During the years 1930–32 there appeared three new deflection values of e/m, and one new spectroscopic value. All four determinations were mutually consistent and apparently of high accuracy. From them I deduced[2] 1.759 ± 0.001 as the best value of e/m. In other words, the 1929 discrepancy had disappeared, and the error had been shown to lie in the 1929 deflection value.

In the succeeding two years three new values of e/m were obtained, all by chance being just 1.757, and in 1936 I gave[3] 1.75762 ± 0.00026 as the most probable value. It appears now that most of these new "low" values represented preliminary results only, and the final values now available are appreciably higher. In fact Dunnington,[4] in connection with his own beautiful work on e/m, gave 1.7584 ± 0.0003 as the most probable value. He found, however, that a discrepancy of 0.0016 still existed between the weighted averages of the spectroscopic and the deflection measurements, and this, although only one-fifth of the 1929 discrepancy, was still, as a result of the greatly increased accuracy of recent work, almost three times the sum of the assigned probable errors.

At the present time there are available ten precision values of e/m, six spectroscopic by four different methods, and four deflection by three different methods. I find that the discrepancy between the two types of experiment has now shrunk to 0.0006, *just the average deviation to be expected from the assigned probable errors*, and that the final weighted average is 1.75909 ± 0.00024 (external consistency).

To obtain these results I have recalculated each published value (with an occasional slight resulting change) in terms of the following set of auxiliary constants, *viz*:[5] $c=299776\pm4$ km/sec., $q=0.99993$, $p=1.00048$, and (all on the *physical* scale) $F=9651.31\pm0.80$ abs. e.m.u., H $=1.00813$, D $=2.01473$, He $=4.00389$, $\bar{\mathrm{C}}=12.0148$. Each result is weighted according to its probable error, and except as noted, the probable error adopted is just that assigned by the respective investigator. The data are (1 to 6 spectroscopic, 7 to 10 deflection)

(a) Separation of He and H lines
 1. $1.7601_5\pm0.0008$[6]

(b) Separation of Hα and Dα lines
 2. $1.7581_4\pm0.0004$[7]
 3. $1.7579_3\pm0.0004$[8]
 4. 1.7592 ± 0.0005[9]

(c) Refraction of x-rays
 5. 1.7601 ± 0.0003[10]

(d) Zeeman effect
 6. 1.7569 ± 0.0007[11]

(e) Direct velocity measurement
 7. 1.7610 ± 0.0010[12]
 8. 1.7588 ± 0.0009[13]

(f) Magnetic deflection
 9. 1.7597 ± 0.0004[4]

(g) Crossed electric and magnetic fields
 10. 1.7571 ± 0.0013[14]

The six spectroscopic results give a weighted average of 1.75895 ± 0.00033 (1.82),[15] the four nonspectroscopic results give 1.75955 ± 0.00033 (0.99), and all ten give 1.75909 ± 0.00024 (1.51) or, considered as the weighted average of the two groups, ±0.00017 (1.07). The nearness to unity of this last ratio, $R_e/R_i=1.07$, shows that the discrepancy between the two groups is just that of the average statistical fluctuation. However, the ratio 1.82 for the six spectroscopic results is unpleasantly large.

That the particular weighting adopted here is relatively unimportant is shown by the fact that the *unweighted* average is 1.75890. As the present most probable value of e/m I recommend $(1.7591\pm0.0003)\times10^7$ abs. e.m.u.

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On the Instability of the Barytron and the Temperature Effect of Cosmic Rays

It is known that the mass absorption of penetrating cosmic rays in air is greater than in earth or water. This effect has been explained by Euler and Heisenberg[1] as due to the instability of the barytrons which form the main part of the penetrating component. These particles are supposed to have a mass M of the order of 150 times the electronic mass and to be of secondary origin. They are produced mainly in the higher levels of the atmosphere by some incident radiation, consisting possibly of electrons.

Following Yukawa, a barytron of energy γMc^2, where $\gamma>>1$, has a mean life $\tau=\gamma\tau_0$, where τ_0 is its mean life when at rest, and is of the order of 10^{-6} sec. In free space, a rapidly moving barytron will travel a mean range $L=c\tau$ before it disintegrates spontaneously into an electron and a neutrino. In dense materials ($\rho\geqq1$) the range as defined by the ionization is much less than L, so almost no barytrons decay spontaneously before they come to rest by ionization. But in gases ($\rho\lesssim10^{-3}$) the ionization range is of the order or greater than L, so many barytrons decay before being stopped by ionization, thus producing an apparent additional absorption. Euler and Heisenberg have shown by a detailed analysis that the observed mass absorption anomaly for air and water can be explained by assuming a value of τ_0 of 2.7×10^{-6} sec. The barytrons are supposed to be formed at the maximum of the transition curve, that is, for vertical rays, at a pressure of about 8 cm Hg, and so at a height of about 16 km.

It can easily be seen that the observed decrease of the cosmic-ray intensity with increasing atmospheric temperature can be explained in a similar way. This decrease results from the greater extension upwards of a warm atmosphere, so that the barytrons are produced at a greater height and so have further to travel to reach sea level, and so have a greater chance of spontaneous decay.

We will simplify the problem by assuming that the barytrons, with which we are concerned, all have an energy[2] of 3×10^9 ev, that is rather less than the measured mean energy of about 4×10^9 ev at sea level in magnetic latitude 54°N. Assuming $M=150\ m_e$, we have $Mc^2=7.5\times10^7$ ev, and therefore $\gamma=40$. With, as before, $\tau_0=2.7\times10^{-6}$ sec., we get $\tau=1.08\times10^{-4}$ sec; and hence $L=32$ km.

If δz is the increase of height of the layer at which the barytrons are formed, due to an increase $\delta\theta$ of mean atmospheric temperature, then the temperature coefficient of the cosmic-ray intensity will be given by

$$\alpha=-\delta z/L\delta\theta.$$

From data given by Humphreys,[3] $\delta z \backsimeq 500m$ for the mean summer-winter temperature difference of 10°C, whence $\alpha=-0.16$ percent per °C. Alternatively instead of using the observed value of $\delta z/\delta\theta$, the atmosphere can be taken as at a uniform temperature $\bar{\theta}$ whence it follows that $\delta z/\delta\theta=z_m/\bar{\theta}$, and so

$$\alpha=-z_m/L\bar{\theta},$$

where z_m is the height of formation of the rays ($z_m=16$ km) and $\bar{\theta}\backsimeq250$°K. We find $\alpha=0.20$ percent per °C. Both these values are in good agreement with the value of $-0.18+.011$ percent per °C observed by Compton and Turner.[4]

Since near the equator, the incident primary rays are more energetic than in moderate latitudes one would expect the barytrons also to be more energetic, thus having a longer lifetime. So the temperature coefficient at the equator should be lower than at moderate latitude. Owing to the small seasonal variations in the equatorial region, it may be difficult to make the necessary observations to test this. If the temperature coefficient is really lower at the equator, the temperature correction applied by Compton and Turner to obtain the true magnetic latitude effect has been overestimated.

It is probable that the second-order meteorological effects (Corlin[5]) of the cosmic radiation are also explicable on this theory, since Priebsch and Baldauf[6] have pointed out that the main part of these variations can be attributed to a change of density caused by changes of temperature. As an example, it is easy to see why, during some cyclonic depressions, the phase of the rise of cosmic intensity must lag on the pressure drop (Messerschmidt and Pforte[7]). Since the average temperature in front of many depressions is greater than that at the rear, the cosmic-ray intensity will be relatively less, thus producing a phase lag of the intensity maximum compared with the pressure minimum. It should be possible to correlate in some detail the cosmic-ray data with the present-day knowledge of the vertical structure of depressions.

To get a reliable test of this theory of the temperature effect it will be necessary to correlate the observed intensity variations, not as has been done in the past with the local ground temperature, but with the mean temperature of the atmosphere up to a great height.

It does not seem possible to explain the diurnal variation of cosmic-ray intensity in the same way as the temperature effect, since the sign of the effect is opposite to that which one would expect, and further the magnitude does not seem to vary with latitude (Thompson[8]).

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October 10, 1938.

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