THE EFFECT OF THE TIME OF FLIGHT OF NEUTRONS ON THE DECAY CONSTANT MEASUREMENTS BY THE PULSE METHOD

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The effect of the time of flight of neutrons escaping from the moderator on the measured time dependence of the neutron density, which in turn serves for determining the decay constant $\alpha$, has been analyzed. The measured values of $\alpha$ have been found to vary considerably with the distance of the detector from the moderator and also with its size described by the buckling $B^2$. Measurement with light water and loose diphenyl has shown that the deviation in $\alpha$ depends also on the type of moderator.

1. INTRODUCTION

When measuring the diffusion constants of moderators by the pulse method [3, 4] one usually assumes that the detector is placed close to the measuring vessel and that, therefore, the time of flight of neutrons escaping from the moderator up to the moment of detection can be neglected. If all the neutrons escaping from the moderator were monoenergetic and followed the same trajectory, then the distance of the detector from the vessel would not be important, for the time of flight of all detected neutrons would be the same, only the time origin being shifted without any effect on the evaluation of the constant $\alpha$. Or, the neutrons escaping from the moderator surface are not monoenergetic. We assume the spectrum of neutrons to be described with sufficient accuracy by the Maxwellian velocity distribution:

$$M(v) = \frac{4}{\sqrt{\pi}} \frac{v^2}{v_0^3} \exp\left(-\frac{v^2}{v_0^2}\right) dv.$$  

Here $M = \int_0^{\infty} M(v) dv$, $v$ being the velocity of neutrons and $v_0$ the velocity corresponding to the neutron gas temperature for a given temperature of the moderator. Hence, for faster neutrons the time of flight is smaller than that for slower neutrons flying in the same direction. In this way, a faster but later neutron can be detected earlier than a preceding slower one and the detector does not register the true time distribution of neutrons escaping from the moderator. This difficulty is avoided by placing the detector close to the moderator. However, there are cases when this is impossible, e.g. if the moderator is kept at a very high temperature and if it has to be isolated from the surroundings. No negligible effects are involved, as follows from the fact that a one centimetre flight path at the most probable neutron energy $\frac{1}{2}E_0 = 0.01265$ eV, i.e. at a velocity of 0.155 cm/$\mu$sec, corresponds to a time delay of about 6.45 $\mu$sec. However, the time delay for neutrons with energy four times greater, whose contribution to the neutron density spectrum represents 45% of that for neutrons with energy $\frac{1}{2}E_0$, is only half that value. Taking into account that neutrons do not...
not escape under the same angles but their angular distribution is proportional to 
\((1 + \sqrt{3} \cos \theta)\) [2], where \(\theta\) is the angle between the normal of the moderator surface and the direction of motion of the neutrons, and considering further, the dependence of the neutron spectrum on \(B^2\) and other parameters, we arrive at a rather unclear picture of the effect of the detector distance from the moderator on the resulting value of \(\alpha\).

Since in one of our experiments we had to place the detector farther from the moderator, we analyzed the effect of the detector distance from the moderator on the measured constant \(\alpha\) for light water and loose diphenyl.

2. THEORETICAL ANALYSIS

The expression for the time distribution of neutron density is given by solving the diffusion equation for the case of a non-stationary pulse source. We have (see [3, 5]):

\[ N(t) = \text{const} \cdot e^{-\alpha t}, \]

where

\[ \alpha = \frac{1}{T} + DB^2 - CB^4. \]

Here \(T\) [sec\(^{-1}\)] is the mean life-time of thermal neutrons in an infinite moderator, \(D\) [cm\(^2\) sec\(^{-1}\)] the diffusion constant, \(C\) [cm\(^4\) sec\(^{-1}\)] the diffusion cooling constant and \(B^2\) [cm\(^{-2}\)] the buckling. For a cylindrical vessel we have

\[ B^2 = \frac{2\cdot4052}{R^2} + \frac{\pi^2}{h^2}, \]

where \(R\) and \(h\) are the extrapolated radius and height of the vessel (in cm) respectively.

In order to estimate qualitatively the effect of the neutron time of flight on the measured value of \(\alpha\), we used the reasoning from a paper by Pál et al. [1]. Let us suppose that the moderator is placed in a cylindrical vessel covered by a cadmium shielding with a slot \(H\) at the bottom, the detector being placed at a distance \(l\) from the vessel. A neutron which leaves \(H\) with velocity \(v\) under an angle \(\theta\) (\(\theta\) being the angle between the direction of motion of the neutrons and the normal of the moderator surface) and covers a distance \(l'\) to the point of detection, is registered with a delay \(l'/v\). The probability that the neutron with a velocity in the interval \((v, v + dv)\) and a flight path in the interval \((l', l' + dl')\) is registered in a time interval \((t, t + dt)\) is proportional to the expression

\[ \exp \left\{ -\alpha \left( \frac{t - l'}{v} \right) \right\} \ dt \cdot f(l') \ dl' \Sigma_v^{\delta(\tilde{\nu} v M(v) \ dv.} \]