one gets[17]

$$C_v = 6.70 \text{ cal./g atom °C.}$$

If one assumes that the specific heat due to the lattice vibrations at this temperature is the Dulong and Petit value of $3R$, then the quantity

$$C_v - 3R = 0.73 \text{ cal./g atom °C}$$

represents the electronic specific heat at this temperature. The theoretical value of the electronic specific heat computed by Eq. (3) is 0.59 cal./g atom °C, and the agreement between these two values is very good.

It is to be expected that the theoretical value of the electronic specific heat would be smaller than the other value. If the lattice vibrations were not entirely harmonic the value of $(C_v - 3R)$ would contain contributions due to the anharmonicity as well as the contribution of the electronic specific heat. Furthermore, the method of calculating the electronic energy bands reported here did not consider such corrections as exchange and correlation, which would tend to make the total spread in energy smaller and hence $n(\epsilon)$ larger. This would make the electronic contribution greater than that found here.

Qualitatively one can see that the electronic specific heat of body-centered iron would be greater than that of face-centered iron because $n(\epsilon_m)$ is greater for the body-centered iron. Manning[8] has already pointed out that it is because of this high electronic specific heat for the body-centered phase that this phase again becomes stable as the temperature increases.

In conclusion it should be pointed out that the same approximations have been made in the calculations for face-centered iron as were made for body-centered iron. A detailed discussion of these approximations and their accuracy has been given by Manning[8] in Appendix III of the paper on body-centered iron.

[17] By a method involving an extrapolation of β, Mme. Lapp has calculated a value of C_v to be 7.66 cal./g atom °C; see reference 16.

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The Nature of the Primary Particles Responsible for Cosmic-Ray Phenomena

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LATITUDE EFFECT CONSIDERATIONS

As a preliminary, we notice that if $\beta = v/c$, the minimum value for vertical entry through the earth's magnetic field H of a particle of mass m and charge ne is given by

$$(m/n)[\beta_m/(1-\beta_m{}^2)^{\frac{1}{2}}] = ef(H), \quad (1)$$

where $f(H)$ involves only the field and terrestrial dimensions, and e is the electronic charge.

We note, therefore, that if subscripts (1) and (2) refer to magnetic latitudes φ_1 and φ_2

$$\frac{\beta_{m1}}{(1-\beta_{m1}^2)^{\frac{1}{2}}} \frac{(1-\beta_{m2}^2)^{\frac{1}{2}}}{\beta_{m2}} = \frac{f(H_1)}{f(H_2)}. \quad (2)$$

We note further that if the primary particle splits into mesotrons which are born at rest in the frame of reference of the primary particles, then the value of β for the primary particle is equal to that for the corresponding mesotrons, and (2) applies for the minimum velocities of the mesotrons at the two latitudes.

Now the writer has shown[1] that if $F(E)dE$ represents the energy distribution of the vertically directed mesotrons at the point of production, then the number of mesotrons at a distance x below this point, and resulting from the group representing the integrated value of $F(E)dE$, is N_x where

$$N_x = \int_{Em}^{\infty} \{[1 + A/(\gamma+1)]e^{-\lambda x} - A/(\gamma+1)\}^{[\lambda c\tau_0(\gamma+1+A)]^{-1}} F(E)dE, \quad (3)$$

[1] W. F. G. Swann, Phys. Rev. 60, 470 (1941).

with

$$A \equiv \alpha\rho_0/\lambda m_0 c^2,$$

and

$$\gamma \equiv E/m_0c^2 = [1/(1-\beta^2)^{\frac{1}{2}} - 1];$$

m_0, τ_0, ρ_0, α, E_m being, respectively, the rest mass of the mesotron, its mean life at rest, the ratio of the atmospheric density at $x=0$ to that at sea level, the ionization energy loss per unit of mass (per unit area) traversed, the minimum energy for entry, and where λ is the constant in the expression $\rho = \rho_0 \exp[\lambda x]$ for the relative atmospheric density at the depth x.

Now if R_{12} is the ratio of the values of N_x at the latitudes φ_1 and φ_2, we see from (3) that R_{12} at sea level depends only upon $(1-\beta_{m1}^2)$, $(1-\beta_{m2}^2)$, and the altitude of production. We can express $(1-\beta_{m2}^2)$ in terms $(1-\beta_{m1}^2)$ by (2) and then, R_{12} depends only upon β_{m1} and the altitude of production.

If now we repeat the process for the *latitude ratio* R_{12}' at another altitude, we shall find another set of values of $(1-\beta_{m1}^2)$ with corresponding altitudes of production necessary to fit the facts. There will be only one value of $(1-\beta_{m1}^2)$ which fits the values of R_{12} and R_{12}' for the same altitude of production. On submitting the matter to calculation, using the sea-level data[2] for latitudes and 0°, and A. H. Compton's data[3] for an altitude of 13,000 feet, we find $(1-\beta_{m1}^2)=0.028$ for the latitude 40°. Using this in Eq. (1), and realizing that $f(H)$ is known for the latitude in question, we find that m/n equals the proton mass. Thus the conditions are satisfied by a primary particle of proton mass and single electronic charge splitting into 10 mesotrons,[4] since the mesotron mass is approximately one tenth that of the proton. Moreover there is no other value of n which would lead to a particle having the mass of any known particle.

[2] E.g., A. H. Compton and R. N. Turner, Phys. Rev. **52**, 799 (1937); T. H. Johnson, Rev. Mod. Phys. **10**, 194 (1938).

[3] A. H. Compton, Rev. Sci. Inst. **7**, 71 (1936); R. T. Young and J. C. Street, Phys. Rev. **51**, 386 (1937).

[4] In the writer's previous paper, Phys. Rev. **60**, 470 (1941), a value 5 instead of 10 was reached. This resulted from considerations founded upon an erroneous value taken for the vertical magnetic cut-off energy.

CONSEQUENCES OF INTENSITY-ZENITH ANGLE CONSIDERATIONS

The writer has called attention[5] to the fact that the flatness of the intensity-zenith angle curves at high altitudes points to a decay of low energy mesotrons, with the creation of electrons whose directions of motion show wide angles with the directions of the primaries.

In an unpublished memorandum, the writer has shown that if electrons are born from mesotrons in such manner that they travel out on the average equally in all directions in the frame of reference of the mesotrons, then viewed from stationary axes they perpetuate the direction of the mesotrons to such an extent that the ratio of the electron intensity in a direction perpendicular to a mesotron stream to that in the direction parallel to it is, in the case of mesotrons of constant velocity βc, given by $1-\beta^2$. If the ratio has to be as great as 50 percent at high altitudes, as experimental data demand, we must have $1-\beta^2$ not much less than 0.5.

Now the value of $1-\beta^2$ which evolves from the foregoing latitude considerations, and appropriate to the mesotrons from protons as primaries is 0.028. Such a value for the mesotrons would result in inappreciable horizontal electron intensity. If, however, we consider singly charged helium atoms as primaries, the value of $1-\beta^2$ for the minimum energy of entry at latitude 40° is 0.45. Such a value of $1-\beta^2$ can provide, therefore, for an appreciable horizontal intensity in the resulting electrons. The inference is, therefore, that there may be two types of primaries—protons which are responsible for the generation of the mesotrons observable at sea level and at semi-high altitudes, and in addition, heavier particles, possibly singly ionized helium atoms which, through their offspring electrons, result in the special features pertinent to the broad intensity-zenith angle curves for high altitudes.

I wish to thank Mr. Paul Weisz for his discriminating computation of the data in this paper.

[5] W. F. G. Swann, Rev. Mod. Phys. **11**, 242 (1939); Phys. Rev. **59**, 770 (1941).