Ni-H Systems

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Abstract

We report the results obtained in three different laboratories on the Ni-H system during several years of experiments. Heat production was observed in different cells for long periods, with a maximum power of 70 W. In several occasions we detected gamma ray emission and in one case also a neutron emission. The analysis of Nickel samples which loaded Hydrogen gas showed the existence of other elements not present in the original specimens. Finally, we present tracks detected in a diffusion chamber of ionising particles from a specimen which produced heat.

1 Introduction

The observation by one of the authors (F. Piantelli) of an anomalous behaviour of the system Ni-H was the starting point of a systematic research on these effects [1]. Different cells and specimens were built and put into operation in order to study the characteristics of the phenomenon. For a detailed description of the cells, the reader is referred to [2] [3]. Nickel specimens or specimens of other nickel plated materials, were put into our cells and treated at various temperatures and hydrogen pressures in order to obtain a high level of H-loading. In some cases a relevant absorption was obtained, while other specimens, even if treated in a similar manner, absorbed much less. Typical values of pressure and temperature employed in the loading operations were in the $200 \div 1000$ mbar and $700 \div 800$ K range. The use of subatmospheric pressures guarantees that the observed pressure decreases were due to Hydrogen absorption and not to cell leakage. During the treatments for loading Hydrogen or as a consequence of Hydrogen absorption, a series of different phenomena, which will described in the following, were observed.

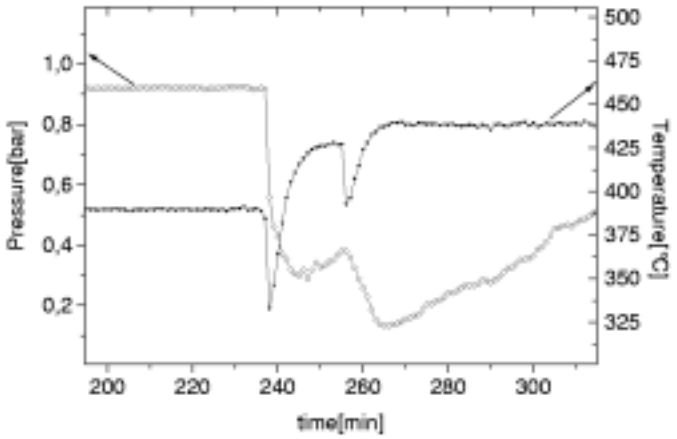

Figure 1: Two pressure shocks causing the sample temperature increase (Termocouple Tc1, figure 1b of reference [2]).

2 Heat production

Apart from the first experiment, whose results are reported in [1], where a heat production effect was deduced by measuring the specimen temperature, in all subsequent experiments heat production was measured with reference to the temperature of the external walls of the cells. In practice, in an initial phase the cell was calibrated: a curve describing the temperature difference between external cell walls and room vs. input power was obtained in equilibrium conditions at a low Hydrogen pressure (200 mbar).

This curve can be approximated as linear in a range of the order of a hundred degrees kelvin and used to calculate the heat exchanged on the basis of the Newton law of convection. The total thermal power emitted from the cell can thus be deduced from a measurement of two temperatures: the wall and the room temperature. Whenever the difference of the two, for a given input power, is above the calibration curve, there must be a power excess coming from inside the cell. In practice the horizontal distance of a point from the curve gives the value of the produced power, as can be seen for example in figure 6 of reference [2]. The apparatus sensitivity to heat production is of the order of a few watts. For this reason we could not observe an eventual excess power production below that a threshold. Usually, the heat production is triggered by a thermal or pressure shock, consisting of a sudden change of input power or of the inside pressure, as shown for example in figure 1. The initial temperature decrease observed in correspondence of pressure jumps is caused by drawing into the sample region of low temperature hydrogen. The successive increase of equilibrium temperature puts in evidence a power production.

For the best case, we obtained an excess peak power up to 70 W, with an average over a period of 10 months of 40 W. During that period of time it was also possible to

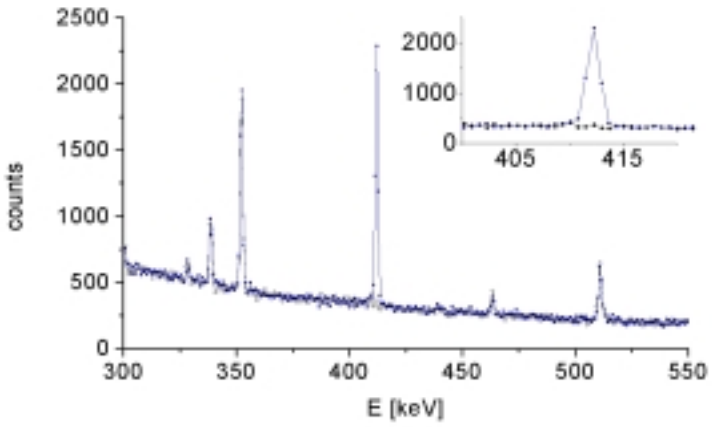

Figure 2: HpGe spectra of activated and not activated Gold. Details of the region around 412 keV are shown in the insert.

stop (typically with an inverse shock) and resume heat production many times. The overall energy production, corresponding in the two best cases [2] to an amount of 600 MJ and 900 MJ, respectively, cannot be explained by chemical reactions because of the low quantity of materials inside the cells. In other shorter experiments, lasting not more than one month, a power production of the order of tents watts was obtained.

3 Neutron emission

Thanks to the long period of heat production of some of the cells it was possible to search for radiation coming from the system, which would be a proof of nuclear reactions occurring inside the cells. In one case alone, we detected neutron emission. This was associated with a spontaneous increase of about 10 W of the power emission, which was kept constant by decreasing the input power. As reported in detail in [4] two methods were used to detect neutrons: one based on the activation of a Gold sheet, the other consisting of counting the neutrons by means of ^{3}He detectors. The activation method is based on the high thermal neutron capture cross section by ^{197}Au, which turns into ^{198}Au. This last isotope decays into an excited state of ^{198}Hg with a 2.7 day halflife. A 411.8 keV gamma ray is emitted in the decay to the ground state of ^{198}Hg. A 5.1x2.4x0.06 cm^3 Gold sheet placed inside a paraffin box was left for 12 days near the cell emitting neutrons. Successively, the sheet was placed above a HpGe detector and the 411.8 keV gamma rays were recorded. The spectrum obtained is shown in figure 2. In the same figure we report in order to exclude effects from cosmic neutrons, the spectrum recorded after the sheet container was kept 12 days 10 m far from the cell. For comparison with the effect produced by an Am-Be neutron source of known strength, it was possible to deduce the intensity of the neutron flux coming from the cell, which resulted in about 6000 neutrons/second. During the same period

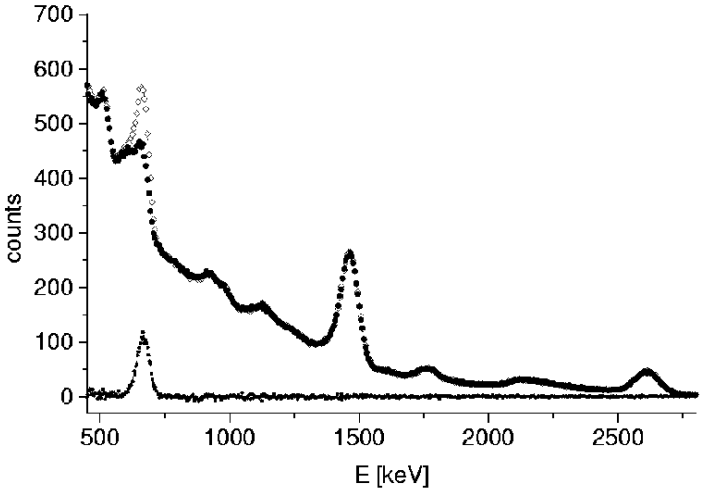

Figure 3: Two consecutive weekly averages of 12000 s NaI spectra, and (lower curve) their difference.

two ^{3}He counters with paraffin and cadmium shielding were placed one near the cell, the other 10 m far away from the cell. Thank to a calibration with the Am-Be source, the counting difference between them permitted us to determine a flux of about 110 neutrons/second from the cell. The apparent disagreement between the two figures can be explained by the time distribution of the neutrons impinging on the near counter, which shows a characteristic arrival in short bursts [4]. Later on, the neutron flux died away. For a period of three months it was monitored by three ^{3}He counters placed near the cell. Data referring to this period, on subtracting the background, give a flux of 2-5 neutrons/seconds. Successively, the heat production was stopped and so did neutron emission. Considering the overall power emitted from the cell and an energy of the order of 1 MeV for each neutron emitted, the ratio between the number of neutron observed and the number of neutron expected is of the order of 10^{-11}.

4 Gamma emission

Another important proof of the existence of nuclear reactions is the emission of gamma rays from the samples. They were measured mainly by means of NaI detectors and also with the use of a HpGe detector. They occurred during periods of cell operation in various experiments. Figure 3 shows two NaI spectra. Each represents the average of 50 runs each lasting 12000 s acquired consecutively. In addition to peaks due to natural background, an extra peak whose energy of 665$\pm$1 keV was measured with a HpGe detector is visible. The 665 keV peak intensity increased with time, as evidenced by the reported difference between the two spectra.

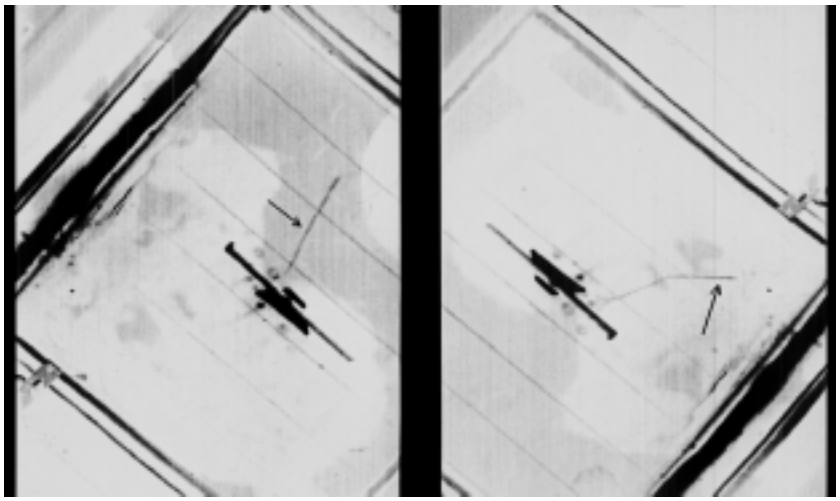

Figure 4: Two tracks from a sample which produced energy.

5 Charged particle emission

The specimen which produced up to 70 watts, at the end of the experiment was extracted from the cell. Two months later it was placed in a diffusion chamber, borrowed from a student laboratory. As shown in figure 4, tracks coming from the sample appeared. The strong ionisation and the absence of straggling allows us to exclude electrons as responsible for the tracks. Unfortunately, this simple kind of chamber cannot be used to make a quantitative and precise measurement. Nevertheless, on having observed tracks of length up to 9 cm, α particles can also be ruled out. In fact α particles of this range would have an energy of about 20 MeV, which is too high for α emission from known radioactive elements.

6 Surface analysis

A surface analysis of the specimens after conclusion of their treatments in the cells was done on some of the first samples [5] and later systematically. These studies were performed by means of a SEM microscope with EDX probe. This analysis was suggested by the observation that those samples which produced energy had a different surface appearance with respect to that at the beginning of the experiment. The surface appeared corroded and sometimes little spots were present. The results of these analysis can be summarised as follows. Whenever there was heat production or a sensible Hydrogen loading, elements not previously detectable by SEM were detected on the surface. These elements are usually found in little spots or in the corroded regions. We found F, Na, Mg, Al, Si, P, S, Cl, K, Ca, Cr, Mn, Fe, Cu, Zn. Apart light elements, not detectable by SEM, we found in practice, with the exception of Sc, Ti, V and Co, all the elements lighter than Ni, plus Cu and Zn. In each spot only some of these were detected, but their EDX signal was in some cases even stronger than that of Nickel. The proportion of the elements changes from place to place. Other

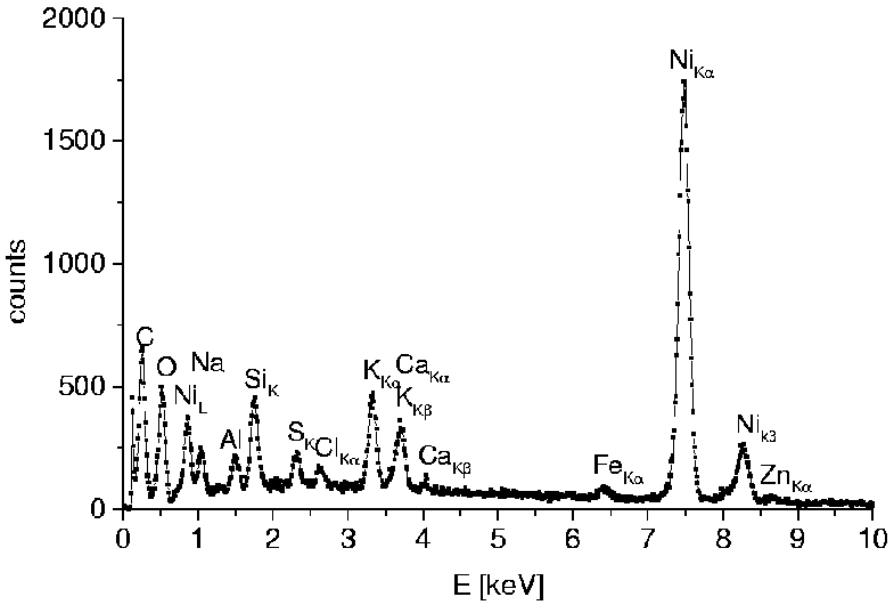

Figure 5: EDX spectrum showing the appearance of elements absent before the run.

authors, working with electrolytic systems, reported the presence of elements different from those initially present in the specimens (see for instance [6] [7]). Figures 5 reports the EDX spectrum relative to a spot with other elements not present before the treatment.

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