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Research Article

Nature of Energetic Radiation Emitted from a Metal Exposed to H_2

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Abstract

Layers of metals were applied so as to cause local stress, which is proposed to create voids in which nuclear reactions can be initiated when the material is exposed to H_2. Photon emission having energy sufficient to pass through 3.86 g/cm^2 of absorbing material was detected using a Geiger-Mueller detector. This radiation was observed to last many hours and is not typical of what is called fracto-fusion.
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Keywords: Cold fusion, Cracks, Fusion, LENR, Radiation

1. Introduction

Numerous reports have been published [1] describing radiation emitted from a nuclear process called LENR when palladium, nickel, and other materials are exposed to deuterium and normal hydrogen. Because such energetic radiation cannot be mistaken for a prosaic or chemical effect and can only result from a nuclear reaction, these observations are highly anomalous and in conflict with conventional understanding. This radiation, in addition to revealing how nuclear reactions can be initiated in ordinary materials, must be explored to avoid health risks when such systems are studied or used as energy sources.

For this study, samples were made and treated to form the kind of voids proposed by Storms [2–4] to be the location of the LENR process. Three different materials were used, with each showing the same behavior once the active conditions were produced and the materials were exposed to H_2. Radiation, which had the characteristics of photons, was detected using large area Geiger-Muller detectors. The amount of material was too small for the nuclear process to produce detectable energy.

Unusual radiation, both particle and photon, has been found when certain materials are exposed to H_2 or D_2. For example, such radiation has been produced during electrolysis [5,6], gas discharge [7–10], and by exposing specially treated metal to H_2 [11,12] or D_2 gas. Focardi [12] places the photon energy resulting from specially treated Ni being exposed to H_2 at 661 ± 0.8 keV. This value was corrected to 744 keV by Takahashi [13]. Piantelli et al. [12,11,14] published a detailed description of various kinds of radiation emitted from Ni rods after being heated repeatedly in H_2,

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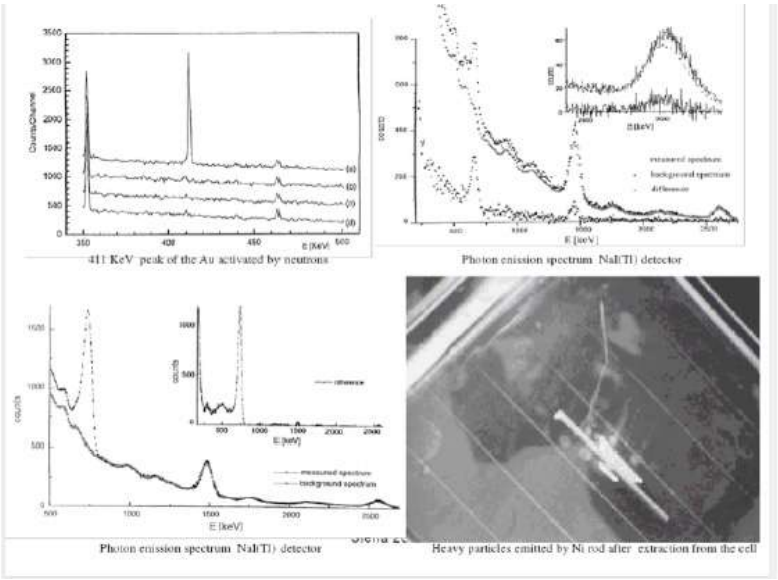

Figure 1. Examples of radiation reported as a result of studies by Piantelli et al. using specially treated Ni exposed to H_2.

after which the metal was found to generate extra energy. Evidence for photon radiation of various frequencies, energetic particles that were visible in a cloud chamber, and neutrons are shown in Fig. 1. Violante et al. [15] electrolyzed a thin layer of Ni that was sputter-deposited on polyethylene. The electrolyte was H_2O–Li_2SO_4 and radiation was detected using a planar HPGe detector after the radiation had passed through the polyethylene cell wall. Figure 2 shows the behavior when a blank cathode was examined and Fig. 3 shows the presence of radiation. Although the amount of radiation leaving the cell as photons is small, radiation is clearly present when none would be expected. Matsumoto [a] [16] detected radiation using X-ray film produced by a nickel cathode in a glass electrolytic cell containing $H_2O + K_2CO_3$. One side of the foil was electrolyzed while the other side was in contact with the film. As a result, any radiation had to pass through 0.1 mm of Ni. Many unusual complex tracks were seen, suggesting secondary nuclear reactions were produced in the film by radiation from the nickel. Bush and Eagleton [17] used a NaI scintillation detector to measure photons from a Ni cathode (fibre x) electrolyzed in H_2O + LiOH. They claimed to find a rough correlation between excess power and the amount of total radiation as shown in Fig. 4. Anecdotal experience has been reported by Rossi [18] and Celani, claiming radiation is detected when heat production is first initiated but is much reduced later while extra energy is being made.

2. Method

2.1. Radiation measurement

Figure 5 shows a cross-section drawing of the sample, cell, vacuum housing, and GM detector (GM No. 1) (LND-7313) and Fig. 6 is a photograph of the system. The radiation had to pass through the absorber material listed in Table 1. As a result, a large fraction of the radiation being emitted by the sample was removed before measurements were made. The

[a] This author has published many papers describing how variations in the cold fusion conditions can generate strange tracks in film

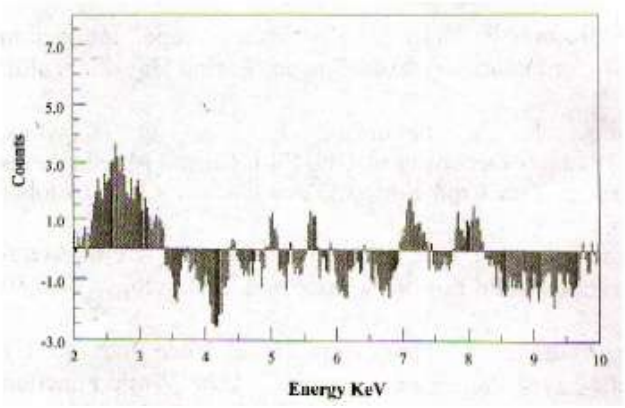

Figure 2. Count rate in excess of background for an inactive Ni cathode reported by Violante et al. [15].

pulses from the detector were fed to an electronic circuit where the pulses were amplified and used to charge a resistor–capacitor circuit to produce an average voltage that was recorded. Consequently, the plotted values are arbitrary units for which only a change is important. The average background was about 60 counts/min for the large-area detector.

A second GM (GM No. 2) of the same type was located about 30 cm from the source (Fig. 6), such that any radiation from the source had to pass through 1 cm of steel and the back of the detector before it entered the active region of GM No. 2. As a result, ambient background radiation was detected along with only very energetic radiation that might be emitted by the sample or less energetic radiation originating at GM No. 1. The background flux at GM No. 2 was found to be essentially constant during the studies.

The sample was contained in an aluminum cup that could be heated in H_2 to 350°C with pressures up to 5 atm. The samples were exposed to a variety of conditions in order to activate the material, a process important to achieving success.

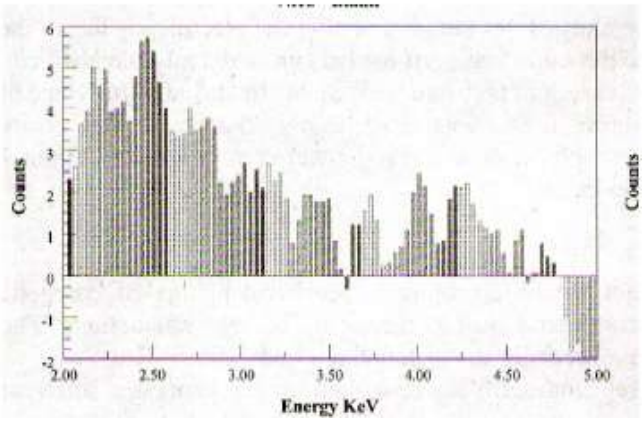

Figure 3. Count rate in excess of background for an active Ni cathode reported by Violanti et al. [15].

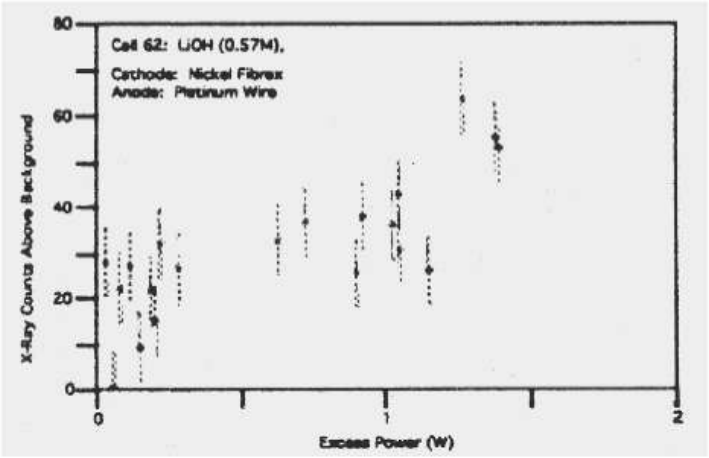

Figure 4. Radiation detected by Bush and Eagleton [17] from a cell having a Ni cathode and H_2O electrolyte while it was making excess power.

2.2. Sample preparation

The samples consisted of palladium or nickel sheet on which various metals were deposited by electroplating or sputtering.

The palladium samples were prepared by reducing the thickness of stock palladium to a convenient value using a rolling mill. The sample was then heated near the melting point using a propane–oxygen torch in air. This treatment

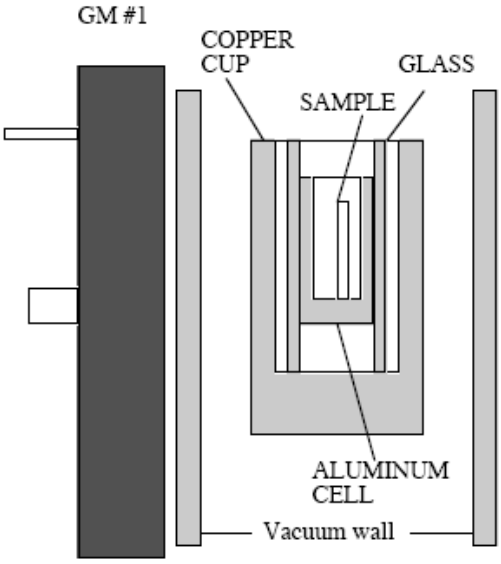

Figure 5. Cross-section of region around sample and relationship to GM No. 1.

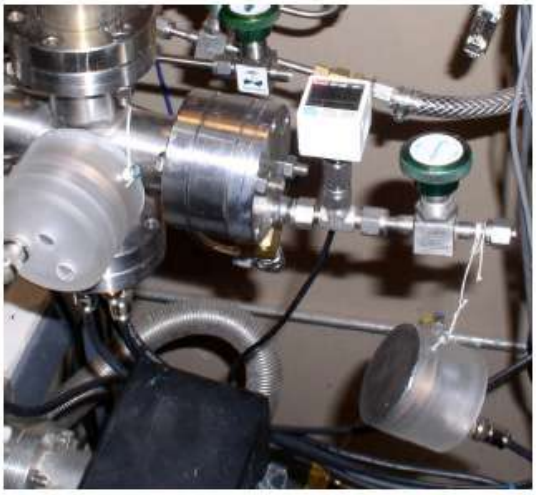

Figure 6. Photograph of apparatus with GM No. 1 attached to the apparatus and GM No. 2 hanging by a wire off to the right.

purified the surface and created a thin oxide coating. Heating to 200–280°C followed by cooling in 30 psi H_2 resulted in the sample coming to equilibrium with the H_2 and acquiring a H/Pd ratio between 0.70 and 0.72. This step was used to make sure the Pd was clean and would react quickly and completely with H_2. The hydrogen was then removed by heating in vacuum to 200 °C before the metal coating was applied.

One sample was made by applying Cr to the clean Pd surface by sputtering to give a thickness of 101 nm on both sides. This was followed by 262 nm of Pd and another 101 nm layer of Cr. The sample was heated in 4.8 atm of H_2 to 213°C and cooled in order to bond the layers to the base material. When the sample cooled in H_2, the Pd expanded as it formed beta-PdH resulting in H/Pd = 0.70, which caused stress in the Cr layer to form the required voids.

A second sample was made by applying 101 nm of Ni, and 252 nm of Pd on the Pd substrate. The sample was heated in vacuum to 415 °C and cooled in 4.9 atm of H_2. This caused the sample to reach a composition of H/Pd = 0.73, which would produce stress in the Ni layer as the Pd expanded while forming beta-PdH and the Ni did not.

A sheet of Ni was cleaned by electrolysis in NaOH solution followed by applying an electroplated layer of Cu 552 nm thick. This was heated to 481 °C in vacuum followed by heating in H_2. The surface is shown in Fig. 7 on which the sought-for pits are clearly seen. Subsequent studies showed that such pits were characteristic of Ni–Cu interaction although radiation was seldom produced.

The active regions were not stable so that the amount of radiation was not constant with time or conditions. Nevertheless, the samples were active long enough to obtain useful measurements and could even be removed to air for weighing without losing the ability to produce radiation once returned to the system

Table 1. Effective stopping power of material between sample and GM No. 1.

0.9 mm Al = 0.24 g/cm^2
2 mm Cu = 1.79 g/cm^2
1 mm Pyrex = 0.22 g/cm^2
2 mm stainless steel = 1.61 g/cm^2
Total = 3.86 g/cm^2

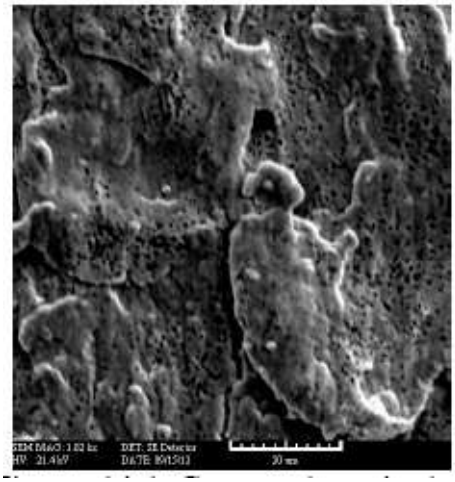

Figure 7. Surface of Ni on which Cu was deposited after heating in vacuum at 481 °C.

The voids proposed to be the nuclear active environment (NAE) appeared to have a range of sizes, some of which were too small to be resolved in the images. Figures 8 and 9 show a topical void formation at different magnifications for samples of Ni applied to Pd. Figure 10 shows the surface after study of a sample created by applying Cr to Pd. This layer delaminated from the Pd at some point during the study, probably when the radiation abruptly stopped at the end of the study.

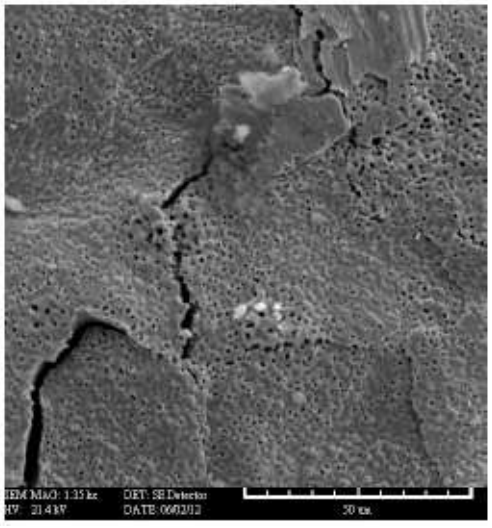

Figure 8. SEM image of a surface of Ni on Pd after the study containing voids and cracks.

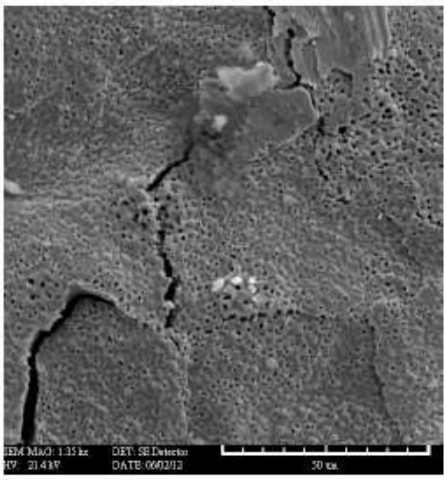

Figure 9. Detailed SEM examination of the Pd–Ni surface after the study.

3. Results

Four samples were found to produce radiation after being prepared using a variety of conditions, three of which are described here. The most important requirement is that the layer not detach from the substrate metal and the pit structure form. These pits are expected to be the mouth of voids that extend into the material. Their formation requires a narrow range of conditions, some of which are described here. Nevertheless, such structures are not always active probably

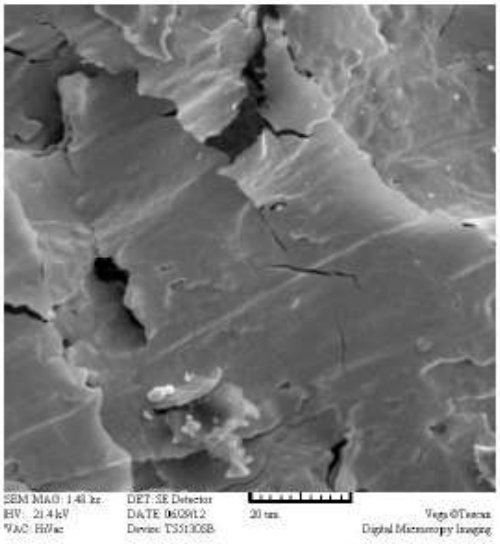

Figure 10. SEM image of surface of Cr on Pd after the study.

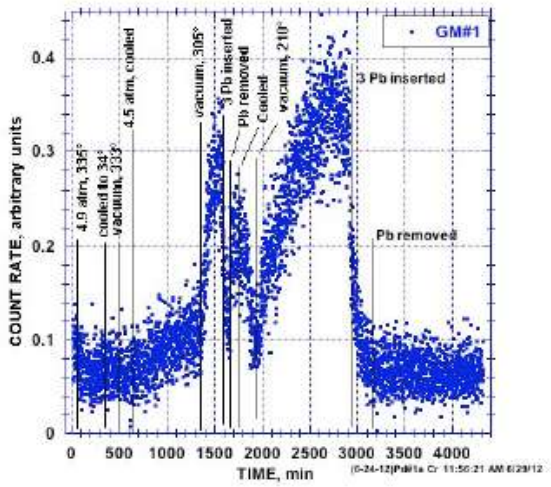

Figure 11. History of sample of Pd coated by Cr.

because the small required size was not formed.

3.1. Pd–Cr

Figure 11 shows the counting history for a sample of Pd coated with 100 nm of Cr followed with about 200 nm of Pd. In this case the voids are produced in a volume of about 0.0001 cm^3 of Cr, which emphasizes the small volume of material from which radiation is typically emitted. A brief exposure to H_2 was done before this sequence was started. Several heating and vacuum cycles were required before significant radiation was started at 1350 min while the sample was at 305°C and H_2 was being pumped out. Such treatment would cause the gap in cracks that had formed during previous treatments to become smaller as hydrogen was lost causing the PdH to contract. Presumably this smaller size was required for the process to function and radiation to be produced. Only this sample required loss of H_2 to produce radiation.

The effect of inserting sheets of lead absorber (1.3 g/cm^2) is shown in Fig. 12. Every time an absorber was inserted, all samples showed an immediate reduction in radiation followed by slow decay. The absorber changed the distance between GM No. 1 and the sample by no more than 2 mm. Once the absorber had been removed, an immediate increase in radiation occurred that was followed by slow increase to a steady value. The effect when Pb was inserted can be seen clearly in Fig. 13, but unfortunately the radiation stopped before the Pb could be removed. This abrupt termination of radiation near 3000 min is presumed to have resulted when the coating detached from the Pd substrate, the consequence of which can be seen in Fig. 10. GM No. 2, located at a distance from the sample, also shows unusual behavior. Radiation was being detected by GM No. 2, which slowly decreased when an absorber stopped radiation from the sample from reaching GM No. 1, as seen in Fig. 13. This means the radiation being detected by GM No. 2 originated from GM No. 1, not from the apparatus. This behavior was observed on several occasions when other samples were treated in the same way.

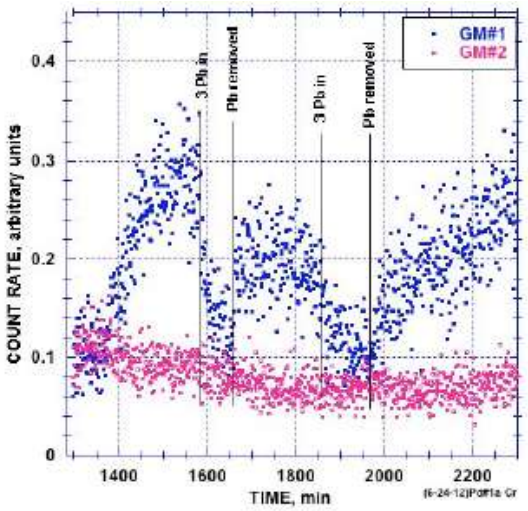

Figure 12. Sample of Pd coated by Cr. Time sequence taken from Fig. 12.

3.2. Pd–Ni

This sample was heated at various temperatures under as much as 5 atm of H_2 over a period of 3000 min before any radiation was detected. The sample was at 33 °C under of 4.4 atm of H_2 when radiation was detected. Figure 14 shows onset of radiation and the effect of inserting a Pb absorber. Once again, immediate reduction was produced followed by

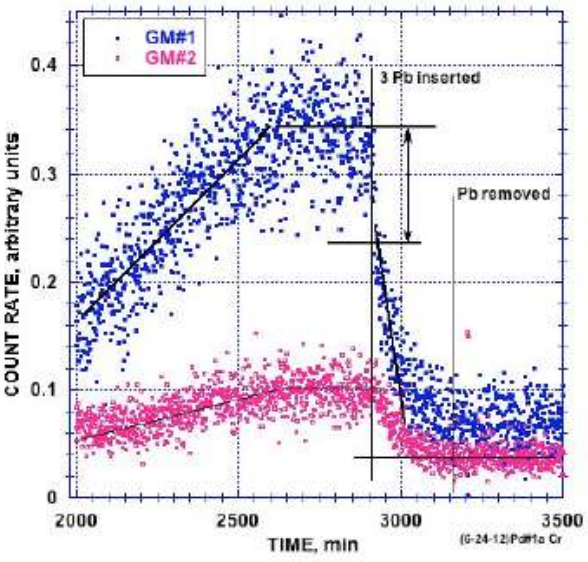

Figure 13. Sample of Pd coated by Cr. Time sequence taken from Fig. 11.

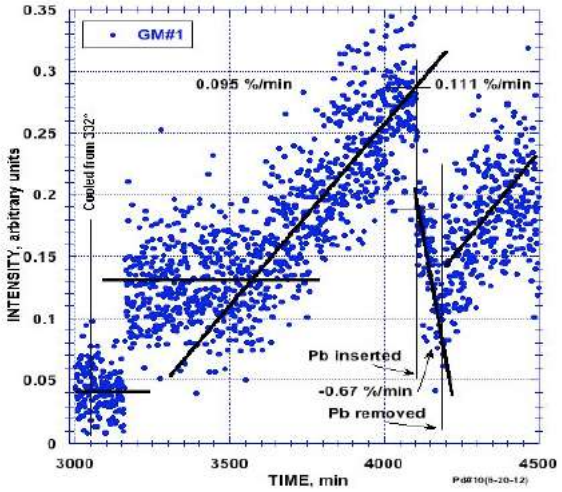

Figure 14. Example of inserting a lead absorber using Pd coated by Ni.

slow decay having a half-life of about 40 min, as calculate using the linear least-squares fit of ln (rate) versus time during the decay phase (Fig. 15). The rate was obtained by subtracting the GM No. 1 signal when no radiation was produced from the value measured for each point during the decay. When the absorber was removed, radiation immediately increased followed by a slow increase with a slope close to the increase observed before the absorber was inserted.

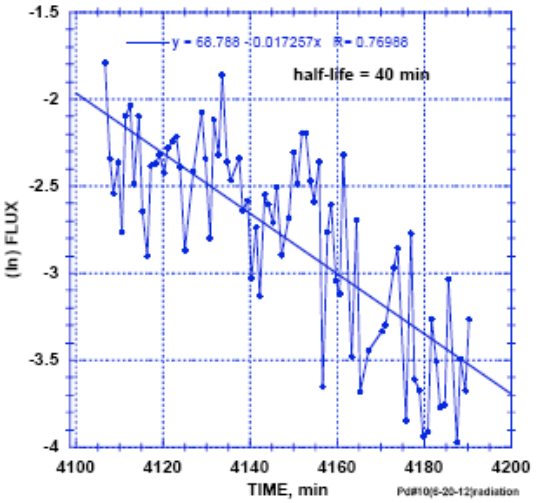

Figure 15. ln (flux) vs time for decay after absorber is inserted.

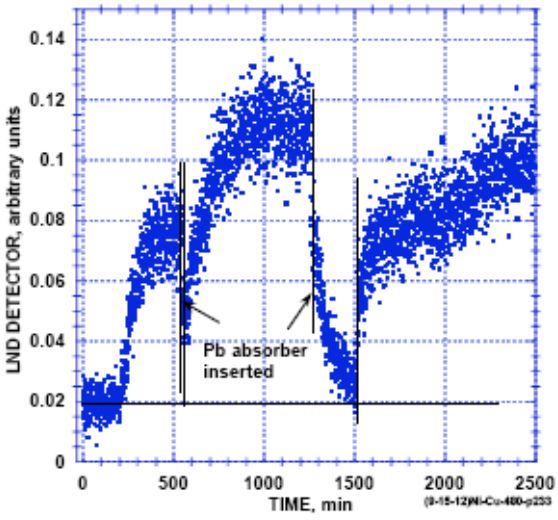

Figure 16. Behavior of radiation during the full study while Ni–Cu was being heated in H_2.

3.3. Ni–Cu

The sample was heated through 212 °C in 3.7 atm of H_2 when the radiation intensity first increased at 200 min. Lead (Pb) was briefly inserted at 548 min and then removed. Lead was again inserted at 1260 min, which had the effect shown in Fig. 16. The decay in Fig. 17 had a longer average half-life (Fig. 18) compared to a shorter time shown in Fig. 15, with an indication that the initial decay had a shorter half-life than the average. This shorter initial decay rate might account for the smaller half-life obtained from the smaller data set shown in Fig. 15.

3.4. Radon

When a fan was used to circulate air around GM No. 1 and the apparatus, the count rate increased and then decreased after the fan is turned off over a period of about an hour. This change is attributed to radon in the air that is made available to the apparatus on which it deposits. Only the count rate of GM No. 1 next to the apparatus was affected. This extra count rate was not present in the absence of the fan. Inactive samples, of which many were studied, and the empty cell show a steady count rate at the normal background level. All data were obtained in the absence of the fan. Figure 19 shows the behavior of a typical inert sample exposed to H_2.

4. Discussion

A recently published explanation of LENR proposes that the nuclear reactions are initiated in voids or cracks [2]. Consequently, these experiments were designed to generate cracks in various materials while photon radiation was measured outside the apparatus using a Geiger-Muller detector. Because the energy of photons is not altered by penetration through matter, only a small flux that leaks from the apparatus is required to identify a source of radiation even though most is stopped by the apparatus.

Two sources of radiation are detected. One source is produced by the sample and can be stopped almost completely by 1.6 g/cm^2 of lead in addition to the 3.9 g/cm^2 provided by the apparatus. This radiation is proposed to originate

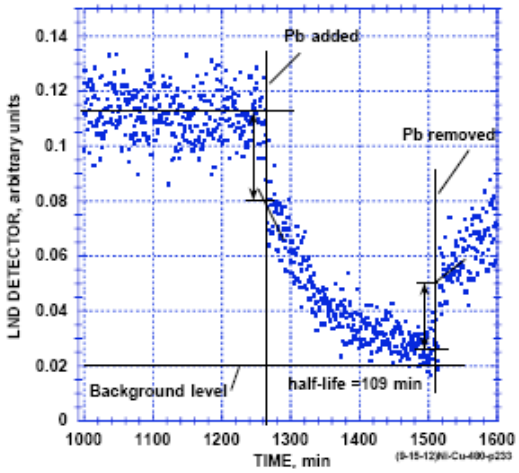

Figure 17. Effect of inserting a Pb absorber between 1262 and 1510 in shown in Fig. 16.

from samples containing characteristic voids in which a fusion reaction can take place. Although the visible voids are too large to be nuclear active, the observed voids are expected to have a wide range of size, suggesting some may have the required small size.

This primary radiation initiates a reaction within GM No. 1 that emits radiation, called secondary radiation. This secondary radiation grows slowly while the primary radiation from the sample bathes GM No. 1 and decays away when an absorber intercepts the primary radiation. As a result, GM No. 1 detects the sum of primary and secondary radiation. Insertion of an absorber immediately stops radiation from the sample, which stops further activation. The secondary

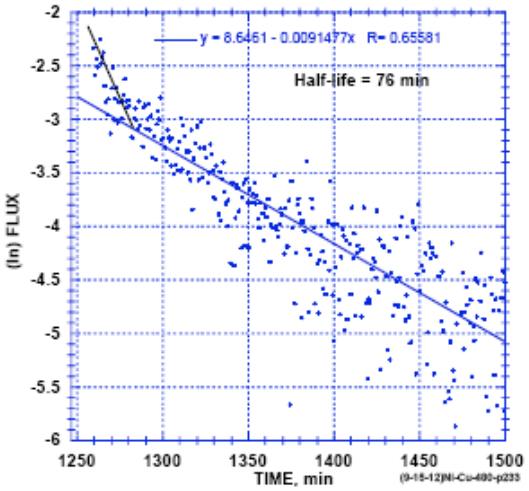

Figure 18. Half-life calculation for decay shown in Fig. 17.

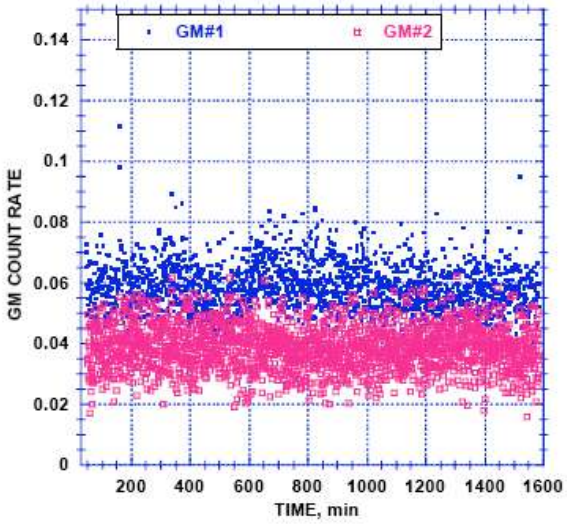

Figure 19. Behavior of GM No. 1 and GM No. 2 when a typical inert sample is in the apparatus. The difference between the two GM count rates is arbitrary. Only the constant value over time is important.

radiation has enough energy to be detected as a small flux by GM No. 2 located well away from the primary source. Because this radiation was created by a reaction inside the GM, it could not be studied by stopping it with absorbers.

The secondary radiation results from a reaction having an average half-life of about 76 min with a faster initial decay after the primary is first removed. When the absorber is removed, activation starts again and the concentration of activated source slowly increases, causing a slow increase in count rate that becomes constant when the activation rate equals the decay rate of the activated source.

The activated nuclei cannot be Al, Si, O, Ni, Fe, or Cr, because these elements are present in the sample and in construction materials, which show no such activation. Only the mica window of GM No. 1 contains elements not present anywhere else. These elements are listed in Table 2 based on EDX analysis. Only C and K are present in the detector and nowhere else, both of which have unstable isotopes. A GM detector having a plastic window containing carbon rather than one made from mica did not show this activation. Consequently, the likely activated nucleus is K^{40}.

The radiation being emitted by the sample is proposed to result from a fusion reaction that produces coherent photons. These photons are proposed to react with K^{40} nuclei in the mica window of GM No. 1 to stimulate its decay by beta and gamma emission that is detected by the GM. Some of the energetic gamma from this decay can reach GM No. 2 and cause a slight increase in count, as shown in Fig. 13.

Table 2. Composition of mica window based on EDX analysis.

C	**55 wt.%**
O	16 wt.%
Si	10 wt.%
Al	9 wt.%
K	**5 wt.%**
Fe	3 wt.%
Mg, Ti, Na	< 1 wt.%

The role of radon in this study is important to acknowledge and address. Radon could be concentrated on the apparatus by a fan blowing air on the apparatus. The radioactive gas accumulated slowly and continued to activate GM No. 1 as long as the fan operated. The radiation slowly decayed away when the fan was turned off. This radiation did not produce secondary radiation and it did not reach GM No. 2. All of the measurements shown here were taken while the fan was off. Many samples were studied without the fan being on and only the three described here produced significant radiation. These facts give confidence that the measured radiation was not caused by spontaneous accumulation of radon. Nevertheless, this study needs to be repeated using a NaI detector when active material can again be made. As is characteristic of this phenomenon, replication of the effect has been difficult.

This study raises many questions that are not answered and demonstrates some very unexpected behavior. Having this behavior made known without delay is more important than taking time to answer all questions before publication. Therefore, this paper should be viewed as a progress report about an important behavior and is made known to encourage further study.

5. Conclusion

Several kinds of material when treated in a manner to produce voids are found to radiate photons typical of a nuclear reaction when exposed to H_2. This radiation is able to activate a nucleus exposed to this radiation, which decays with an average half-life of about 76 min. This photon radiation can be produced using Cr, which is not magnetic, and Ni, which is magnetic after the metals are subjected to stress by creating concentration gradients. Ni also reacts with Cu to form the same type of structure, after which photon radiation is produced when the alloy is exposed to H_2.

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