Law of radioactive decay

LEP 5.2.02

Related topics

Parent substance, daughter substance, rate of decay, disintegration or decay constant, counting rate, mean life, disintegration product.

Principle and task

The particle current (quantum current) given off by the radioactive radiator decreases in the course of time. The radioactive substance decays according to a certain law (law of deterioration).
If the radioactive substance consists of only one radiating component in particular, then the quantity of its material decreases exponentially with time.

Equipment

Isotope generator U-238, 45 kBq	09048.00	1
Counter tube, type A, BNC	09025.11	1
Screened cable, BNC, l 300 mm	07542.10	1
Counter tube holder for 09053.01	09053.02	1
Magnetic base for 09053.88	09053.01	1
Base plate	11600.00	1
Counter tube module	12106.00	1
COBRA-interface 2	12100.93	1
PC COBRA data cable RS 232, 2 m	12100.01	1
Softw. COBRA Radioactivity	14256.51	1

Set-up and procedure

– The experiment is set up as shown in Fig.1.
– Load the programme “Radioactivity” (Radio 1) and start it.
– Background noise: Plaoe the preparation in front of the counter tube but without shaking it beforehand (the separation pomt must be clearly visible through the transparent part of the flask). The radiation of the mother substance (U-238) must be taken into consideration when measuring the zero rate.
<measure>, <zero effect>, <measure>, “Time interval: approx. 500 s”, <Ok>
– Parameter adjustments (<measure>, <parameters>):

Type of measurement	Automatic measuring sequence
Zero effect	subtract
Measuring time	15 s
Number of measurements	25

– Shake the preparation for a few seconds and place it directly in front of the counter tube.
– After approx. 70 s press <measure>, <start>, <Ok>. Taking the measurement values now begins.
– After finishing the measurement sequence, a diagram with an optimal scale appears if autorange “yes” is adjusted under <graphics>, <options>. (cf. Fig. 2>.
– Calculation of the half life <graphics>, <dependence>

Fig. 1: Experimental set-up; Stern-Gerlach apparatus with high-vacuum pump stand.

y-axis	$N/\Delta t$
y-scale	logarithmic
t in	sec
Zero effect	subtract
x-axis	*t*
<Ok>	
<graphics>, <straight compensating line> <Ok>.	

Fig. 3 shows the semi-logarithmic representation with the calculated line ot regression. The half-life of the radiator used can be obtained from the parameters of the regression calculation in the following way: <edit>, <calculation>, Window “2”, <Ok>. In this example the half-life becomes 82 s.

Theory and evaluation

Fig. 2 shows the counting rate as dependent on time. The result is a counting rate which decreases with time (see hints). If the counting rate is placed in a simple logarithmic scale dependent on time, the result will be the straight line shown in Fig. 3. The counting rate decreases after a period in time of τ = 82 s to half the value.

Therefore

$$\dot{N} = \dot{N}_o \, e^{-\lambda t}$$

and

$$\frac{1}{2}\dot{N} = \dot{N}_o \, e^{-\lambda t}$$

where

$\dot{N}$ present rate of decay

$\dot{N}_o$ counting rate at zero point

λ deterioration constant

t time

τ half-life

The result is therefore

$$\lambda = \frac{\ln 2}{\tau}$$

By using logarithms on

$$\dot{N} = \dot{N}_o \, e^{-\lambda t}$$

we obtain

$$\ln \dot{N} = -\lambda t + \ln \dot{N}_o$$

The comparison of coefficients with the line of regression

$$y = mt + b$$

shows, that the increase in the line of regression *m* of the negative deterioration constant is the same as

$$m = -\lambda$$

The deteriorating constant λ is characteristic for the fading out of radioactivity. It is connected to the period in time in which the quantity of material has decreased to half the value (half-life τ).

Note

An initial increase in the impulse rate can be traced back to the progressive separation of both non-mixable liquids in the sample flask (cf. Fig. 4). By shaking it, Protactinium-234 is released in the lighter liquid which settles on top. Its β-radiation is available at the time of determining the half-life. A short while after the shaking, the concentration of Pa-234 increases in the upper area of the flask when the lighter liquid rises to the top. The counting rate also increases and overlaps the radioactive deterioration.

Fig. 3: Logarithmed counting rate as dependent on time.

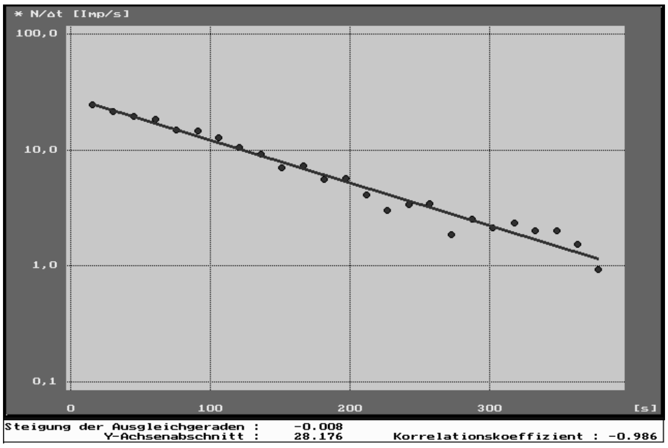

Fig. 2: Counting rate as dependent on time.

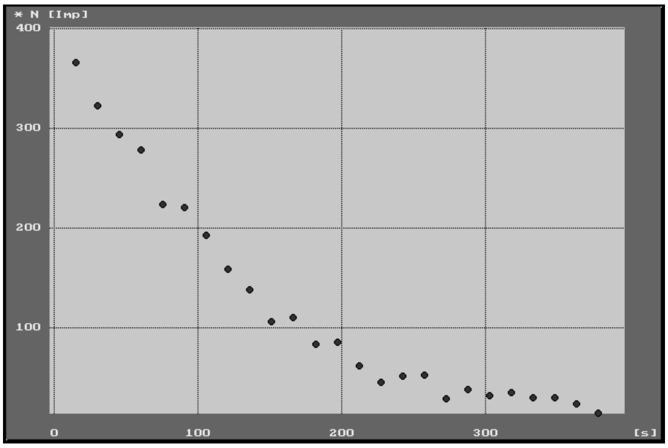

Fig. 4: Increasing counting rate by means of phase separation of the two liquids.