Internal conversion in ^{137m}Ba

LEP 5.2.45

Related topics

γ-radiation, nuclear transitions, transition probability, duration, metastable states, isotopic spin quantum numbers, rules governing selection, multipole radiation, isomeric nuclei, photonuclear reaction, conversion electron, characteristic X-ray radiation, scintillation detectors.

Principle and task

The radiation emitted during the decay of the ^{137}Cs isotope is measured with a scintillation detector and the energy spectrum determined with a pulse height analyzer. The spectrum contains fractions due to a γ-transition and fractions originating from a characteristic X-ray radiation. The areas of the fractions in question are determined and the conversion factor obtained from them.

Equipment

Source Cs-137, 37 kBq	09096.01	1
Impulse height analyser	13725.93	1
Gamma detector	09101.00	1
Operating unit f. gamma detector	09101.93	1
High-voltage connecting cable	09101.10	1
Oscilloscope, 20 MHz, 2 channels	11454.93	1
xyt recorder	11416.97	1
Support rod -PASS-, square, l 400 mm	02026.55	1
Right angle clamp -PASS-	02040.55	1
Tripod base -PASS-	02002.55	1
Adapter, BNC-socket/4 mm plug pair	07542.27	1
Screened cable, BNC, l 750 mm	07542.11	3
Connecting cord, 750 mm, red	07362.01	2
Connecting cord, 750 mm, blue	07362.04	2

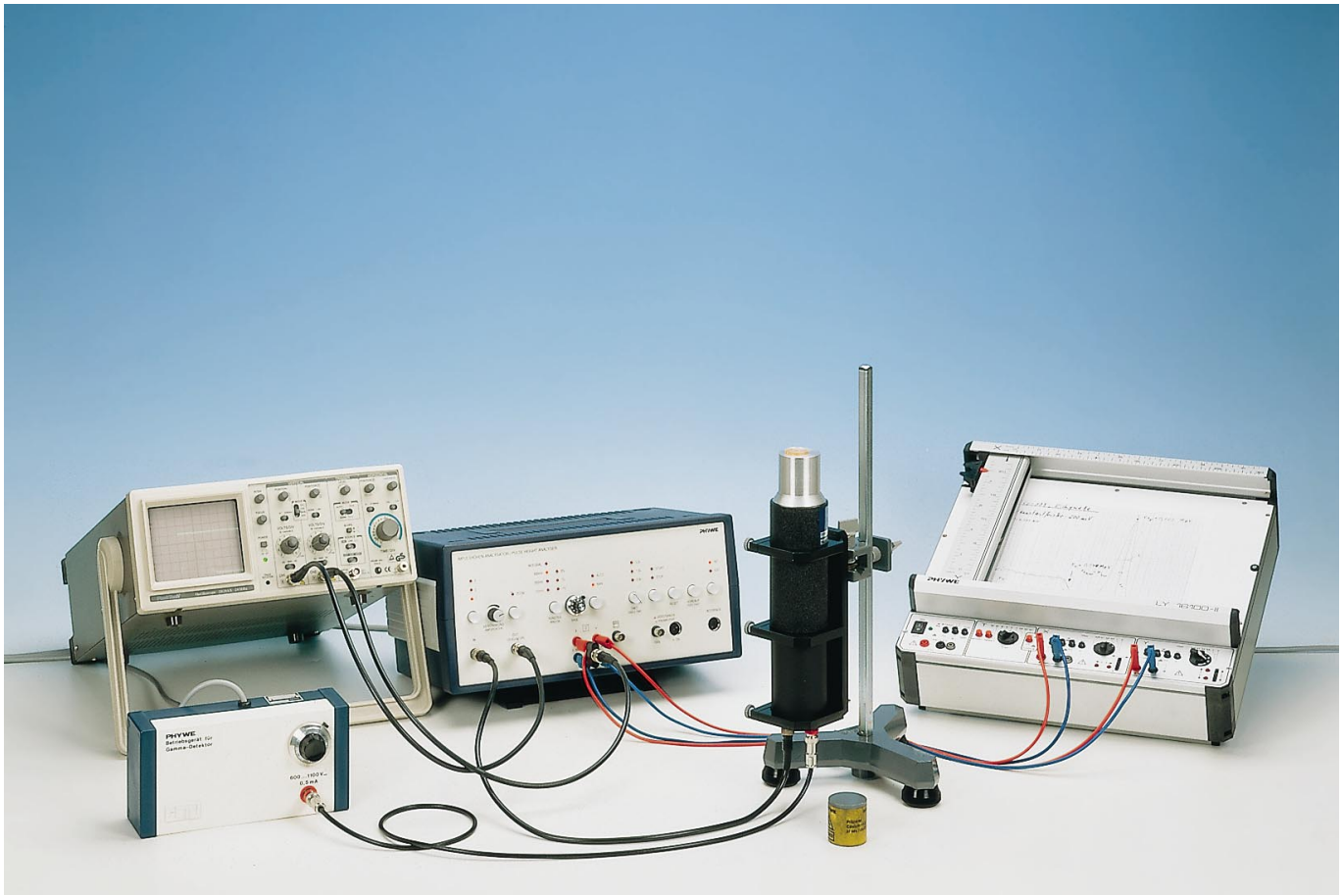
Problems

1. Measurement of the γ-spectrum of ^{137}Cs using a scintillation detector.
2. Determination of the conversion factor of the ^{137m}Ba excited nucleus.

Set-up and procedure

The layout of the detection apparatus is shown in Fig. 1, a layout in which very few γ-quanta occur which have undergone backscattering on contact with the environment. The detailed directions in the operating instructions of the γ-detector, the pulse height analyzer, the oscilloscope and the recorder, should be complied with. The detection apparatus must be calibrated before the measurement. The following settings should be selected:

Fig. 1: Experimental set-up: Internal conversion in ^{137m}Ba.



Detector voltage:	10.00 scale divisions
Pulse height analyzer:	
Method of operation:	automatic
Window:	200 mV
Magnifier:	Off
Base:	10.00 scale divisions
Timing Cycle:	3.2 s

Amplification:

Coarse and fine adjustment to be made with the oscilloscope in such a way that the maximum pulses on the analogue output reach a height of 9 V.

Recorder:

Input amplification in accordance with the paper format; zero point and coordinate system to be exactly marked.

Oscilloscope:

Apply the analogue signal to input 1 of the pulse height analyzer; apply to input 2 the relevant discriminator threshold from the *x*-output of the pulse height analyzer and adapt it to the other input signal.

After these settings have been made, no further changes may be made to the detection apparatus or to the counter geometry.

Theory and evaluation

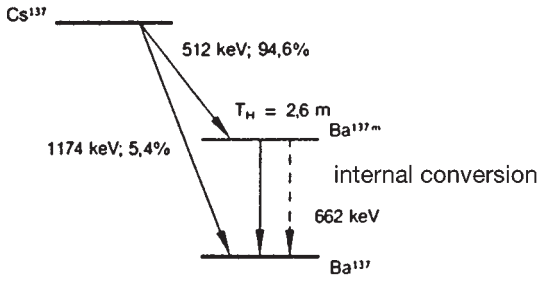
Excited states in atomic nuclei return to the basic state as a result of the emission of γ-radiation. The durations of the excited states are within the psec range.
Any nuclear state is characterized by a spin quantum number *j* and its parity *p*. The most frequent type of transition is electric dipole radiation, involving a variation in spin of $\Delta j = 1$ and a variation in the parity. One spin unit corresponds to a rotary pulse of $h/2\pi$. On exposure to electric quadrupolar radiation the spin varies by an amount of $\Delta j = 2$ with an unchanged parity, and on exposure to magnetic dipole radiation by $\Delta j = 1$, again with an unchanged parity. On exposure to higher orders of radiation, the change in the spin and the parity condition follow a systematic pattern. A very sharp fall occurs in the probability of higher order multipolar radiation transfers with an increase in the order. The probability of magnetic *n*-pole radiation corresponds approximately to that of an electric (*n*+1)-pole radiation.

The β-decay process of ^{137}Cs ends in a metastable state of ^{137}Ba, the spin quantum number of which deviates to such an extent from the basic state that only higher order transitions are possible. This state has the unusually long duration of 2.6 min in view of the low transition probability.

In isomeric atomic nuclei, internal conversion, in which the excitation energy is transmitted to a shell electron, competes with the higher order radiation transition. In consequence, the excited atomic shell emits characteristic X-ray radiation. The characteristic K-radiation of Cs occurs at 32 keV.
The conversion factor *P* is obtained from the X-ray quantum fraction N_X and from the γ-quantum fraction N_Y in accordance with the following formula:

$$P = \frac{N_X}{N_X + N_Y}\ 94.6\%$$

Fig.2 : Decay diagram of the ^{137}Cs isotope.



in which the overall frequency of occurrence has already been taken into account.

The N_X and N_Y fractions are obtained by means of a planimetric evaluation of the ^{137}Cs spectrum.

The spectrum is in this case approximated by rectilinear partial areas. The two lines are almost gaussian, so that their area *A* is obtained from the height of the apex *a* and the half-width *b*:

$$A = a \cdot b \cdot \sqrt{\frac{\pi}{2}} \cdot \sqrt{\text{Log } 2}\ .$$

In Fig. 3 the area F_1 is found to be 574 mm^2, while the sum of the areas from F_2 to F_6 amount to 5231 mm^2. It has to be borne in mind that the soft X-ray radiation only partially passes through the aluminium casing of the scintillation crystal. The transmission factor is about 90%.

The probability of detection in the detector is about 95% for X-rays and about 72% for 662-keV γ-quanta.

This yields the following conversion factor:

$$P = 0.080$$

Notes

1. The accuray of the method of measurement has been estimated at about 10%, subject, in addition, to the following systematic errors:

Self-absorption of X-ray quanta in the source
Occurence of indirect, scattered γ-quanta

The value of the conversion factor in the literature is:

$$P = 0.095.$$

2. The conversion electrons have insufficient energy to penetrate the aluminium casing of the detector and do not influence the spectrum.

Fig. 3: γ-spectrum of ^{137}Cs.