One uses the isotope generators for producing short-lived radio nuclides. In these generators, the mother substance with a long half-life decomposes and gives rise to daughter nuclei with a shorter half-life. The daughter nuclei are separated from the mother nucleus by means of suitable methods and then can be used.

In the Uranium-Protactinium-Isotope generator used in the experiment, Th-243 nuclei arise first due to a decomposition of the U-238 nuclei, and subsequently the Pa-243 nuclei arise, which get converted into the longer living Th-230 nuclei through a β^{-}-process. The β-radiation arising thereby penetrates through the synthetic container of the isotope generator and can be measured.

The short-lived products are separated by making use of the fact, that the protactinium atoms dissolve in a specific light organic solvent and hence accumulate in the upper part of the container after it is shaken vigorously.

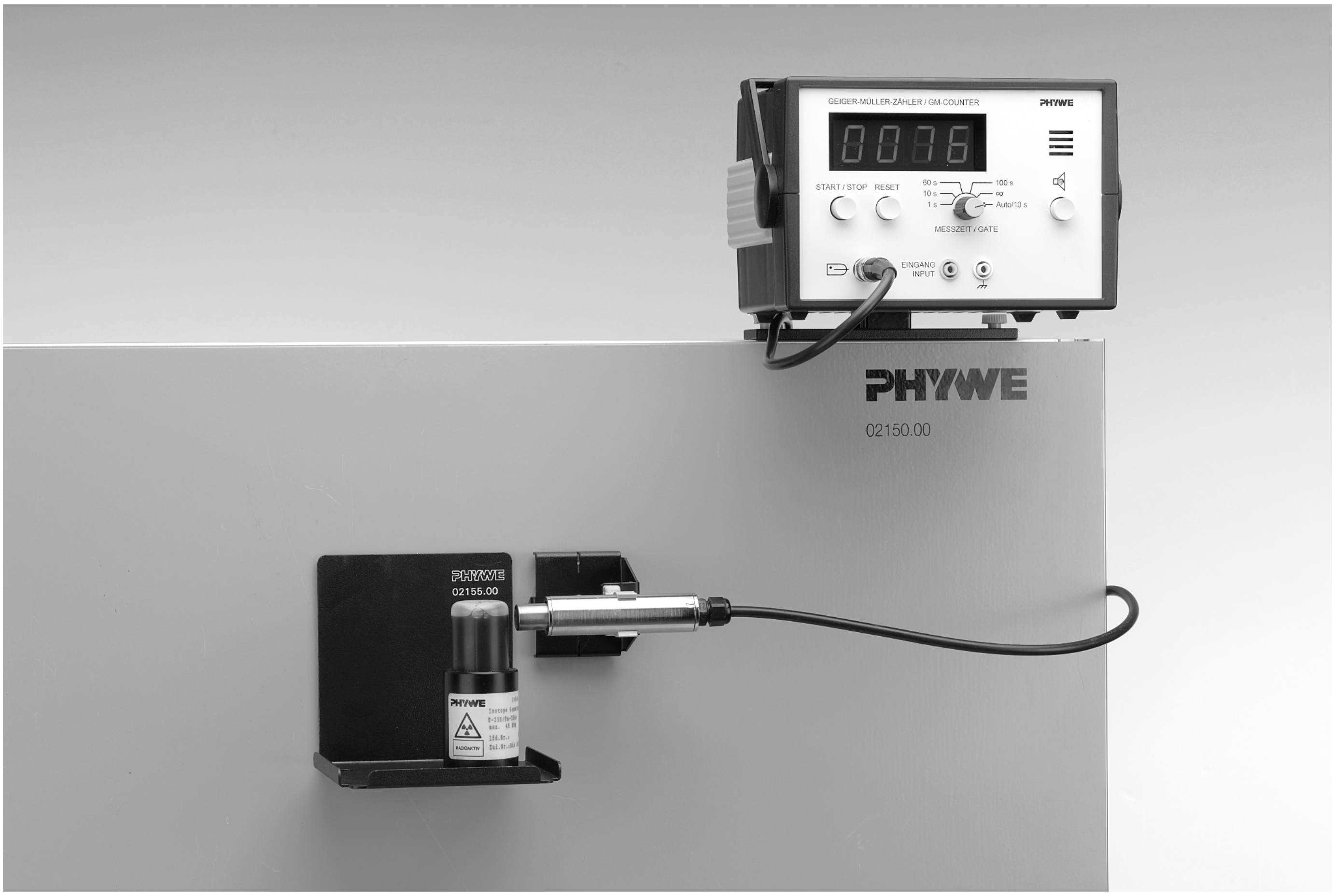
Equipment

Support clamp for small case	02043.10	1
Clamp on holder	02164.00	1
Support rod, stainless steel	02030.00	1
Counter tube holder on fix. magnet	09201.00	1
Support plate on fixing magnet	02155.00	1
Counter tube Type B	09005.00	1
Geiger-Müller-Counter	13606.99	1
Demo-Board for Physics with stand	02150.00	1
Isotope Generator U-238, Pa-234, 45 kBq	09048.00	1

Set-up and procedure

Instruction: For observing the time run of the count rate, the automatic time selection “Auto/ 10 s” can be selected at the counter, in which the registered number of impulses can be read without interrupting the measurement process. The disadvantage of this process is the low number of impulses, which cause a relatively larger statistical error. To get higher impulse rates with lower statistical errors, it is recommended to use the sum of the impulse rates from a measurement time of 3 x 10 s. The underground radiation must be given special consideration in this experiment, because to this gets added the base radiation caused by the mother substance of the unshaken generator.

Fig. 1: Experimental setup



1. Measuring the underground rate:

— Take out the isotope generator from the container without shaking it and place it on the support plate on the demo board.

— Place the counter tube in its holder without the protective cap and position it near the top of the isotope generator, such that the counter tube window is directly above the synthetic cap of the isotope generator.

— Select a measurement time of 60 s and determine the zero rate three times; Enter the values in the table 1

2. Measuring the radioactive half-life:

— Select automatic time selection “Auto/10 s”

— Pick up the isotope generator and shake it vigorously many times; place it again on the support plate in the same position.

— Start taking the measurements after about 30 s; enter the pulse rates in Table 2

— The total measurement time should be about 6 minutes.

— After concluding the measurements place the isotope generator back in the protective container and replace the protective cap again on the counter tube.

Result

Table 1

Zero rate Running no.	$\frac{Z_0}{\text{Imp}/60\text{ s}}$
1	35
2	27
3	31

Table 2: time curve of the count rates

t/s	$\frac{Z}{\text{Imp}/10\text{ s}}$	$\frac{\overline{Z}-\overline{Z_0}}{\text{Imp}/10\text{ s}}$	t/s	$\frac{Z}{\text{Imp}/10\text{ s}}$	$\frac{\overline{Z}-\overline{Z_0}}{\text{Imp}/10\text{ s}}$
10	109	104	190	23	18
20	97	92	200	25	20
30	108	103	210	16	11
40	103	98	220	30	25
50	84	79	230	27	22
60	85	80	240	20	15
70	84	79	250	11	6
80	79	74	260	22	17
90	61	76	270	18	13
100	62	77	280	17	12
110	54	49	290	18	13
120	46	41	300	10	5
130	46	41	310	17	12
140	49	45	320	15	10
150	46	41	330	9	5
160	28	24	340	11	6
170	35	31	350	10	5
180	15	10	360	11	6

Evaluation

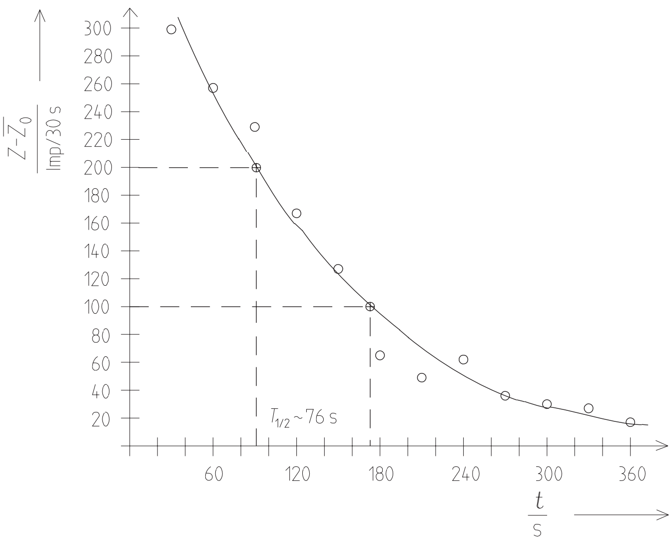
The mean value of the zero rates is $\overline{Z_0}$ = 5 Imp/10s. The mean value of the zero rate is subtracted from the registered pulses rate Z; the corrected pulse rates are to be entered in the last column of Table 2.

For the sake of simplicity and for reducing the statistical scattering, the sum of the corrected pulse rates of 3 x10 s is represented as a function of time. (Fig. 2).

It can be seen that the activity of the radioactive substance reduces with time. From Fig. 2 one gets the value $T_{1/2}$ = 76 s for the radioactive half-life.

This value is greater than the value given in the table $T_{1/2}$ = 70.8 s.

Fig. 2: Counting rate as a function of time



Note

The decay law:

$$Z(t) = Z(t = 0)\, e^{-\lambda t}$$

applies to the time curve of the activity $Z(t)$.
Here $Z(t = 0)$ is the initial activity at the point of time $t = 0$ of the measurement and λ is the decay constant of the radio nuclide, which specifies the constant, relative portion of the decaying nucleus in a unit of time.

$$\lambda = dZ / Z\, dt.$$

When logarithms are applied to the law of decay, one gets:

$$\ln Z(t) = \ln Z(t = 0) - \lambda t.$$

In the logarithmic representation one gets a linear function for the time curve of the activity and hence also for the curve of the count rate $Z(t)$, which can be lengthened to any extent beyond the measured time period and from which one can determine the half-life or the decay constant λ from the slope of the line. With the help of

$$\lambda = \frac{\ln Z(t = 0) - \ln Z}{t}$$

one gets the following from Fig. 3:

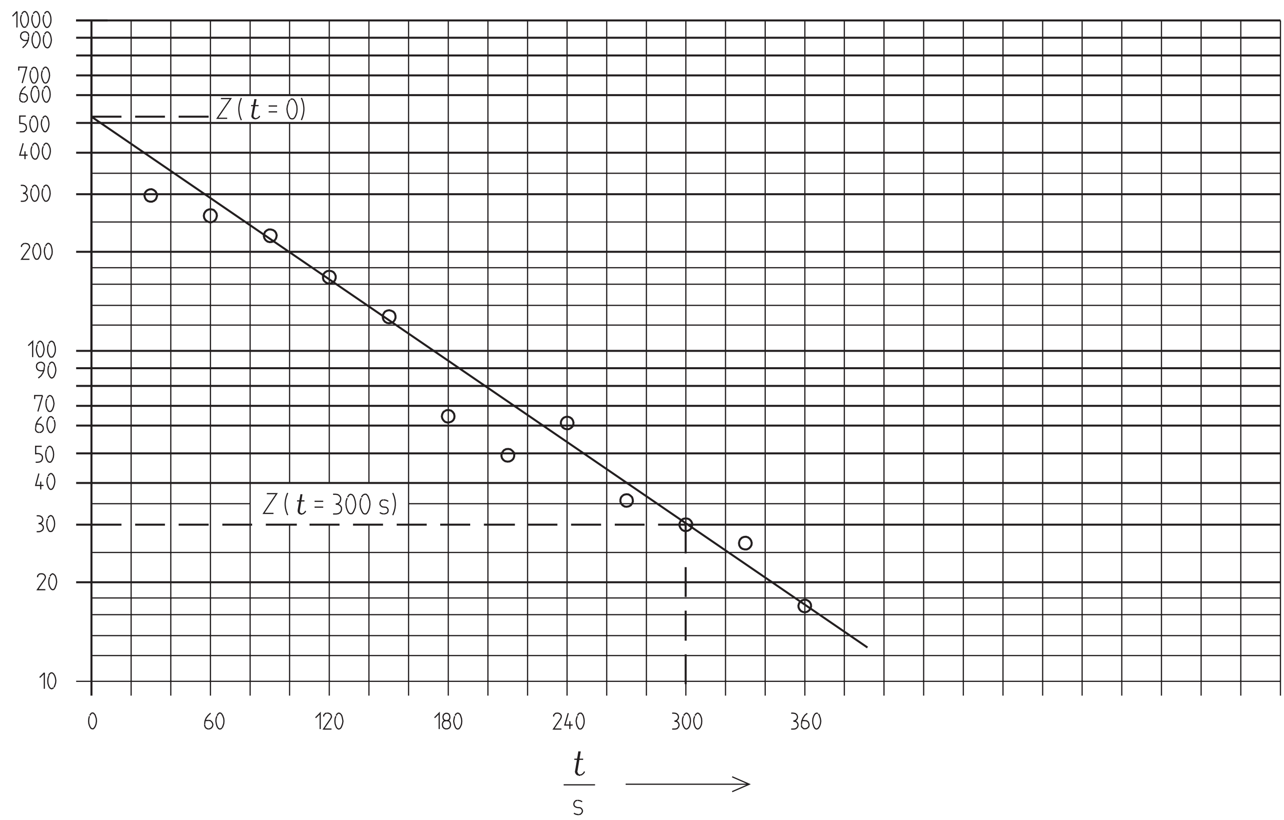
$$\lambda = (\ln 520 - \ln 30)/300 \text{ s} = 0.00951 \text{ s}^{-1}.$$

One gets the relationship between the decay constant λ and the half-life $T_{1/2}$ is substituted for $Z = Z(t = 0)/2$ in the logarithmic law of decay:

$$\lambda = \ln 2 / T_{1/2} \text{ or } T_{1/2} = \ln 2 / \lambda.$$

This results in a half-life value of $T_{1/2}$ = 73 s.

Fig. 3: Count rate as a function of time in a logarithmic representation



Room for notes