Fluctuations of Residual Ionization Current at Great Depths

Recently there appeared in the *Physical Review*[1] a paper by Volney C. Wilson on cosmic-ray intensities at great depths. Wilson has determined these intensities in a copper mine by means of a fourfold Geiger-Müller tube telescope, down to the depth equivalent to 1106.7 m of water. He has not found the very sharp decreases of intensity of cosmic rays at the depths of 250 m and 500 m water equivalent, which were found by Clay[2] and Corlin[3] with ionization chambers. To be sure, when determining the shower intensities by means of Geiger-Müller tube coincidences, Wilson has found slight decreases of intensity at the depths indicated by Clay and Corlin, but in view of possible statistical errors, he is not very positive as to these anomalies.

We believe we are able to indicate a possible explanation of the anomalies found by Clay and Corlin. We have measured residual currents in ionization chambers filled with argon or with air under pressures up to 34 atmospheres. These observations were made in a rocksalt mine (at Wapno, province Poznań, Poland), at a depth equivalent to 900 m of water; the salt was nearly free from potassium contaminations. We have found that the residual current at this depth shows very marked fluctuations, when measured during relatively short time intervals (not over 30 min.). The conditions of work in the mine were very favorable: very constant temperature, nearly total absence of moisture and very low intensity of local radiation (only 0.01 of that found usually in closed spaces at sea level); moreover, the local radiation was cut off by lead 10 cm thick.

At the depth of 406 m under the earth surface (equivalent to 900 m of water) the residual current in the ionization chamber filled with argon under pressure of 29 atmospheres amounted to 1/320 of the value observed at the earth surface. This corresponds to the lowest intensity found by Clay in the Gulf of Aden at a depth of 270 m of water.

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[1] V. C. Wilson, Phys. Rev. **53**, 337 (1938).

[2] J. Clay, Physica **1**, 373 (1934).

[3] A. Corlin, Nature **133**, 63 (1934).

The Physical State of Chromium Impurity in Corundum

It is well known that the intense red fluorescence shown by ruby when excited by blue light is due to the chromium impurity included in the crystalline ground material corundum Al_2O_3. The spectrum of the fluorescence light at low temperatures shows a sharp intense red doublet at λ6920 and 6934A. Previous observers have pointed out that this sharp doublet is due to the chromium ion Cr^{+++}, and arises as a result of the transitions ${}^2G_{7/2}\rightarrow{}^4F_{7/2}$ and ${}^2G_{9/2}\rightarrow{}^4F_{9/2}$. But the exact physical state of these fluorescent Cr^{+++} ions, in relation to their surrounding ground material is still a matter of doubt and uncertainty.

I came across an old and neglected observation of Mendenhall and Wood[1] which when interpreted throws some light on the question in a striking manner. They found that under the action of a magnetic field each line of the doublet is split up into four components. As the transitions concerned here are between states with $J=7/2$ or $9/2$, the Zeeman pattern in usual circumstances would consist of 18 or 14 components. Actually it is observed that there are only four components for each line of the doublet.

This fact can be satisfactorily explained only on the assumption that the fluorescent ions of chromium actually replace the aluminum ions of the lattice of the crystalline ground material Al_2O_3 and that they are not scattered at random in the body of the corundum as stray impurity in the form of Cr_2O_3 having no definite relationship with the surrounding ions and atoms. For, the chromium ions considered here are paramagnetic and following Bose and Stoner we can suppose that the L moment of the ion is unable to respond to the external magnetic field as it tends to assume a definite orientation with respect to the neighboring ions and atoms. Only the spin moment is free to orientate and this alone will be quantized under the magnetic field. Thus the upper as well as the lower energy level which gives either line of the doublet will be split up into two sublevels, according as the spin is parallel or antiparallel to the direction of the magnetic field, H. The transitions from the two upper levels to the two lower ones will then give four Zeeman components, for each line of the doublet.

The components in the Zeeman pattern are sharp. All the fluorescent Cr^{+++} ions scattered in the ground material must, therefore, have their L moments orientated in a like manner with regard to the surrounding ions and atoms, so that they will all be in identical energy states. This equivalent inability of the L vectors in all the Cr^{+++} ions to respond to the magnetic field is possible if it is assumed that the Cr^{+++} ions replace the Al^{+++} ions of the ground material and are thus constituents of the regular crystal lattice.

The interval between the outermost two components of the Zeeman pattern can be calculated if the Landé factor g is taken to be 2, as only the spin is quantized.

$$\begin{aligned}\Delta\nu &= (\Delta m-\Delta m')\times g\times L\times H.\\ &=4\times 2\times 4.674\times 10^{-5}\times 22000.\\ &=8.23\ \text{cm}^{-1}.\end{aligned}$$

The interval actually observed is about 10.4 cm^{-1}, i.e., of the same order of magnitude as the one calculated above.

A detailed account of this and other aspects of the question will appear elsewhere.[2]

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[1] Mendenhall and Wood, Phil. Mag. **30**, 316 (1915).

[2] To be published in Phil. Mag.