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Confusion over Cold Fusion: A Possible Explanation

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Abstract

The famous 1989 "cold fusion" experiment of Fleischmann and Pons is revisited and the results are discussed. It is shown that these results, which were attributed to nuclear fusion near or at room temperature but were never validated in any other environment, can be explained by presence of radon gas in the laboratory where the experiments were performed.

Keywords

Cold Fusion, Fleischmann and Pons, Experiment, Radon Gas

1. Introduction

Cold fusion is a hypothetical nuclear reaction that takes place at or near room temperature in which nuclei of the hydrogen isotopes fuse together to form heavier nuclei. This is in contrast to the normal or "hot" fusion which occurs naturally within the core of stars or artificially in a hydrogen bomb and some reactors at extremely high pressures and temperatures.

Cold fusion, the history of which goes back to the 1920s, is based on the idea that isotopes of hydrogen can dissolve to very high concentrations in certain solids, such as palladium. As a result, the hydrogen nuclei can come closer together than even in solid hydrogen. Furthermore, the negatively charged electrons of the solid host partly cancel the electrostatic repulsion between the hydrogen nuclei. However, early experiments on the subject did not detect any signs of fusion, and modern theoretical calculations show that the proposed effects, even if real, are too small to produce detectable rates of fusion [1].

On March 23, 1989, two electrochemists, Martin Fleischmann and Stanley Pons [2] from the University of Utah, announced that during electrolysis of heavy water (D_2O) using palladium cathode, the energy produced exceeded the energy input in the experiment. They speculated that this excess energy was the result of the following possible nuclear fusions of deuterons into heavier nuclei at room temperature,

$$ {}_{1}^{2}\text{D} + {}_{1}^{2}\text{D} \rightarrow {}_{1}^{3}\text{T} + {}_{1}^{1}\text{H} \tag{1} $$

or

$$ {}_{1}^{2}\text{D} + {}_{1}^{2}\text{D} \rightarrow {}_{2}^{3}\text{He} + \text{n} \tag{2} $$

This experiment, which is known as cold fusion, subsequently failed to reproduce the effect and consequently raised scepticism. After months of investigating Fleischmann and Pons's claim, the scientific community came to the conclusion that the effect was inconsistent or nonexistent and that the scientists had made experimental errors [3]. This led to the disqualification of the subject from further study. Nevertheless, the idea of cold fusion has haunted the scientists over the years, and many articles have appeared in the literature ever since [4] [5] [6]. Even recently, a very comprehensive study has been carried out and published in *Nature*, to re-examine the validity or invalidity of the cold fusion experiment [7]. Yet another recent article which is somehow, but not directly, related to the cold fusion experiment, discusses the possibility of producing energy based on the annihilation of matter and antimatter particles in molecular crystals [8].

Despite many attempts by investigators ever since to validate cold fusion, no evidence of such reaction has been observed. But the question remains as to why Fleischmann and Pons reported cold fusion in their laboratory. It is unimaginable that two competent and highly experienced physical chemists made a mistake. Therefore, something must have happened in their laboratory during the experiment. The objective of this article is to provide an explanation of what possibly went wrong during the original experiment of Fleischmann and Pons, resulting in what appeared to be cold fusion. But first let us briefly discuss some of the basic facts about the Fleischmann and Pons' Experiment.

2. The Fleischmann and Pons' Experiment

In their search for cold fusion, Fleischmann and Pons ran electric current through an electrolytic cell consisting of a palladium cathode, a platinum anode, and a solution of LiOD in heavy water D_2O as electrolyte. The cell liberates atomic deuterium, which enters palladium much more rapidly than deuterium molecules. It turns out that under proper conditions, the concentration of deuterium in palladium can be as high as 0.9 or more deuterium atoms per palladium atom [1]. This high concentration of deuterium in palladium was believed to bring the nuclei of deuterium close enough together to start a nuclear fusion. The Fleischmann and Pons' cell was part of a calorimeter which, in a few occasions, indicated an excess heat generated of the order of about 10% higher than the input electrical energy. Fleischmann and Pons also thought they had detected gamma radiation as a result of neutrons passing through water.

Following the results of the Fleischmann and Pons' experiment, which were announced in a news conference on March 23, 1989, many investigators tried to duplicate the experiment. Of those experiments, many were unsuccessful, and some reported success but with difficulty to reproduce their results. However, no one detected any of the products of the possible deuterium-deuterium fusion reaction, two of which are those in Equations (1) and (2), and the third is [1]

$$ {}_1^2\text{D} + {}_1^2\text{D} \to {}_2^4\text{He} + \gamma \tag{3} $$

with an energy of 23.8 MeV for the emitted gamma radiation. Based on the conventional branching ratios for deuteron-deuteron fusion, Berlinguette st al. have argued that far too few neutrons and tritons (${}_1^3\text{T}$) were detected in the Fleischmann-Pons experiment to account for the quantity of heat observed [7]. Therefore, they concluded that reactions (1) and (2) could not have taken place in the Fleischmann-Pons experiment, and only reaction (3) could have taken place with essentially all of the released energy (23.8 MeV) transferred to the palladium lattice as heat. In fact, at a cold fusion press conference at the University of Utah on March 23, 1989, Fleischmann and Pons announced that they did not detect any ${}_2^3\text{He}$ in their experiment [9]. But some experiments eventually reported production of ${}_2^4\text{He}$ [1]. However, generation of the excess heat or the nuclear fusion products during electrolysis of D_2O has not been confirmed, and the claims have been dismissed by the scientific community [10] [11] [12].

Regarding detection of gamma ray in the Fleischmann and Pons' experiment [2], Petrasso *et al.* have provided four reasons to show that the claim of the observation of a 2.22-MeV gamma ray is unfounded [13].

3. A Possible Source of the Confusion: Radon Gas

Radon, the element with atomic number 86, is the heaviest noble gas. The most stable isotope of radon, ${}_{86}^{222}\text{Rn}$, is a natural radioactive gas that is produced in the soil as a result of radioactive decay chain of naturally occurring uranium, shown in **Figure 1** [14]. The first five daughters of the decay are solid and remain in the soil. The sixth daughter, ${}_{86}^{222}\text{Rn}$, however, is a radioactive gas with a half life of 3.82 days, long enough to seeps through the soil into the atmosphere [15]. This gas from the soil can also seep through the cracks of basement floors into basements.

Once in a basement, radon gas does not leave easily and tends to remain and decay within the basement, which is a matter of concern in many buildings and houses. Therefore, radon mitigation systems need to be installed in such buildings. The reason for confinement and higher concentration of radon in basements lies in the Graham's law of effusion. According to this law, the rate of effusion of different gases in a mixture through an orifice is inversely proportional to the square root of their molecular masses [16] [17],

$$ \frac{J_1}{J_2} = \sqrt{\frac{m_2}{m_1}} \tag{4} $$

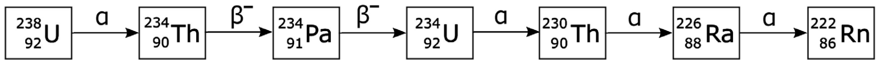

Figure 1. The radioactive chain of ${}^{238}_{92}\text{U}$.

where J is the flux of the molecules, *i.e.*, the number of molecules that effuse through the orifice per unit area per unit time, and m is the molecular mass. Consequently, heavier molecules effuse through an opening slower than the lighter ones. Thus, in a mixture of air molecules (N_2 and O_2) and radon gas in a basement, radon effuses out through the cracks and openings at a much slower rate that the other gasses, which results in an increase in the concentration of radon in the basement.

The isotope ${}^{222}_{86}\text{Rn}$ has a half life of 3.82 days, and undergoes α decay according to [15]

$$ {}^{222}_{86}\text{Rn} \rightarrow {}^{218}_{84}\text{Po} + {}^{4}_{2}\text{He} \tag{5} $$

The reaction releases 5.49 MeV of energy, almost all of which is carried away by ${}^{4}_{2}\text{He}$ according to the laws of conservation of momentum and energy. The helium atom (nucleus) subsequently releases this energy as gamma rays as a result of a series of collisions with other particles. This can be responsible for the detection of gamma rays adjacent to the electrolytic cell claimed by Fleischmann and Pons [2]. If reaction (3) did in fact take place in the palladium cathode, as stated earlier, almost the entire 23.8 MeV energy would be concerted into heat inside the palladium leaving essentially no gamma ray outside to be detected. Furthermore, as stated earlier, some experiments did report detection of ${}^{4}_{2}\text{He}$ [1], which could have come from the decay of ${}^{222}_{86}\text{Rn}$ according to Equation (5).

4. Discussion and Conclusions

According to a study, Utah has one of the highest concentrations of radon gas of any state in the United States [18]. In particular, Salt Lake city, where the University of Utah is located, has a relatively high radon level. While the average of radon level in homes of Salt Lake City is 5.3 piC/L, a number of the buildings have tested between 20.7 piC/L to 140.5 piC/L [19].

The laboratory in which Fleischmann and Pons carried out their experiment was located in the basement of a then new building overlain by five floors of concrete [2]. They measured the gamma rays using a sodium iodide scintillation detector and corrected their results by measuring the background radiation at a different time and in a different part of the building. However, because concentration of radon gas in a basement fluctuates considerably from location to location and from time to time, unless the background radiation is measured at the time of the experiment and at the same location, the correction is not very meaningful.

In conclusion, since the results of Fleischmann and Pons's experiment have not been validated in other laboratory environments and by other investigators, it is possible that presence of radon gas in their laboratory was responsible for them. But the question remains as to why should we still bring the subject up and discuss it. The answer to this question, as also pointed out by Berlinguette *et al.* [7], is that the world is in urgent need of discovering a clean energy [20]. Such a discovery requires risk taking, and revisiting cold fusion is a risk worth taking.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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