ANOMALOUS INTERACTION OF ULTRACOLD NEUTRONS WITH BERYLLIUM TRAP SURFACE

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In connection with the task of neutron lifetime measurement [1] UCN interaction with walls of the beryllium trap has been investigated. The well-known problem of UCN prolonged confinement connected with UCN inelastic scattering on trap walls due to hydrogenous compounds [2] was supposed to be solved by preliminary traps degasing in vacuum at 700 *K* temperature followed by their cooling to the low (10—15 *K*) temperature during the measurements.

A theoretically attainable loss level for a beryllium trap at the (10—15 *K*) temperature should be much less than 1 per cent of a neutron β-decay probability. Previous studies of temperature dependencies of a total cross-section for "very cold" neutrons (VCN) (8—15 *m/s)* interaction with beryllium [3], when passing through Be samples, testifyed to it (fig.1, curves *1a,2a,3a*). The theoretical dependency of a loss cross-section (heating plus capture) of UCN in beryllium being calculated in the framework of Debye model (fig.1, curve *1b*) describes well the experimental results with the accuracy to scattering on structure inhomogeneities ($\approx$ 0.1 *barn*).

But in the course of measurements it became clear that UCN loss probability during storage in a beryllium trap at low temperature made 5-6% of neutron β-decay probability and turned out to be independent of the way of a trap manufacturing and a degree of its surface cleaning. Fig.1 (curves *1c,2c,3c,4c*) shows the results of temperature dependence of UCN losses total cross-section, when UCN interact with a beryllium trap's surfaces, on the degree of their cleaning. One of the traps (curve *3c*) was made of powdery Be by hot compaction. The two different traps, the cylinder and the sherical one, were made of aluminium-magnesium alloy. Their inner surface was covered with a layer of beryllium 3000÷5000 Å thick. It is of impotance, that irrespective of the way of manufacture and previous history of a trap surface preparation for measurements, with the trap's temperature lowering to 13 *K* all the four curves concentrate to a residual loss cross-section $\approx$0.9 *b*, which does not correspond to the value of the neutron's interaction cross-section inside a substance. For the best degased and cleaned trap (curve 4 c) the form of the temperature dependency copies well the form of calculated dependency of inelastic scattering cross-section for beryllium (curve 1 the calculated cross-section by the value $\approx$0.9 *barn* in the whole temperature range up to 10 *K*. The result does not change at 6.5 *K* [4]. The observed effect's temperature independency points out that it cannot be explained by inelastic scattering process. For a more detailed analysis of the situation measurements of UCN inelastic scattering process on an outgased Be foil by a heated neutrons detection method [5] have been drawn. The results recalibrated into a temperature dependence of heating cross-section (fig.2) show that even at 80 *K* the process of neutron heating by hydrogenous admixtures presence dies out lower then the level of 140 *millibarn* and cannot explain the observed effect. The absorbtion of UCN by the hydrogen on the surface of the trap can not explain this result, because the value of absorbtion cross-section of hydrogen (0.33 *b*) is too small for the level of hydrogen concentration on the surface being observed. Searching for an explanation of the disagreement we have carried out measurements of possible surface contaminations with strongly absorbing elements able to imitate a temperature independent addition $\approx$0.9 *barn*.

Composition of impurities in Be magnetron cathode, from which beryllium on the trap's walls was deposited has been studied by X-ray fluorescent analysis. Concentration of impurities in the surface of the all-metal beryllium trap was studied on an electrostatic accelerator by the method of proton-induced X-ray emission on the depth of $\approx$20 *micrometres*. Total UCN loss cross-section is equal to 12.6 *mb* for the all-metal trap and 23.6 *mb* for the sputtered beryllium trap. The trap's surface contamination with light elements, e.g. with nitrogen and borum, has been studied in reactions $^{14}N + n = {}^{14}C + p$ and $^{10}B + n = {}^{7}Li + \alpha$ on the beam of cold neutrons. To obtain the loss cross-section 0.9 *b* it is necessary to assume the surface concentration of nitrogen $5.5 \cdot 10^{16}$ *atom/cm*^{3}. The nitrogen surface concentration has been found experimentally to be less than $4 \cdot 10^{15}$ *atom/cm*^{2}. Boron impurities were found to be

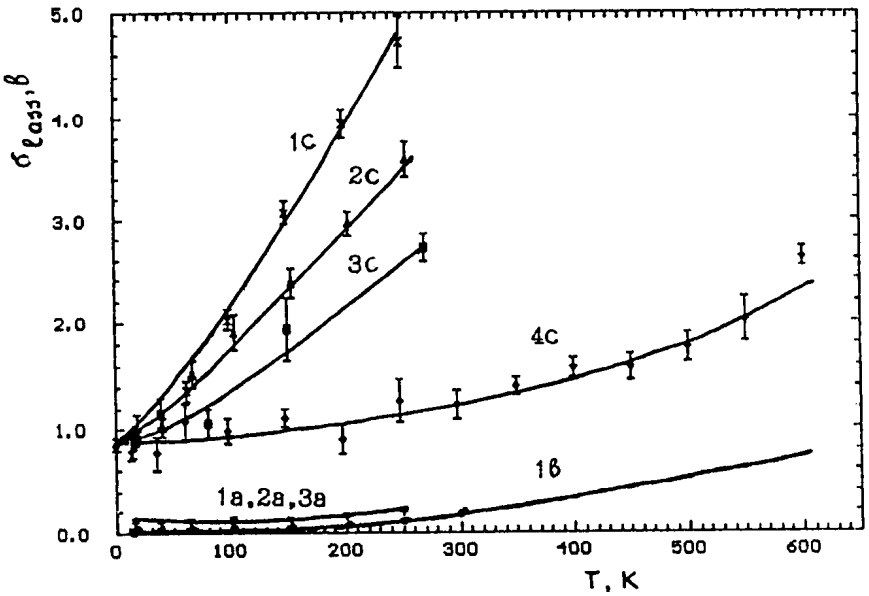

Fig.1. *1a* - melted beryllium, *2a* — quasi-single cristal beryllium, *3a* — pressed bakened beryllium, *1b* — theoretical dependence of loss cross-section ($\sigma_a + \sigma_{in}$ of beryllium on temperature, *1c* — spherical coated Be non-outgased trap, *2c* — cylinder coated Be trap outgased at 250, *3c* — cylinder all-metal Be trap outgased at 300 *K*, *4c* — spherical coated Be trap outgased at 350 *K*

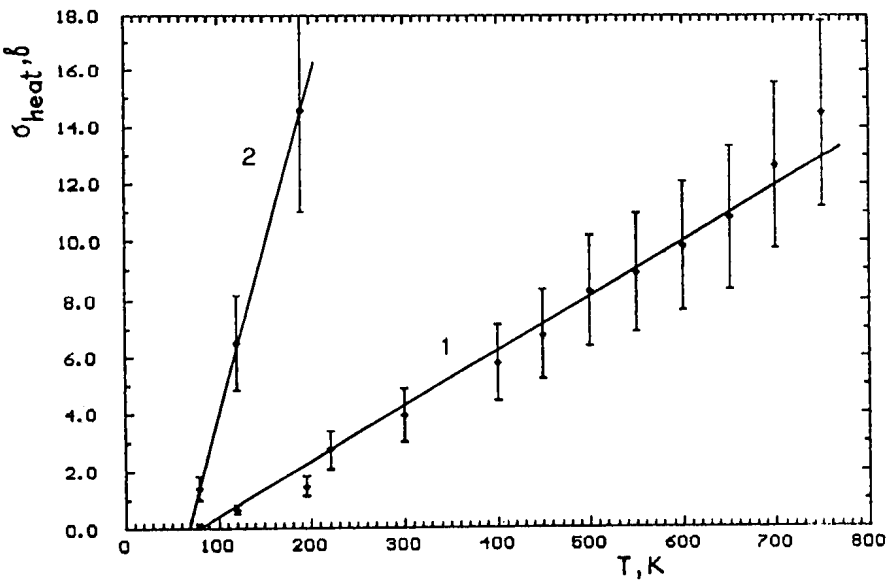

Fig.2. *1* — cross-section of UCN heating on a degased Be foil depending on temperature, *2* — the first three points of this dependence 10 times increased on the ordinate

$(4 \pm 1.5) \cdot 10^{12}$ *atom/cm*^{2} and to explain the observed effect they should be $4.3 \cdot 10^{14}$ *atom/cm*^{2}. Neither has been found UCN milliheating due to the set-up vibration.

With the same purpose in mind a hypothetical probability of subbarier neutrons anomalous passage through a two hundred micrometer vacuum-tight beryllium foil has been studied in special experiment. UCN having tunnelled through the foil have not been found on the level $6 \cdot 10^{-6}$. The effect sought to explain the observed loss cross-section of UCN in a beryllium trap should appear on the level $3 \cdot 10^{-5}$.

The mechanism of an enforcing of losses, such as enlarging the roughness of a surface and so on [6,7], contradicts the fact of constancy of the loss cross-section temperature dependence in the whole temperature range.

Thus, the revealed disagreement finds no explanation within the limits of known ideas of UCN interaction with matter.

References

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