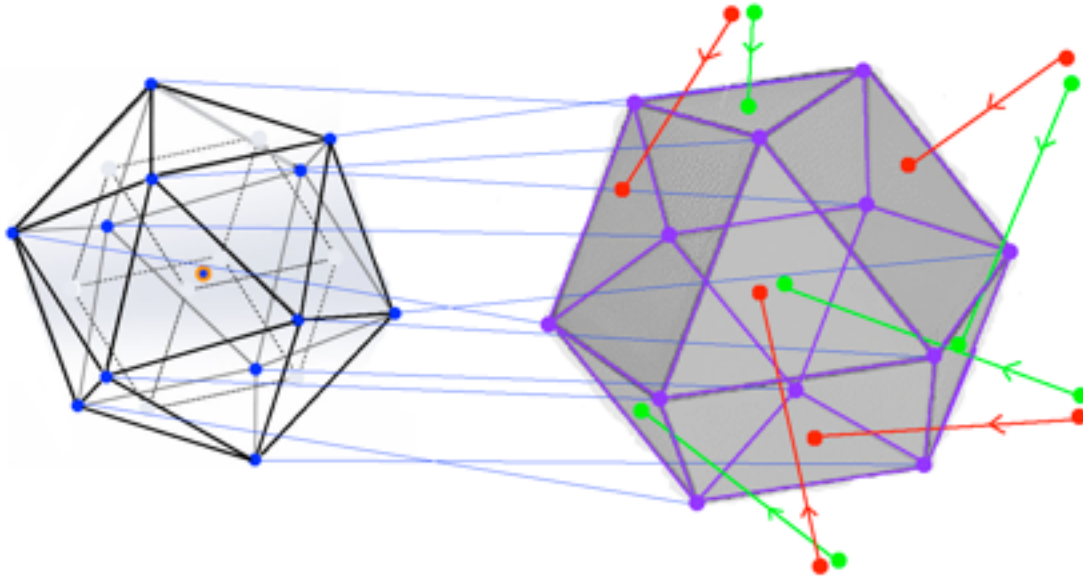
$$\text{Cuboctahedron volume} = (5/3) \text{sqrt}(2) = 2.3570226$$

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

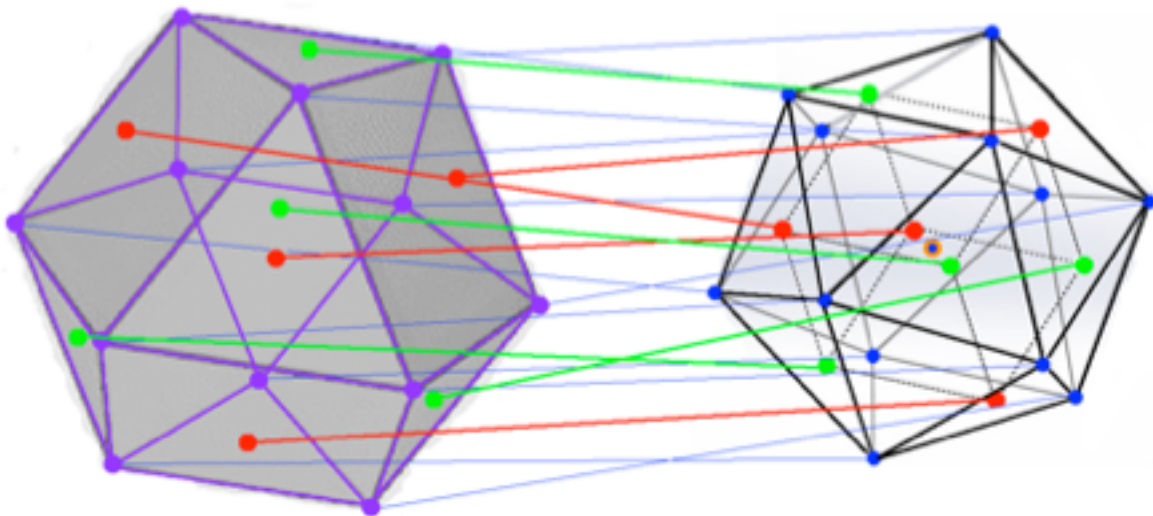
$$\text{Cuboctahedron/Icosahedron volume ratio} = 1.0803630254$$

How do Jitterbug Transformations enable D reloading ?

The cuboctahedral configuration resulting from Fusion Energy Jitterbug is not only larger than the Icosahedral configuration, it has 6 large square openings allowing easier entry into the Pd cluster of the Deuterium Nuclei (red dots) and Electrons (green dots)



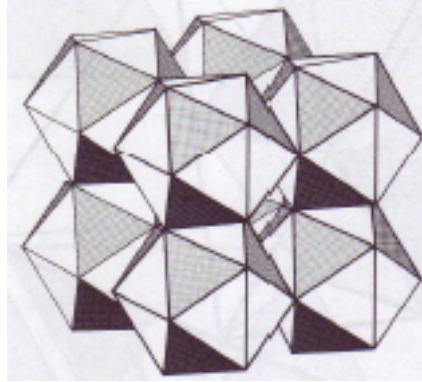
Also, the cuboctahedral configuration has 8 small triangle faces to which the 4 Nuclei and 4 Electrons of the Deuterium are attracted to form the Tetrahedral Symmetric Coherent Quantum State which is maintained after the second Jitterbug to the icosahedral ground state



thus producing a reloaded icosahedral configuration for another round of TSC fusion.

Jitterbug D-Loading analogy with Browning M1911 and Maxim Gun

(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]

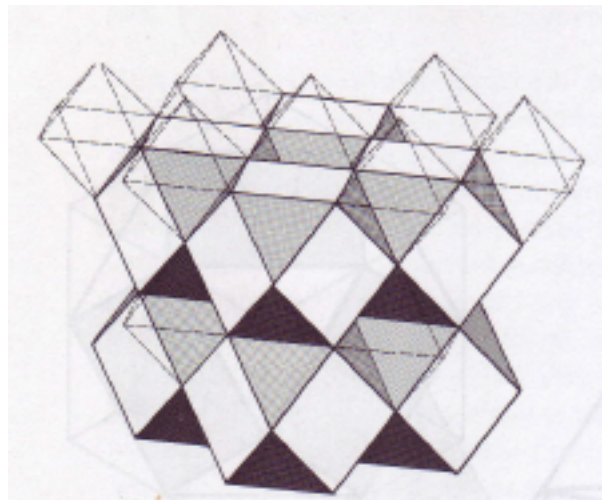
3. The barrel stops, but the unlocked [slide] continues to move to the rear, ejecting the empty shell and compressing the recoil spring.

[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. ..."

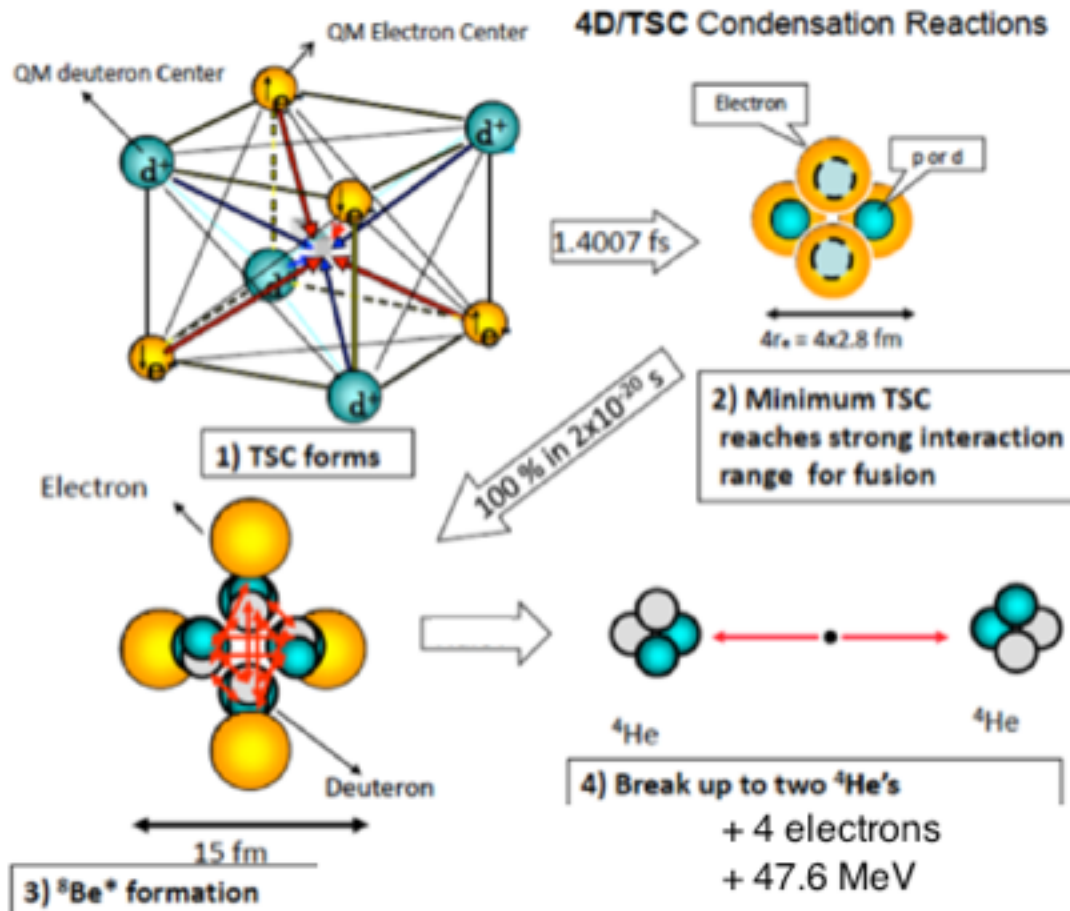
(quote from Wikipedia entries on M1911 pistol and on Recoil operation)

TSC Fusion of 4D to 8Be* to 2 alpha giving 47.6 MeV

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,

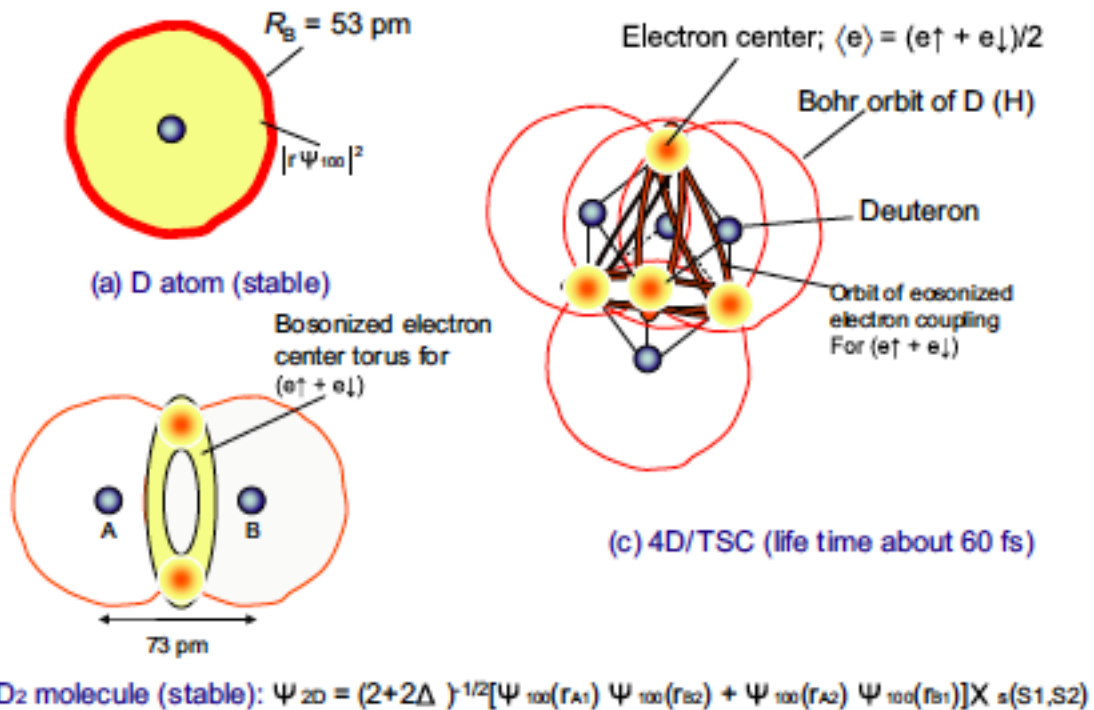
$\langle e \rangle = (e\downarrow + e\uparrow)/2$ for QM view at four electron centers ...



[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 ...

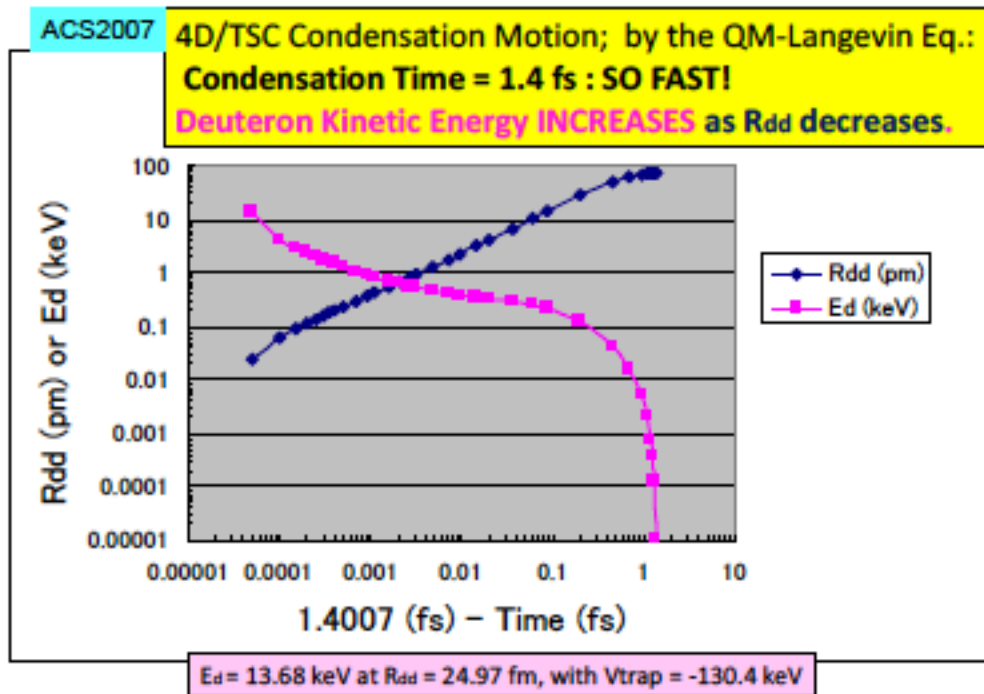
Immediately at ... 8Be^* formation ... 4d-cluster shrinks to much smaller size (about 2.4 fm radius) of 8Be^* nucleus, and four electrons should go outside due to the Pauli's repulsion for fermions. Shortly in about few fs or less (note; Lifetime of 8Be at ground state is 0.67 fs), 8Be^* will break up into two 4He particles ... [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 $\langle e \rangle = (e\downarrow + e\uparrow)/2$, Bosonized electron pair ...) ... locates at vertexes of regular cube with tetrahedral combining orbits and outer dilute clouds ...



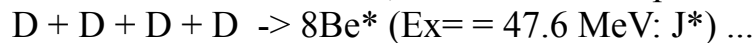
... At ... cube ... vertexes ... three Bohr wave functions superpose and electron density is about nine times larger than that of outer dilute cloud. Therefore, the semi-classical treatment of central squeezing motion by Newtonian is approximately fulfilled for "coherent" central averaged momentums for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

As soon as 4D/TSC($t=0$) state with D_2 molecule size ($R_{dd} = 74 \text{ pm}$) 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 ...".

TSC 47.6 MeV energy release mechanisms

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^* ($E_x = 47.6$ MeV):

1 - 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.

2 - Each of the **two 4He alpha particles carry away about 23.8 MeV.**

Experiments by Roussetski indicate that this does not occur.

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

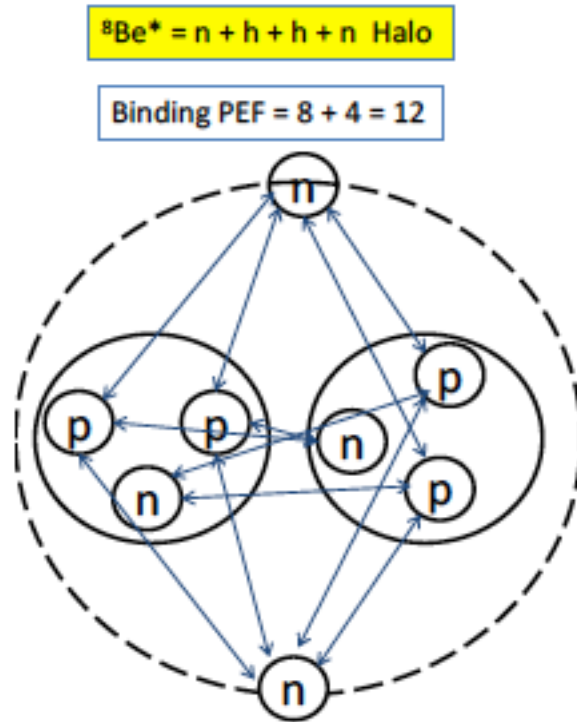
producing 1 - 10 keV soft X-rays.

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 ...".

Takahashi's paper JCF13 says

“... The 8Be^* ($E_x = 47.6$ MeV) may damp its excited energy by major BOLEP (burst of low energy photons) process from $\langle n-h-h-n \rangle$ 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 ($E_x = 34, 27.5, 22.98, 22.0, 20.1, 16.6, 11.4$ and 3.04 MeV), from where two-alpha break-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 $E_x = 34$ MeV state has a branch to emit 5.2 MeV triton, which will induce secondary D-t reaction ... to emit 9-19 MeV (E_n) neutrons ...”.

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

Parchamazad experiments: D-loaded Palladium in Sodium Zeolite Y

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 filling 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 between 147 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:**

$$47.6 \text{ MeV} \times 14 \text{ TSC Sites} / 147\text{-atom Pd Cluster} \times 4.45 \times 10^{-17} \text{ Watt-Hours} / \text{MeV} = \\ = \mathbf{2.965 \times 10^{-14} \text{ Watt-Hours} / 147\text{-atom Pd Cluster for each Jitterbug Cycle}}$$

Mass of 147-atom Pd Cluster $147 \times 106 \times 1.66 \times 10^{-21} = 2.587 \times 10^{-17}$ 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:

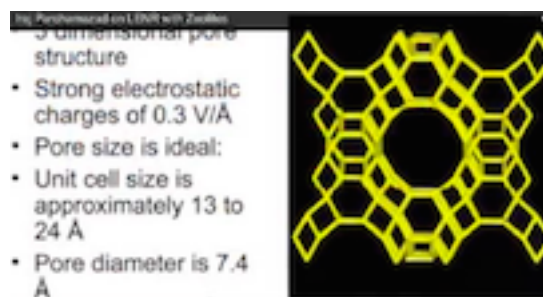
“... The faujasite framework consists of sodalite cages which are connected through hexagonal prisms.

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 \AA [0.74 nm]

The inner cavity has a diameter of 12 \AA [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.

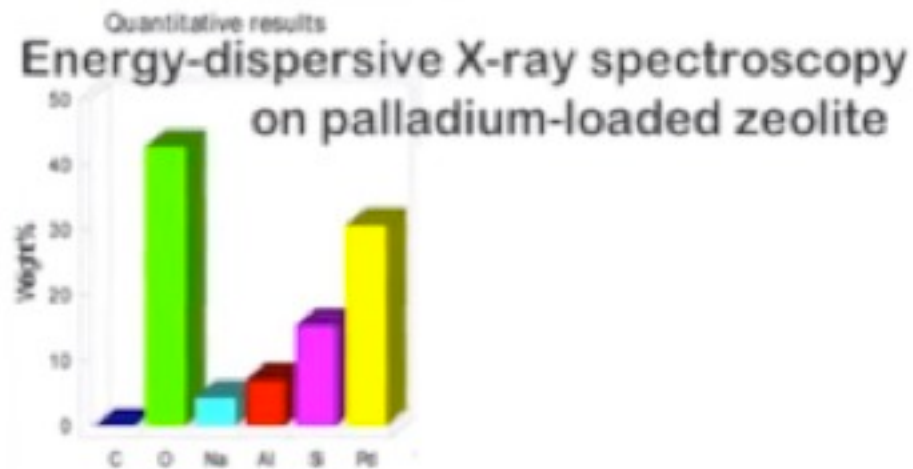
Iraj Parchamazad did not use Sandia's 1.5 nm Palladium clusters in his Zeolite but

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.

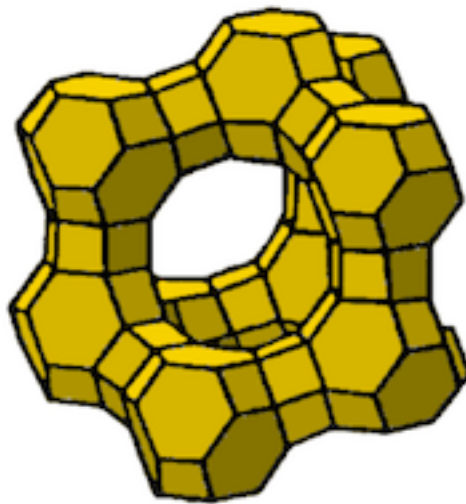
Then he exposed the Zeolite/Palladium to Deuterium, and got excess heat 10 out of 10 times, indicating fusion.

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.

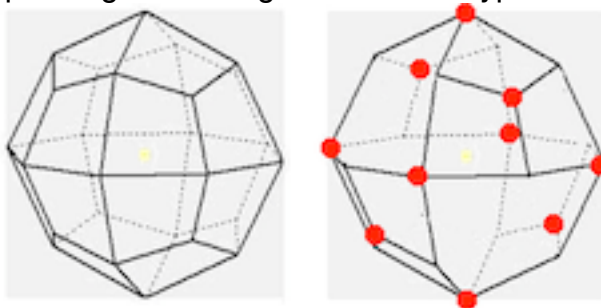
Each Zeolite Cavity is surrounded by 10 sodalite cages which are arranged in a 3-dimensional Diamond network as shown in this image



from

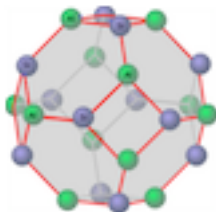
<http://www.vurup.sk/sites/vurup.sk/archivedsite/www.vurup.sk/english/products/molek/slovsit1/english.html>

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



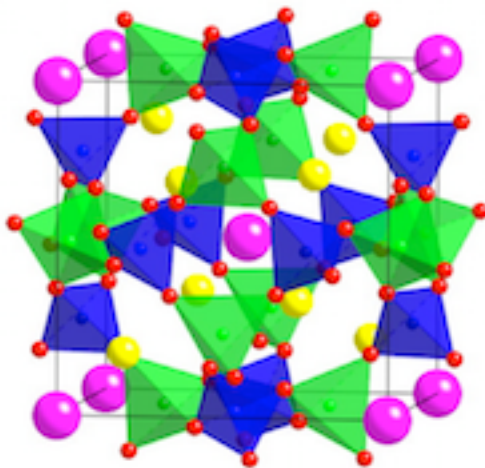
The 10 red dots correspond to the 10 sodalite cages.

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 $10 \times 12 = 120$ 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 32 for Palladium so **the number of Palladium atoms in each Zeolite Cavity** is about

$$N_{pd/z} = 120 \times (32 / 7) \times (27 / 106) = 140 \text{ atoms}$$

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 47.6 MeV

$$47.6 \text{ MeV} \times 14 \text{ TSC Sites} / 147\text{-atom Pd Cluster} \times 4.45 \times 10^{-17} \text{ Watt-Hours} / \text{MeV} = 2.965 \times 10^{-14} \text{ Watt-Hours} / 147\text{-atom Pd Cluster for each Jitterbug Cycle}$$

$$\text{Mass of 147-atom Pd Cluster} = 147 \times 106 \times 1.66 \times 10^{-21} = 2.587 \times 10^{-17} \text{ milligrams}$$

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.

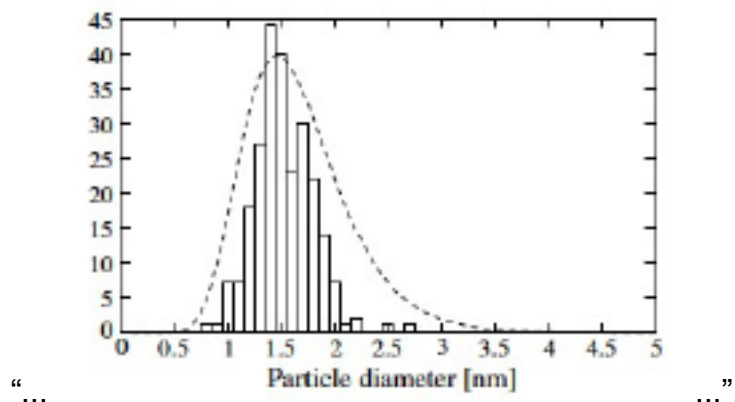
**147-atom Pd clusters have diameter about 1.5 nanometers.
1.5 nm Pd Clusters have been produced
at Sandia National Laboratories
and University of New Mexico Center for Micro-Engineered Materials**

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.

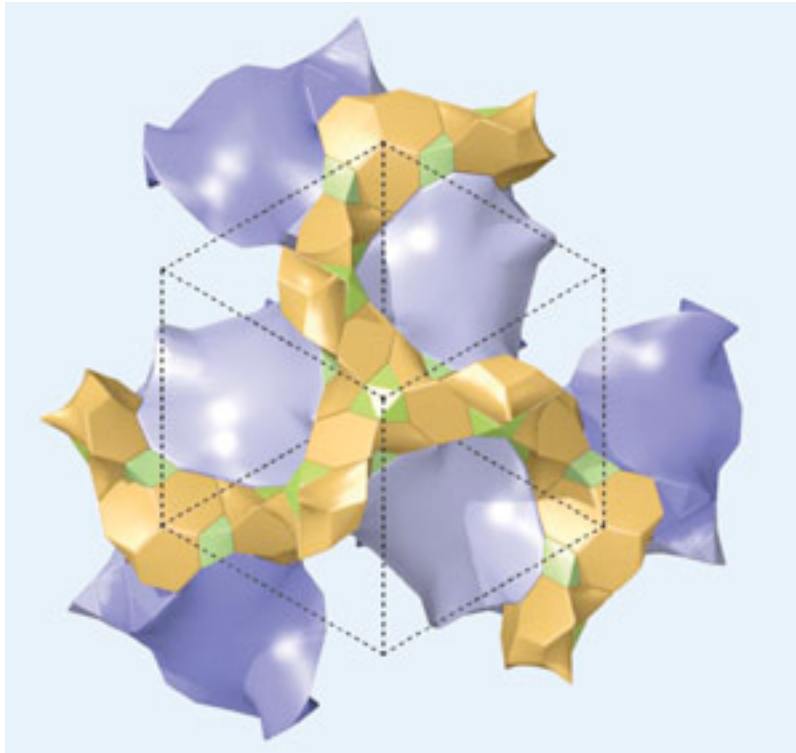
we can try to deposit the materials on a number of surfaces and just let it dry.

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 **UltraCapacitor**:

Heat

According to a 7 June 2012 techthefuture.com web article by Tessel Renzenbrink:

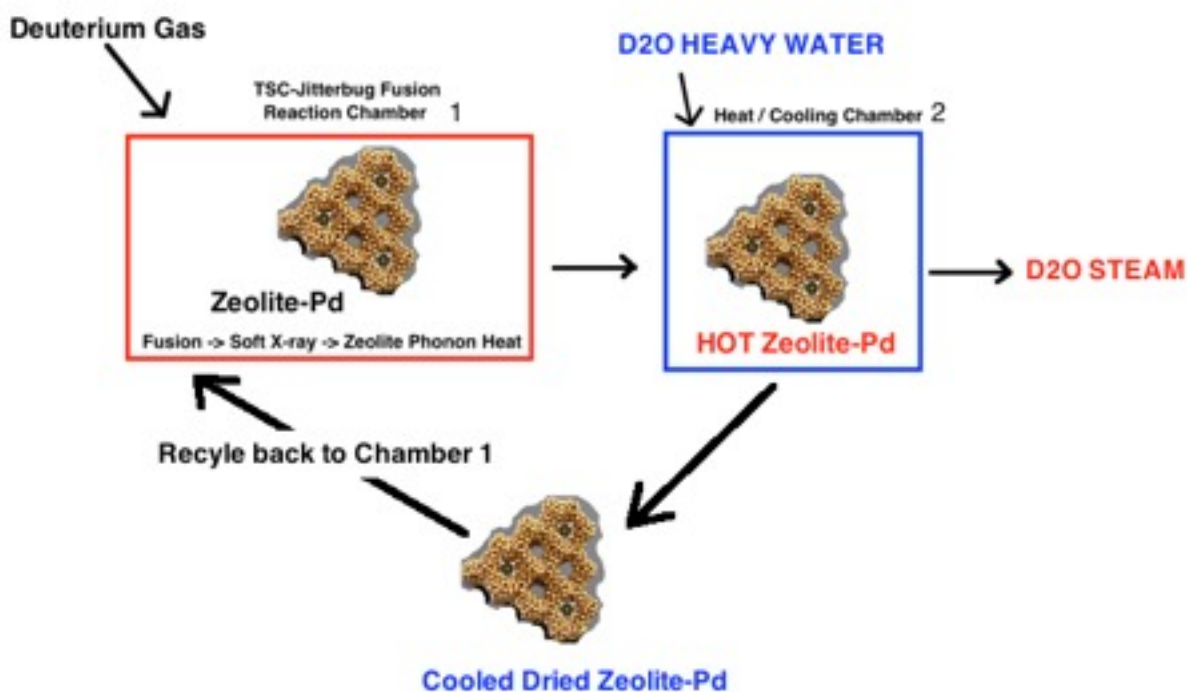
“... Zeolite is a mineral that can store up to four times more heat than water ... zeolite retains a hundred percent of the heat for an unlimited amount of time ... When water comes into contact with zeolite it is bound to its surface by means of a chemical reaction which generates heat. Reversely, when 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. ...”.

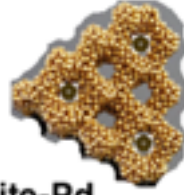
Here is my design for a TSC-Jitterbug Zeolite Pd-D fusion heat engine:



(Zeolite-Pd images adapted from Calvo and 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.

D2O 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 stabilisation of nanoscale zeolite particles ...

Zeolite Y is of great interest ... Zeolite crystals prepared under conventional synthesis conditions frequently 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 $\text{Pd}(\text{OAc})_2$ 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:

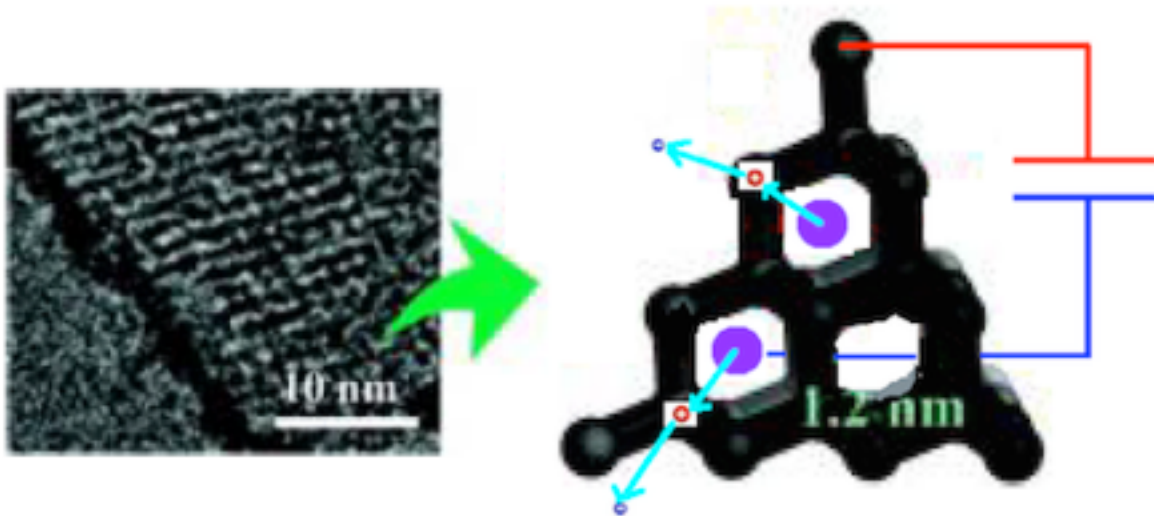
The atomic mass of a Zeolite Y unit cell is
 (from nptel.ac.in Introduction to Catalysis Lecture 36 Zeolites)
 $(56 \times 23 \text{ Na} + 56 \times 59 \text{ AlO}_2 + 136 \times 60 \text{ SiO}_2 + 264 \times 18 \text{ H}_2\text{O}) = 17,504$
 for actual mass = $17504 \times 1.66 \times 10^{(-21)} = 2.906 \times 10^{(-17)}$ milligrams

The atomic mass of a 147-atom Pd nanocluster is
 $147 \times 106 = 15,582$
 for actual mass = $15,582 \times 1.66 \times 10^{(-21)} = 2.587 \times 10^{(-17)}$ 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.

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 ...

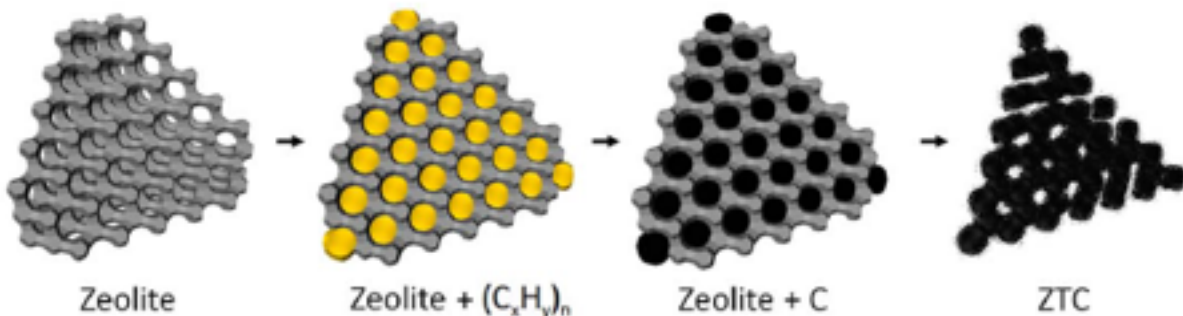


Figure 4.1. A schematic of template-carbonization in a porous zeolite framework, to produce zeolite-templated carbon (ZTC).

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 tetrahedral 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	1.9×10^9 (1/1000 of Earth supply)	2,000,000
Thorium	7.9×10^9 (1/1000 of Earth supply)	8,000,000
Deuterium	1.9×10^9 (1/1000 of ocean supply)	2,000,000
Lithium	1.9×10^9 (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 $\pi \times 6,000^2 = 1,000,000 \text{ km}^2 = (1,000 \text{ km})^2$ 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 10⁹ (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 $4 \times 4300 / 1340 = 13$ 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 5×10^{-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