Radiation Produced By Glow Discharge in Deuterium

Edmund Storms and Brian Scanlan
KivaLabs, LLC

ABSTRACT

Radiation produced by low-voltage discharge in a gas containing deuterium was measured using a Geiger counter located within the apparatus. This radiation was found to consist of energetic particles that were produced only when the voltage was above a critical value. In addition, the emission was very sensitive to the presence of oxygen in the gas. In the presence of the required conditions, emission occurred reliably with reaction rates in excess of 10^8 events/second.

I. INTRODUCTION

Evidence for the LENR effect was and still is based to a large extent on production of anomalous energy. Many of the observations imply nuclear reaction rates in excess of 10^{12} events/sec. In addition, the presence of detectable helium, tritium, and transmutation products show that nuclear products are, in fact, produced. Absence of expected conventional radiation, consisting of neutrons and gamma, has long since been acknowledged. Nevertheless, such a high reaction rate is expected to produce detectable X-ray emission even if the primary radiation cannot penetrate the surrounding wall. Failure in the past to detect any kind of radiation has led some theoreticians to propose a direct coupling of energy to the lattice, without need for emission of radiation or energetic particles of any kind.

With increasing frequency, as proper detectors are used, researchers are observing several types of radiation, as summarized in a recent book [1]. These emissions consist of X-ray, gamma ray, and various charged particles. Although the intensity of these emissions cannot explain the high levels of heat observed during some experiments, the mere existence of such energetic radiation raises important questions, such as the following.

1. Does the detected radiation result from one nuclear reaction or do several energetic processes occur at the same time?
2. Is any of the energy generated by these nuclear reactions coupled to the lattice? If so, why is the energy associated with the detected emissions not coupled?
3. Does the primary nuclear reaction produce the reported X-radiation or does it result when emitted energetic particles are absorbed by the surrounding material?

This study was initiated in an attempt to answer these questions using low-voltage gas discharge in low-pressure deuterium containing gas. A Geiger-Müller (GM) detector and a silicon barrier detector were located within the apparatus near the discharge. In the process, very energetic electron and particle emission were detected and characterized. These emissions occur at very high intensity and occur reliably within the appropriate voltage, current, pressure, and gas composition. This work is preliminary and is presented only to demonstrate that such radiation can be produced without making claims about its source or the mechanism of its production.

II. EXPERIMENTAL

The apparatus is shown in Fig 1. A turbomolecular pump is located below the table on which the apparatus is supported. This pump can produce a vacuum of less than 10^{-6} Torr in the discharge cell prior to adding deuterium-containing gas. Gas pressure within the cell during discharge is measured by Baratron gauges (0-10 and 0-100 Torr) located at the rear. To the left of the cell are connections for the GM detector, which has an end-window of mica (1.7-2.2 mg/cm^2, LND 712). To the right are connections to the water-cooled cathode, which is grounded to the apparatus. Connection to the anode is made out of sight at the rear of the cell. A residual gas analyzer (RGA) is provided to allow gas in the discharge chamber to be analyzed up to mass/charge of 50. Figure 2 shows the anode, which is a 2 mm diameter palladium wire and the cathode, which is surrounded by an insulating shroud. This arrangement allows the radiation detector, located at the left, a clear view of the cathode surface, as can be seen in the cathode-eye view in Fig. 3. The cathode is a thin metal disc directly cooled by flowing water, a design that allows the cathode surface to be easily examined. Details of cathode assembly are shown in Fig. 4. This design can dissipate power in excess of 300 watts, permitting a wide range of current and voltage to be used. A collection of absorbers of different thickness can be placed between the cathode and detector to allow the energy and type of the radiation to be determined. These are moved by magnets from outside the vacuum, as shown in Fig. 5.

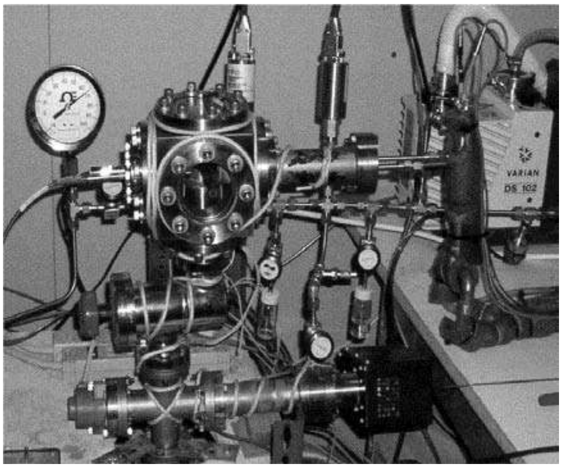

FIGURE 1. Overall view of the apparatus.

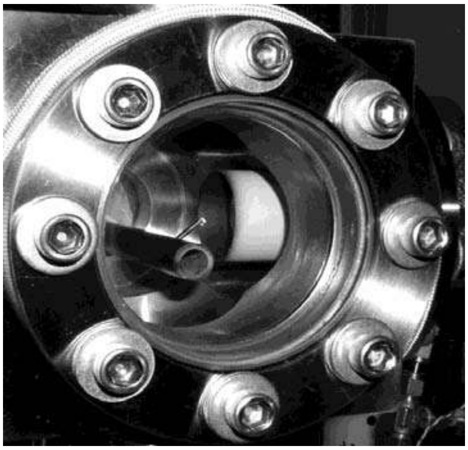

FIGURE 2. View of anode (left) and cathode (right).

FIGURE 3. Cathode-eye view of the GM radiation detector. One of the copper absorbers is seen on the left. The anode is one of several designs using 2 mm wire covered by a glass insulator. The large tube from which it emerges is a glass-filled insulator.

FIGURE 4. Exploded view of the cathode showing the insulating shroud. The cathode disc can be removed and is sealed using a rubber O-ring.

Discharge is produced using a power supply rated at 1.5 A and 2000 V running under current control. Voltage is supplied to the anode through a forced-air cooled resistor of 300 ohm. The supplied current and the voltage at the anode are measured and stored approximately every 6 to 60 sec. Although calorimetry could be done using this apparatus, none was attempted during this study.

A Geiger counter alone or combined with a silicon barrier detector was used to measure radiation. During the first part of the study, the amount of radiation was proportional to a voltage produced by the GM counting circuit that averaged the count rate. A maximum count rate of approximately 5000 counts/sec on scale 10 was limited by the circuit becoming saturated. Later, the count rate was measured directly by counting individual pulses produced by the GM tube, which permitted much greater values to be determined. This design allowed particle production rates in excess of 10^6/sec to be measured, a limit that was imposed only by unwanted electrical discharge to the body of the cell. The energy and type of radiation was determined by placing absorbers of varying thickness between the GM tube and the discharge. Later in the study, the output of the Si barrier detector, shown in Fig. 6, allowed the energy of radiation to be determined directly.

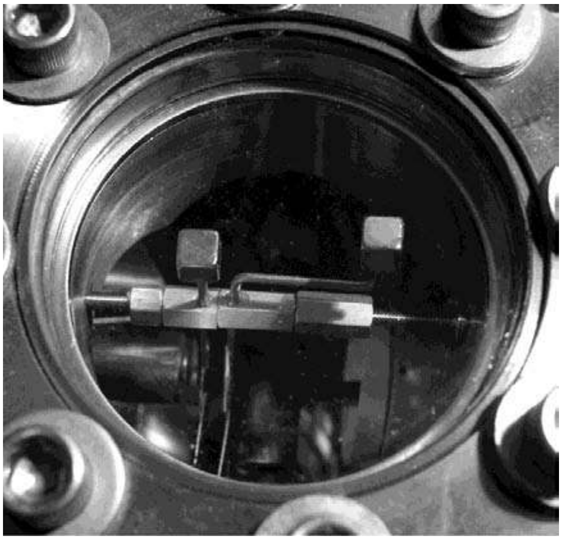

FIGURE 5. View of the mechanism used to move absorbers of varying thickness in front of the GM tube with magnets. Each assembly has two different thickness and an open position, which allows 8 combinations of thickness. The GM tube can be seen on the left.

FIGURE 6. Si barrier detector (Ortec TB-016-050-1000) and GM tube (2.2-2.6 mg/cm^2).

Energetic electrons and charged particles, having several energies, were detected. As yet, these charged particles have not been sorted into proton, triton, or alpha, although the energetic electrons have been clearly identified. Which of these emission, if any, is produced depends critically on small impurities in the deuterium gas and the nature of the glow discharge including its voltage and current.

Before discussing the observed radiation, understanding the nature of a glow discharge is necessary. A discharge consists of three parts; the cathode bright zone, the dark zone, and the anode bright zone. The bright zones occur where sufficient energy is available to cause ionization as electrons move from the cathode to the anode. In this study, the cathode bright zone grows in thickness as applied voltage is increased until it engulfs the anode. Ions created in the bright zones bombard the cathode causing changes in the cathode surface. The resulting sputtering of cathode material causes growth of cones, shown in Fig. 7. As a result, thickness of the cathode increases while its weight decreases. Consequently, material is being lost from regions between the cones while it is deposited on their tops. In addition, any material sputtered from the shroud also deposits on the tops, as indicated by the dark regions seen in Fig. 7. Shroud materials consisting of Al_2O_3, BN, mica-based ceramic, or Teflon were used. All except Teflon worked well. Teflon caused the electron radiation to decay away over about 10 minutes during glow-discharge when it was used with a previously active cathode. When sufficient oxygen is present in the gas in any chemical form, detectable oxide also forms in these regions. The cones are proposed to be the radiation source.

During the first part of the study, only D_2 at a pressure of about 30 Torr was used in the cell to generate the radiation described below. Subsequent work suggested that the presence of a small amount of carbon-containing impurity in the gas was required for success. Too much hydrocarbon in the gas impedes the discharge as carbon is deposited on the cathode surface. On the other hand, a system that is too clean will not produce energetic electrons having an energy described here. Once the discharge become stable and uniform over the cathode surface, the relationship shown in Fig. 8 is obtained. Although variations in this behavior are seen, in all cases this radiation is sensitive to applied current but not to cell voltage. Little change in behavior was found when copper, copper plated with palladium, palladium, Sterling silver, or a Pd+Pt alloy are used as the cathode for producing this type of radiation. The anode is a 2 mm diameter palladium wire in all cases. A distance of 6 mm to 10 mm between the anode and cathode was used, all of which successfully produced the effect.

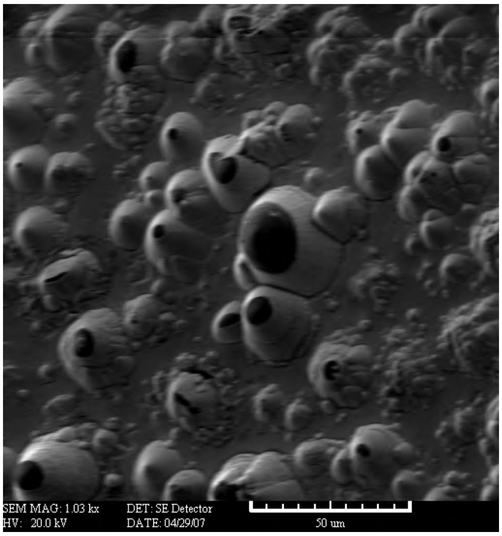

FIGURE 7. Surface of a Pd+Pt alloy after being subjected to gas discharge in D_2 using a ceramic shroud containing the oxides of Mg, Al, Na, Si and K. The black regions contain shroud material that is not present elsewhere.

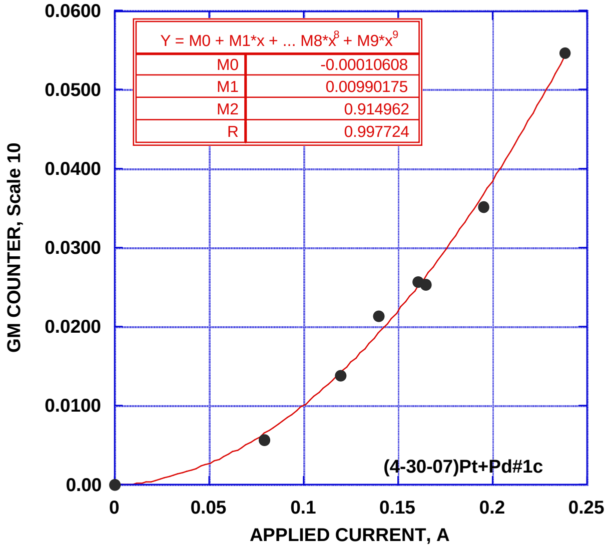

FIGURE 8. Effect of cell current on output of GM counter.

A combination of copper foils of varying thickness were placed between the GM tube and the glow discharge using a cathode made from an alloy of Pd + Pt, surrounded by a mica-based ceramic The result is shown in Fig. 9. As absorber thickness is increased, the amount of radiation reaching the GM tube decreases. However, near the limit, the amount of radiation abruptly increases. This increase is caused by X-radiation, generated by the absorption process (Bremsstrahlung), adding to the remaining electron radiation. Above the limit, only X-radiation remains, which is slowly reduced as thickness is increased. This limit shows that the electrons have nearly a single energy of 0.8±0.1 MeV based on the equation given by Katz and Penfold.[2] Because these electrons are monoenergetic, they do not result from beta decay. Also, when cell current is stopped, the reaction stops abruptly without an apparent decay.

When oxygen containing gas, such as O_2, D_2O, or H_2O is added to the D_2, a different kind of emission is produced. This radiation is completely stopped by an absorber having 1.74 mg/cm^2 added to the absorption produced by the GM counter window of 2.0 mg/cm^2 for a total of ~3.74 mg/cm^2. The radiation could be protons with an energy of at least 0.7 MeV but less than about 1.2 MeV or alphas with an energy of at least 2.9 MeV but less than 4.7 MeV. The low value of this range is required for the particle to pass through the window of the GM tube and a particle having the upper value is stopped by the sum of the window and absorber. Onset of this emission was very sensitive to applied voltage, with a critical voltage below which no radiation was detected. In addition, this behavior was altered by changing the D/O ratio in the gas. Least squares lines drawn through the data were used to obtain values for the slope and the critical voltage at which no radiation was detected. Examples of these effects are shown in Fig. 10 where various isotopes of oxygen are used as the source of oxygen. The effect is not sensitive to the isotopic composition of oxygen. When all measurements are compared, the maximum effect is found to occur when the D/O ratio in the gas is near 0.1, as shown in Fig. 11. In other words, once voltage is increased above the critical value, the voltage has a maximum effect on emission when about 10 atoms of O are present for each atom of D in the gas. When oxygen is added in the form of H_2O, the behavior is the same as when D_2O or O_2 are used. This effect only applies to relatively low emission rates. When the system was designed to measure higher rates and greater voltage was applied, the emission rate is found to increase in a nonlinear way, as shown in Fig. 12, but with the expected effect of increased oxygen.

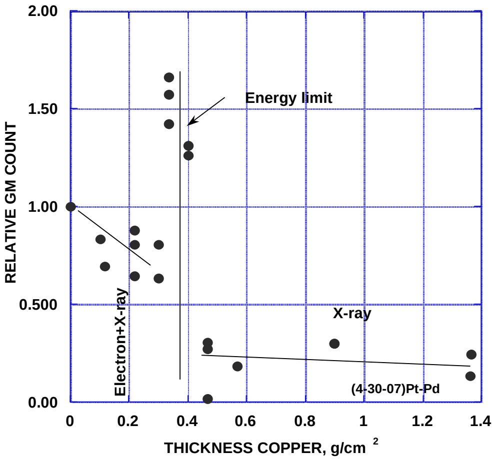

FIGURE 9. Effect of copper absorbers on the amount of radiation reaching the GM tube from a Pd+Pt cathode.

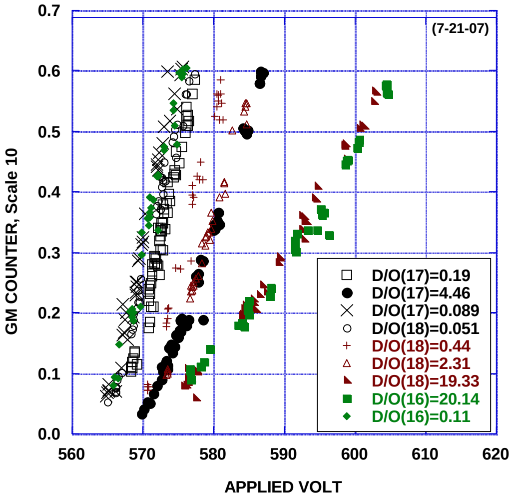

FIGURE 10. Effect of voltage on emission at various D/O atom ratios and with various isotopic compositions of oxygen.

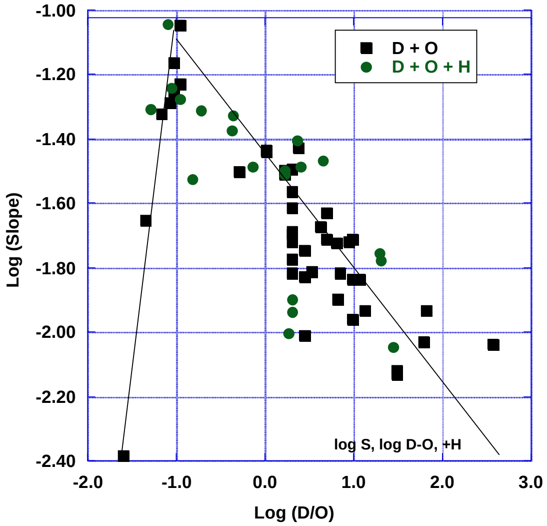

FIGURE 11. Relationship between log slope produced by changing the applied voltage above the critical value vs log D/O atom ratio in the gas. Oxygen was supplied by H_2O in some samples.

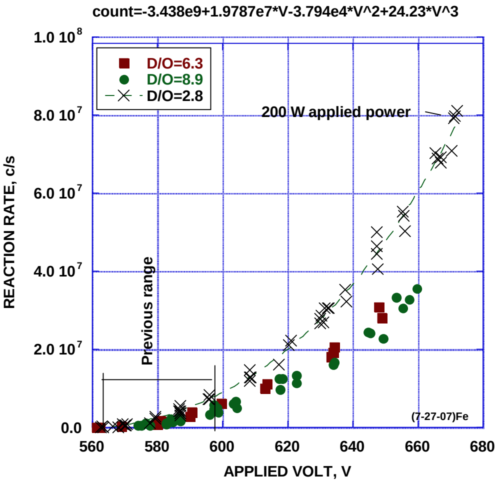

FIGURE 12. Reaction rate, corrected for detector size and distance, vs applied voltage at various D/O atom ratios.

The GM tube is stated by the supplier to have a window with an area density of 1.5-2.0 mg/cm^2. Because this window limits the energy of detected radiation, its value must be known more accurately. For this measurement, a Po^{210} alpha source was moved at various distances from the tube in air and the distance at which no counts were detected was determined. Counts stopped between 2.42 mg/cm^2 and 2.91 mg/cm^2, based on the density of laboratory air. The range of the 5.30 MeV alpha in air is 4.57 mg/cm^2. Consequently, the thickness of the GM window is equivalent to 1.7 mg/cm^2 to 2.2 mg/cm^2. A value of 2.0 mg/cm^2 was used to calculate the absorption characteristics of the GM counter using published values.[3]

IV. CONCLUSION

Energetic emissions are produced during gas discharge that cannot be detected outside of the apparatus. Nevertheless, their energy is so large that they can only result from nuclear reactions. If conditions are appropriate, the emissions are easily reproduced and imply a reaction rate at the cathode in excess of 10^9 reactions/sec, limited only by the design of the apparatus. Consequently, these energetic emissions are completely anomalous, are produced at high rates that can be increased to the rates associated with anomalous heat production, and are not difficult to generate. The observations show that energetic electrons make up part of this emission and energetic particles that might be protons and/or alpha particles add to the radiation, depending on the chemical composition of the cathode and gas. The type of radiation, its energy, and the rate are all sensitive to the presence of certain elements in the environment.

This work indicates that when nuclear reactions are generated at the cathode surface using glow discharge, the energy is not coupled to the lattice, but appears as very energetic charged particles. Because the particles cannot escape most apparatus and their presence can only be discovered when certain kinds of detectors are used, their presence has not been detected before at the rates generated in this study.

If these observations apply to LENR in general, the chemical composition of the environment in which the nuclear reactions are initiated would play a significant role in permitting nuclear reactions to take place and would determine the resulting nuclear products.

References

[1] Storms, E., “The Science of Low Energy Nuclear Reaction”, World Scientific Publishing Co., 2007.
[2] Katz, L and Penfold, A.S., Rev. Mod. Phys., **24** (1952) 28.
[3] Radiological Health Handbook, U.S. Dept. of Health, Education and Welfare, Washington, DC. 1970.