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SUMMARY OF THE RESEARCH PROGRESS MEETING of December 15, 1949

Henry P. Kramer

January 25, 1950

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Electron Showers from Synchrotron: Theoretical Interpretation. Walter Aron.

In conjunction with the experimental investigation of showers initiated by 335 Mev photons from the synchrotron which is being carried out by R. Kenney, the speaker is organizing theoretical calculations with the aim of drawing quantitative conclusions about the processes that give rise to these showers.

The two processes of interest that participate in the production of electron showers are bremsstrahlung and pair production. The initial photon produces two electrons by pair production. These electrons in turn are capable of releasing a photon by bremsstrahlung. The photon that is thus liberated may again produce two electrons. By a repetition of these two alternating processes, a shower of electrons is built up in the material. It is the object of theory to describe the intensity of the shower in terms of the ionization that it is capable of producing as a function of the thickness of material into which it has penetrated.

H. Snyder has discussed the problem of shower production in connection with cosmic ray research. In his treatment he has used several simplifying assumptions that may not suffice for the present requirements. In dealing with the two afore mentioned processes that account for the production of showers, he used the asymptotic cross section rather than the true one. That is, he made the assumption in each case that the initiating particle possesses unlimited energy. It is apparent that this assumption is not satisfactory since a large number of photons at low energies is initially present in the synchrotron beam

and the total energy carried by the shower may be expected to decrease in the course of repeated alternations of pair production and bremsstrahlung.

Another assumption that is commonly employed in shower theory is that scattering is negligible so that the shower proceedes in the direction of the initiating particle. However, in lead a root mean square scatter angle of 45° corresponds to an energy of the incoming particle of 25 Mev.

A further unwarranted assumption that is used in shower theory is that no backscattering occurs. That is, it is thought that the number of electrons that are reflected back into the layer of material at thickness t is negligible. That this is not the case in heavy material at any rate has been shown experimentally by R. Kenney. The number of counts in an ionization chamber inserted between two blocks of lead decreased by forty percent when the portion of lead farther removed from the synchrotron was taken away.

In spite of its insufficiencies, shower theory as discussed by H. Snyder and employed in its essentials by the speaker is the most accessible method that attempts to calculate the number of electrons of energy E that arrive at a thickness t. It does this by summing up the various constituents of the shower as follows:

1. electrons produced by pair production
2. electrons that loose just enough energy by a bremsstrahlung to arrive with energy E
3. electrons that are removed from those that are of interest by bremsstrahlung that diminishes their energy below E
4. electrons that are lost from the energy range E through ionization.

From these considerations the following equation results:

$$\frac{\partial P(E,t)}{\partial t} = 2 \int_E^{W_0} \gamma(W,E) \; \varphi(W, E/W) \, dW$$

$$+ \int_E^{\infty} P(E',t) \; \rho\left(E', \frac{E'-E}{E'}\right) dE'$$

$$- P(E,t) \int_0^E \rho(E, W/E) \, dW$$

$$+ \beta \frac{\partial P(E,T}{\partial E}$$

$P(E,t)$ - no. of electrons of energy E at thickness t.

$\gamma(W,T)$ - no. of photons of energy E at thickness t.

$\beta = \lambda_r \left(\frac{\partial E}{\partial \lambda}\right)_{ion}$ - energy loss due to ionization.

λ_r - radiation length (average distance between bremsstrahlung events on the trajectory of an electron)

Here $\rho(E,\frac{W}{E})$ (Fig. 1) represents the cross section for the production of bremsstrahlung and $\varphi(W,\frac{E}{W})$ (Fig. 2) the cross section for pair production. Ordinarily, the asymptotic cross sections are used in calculations. It is known however that in showers from the synchrotron one is dealing with a large number of low energy processes which cannot be properly accounted for by assuming the asymptotic cross sections. It was thought therefore that by an arbitrary choice of numerically lower cross sections the results of the calculations would come closer to reality. Fig. 3 gives an indication of the outcome of the calculations. All curves were normalized so that the maximum for lead corresponds to an ionization of 100 in arbitrary units. In spite of the many omissions and inaccuracies of the theory

there exists a fair qualitative agreement between the experimental and the theoretical results.

Low Mass Francium and Emanation Isotopes of High Alpha Stability. Earl K. Hyde.

Guided by the correlations between mass number, energy of emitted alpha-particle, and half-life of decay which have been made by Perlman, Seaborg, and Ghiorso (P.R. 74, 1730 (1948)), and which indicate remarkable alpha emission stability for nuclides containing about 126 neutrons, a search was instituted for alpha-stable francium and emanation isotopes in this region.

Fr^{212} and Em^{212} were found in the francium fraction obtained from an irradiated Th target. Fr^{212} decays with an alpha energy of 6.25 Mev and with a half-life of 19 min. The K-capture daughter Em^{212} was observed to decay with a similar energy and half-life of 23 min. The decay scheme on the basis of which assignments were made is shown in Fig. 4.

A more detailed discussion of this work will be found in UCRL 460, Chemistry Division Quarterly Report for June, July and August 1949.

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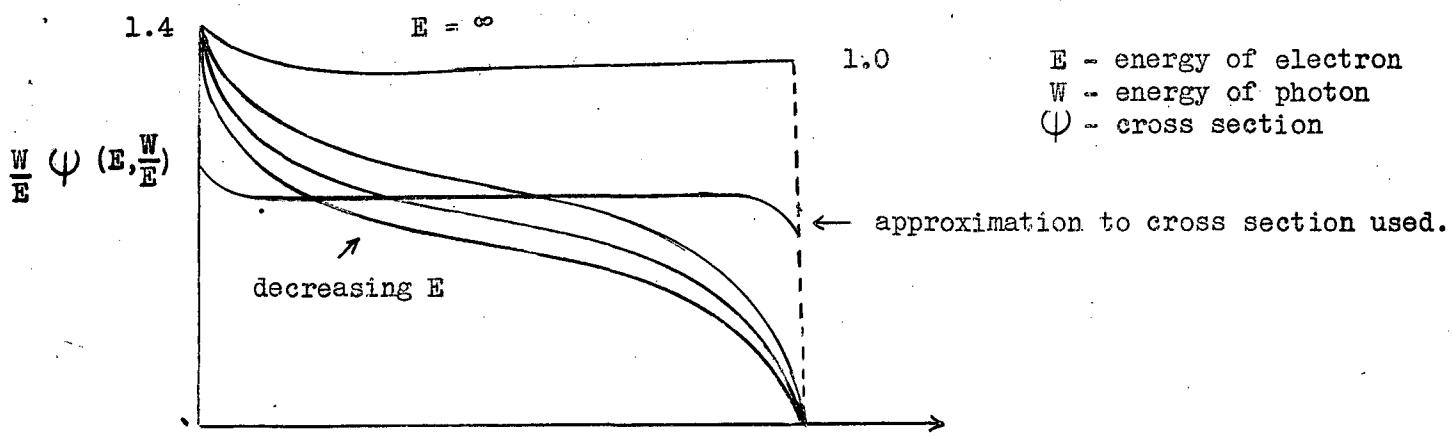


Fig. 1
Cross Section for the Production of Bremsstrahlung

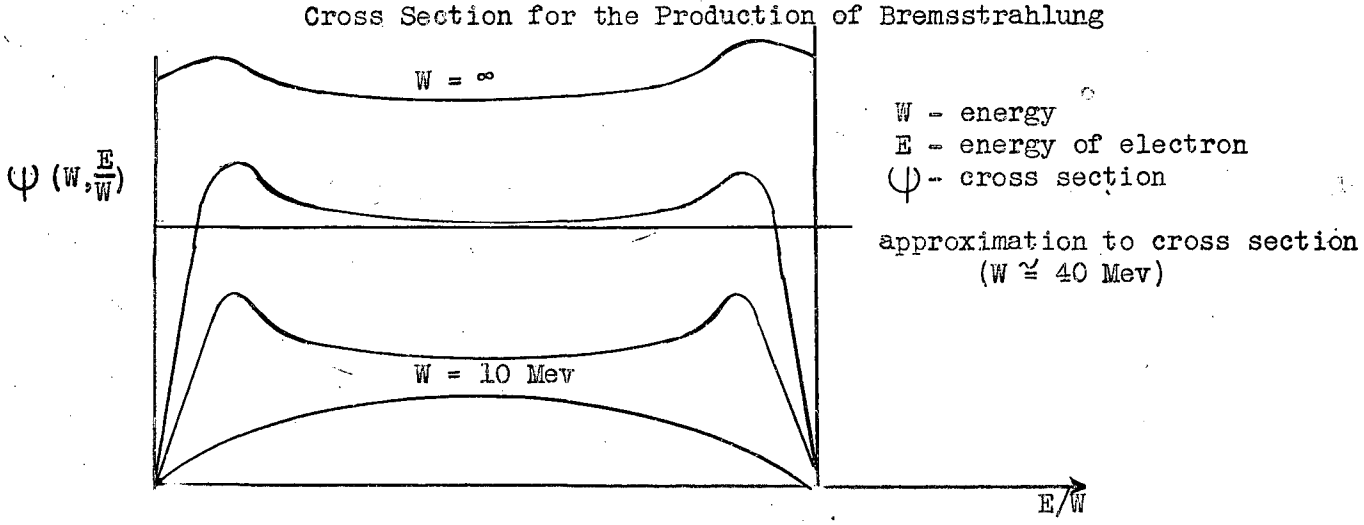


Fig. 2
Cross Section for the Production of Pairs of Electrons

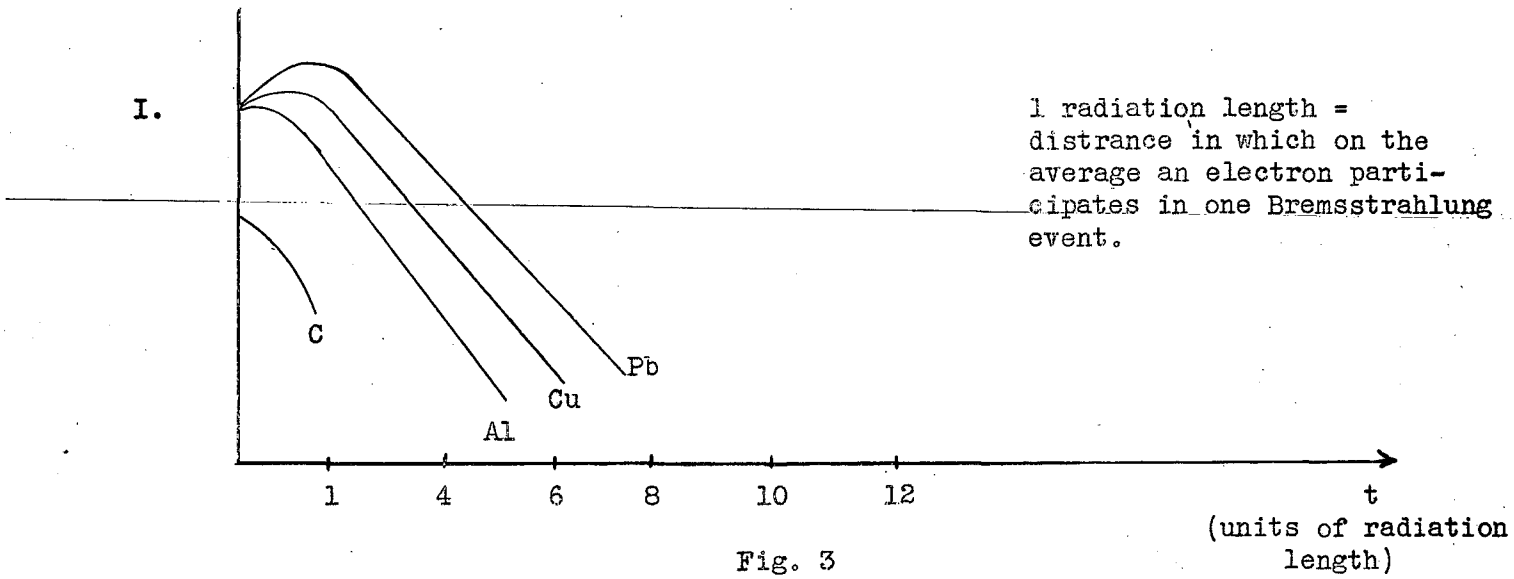
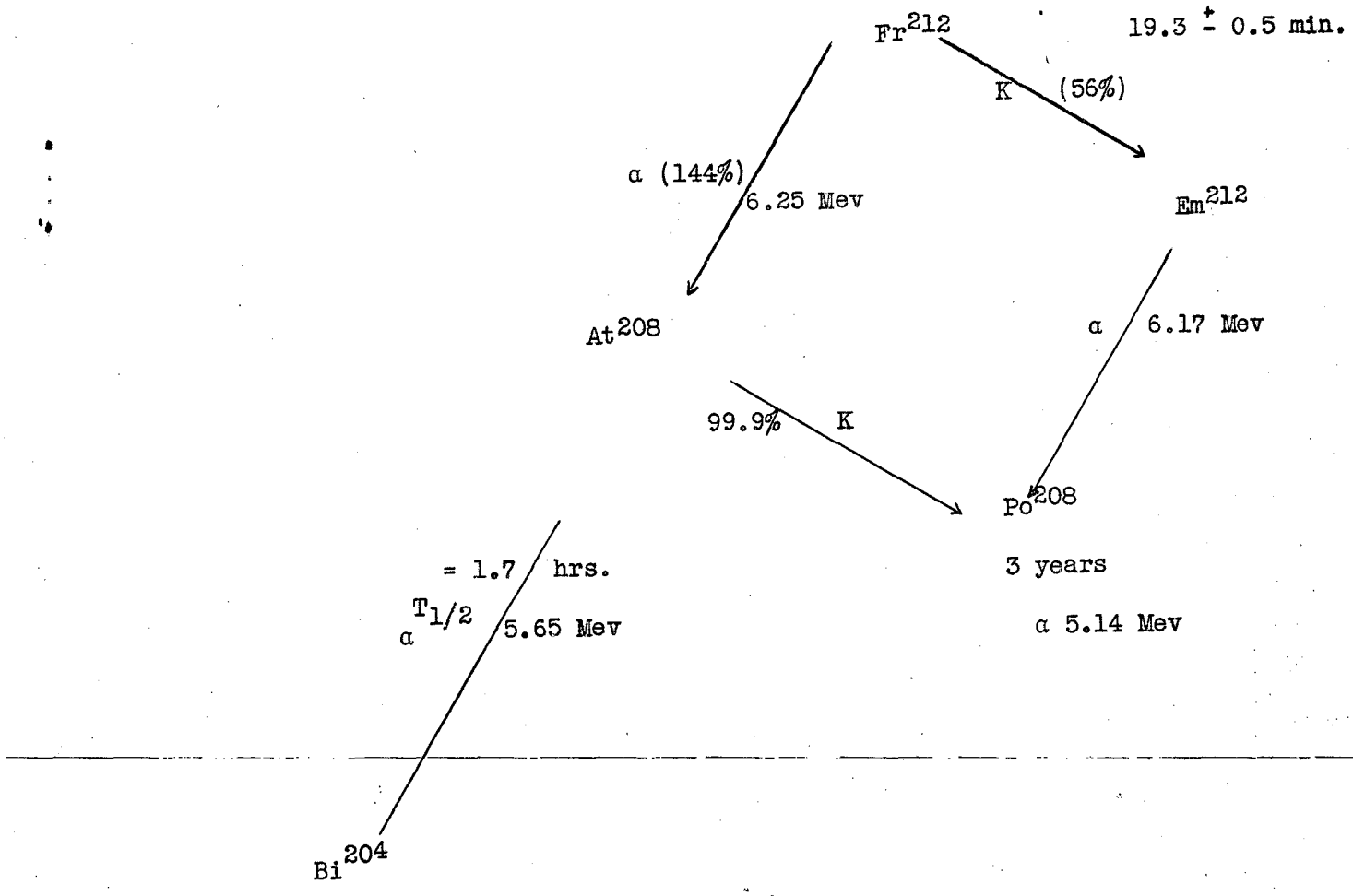


Fig. 3
Ionization from a Shower vs. Thickness of Material


Fr212
19.3 ± 0.5 min.
K
(56%)
α (144%)
6.25 Mev
Em212
At208
α
6.17 Mev
99.9%
K
Po208
= 1.7
hrs.
3 years
α T1/2
5.65 Mev
α 5.14 Mev
Bi204