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New Problems in Quantum Theory.

FIFTEEN years have elapsed since Niels Bohr first published a series of papers which were the beginning of a new epoch in the development of the quantum theory. Adopting the atomic model proposed by Rutherford, in which electrons circle round a massive nucleus under the action of a Coulomb force of electric attraction, Bohr gained immediate success in interpreting the spectrum of hydrogen and of ionised helium. For his purpose he was compelled to assume the existence of 'stationary states,' and the emission of monochromatic radiation in the transition between two such states of an atomic system.

In one sense the new method raised as many difficulties as it removed, and to some of the more conservative physicists the account of Bohr's atom read like a fairy tale. Further progress in the interpretation of line spectra was made through the generalisations of Wilson and Sommerfeld, but in spite of the inclusion of a widening circle of facts and the fulfilment of predictions, it came to be realised that a more radical procedure was necessary before a consistent and complete theory could be evolved. In the forward movement few have been more active than Bohr himself. The employment of a spinning electron by Goudsmit and Uhlenbeck removed many discrepancies, and it seems as if some form of magnetic electron is likely to be accepted as a fundamental constituent of an atomic system. The magneton of S. B. McLaren with its quantum of angular momentum may be regarded as the prototype of all such magnetic electrons.

Within the last few years the matrix mechanics of Heisenberg, Born, and Jordan, the quantum algebra of Dirac, and the undulatory mechanics of Schrödinger, have led to remarkable theoretical developments. The new wave mechanics gave rise to the hope that an account of atomic phenomena might be obtained which would not differ essentially from that afforded by the classical theories of electricity and magnetism. Unfortunately, Bohr's statement in the following communication of the principles underlying the description of atomic phenomena gives little, if any, encouragement in this direction.

In classical mechanics it is assumed that the position of a particle (such as an electron) can be determined at a specified instant of time by means of its co-ordinates. As the time varies it is supposed to be possible to trace the path of the particle through space, or to determine its 'world line' in the four-dimensional world. Further, it is assumed that the concept of causality may be applied in considering the effect of the action of external forces. Thus in classical physics we have a causal space-time co-ordination, based on the assumption that the methods or tools of measurement do not affect the phenomena which are observed.

In the new quantum theory the outlook is changed, for any attempt to observe the position or motion of an electron involves illumination by light, and this implies interaction between the electron and the light employed in making the measurement. The position and the path of an electron become vague. Thus there is introduced in the new quantum mechanics an indefiniteness which contrasts with the clear-cut concepts of classical mechanics. Bohr asserts that in any phenomenon which we may attempt to observe there is an essential discontinuity, or rather individuality, which may be symbolised by Planck's constant h. The causal space-time co-ordination of atomic phenomena must on this view be abandoned, and we are left with a somewhat vague statistical description.

The strange conflict which has been waged between the wave theory of light and the light quantum hypothesis has resulted in a remarkable dilemma. But now we have a parallel dilemma, for a material particle manifests some of the attributes of wave motion. Can these apparently contradictory views be reconciled? According to Bohr, the pictures ought to be regarded not as contradictory but as complementary. Radiation in free space is not open to observation, and is a mere abstraction. An isolated material particle likewise can never be observed and is also an abstraction. It is only through their interaction with other systems that the properties of these abstractions can be defined and observed.

It must be confessed that the new quantum mechanics is far from satisfying the requirements of the layman who seeks to clothe his conceptions in figurative language. Indeed, its originators probably hold that such symbolic representation is inherently impossible. It is earnestly to be hoped that this is not their last word on the subject, and that they may yet be successful in expressing the quantum postulate in picturesque form.

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