Ionosphere Studies During Partial Solar Eclipse

The partial solar eclipse of February 3, 1935, offered an opportunity for further study of the effects of eclipses on the ionosphere. Experiments made by the National Bureau of Standards[1] and others during the solar eclipse of August 31, 1932, had indicated that the main source of ionization of the E and F_1 layers is ultraviolet light. Similar evidence for the F_2 layer was not found. There was no positive evidence that the 1932 eclipse (about 90 percent total at Washington) produced any change in the F_2 layer ionization. During the eclipse of February 3, 1935, about 30 percent of the sun's disk was obscured and a positive decrease in the ionization was found in the F_2 as well as in the E and F_1 layers.

The solid-line graphs of Fig. 1 show the average critical frequencies for several days immediately before and after the eclipse day. The $f^x_{F_2}$ values (i.e., the extraordinary-ray critical frequency) for February 2 were not averaged with results of the other days because a moderate magnetic storm occurred on this day and the $f^x_{F_2}$ values were much lower than those taken on other days of this series of observations. No consistent evidence has been obtained to indicate that the low critical frequencies obtained on February 2 might be caused by the magnetic disturbance on this day. The broken-line graphs represent critical frequencies as measured on the day of the eclipse.

The E layer was complex throughout this series of measurements. It appeared to be stratified. Two or three critical frequencies appeared much of the time. The values of these critical frequencies varied independently, and frequently one critical frequency would disappear or a new one appear between sweeps of six minutes separation. The upper branch of the f_E graph between the hours 1016 and 1112 on February 3 is an example of this complexity. It was often impossible to follow a particular E critical frequency through a series of records. Nevertheless a clear decrease of f_E and therefore of the ionization density of the E layer is shown at the time of the eclipse. The ratio for the E layer of ionization density at eclipse maximum to ionization density at the same hour on normal days was 0.86. The maximum ionization density varies as the square of the critical frequency of the ordinary ray.

As has been described in previous publications, the F_1 critical frequency is not sharply defined at this time of the year. The sharpness of definition was decreased by the eclipse and increased after the passage of the eclipse. For the F_1 layer the ratio between the maximum ionization densities at the eclipse maximum and at the same hour on normal days was 0.88.

The F_2 layer critical frequencies were well defined. Magnetic splitting was present. The minimum of ionization of the F_2 layer occurred within 9 minutes after the maximum of the eclipse. The ratio of the ionization densities at the eclipse maximum and at the same hour on the normal days averaged was 0.58.

It is well known[2] that the day to day variations of $f^x_{F_2}$ may be quite large. If the possible effect of the magnetic storm be ignored, the results of February 2 taken with the results of the other days discussed here, would be an example of this. In the light of this known variation it is possible that without the eclipse $f^x_{F_2}$ might have been low on February 3. The afternoon results suggest 6000 kc/sec. as the normal value for $f^x_{F_2}$ on this day. Assuming 6000 kc/sec. as the normal value of $f^x_{F_2}$ on the day of the eclipse the ratio of ionization density at eclipse maximum to the normal ionization density at the same hour would be 0.69.

These observations substantiate the conclusions drawn from the 1932 eclipse, *viz.*, that the daytime E and F_1 layer ionizations are predominantly controlled by ultraviolet radiation from the sun. The present measurements

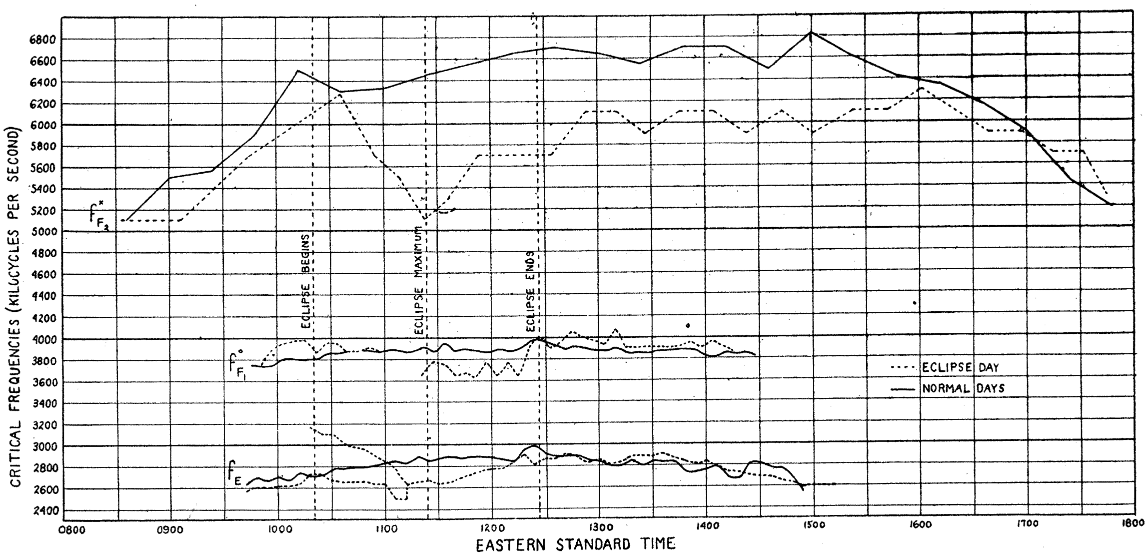

FIG. 1. Graphs showing critical frequencies on day of eclipse and on several days preceding and following the eclipse.

indicate that the F_2 layer ionization also, at the time of the eclipse, was predominantly controlled by ultraviolet radiation from the sun. A comparison of the F_2 layer results of the August, 1932, eclipse with the February, 1935, eclipse indicates that the F_2 layer ionization is produced in a different manner during the summer than during the winter.

These results emphasize the importance of seizing every opportunity for ionosphere observations presented by eclipses, even though a particular eclipse may not seem entirely promising in respect to season, time of day, or latitude.

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[1] Kirby, Berkner, Gilliland and Norton, Bur. Standards J. Research, **11**, 829, Dec. 1933 (RP629). Proc. I. R. E. **22**, 247 (1934).

[2] Kirby, Berkner and Stuart, Bur. Standards J. Research **12**, 15, 1934 (RP632). Proc. I. R. E., **22**, 481 (1934).

Masses of Light Atoms from Transmutation Data*

The difficulty of reconciling the stability of the Be nucleus with its high mass (9.0154) derived from the mass spectroscopic measurement of Bainbridge is well known. On the other hand, all transmutation data point to a much lower value (about 9.011). If one tries to account for the disintegrations of Be assuming the Bainbridge mass, one is forced to assume the existence of new nuclei, *viz.*, Be^8 and He^5. These present new stability difficulties; e.g., for He^5 a mass of 5.006 can be derived from transmutation data,[1] which would make Li^6 unstable against proton emission.

The difficulties are not restricted to Be. Indeed, the energy balance of the disintegration of B^{11} under proton bombardment can only be brought into agreement with nuclear masses, by making very artificial assumptions.[2] Other evidence of a wrong determination of the B mass is the transmutation $B^{10}+n^1=Li^7+He^4$ recently observed by Taylor and Goldhaber.[3]

The most striking instance seems however to be provided by C^{12}. The C^{12} nucleus is known to emit γ-rays of 5.5 MV,[4, 5, 6] therefore it must have an excited level of this energy which does not disintegrate into 3 α-particles before the γ-ray is emitted. The probability of emission of a γ-ray is about 1 in 10,000 periods of oscillation of the α-particle in the nucleus. The penetrability of the nuclear barrier for α-particles must therefore be smaller than 1/10,000 for the excited state, in order that strong γ-radiation can be observed. The energy of the excited state can, then, not be greater than that of 3α-particles $+0.7$ MV; and therefore the energy of the ground level must be at least 4.8 MV lower than 3α's. Hence

$$C^{12}<3\times 4.002\,16-0.005\,1=12.0014$$

as compared to Aston's value 12.0036.

On the other hand, a lower limit for the mass of C^{12} can be obtained from the γ-rays emitted by O^{16}, having an energy of 5.4 MV.[5, 6, 7] By the same reasoning as before we conclude that the excited state of the O nucleus could not emit γ-rays in appreciable amount if its energy would exceed that of $C^{12}+He^4$ by more than 1 MV. Therefore the energy of the O ground state must at least be 4.4 MV lower than that of $C^{12}+He^4$, so that

$$C^{12}>16.0000-4.0022+0.0047=12.0025.$$

This "lower" limit is thus seen to be higher than the upper limit derived above. The only possible way out is to assume that the mass of helium with respect to oxygen is completely wrong.

Such an assumption would immediately explain why all transmutations of the light elements H, He and Li among each other have energy balances fitting beautifully[1] with the mass spectroscopic values whereas for all nuclear processes in which a heavier atom (Be, B) is transformed into light ones the energy balance seems to be completely wrong. Namely, all the light atoms have been compared very accurately to He in Bainbridge's work, whereas the heavier ones have been referred to oxygen.

The change of the ratio He : O seems also to be in accord with the chemical determinations[8] of the atomic weight of H.

Consequently the derivation of atomic weights purely from disintegration data was attempted. Of the transmutations connecting the elements of the "heavier" to those of the "lighter" group the best investigated is the transformation $B^{11}+H^1=3\ He^4$. Since all considerations involving the upper limit of the α-particle energy are open to criticism,[2] we have used the mean energy of the emitted α-particles rather than the maximum energy. This is justified in the case of boron, because it is known[2] that, if γ-rays are emitted at all in the process, there must be less than one γ-ray in 50 disintegrations. Also, there is no other conceivable process which could lead to the emission of low energy particles which could falsify our mean energy: The process $B^{10}+H^1=2\ He^4+He^3$ would, even with so high a value for the B^{10} mass as 10.0146, set free an energy of only 1 MV, therefore the α-particles of this process could, even under most favorable conditions, not have more than 4 mm range. On the other hand, in the Wilson chamber measurements of Kirchner[9] which we have used for determining the energy distribution of the α-rays, no tracks under 5 mm have been measured at all. The latter fact makes incidentally our determination of the energy evolved in the process an upper limit.

The actual calculation gave for the mean energy of the α-particles observed by Kirchner 2.85 ± 0.03 MV, corresponding to a total energy of all three particles of 8.55 ± 0.10 MV, in perfect agreement with the value deduced from the upper limit of the α-particle energy (8.7 MV) under the assumption that the fastest α-particles get just $\frac{2}{3}$ of the total energy available which follows from momentum considerations.[10] Therefore we consider it as definitely established that the energy evolved in the disintegration of B^{11} by proton bombardment is 8.5 ± 0.2 MV, the energy