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Research Article

Investigation of Radiation Effects in Loading Ni, Be and $LaNi_5$ by Hydrogen

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Abstract

The installation permitting to investigate gamma, X-ray and neutron radiations emitted by metals loaded with protium–deuterium mixture at temperature up to 750°C and pressure up to 100 bar is created. It was discovered that $LaNi_5$ powder, nickel and beryllium are radiated presumably X-rays and neutrons. Radiation emission occurs in the form of short bursts or series of bursts lasting up to several tens of minutes.

Keywords: Gamma, Metals loaded with protium–deuterium mixture, Short bursts or series of bursts, X-ray and neutron radiations

1. Introduction

Detailed study of nickel–hydrogen system properties, provided by F. Piantelli, S. Focardi, A. Rossi and other researchers, clearly showed that in this system occurs not only chemical but also Low-Energy Nuclear Reactions [1–3]. Based on these studies, installation emitting hundreds kilowatts of energy have been created with a very low hydrogen consumption [4,5].

Our researches have purposed to check the presence of nuclear transmutations in loading of different metals by hydrogen with registration of radiation with which the nuclear transformations should be accompanied. Apart from nickel, we investigated intermetallic compound type of $LaNi_5$, which is able to absorb hydrogen multiply exceeds a pure nickel [6]. Beryllium was investigated as material which has ability to undergo cold transmutations is predicted by Erzion model [7–10].

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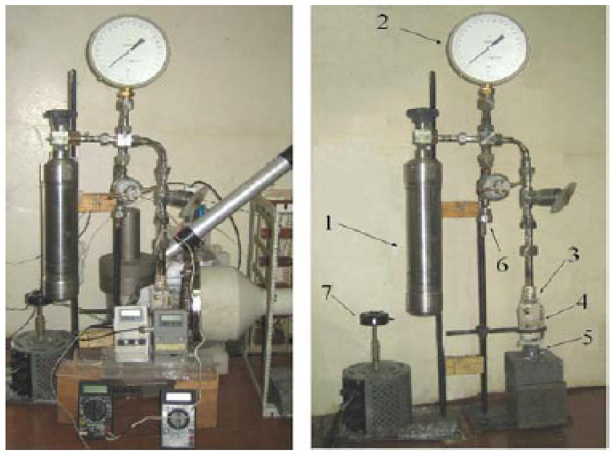

Figure 1. The experimental set-up. *Left*–a view with a complex of measuring apparatus, *right* – without it.1- vessel with protium–deuterium mixture, 2- manometer, 3 – cylindrical cell containing substance under investigation, 4 – electric heater, 5 –collimator for gamma source, 6– offshoot to the vacuum pump, 7 – heater power regulator.

2. The Experimental Set-Up

The experimental set-up (Fig. 1) consists of a vessel with protium–deuterium mixture under the pressure of several tens of atmospheres: (1) the intermediate pipe and the cylindrical cell, (3) containing substance for investgation. The cell is surrounded by electric heater (4) that provides heating up to 700°C. The intermediate pipe has offshoots to the manometer (2) and oil-free vacuum pump (6). The temperature of the cell is measured using thermocouples mounted on it. Determination of investigated substance saturation degree was by dimension of hydrogen pressure changing in the vessel of known volume.

Particular attention was paid to the registration of radiation that may arise during experiments (Fig. 2). A counter with NaJ (Tl) scintillator Ø40 $\times$ 40 mm was used for detecting gamma radiation. In adition to it, four Geiger counters were used in the experiments. Two counters have a window made of thin mica (about 10 μm thick). Such counters are able to detect X-rays and gamma rays with quanta energies as low as several keV, beta radiation and even alpha particles. One of them was covered with 2 mm thick Teflon layer. In addition, two Geiger counters with metallic walls were also used with one of them also carrying additional 2 mm Teflon layer. These counters are able to detect gamma rays with quanta energies above 50 keV and beta particle energies above 0.5 MeV. For the detection of neutrons ^{3}He-counter, located in water serving as a moderating medium, is used. Such detector possesses high and approximately the same sensitivity to neutrons over a wide energy range – from 10s of eV to several MeV, coupled with extremely low sensitivity to gamma radiation.

We used a specially equipped computer for automatically recording temperature and count rate of radiation detectors information. The peculiarity of the used recording system is the ability to record short bursts.

3. Investigations of Thermodynamic Properties of Researched Substances

Figure 3 shows a typical course of interaction between doped $LaNi_5$ powder and hydrogen: loading and releasing when heated in fixed volume. Short-term opening of the vessel with hydrogen leads to a jump in pressure, which immediately begins to drop as a result of hydrogen absorption. This is accompanied by an increase of the cell temperature by

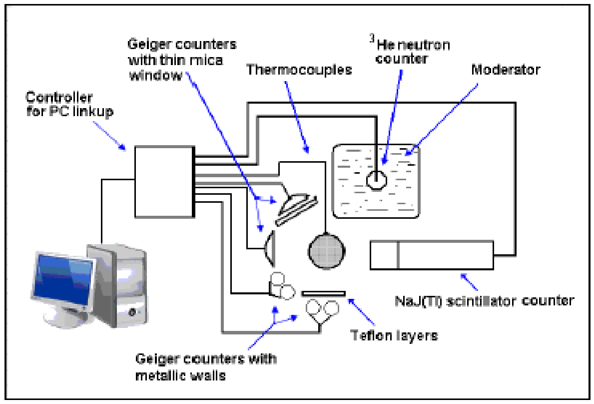

Figure 2. Equipment complex for radiation and thermal measurements.

several °C. After switching on the external heater at a temperature near 80°C begins a rapid release of absorbed hydrogen, resulting in rapid growth of the pressure. After reaching a temperature of 250°C, the pressure is almost stabilized and may even decline, despite the rising temperature. This effect can be explained by the fact that in this temperature range, absorption capacity of powder as the pressure increases faster than the release of hydrogen associated with the heating. After turning off the heater, a rapid decrease of pressure begins only after the temperature drops below 200°C. After cooling to room temperature, the pressure returns to a value close to the initial.

The pressure diagrams obtained in the experiments with nickel and beryllium are similar to the diagrams obtained in the experiments with $LaNi_5$, but pressure modifications are less, as ability of these substances to absorb hydrogen is smaller than $LaNi_5$.

4. Detection of Neutron Radiation

The character of signals registered by ^{3}He neutron counter in the experiments with nickel and beryllium foils and with nickel powder, is similar (Fig. 4). Registration of neutrons, is authentic exceeding background, is observed only at

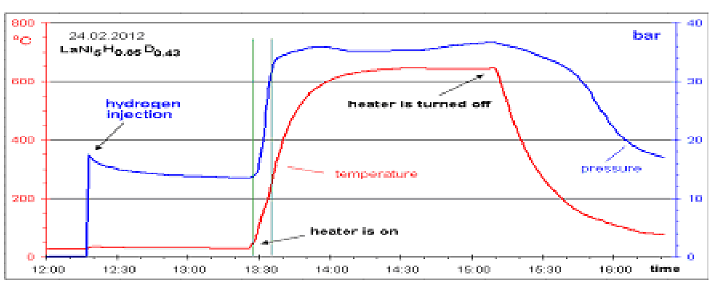

Figure 3. Typical course of interaction between doped $LaNi_5$ powder and hydrogen. Hydrogen injection leads to a jump in pressure, which immediately begins to drop as a result of hydrogen absorption. This is accompanied by an increase of the cell temperature by several °C. At temperature of 80°C begins a rapid release of absorbed hydrogen, resulting in rapid growth of the pressure. After reaching a temperature of 250°C, the pressure is almost stabilized. After cooling to room temperature, the pressure returns to a value close to the initial.

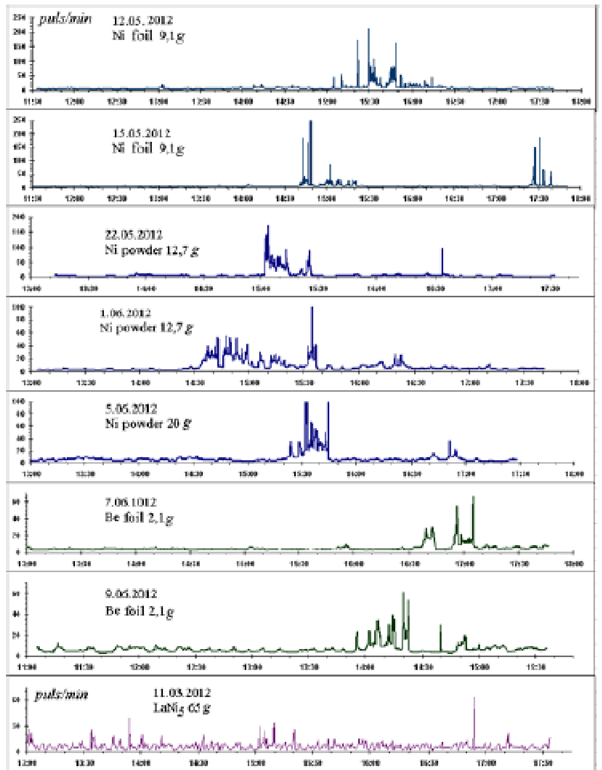

Figure 4. Character of signals registered by ^{3}He neutron counter. One registered impulse corresponds approximately 200 emitted neutrons.

temperatures above 200–300°C, and count rate fluctuates over a wide range. Common number of emitted neutrons - from several tens of thousands up to several hundred thousands in one experimental run.

Differently $LaNi_5$ powder exhibits. Signals from the counter of neutrons have an aspect of separate short bursts appearing even at room temperature. Let us consider some experiments closer. In Fig. 5, the outcomes one from experiments with nickel powder are shown. During 60 min, 1230 impulses over background are registered. It corresponds to 245,600 neutrons emitted from the sample. The intensive neutron counter impulses registration happened at pressure 64 bar and temperature 250–350°C.

In Fig. 6, the outcomes one from experiments with beryllium foil are shown. During 25 min, 232 impulses over background are registered. It corresponds to 46,400 neutrons emitted from the sample. The intensive neutron counter impulses registration happened at pressure about 56 bar and temperature 250–350°C.

In one experiment with nickel powder by means of alternative activation measuring technique, we checked that the used ^{3}He counter registered *just neutrons* (see Fig. 7). From 15:21 till 15:44 June 5 the neutron counter has registered 577 pulses over background. It corresponds to 11,5000 neutrons, emitted from the sample. The radiation of neutrons happened at pressure 61 bar and temperature about 350°C.

Same time on a distance about 4 cm from the sample, the indium foil by square 6.6 cm^2 and 0.35 mm thickness was placed. The measurement of indium activity was made by means of thin mica window Geiger counter. The measured

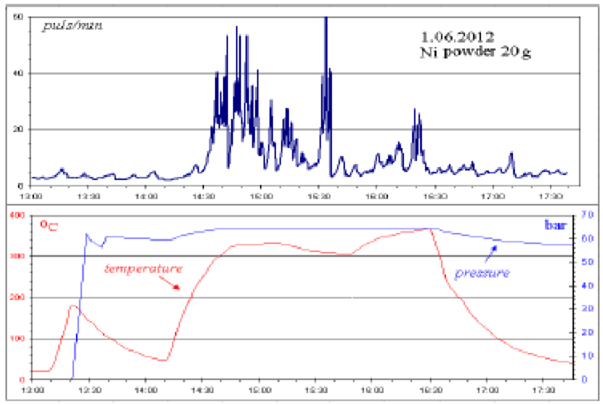

Figure 5. Experiment with nickel powder. From 14:30 till 16:30 1230 impulses over background are registered. Intensive neutron counter impulses registration happened at pressure 64 bar and temperature 200–350°C.

count rate of activated indium foil in view of a decay with a half-life 54 min was (0.432 ± 0.022 s^{-1}). Background was (0.383 ± 0.016 s^{-1}). With the account of beta particles absorption in a foil and counter window it corresponds to indium activity ($0.6 \pm 0,3$) Bq. Such activity could be created by neutrons flux 2000 cm^{-2}. In view of geometry full number of the radiated neutrons 400,000 $\pm$ 200,000, which is equal (115,000 $\pm$ 500) neutrons.

Taking into account neutron spectrum uncertainty and weakness of activation effect, it is possible to recognize satisfactory fit of two methods measurements. It confirms the neutron reason of neutron counter impulses.

In difference from experiments with a nickel and beryllium, the signals from loaded by hydrogen LaNi5 sample has an aspect of separate short bursts (Fig. 8). It is visible that count rate bursts happen not only at high temperature and pressure, but also at room temperature and pressure close to atmospheric. It confirms experiment realized at room temperature in air environment at atmospheric pressure (Fig. 9).

Figure 10 shows time intervals distribution for small (four neutron events in counter) neutron bursts which gives us

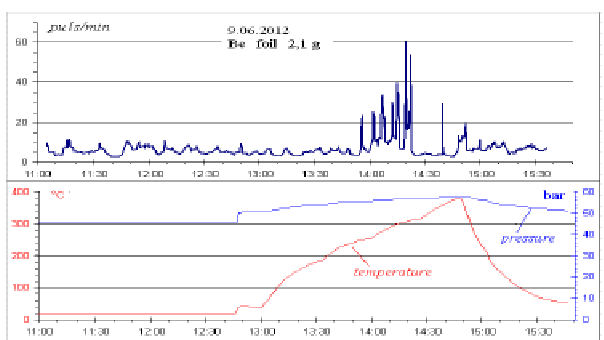

Figure 6. Experiment with beryllium foil. From 13:55 till 14:20 232 impulses over background are registered. It corresponds to 46,400 neutrons emitted from the sample. The intensive neutron counter impulses registration happened at pressure about 56 bar and temperature 250–350°C.

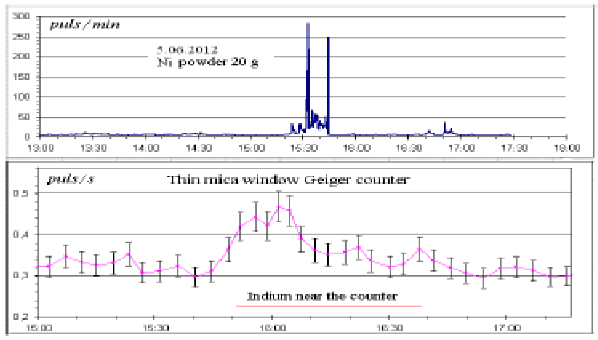

Figure 7. Experiment with nickel powder. Measurements of emitted radiation by two various techniques. Count rate of the neutron counter (*above*) and outcomes of indium activity measurement (*below*).

mean time interval value about 5 s in experiment with Ni powder loaded by hydrogen. Neutron bursts emission from $LaNi_5$ sample were found out in a wide range of temperatures (from room temperature to 650°C) and pressures (from

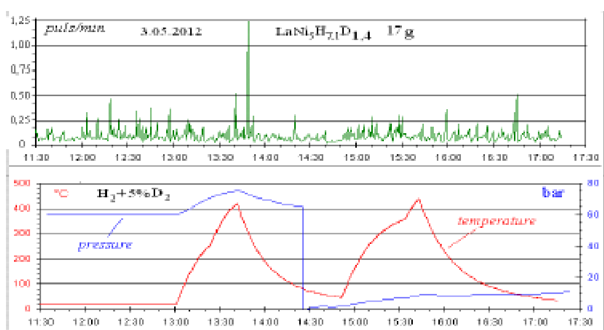

Figure 8. $LaNi_5$ powder. Signal from the neutron counter during temperature and pressure variations.

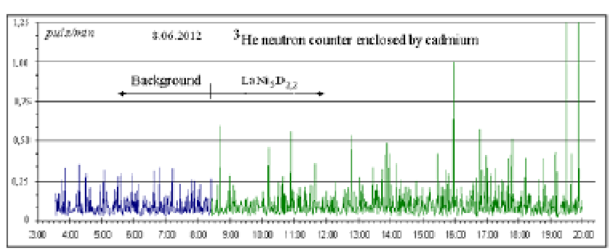

Figure 9. Count rate of ^{3}He neutron counter, wrapped up in cadmium sheet. Arrangement under cadmium of $LaNi_5$ sample, loaded by deuterium, increases significantly of bursts frequency and amplitude.

atmospheric pressure to 75 bar) and at different ratios of deuterium–protium (from tenths of percents up to 100%). Mandatory condition of bursts emission is sufficiently high saturation with hydrogen – greater than one hydrogen atom per one $LaNi_5$cluster.

5. Gamma and X-ray Detectors Measurements

Detection of gamma radiation with photon energy with the threshold of about 50 keV by means of metallic Geiger counter and scintillation gamma-radiometer not found any effects. The most productive were Geiger counters with thin mica window, including a counter screened with Teflon. The emission occurs mainly in the form of short bursts or series of bursts lasting up to several minutes. Usually bursts in different detectors did not coincide in time. But several instances of quite credible coincide in two and three channels were registered.

In Fig. 11, two series of count rate bursts of the thin window Geiger counter and two series of a signal from the neutron counter which is not were synchronized to bursts, registered by the Geiger counter are visible. Two Geiger counters with metal walls not revealed noticeable effects at this time.

Figure 12 shows example of bursts synchronously recorded by three detectors. The strongest count rate bursts, as usual, gave a counter with a thin mica window – the excess above the background up to 200 times. Counter screened by Teflon gave peaks in excess of 10 times higher than the background value. Splash of more than four times of the background gave the metal counter, screened by Teflon, while the counter with metal walls and no Teflon layer did not give signals rising above background.

What did counters register? Detection of gamma radiation by means of metal Geiger counter and the scintillation

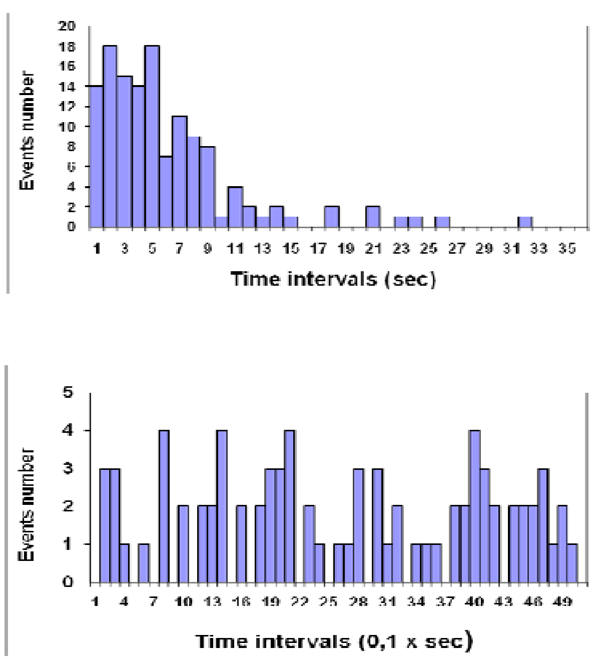

Figure 10. Time intervals distribution for which recorded every four events between 15:22 and 15:44, when the effect was strongest (06.06.12).

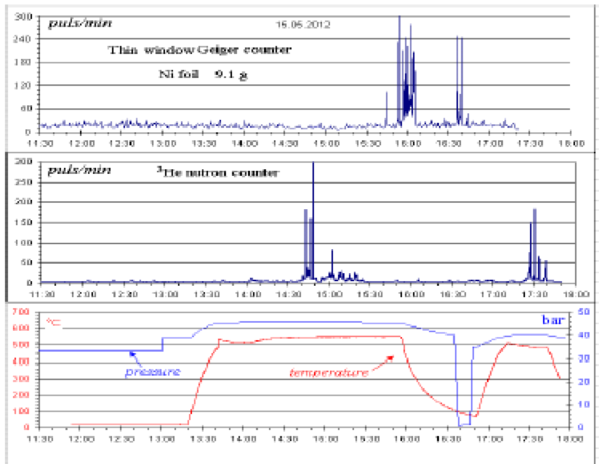

Figure 11. Bursts registered by thin window Geiger counter and ^{3}He neutron counter during experiment with nickel foil.

gamma-radiometer with energy threshold of about 50 keV did not reveal any effects, as noted above. Consequently, registered radiation cannot be gamma rays with energies above 50 keV. Such radiation would have made all the counters to respond. The assumption that it was beta radiation does not hold either, because beta particles with energies of less than 0.5 MeV, which cannot be registered by metallic Geiger counter, also would not have been registered by counters with a Teflon layer which is thick enough to absorb such beta particles completely. But they did show the effect. For the same reasons, any strongly ionizing radiation like alpha particles must be excluded from consideration.

The only radiation whose properties can explain the totality of the results is the X-rays with photon energies less

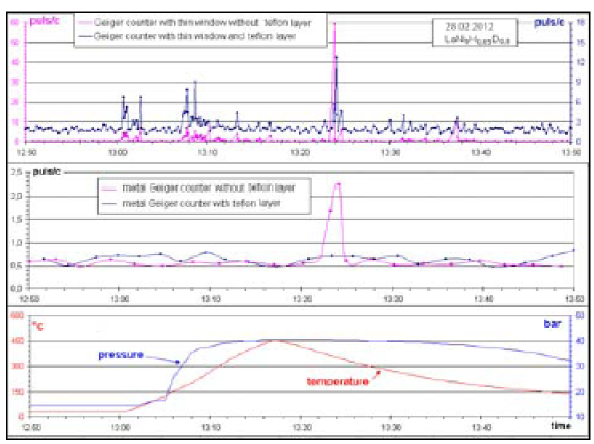

Figure 12. Synchronous count rate bursts of two Geiger counters with thin windows, one of which is screened with Teflon thickness of 2 mm (*top*) and count rate spike of Geiger counter with a metal wall (*middle*). Counter not covered with Teflon showed no discernible signals over the background level.

20 keV. It is almost completely absorbed by thin layers of materials with sufficiently high atomic weight, such as iron or copper, and only weakly attenuated by substances with low atomic weight, including Teflon. The walls of the metal used in our Geiger counters are made of stainless steel with a thickness of 0.1 mm. Such wall weakens X-rays with energies of 20 keV to more than 10 times, whereas the Teflon layer thickness of 2 mm reduces it only two times. It is clear that such radiation could hardly be registered by counters with metals walls but can easily produce significant effects in counters with thin window even if they are covered with Teflon.

However, analyzed sample cannot be the *immediate* source of registered X-rays with energies of about 20 keV because it is located in metallic vessel with walls thick enough to cause a complete absorption of this kind of radiation. It can be assumed that the powder emits a kind of radiation, having a relatively high penetrating power, which generates X-rays outside of the vessel, during interactions with Teflon or other substances. This may explain the fact that the bursts were observed in the metal counter, only if it was covered with Teflon.

6. Conclusions

- $LaNi_5$ powder loaded by hydrogen, and also nickel and beryllium in atmosphere of hydrogen at the increased pressure and temperature, are radiated presumably X-rays and neutrons. It indicates that in these substances under some conditions happen not only chemical or structural modifications, but also nuclear.
- Radiation emission occurs in the form of short bursts or series of bursts lasting up to several tens of minutes.
- Radiation emission occurs at different ratios of deuterium–protium (from 10s of percents up to 100%).
- Radiation emission from a nickel and beryllium are found out at pressure above 50 bar and temperature above 200°C.
- Radiation emission from $LaNi_5$ powder occur at a sufficiently high saturation with hydrogen – greater than one hydrogen atom per one $LaNi_5$cluster.
- Radiation emission from $LaNi_5$ powder occur in a wide range of temperatures (from room temperature to 650°C) and pressures (from atmospheric pressure to 75 bar).
- Neutron generation corresponds up to $\sim$500,000 neutrons emitted from the sample during $\sim$1 h.
- Time intervals distribution for small (four neutron events in counter) neutron bursts gives mean time interval value about 5 s

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