PHYSICS

1957

SovietRxiv

Abstract

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PHYSICS

G. V. GORSHKOV and V. I. MATVIENKO

NEUTRON YIELD FROM SOURCES Rn + B, Rn + C, Rn + CaF , Rn + Mg, Rn + Al, Rn + Si, Rn + SiO , Rn + GRANITE

(Presented by Academician A. P. Vinogradov on 16 V 1957)

It is known that when light elements are irradiated with alpha particles from natural radioactive substances, neutrons are produced. The principal characteristic of such neutron sources is the yield, i.e., the number of neutrons emitted per second per unit activity. In the present work we give the results of an investigation of yields and of other quantities characterizing radon neutron sources.

All neutron sources were made in the form of cylindrical glass ampoules, 20 mm in diameter and 40 mm high. These dimensions were chosen after an analysis of the yield of sources of various sizes.

The ampoules were tightly filled with powders of the target material. The fillers used were: beryllium, boron, carbon, calcium fluoride, magnesium, aluminum, silicon, silica, and granite (porphyritic granite, 1.3 billion years old, from the Kirovograd region).

The neutron yield was also measured for ampoules without filling, for boron-containing and boron-free glass. Impurities in the materials made of pure elements and compounds amounted to no more than one percent; the exception was amorphous boron, whose purity was 96%. The sources were filled with radon on an ordinary emanation apparatus. The radon content was determined from the external gamma radiation by comparison with a radium standard. Appropriate corrections were introduced for absorption of gamma rays in the source itself and in the standards.

The total number of neutrons emitted by the sources was determined by two methods: with an all-wave boron counter and by recording the distribution curve of the density of slow neutrons in a tank of water.

The boron counter, owing to its high sensitivity and low background, made it possible to measure rapidly weak neutron intensities in the presence of a considerable gamma background.

Since immediately after the preparation of a radon source there is a short period during which RaA has almost come into equilibrium with radon, while RaC has not yet accumulated in appreciable quantity, measurements carried out during this period with the given counter make it possible to determine the relative value of the yield of the source Rn + RaA (alpha-particle energies 5.5 and 6 MeV) with respect to the yield of the source Rn + RaA + RaC (the energy of the latter is 7.7 MeV).

Despite the large error caused by the limited measurement time, it is evident that the increase in neutron yield due to the alpha particles of RaC differs for different elements.

The second method of measuring the number of neutrons made it possible to check the all-wave character of the boron counter, to increase the total accuracy of the measurements, and also to estimate the mean neutron energy, since the latter is linearly related to the relaxation length L—the reciprocal of the exponent in the exponential decay of the distribution of neutron density in water (^{1}).

The neutron background was taken to be the yield of radon ampoules filled with powders of zinc, selenium, and cadmium. The obtained background value of 4 ± 1.5 n/sec per 1 mCu is apparently explained for the most part by neutron emission from the short-lived radon deposit (^{2}), since the calculated upper limit of the background due to bombardment of the ampoule glass by alpha particles is 1—1.5 n/sec per 1 mCu Rn.

For all sources, the relative yield (in percent of the yield of the $Rn + Be$ source) and the absolute yield were found. The error includes only the errors of the relative measurements. The systematic error associated with calibration of the neutron standard does not exceed 4%.

To check the reproducibility of the entire process of preparing and measuring the sources, repeated experiments were carried out with beryllium, boron, granite, and glass; within the measurement errors these gave consistent results. This may serve as confirmation that the yield is free from side effects associated with self-absorption of alpha particles, nonuniform distribution of the active substance, etc.

The experimental results obtained are given in Table 1.

Table 1

Target material	Ratio to the yield of the $Rn + Be$ source, in %	B, n/sec · mCu	Ratio of the $Rn + RaA^*$ yield to the $Rn + RaA^* + RaB + RaC$ yield, in %	L, cm	$\overline{E}_n$, MeV
Beryllium	100	14800 ± 200	45.5 ± 2.5	9.6	4.74
Boron	21.7	3220 ± 36	54.5 ± 2.7	8.1	3.66
Carbon	0.25	37.0 ± 2.0	33 ± 6.6	7.1	2.93
CaF_2	8.31	1230 ± 15	33 ± 2.5	6.1	2.20
Magnesium	2.85	422 ± 6	34 ± 3	8.1	3.66
Aluminum	2.53	374 ± 5	20 ± 2	5.8	1.98
Silicon	0.37	55 ± 2.0	24 ± 5	6.7	2.56
SiO_2	0.22	32.2 ± 3.6	–	–	–
Granite	0.54	80.7 ± 4.0	28 ± 4.5	–	–
Glass, boron-containing	0.92	136 ± 8	–	–	–
Glass, boron-free	0.74	109 ± 7	–	–	–

In conclusion, the authors consider it their pleasant duty to express their gratitude to V. M. Permyakov for providing the opportunity to carry out the work, and to O. M. Nechaeva for preparing the sources.

Radium Institute named after V. G. Khlopin
Academy of Sciences of the USSR

Received
2 XI 1956

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Note: Figure translations are in progress. See original paper for figures.