

Letters to the Editor

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Stopping of Fast Particles with Emission of Radiation and the Birth of Positive Electrons

WE have used Dirac's theory of the electron to calculate (1) the probability that a fast electron, passing through matter, emits a quantum of radiation with energy comparable with its own, and (2) the probability that a quantum of radiation, colliding with a nucleus, gives birth to a positive electron. We use Born's approximation for both processes. Provisional estimates for these two probabilities have been given by Heitler¹ and by Oppenheimer and Plesset².

We find for the cross-section for the former process a complicated formula; if, however, the energy E_0 of the particle is much greater than mc^2 , the formula reduces to

$$\sigma_{\text{rad}} = \frac{Z^2}{137} \left(\frac{e^2}{mc^2}\right)^2 \left[4 \log \frac{2E_0}{mc^2} - \frac{4}{3}\right], \quad (1)$$

where Z is the nuclear charge. This differs in the logarithmic term from the cross-section mentioned above. The cross-section should therefore increase with the energy.

The accompanying table shows the range R_{rad} of an electron in water, calculated from (1), assuming that the loss of energy is all due to radiation. (The range in this case is the distance in which the intensity of the beam is reduced by $1/e$.) This is compared with the range R_{ion} due to loss of energy by excitation and ionisation.

E_0	10	100	1000	10 ⁶ volts
R_{rad}	62	37	25	cm. in water.
R_{ion}	5	39	320	

For energies $E_0 \sim mc^2$ the radiative stopping power is negligible. For $E_0 \sim 100 \times 10^6$ v., R_{rad} is of the same order of magnitude as R_{ion} . For higher energies, R_{rad} is much smaller than R_{ion} . According to the theory, therefore, no particles of any energy can have ranges greater than about 20 cm. of water. But if the cosmic ray particles consist partly of electrons, we know that particles exist with ranges up to 100 metres of water.

The theory seems to be here in disagreement with experiment. On the other hand, perhaps one should not expect the theory to give correct results for energies greater than $137 mc^2$, since the wave-length then becomes smaller than the classical electron radius e^2/mc^2 , and Dirac's wave equation probably no longer applies.

One can also consider the case in which the electron makes a transition to a state of negative energy E . On Dirac's hole theory, this can only happen if a hole of energy E was previously present. Assuming that a hole is a positive electron, we have simply the recombination of a positive electron with energy E and a negative electron with energy E_0 to form a light quantum of energy $h\nu = E_0 + |E|$. This is the inverse process to the production of a pair of

electrons by a light quantum in the presence of a nucleus. This process has been detected by Blackett and Occhialini and has been calculated by Oppenheimer and Plesset. We find the cross-section for such a process, for a quantum of energy $h\nu \gg mc^2$, to be

$$\sigma_{\text{pos. El.}} = \frac{Z^2}{137} \left(\frac{e^2}{mc^2}\right)^2 \left[\frac{28}{9} \log \frac{2h\nu}{mc^2} - \frac{218}{27}\right] \quad (2)$$

This differs from Oppenheimer and Plesset's formula by the $\log h\nu$ and the numerical factors.

The cross sections in water and lead calculated from (2) are as follow, the first two values being obtained by numerical integration from the exact formula:

$h\nu$	3	6	100	mc^2
H ₂ O	0.32	3.3	32	10 ⁻²⁶ cm. ²
Pb	0.33	3.4	33	10 ⁻²⁴ cm. ²

The values for 3 and 6 mc^2 seem to be roughly in agreement with the experimental results for γ -rays of these energies.

The complete calculations will appear later.

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¹ *Z. Phys.*, **84**, 145.
² *Phys. Rev.*, **44**, 53.

Inheritance of Egg-Colour in the 'Parasitic' Cuckoos

THE interesting suggestion recently made by Mr. Wynne-Edwards in these columns¹ with respect to the inheritance of egg-colour in the 'parasitic' cuckoos calls for a few remarks from the genetical point of view. Granting for the moment that the various types of egg-coloration in a polymorphic species such as *Cuculus canorus* are dependent upon a series of multiple allelomorphs, the location of such a series in the X-chromosome means that the nature of the egg laid by any hen must always depend upon the nature of the X-chromosome which she receives from her father. It is, therefore, rather misleading to state that the male cuckoo does not belong to the *gens* (in the Newtonian sense) at all. True, he may carry X-chromosomes characteristic of two distinct *gentes*, but since he must be supposed to determine the *gens* of all his daughters, it seems rather harsh to ostracise him as Mr. Wynne-Edwards would have us do.

There is, however, another possibility which would theoretically depose the male to the status for which Mr. Wynne-Edwards argues, namely, the location of a series of multiple allelomorphs for egg-colour and pattern in the Y-chromosome of the hen. On this hypothesis every daughter of a hen cuckoo would resemble her mother in the character of the eggs laid by her, no matter who her father was. On general grounds there are no reasons why the Y-chromosome should not carry genetical factors. Indeed, some years ago, P. G. Bailey and I² showed that the simplest explanation of hen-feathering in the cocks of certain breeds of poultry involved the existence of a factor for hen-feathering in the Y-chromosome of the hens of all breeds. Moreover, the work of Schmidt and of Winge³ on *Lebistes*