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H. P. Kramer

August 31, 1949

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SUMMARY OF THE RESEARCH PROGRESS MEETING OF JULY 28, 1949

H. P. Kramer

August 31, 1949

Scintillation Counters for General Research Use. L. Wouters.

A number of scintillation counters have been designed and produced and are available for general research. Two mountings are available. One consists of a single crystal and photomultiplier tube and the other one contains two photomultiplier tubes and is to be used with a single crystal in detecting radiation that produces low ionization in the crystal.

Each mounting is equipped with a switch that will allow the operator to use the instrument in connection with a linear amplifier or else with a linear amplifier in conjunction with a feed-back loop to produce a square pulse.

The counters are expected to be capable of registering about 3000 counts/sec. in coincidence and about 10^5 counts/sec. when used separately. The resolving time of the circuit is about .25 microseconds. It depends on the time constant of the RC loop, .2 microseconds, which cannot be reduced further without electron accumulation at the counting end of the circuit.

In the present design, electronic and mechanical counting devices are used in preference to an oscilloscope. In the design of a proper mixing unit for coincidence counts the discrimination between almost coincident and coincident counts poses a delicate problem. In an improperly designed mixing unit pulses that are separated in time may show as a coincidence because of a random distribution of pulse heights and widths. A partial solution of this difficulty has been achieved in the present apparatus. All pulses are of the same height, 30 volts, and last for .15 microseconds. Pulses that overlap more than .05 microseconds will be counted as coincidences.

The present equipment has been designed for use with anthracene crystals. Anthracene was chosen in preference over the faster transtilbine because it produces bigger pulses. Diphenyl acetylene, a material that has newly been suggested for scintillation counters, may combine the advantages of both anthracene and transtilbine.

The Study of U^{231}. W. Crane.

U^{231} decays both by K-capture and α-emission. As a step in the general development of regularities among heavy α-emitters it was decided to make a detailed examination of the mode of decay of U^{231}. The isotope was produced by the bombardment of thorium with 150 Mev helium ions. By milking the α-daughter Th^{227} and the K-capture daughter Pa^{231} it was possible to determine the half-life for α-decay as being 208 years and to fix the K-capture half-life at 4.2 days.

The following equations embody the assumed mechanism of K-capture decay and suggest alternative experimental procedures:

$$C_K \cdot 1/\varepsilon_K \cdot 1/\rho_K = N \qquad (1)$$

$$C_L \cdot 1/\varepsilon_L \cdot 1/\rho_L \cdot 1/\mu_\alpha + 1 - \rho_K = N \qquad (2)$$

$$Q_{K-L} \cdot 1/\varepsilon_L \cdot 1/\rho_L \cdot 1/\varepsilon_K \cdot 1/\rho_K \cdot \frac{\mu_\alpha + 1 - \rho_K}{\mu_\alpha^2} = N \qquad (3)$$

$$Q_{L-L} \cdot 1/\varepsilon_L^2 \cdot 1/\rho_L^2 \cdot 1/\mu_\alpha^2 \, (1-\rho_K+\mu_\alpha)^2 = N \qquad (4)$$

In these equations, N represents the number of K-capture disintegrations per minute, C the number of counts per minute, Q the number of coincidences per minute, ρ the fraction of x-rays produced that remains unconverted, and ε the external counting efficiency which is the fraction of emitted x-rays of one kind that is actually detected by the counters. The external counting efficiency ε therefore involves both geometrical and electronic considerations. The subscripts refer to the place of origin of the x-rays. The index K, for example, shows that the quantity under consideration pertains to x-rays that are emitted when a vacancy in the K shell is filled by an electron from a higher level. A certain fraction μ_α of all K x-rays produced arises when the vacancy in the K shell is filled by an electron from the L shell. Such K x-rays are called K_α x-rays.

Equation (1) expresses the assumption that every disintegration proceeds by the nuclear capture of an electron from the K shell. Every disintegration thus leaves a vacancy in the K shell which must be filled by the drop of an electron from a higher level and therefore must be accompanied by the production of a K-x-ray. The production of a K_α x-ray is accompanied by the production of an L x-ray since a vacancy is left in the L shell when one of its electrons serves to replenish the K shell. The other source of L x-rays is the internal conversion of K x-rays in the L shell. A K x-ray yields its energy to an electron in the L shell and thereby causes its emission as an Auger electron from the atom. In this way a vacancy arises in the L shell. When this vacancy is filled from a higher level an L x-ray is produced. These notions are expressed in equation (2). It is assumed throughout this work that all K x-rays which are converted are converted in the L shell and thus serve to produce L x-rays. By making use of equations (1) and (2), equation (3) may also be expressed in the form:

$$C_K \cdot C_L/Q_{K-L} \cdot \mu_\alpha{}^2/(\mu_\alpha+1-\rho_K)^2 = N$$

Finally, equation (4) expresses the supposition the L-L coincidences arise by the simultaneous detection of L x-rays that are produced in conjunction with K_α x-rays and L x-rays whose production is incident on the conversion of K x-rays in the L shell.

An attempt has been made to determine the fraction of all disintegrations that culminate in the ejection of an Auger electron by a photographic technique. A drop of solution containing U^{230} and U^{231} was placed on an electron sensitive photographic plate and the number of electron tracks from U^{231} conversions and the number of α-stars from U^{230} disintegrations were counted. Some difficulty was caused by the high electron background. Using U^{230} as a time standard, the fraction of Auger electron emissions among the total number of disintegrations was found to be .08 on the basis of the disintegration rate that was determined from the time wise yield of Pa^{231}.

The number of coincidences was counted by two tubes separated by an angle of 180°. The x-rays were analyzed by various foils placed between a mica sheet permeated with active solution and the counter windows. In coincidence counting, Auger electrons also were stopped by the foils and counter windows. A typical arrangement is sketched in Fig. 1. The efficiency for counting L x-rays was considerably higher than that for counting K x-rays: $\mathcal{E}_L = 0.5$ percent and $\mathcal{E}_K = 0.2$ percent. For this reason the L-L coincidence rate was about 10 times as large as the K-L coincidence rate.

Seventy-eight percent of all disintegrations produce K_α x-rays and therefore also L x-rays, that is, $\mu_\alpha = .78$. Eight percent of all disintegrations give rise to Auger conversion electrons and hence presumably to L x-rays. Therefore, 86 percent of all disintegrations are expected to be accompanied by the emission of L x-rays. Only 51 percent of the disintegrations are however observed to be accompanied by L x-ray emission. It is therefore assumed that 42 percent of the L x-rays are internally converted.

At present, work is continuing in view of the fact that when the observed value for Q_{L-L} is substituted in equation (4) one arrives at a value for N that is four times as large as that observed in milking experiments. In order to explain this discrepancy, it may be necessary to postulate a γ-ray that is completely internally converted primarily in the L shell.

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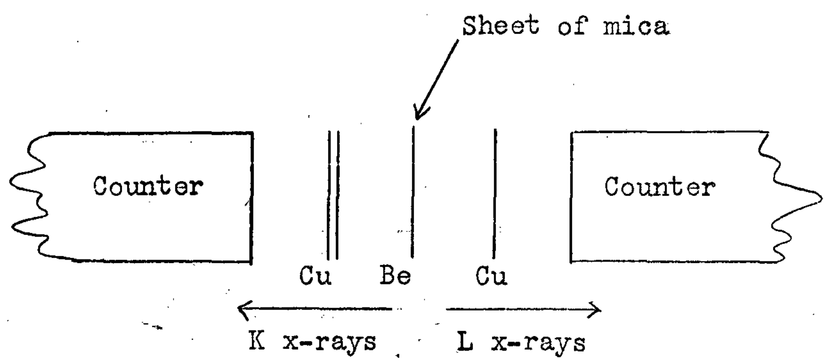

Fig. 1

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