the forward edge of a rain area, and to stop short of actual thunderstorm formation, while still being sufficiently marked for the necessary readjustment of charge to originate electro-magnetic waves. The difficulty of picturing readjustments propagating radiation of such energy content as to produce audible atmospherics at distances of more than 1000 kilometres, without producing visible lightning or audible thunder at ground stations near the source, is considerable, but not so great as the difficulty of picturing sufficient "full scale" lightning discharges, or other known phenomena, to account for the reception of atmospherics at an annual average rate of more than one per second at a station in these latitudes.

The writer desires to acknowledge his indebtedness to the Meteorological Office and to the Radio Research Board, for providing the facilities for carrying out this work, and for granting permission to publish the results.

X-Ray Electrons.

AMONG the items of the programme of section A of the British Association at Hull this year, there was one of outstanding interest consisting of the description of some very beautiful experiments which apparently constitute still another triumph for the quantum theory and the atomic theory of Bohr. Both M. le Duc de Broglie and Prof. R. Whiddington, who described the experiments, have recently been working on the same subject, namely, the properties of the electrons ejected from metallic atoms by the incidence of X-rays; and their results are in general agreement. The method of procedure has been to allow a beam of characteristic X-rays of known frequency, for example from a tungsten anticathode, to fall upon a prepared metallic surface, say of silver. The electrons which, as a consequence, emerge from the silver do not all possess, as Barkla at first supposed, equal amounts of energy. They thus have different velocities, and, by the well-known method of the application of a suitable magnetic field, the original mixed bundle of electrons can be differentially deflected, and spread out into a "magnetic spectrum." A focussing device is employed whereby the electrons of the same speed are concentrated upon the same part of the photographic plate, so that each line in the spectrum corresponds to a group of electrons having a definite velocity. There is a certain amount of general fogging of the plate, but the comparatively sharp lines superimposed are unmistakable. Several actual plates were shown both by M. de Broglie and Prof. Whiddington.

The interpretation of these spectra, which are of somewhat simple appearance, proves to be most important in relation to current theories of quanta and atomic structure. In the first place, the phenomenon obeys the general law of photo-electric effects, in that the velocity, and therefore the energy, of the electrons expelled depends only on the frequency, and not on the intensity, of the exciting X-radiation.

Of still greater importance is the bearing of the experimental results on Bohr's theory of atomic constitution. As is well known, this theory involves that the electrons, in number N, which surround the nucleus of an atom of atomic number N, are distributed in a certain number of regions, or layers, each characterised by the work which it is necessary to expend in order to remove an electron from the region under consideration, and bring it to the exterior of the atom. If we denote by the letters K, L, M, etc., the levels of these regions, we can attribute to them energies of extraction W_K, W_L, W_M, etc. The fundamental principle underlying the production of the magnetic spectra above mentioned will be made clear by quoting from M. de Broglie's remarks:

"What appears to happen is that if radiation of frequency ν strikes one of these electrons, situated, for example, in the region K, it communicates energy equal to $h\nu$ in order to extract the electron from the atom; it is clear that the corpuscle, once removed from the atomic edifice, will possess a resultant energy equal to $h\nu - W_K$."

In this, of course, h is Planck's constant, and the resultant energy of the electron, which proves to have the value specified, is that which is measured experimentally by means of the magnetic deflection. For truly monochromatic X-radiation, the magnetic spectrum would thus consist of a few lines, corresponding to the various different regions in the atom from which electrons may be ejected, *i.e.* to the various possible values of W. Unless $h\nu$ is greater than W the radiation is incapable of extracting electrons from the atomic region in question. This proves to be true experimentally; unless an anticathode is used for which the frequency of the characteristic radiation is sufficiently large in relation to at least some of the energies of electron extraction for the irradiated metal, no magnetic spectrum appears. With a Coolidge tube as the source of X-rays it has not been possible to make $h\nu$ large enough to extract the more deep-seated electrons in metallic atoms of high atomic number; but the employment of γ-rays, with their much greater frequency, has enabled Ellis to extend the process to these regions, and to prove in this case also the validity of the general relation.

The lines in the magnetic spectra are usually composite. This arises from the fact that the X-rays used are seldom monochromatic, the characteristic radiation from the anticathode having several components. Again quoting M. de Broglie:

"Each line of the spectrum of the incident X-rays re-echoes on each level of the illuminated atom in such a way that we obtain at once an analysis both of the spectral lines of the illuminating beam and of the Bohr levels of the illuminated atom."

The method, as M. de Broglie pointed out, serves for measuring, without the intervention of a crystal, the frequency and wave-length of X-radiation. It thus furnishes a means of checking the magnitudes of the crystal spacings which form the basis of X-ray analysis.

The papers of M. de Broglie and Prof. Whiddington evoked great interest in the Section. There was some discussion, particularly with reference to the general fogging of the magnetic spectrum plates, which seemed to point to some of the ejected electrons having all sorts of emergent velocities. Prof. Lindeman suggested the possibility of having to assume that in the atom there were numerous electron levels, instead of the comparatively small number assumed by Bohr. Sir Ernest Rutherford, however, was satisfied that no such explanation was needed, for the reason that the fogging was inevitable, owing partly to the general radiation from the anticathode, and partly to the fact that some of the ejected electrons would lose random amounts of energy from various causes along their paths to the photographic plate.

A. O. RANKINE.