ECAT Science
How the E-Cat Works

- The theory states that once some energy is added to surfaces loaded with protons, if the surface morphology enables high localized potential gradients, then heavy electrons (muons) leading to ultra low energy (cold) neutrons will form that never leave the surface.
- The neutrons set up isotope cascades which result in beta decay and gamma emission. This results in interactions with heavy electrons which convert the gamma into heat.

Nano-sized particles of nickel, pressurized hydrogen and a catalyst are heated in a small reactor to the point at which weak interactions between the reactants cause transmutation (ie some of the nickel is converted to copper). Considerable excess heat is emitted during this process. Once the reaction becomes self-sustaining, the input power can be reduced significantly and excess heat (up to 650 degrees C) is generated in a range of five to 30 times the input energy. The E-cat, Andrea Rossi invention, is guaranteed to work at a COP of 6:1. This can be used for steam, hot water, heating and generating electricity. Future uses include desalination and agricultural purposes. One day it could be used for transportation vehicles, aircraft and ships.

The system is inexpensive, emits no green house gases and there is no radioactivity. The amount of 1 gram of nickel with this reaction is equivalent to one barrel of oil, or one barrel of nickel creates the same energy as a super tanker of oil!

LENRs are weak interactions and neutron-capture processes that occur in nanometer- to micron-scale regions on surfaces in condensed matter at room temperature. Although nuclear, LENRs are not based on fission or any kind of fusion, both of which primarily involve the strong interaction.

The Anatomy of the Ecat

The heart of an E-Cat (Energy Catalyzer) is the reactor core. This is the metal tube in which the cold fusion nuclear reactions take place. Due to the high power density of the E-Cat technology, extremely large reactor cores are not required. Most E-Cat reactor core models have an internal volume that is smaller than a can of soda. Others are as small as a D-Cell battery, with an internal volume of around 50 cubic centimeters.

In the tube that composes the reactor core, a small quantity of specially processed, micron grain sized, nickel powder is placed. The nickel powder has been enriched in two specific isotopes (Ni-62 and Ni-64) via a proprietary and cheap method that only adds 10% to the final cost of the raw material. Enriching the nickel powder in Ni-62 and Ni-64 is important, because it is these two isotopes that undergo the most nuclear reactions. All reagents and resulting products, Cu-63 and Cu-65, are stable.

Once the nickel powder is placed in the reactor core, an even smaller quantity of catalyst material is inserted into the same metal tube. Without the catalyst, the E-Cat could not produce practical levels of output. The catalyst is composed of one or more chemical elements that are not radioactive, rare, or expensive. In fact, the cost of the catalyst is considered to be insignificant.

Next, the reactor core is filled with a small quantity of pressurized hydrogen gas, from an internal canister. The pressure of the hydrogen gas is a key factor in moderating the intensity of the reactions that take place in the reactor core. Higher hydrogen pressure increases the rate at which nuclear reactions take place, and lower hydrogen pressure reduces the rate.

Once the hydrogen gas has been inserted, external electrical resistors apply heat to the reactor core. At this point, the catalyst starts breaking down the molecular hydrogen gas (the normal form of hydrogen gas in which two hydrogen atoms are bonded together to form a single molecule), into atomic hydrogen gas. In the atomic state, the hydrogen atoms are not bonded to another hydrogen atom, and are isolated from each other.

These atomic hydrogen atoms then start interacting with tubercles on the surface of the nickel powder, where the reaction sites are located. The atomic hydrogen starts to fuse with atoms of nickel located at these reaction sites. As the nuclear reactions take place, the vast majority of gamma radiation that would be produced in such a nuclear reaction, are instantly converted into heat energy. A portion of this heat energy helps keep the reactions going, and at a certain point when the reactions are frequent enough, the input resistors can be cut off. At this point, the device is in a self-sustaining mode of operation.

Upon entering the self-sustaining mode of operation, a radio frequency generator may be turned on to help perpetuate and stabilize the cold fusion nuclear reactions taking place inside of the reactor core.

Extracting Energy

The reactor core is only one part of an E-Cat (Energy Catalyzer). It is simply the part that generates energy in the form of heat. To extract energy from the sealed reactor core, a coolant flows past it extracting heat energy from the outer surface of the reactor core. The coolant can be water, glycol, or another liquid with appropriate heat transfer properties. In some experiments, it has even been a flow of air.

It is important to note that the flow of liquid also serves another purpose. This additional purpose is keeping the reactor core from over heating. If the reactor core is allowed to become too hot, the nickel powder would melt and all nuclear reactions will cease. If such an event happened, the reactor would be "dead" and non-operative until a replacement reactor core was installed.

The heated coolant is transferred through a primary circuit, and then to a heat exchanger. The heat exchanger transfers the heat from the coolant to a liquid in a secondary circuit (such as water). The coolant in the primary circuit -- now at a lower temperature -- can then be re-used to extract heat energy from the reactor core once again.

Energy collected by the secondary circuit can be used for many industrially useful purposes such producing hot water, producing steam, turning a turbine, or producing electricity.

Exothermic Chemical Reactions

Heat is produced in the chemical reaction in which hydrogen and oxygen are combined into water; i.e. the combustion of hydrogen. Such chemical reactions in which heat is produced are called exothermic reactions. The chemical equation for this reaction for one mol of hydrogen is written,

$H_2+1/2\ O_2=H_2O+286$ kJ

That means, when one mol of hydrogen burns in oxygen (or air), 286 kJ of heat is produced.
Another example is,

$C+O_2=CO_2+394$ kJ

where one mol of carbon is combusted into carbon dioxide under the production of 394 kJ of heat.

The heat productions of the above chemical equations, (1) and (2), represents one mol of hydrogen and carbon, respectively. In order to compare these chemical reactions with nuclear reactions, it is convenient to recalculate the heat production for one molecule or one atom. For this, let us divide the heat production by the Avogadro constant

$N_A=6.02\times10^{23}mol^{-1}$

The results are

$H_2+1/2\ O_2=H_2O+3.0$ eV

$C+O_2=CO_2+4.1$ eV

Equation (3) means that the process in which one hydrogen molecule (two hydrogen atoms) and one half oxygen molecule combine into one water molecule generates 3.0 eV energy in the form of heat (i.e. 1.5 eV per hydrogen atom). And Eq. (4) says that, when a carbon atom combines with an oxygen molecule and become a carbon dioxiside molecule, 4.1 eV energy is released.

The use eV is because it is the most common unit of energy used in the atomic and nuclear world. It is the work done on an electron that is accelerated through a potential difference of one volt. Its value is

$1\ eV = 1.6 \times 10^{-19}$ J

Moreover, the units of energy, keV and MeV, are often used in the nuclear world; the former is 1,000 times eV and the latter 1,000,000 times eV.

When it comes to arbitrary carbohydrate based fuels the energy production will be of the oreder of 4 eV x #(carbon atoms) +1.5eV x #(hydrogen atoms) per molecule combusted in oxygen.

Exothermic Nuclear Reactions

Nuclei show various types of reactions: For example, one nuclide splits into two or more fragments. This type of reaction is called nuclear fission. Contrarily, two nuclides sometimes combine with each other to form a new nuclide. This type of reaction is called nuclear fusion. There are many other types of reaction processes; they are generally simply called nuclear reactions and contain everything from gamma emission to alpha deacys.

Among these various types of nuclear reactions, there are some types of exothermic reactions which are sometimes called “exoergic” reactions in nuclear physics.

The nucleus of deuterium atom is called deuteron which consists of a proton and a neutron. It is represented by a symbol “d”. The nuclear reaction in which two deuterons bind with each other is an example of nuclear fusion. This exoergic reaction is written has 3 forms,

$d+d \to {}^{3}_{2}He+n+3.27$ MeV
$d+d \to {}^{3}_{1}T+p+4.03$ MeV
$d+d \to {}^{4}_{2}He+24$ MeV

If a neutron is absorbed in the uranium-235 nucleus (${}^{235}_{92}U$), it would split into two fragments of almost equal masses and produce some number of neutrons and energy Q. One of the equations for the processes is

${}^{235}_{92}U+n \to {}^{137}_{56}Ba + {}^{97}_{36}Kr + 2n + Q$

This is an example of nuclear fission.
The amount of energy released in this process is about 200 MeV which will be explained in more detail in next section.

The Origin of the Nuclear Energy

Let us take up the d-d fusion reaction shown by the above Eq. (5) as an example. Since the experimental value of the binding energy of deuteron is 2.2246 MeV, the sum of the binding energies of the two deuterons before the reaction (on the left-hand side of Eq.(5)) is 4.449 MeV. On the other hand, the experimental value of the binding energy of (${}^{3}_{2}He$) is 7.719 MeV. Therefore the total binding energy after the reaction (on the right-hand side of Eq. (5)) is 3.27 MeV (= 7.719 – 4.449) larger than the binding energy before the reaction (on the left-hand side of Eq. (5)). Thereby the total mass decreases after the reaction and the mass defect corresponding to the above increase of the binding energy occurs. This mass defect is released as heat (or energy) in this exothermic (or exoergic) process.

Looking at the fission of uranium-235 (${}^{235}_{92}U$) shown by Eq. (6), the binding energy per nucleon in nuclei around A = 240 is about 7.5 MeV. On the other hand, that in nuclei around A = 120 is about 8.5 MeV. Accordingly, if a uranium nucleus splits into two fragments with almost equal masses, the binding energy per nucleon would increase by about 1 MeV and the total mass of the fission fragments would decrease by the corresponding amount. This loss of mass (or mass defect) is converted into the heat (or energy) product Q. Since an energy of about 1 MeV per nucleon is released, the total energy Q would be more than 200 MeV.

According to the above discussions, it becomes clear that the origin of nuclear energy is the change of nuclear masses, and it is based on the principle of Einstein's Mass-Energy Equivalence.
If the total binding energy after the reaction is larger than before, the total sum of the masses of the reaction products becomes smaller than that before the reaction. This decrease in mass is converted into an energy, so that the process would be an exothermic (exoergic) reaction.

The Origin of the Heat in Exothermic Chemical Reaction, Law of Energy Conservation

If hydrogen and carbon burn in oxygen gas, heat or energy is produced but what is the origin of this heat or energy?
The principle of the heat production in chemical reaction is just the same as that in the nuclear reaction.
The hydrogen molecule is a bound system of two hydrogen atoms. The mass of a hydrogen molecule is slightly smaller than the sum of the masses of two hydrogen atoms. Converting this difference (= mass defect) into an energy with Einstein's Mass-Energy Equivalence, we have the binding energy of the hydrogen molecule.
In the process of combustion of hydrogen represented by Eq. (3), the total mass after the reaction is slightly smaller than before, and this decrease in mass is transformed into heat in the exothermic reaction.
Strictly speaking, conservation of mass does not hold in a chemical reaction, though, both in chemical and nuclear reactions, the energy of the total system with converting mass into energy is conserved before and after the reaction.

Huge Amount of Nuclear Energy

Comparing Eq. (3) with (5), and Eq. (4) with (6), we can easily understand that the nuclear reactions yield a huge amount of energy in comparison with ordinary combustion processes.

As explained above, the energy produced from an exothermic chemical reaction like combustion of hydrogen or carbon is about 3 or 4 eV per molecule and atom, respectively. In contrast, d-d fusion reaction shown by Eq. (5) releases at least 3.27 MeV of energy. It is about one million times as large as the ordinary combustion.

In the fission of uranium-235 shown by Eq. (6), more energy than 200 MeV is released. It is about 100 million times as large as an ordinary chemical reaction.

Thus, the nuclear energy released in nuclear fission and fusion is several millions times as large as an ordinary chemical reaction like a combustion process.

ECAT Reactions

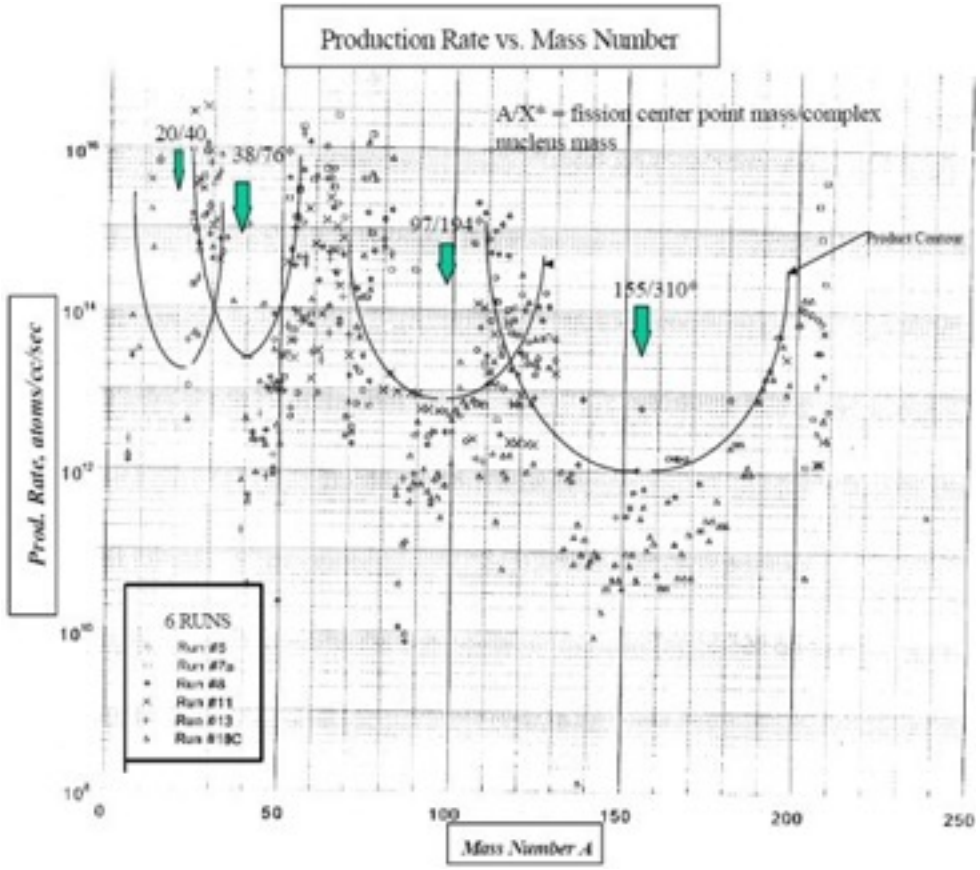
The reactions in the ECAT is called Cold Fusion or Low Energy Nuclear Reactions (LENR). Cold Fusion has had some bitter taste to its name the recent decenia due to the lack of repeatability in the experiments and because of the pressure from the Hot Fusion establishment which have been receiving over 50 billion dollars of funds during the last 50 years without any major breakthroughs. Add to that the fact that the theorists have had a hard time explaning the reactions going on in the Cold Fusion processes. The biggest challenge they face is to explain the three miracles of Cold Fusion reactions, namely

1. The Penetration of the Coulomb Barrier
2. The lack of strong Neutron Emissions
3. The lack of strong Gamma Ray Emissions

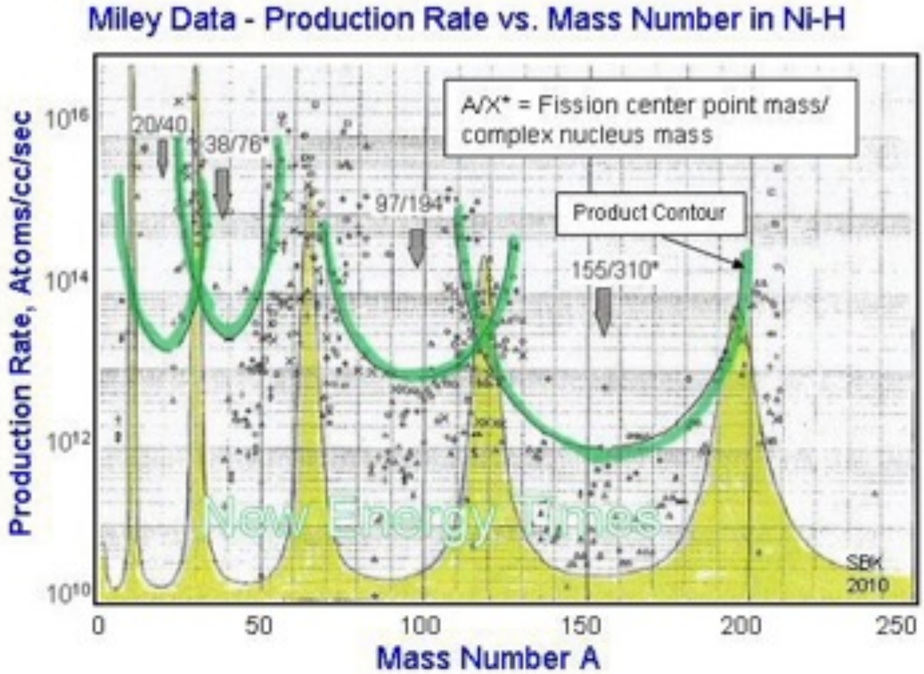
One theory worth mentioning is the Widom-Larsen theory and the Widom-Larsen Theory of Transmutations. It explains the Cold Fusion process by the Standard Model using weak interactions, without the need of introducing any new physics. This is also the theory NASA recently started to put to the test. When it comes to Cold Fusion mainly two types of processes have been experimented with, namely Palladium-Deuterium (Pd-D) and Nickel-Hydrogen (Ni-H). In the Palladium Deuterium fusues to $Helium_4$ and releases 24 MeV per reaction while in the Ni-H process Nickel transmutes into mainly copper. The ECAT is built around the Ni-H process where Andrea Rossi through an ingenious catalyst has reached reaction rates which corresponds to several kW/kg. One of these processes is,

Ni62+H->Cu63+6.12 MeV.

What is significant with all these proton capture processes is that most are exothermic releasing energy of just short of one unit of the normal nuclear binding energy (7.5-8.5 MeV). The extremely interesting part of the Ni-H process is the severe amount of different transmutations occuring.



More or less all sorts of elements are created in the process, all with different reaction rates where the most frequent reactions surpasses the least frequent ones with a factor million. This is one of the things the Widom-Larsen theory is able to explain.



Upper 5-peak peak curve drawn by Miley in 1996 based on 6 experimental runs of transmutation yields from Ni-H LENR systems [1]. Lower curve, shaded in yellow, drawn by Larsen in 2006 with no fitting, based on Widom-Larsen ultra-low momentum neutron absorption model. [2]

1. Miley, G.H, and Patterson, James, "Nuclear Transmutations in Thin-Film Nickel Coatings Undergoing Electrolysis," Journal of New Energy, Vol. 1(3), pg. 5, (1996)
2. Larsen, Lewis, Feb. 7, 2009 slides

The Widom-Larsen theory is just one of many theories trying to explain the physics that occur in Low Energy Nuclear Reactions. Before the theorists reach a consensus on how the reactions occur one can only speculate on which theory is true and which is not.

For the interested ECAT.com has calculated the energy release of all known isotopes for both proton capture and deutron capture

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