a voltage of only about 13 volts, while about 80 volts are necessary to produce the lines of the 4686 series and the Pickering series. According to the theory of the writer, the energy necessary to remove the electron from the hydrogen atom corresponds to a fall of an electron through a potential difference of 13·6 volts, while the energy to be used in removing one electron from the helium atom corresponds to a fall of 29·0 volts, and in removing both electrons to a fall of 83·4 volts. N. BOHR.

Physical Laboratory, University of Manchester, February 21.

X-Ray Fluorescence and the Quantum Theory.

THE experimental conclusions which I briefly outlined in a letter to NATURE of February 18 point directly to a theory of X-ray fluorescence and of the emission of radiation in quanta, which certainly bears a resemblance to Bohr's theory of line spectra. The experimental evidence obtained is, however, so direct that there seems little possibility of escape from the conclusions given below. Indeed, the theory was forced upon the writer directly by the experimental results, and it was only afterwards that he was reminded of some similarity with the theory of Bohr based on the Rutherford atom.

It is an experimental fact that in the case carefully investigated (and obviously in many, if not in all, other cases), the ejection from an atom of an electron associated with a fluorescent X-radiation of frequency n necessitates an absorption of energy greater than the kinetic energy carried away by the electron by approximately the energy (hn) of one quantum of radiation of frequency n. Thus:—

(1) Total absorption per electron emitted $= \frac{1}{2}mv^2 + hn$ (approximately)—that is, the energy required to separate the electron (a K electron, say) from the parent atom, is approximately equal to the energy of a quantum of the fluorescent radiation of series K associated with that electron.

The energy of a quantum of radiation may therefore be regarded as the mutual potential energy of the separated atom and electron, measured from the zero given by the electron in its normal position and state. When the displaced or any other electron falls back into the position of the displaced electron, the energy is re-emitted as a radiation characteristic of the atom, and this, of course, in definite quantity. So much may be claimed as at any rate giving a first approximation to the truth. The results of experiments, however, suggest the possibility of the necessity for some modification of this theory in detail, though not in principle. For in the one case thoroughly investigated we get a nearer approximation to the experimental results by writing

(2) Total absorption per electron emitted $= \frac{1}{2}mv^2 + hn_K + hn_L$, where n_K and n_L are the frequencies of the K and L fluorescent radiations respectively. As the third term (hn_L) is at its maximum value only about 7 per cent. of the whole, it is impossible at this stage to say definitely whether or not it expresses a physical fact. This term was, however, suggested by a consideration of the probable process following the ejection of a K electron. The relation indicates that *possibly* the energy required to free a K electron is equal to the sum of the energies of quanta of K, L, and any other fluorescent radiation of lower series M, N, etc.—presumably originating in vibrations in the outer rings of the atom.

If we accept this provisionally it means that the energy of a quantum of K radiation is that required to displace a K electron into the position of an L electron, while the energy of a quantum of L radiation is that required to displace an L electron into the position of an M electron, and so on. Such a process may never occur; it is, however, a convenient way of expressing the energy required completely to eject the electron in terms of steps which can only be regarded as extremely probable in the inverse process involving radiation.

Thus the energy of a quantum of K radiation is left in the atom from which a K electron is hurled; or *possibly* the energies of one quantum of each of the fluorescent radiations, K, L, M, etc., are left in the atom. This energy must, of course, be radiated while the atom is regaining its original configuration by the absorption of an electron into the K position. It seems probable, however, that the readjustment of the atom and the principal radiation take place even before the atom as a whole regains an electron, by an L electron falling into the position of a displaced K electron, an M electron replacing an L electron, and so on; only the final stage of the readjustment being completed by the absorption of an electron into an outer depleted ring.

It is obvious in this case—unlike that studied by Bohr—when and why an electron falls into an inner ring; it is simply subsequent to and due to the removal of an inner ring electron. No new principle of radiation is involved, yet it accounts for radiation taking place in quanta. We should thus expect L radiation to be associated with the emission of K electrons as well as with L electrons. Search for such a radiation is at present being made. Pointing to the probability of such an associated radiation is the fact that when hn_L becomes a smaller fraction of the whole absorption, the discrepancy found when it is omitted, as in equation (1), diminishes. Not only is this so, but the energy of the corpuscular radiation and of the K fluorescent radiation actually emitted, do not quite fully account for the whole energy absorbed. The discovery of the L radiation in calculated intensity would give almost perfect agreement.

In spite of these indications the writer hesitates to make a definite statement about the physical reality of the third term concerned with L radiation; experiments will very soon decide the point.

In either case we have the direct evidence that the energy of a quantum is simply energy absorbed in removing the corresponding electron from its normal orbit; it is the energy afterwards set free, presumably when the electron returns.

It is hoped that experiments now being undertaken will determine also if X-ray fluorescence—that arising from the vibration of inner ring electrons—can be appreciably delayed by retarding the return of the ejected or other electrons from outside the atom. It is more probable that X-ray *phosphorescence* will not be detected, the readjustment of the interior of the atom taking place immediately after the ejection of an inner electron, and the final absorption of an electron into a surface ring being the only part of the process susceptible to external conditions. The subject can, however, only receive adequate treatment in communications to other journals. C. G. BARKLA.

University of Edinburgh, February 27.

The Physical Properties of Isotopes.

PROF. SODDY's letter in NATURE of February 4 would seem to lead to certain interesting conclusions about the structure of the atom. It is easy to show that two elements of different atomic weight must differ either in their chemical or in their physical properties. If elements are inseparable chemically their affinity A must be equal. Now $A = -T\int_0^T \frac{U}{T^2} dT$ if T is the tem-