Measurement of the Disintegration Rate of Sodium^{22} by the Coincidence Method[1]

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A coincidence method of measuring the absolute disintegration rate (total strength) of sodium^{22} sources is described.

Prevention of false coincidences and the separation of the total gamma counts observed in the basic measurements into nuclear and annihilation radiation incident to the positron emission is accomplished by magnetic deflection and a series of supplementary measurements in which a platinum-cylinder Geiger-Müller gamma counter is used. A copper cylinder gamma counter was used in the basic measurements.

The radioactive preparation was an aqueous solution of NaCl of 1 milligram per milliliter concentration and with a ratio of radioactive Na^{22}Cl to carrier (stable) NaCl of the order of 1 to 10^{10}. The disintegration rate of the test source (0.8 milliliter of this solution) was found to be 2.15×10^4 disintegrations per second with a conservatively estimated accuracy of ± 5 percent. Of the total gamma counts, 70 percent was of nuclear origin; whereas 30 percent were due to annihilation radiation.

The efficiency of the platinum counter relative to that of the copper counter in detecting annihilation radiation (0.51 Mev) was 2.9. Their detecting efficiencies for nuclear gamma radiation (1.3 Mev) were nearly alike.

I. Introduction

The absolute disintegration rate of a radioactive preparation can be readily determined by the coincidence method if the disintegration scheme is known to be simple. Thus, if the isotope in question emits one beta followed by one gamma ray, observations are made of the beta, gamma, and beta-gamma coincidence rates and the absolute disintegration rate determined without reference to the efficiencies of the detectors or the geometry of the arrangement, from the relation

$$N = \frac{B \times G}{C}, \qquad (1)$$

where

B = beta counting rate;
G = gamma counting rate;
C = beta-gamma coincidence rate.

In the case of positron emitters, the application of the coincidence method presents two difficulties.

a. False coincidences result from the positrons registered by the beta counter and the associated annihilation radiation registered by the gamma counter.

b. The gamma counter responds to nuclear gamma rays as well as to the annihilation radiation; and there is no simple way of ascertaining what fraction of the total counts is due to the nuclear gamma rays alone.

Sodium ^{22} is a positron emitter and exhibits a simple disintegration scheme: 0.6 Mev positron followed by a 1.3 Mev gamma ray. To circumvent the above mentioned difficulties, a somewhat more elaborate coincidence method first employed by Leibnitz[2] was used.

[2] Z. f. Phys. **122**, 233 (1944).

[1] This work was done with the assistance of the Atomic Energy Commission.

II. Source and Experimental Arrangement

The radioactive sodium used in these measurements was produced in a cyclotron by the reaction Mg (d, α) and received here in the form of magnesium uranyl acetate. It was converted to NaCl by using a process developed by J. W. Irvine of MIT. The source was prepared by four successive depositions of 200 μl of the NaCl solution on paraffin coated cellophane.

The experimental arrangement is shown schematically in figure 1. The source and the two counters were placed between the pole pieces of an electromagnet. A lead block was placed between the two counters. With this arrangement the counted positrons follow a semicircular path, and the annihilation radiation produced in and near the beta counter is prevented from reaching the gamma counter and registering false coincidences. The magnetic field used throughout these measurements was about 300 gausses.

III. Procedure

As in the standard coincidence method, measurements were first made of the positron, gamma, and coincidence rates (B, G_1, and C_1) with the application of the usual corrections for background, accidentals, and cosmic coincidences. Following these principal measurements a series of supplementary tests was made as follows:

An aluminum cover about 1/32 in. thick was placed over the source and the gamma counting rate again observed. Although the counter now registered the same number of nuclear gamma's as in the previous test, additional annihilation quanta were produced by the interaction of the positrons with the aluminum, and the total counting rate increased to a new value (G_2).

The copper-cylinder gamma counter used in the preceding measurements was then replaced with a platinum-cylinder gamma counter of the same dimensions, the aluminum cover was removed, and the coincidence rate (C_2) again measured. The platinum counter is known to have a different detecting efficiency characteristic as a function of gamma-ray energy, the efficiency being particularly higher for low energy gamma rays. Since the annihilation radiation did not contribute to the observed coincidences (C_1 and C_2), the ratio of

the coincidence rates is also the ratio of the efficiencies of the respective counters in detecting the nuclear gamma radiation. We designate the ratio as $m = C_2/C_1$.

The gamma counting rate of the platinum-cylinder gamma counter was then measured; first without any cover over the source (G_3) and then with an aluminum cover placed over the source (G_4). As in the case of the similar measurement with the copper-cylinder counter, G_4 was greater than G_3 due to the additional annihilation radiation.

The increase in the gamma count could conceivably be produced partially by the Compton-effect photons, but this increase, if present, will be small and has been neglected.
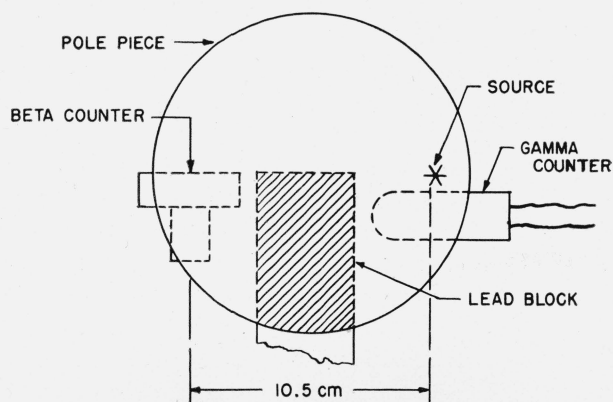

FIGURE 1. *Experimental arrangement for measuring the disintegration rate of* Na^{22}.

IV. Interpretation of Experimental Data

To derive the desired information from the experimental data, the following quantities are introduced:

y, counting rate due to nuclear gamma rays only in the determination of G_1.

x, counting rate due to annihilation radiation only in the determination of G_1.

n, the ratio of the annihilation counts in the measurement of G_2 (using aluminum cover) to the annihilation counts in the measurement of G_1 (without aluminum cover).

l, relative efficiency for detecting annihilation quanta of the platinum gamma counter with respect to the copper counter.

The following four equations relate these four quantities to the measurements data

$$\left.\begin{array}{l} G_1 = y + x \\ G_2 = y + nx \\ G_3 = my + lx \\ G_4 = my + nlx \end{array}\right\} \quad (2)$$

These equations can be solved, and it is the value of y rather than G_1 that is used in eq 1 in computing the absolute strength of the source.

V. Numerical Values

The following numerical results were obtained in our measurements

$$B, 2,067/\text{min.}$$

$$C_1, 1.98/\text{min.}$$

$$C_2, 1.93/\text{min.}$$

$$m = \frac{C_2}{C_1}, 0.97$$

$$G_1, 1,766/\text{min.}$$

$$G_2, 1,903/\text{min.}$$

$$G_3, 2,751 \text{ min.}$$

$$G_4, 3,152/\text{min.}$$

The set of equations then yielded:

$$y = 1,236/\text{min.}$$

$$x = 530/\text{min.}$$

$$l = 2.9$$

$$n = 1.26$$

Using the value of y in place of G in eq 1, the disintegration rate of the test source (800 μl)

$$N = \frac{2,067 \times 1,236}{1.98 \times 60} = 2.15 \times 10^4 \text{ disintegration/sec.}$$

$$= 0.0215 \text{ rd.}$$

A sample taken from the same preparation was later measured by an independent method of positron counting and comparison with a known standard. Both results were in agreement to within less than 1 percent.

It is interesting to note that of the total gamma counts observed in the main test only 70 percent was due to nuclear gamma rays, and the remaining was due to annihilation radiation. Without any correction derived from the supplementary measurements, a 43-percent error would have been incurred. The value of 1 (2.9) is significant, showing that for gamma rays of 0.5 Mev. the platinum counter is 2.9 times more efficient than the copper counter, whereas their efficiencies do not differ for 1.3-Mev gamma rays.