A New Hard Component of the Cosmic Ultra-Radiation

THE Steinke apparatus, which recorded the ionisation caused by the cosmic ultra-radiation at Abisko in northern Sweden during the polar year 1932–33[1], was moved in the middle of July to the iron ore mine Kiirunavaara, near Kiruna, in order to record the absorption curve of the cosmic ultra-radiation below various thicknesses of iron ore. The Kiirunavaara mountain is pierced at different levels by numerous galleries with rail tracks, some of which follow the ore body through its whole length (4 km.). It was therefore possible to move the apparatus, placed on a wagon or trolley, below layers of pure iron ore of different thickness from 160 to 10 metres, corresponding to water equivalents of 800–50 metres (the specific gravity of the ore being 5). Above the ore is only the atmosphere.

During three weeks in July there were holidays in the mines, and the management kindly lent me an electric train for the investigation of the cosmic ultra-radiation in the main galleries of the Kiirunavaara mountain. The apparatus and a lead shield of 10 cm. thickness were assembled in a wagon and kept at constant temperature, and the wagon was moved below thicknesses of 107–60 metres of ore. It immediately appeared, however, that the ore sends out an unexpected and rather strong penetrating radiation; later investigation showed that the ore in this gallery had a radium content up to 0·05 mgm. per ton. (So far as I have been able to find from the literature accessible to me, this is the first time that radium has been found in iron ore.) Also the air in the gallery was highly radioactive and increased the ionisation within a 10 cm. lead shield to values which were impossibly high for the cosmic ultra-radiation. Nevertheless, if these values were reduced to their equivalent in radium radiation (which was taken up without shield), they showed an increase with decreasing thickness of the ore, and this increase indicated an absorption coefficient of the cosmic ultra-radiation about ten times less than that of the hardest component found by E. Regener[2]. At the beginning of August, V. F. Hess, W. Kolhörster, E. Regener and E. Steinke were privately informed about this result.

In order to eliminate the radium radiation, especially that from the air, special precautions and arrangements were necessary for the following measurements. A large airtight iron box of the dimensions 120 cm. × 80 cm. × 85 cm. was constructed containing two chambers, one above the other. This box was placed upon a trolley and in the lower chamber the ionisation cylinder of the Steinke apparatus was placed within a lead shield of 20 cm. thickness open upwards. Before the microscope was a window, and the photographic recorder was placed outside the box before this window. The airtight floor of the upper chamber was laid directly upon the lead shield, and upon this floor the upper lead shield of 10 or 20 cm. thickness was placed. Also the upper chamber could be made airtight. At the request of the management of the mines, measurements of the radium radiation were also carried out, and therefore the ionisation was recorded both with the shield open above (that is, with no shield in the upper chamber) and with shields of 10 cm. and 20 cm. above. During a month and a half, seven series of measurements were taken below 13–104 metres of ore; one series was taken without a shield in the upper chamber in order to get the radium radiation. The apparatus stood generally twenty-two hours at every place in every series and recorded the ionisation during every hour.

As might have been expected with respect to the radioactive air enclosed in the box, the values decreased steadily until the last two series, but the differences between daily values and the corresponding values of the last series were found to fit closely to the curve of decreasing radium emanation as given by Meyer and Schweidler[3], so that daily values could be accurately reduced for this air radiation. The values were further reduced for some radium radiation, which entered around the microscope, where it is impossible to make the shield as thick as elsewhere. The resulting mean values of the cosmic ultra-radiation plus the zero ionisation of the apparatus are: below 13 m. ore, 0·1346 J.; below 28 m., 0·0615 J.; below 53 m., 0·0402 J.; below 75 m., 0·0374 J.; below 86 m., 0·0366 J.; and below 104 m., 0·0366 J.

Irrespective of the value of the zero ionisation (*Restgang*), these numbers indicate three components of the cosmic ultra-radiation penetrating 13–86 metres of ore, and the softest component has an 'apparent' mass absorption coefficient of $(\mu/\rho)_{H_2O}$ 0·00020 cm.^{2} gm.$^{-1}$; that is, is identical with the hardest component of E. Regener[2] ($\rho = 5$; $(\mu/\rho)_{H_2O} = 1{\cdot}19\ (\mu/\rho)_{Fe}$). The coefficients of the two harder components are rather sensitive to the magnitude of the zero ionisation, the exact value of which is not yet known but will be observed by the forthcoming measurements below 160 metres of ore at a deeper level of Kiirunavaara. The zero ionisation cannot, however, be much less than the value now observed, namely, 0·0322 J., and, taking 0·0300 J. as preliminary value, we obtain as apparent mass absorption coefficients of the two still harder components: $(\mu/\rho)_{H_2O} = 0{\cdot}00011$ and 0·00003 cm.^{2} gm.$^{-1}$ respectively. The first coefficient agrees rather well with that recently found by W. Kolhörster[4] $(\mu/\rho)_{H_2O} = 0{\cdot}00013$ cm.^{2} gm.$^{-1}$, but the second coefficient indicates a hitherto unknown component, much more penetrating than the others, and the existence of this hardest component seems well established by the present measurements. The exact mass absorption coefficients will be calculated, when the zero ionisation has been determined below 160 metres of iron ore.

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[1] *Lund Obs. Circ.*, 6, 1931.
[2] *Phys. Z.*, **34**, 306; 1933.
[3] "Radioaktivität", p. 419; 1927.
[4] *Berlin Ber.*, **23**; 1933.

Cosmic Rays and the New Field Theory

REGENER[1] has found that cosmic rays can be observed at 230 m. below the level of Lake Constance. If these rays, as is generally assumed, consist of electrons (not of protons) the great penetrating power raises a serious difficulty in the adopted theory of electronic motion, that is, Dirac's equation. Using this equation, Heitler and Sauter[2] have shown that a beam of very fast electrons (with an energy $E > 200\ mc^2$) should penetrate not more than 1 m. of water when all kinds of absorption processes are taken into account.