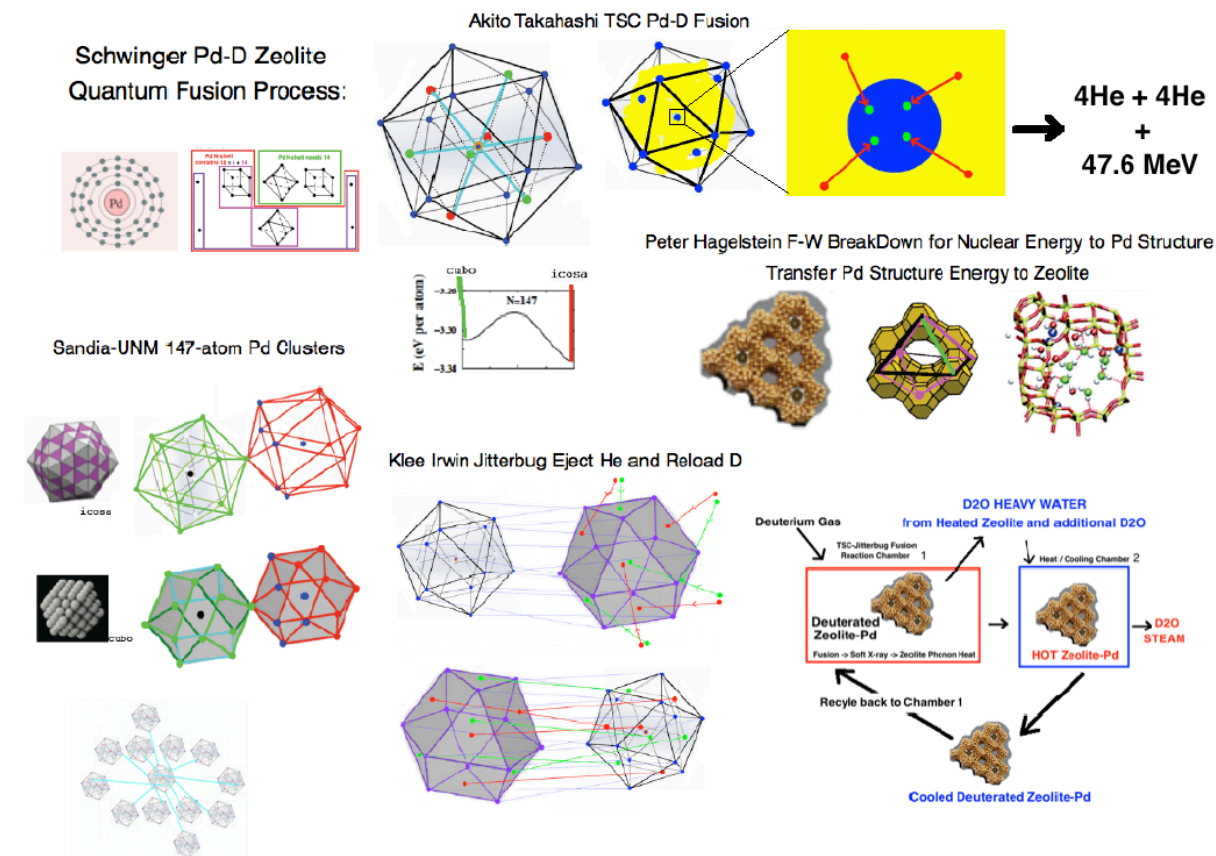


Cold Fusion - Deuterium in 147-atom Pd nanoclusters embedded in Zeolite Cages

Frank Dodd (Tony) Smith, Jr. - 2016 - viXra 1603.0098



Abstract:

147-atom Palladium clusters embedded in Zeolite cavities enable Cold Fusion when exposed to Deuterium gas by Klein Paradox Tunnelling of D+D+D+D producing He + He + 47.6 MeV. Cold Fusion Energy goes to Optical Mode Phonons in the Pd clusters and then to the Zeolite where it is stored as Heat that is released by D2O Heavy Water to produce useful energy. Ejection of He + He and reloading of D+D+D+D is done by Jitterbug transformation between Icosahedral Ground State and Cuboctahedral Metastable State of 147-atom Pd clusters. Synthesis of 147-atom Pd clusters has been done by Burton, Boyle, and Datye at Sandia / U. New Mexico, USA. Zeolite synthesis has been discussed by Sharma, Jeong, Han and Cho at Chungnam Nat. Un., Korea. Based on prior experimental results of Arata and Zhang (replicated by McKubre at SRI) and of Parchamazad the expected energy production is on the order of kilowatts per milligram of Palladium.

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How does Pd-D Cold Fusion Work ?

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 ...”.

Akito Takahashi proposed a process Tetrahedral Symmetric Condensation (TSC) that for 4 Deuterons (D) in an icosahedral cluster of Palladium (Pd) atoms produces a Schwinger coherent quantum state

that effectively distributes the electron population among deuterons so that the Coulomb barrier is eliminated and the four Deuterium (D) nuclei can simultaneously interact and fuse, forming two 4He nuclei plus 47.6 MeV energy.

Peter Hagelstein used phonon models for Relativistic Coupling Between Lattice Vibrations and Nuclear Excitation, enabled by break-down of Foldy-Wouthuysen transformation due to 8-15 THz Lattice Vibration Modes, to show direct transfer of the 47.6 MeV energy of Cold Fusion to the Pd lattice as excited optical phonon modes.

The only Cold Fusion experiments producing heat consistently and reproducibly are the detections of heat using Pd Clusters and Deuterium gas

by Arata and Zhang (replicated by McKubre at SRI) and by Iraj Parchamazad.

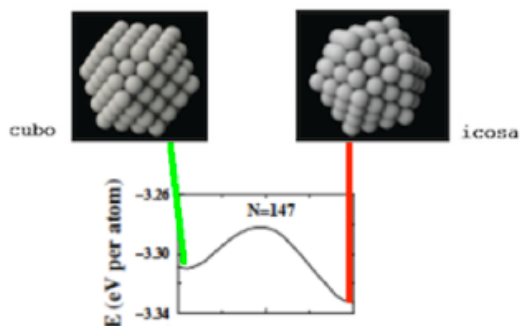
Arata and Zhang (and SRI) used Palladium black with initial cluster sizes distributed around 5 nm so that a substantial number of Pd clusters had diameter 1.5 nm. However, clumping increased the cluster size to around 40 nm at which size Takahashi et al said, based on their similar work, the “heat-power level drop[ped]... drastically”.

(see Current Science 108 (25 Feb 2015) LENR Special Section Preface)

Iraj Parchamazad and Melvin Miles avoided the clumping problem by growing the Pd clusters within Zeolite cavities. Using Sodium Zeolite Y whose cavity size is around 1.2 nm (but capable of expansion by about a factor of 2), they produced Pd clusters of 1.5 nm size size which were dispersed within the Zeolite cavities thus preventing clumping. Upon exposure of his Pd clusters in Zeolite to Deuterium gas, he produced heat in 10 out of 10 experiments with **Cold Fusion Energy on the scale of kiloWatts per milligram of Palladium.**

(see coldfusionnow.org/iraj-parchamazad-lenr-with-zeolites/)

1.5 nm diameter Pd clusters have 147 atoms and can be in two states: an Cuboctahedral Metastable State and an Icosahedral Ground State

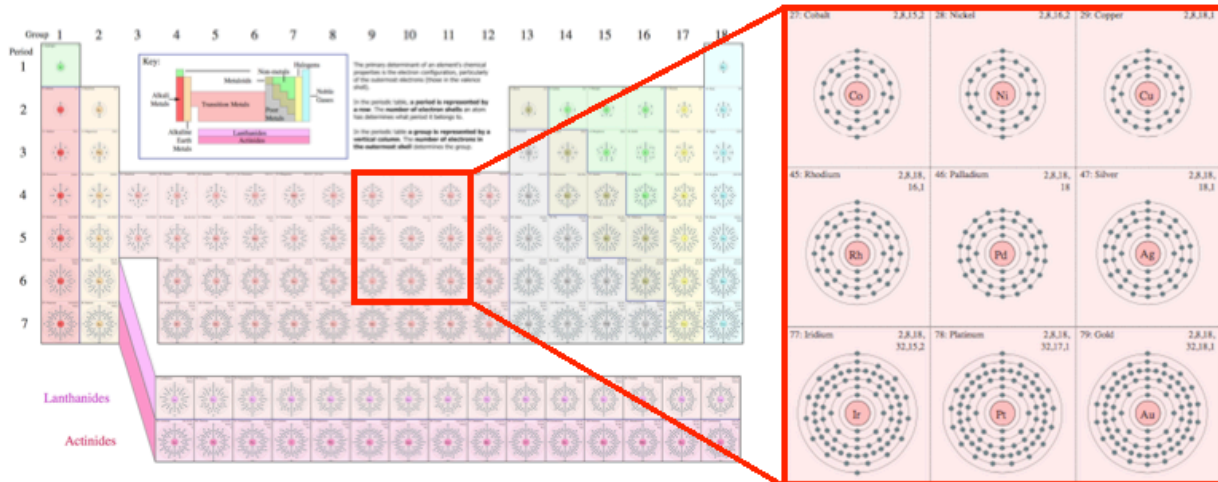


that can transform into each other by a Fuller Jitterbug Transformation.

Why is Palladium uniquely useful for Deuterium Cold Fusion ?

Pd has uniquely closed electron shell structure.

Wikipedia says (I added red material specifically about Pd): “...



... Each s subshell holds at most 2 electrons
 Each p subshell holds at most 6 electrons
 Each d subshell holds at most 10 electrons
 Each f subshell holds at most 14 electrons
 Each g subshell holds at most 18 electrons ...

Shell name	Subshell name	Subshell max electrons	Shell max electrons
K	1s	2	2
L	2s	2	2 + 6 = 8
	2p	6	
M	3s	2	2 + 6 + 10 = 18
	3p	6	
	3d	10	
N	4s	2	2 + 6 + 10 + 14 = 32
	4p	6	
	4d	10	
	4f	14	

Palladium

$$2$$

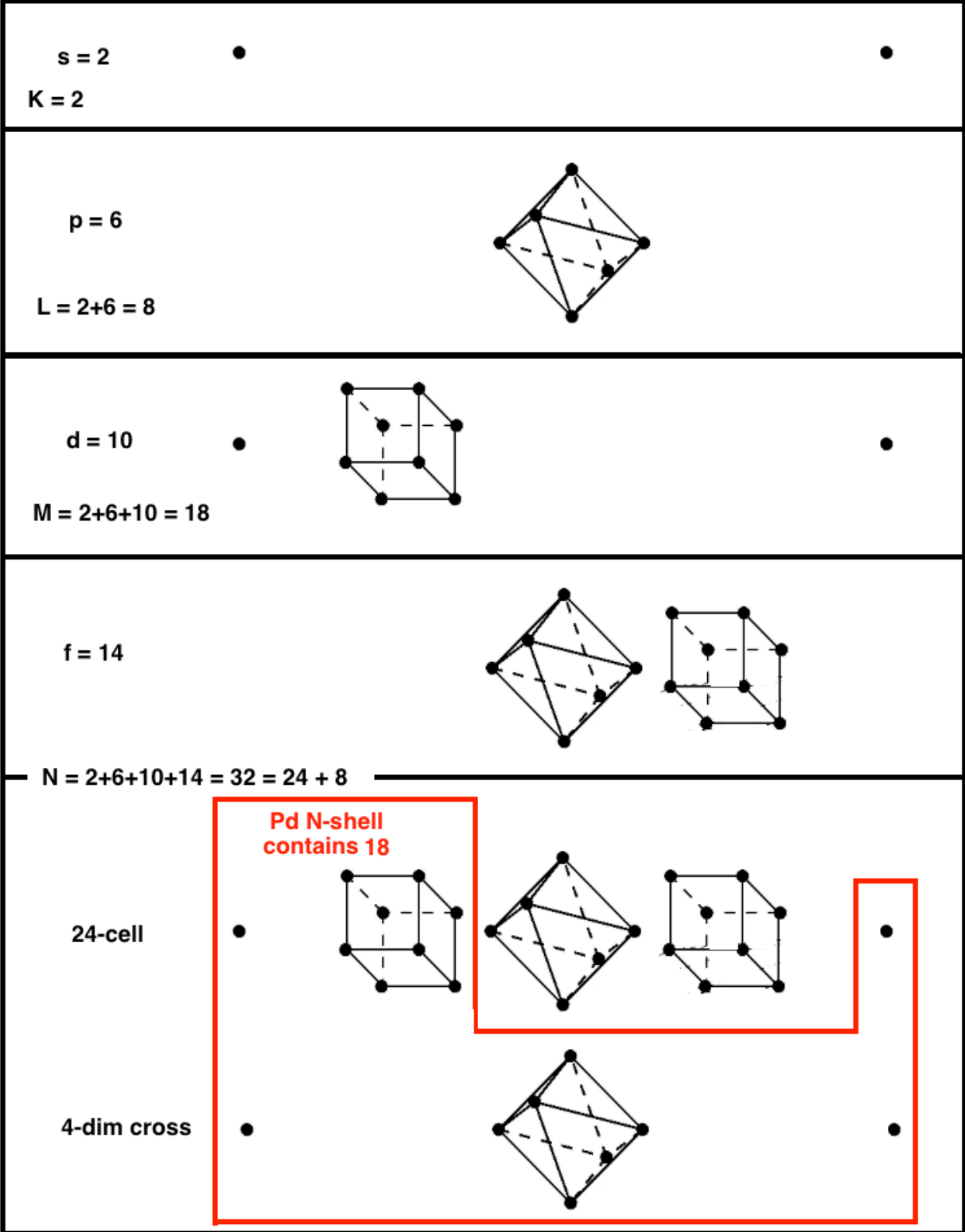
$$2+6 = 8$$

$$2+6+10 = 18$$

$$2+6+10 = 18$$



... palladium (atomic number 46) has no electrons in the fifth shell, unlike other atoms ...[in its periodic table neighborhood]...”



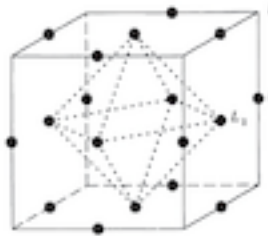
(24-cell image from John Baez review of "On Quaternions and Octonions" by Conway and Smith)

Geometrically:

2 of the First Shell correspond to the Root Vectors of $B_1 = \text{Spin}(3)$

8 of the Second Shell correspond to the Root Vectors of $B_2 = \text{Spin}(5)$

18 of the Third Shell correspond to the Root Vectors of $B_3 = \text{Spin}(7)$



(image from Representation Theory by Fulton and Harris)

The B_3 Root Vectors live in 3-dim space, which is where Element Electron Shells live.

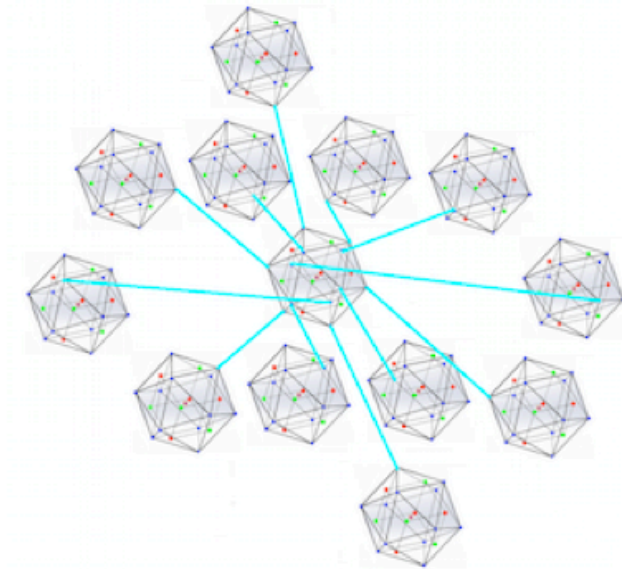
32 of the Fourth Shell correspond to the Root Vectors of $B_4 = \text{Spin}(9)$

Palladium is the only element whose outer shell has more electrons than the 8 electrons of noble gases beyond Helium.

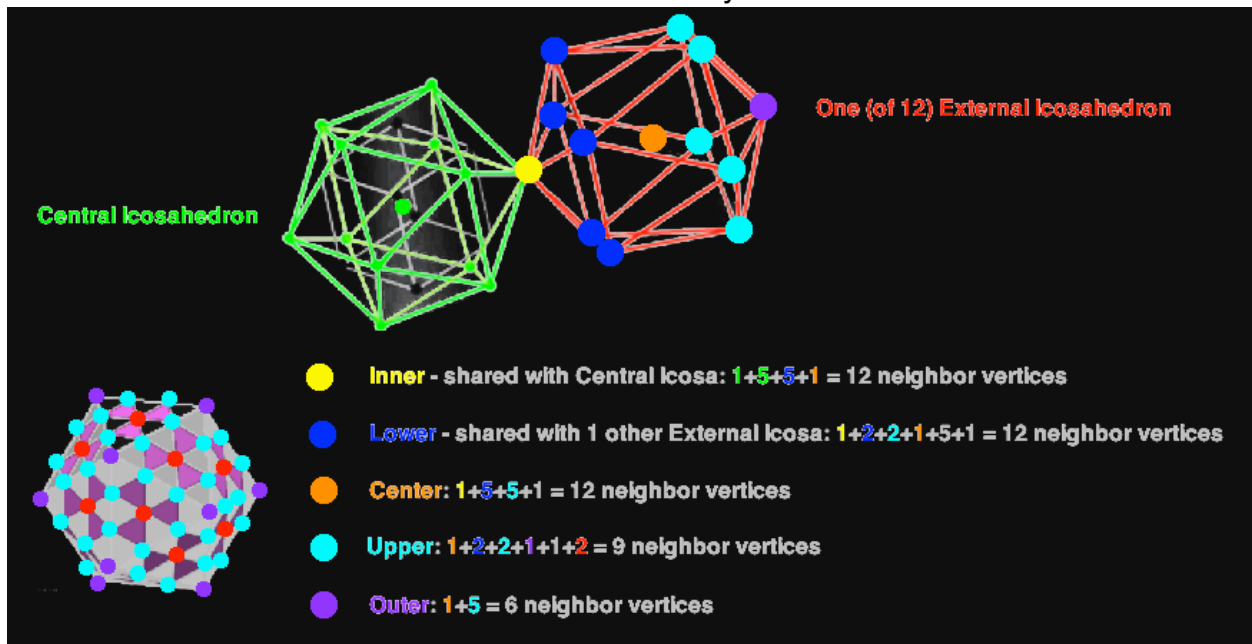
The 18 electrons in the outer shell of Palladium replicate the full state of the Third Shell (M shell).

What is the structure of the icosahedral 147-atom Pd cluster ?

The icosahedral 147-atom ground state has 12 exterior icosahedra and a central icosahedron with 12 interior vertices which are the innermost vertices of 12 exterior TSC Fusion site icosahedra:



The 12 exterior icosahedra each have outer faces on the outer boundary of the 147-atom cluster.



$$147 = 1+12+30+12+72+20:$$

1 atom is at the cluster center

12 atoms surround the cluster center

$5 \times 12 / 2 = 30$ atoms are in the next layer out

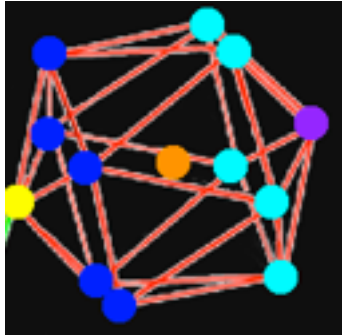
12 atoms are at centers of exterior icosahedra

$12 \times 6 = 72$ atoms are on outer surface of exterior icosahedra

20 atoms are on outer surface between exterior icosahedra

The **20 Exterior-Face-Center** Pd atoms each have $3+6 = 9$ neighbors.

Each of the 12 exterior icosahedra of the 147-atom cluster has 13 Pd atoms:

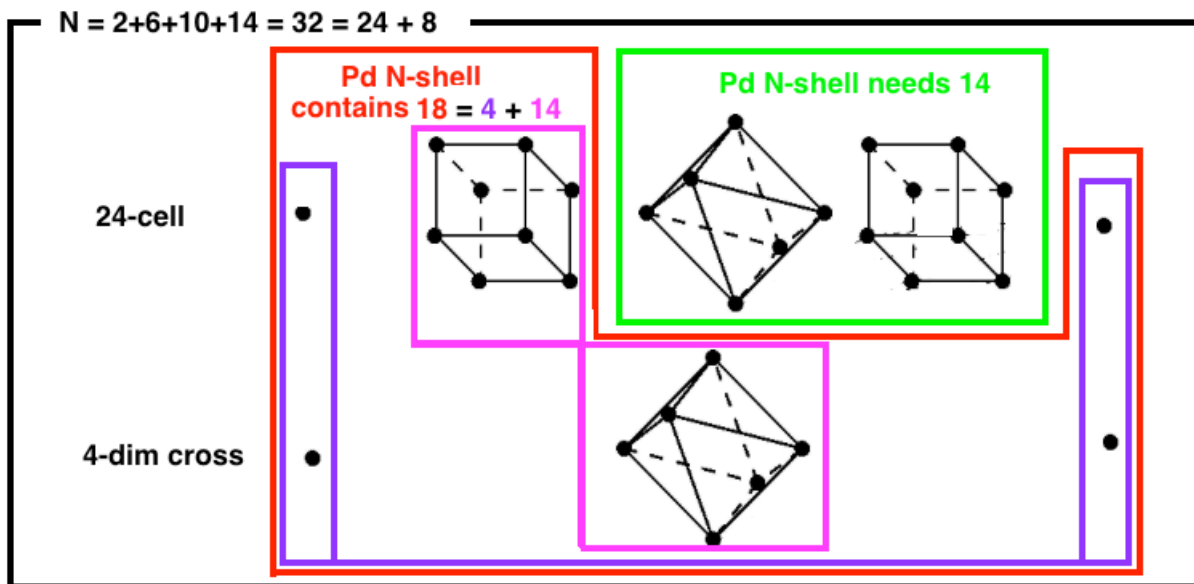


How do the Palladium atoms in a cluster interact with each other ?

The interaction is primarily through the outer shell of electrons (N-shell for Palladium).

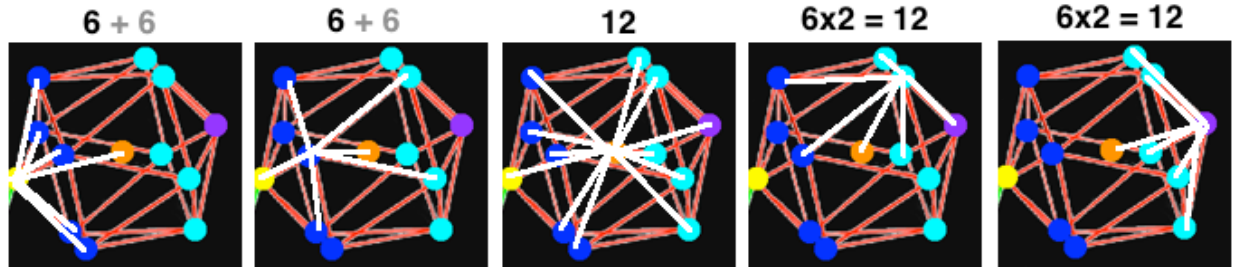
A full N-shell has $s + p + d + f = 2 + 6 + 10 + 14 = 32$ electrons.

Palladium N-shell has $2 + 6 + 10 = 18$ electrons and “holes” to receive 14 electrons:



Each Palladium atom has $18-14 = 4$ N-shell electrons that can interact with 4 electrons of 4 Deuterium atoms absorbed into a Pd cluster, helping them to participate in a Schwinger coherent quantum state for TSC Fusion.

Further, each Palladium atom has 14 N-shell electrons 12 to fill needs of other Pd atoms and 2 for a Dirac Fermion Band for Klein Paradox Tunnelling.



6x2 = 12: For the **1** exterior vertex Pd with 6 neighbors, all 6 of which are in the icosahedron, 12 electrons go 2 to each icosahedron neighbor and $14-12 = 2$ electrons go to a Dirac Fermion Band for Klein Paradox Tunnelling. It receives 12 electrons, 2 from each of its **1**+5 = 6 icosahedron neighbors leaving 2 holes related to Dirac Fermion Band for Klein Paradox Tunnelling.

6x2 = 12: For each of the **5** exterior surface Pd with 9 neighbors, **2**+**1**+**2**+**1** = 6 of which are in the icosahedron, 12 electrons go 2 to each icosahedron neighbor and $14-12 = 2$ electrons go to a Dirac Fermion Band for Klein Paradox Tunnelling. It receives 12 electrons, 2 from each of its **2**+**1**+**2**+**1** = 6 icosahedron neighbors leaving 2 holes related to Dirac Fermion Band for Klein Paradox Tunnelling.

12: For the **1** central Pd with 12 neighbors, all 12 of which are in the icosahedron, 12 electrons go 1 to each icosahedron neighbor and $14-12 = 2$ electrons go to a Dirac Fermion Band for Klein Paradox Tunnelling. It receives 12 electrons, one from each of its **1**+**5**+**5**+**1** = 12 icosahedron neighbors leaving 2 holes related to Dirac Fermion Band for Klein Paradox Tunnelling.

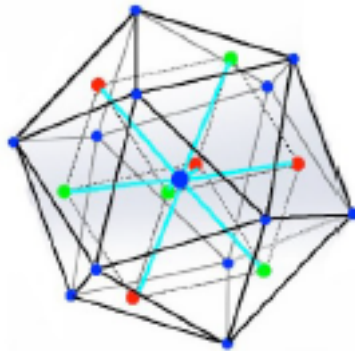
6 + 6: For each of the **5** interior Pd shared with 1 other icosahedron and with 12 neighbors, **1**+**2**+**1**+**2** = 6 of which are in the icosahedron, 6 electrons go 1 to each icosahedron neighbor and $14-6 = 8$ electrons go 2 to a Dirac Fermion Band for Klein Paradox Tunnelling and 6 to the other icosahedron. It receives $6+6 = 12$ electrons, 1 from each of its **1**+5 = 6 icosahedron neighbors and 6 from the other icosahedron, leaving 2 holes related to Dirac Fermion Band for Klein Paradox Tunnelling.

6 + 6: For the **1** interior Pd shared with the central icosahedron and with 12 neighbors, **5**+**1** = 6 of which are in the icosahedron, 6 electrons go 1 to each icosahedron neighbor and $14-6 = 8$ electrons go 2 to a Dirac Fermion Band for Klein Paradox Tunnelling and 6 to the central icosahedron. It receives $6+6 = 12$ electrons, 1 from each of its **5**+**1** = 6 icosahedron neighbors and 6 from the central icosahedron, leaving 2 holes related to Dirac Fermion Band for Klein Paradox Tunnelling.

All 13 Pd atoms in the icosahedron have $18-14 = 4$ electrons for TSC condensation guidance.

In TSC Icosahedra of a Pd cluster 4 D (D+D+D+D) form a Schwinger Coherent Quantum State

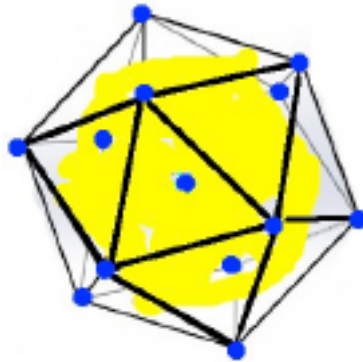
From a classical approximation point of view there are $12+1 = 13$ Pd nuclei (blue) within which there is a 2-tetrahedral configuration of 4 D nuclei (red) and 4 D electrons (green)



In the Schwinger coherent quantum state (yellow) the 4 D nuclei and 4 D electrons are smeared out all over the interior of the icosahedral TSC cell

and

the 4 D electrons screen out the positive charge of the 4 D nuclei making the Schwinger coherent quantum cloud effectively neutral with no Coulomb repulsion or attraction.



The process of forming the Schwinger State which collapses to the central Pd atom

where Deuterium nuclei undergo Cold Fusion is called by Akito Takahashi Tetrahedral Symmetric Condensation (TSC).

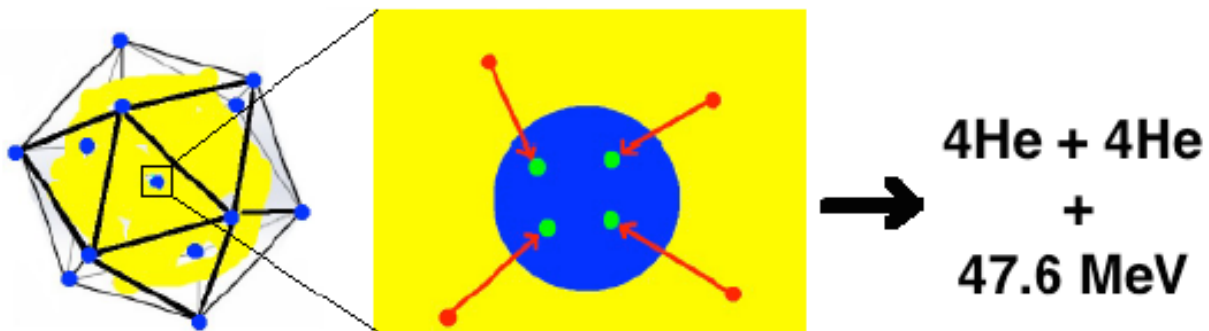
**The D Schwinger State nuclei go to the central Pd atom
and by Klein Paradox Tunnelling 4 D nuclei undergo TSC Cold Fusion
producing 4He + 4He + 47.6 MeV**

Now look at the central Pd atom in the TSC cell.

Its outer electron shell of 18 electrons has 4 free electrons

(14 of them being bound to the outer 12 Pd atoms plus 2 forming a Dirac Fermion Band)

which 4 free electrons pull the 4 D nuclei out of the Schwinger quantum cloud
into the Central Pd Atom



When the 4 D nuclei get into the small volume of the Central Pd Atom
they “see” each other as repulsive like electrical charges
resulting in a very high Coulomb barrier between them

but

that is when the Dirac Fermion Band takes effect
and gets them to rapidly penetrate the barrier by Klein Paradox Tunnelling

(see Appendix for deescription of Klein Paradox Tunnelling)

and

then all 4 Deuterium nuclei undergo TSC Fusion to produce energy + 2 Helium nuclei
which then pick up the left-over 4 Deuterium electrons to form 2 Helium atoms.

Takahashi said, about his TSC process $4D \rightarrow 8Be^* \rightarrow 4He + 4He + 47.6 \text{ MeV}$:

“... 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”

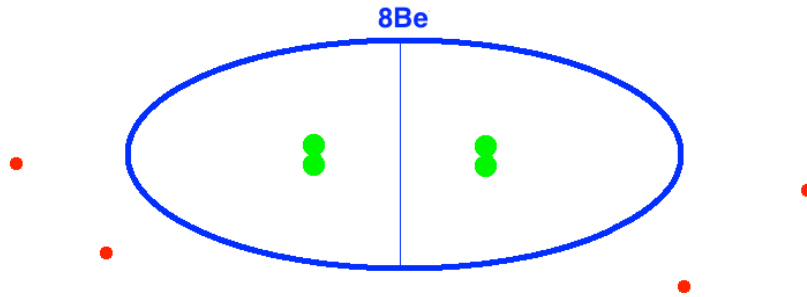
plus energy release of 47.6 MeV.

In more detail:

The D + D + D + D (two pairs of green dots) form an 8Be nucleus.

The e + e + e + e (two pairs of red dots) form the electrons of an 8Be atom.

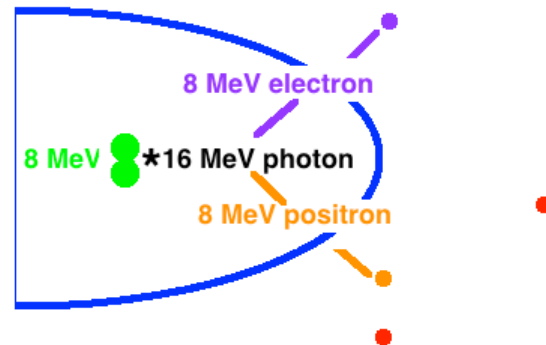
All of them (D + D + D + D + e + e + e + e) are in a single Coherent Quantum State.



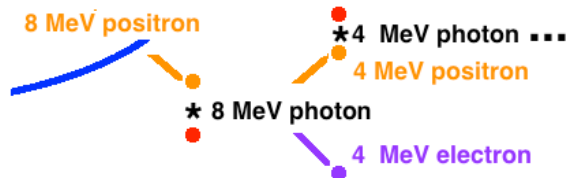
Two of the D (one half of the 8Be nucleus) undergo TSC Fusion to produce about 24 MeV which excites the 8Be nuclear state to 8Be^* .

About 8 MeV goes from the 8Be^* excited nuclear state by the Hagelstein Process to Pd Cluster Optical Phonon Energy.

About 16 MeV goes by Internal Photon Pair Creation to an 8 MeV Electron + 8 MeV Positron Pair.



The 8 MeV Positron annihilates one of the coherent Electrons



producing an 8 MeV photon which creates a 4 MeV Electron + 4 MeV Positron Pair with the 4 MeV Positron annihilating the other of the two relevant coherent Electrons.

Effectively the two zero kinetic energy coherent Electrons (red dots)

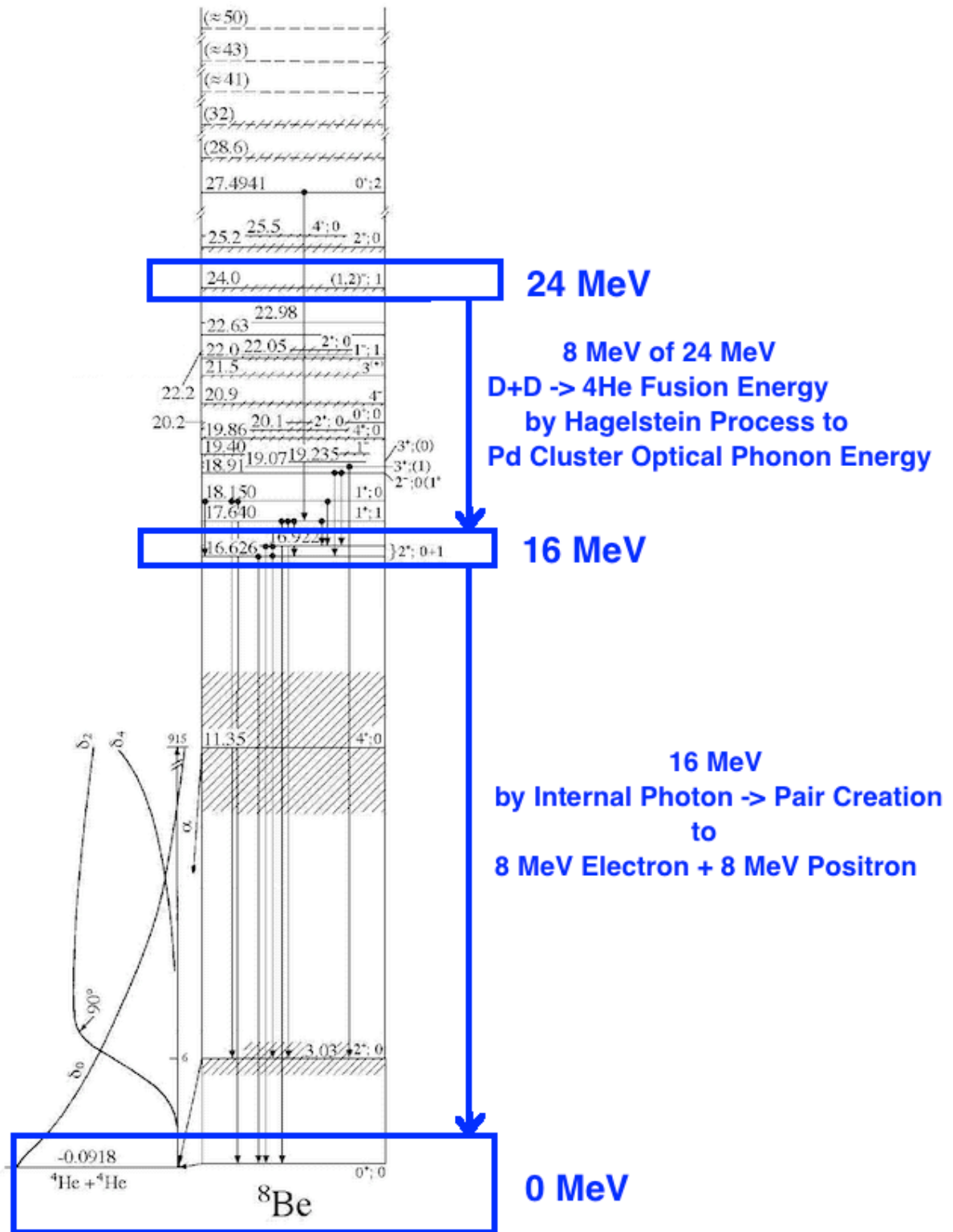
are replaced by an 8 MeV Electron + a 4 MeV Electron (purple dots)

whose 12 MeV kinetic energy becomes vibrational energy of the Pd Cluster.

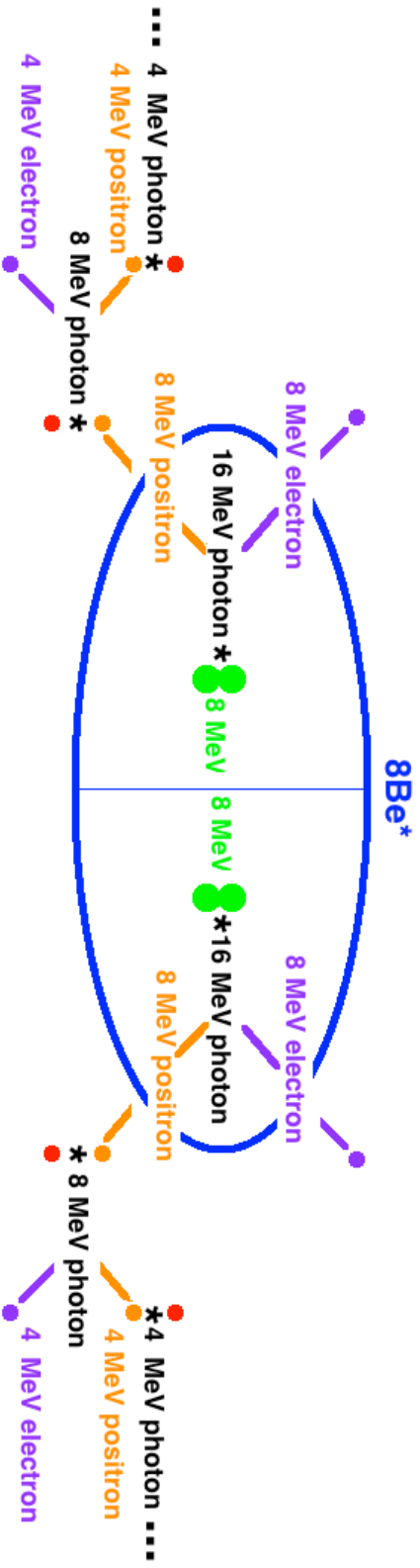
The $16 - 12 = 4$ MeV photon may continue the annihilation to vibrational energy process.

The other half of the 8Be structure will undergo the TSC Fusion energy process in the same way at a slightly different time.

Here is a more detailed ^8Be energy level chart:



(image from "Energy Levels of Light Nuclei A = 8" by Tilley, Kelley, Godwin, Millener, Purcell, Sheu, and Weller 2012)
 The overall process looks like this:



47.6 MeV TSC Cold Fusion energy goes to Pd cluster Optical Phonons

Hagelstein and Chaudhary in ICCF 18 (Missouri 2013) Poster:

Relativistic Coupling Between Lattice Vibrations and Nuclear Excitation said:

“... for relativistic dynamics ... the fundamental theory includes a very strong coupling between the center of mass momentum operator, and internal nuclear transitions.

This coupling is connected to changes in the internal structure of a composite when it moves (as a result of the Lorentz transform), compared to the rest frame wavefunction.

Under normal conditions a generalized Foldy-Wouthuysen transformation eliminates this strong coupling, which results in a model in the rotated frame with no residual first-order interaction. As a result, one would expect generally not expect any significant coupling to survive.

The conditions under which any residual coupling would be expected are the same conditions where the generalized Foldy-Wouthuysen rotation "breaks down" ...

in that it becomes very difficult to deal with the loss operator in the rotated picture.

Under conditions where the Foldy-Wouthuysen transformation "breaks down" in this sense due to the presence of a strong Brillouin-Wigner loss operator, there exists no useful general nonrelativistic limit. In this case,

the strong coupling between the center of mass momentum and internal nuclear states remains, and can be used for coherent dynamical processes. ...”.

Wikipedia says: “... **Optical phonons** are out-of-phase movements of the atoms in the lattice, one atom moving to the left, and its neighbour to the right. This occurs if the lattice basis consists of two or more atoms. They are called *optical* because in ionic crystals, like sodium chloride, they are excited by infrared radiation. The electric field of the light will move every positive sodium ion in the direction of the field, and every negative chloride ion in the other direction, sending the crystal vibrating. Optical phonons have a non-zero frequency at the Brillouin zone center and show no dispersion near that long wavelength limit. This is because they correspond to a mode of vibration where positive and negative ions at adjacent lattice sites swing against each other, creating a time-varying electrical dipole moment. Optical phonons that interact in this way with light are called *infrared active*. Optical phonons that are *Raman active* can also interact indirectly with light, through Raman scattering. Optical phonons are often abbreviated as LO and TO phonons, for the longitudinal and transverse modes respectively; the splitting between LO and TO frequencies is often described accurately by the Lyddane-Sachs-Teller relation.

When measuring optical phonon energy by experiment, optical phonon frequencies are sometimes given in spectroscopic wavenumber notation, where the symbol ω represents ordinary frequency (not angular frequency), and is expressed in units of cm^{-1} . The value is obtained by dividing the frequency by the speed of light in vacuum. In other words, the frequency in cm^{-1} units corresponds to the inverse of the wavelength of a photon in vacuum, that has the same frequency as the measured phonon. The cm^{-1} is a unit of energy used frequently in the dispersion relations of both acoustic and optical phonons ...”.

Hagelstein and Chaudhary in Current Science 108 (25 Feb 2015): Low Energy Nuclear Reactions : Phonon Models for Anomalies in Condensed Matter Nuclear Science said: "... a... new physics model which addresses the fractionation of a large quantum; and a new fundamental Hamiltonian which describes the coupling between vibrations and internal nuclear degrees of freedom ...

the nuclear energy quantum is fractionated into much smaller quanta, which can go into vibrational modes.

For this to work in the model, the vibrational modes first need to be highly excited

...

deuterons are responsible in fractionating the nuclear quanta in operation with excited optical phonon modes, and the deuterons can accomplish this cleanly. However, THz acoustic mode excitation would also be expected to produce fractionation with participation of the host Pd nuclei, which do not fractionate cleanly (leading to disintegration of the Pd nuclei) ...

there is a strong coupling between the vibrational degree of freedom and internal nuclear degrees of freedom implicit in a relativistic model, but this coupling is normally eliminated by a generalized Foldy–Wouthuysen transformation ...

The fundamental relativistic Hamiltonian under discussion is

$$\hat{H} = \sum_j (Mc^2 + \mathbf{a} \cdot c\hat{\mathbf{p}})_j + \sum_k \frac{|\hat{\mathbf{p}}_k|^2}{2m} + \sum_{j < j'} \frac{Z_j Z_{j'} e^2}{4\pi\epsilon_0 |\mathbf{R}_j - \mathbf{R}_{j'}|} + \sum_{k < k'} \frac{e^2}{4\pi\epsilon_0 |r_k - r_{k'}|} - \sum_{jk} \frac{Z_j e^2}{4\pi\epsilon_0 |\mathbf{R}_j - \mathbf{r}_k|} \quad (5)$$

If we use a Born–Oppenheimer approximation, then the lattice nuclear problem that remains is

$$\hat{H} = \sum_j (Mc^2 + \mathbf{a} \cdot c\hat{\mathbf{p}})_j + \sum_{j < k} V(\mathbf{R}_j - \mathbf{R}_k) - \frac{i\hbar \hat{\mathbf{M}}(E)}{\hbar}, \quad (6)$$

where we have augmented the normal Born–Oppenheimer model with a loss term due to coupling with the electrons.

... we have in this a starting place to analyse coherent energy exchange between nuclei and vibrations under conditions of fractionation ...

phonon - nuclear coupling matrix element... in the case of the D2 / 4He transition ... is consistent in magnitude with what is needed to account for the rate at which excess heat is observed in experiments

...

Fractionation is easier when fewer oscillator quanta are involved, so we would expect the highest frequency vibrational modes to be involved (THz frequency vibrations).

There is only a weak coupling between vibrations and the D2 / 4He transition ...

the D2 / 4He transition occurs with a single phonon exchange with the large nuclear energy quantum transferred to other more strongly coupled transitions and subdivided (many nuclear excitations for a single D2 / 4He de-excitation),

and subsequently fractionated to optical phonons ...excess heat is basically 'silent' (in that there is nothing energetic emitted in the primary reaction) ...

The rate of fractionation without subdivision then has to match the energy release rate.

For example, if the system produces excess heat at the 1 W level,

then there are 2.6×10^{11} reactions/sec and it must take 3.8×10^{-12} sec for each of

the large 24 MeV quanta to be fractionated. If the optical phonon mode has an energy of 36 MeV, then the average time associated for the net transfer of a single phonon in connection with fractionation must be 5.7×10^{-21} sec. These numbers are consistent with the models we have studied over the years

...

If the nuclear system is treated relativistically, there is a very strong coupling present between the vibrational and internal nuclear degrees of freedom ...

there exists a unitary transformation that eliminates this very strong first-order coupling. Under conditions where this unitary transformation is useful, the vibrational and nuclear degrees of freedom are nearly independent ...

when the ... destructive interference ...[of]... the unitary transformation which eliminates the strong first-order coupling ... is spoiled ... there will be a[n]... enhanced rate for coherent energy exchange under conditions of fractionation ...

a highly excited vibrational mode ... remove[s]... the destructive interference ...”.

Letts in Current Science 108 (25 Feb 2015): Low Energy Nuclear Reactions : Dual Laser Stimulation says: “... PdD lattice vibrations might occur around 8 and 15 THz ...”.

8 - 15 THz Pd-D Fusion Frequency is interestingly coincident with:

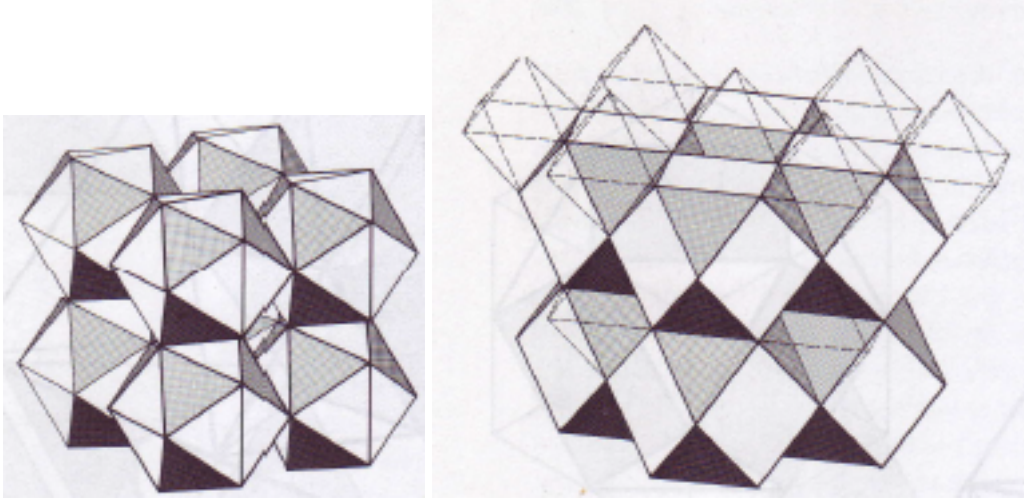
Critical Temperature of BSCCO superconducting crystals

Beck - Mackey Dark Energy Josephson Junction Frequency

Energy of Neutrino Masses

Reloading D with Pd cluster Jitterbug from Icosahedron to Cuboctahedron

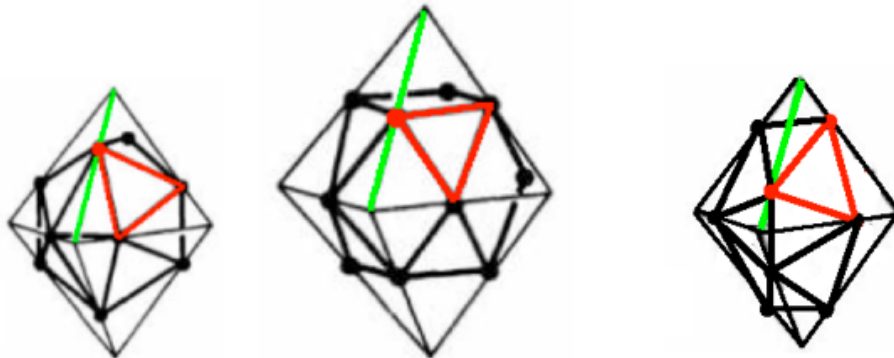
Icosahedra and Cuboctahedra both have 12 vertices so that it is possible to transform them into each other. Buckminster Fuller called that transformation the Jitterbug



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

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:

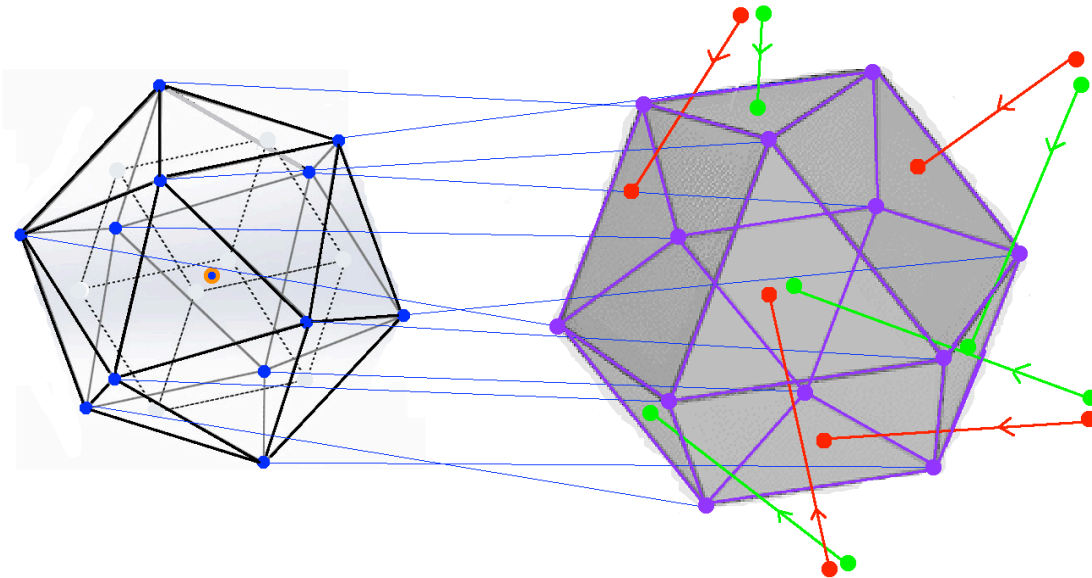
$$\text{Icosahedron volume} = (5/12) (3 + \text{sqrt}(5)) = 2.18169499$$

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

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

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

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) as well as easy exit of the Fused Deuterium $4\text{He} + 4\text{He}$ nuclei from the Pd cluster.



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.

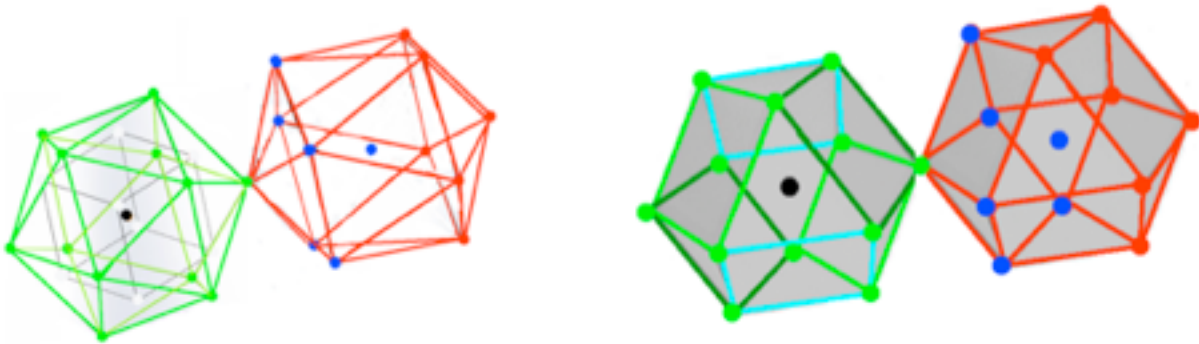
The size required for Jitterbug / TSC Fusion is a Palladium atomic cluster whose ground state is icosahedral and can easily Jitterbug Transform into a cuboctahedral state and whose size is large enough to contain several TSC Fusion Cluster sites, each of which is an icosahedron that can Jitterbug transform into a cuboctahedron.

The 13-atom Pd/Ni cluster (0.70 nm) is an icosahedron, for 1 TSC Fusion Cluster site.

The 2-shell 55-atom Pd/Ni cluster (1.13 nm) has two icosahedra that share a central vertex, for only TSC Fusion Cluster sites.

Clusters of between 56 and 147 atoms contain from 2 to 13 TSC Fusion Cluster sites by partially filling the 3rd shell of atoms.

The 3-shell 147-atom Pd/Ni cluster (1.56 nm) has 12 exterior TSC Fusion Cluster sites plus 1 central TSC Fusion Cluster sites, so it contains 13 TSC Fusion Cluster sites.



(see viXra 1502.0069)

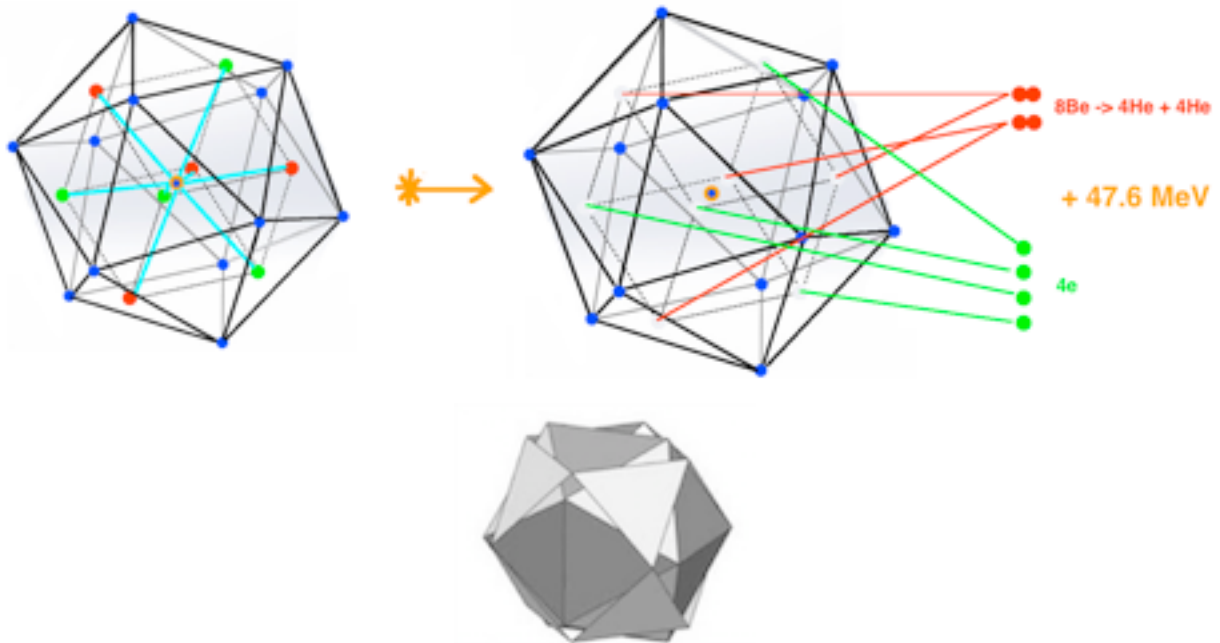
Clusters of between 147 and 309 atoms contain at least 13 TSC Fusion Cluster sites. The 4-shell 309-atom Pd/Ni cluster is 2.00 nm in size, so it is disfavored with respect to the 3-shell 147-atom cluster for use with Sodium Zeolite Y whose pore size is 0.74 nm expandable to 1.5 nm.

Most of the TSC Fusion Energy is carried to the Pd Cluster Structure by the $4\text{He}+4\text{He}$ and the $4e$ electrons of the TSC coherent quantum state according to the Hagelstein Coupling between Nuclear Excitation and Atomic Structure.

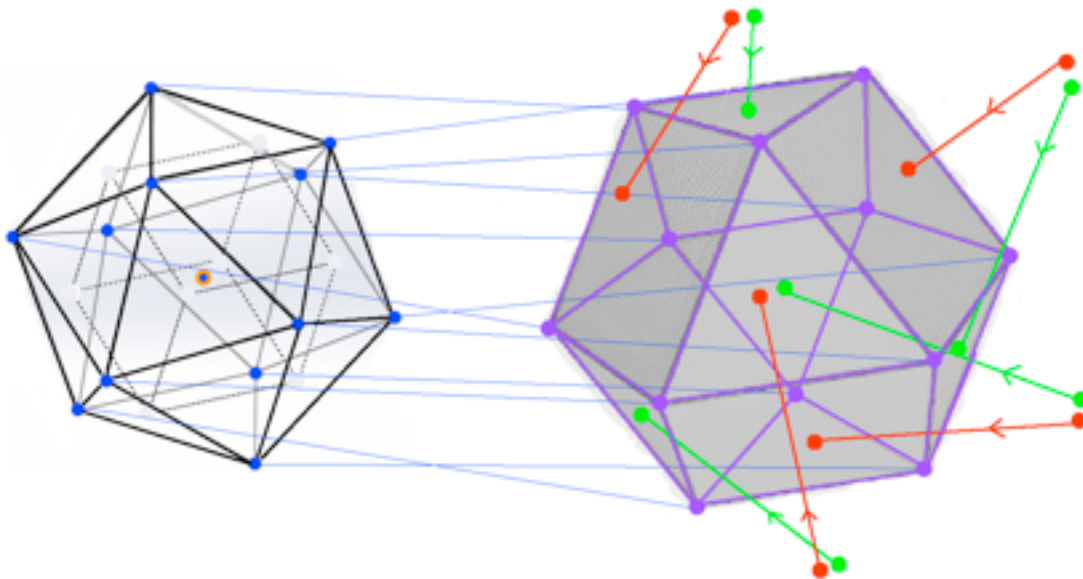
The Pd Structure Energy of Excited Optical Phonon Modes is carried by the Zeolite Cage Electrostatic Field (on the order of 3 V/nm) to be stored in the Zeolite as heat which Heat can be accessed by Zeolite-Water reaction.

Each of the 13 TSC fusion icosahedra is capable of TSC fusion

Some of the TSC Fusion Energy goes to a Jitterbug transformation

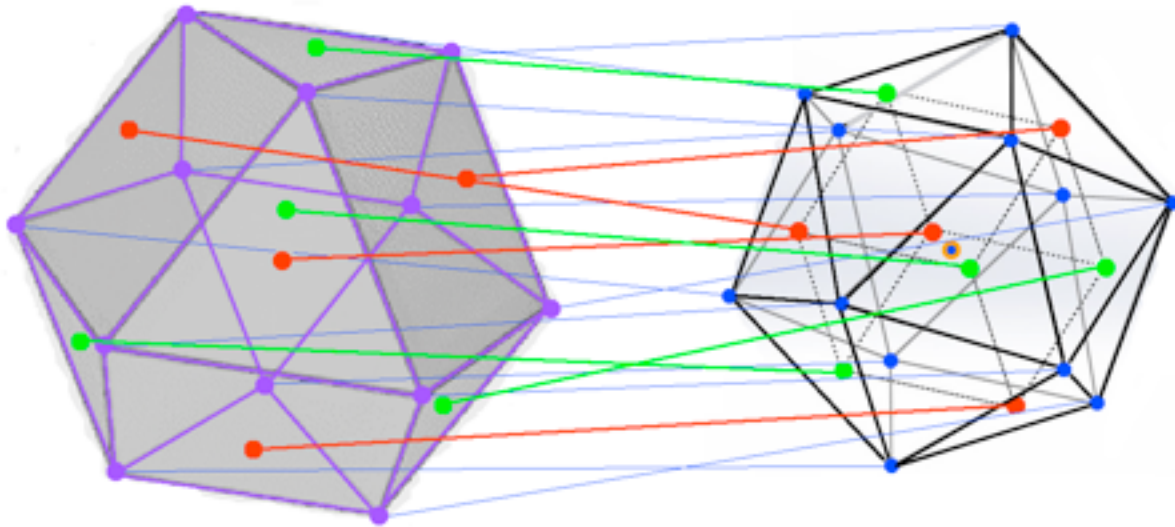


of the icosahedral Palladium, depleted of Deuterium fusion fuel,
to a cuboctahedral configuration

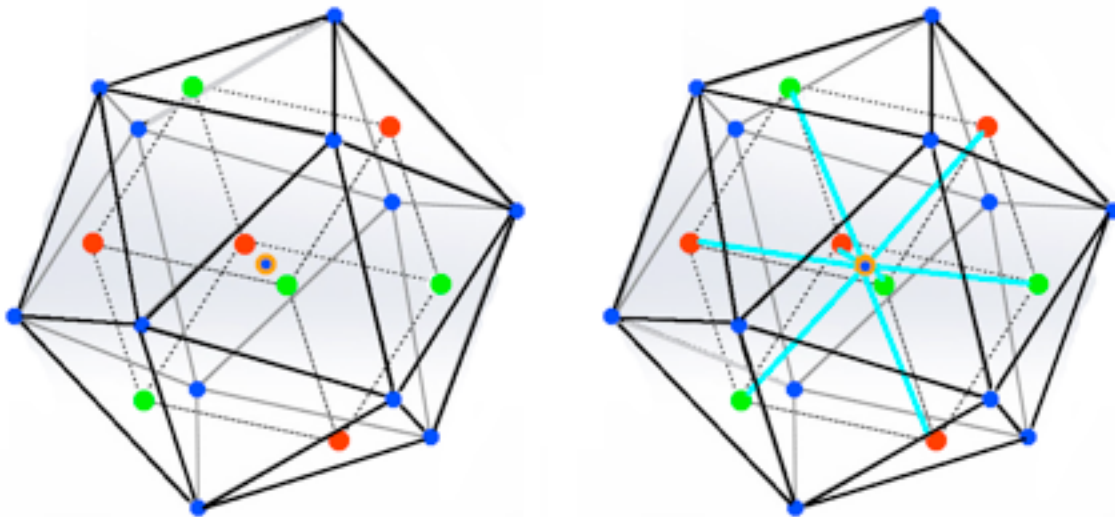


which has 6 large square openings through which
the 4He TSC Fusion Product Ash can leave the Pd cluster
and ambient Deuterium Fuel can enter to reload the Palladium cluster.
Replacement is easier for the 12 outer TSC configurations than for
the 1 central TSC configuration which is not directly exposed to ambient D gas

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



How much energy does TSC Cold Fusion produce ?

According to Hagelstein's model for fusion energy going to excited optical phonons in the Pd cluster, instead of the "... four electrons ... go[ing] outside ...", the four electrons should remain part of Schwinger's "coherent ... single state" until after fusion when the four electrons and the two 4He nuclei would produce two 4He atoms, with most of the 47.6 MeV going to excited optical phonons in 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.

A 3-shell 147-atom icosahedral Palladium atomic nanocluster contains 13 TSC Fusion Site Icosahedra and each TSC Fusion event produces 47.6 MeV
 $47.6 \text{ MeV} \times 13 \text{ TSC Sites} / 147\text{-atom Pd Cluster} \times 4.45 \times 10^{(-17)} \text{ Watt-Hours} / \text{MeV} = 2.754 \times 10^{(-14)} \text{ Watt-Hours} / 147\text{-atom Pd Cluster}$ for each Jitterbug Cycle

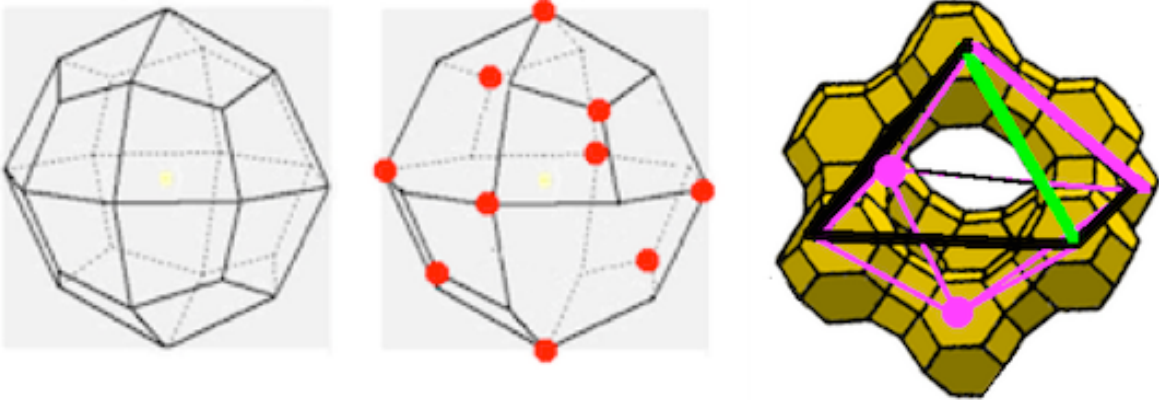
Mass of 147-atom Pd Cluster $147 \times 106 \times 1.66 \times 10^{(-21)} = 2.587 \times 10^{(-17)}$ milligrams
so
a milligram of 147-atom Pd Clusters gives about 1 KiloWatt-Hour each Cycle.

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

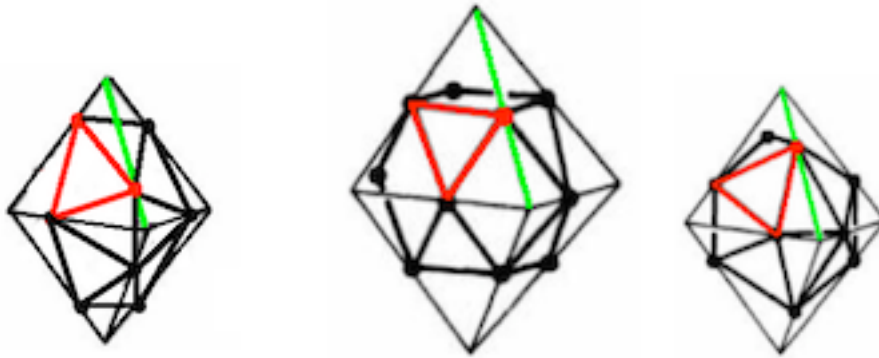
a TSC-Jitterbug Fusion device with 1 milligram of Palladium in the form of 147-atom Pd clusters with full D-Loading should produce 100 KiloWatt-Hours in an hour.

Zeolite Structure

The Zeolite Y Cavity has geometric symmetry related to an isometric trapezohedron = tetragonal trisoctahedron with the 4 holes corresponding to deleting 4 octahedral-type 3-face groups



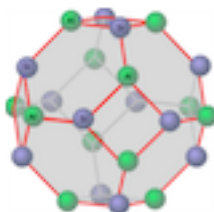
In the center image, the 10 red dots correspond to the 10 sodalite cages.
In the right image, magenta is used for hidden lines and for the 2 hidden sodalite cages and
the green octahedron edge corresponds to the green edge in these Jitterbug process images



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

The green edge midpoint cuboctahedral vertex is at the widest point of the cavity mouth as expected for the larger cuboctahedron volume
and
the green edge Golden Ratio point icosahedral vertices are at narrower points of the cavity mouth as expected for the smaller icosahedral volume.

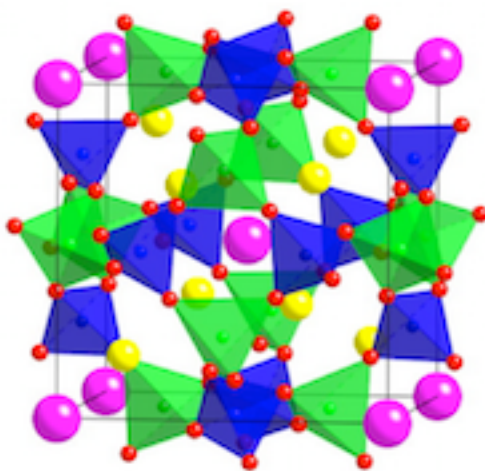
Each sodalite cage is a 24-vertex truncated octahedron as in this image from Wikipedia



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.

Zeolite Cavities have Electrostatic Fields on the order of 3 V / nm .

R. A. van Santen and D. L. Vogel, in *Lattice Dynamics of Zeolites* (*Advances in Solid-State Chemistry*, Vol. 1 (1989) 151-224), said: "... The vibrational spectrum of a zeolite may be visualized as the sum of three contributions,

the first of which which is given by the zeolite framework, the network formed by SiO_4 and AlO_4 tetrahedra sharing corners.

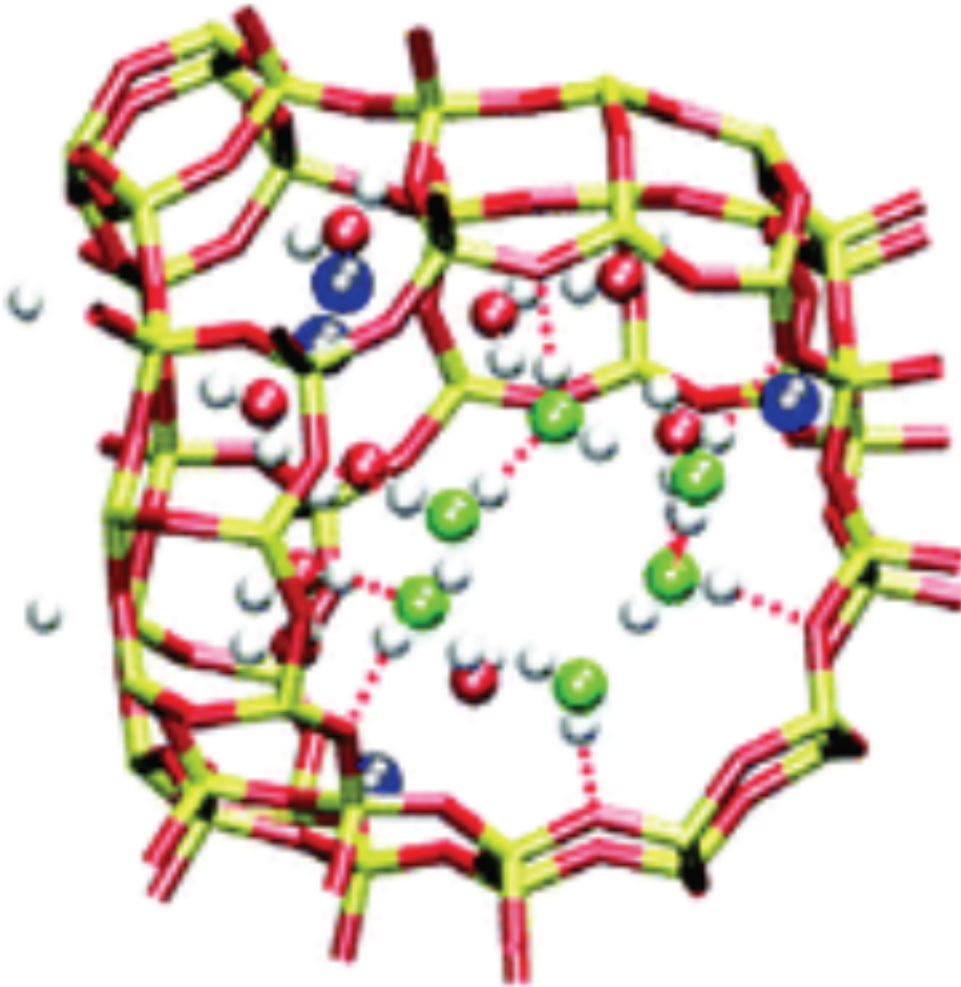
The second contribution originates from the ...[material]... located in the cages and channels formed by the framework ... The [material] vibrate[s] against the framework ...

The third contribution is given by the presence of hydroxyl groups and water molecules. Hydroxyl groups are either located in lattice vacancies, or present as isolated groups bound to the external zeolite surfaces, or internally bridging two tetrahedra. ... Due to the very high oscillator strength of the hydroxyl group, water and hydroxyl groups give rise to strong absorption bands between 3200 cm^{-1} and 3750 cm^{-1} (symmetric and antisymmetric stretching modes). ...".

Angela Di Lella, Nicolas Desbiens, Anne Boutin, Isabelle Demachy, Philippe Ungerer, Jean-Pierre Bellat, and Alain H. Fuchs, Phys. Chem. Chem. Phys. 8 (2006) 5396-5406) studied water in Zeolites, saying: "... We report ... Monte Carlo simulations of water



adsorption in [Zeolite] NaY ... faujasite ... The existence of cyclic water hexamers ... located in the 12-ring windows ... recently disclosed by neutron diffraction ...



... experiments ... were ... observed in the case of NaY ...".

Dmitry Kopelevich and Chia-Yi Chen, in Phonon interactions in zeolites mediated by anharmonicity and adsorbed molecules (Molecular Simulation 2008), said: "... thermal conductivity of nanoporous materials can be significantly affected by adsorption of guest molecules. These molecules serve as moving defects and provide additional scattering centers for heat-carrying phonons. ...

we perform molecular dynamics simulations of a model system, namely sodalite zeolite with small molecules ... encapsulated in its cages. We measure effects of sorbates ... such as correlations between different phonon modes and the phonon frequency and lifetime. ... The phonon lifetime often increases upon encapsulation of a sorbate into the zeolite which suggests that the sorbate-phonon interactions are qualitatively different from phonon scattering by point defects fixed in the lattice. ...”.

Iraj Parchamazad used Sodium Zeolite Y also known as faujasite.

The Wikipedia page for faujasite says:

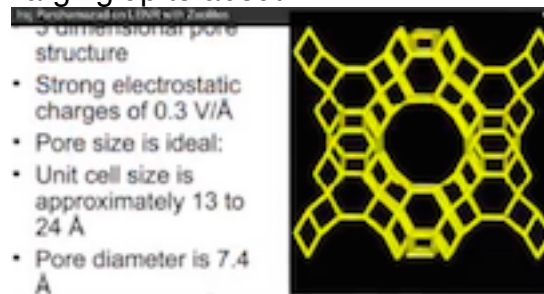
“... The faujasite framework consists of sodalite cages which are connected through hexagonal prisms.

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

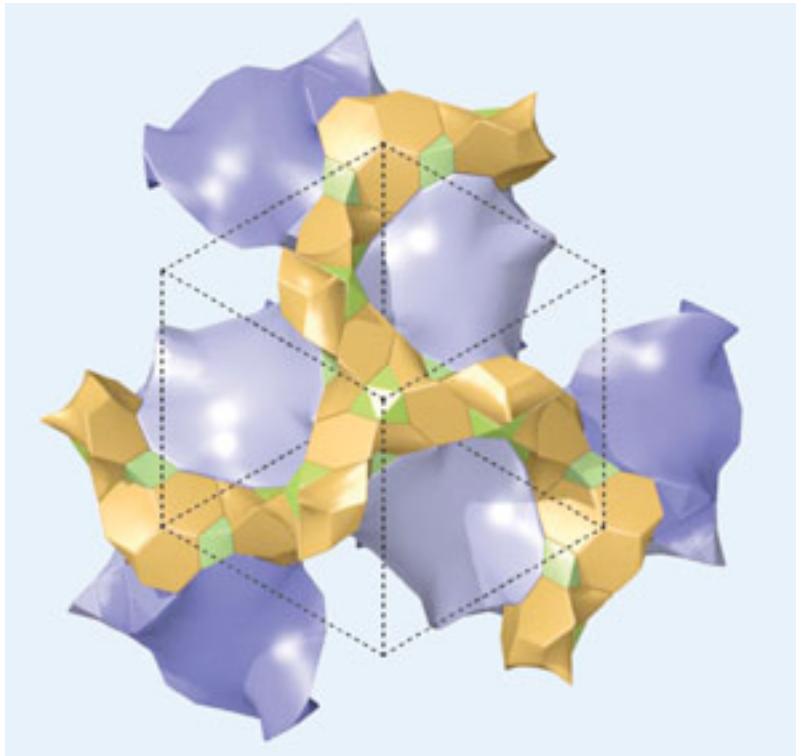
leaving a Zeolite and some Palladium.

Then he exposed the Zeolite/Palladium to Deuterium,

and got excess heat 10 out of 10 times, indicating fusion.

**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)

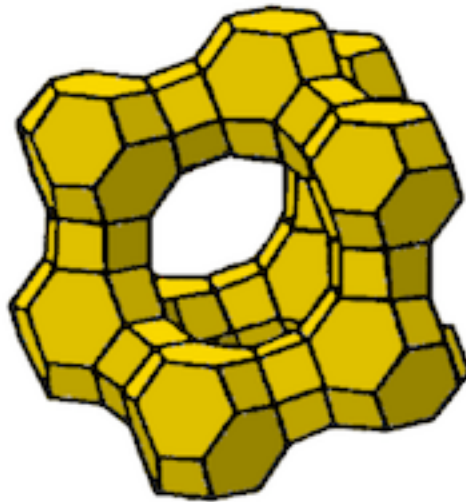
Transfer of Energy from Pd Cluster Structure to Zeolite Structure

After TSC Fusion, by Hagelstein's process, the energy is stored in the Pd cluster as excited Optical Phonon modes.

The Pd Structure Energy of Excited Optical Phonon Modes is carried to the Zeolite in which the Pd cluster is caged to be stored as Zeolite heat.

Each Zeolite Y 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>

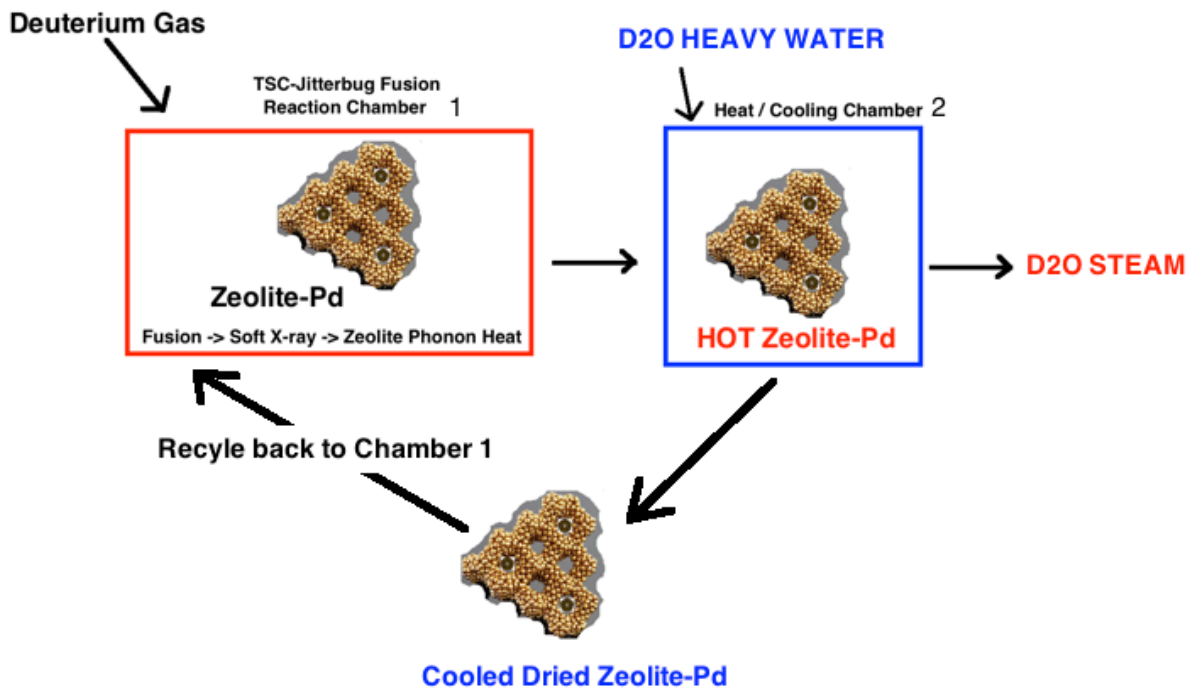


The Pd Structure Energy of Excited Optical Phonon Modes is carried by the Zeolite Cage Electrostatic Field (on the order of 3 V/nm) to be stored in the Zeolite as heat which Heat can be accessed by Zeolite-Water reaction.

Extraction of Cold Fusion Energy from Zeolite Structure

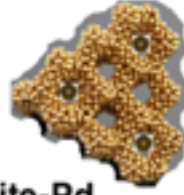
According to a 7 June 2012 techthefuture.com web article by Tessel Renzenbrink: "... Zeolite is a mineral that can store up to four times more heat than water ... zeolite retains a hundred percent of the heat for an unlimited amount of time ... When water comes into contact with zeolite it is bound to 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 octahedral structure.

According to <http://www.google.com/patents/US20040047803>

“... Synthesis and stabilization 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 Journal of the Taiwan Institute of Chemical Engineers 50 (2015) 259–265 by PankajSharma, Su-JungJeong, Moon-HeeHan, and Churl-HeeCho

“... nanosized NaY zeolite crystals from clear solution using ... (TMAS) ... tetramethylammoniumsilicate ... yields particle of size around 50 nm but in aggregated form ...”.

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.

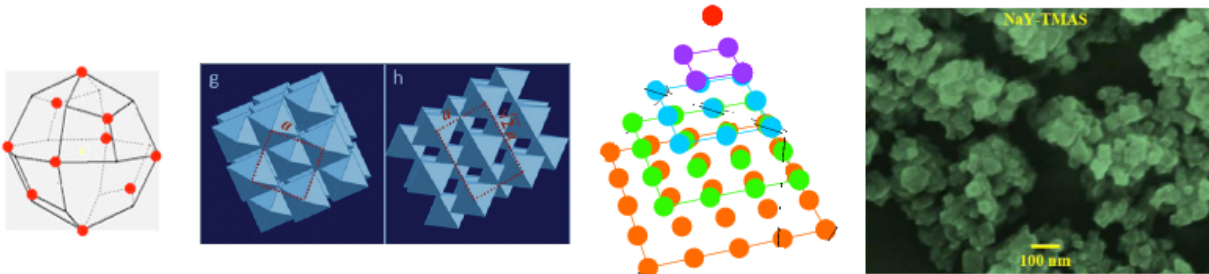
The Zeolite Y Crystal has octahedral structure

(images from

news.chess.cornell.edu/articles/2011/OctahedralNanoparticles.html

mathworld.wolfram.com/SquarePyramidalNumber.html

Journal of the Taiwan Institute of Chemical Engineers 50 (2015) 259–265)



and each unit cell with 1 Cavity is 2.5 nanometers in diameter
so an octahedral Zeolite Y Crystal with diameter 35 nanometers
would have an edge length $35 / \sqrt{2} = 25 \text{ nm} = 10 \text{ cells}$
and the octahedron would have 19 square layers:

layer 1 = 1 external + 0 internal = 1 for total of 1 of which 1 is external

layer 2 = 4 external + 0 internal = 4 for total of 5 of which 5 are external

layer 3 = 8 external + 1 internal = 9 for total of 14 of which 13 are external

layer 4 = 12 external + 4 internal = 16 for total of 30 of which 25 are external

layer 5 = 16 external + 9 internal = 25 for total of 55 of which 41 are external

layer 6 = 20 external + 16 internal = 36 for total of 91 of which 61 are external

layer 7 = 24 external + 25 internal = 49 for total of 140 of which 85 are external

layer 8 = 28 external + 36 internal = 64 for total of 204 of which 113 are external

layer 9 = 32 external + 49 internal = 81 for total of 285 of which 145 are external

layer 10 = 36 external + 64 internal = 100

layers 11 through 19 are mirrors of 1 through 9, for a total of 285 with 145 external

so an octahedral Zeolite Y Crystal with diameter 35 nm would have

$285 + 100 + 285 = 670$ cavities with $145 + 64 + 145 = 354$ (52.8 %) external and

therefore relatively easily accessible to the Pd nanoclusters in the colloidal suspension.

Zeolite Y unit cell atomic mass 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

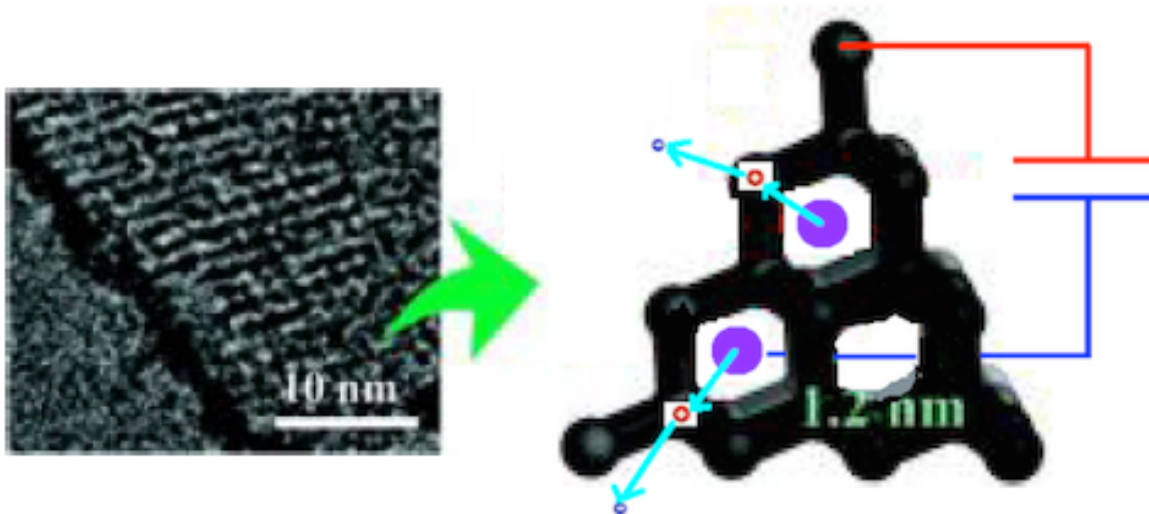
For 35 nm Zeolite Y Crystals only about 1/2 of their Cavities are External so it may be

optimal to use Zeolite Y Crystal mass = 2 x Palladium mass in the colloid.

Zeolite Heat and Capacitor Electricity

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,
 Excited Optical Phonons from TSC-Jitterbug Fusion as Cyan arrows
 ionize parts of the ZTC, 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 ...

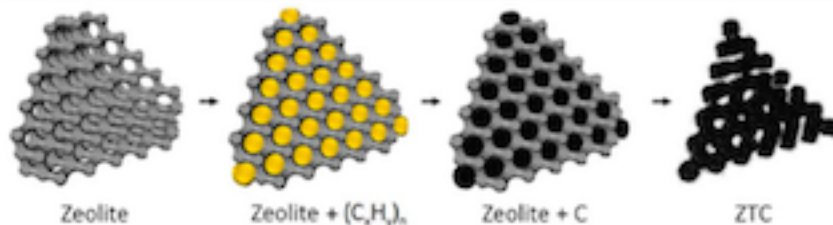


Figure 4.1. A schematic of template-carbonization in a porous zeolite framework, to produce zeolite-templated carbon (ZTC).

...”

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 ZTC structure is attached to the carbon substrate by a base face,
thus eliminating the Exterior Cavities on that base face
so that
for 35 nm ZTC structures only about 1/3 of their Cavities are External
(as opposed to about 1/2 for free-floating 35 nm Zeolite Y)
so it may be optimal
for the number of ZTC Cavities to be 3 x the number of Pd 147-atom nanoclusters.

Synthesis of 147-atom Pd clusters and Embedding into Zeolite

147-atom Pd clusters have diameter about 1.5 nanometers.

1.5 nm Pd Clusters have been produced

at Sandia National Laboratories

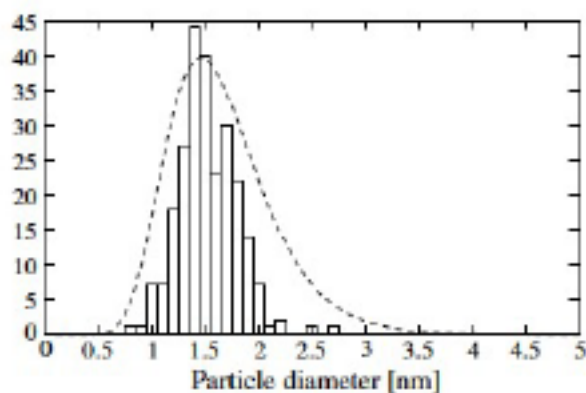
and University of New Mexico Center for Micro-Engineered Materials

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. ...”

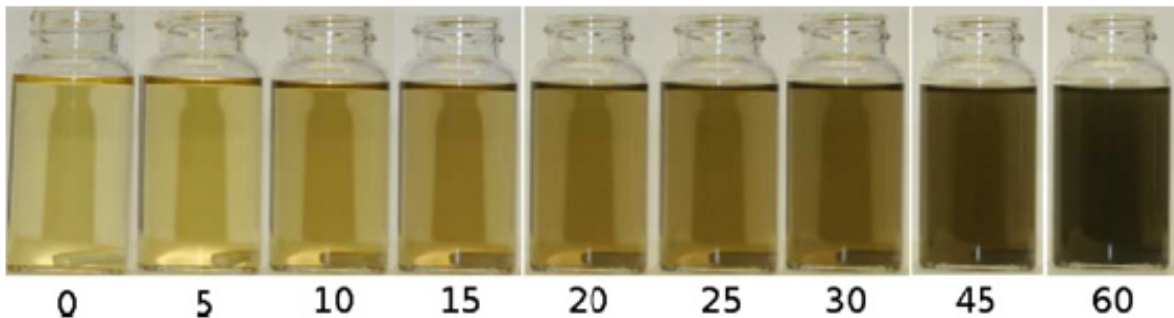
Sandia Pd Cluster Recipe

- 1 - 15 ml of methanol (MeOH) in a scintillation vial
- 2 - Add 5 mg palladium acetate ($\text{Pd}(\text{OAc})_2$) whose color is red-orange
- 3 - Reduce the $\text{Pd}(\text{OAc})_2$ by MeOH to Pd atoms by stirring for 5 minutes with unobstructed exposure to room lighting.
- 4 - Add 10 mg of substrate in colloidal suspension
- 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 onto the substrate 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 substrate (and any remnant Pd still in colloidal suspension) are removed and the Pd-loaded substrate dried

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

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

The substrate used initially by Sandia was SBA-15 mesoporous silica. In future experiments the substrate may be 30-40 nm Zeolite Crystals, such as Sodium Zeolite Y or ITQ-37.

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

Global Energy and TSC-Jitterbug-Zeolite Fusion machines

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

Appendix A: Details of Structure of 147-atom Pd 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

icosahedral



cuboctahedral



icosahedral



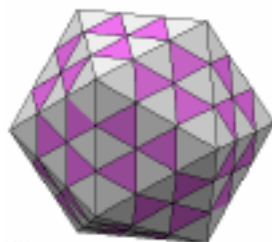
cuboctahedral



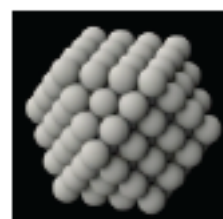
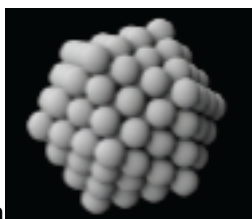
icosa



cubo



icosa



cubo

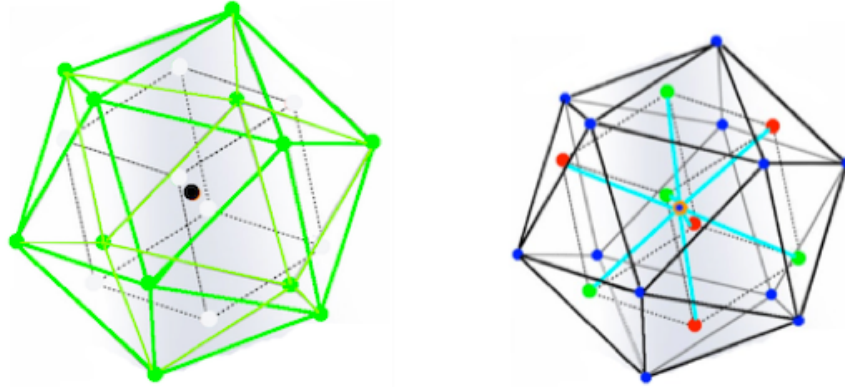
(Images from: Polyhedral Clusters by Lord et al; Frank and Kasper in Acta Cryst. 11 (1958) 184-190; Mackay in Acta Cryst. 15 (1962) 1916-1918; vimeo.com/27662398 by Yan Liang (L2XY2) August 2011. Data for n, N, and d from Shtaya-Suleiman dissertation Gottingen 2003.)

147-atom Icosahedral Geometry

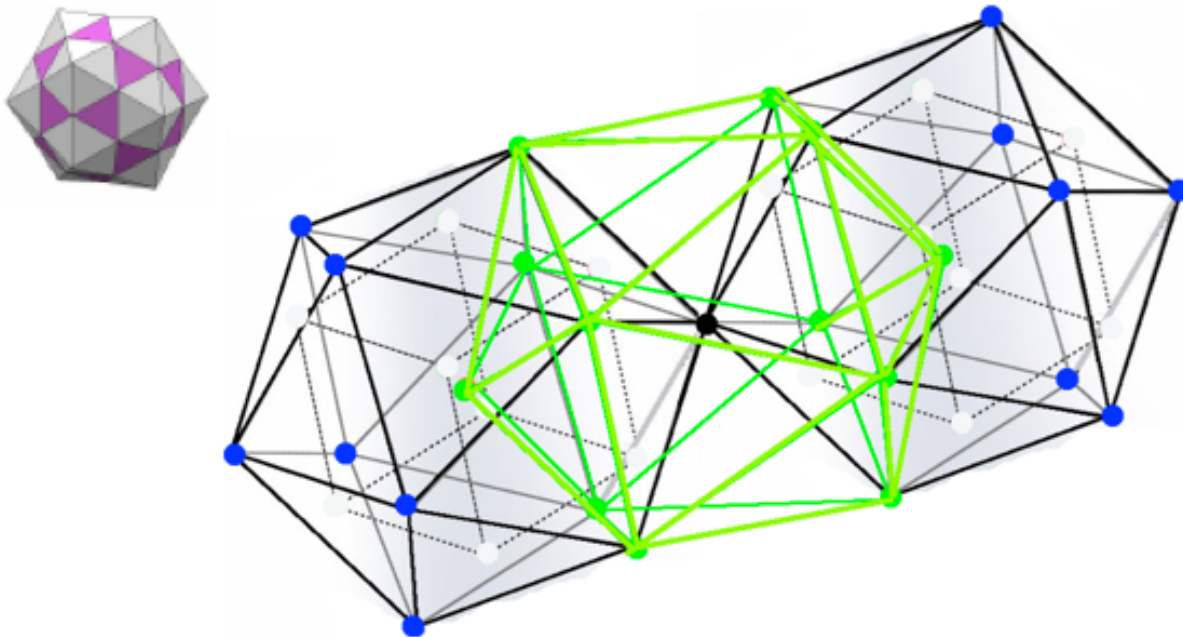
The 147-atom cluster is a central Palladium atom surrounded by 3 layers of Pd atoms:

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

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

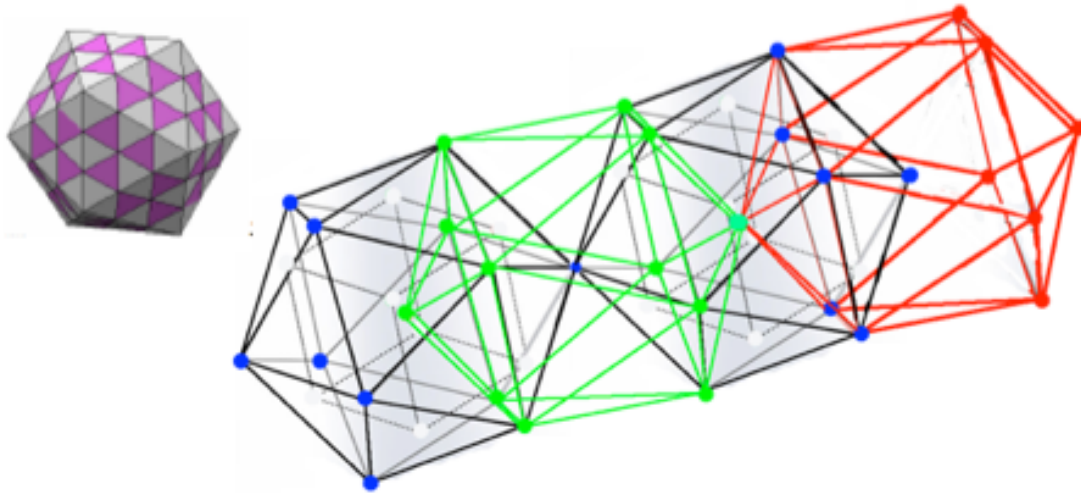


Layer 2 adds 42 vertices (blue) for total of 55
and 60 tetrahedral + 20 cuboctahedral cells for total 80 tetra + 20 cubo = 100

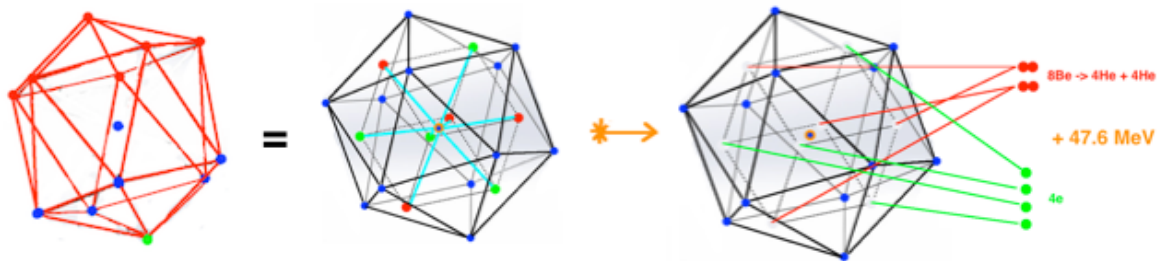


It is a configuration of 2 TSC fusion icosahedra sharing the central vertex
with the remaining $55 - (26-1) = 30$ vertices in 3 10-vertex bands

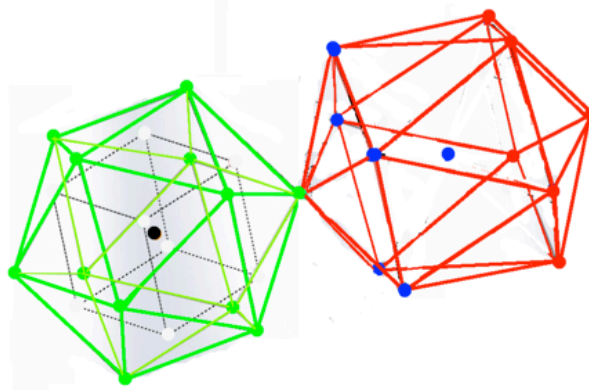
Layer 3 adds 92 vertices (red) for total of 147
 and 120 tetrahedral + 60 cuboctahedral cells for total 200 tetra + 80 cubo = 280



It is a configuration of 12 TSC fusion icosahedra

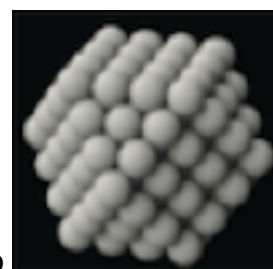


each of which shares a vertex with one of the 12 vertices of the Layer 1 icosahedron.

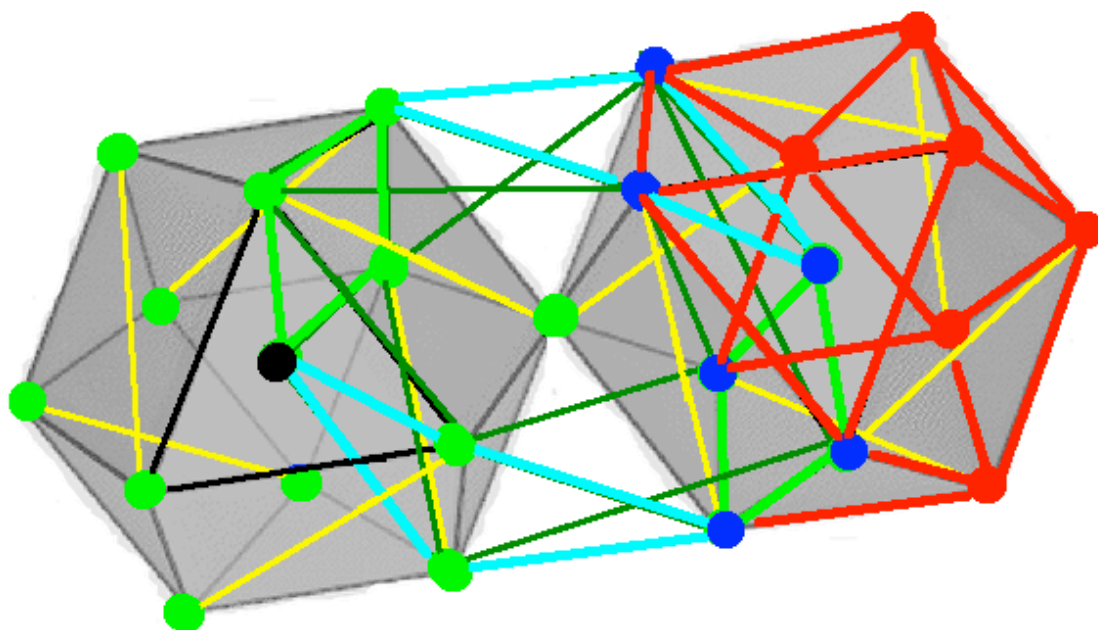


so that the entire 3-layer 147-atom configuration has 13 TSC fusion icosahedra:
 12 outer icosahedra and 1 central icosahedron.
 The 13 TSC configurations have $13 \times 13 = 169$ vertices but
 24 vertices are shared between an outer and the central TSC
 and $5 \times 12 = 60$ vertices are shared between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

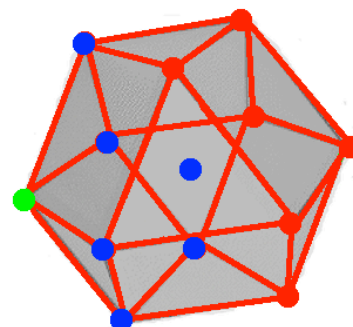
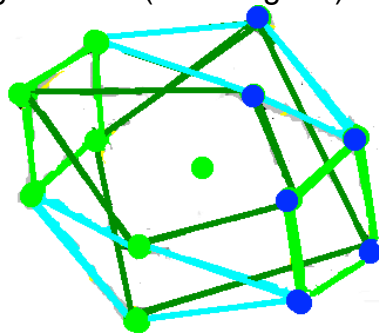
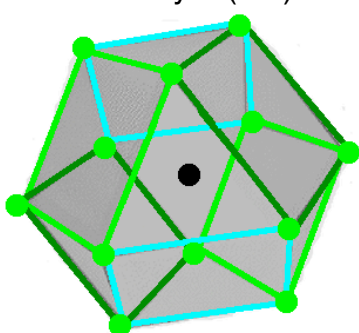
147-atom Cuboctahedral Geometry



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



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



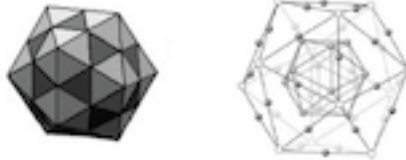
In the cubo case, there are also 12 outer TSC Jitterbug cuboctahedra plus a single central TSC Jitterbug cuboctahedron, so Jitterbug transformation of the entire 147-atom Pd cluster works consistently with individual Jitterbug transformations of the 13 TSC icosahedra and TSC Jitterbug cuboctahedra.

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 +1 center = 13 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 + 1 center = 55 vertices]...



... The [55]-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 2 TSC Fusion structures sharing a central vertex.
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 + 1 center = 147.



147-atom cluster

has 12+1 = 13 TSC Fusion 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.

How many D atoms can live in a 147-atom Pd 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.

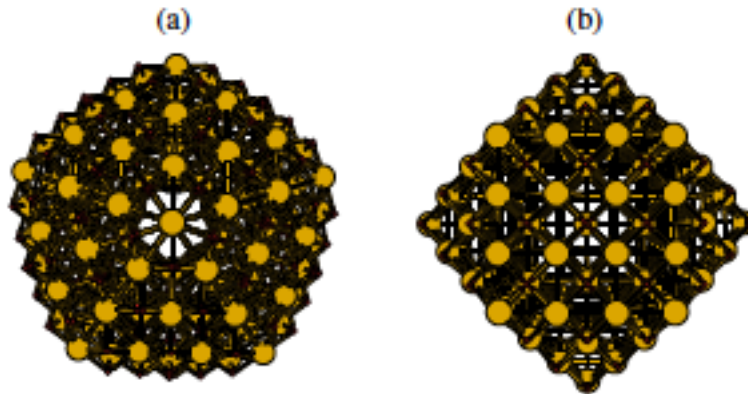


Figure 1. Palladium clusters fully loaded with hydrogen.

(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.

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:

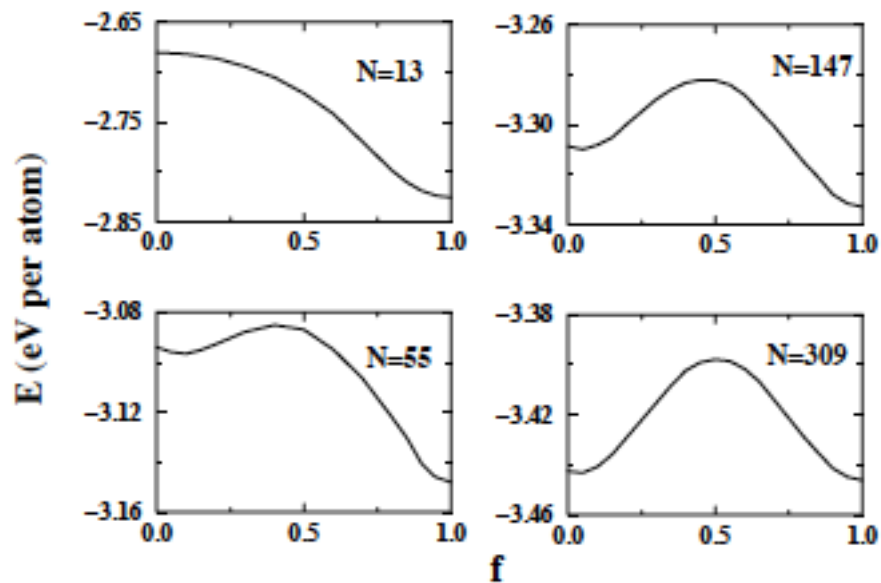
“... the icosahedron is the preferred structure at small sizes, and the critical size at which the relative stability becomes favorable to cuboctahedrons is $N = 561$ for PdN clusters ...[for which]...

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 icosah transition

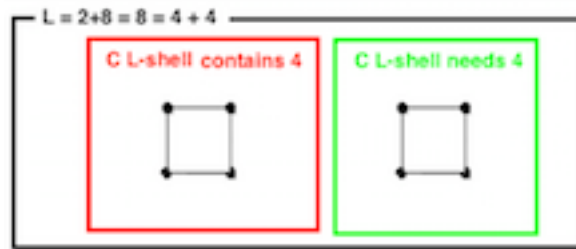
$N = 309$ Pd Cluster is too large (2 nm) to fit
through 1.5 nm expanded Sodium Zeolite Y pore

so

147 atoms is optimal for Pd cluster Cold Fusion

Appendix B: Graphene and Klein Paradox Quantum Tunnelling

Consider the outer shell (L-shell) of Carbon:



The useful chemistry of Carbon (graphite, diamond, buckyballs, graphene, organics) is due to the fact that

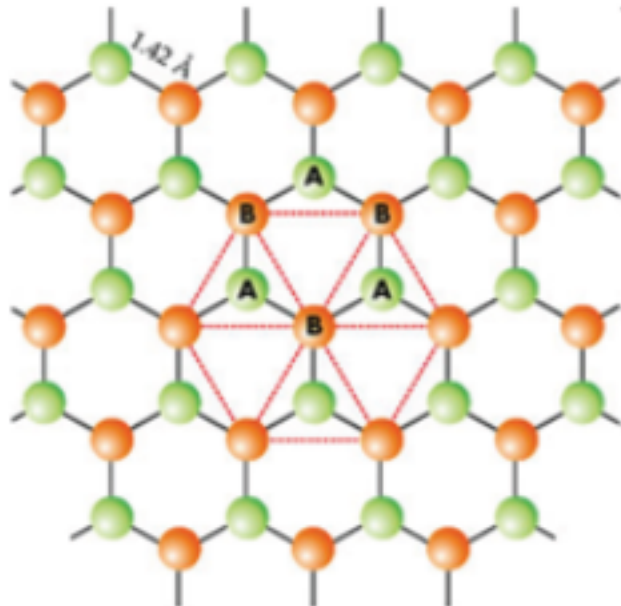
each Carbon atom has the 4 L-shell electrons that every other Carbon atom needs.

If each Carbon atom is connected to 4 other Carbon atoms

then the result is a 3-dim Diamond Packing with Tetrahedron Vertex Figure.

However, Diamond is only a metastable state. Graphene is a stable state.

P. B. Allen and B. K. Nolic, in University of Delaware PHYS 824: Introduction to Nanophysics - Electronic band structure of graphene, said: "... Band structure of graphene ... originates from orbital hosting the fourth valence electron. The bands which correspond to the dispersion of bonding and antibonding molecular orbital (constructed from orbitals on two carbon atoms) are called pi and pi* bands ...



The honeycomb lattice of graphene ... is not a Bravais lattice. Instead, it can be viewed as bipartite lattice composed of two interpenetrating triangular sublattices ...

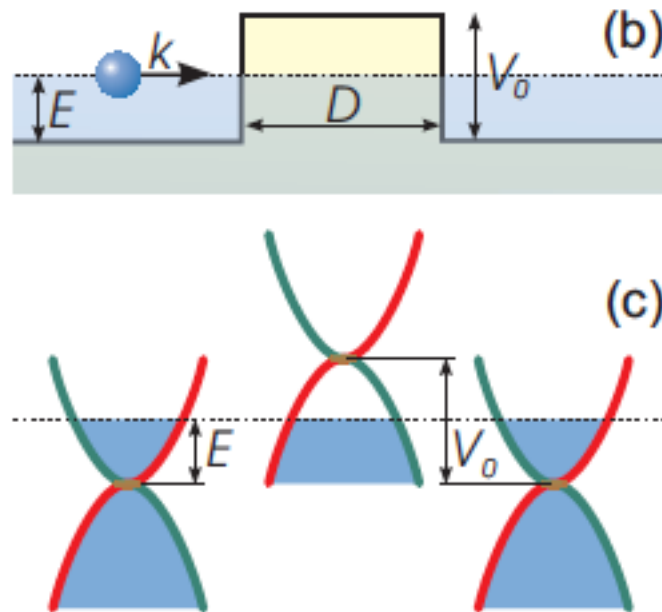
the single-particle electron states are ... two classes, called sigma and pi.

The even sigma states are derived from carbon s and px , py orbitals (i.e., their hybridized sp² orbitals ...),

while **the odd pi states are derived from carbon pz orbitals** ... electron and hole states in graphene should be interconnected, exhibiting properties analogous to the

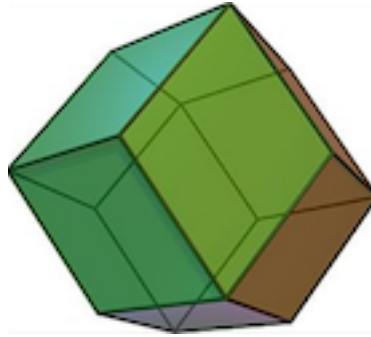
charge-conjugation symmetry in quantum electrodynamics ... because graphene low-energy quasiparticles have to be described by two-component wave functions ... which are needed to define the relative contributions of the A and B sublattices in the quasiparticles make-up. The two-component description for graphene is very similar to the [Dirac Equation] spinor wave functions in QED...”.

I. Katsnelson, K. S. Novoselov & A. K. Geim, in Chiral tunnelling and the Klein paradox in graphene (arXiv cond-mat/0604323), said: The ... Klein paradox - unimpeded penetration of relativistic particles through high and wide potential barriers - ... can be tested ... using electrostatic barriers in single- and bi-layer graphene. Due to the chiral nature of their quasiparticles, quantum tunnelling ... becomes ... qualitatively different from ... normal, non-relativistic electrons. ...



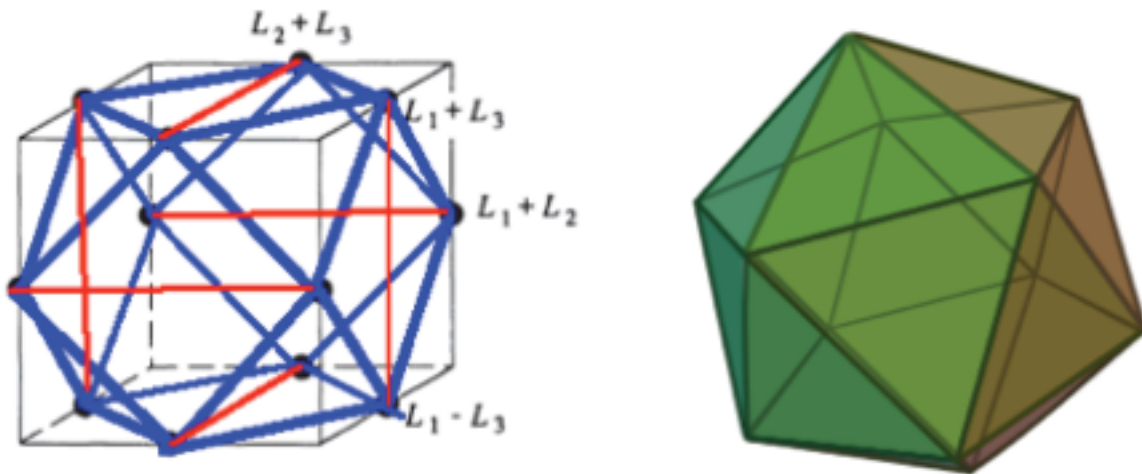
... Tunnelling through a potential barrier in graphene: ... (b) ... diagrams ... show the positions of the Fermi energy E across such a barrier. The Fermi level (dotted lines) lies in the conduction band outside the barrier and the valence band inside it. The blue filled areas indicate occupied states. The pseudospin ... is parallel (antiparallel) to the direction of motion of electrons (holes), which also ... keeps a fixed direction along the red and green branches of the electronic spectrum. (c) - Low-energy spectrum for quasiparticles in **bilayer graphene**. The spectrum is isotropic and, despite its parabolicity, also originates from the intersection of energy bands formed by equivalent sublattices, which ensures charge conjugation, similar to ... single-layer graphene. ... charge carriers in bilayer graphene ... are massive quasiparticles with a finite density of states at zero energy, similar to conventional nonrelativistic electrons. On the other hand, these quasiparticles are also chiral and described by spinor wavefunctions, similar to relativistic particles or quasiparticles in single-layer graphene ... the origin of the unusual energy spectrum can be traced to the crystal lattice of bilayer graphene with four equivalent sublattices. ... **the relevant QED-like effects appear to be more pronounced in bilayer graphene ...**”.

If each Palladium atom were to be connected to 14 other Palladium atoms then the result would be a 3-dim FCC Lattice with Rhombic Dodecahedron Vertex Figure



However, it may be that the Rhombic Dodecahedron FCC Lattice is only metastable and

more stable state may be based on its dual, the Cuboctahedron



which can transform by Jitterbug Transformation into an Icosahedron.

Just as Graphene directly uses 3 of the 4 Carbon electrons
the Cuboctahedron / Icosahedron directly uses 12 of the 14 Palladium electrons.

Just as the 4th Carbon valence electron in Bilayer Graphene produces a Dirac Fermion band with Klein Paradox Tunneling through Potential Barriers
the $14 - 12 = 2$ Palladium valence electrons produce a **Dirac Fermion band** which, using Klein Paradox Tunneling through Potential Barriers, enable TSC Fusion of Deuterium in Palladium Cluster structures.