The Electrical State of the Upper Atmosphere.[1]

By Prof. S. CHAPMAN, F.R.S.

DIRECT simultaneous measures of temperature and pressure up to 25 kilometres, by sounding balloons, give complete information as to the variation of pressure, density, and temperature over this range. The temperature falls in the first 10 kilometres from 285° absolute to 220°, and then remains constant up to 25 or 30 kilometres. The temperature above this height was a subject merely for speculation until Lindemann and Dobson published their theory and discussion of meteors. They concluded that the temperature remains at 220° up to 50 or 60 kilometres, after which it rises (perhaps rather rapidly) to about 300°, which is its value up to about 140 kilometres; thus at this height the air is warmer than near the ground. This rise of temperature is inferred from the estimated densities of the air between 60 and 150 kilometres, the density at 100 km. being more than ten times as great as it would be if the temperature had remained at 220°. Higher up the difference between the estimated density and that calculated on the latter assumption is still greater. The mean free molecular path, calculated on the assumption that the air is mainly nitrogen over this range, increases from about 1 cm. at 90 km. to about 10 cm. at 130 km.

Above this level, even if the temperature were fully known, the pressure and density could not be inferred without a knowledge of the composition, as to which, at present, there is much uncertainty. In the lowest 10 km. the air is thoroughly mixed by winds, but at some height H in the stratosphere diffusive separation may begin, the heavier constituents settling out so that the proportion of the lighter constituents steadily increases upwards. Up to about 100 km. the pressure and density do not depend much on H, but the composition is largely affected by it: $H=20$ km. and $H=50$ km. would give very different results. If we take $H=20$ km. as a likely value, nitrogen is still the main constituent at 100 km., its molecules being about fifty times as numerous as those of oxygen and helium. Above 150 km. there will be very little oxygen, and such lighter gases as are present (possibly helium and hydrogen) should be the main constituents.

The question of the composition at 90 km. or 100 km. is of interest in connexion with the auroral spectrum. The conditions there, in any case, are by no means those of a large excess of helium, as supposed by McLennan and Shrum in their discussion of the auroral spectrum. The auroral spectrum shows that nitrogen and oxygen (accepting McLennan and Shrum's identification of the green auroral line) are present at auroral heights. At the lower auroral levels this is quite in accordance with expectation, but auroræ are also said to appear at heights of 500 km. The evidence for this, given by Störmer and Vegard, seems quite satisfactory. The presence of nitrogen and oxygen at such levels seems explicable only on the assumption that the atmosphere is partly supported at great heights by electrical forces, such as were discussed by Atkinson in his criticism of Vegard's theory of the aurora. If such electrical forces operate, either permanently or merely temporarily when auroræ occur, they may have the effect of allowing the lighter gases, hydrogen and helium, to escape altogether: a suggestion which would, if substantiated, explain the rather remarkable absence of hydrogen and helium lines from the auroral spectrum.

Another matter of interest concerning the upper atmosphere is the highly conducting layer, the existence of which is indicated by the diurnal magnetic variation, according to the theory of Balfour Stewart and Schuster. The conductivity of the layer must be of the order 3×10^{-6}, which is so great as to be difficult to explain. But recently Appleton and Barnett have assigned 10^5 as a lower limit to the number of electrons per c.c. at the level, about 80 km. high, at which wireless waves are reflected at night. From this it appears that the specific conductivity must be 10^{-14} c.g.s. units at this height; a layer having this specific conductivity would require to be 3000 km. thick to account for the total conductivity 3×10^{-6}. This excessive thickness can be reduced to a more reasonable figure, however, if the ionisation by day is several times as great as by night (as the diurnal magnetic variations themselves indicate), and if allowance is made for the increase in the mean free path above 100 km. The downward extension of the conducting layer, by day, into regions where the mean free path is less than at 100 km., may not add very much to the total conductivity. There seems no longer, however, any insuperable difficulty in supposing the thickness of the conducting layer to be of the order of 200 or 300 km., without assuming an excessive specific conductivity.

By Sir HENRY JACKSON, G.C.B., F.R.S.

Radio communications have never been noted for their consistency. At first this was attributed to atmospheric disturbances and to the low energy emitted, with reception by unreliable apparatus, but when the power radiated was greatly increased and modern appliances of great sensitivity and constancy were brought into daily use, it was still found that the intensity of the received signals from any station at long distances was variable at times, though it was seldom if ever that signals were entirely lost at the stations designed to receive them. When directional wireless was brought into use, it was found that, in addition to variable strength of signals, great variations were experienced at night in the bearings of the observed stations.

The cause of these variations in intensity and direction have been very systematically investigated during the last five years by the International Union of Scientific Radiotelegraphy and others, and in Great Britain especially by the Radio Research Board; many hundreds of thousands of observations have been made by skilled observers with suitable and reliable apparatus, and the results have been carefully analysed to try to find a law which could explain the reason of the variations.

The analysis showed plainly that both types of variations were subject to seasonal, diurnal, and 'untraced' effects, and that the altitude of the sun had evidently a great effect on them, but nothing more

[1] Contributions to a discussion at the Royal Society on March 4.