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RADIATION MEASUREMENTS AT CHINA LAKE: REAL OR ARTIFACTS?

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ABSTRACT

Anomalously high radiation counts were observed using several different Geiger-Mueller (GM) detectors as well as sodium iodide (NaI) detectors during electrolysis experiments with palladium cathodes in heavy water. These high radiation counts were often observed in co-deposition experiments where palladium metal is deposited from a D_2O solution onto a copper cathode in the presence of evolving deuterium gas. The anomalous radiation counts reached values as high as 73 sigma above normal background counts. The anomalous radiation would appear within a few hours in the co-deposition experiments where the palladium is loaded with deuterium as it deposits from solution. In contrast, the appearance of anomalous radiation required days of electrolysis for the palladium rods that load much slower. The real or artifact question stems mainly from the fact that two similar GM detectors often gave different results in monitoring the excess radiation. A few experiments, nevertheless, gave simultaneous anomalous effects from two different radiation detectors.

INTRODUCTION

Anomalous radiation at China Lake was first detected by the exposure of dental X-ray film in two experiments producing excess power (Ref. 1). Anomalous radiation counts were simultaneously observed with a GM detector during the time of the dental X-ray film studies (Ref. 2). There was no exposure of similar X-ray film and no anomalous GM results in more than 20 following experiments where no excess power was detected (Refs. 2, 3).

EXPERIMENTAL DESIGN AND PROCEDURE

Radiation monitoring was imposed due to safety concerns about our experiments. The detection of anomalous radiation generally involved the use of a thin end window GM alpha-beta-gamma detector (Ludlum model 44-7) positioned within 6 cm from the tops of the electrochemical cells. According to the tube manufacturer (LND, Inc.), the energy response for this detector shows a peak in the relative count rate for photon energies near 60 to 80 keV. Photon energies below 40 keV can enter the detector only through the thin end window and

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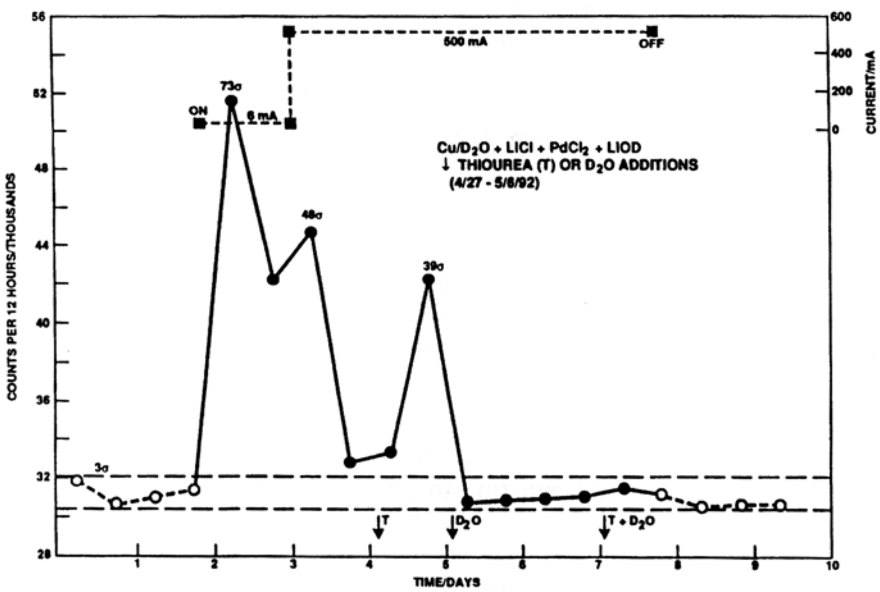
would not escape from the electrolysis cell submerged in a water bath to reach the detector. Several different Ludlum model 44-7 detectors were used in our experiments as well as GM detectors from another company (TGM Detectors, Inc.). There was considerable variation between supposedly identical GM detectors with regard to their voltage plateau (Ref. 2) and sensitivity. Sodium iodide (NaI) gamma scintillator detectors (Ludlum model 44-2) were used in some experiments. The selected detectors were connected to scalar ratemeters (Ludlum model 2200) and printers (Casio model HR-8A).

RESULTS

The Ludlum GM detector (model 44-7) used in most experiments gave a mean background of 31296±275 counts per 12 hours (Ref. 2). Most Pd-D_2O+LiOD electrolysis experiments gave normal counts with all results falling with ± 3σ of the mean background (Ref. 2).

Our exploration of the co-deposition method reported by Szpak et al. (Ref. 4) produced



the rapid appearance of anomalous radiation counts as shown in Figure 1.

Figure 1. Anomalous radiation counts observed during a palladium-deuterium co-deposition experiment. The black circles show radiation counts during electrolysis.

This method involves the simultaneous deposition of palladium metal and deuterium onto a copper cathode from a D_2O solution containing 0.05 M $PdCl_2$ and 0.3 M LiCl. The first 12-hour count after switching on the electrolysis current (6mA) gave an anomalously high value that was 73 sigma above the normal background count (Figure 1). The anomalously high counts continued for several days before returning to normal. Several other co-deposition experiments gave similar anomalously high-count rates shortly after switching on the electrolysis current (Ref. 3).

In an effort to identify this anomalous radiation, two experts in radiation studies brought X-ray and germanium detectors from the Naval Research Laboratory (NRL) to China Lake. We could never reproduce this effect during these visits. An example of five short experiments during one of their visits is shown in Figure 2.

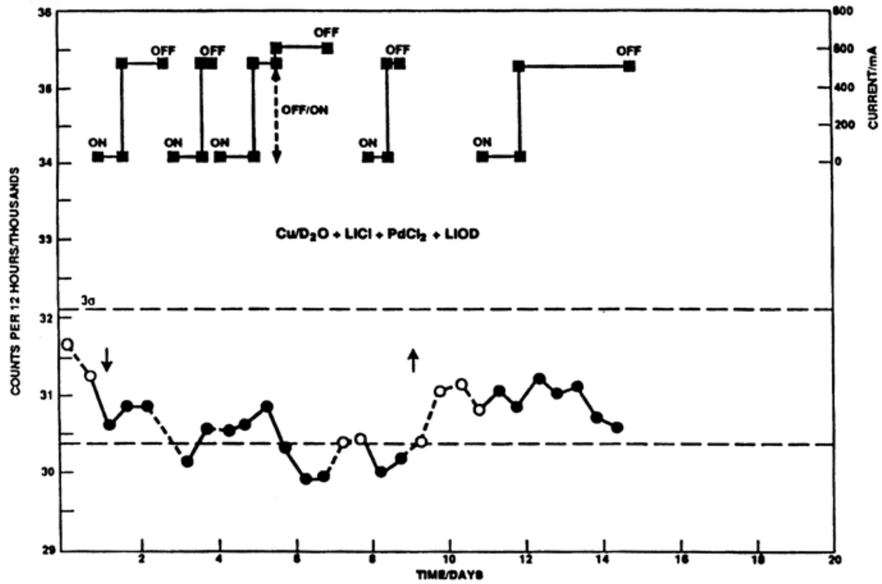


Figure 2. Five successive palladium-deuterium co-deposition experiments that showed no anomalous radiation. The same GM detector as in Figure 1 was used. NRL X-ray and germanium detectors placed near the cells also showed no anomalous radiation.

It can be seen from Figure 2 that the NRL X-ray and germanium detectors actually blocked some of the background radiation to give unusually low counts for our GM detector.

We later realized that the faster we set up the experiments, the less likely it would be that the anomalous radiation effect would appear. We always performed experiments as rapidly as possible when the NRL equipment and experts were available. This "NRL Effect" was probably related to the presence of residual chlorine in our system. The use of the PdCk-LiCl-D_2O system produces chlorine gas as well as oxygen gas at the anode. This chlorine gas would linger in the tubing connecting the cell to the oil bubbler and would affect the next experiment if it were not flushed out or given sufficient time to dissipate. In experiments that were conducted quickly where there would be chlorine in the system from the previous experiments, we observed no anomalous radiation in eleven experiments (0/11). These experiments included all the studies where NRL equipment was used. Studies that involved a N_2-flush of our system to remove chlorine or no prior experiment with that system gave anomalous radiation in five out of eight experiments (5/8). Whenever we allowed three days or longer between experiments, anomalous radiation was observed in three out of five co-deposition experiments (3/5). It is unlikely that this relationship to the presence of chlorine and the anomalous radiation would be observed if our measurements were due to some experimental artifact. The chlorine present in the system can passivate the copper cathode and hinder the palladium deposition.

There was no obvious correlation between the anomalous radiation effect and excess heat measurements in the co-deposition experiments. However, the volume of the deposited palladium was less than 0.002 cm^3 based on the amount of the palladium chloride that was present in the solution. Assuming that the excess heat effect would be in our usual range of 1 to 5 watts per cubic centimeter of palladium, the amount of excess heat would have been too small to be detected by our calorimeter (± 20 mW sensitivity). Excess heat was measurable in only 2 out of 34 co-deposition experiments (Ref. 3).

Anomalous radiation effects were also observed using palladium rod cathodes in LiOD-D_2O electrolysis (Ref. 2), but this effect appeared much less frequently than in the co-deposition experiments. For example, there was one period of time lasting almost a year where there was no anomalous excess heat or radiation from our experiments. A major difference for experiments using palladium or palladium alloy cathodes was that a week or two of electrolysis was required before the anomalous radiation counts appeared. An example of this is shown in Figure 3 for a Pd-Ag alloy cathode. This experiment also demonstrates anomalous radiation counts from both a GM detector and a sodium iodide detector. This experiment involved two cells run in series with the GM detector near Cell A while the sodium iodide detector was placed near Cell B (Ref. 3). Although, the detectors were focused on two different cells, they were both above the same water bath and less than 30 cm apart. Many of the peaks for anomalous radiation seemed to occur simultaneously for both detectors as seen in Figure 3. The radiation counts returned to normal for both detectors when the electrolysis was turned off (Figure 3). There was no excess heat detected in either cell.

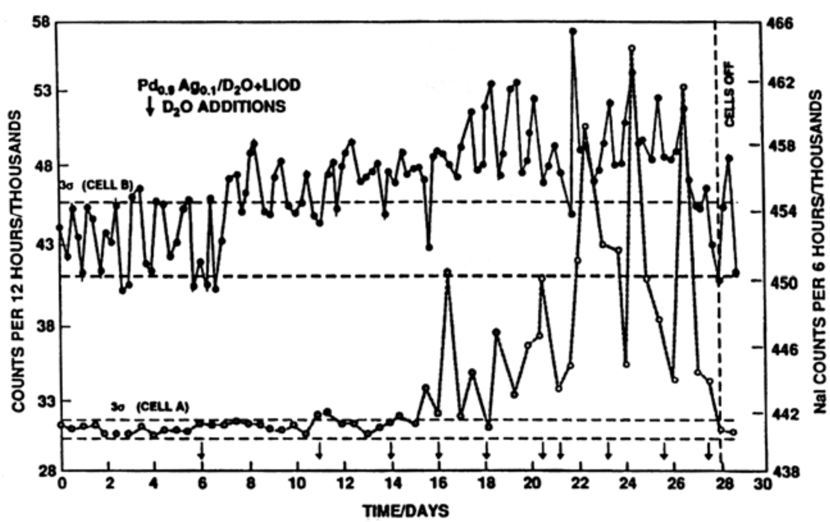


Figure 3. Anomalous radiation during Pd-Ag alloy experiments in D_2O+LiOD using two different detectors. Both the GM detector (bottom curve) and the sodium iodide detector (top curve) showed anomalous radiation after 8-15 days of electrolysis.

The question whether these anomalous radiation measurements are real or experimental artifacts stems from the fact that two similar detectors often gave different results in monitoring the excess radiation. One GM detector would measure anomalous radiation while another GM detector would be "blind" to any anomalous effect. A few experiments such as the one shown in

Figure 3, nevertheless, gave simultaneous anomalous effects from two different radiation detectors.

There was always a decrease in the anomalous radiation when the detectors were moved away from the electrolysis cells (Ref. 5). There was no observable change in the anomalous radiation when the scalar ratemeters used in these experiments were switched to battery power and disconnected from the electrical lines. No anomalous count rates were ever observed when the electrolysis experiments were off

CONCLUSIONS

The question posed in our title concerns whether the anomalous radiation effect is real or due to experimental artifacts. The arguments for artifacts are that the effect was never reproducible and that many GM detectors were blind to the anomalous radiation counts being measured by another detector. Furthermore, the anomalous radiation counts often did not correlate with the detection of excess heat in the experiment. There are stronger arguments, however, that the anomalous radiation effects were real. First, the radiation was observed by several techniques including X-ray film exposure, several different GM detectors, and by sodium iodide detectors. Second, there was a decrease in the anomalous radiation when the detectors were moved away from the electrolysis cells. Third, the anomalous radiation appeared within a few hours of starting the electrolysis for co-deposition experiments where there is rapid loading of deuterium into the palladium. Fourth, the anomalous effect required one to two weeks of electrolysis for solid palladium rod cathode materials where the loading is much slower. Fifth, no anomalous radiation counts were ever observed when the electrolysis experiments were off. Perhaps the strongest evidence that the anomalous radiation effects at China Lake were real comes from later experiments conducted at another Navy laboratory. The anomalous emission of low-intensity X-rays during the cathodic polarization of similar Pd/D systems was reported by Szpak et al. (Ref. 6) using special cell designs that allowed the positioning of X-ray and γ-ray detectors close to the cathode.

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