Practical no 21

DETERMINATION OF DEAD TIME OF GEIGER-MÜLLER COUNTER BY THE TWO-SOURCE MODEL

Attention! This material contains only a part of required theoretical background. The whole required information can be found in the attached literature list.

The number of physical phenomena in a random process can be recorded by a proper detector. If the number of these phenomena is big enough, the obtained result is given with an error, which is a consequence of work of the detector and does not depend of detection method. The main source of this error is an electronic circuit, which transforms a physical phenomenon into an electric signal recorded in the acquisition modulus of a detector. Because of this error, the number of ionising particles detected by a counter is lower than number of the particles really coming to the detector's input. A given particle can be detected and recorded as an electric signal only after the process of recording of the previous particle is finished. It means that recording of any two ionising particles must be separated by a time known as the DEAD TIME. During the dead time, recording of next ionising particle is not possible. The idea of each dosimetric measurement is estimation of a real intensity of the radiation, which is related to real number of ionising particles coming to the detector. To calculate the real intensity of the radiation, the intensity measured by the detector must be corrected. To calculate the corrected intensity of the radiation, following parameters must be defined:

t – time of counting ionising particles by the detector

T – time, during which the detector can really count the particles (depends on the dead time)

τ – detector's dead time, very small compared to the t and the T

C – total number of recorded ionising particles

n – measured counting rate of ionising particles, $n = \frac{C}{t}$

N – corrected counting rate of ionising particles, $N = \frac{C}{T}$, (real number of the coming to the detector's input window in a given time) particles

According to the above-mentioned definitions:

$$T = t - \tau \qquad (1)$$

According to what is mentioned above, $\tau \ll t$ and $\tau \ll T$ (several orders of magnitude), which leads to physically irrelevant equation $T \cong t$. Because of that it is useful to put the C number into the equation (1) and re-arrange this equation to the form:

$$T = t - C\tau \qquad (2)$$

which will enable to calculate the real intensity of the radiation detected by the counter.

On the other hand, we can calculate the n/N ratio:

$$\frac{n}{N} = \frac{C}{t} \cdot \frac{T}{C} = \frac{T}{t} \qquad (3)$$

By dividing the equation (2) by the t, we obtain:

$$\frac{T}{t} = 1 - \frac{C}{t}\tau \qquad (4)$$

Taking into account that $\frac{C}{t} = n$ and $\frac{n}{N} = \frac{T}{t}$ and re-arranging of the equation (4), we obtain formula for the corrected intensity of the radiation:

$$N = \frac{n}{1 - n\tau}$$

which describes the real number of ionising particles N coming to the detector, which had the possibility to record n particles only, due to the dead time τ.

In order to estimate the dead time, the two-source method is used. Firstly, the counting rate of the first source n_1 is determined, then the counting rate of both sources $n_{1,2}$ and finally the counting rate of the second source n_2 (details are given in the instructions). In theory, the results should obey the equation:

$$n_1 + n_2 = n_{1,2}$$

However, this equation is not obeyed, because the dead time influences the $n_{1,2}$ more significantly, therefore $n_{1,2} < n_1 + n_2$. Because of this fact, to determine the dead time, the corrected counting rates must be taken in consideration:

$$N_{1,2} = N_1 + N_2$$

Taking into account the formula for calculation of the N, we obtain the following equation,

$$\frac{n_{1,2}}{1-\tau n_{1,2}} = \frac{n_1}{1-\tau n_1} + \frac{n_2}{1-\tau n_2} \qquad (5)$$

which can be used to calculate the dead time.

$$\tau \cong \frac{n_1+n_2-n_{1,2}}{2n_1 n_2} \qquad (6)$$

The symbol „$\cong$ - almost equal" in the equation (6) is necessary, because estimation of the τ from the equation (5) omits the values due to τ^2 value because they are very low. Because the counting rate is given by the equation $n = \frac{C}{t}$, the dead time can be calculated applying the equation:

$$\tau \cong \left(\frac{C_1 + C_2 - C_{1,2}}{2C_1 C_2}\right) \cdot t$$

where the C is the number of counted ionising particles recorded in the time t.

Required theoretical knowledge:

1. Natural radioactivity: alpha (α), beta (β), gamma (γ) radiation.
2. Ionising radiation decay law.
3. Principles of work of the Geiger-Müller counter and the semiconductor detector of ionising radiation
4. Explain definition of the dead time of ionising radiation detectors
5. Units of ionising radiation activity
6. Radioactive series.

Recommended literature:

1. P.R. Bergethon “The Physical Basis of Biochemistry”, Springer 1998
2. R. Cotterill “Biophysics An Introduction”, Wiley 2003