Related topics

Decay series, radioactive equilibrium, isotopic properties, decay energy, particle energy, potential well model of the atomic nucleus, tunnel effect, Geiger-Nuttal law, semiconductor, barrier layer.

Principle and task

An α-spectrometer, consisting of a silicon surface barrier layer detector, a preamplifier, a pulse height analyzer and a recording device for registration of the spectra is calibrated by means of an open α-emitter of known α-energy (^{241}Am).

The energy spectrum of a radium source which is in equilibrium with its decay products, is recorded and evaluated. The α-energies found in this way are allocated to the corresponding nuclides of the radium decay series.

Equipment

Americium-241 source, 3.7 kBq	09090.03	1
Source Ra-226, 3.7 kBq	09042.03	1
Container f. nuclear phys. expts.	09103.00	1
Alpha detector	09100.00	1
Pre-amplifier f. alpha detector	09100.10	1
Impulse height analyser	13725.93	1
xyt recorder	11416.97	1
Oscilloscope, 20 MHz, 2 channels	11416.97	1
Range multiplier, vacuum	11112.93	1
Moving coil instrument	11100.00	1
T-connection NW 10	02668.13	1
Hose nipple NW 10	02668.12	2
Centring and sealing ring NW 10	02668.04	3
Clamping ring NW 10	02668.03	3
Vacuum pump, one stage	02750.93	1
Adapter for vacuum pump	02657.00	1
Rubber tubing, vacuum, i.d. 8 mm	39288.00	1
Pinchcock, width 20 mm	43631.20	1
Screened cable, BNC, l 750 mm	07342.11	1
Connecting cord, 750 mm, red	07362.01	2
Connecting cord, 750 mm, blue	07362.04	2

Problems

1. The α-spectrum of the ^{226}Ra is recorded, the settings of the pulse analyzer (amplification) and recorder (x and y input sensitivity) being selected so as to make best possible use of the recording width.
2. The calibration spectrum of the open ^{241}Am-emitter is recorded at the same settings.
3. The α-energies corresponding to the individual peaks of the α-spectrum of the radium are calculated and, on the assumption of a constant energy loss in the source covering, the α-active nuclides of the radium decay series corresponding to the individual peaks are determined on the basis of the values in the literature.

Set-up and procedure

Fig. 1 shows the complete experimental layout. The α-detector is enclosed in the vessel and the radium source is screwed into the source holder inside the vessel. The remaining details of the layout can be seen in Fig. 1.

Fig. 1: Experimental set-up: Study of the α-energies of ^{226}Ra.

Preparation

- The pulse hgieht analyzer is initially switched off (no voltage applied to the α-detector).
- Evacuate the vessel to about 0.5 – 1 hPa. Close the rubber hose with a pich cock. Disconnect the pump (the vacuum is adequate provided that the pressure remains clearly below 5 hPa).
- Switch on the pulse height analyzer.
- Bring the source to within about 1 mm of the detector.
- Note the pulse height shown on the oscilloscope (time factor: 20 μs/cm) and adjust the amplification on the pulse height analyzer so as to obtain a maximum pulse height of about 7 V.

Warning: The “Magnifier” (Lupe) key must not be pressed.

Setting of the *xy* recorder

- Adjust the zero point so that, if no input voltage is applied (i. e. with the zero keys pressed on the recorder), the recording stylus is in the lower left corner of the recording surface.
- Switch the pulse height analyser to “Manual” and move the “Base” adjusting knob to the 0.5 V position (scale value 0.50).
- Select the 5 % window.
- Set the *y*-sensitivity on about 5 mV/cm. Using the “Base” adjusting knob, advance the spectrum slowly to 8 V; when the recording stylus reaches the upper edge of the recording surface, reduce the sentivity of the recorder until the stylus is clear of the edge.
- With the “Base” adjusting knob in the 8 V position (scale value 8.00), select the *x*-sensitivity so that the recording stylus is immediately adjacent to the right hand limit of the recording surface. Mark this point by a brief lowering of the stylus on to the recording surface.

Recording of the radium-226 spectrum

- The following pulse height analyzer settings are recommended:

Window	5 %
Base	8 V
Timing cycle	1.6 s.

- Press the “Auto/Man” key.
- Lower the “Zero” key.
- Lower the “Start/Stop” key and record the spectrum (in the initial range the stylus will temporarily move in the *y*-direction against the end stop as a result of the noise).

Calibration of the measurement layout

For calibration of the measurement layout, the α-spectrum of the open ^{241}Am-emitter is recorded without altering the amplification on the pulse height analyzer or the *x*-sensitivity on the recorder, using the following procedure:

- Temporarily switch off the pulse height analyzer, so that no voltage is applied to the α-detector during ventilation and evacuation.
- After ventilation, open the vessel (at the source holder side).
- Withdraw the radium source and in its place screw the americium source to the source holder.
- Close the vessel, evacuate once again to 0.5 – 1 hPa and switch on the pluse height analyzer.
- Bring the source to within about 4 mm of the detector.

Adjustment of the γ-sensitivity of the recorder for calibration

- Raise the recording stylus.
- Temporarily switch the pulse height analyzer to “Manual”.
- Select the 1 % window.
- Using the “Base” adjusting knob, search for the peak on the ^{241}Am line (the picture ont the oscilloscope screen can be used as a guide; discovery of the line can be facilitated by means of a counter at the discriminator output).
- Select the γ-sensitivity so as to make optimal use of the height of the recording surface.

Recording the ^{241}Am spectrum

- The following settings are made on the pulse height analyser:

Window	1 %
Base	8 V
Timing cycle	3.2 s

  Record the spectrum as for ^{226}Ra.
- It is sufficient to scan a very narrow range on either side of the ^{241}Am-line (using the fast forward mechanism).

Theory and evaluation

α-particles penetrating the barrier layer of a semiconductor detector give rise to free charged particles along their path, having a charge strictly proportional to the energy of the incident α-particles. These charge pulses are converted in the preamplifier of the α-detector into voltage pulses, the peak values of which are again strictly proportional to the charge of the input pulse. As a result also of the strictly linear operation of the main amplifier, a simple linear relation is obtained in the pulse height analyzer between the α-particle energy and the height of the pulses analyzed by the discriminator.

An α-emitter of known particle energy E_0, yielding pulses of height U_0, is used for calibration of the experimental layout. The α-energy E of particles yielding pulses of height U is governed by the expression:

$$E = \frac{U}{U_0} \cdot E_0$$

For the ^{241}Am source used here E_0 = 5.486 MeV.

1. Each ^{226}Ra source contains the following nuclides in the uranium-radium decay series (disregarding nuclides such as ^{218}At, ^{218}Rn, ^{210}Tl and ^{206}Tl which only occur with very low activities):

Nuclide	Type of decay	α-energy / MeV
Radium-226	α	4.78
Radon-222	α	5.48
Polonium-218	α	6.00
Lead-214	β^-	–
Bismuth-214	β^-	–
Polonium-214	α	7.68
Lead-210	β^-	–
Bismuth-210	β^-	–
Polonium-210	α	5.30
Lead-206	Stable	–

With the exception of radon-222 and polonium-210 these energies are so widely separated that they can be easily resolved for a covered source.

Fig. 2 shows a typical ^{246}Ra pulse height spectrum including the ^{241}Am calibration line. The pulse heights corresponding to the peak values of the lines have also been entered so as to permit calculation of the α-energies.
The four lines can be allocated to nuclides of the ^{226}Ra decay series in accordance with the table below. The energy loss is given as ΔE, obtained from the difference between the measured value difference between the measured value and that given in the literature.

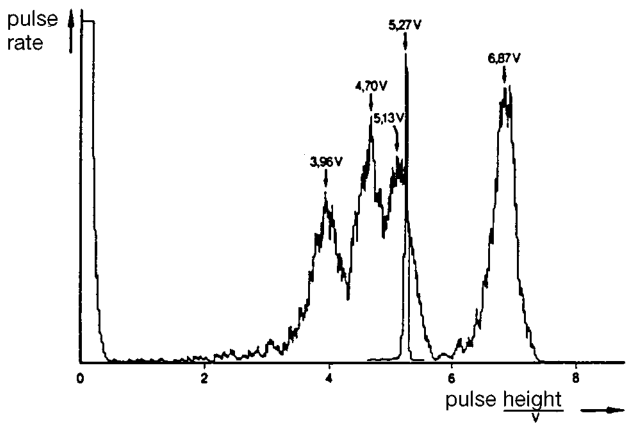

Fig. 2: ^{226}Ra pulse height spectrum including the ^{241}Am calibration line.

Serial No.	E/MeV (measured value)	E/MeV (literature value)	ΔE/MeV	Nuclide
1	4.12	4.78	0.66	Radium-226
		5.30	0.41	Polonium-210
2	4.89	5.48	0.59	Radon-222
3	5.34	6.00	0.66	Polonium-218
4	7.15	7.68	0.53	Polonium-214

It is evident that the energy loss in the source cover depends only to a very slight extent on the α-energy in question (mean value ΔE = 0.57 MeV). This substantial energy loss causes a widening of the lines, so that the α-lines of ^{210}Po and ^{222}Rn cannot be separated.