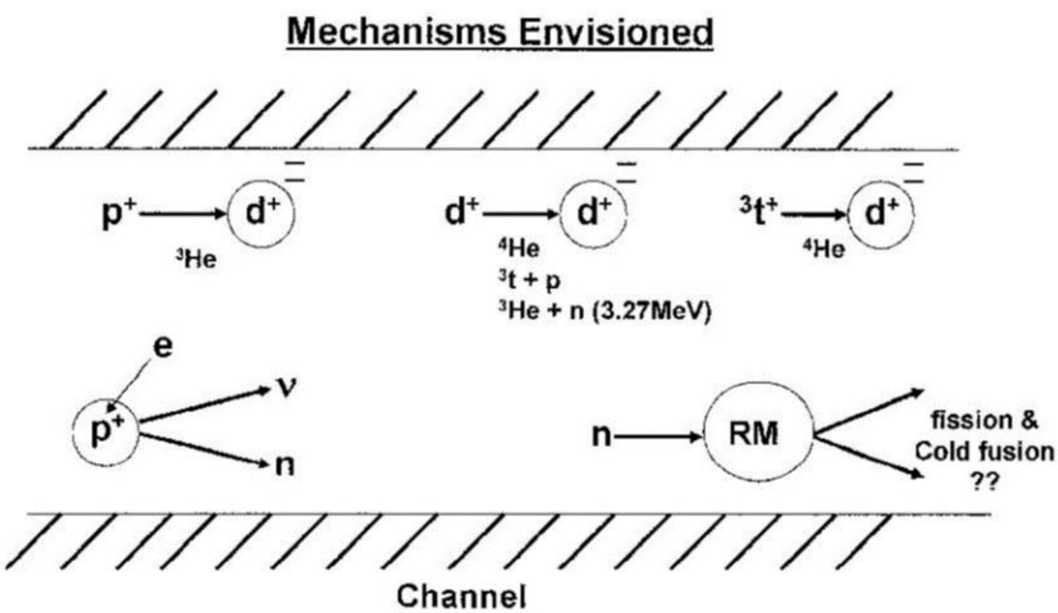
Theoretical Basis for Cold Fusion

About two dozen theories were proposed by the mid-1990s to explain how cold fusion could occur. Going forward now from experimental results over the last 20 years, it is essential that cold fusion theory be understood with respect to those experiments. Scientists have been able to conclude that the cold fusion reactions must occur in the extremely small, linear defects, cracks and crevices of the cathode reaction material, rather than in perfect bulk material devoid of defects as previously thought. Scientists have theorized that cold fusion reactions in the cathode are caused by the small, high frequency vibrations of atoms in the cathode material interacting strongly with electrons of adjacent deuterium and hydrogen atoms in the defects. The atomic vibrations are called "phonons" and have energies and vibration frequencies related to temperature of the cathode material. The purpose of this blog is to provide background into this development.

Some of the technical background known by physical chemistry students and scientists in universities and industry is that, rather than representing electrons in orbits around a nucleus (i.e, the Bohr model), the electric charge of electrons should be considered to be in an electron cloud, some of which can pass through the nucleus. A neutron can be produced within an atom when an electron is captured by a proton in the nucleus in a process called "k-capture" [click on https://www.youtube.com/watch?v=sg_XoUDsP08]. Electron capture can also occur with more distant L-electrons. Electron capture occurs spontaneously, without the addition of outside energy. It is possible for proton-rich isotopes above the line of stability in the chart of the nuclides [click on https://www.nndc.bnl.gov/nudat2/]. For example, a proton in the nucleus of potassium-40 is able to capture an electron, turning it into argon-40. The captured electron is already part of the potassium-40 atom, so the amount of energy produced can be determined just by subtracting the mass of the argon-40 atom (39.962383 amu) from the mass of potassium-40 atom (39.963999 amu) and multiplying the result by 931 MeV/amu. A gamma ray would be produced with an energy of about 1.5 MeV. As another example, a proton in the nucleus of beryllium-7 consisting of only 4 protons and 3 neutrons is able to capture an electron, turning the beryllium-7 into lithium-7. Outside an atom, by comparison, neutrons can be produced from nuclear fission or by high-energy particle scattering (such as alpha particles from polonium-210 striking beryllium). But, the electron in a hydrogen atom normally cannot collapse into the nucleus (it doesn't emit a photon and loose energy) to produce a neutron. And, the neutron mass cannot result from combining an electron with a proton, as the rest mass of an electron (0.00054858) in combination with a proton (1.00727647) is insufficient to produce the mass of a neutron (1.008664). An additional 0.00083895 amu or about 780 keV would be required.

A theory of cold fusion that appears to be consistent with these and other ideas from chemistry and physics was detailed in a paper written by Dr. K.P. Sinha in June-July 1999, while he was a visiting professor at Harvard University. The theory suggests that cold fusion nuclear reactions can occur as a result of interactions between phonons, i.e., high frequency vibrations, in cathode reaction material and electrons (electric charge) of hydrogen and deuterium atoms in defects, cracks and crevices of the reaction material.



Reactions in Cold Fusion Cathodes

A mathematical description of the process involves the following:

- Hydrogen and deuterium molecules, atoms and ions are contained by the small defects, cracks and crevices. When the deuterium and hydrogen species lie in these channels, they are assumed to be affected by the associated electric potentials within these small volumes and to have their own spacing in the chain.
- The atoms of reaction material can be made to produce optical (high frequency) phonons. Phonons are a quantized form of lattice vibration (the energy is carried in discrete quanta).

- The hydrogen species in the channels thermally vibrate with a common frequency as "Einstein oscillators". Energies of these vibrations are quantized into levels separated by $E = h f$, where h is Planck's constant (6.63×10^{-34} joule-seconds) and f is frequency.
- High frequency (longitudinal) vibrations of reaction material atoms in/near the surfaces of the channels interact strongly by electrostatic fields with electrons of the hydrogen and deuterium, causing the electrons to pair up around individual hydrogen or deuterium atoms. With a pair of electrons, the atom has a negative charge. It is also more stable than if it had one electron.
- An electron or electron pair located on a proton or deuteron and interacting with the phonons can acquire an effective heavy mass; and, the corresponding atoms or ions are squeezed to much smaller size.
- A negatively charged deuterium or hydrogen ion that results can strongly attract its complementary positive deuterium ion in a molecule that, for a small instant of time, has no electrons. The electrons can negate the positive coulomb barrier between the ions, enabling the ions to fuse (a comparison can be drawn to muon-catalyzed fusion).
- Since the channels are essentially one-dimensional, distantly-spaced positive and negative ions can also move rapidly toward each other and fuse.
- A heavy electron or pairs of heavy electrons close to the nucleus can be captured by a proton to form a neutron through an electron capture process. The neutrons can cause transmutation of adjacent reaction material.

The above drawing indicates related reaction mechanisms. The double dash indicates two electrons around a deuteron, causing it to have a negative charge. Examples of "fusion" occur when protons, deuterons, or tritons (tritium) are made to combine with the negatively charged deuteron ion as shown on the top row of the drawing. Fusion of deuterium (deuterons) and deuterium to produce neutrons, protons and tritium, along with helium-4 and helium-3 is not desired due to local heating or transmutation that could be produced in the reaction material. In the bottom row, the right side of the drawing depicts a way that "transmutation" may occur, where the adsorption of a very low energy neutron into an element may help to convert it into another element. An example is the transmutation of nickel reaction material into cobalt and copper (although this also is undesired). The left side of the bottom row depicts electron capture in one of the protons of a hydrogen molecule to produce a neutron (the other proton or atom of the molecule is not shown). The captured electron is already part of the hydrogen molecule, so the energetics of the process can be estimated by subtracting the mass of the other proton (1.0072647 amu) from the mass of hydrogen (2 x 1.00794 or 2.01588 amu), which takes hydrogen's binding energy taken into account. The difference of 1.0086153 indicates that hydrogen has almost enough mass-energy to form a neutron (1.008664 amu). A mass of 0.000049 amu, however, is still needed, which, when multiplied by 931 MeV/amu, is equivalent to 46 keV. This may be able to be provided by the heavy effective electron mass or phonon energy. Another theory discussed below provides further support.

Professor Sinha initially suggested the role of electron pairing during a cold fusion meeting in 1989 held in Bangalore, India. The idea was also mentioned in an obituary for Professor F.C. Frank that he wrote in 1998. Dr. Sinha then indicated that he can explain how cold fusion works during an April 1999 conference hosted by Integrity Research Institute at the Holiday Inn in Bethesda, Maryland. In the summer and fall of 1999, the staff and technical consultants for Epoch Engineering, Inc., a systems engineering company in Gaithersburg, Maryland, assisted him in further documenting his theory. Details were presented in a meeting at the Hilton Arlington, VA hotel on November 18, 1999 (see above photograph where Professor Sinha is briefing participants in the meeting on "The Role of Electron Pairing in Facilitating Fusion, Fission and Other Mechanisms in Reproducible Experiments"). This location was chosen for its proximity to the Defense Advanced Research Projects Agency (DARPA), the Office of Naval Research, the Air Force Office of Scientific Research, and the National Science Foundation. About 40 copies of the briefing charts were distributed to scientists across the nation as a technical note (NEPS-TN-003). The theory was subsequently described in "A Theoretical Model for Low-Energy Nuclear Reactions," by K.P. Sinha [click on attached TIF file], dated 1999 and published in Infinite Energy magazine, Issue 29, pages 54-57, January/February 2000. The theory was also included in a March 2000 technical proposal from Epoch Engineering to DARPA on "New Power Production Technology Reaction Material".

Dr. Sinha continued his theoretical work on cold fusion as a visiting scientist at the Massachusetts Institute of Technology (2000-2003). He met Andrew Meulenberg (PhD, Vanderbilt University in Nuclear Physics) who has been working with him under the aegis of the Science for Humanity Trust in Bangalore, India, which they founded. Since that time, they have co-authored about a dozen related papers and briefings that can be found on the web. Information on electrostatic fields in the channels was discussed in 2006 and 2007, and information on reaction rates in the channels was discussed in 2012.

This theory has several important implications for development and long-time operation of cold fusion systems. The most important is that, since melting of channels where reactions can occur should be prevented, the system should be designed to support fusion of hydrogen and deuterium (p-d). Fusion of deuterium with deuterium (d-d) can produce neutrons and protons that deposit their energy locally in the channels. Second, the reaction material should be made to contain a sufficiently large number of extremely small, one-dimensional channels for the power level of interest. The channels should allow distantly-spaced positive and negative ions to move rapidly towards each other and fuse. Specifications will need to be developed for consistent manufacturing of reaction material. Another implication of the theory is that cold fusion systems should be made to operate when all modes of vibration are active, i.e., above the Debye temperature of reaction material from which cathodes are made. Cathodes should be made of materials that have a high Debye temperature. Also, production of slow neutrons and transmutation should be prevented. This may be able to be regulated by controlling the environment, e.g., temperature and the relative amounts of hydrogen and deuterium in the reaction chamber.

Mathematics for a supportive theory is discussed by Dr. Alan Widom and Lewis Larsen in "Ultra Low Momentum Neutron Catalyzed Nuclear Reactions on Metallic Hydride Surfaces," that was published in Condensed Matter on May 2, 2005. This paper shows how mass of electrons on reaction material surfaces can be increased by electromagnetic radiation on the surfaces. The heavy mass electrons can interact with protons and deuterons on the surfaces to produce very low energy neutrons in a manner similar to that shown in the lower left of the above diagram. The low energy neutrons can be captured by the reaction material, and new isotopes produced that decay by beta emission into other elements. Heat is produced by the radioactive decay and gamma ray adsorption.