REFERENCES

[1] Heisenberg, *Zeits. f. Phyes*, **77**, 1, 1932; **78**, 156, 1932; **80**, 587, 1933.
[2] Lande, *Phys. Rev.*, **43**, 620, 624, 1933.
[3] Rutherford, etc., Radioactivity, p. 541.
[4] Rutherford, etc., Radioactivity, Chap. XIII.
[5] Ellis and Wooster, *Proc. Roy. Soc.*, **117**, 109, 1927; Meitner, *Zeits. f. Phys.*, **60**, 143, 1920.
[6] Sargent, *Proc. Roy. Soc.*, **139**, 659, 1933.
[7] Beck and Sitte, *Zeits. f. Phys.* **86**, 105, 1933.
[8] Anderson and Neddermeyer, *Phys. Rev.*, **43**, 1034, 1933.
[9] Meitner and Hupfeld, *Naturwissensch*, **21**, 286, 1933.
[10] Curie and Joliot, *Jour. de Physet Rad.*, **4**, 492, 1933.
[11] Blackett and Ochialini, *Proc. Roy. Soc.*, **139**, 699, 1933.
[12] Gray and Tarrant, *Proc. Roy. Soc.*, **136**, 662, 1932.
[13] Gentner, *Comptes Rendus*, **197**, 403, 1933.
[14] Oppenheimer and Plessett, *Phys. Rev.*, **44**, 53, 1933.
[15] Dirac, *Proc. Roy. Soc.*, **126**, 360, 1930; **133**, 60, 1931.
[16] Kunz, *Zeits. f. Physik.*, **80**, 559, 1933.
[17] Eastermann and Stern, *Zeits. f. Phys.*, **85**, 17, 1933.
[18] Chadwick, *Proc. Roy. Soc.*, **142**, 1, 1933.
[19] Eddington, Internal Constitution of Stars.
[20] Dirac, *Proc. Camb. Phil. Soc.*, **26**, 361, 1930.
[21] Gamow, *Zeits. f. Phys.*, **51**, 204, 1928; Gurney and Condon, *Nature*, **122**, 439, 1928; Laue, *Zeits. f. Phys.*, **52**, 726, 1928; Houtermans, *Engeb d. eaxkt. Naturwissensch.* IX, p. 100, 1930.
[22] Gamow, Radioactivity, Chap. II.

56 (a). A SUGGESTED EXPLANATION OF BETA-RAY ACTIVITY

M. N. SAHA and D. S. KOTHARI

(*Nature*, **132**, 747, 1933)

THE β-ray activity of radioactive bodies has until now proved to be a very baffling problem. The points at issue are summarised in Gamow's "Constitution of Atomic Nuclei", etc. (pp. 52-54), and in "Radiations from Radioactive Bodies" by Rutherford, Chadwick and Ellis (p. 385). They are also discussed at some length by Bohr in his Faraday lecture (1930).

Briefly speaking, the chief points under discussion are the following: the disintegration electrons (β-rays) from a radioactive body are not emitted with a single velocity as in the case of α-rays, but show a distribution of velocities over wide ranges, though the breaking-up of the atom is a unitary process, as is proved by the fact that the life-period is definite and there is one electron for each disintegrating atom. It has further been proved that the continuous distribution of velocities is a nuclear process, and not due to action of the surrounding shell of electrons.

It appears that the β-ray disintegration admits of a very simple explanation on the basis of the recent experiments by Anderson and Neddermeyer, and Curie and Joliot on the production of positrons by the impact of hard γ-rays with the nuclei of elements. These experiments have been interpreted by Blackett and Occhialini as indicating the conversion of a γ-ray quantum into an electron and a positron near the nucleus. Curie and Joliot have brought further evidence in favour of this view by showing that γ-rays of thorium C'' (energy $2{\cdot}6\times10^6$ electron volts) are converted inside all matter into an electron (mass 9×10^{-28} gm., energy $m_0c^2=0{\cdot}51\times10^6\ eV$) and a positron (having the same mass and energy as the electron), the excess energy being distributed as the kinetic energy of the two particles, and the energy of the residual quantum. They have denoted this phenomenon by the term 'materialisation of light quanta'. They have further shown that a proton is a complex structure, being a compound of the neutron and a positron. As pointed out by Blackett and Occhialini, this explains the anomalous absorption of γ-ray quanta observed by Gray and Tarrant, which Gentner has found to commence with the γ-ray possessing the limiting energy 1·1 million electron volts.

The discovery, which is confirmed by so many workers, promises to be of great importance, as it establishes for the first time, on experimental grounds, the splitting up of a quantum into two charged particles of opposite sign. Many astrophysicists have postulated the probability of the annihilation of the proton and the electron with their mass energies converted into quanta, but the actual process, as revealed by these experiments, seems to be very different. For the quantum breaks up into charged particles possessing opposite charges, but having equal mass, and the positron being absorbed by the neutron forms the proton which is thus seen to be complex. The phenomenon is therefore not a "materialisation of the quantum" as Curie and Joliot suggest, for the neutron appears to be the fundamental mass-particle, but it consists in a splitting of the quantum into two fundamental opposite charges. We may call it 'electro-division of the quantum'.

Let us see how we can explain β-ray activity. If the 'electro-division of a quantum' can be brought about by a nucleus when the quantum hits it from the outside, it is

much more probable that the γ-rays produced within the nucleus itself should be completely split up into an electron and a positron. The electron will come out as a β-ray, but a positron will not be able to come out if the conversion takes place within the potential barrier. It will attach itself mainly to some one of the numerous neutrons which are present in the nucleus, and thus form a proton. The positive charge of the nucleus will therefore be increased by unity.

It is not difficult to explain the continuous distribution of β-ray energy. The γ-ray may suffer this 'internal electrodivision' anywhere within the nucleus, and hence the velocities imparted to the resulting electrons may vary within wide limits. The exact mathematical calculation can be carried out only when more data are forthcoming. The positron combining with the neutron will give rise to the softer γ-rays which are always present in a β-ray disintegration.

According to the above view, the β-ray emission is only a secondary process, the primary phenomenon which starts this chain of events being the generation of a primary γ-ray. We can now ask ourselves: How is this γ-ray generated ? It must be due to the passage of an α-particle or proton from one barrier to another. Gamow, and also Condon and Gurney have postulated the existence of only one barrier in a radioactive nucleus for explaining the emission of α-rays, with definite velocity, but several lines of argument indicate that there may be more than one barrier present in the nucleus. When an α-particle crosses from one barrier to the other, the γ-ray responsible for the whole chain of events leading to the β-ray disintegration is emitted. The life-period is therefore determined by the time of leakage of an α-particle or proton from one barrier to another, and this explains why the life-periods of β-ray bodies are of the same order as those of α-ray bodies, and have a definite value.

Department of Physics.
Allahabad University. Oct. 20.

56 (b). A SUGGESTED EXPLANATION OF BETA-RAY ACTIVITY

M. N. Saha and D. S. Kothari

(*Nature*, **133**, 99, 1934)

In continuation of our letter on the above subject which was published in Nature of November 11, 1933, p. 747, we wish to add the following remarks:—

We have changed the term 'electrodivision of quantum' used in that letter to 'electrofission of quantum'. Under the intense electrical field of the nucleus, a quantum of sufficient energy undergoes *fission* into an electron and a positron, the energy being distributed between them in varying proportions, but the law of conservation of energy continues to hold good.

Our interpretation offers an unforced solution of Bohr's paradox that though the nucleus contains no electrons, free or bound, but only positive particles (α-rays, protons) and neutrons—a view which is now universally held—a β-ray can be created inside it and ejected with high speeds. It has further been established that radioactivity, whether marked by an α-ray or a β-ray disintegration, is mainly due to the leakage of loosely bound α-particles through the potential barrier. The β-ray is only a by-product, when the α-particle cannot escape, but on leaking to the second crater falls into a lower level, and gives rise to a γ-ray which undergoes fission into an electron and a positron.

We should further add that the phenomenon of 'electrofission' is different from the reverse process of annihilation of charges or conversion of radiant energy into mass postulated by many astrophysicists. For when a positron and an electron combine to form one or two γ-ray quanta, the charges do not neutralise but form a dipole which can be again disrupted into its constituents. This does not bring us nearer to the problem of the total conversion of mass to radiation, for the main amount of mass resides in the neutron, which according to one of us (Kothari) is a dipole formed of two Dirac magnetic poles of opposite sign, separated by a distance of e^2/Mc^2. The neutron evidently cannot be disrupted by the nucleus; the binding is too strong. It may be disrupted, however, by the electromagnetic action of cosmic rays, giving rise to free magnetic poles. Such phenomena, to our knowledge, have not yet been observed.

Much other evidence, physical as well as astrophysical, in favour of these views has been obtained.

Allahabad.
Dec. 5.