Introduction to Energetic Particle Measurements

The last two sections dealt with two of the three main types of measurements that establish the ability to initiate nuclear reactions with chemical energies. We now turn to the third, namely the measurement of energetic particles immediately given off by LENR. For some scientists in the field, these provide the best evidence of nuclear reactions. The large values of excess heat can be explained only as due to nuclear reactions. However, that logical path is inferential, a matter of eliminating other possible explanations of the heat. And, for many researchers, there are two main problems with looking for new elements (transmutation products) that result from LENR. First, many of the experiments have not been as rigorous as is desired. And, there is the nagging possibility that the elements measured after an experiment were there at the beginning, albeit with very different spatial distributions.

The detection of the prompt emission of energetic particles is thought by many scientists to be the only ironclad means of proving that LENR occur. Such detection, and the quantification, identification and determination of the energy, of neutrons, protons and alpha particles (Helium nuclei), constitute important diagnostics in many LENR experiments. The operation of chemistry does not generate neutrons or ions, such as protons and alpha particles, with energies in excess of 1 MeV. For this reason, the measurement of neutrons and ions has been a part of this field since 1989.

The remarkable fact, now widely known, is that the number of neutrons is dramatically less than would be indicated by the amount of heat produced, if the branching ratios applicable to hot fusion also applied to LENR. The rate of tritium production is also orders of magnitude less than would be consistent with the energy production in the case of hot fusion. In fact, the rate of tritium production is very highly variable, and sometimes tritium is undetectable after a LENR experiment. A compilation by Storms from 15 papers reporting both quantitative neutron and tritium production gives ratios of neutrons to tritium ranging from 10^{-4} to 10^{-9}. Unlike hot fusion, there is no fixed ratio of neutrons or tritium to heat, or to each other. Researchers have struggled to get neutron background levels low enough to confidently detect neutrons from LENR experiments. Many experiments have been done deep in mines, away from the neutrons that come from space.

The other problem with neutron measurements is their small interaction cross sections with matter, liquids and solids included. That is why energetic neutrons are so penetrating, and why the shielding around fission reactors and planned fusion reactors must be heavy and thick. The interaction of neutrons with small detectors is relatively weak. Generally, it is necessary to degrade the energies of neutrons, a process called thermalization. This is done by having the energetic neutrons pass through a material, such as plastic, which has a high fraction of hydrogen atoms. Collisions between fast neutrons and protons share energy due to their similar masses. Hence, the neutrons lose energy relatively quickly in hydrogenous materials. Then, the thermal neutrons have a much higher interaction probability with some elements, notably boron. Such interactions lead to ionization that can be detected electronically. One alternative approach is to cause the thermal neutrons to interact with a scintillation material. Those interactions produce light that can be detected with an optical sensor. Of all the active detectors for neutrons, BF_3 and scintillation detectors have been used most widely in LENR experiments.

In contrast to neutrons, which penetrate long distances through matter, energetic particles have very short ranges. Their charged character leads to strong interactions with the electrons in material, which slows them quickly. Protons with MeV energies have ranges in air of about 1 cm and in plastic of about 10 micrometers. MeV alpha particles can be stopped by a sheet of paper. In the case of these energetic particles, the experimental challenge is to configure experiments and detectors such that the particles can enter the sensitive parts of the detectors. Semiconductor detectors for ions are most widely used in LENR experiments, especially those conducted in low pressure conditions. Such detectors directly produce electrical pulses that are measured to indicate energetic particles. Active electronic detectors require critical downstream electronics, which can quickly register their output. This can be done by a variety of means depending on the type of signal the detector puts out.

In contrast to the active detectors just described for measuring energetic neutrons and ions, there are also passive sensors for both neutrons and ions. Passive detectors, such as photographic film, track detectors (including the polymer CR-39 and some minerals like mica), thermoluminescent detectors and bubble detectors, can be used for particle detection. They have the advantage of integrating over time during an experiment. However, most, but not all of the passive detectors require some type of chemical development or other processing, after exposure. These processes can introduce many variables into the use of the otherwise simple passive detectors.

CR-39 is a type of plastic that is used in some lenses for eyeglasses. It has been quite widely used for particle detection in LENR experiments. Passage of an energetic particle through this material produces chemical changes, sort of like the latent images in exposed but undeveloped photographic film. Neutrons can also cause such changes, if they first interact strongly with some nucleus, which can then move at high speeds through the CR-39 and cause similar latent effects. Chemical etching of exposed CR-39 will preferentially remove the damaged materials, leaving pits, structures that are called tracks. The geometry of the track depends on the type of fast particle and its energy. Calibration data relating track diameters and lengths to the particle type and energy are available, and have been employed to interpret tracks from LENR experiments. In general, there is considerable need for more calibration data for energetic particles and all types of sensors used to detect them.

This conference included a few papers dealing with the measurement of energetic particles or instrumentation for such measurements. They are briefly summarized in the following paragraphs. Then, some general comments are offered.

Lipson and his colleagues measured particle emission from electron irradiated samples of deuterated Pd and Ti using CR-39 covered with foils to provide energy discrimination. Protons with energies near 3 MeV and alpha particles with energies in the 11-20 MeV range were detected in statistically significant numbers.

Oriani also used Cr-39 in two dozen electrolysis experiments. The detectors were in air and close to the cathode for both light and heavy water solutions, but separated from the electrolyte by 6 micrometers of mylar. Significant track densities were found in all cases. In some instances, the tracks were clustered near each other within an area of about one millimeter squared. Sometimes, the orientations of the tracks were such that the particles causing them appeared to be radiating from a small region.

Storms and Scanlan sought to measure energetic particle emission and x-rays from low-voltage discharges in deuterium gas with cathodes of several materials, including Pd. They employed two active detectors, one a gas-filled Geiger-Mueller counter and the other a solid-state silicon surface barrier detector. Many combinations of materials and conditions were explored. They found evidence for both deuterons with energy in the 0.5 to 3 MeV range and for x-rays emitted at rates about 10,000 times the particle emission rates. The particle data is certainly anomalous because the voltages applied to the discharge cell did not exceed 900 V.

Cantwell and McConnell sought to replicate experiments reported earlier by Storms and Scanlan. Two types of radiation had been measured. The paper at this conference reported observations of radiation similar to one of the earlier findings. Low energy x-rays would produce the newly observed behavior.

The work reported by Jiang and his colleagues was motivated by their interest in the geophysical origin of ^{3}He and ^{3}H in the earth. They used gas loading to deuterate samples of foil and powder of Ti and Ti-Mo. Ratios of D to Ti atoms in excess of 1.2 were achieved. The samples were then measured with an energy-sensitive silicon detector. Evidence for proton emission with energies of 2.8 MeV was obtained.

The paper by Toriyabe and Kasagi described a new detector system for charged particle detection in high-temperature gas permeation LENR experiments. The detector consists of two scintillators viewed by a photomultiplier tube. Individual pulses were recorded for off-line pulse shape discrimination to eliminate extraneous counts. Cosmic ray events were excluded by use of large scintillator veto counters. The result was a system with the ability of measure charged particle emissions at the remarkably low rate of 3 counts per day. Permeation of a Pd multilayer foil gave a slight difference in count rates between hydrogen and deuterium at high energies. This might be due to alpha particle emission.

In summary, the evidence for particle emission presented at ICCF-14 added to the database that indicates it is indeed possible to stimulate nuclear reactions at low input energies. As with heat and transmutation measurements, there is great need for additional experimental work on energetic particle emission measurements. The many combinations of materials, loading methods, measurement techniques, and particle types and energies call for exploration. More work is also needed on the development and calibration of detectors and systems to detect and quantify the characteristics of particles emitted from LENR experiments.