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The Status of "Cold Fusion"

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The phenomenon initially called "Cold Fusion" should now more appropriately be called "Chemical Assisted Nuclear Reactions" (CANR). This new field, founded most recently[1] by Drs. Pons, Fleischmann[Fleischmann 1989], and Jones [Jones 1989], is continuing to grow as a variety of nuclear reactions are discovered to occur in a variety of chemical environments at modest temperatures. These environments include electrolytic cells containing D_2O or H_2O, gas discharge cells containing D_2 and palladium, various metals loaded with pressurized D_2, ion implantation using D^+, and chemical reactions of various types involving compounds of deuterium with other reactants. These environments appear to initiate a reaction between a deuteron or proton and other nuclei that are present. Fusion between two deuterium atoms can also occur and the resulting products can be altered by the chemical environment. Unfortunately, citation and analysis of all this work can not be done in this limited space.

Repeated observation using a variety of techniques and detection devices have consistently shown nuclear products that should not be present. In addition, these products are associated with much less high energy radiation than current theory would predict. The nuclear products include tritium, neutrons, or ^{4}He, accompanied by low level electromagnetic (EM) radiation. Tritium and helium have been seen as gas as well as energetic ionic emission. The EM radiation extends from energies that are characteristic of electron transitions to energies characteristic of a nuclear origin.

Excess energy[2] has been measured many times at levels and rates that far exceed any known chemical source. Total amounts have sometimes reached 100 MJ/(mol Pd) and at power densities in excess of 1 kW/cm^3. Unfortunately, not all attempts have succeeded in producing excess heat or nuclear products nor do successful studies all have the same pattern of production. It is becoming increasingly clear that subtile aspects of the chemical environment are critical in determining which nuclear reaction is initiated and at what rate. These special conditions are not normal to the material and are difficult to achieve.

All of these nuclear reactions have the "two miracle" problem that caused so much skepticism from the very beginning. These miracles involve the process of overcoming the coulombic barrier using only the chemical environment and the process of coupling the resulting release of nuclear energy to the surrounding atoms without the emission of significant high energy radiation or neutrons. An electron-rich environment apparently can couple energy to and from the nucleus, a mechanism that makes this field unique and not relatable to conventional experience based on interactions between isolated atoms at high energy.

These extraordinary and unexpected processes are still not understood. However, the

1. The effect was first proposed by the Alchemists during the sixteen hundreds. The relatively primitive understanding of the times and the secrecy surrounding the methods make an evaluation of the claims impossible.

2. Excess energy or heat is defined as the amount in excess of that applied to the device in order to initiate the reaction.

same cooperative process involving electrons is likely present in both miracles. It is important to emphasize that the unique mechanism must be understood before the nuclear aspects of this phenomenon can be made reproducible and properly studied. Until this aspect of the problem has been solved, the phenomenon will not be sufficiently reproducible to achieve wide acceptance or to justify potential application.

Discussion of Selected Results

Results published prior to mid 1991 have been reviewed by a number of authors. These scientific reviews [Bockris 1990; [Hurtak 1990; Rabinowitz 1990; Miley 1990; [Srinivasan 1991; Storms 1991a], popular books [Peat 1989; Mallove 1991; Close 1991; Huizenga 1992], and the original papers should be consulted for an evaluation of this work. Most authors who have reviewed the field came to the conclusion that a new phenomenon has been discovered. A series of articles that chart the recent history of the field can be found in 21st Century Science and Technology [21st Century]. Abstracts of current scientific papers are available in Fusion Facts [Fusion Facts]. Tsarev and Worledge [Tsarev 1990] have prepared overviews of the two conferences held in Utah, one in March 1990[1st-Conf.] and the other in October 1990[Anomalous]. A video tape of selected parts of the 2th Annual Conference on Cold Fusion, held in Como, Italy [2th-Conf.(Video)], and the published proceedings [2th-Conf.(Proc.)] are available. The proceedings of the 3rd International Conference on Cold Fusion [3rd-Conf.] will be available soon.

A considerable number of excellent studies describing all aspects of the phenomenon are now published and are available to the interested student. Only a few recent papers are used here to give examples of heat and tritium production under a variety of conditions.

Heat

Calorimetry in this field has now reached a level such that errors in measurement can no longer be used to dismiss the reality of the phenomenon. While some measurements are better than others, the amount of excess heat observed far exceeds any suggested error or chemical source and shows a similar pattern of production at various laboratories using a variety of techniques.

Heat production requires the attainment of a high D/Pd ratio within the palladium.[McKubre 1992; Kunimatsu 1992] This is not an easy task and requires at least five conditions be met:

1. The presence of certain surface impurities that improve the transfer of deuterium ions through the surface barrier.[McKubre 1992]
2. Palladium that is free of impurities, defects, and cracks.[Storms 1993; Storms 1991b]
3. Uniform current density at the cathode surface.
4. Absence of various impurities, including protium, in the electrolyte.
5. Use of a sufficiently high electrolysis current.

If these conditions are satisfied, the probability that an electrolytic cell will produce excess heat after sufficient time is greatly improved. Reproducibility will no longer be a serious problem when the new methode now being used are published.

Heat production rate is proportional to the D/Pd ratio when the deuterium content exceeds a critical value near 0.85 for the average bulk composition [Kunimatsu 1992; [McKubre 1992]. This ratio in the bulk material, and especially in the surface, increases as the cell current is increased. Consequently, heat production increases as the cell current is increased. This effect is seen when all data are compared [Storms 1991a] as well as in individual studies [McKubre 1992; Eagleton 1991; [Kainthla et al. 1989]. In addition to the effect of cell current, heat production requires a critical electrolysis time that can range from days to weeks. After this critical time is reached, heat production tends to increase as the cell continues to be electrolyzed. [Storms 1993; Takahashi 1992]

No heat is expected using palladium that forms cracks or other paths for loss of deuterium[Storms 1991b; Storms 1993]. Palladium that is free of these defects is rare. Therefore, success in producing heat is very unlikely when random pieces of palladium are used. Pretesting the palladium for a tendency to form microcracks when loaded with hydrogen allows poor metal to be rejected.[Storms 1991b] Certain alloys behave better in this respect than pure metal.

The main nuclear reaction producing this heat is proposed to be fusion of two deuterons producing normal helium. [Miles 1992; [Liaw 1993]. An extensive study of low level neutron emission during heat production has been reported by Takahashi[Takahashi 1992]. He found that neutron emission increased with heat production on a daily basis but decreased over a long time while the average heat increased. Tritium is not normally observed during heat production.

Since the initial suggestion by Mills and Kneizys[Mills 1991], numerous studies have shown the production of excess heat using a high-surface-area nickel cathode and normal water containing various alkali carbonates as the electrolyte. In addition to excess heat, tritium has also been found in certain cells and excess power has been seen when titanium was used as the cathode[Srinivasan 1992]. This heat was initially proposed to result from unusual electron shifts in the hydrogen atoms [Mills 1991]. However, evidence is accumulating that a nuclear transmutation reaction occurs between the alkali element and a proton.[Bush 1992]. This method for producing energy shows greatest energy amplification at low currents where absolute values of excess power are small. This behavior is in contrast to the D_2O containing cells that show increased power amplification as the applied current is increased. This behavior makes scale up of the H_2O cells less attractive than the D_2O containing cells.

Heat and nuclear products have been produced in palladium that is loaded with deuterium by low energy gas discharge. [Karabut 1992] This was accomplished by creating an ion current (10-100 ma) using 100-500 V applied between a Pd cathode and a metal anode in deuterium at 3-10 Torr. Heat production at ≈5 times the applied power was measured. The presence of helium, very energetic charged particles (proposed to be α-particles), γ-, and X-rays (EM) were reported. This latter EM radiation, originating from both electron and nuclear transitions, was emitted in beams of various sizes and intensities. This behavior strongly suggests that the energy is able to couple to the lattice and be influenced by the orientation of random crystals within the palladium cathode.

Tritium

Tritium has been made by electrolysis, and by gas loading of various metals. Non-steady state conditions appear to improve the production rate. The amounts reported frequently greatly exceed any conceivable natural source. For example, any tritium that appears in the electrolyte after cathodic electrolysis cannot be caused by tritium originating from contamination of the palladium[Storms 1991b]. Tritium contained in palladium as contamination is released almost exclusively into the gas while most of the detected tritium is found in the electrolyte. Concentration of tritium in the environment and in palladium metal is many orders of magnitude lower than that usually observed in cold fusion cells, many of which were completely sealed. Consequently, the suggestion that observed tritium is owing to contamination is not supported by experience.

Recent work [Chien et al. 1993] used several methods to prove that the observed tritium (10^{15} atoms) could not have been present in the palladium before the study. They found that the production rate was sensitive to the applied voltage and was constant with time at constant voltage, Production stopped when D_2O was added, and when the cell was vibrated. Production of ^4He also occurred. No effort was made to observe heat production.

Tritium has also been observed in cells using normal water as the electrolyte and a nickel cathode.[Srinivasan 1992] The highest concentrations were found when D_2O was added or when the electrolyte contained Li_2CO_3.

Discussion

Other observations too numerous to mention here have clearly demonstrated that a new phenomenon has been discovered. This phenomenon involves the ability of the chemical (electron) environment to reduce the barrier between nuclei and to dissipate the resulting nuclear energy through out the surrounding atomic lattice. Because the environment used for these studies is greatly different from that used when isolated ions are interacted at high energy, the process and the products are expected to be different as well. Consequently, most past experience using high energy plasmas might not apply and should not be used to dismiss the new observations out of hand. It is not yet known in what ways this phenomenon might be applied. The possibilities exists to change one element into another and to produce large amounts of clean energy. If ways can be found to scale the heat producing process to industrial levels, an inexhaustible and clean source of CO_2-free energy would be available. If ways can be found to properly tailor the electron environment, harmful radioactive isotopes might be converted to nonradioactive elements and rare elements might created from common elements. These extraordinary possibilities are too important to ignore just because they are inconsistent with present knowledge. Even if these applications are not realized, a new understanding of nucleus-electron interaction is already in process.

We all must be reminded periodically that science involves the open minded search for new knowledge. It is the nature of this search that new knowledge will always conflict with old. When this conflict becomes too great, individuals are required to reexamine their commitment to objectivity and to the absence of emotional bias.

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