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Thermodynamics, wave-theory and the Compton effect

Prof. A H Compton's own explanation of the remarkable phenomenon discovered by him is well known and is set out very clearly in his recent book on "X-rays and Electrons". Briefly, it is that radiation is of a corpuscular nature, that the momentum of the impinging quantum detaches the electron from the atom and causes it to recoil, while the deviated quantum loses energy in the process and degrades in frequency. This view of the Compton effect, like Einstein's explanation of the emission of photoelectrons, approaches the relations between matter and radiation from a point of view so divergent from that of the familiar concepts of Maxwellian electrodynamics, that it is scarcely possible to understand how this conception of radiation is physically reconcilable with the familiar explanations of interference and diffraction phenomena.

As is well known, there is an addition to the X-ray scattering of degraded frequency, an unmodified secondary radiation the existence of which has been explained by Prof. Compton as due to the whole group of electrons in the atom scattering conjointly. To this view, the objection might be raised that if one electron acting alone can scatter a quantum, and also all the Z electrons in the atom acting together, then why do we not observe scattering by two, three, or more electrons acting together at a time, with their corresponding fractional Compton shifts in wavelength? To the alternative explanation of the unmodified scattering given by Profs. Compton and Jauncey that it represents the scattering by an electron which the impinging quantum is unable to detach from the atom, the equally pertinent query may be asked, then why is the intensity of this type of radiation proportional to Z^2 and not to Z?

In addition to these objections of Prof. Compton's explanations of his own discovery, there is another of a very fundamental nature which was also urged by me when, by invitation, I spoke at the British Association meeting at Toronto in August 1924, on the problems of the scattering of radiation. Maxwell's theory of light not only explains the classical phenomena of interference and diffraction, but also, when taken in conjunction with the principles of thermodynamics, affords a very complete explanation of the phenomena of the scattering of ordinary light in gases, liquids, and crystals under the widest range of physical conditions. This has been fully demonstrated by me and my associates in a series of experimental and theoretical researches during the last six years. Is it conceivable, then, that Maxwell's theory and thermodynamics taken together would fail in the closely allied field of X-ray research? Urging this point of view, I referred at the Toronto meeting to the beautifully simple explanation which the classical wave-theory and thermodynamics together give of the X-ray diffraction haloes in liquids.

During the current year I have returned to this subject, and in a series of memoirs which are being published in the *Indian J. Phys.*, have developed a general theory of X-ray diffraction and scattering in which thermodynamics, the classical wave-principles and modern views of atomic structure are brought together and shown to afford a simple and intelligible explanation, not only of Prof. Compton's own discovery, but also of the crucial experiments of Bothe and Geiger and of Compton and Simon, which at first sight seem so destructive of the classical wave-ideas. It is not possible in the columns of *Nature* to afford more than the briefest indication of the line of thought followed in these memoirs.

The facts of temperature radiation from solids and fluids compel us to assume that the thermal agitation of bodies excites not only the atoms but also the electrons contained in them. Starting from this premise, it is shown on Maxwellian wave-principles that we must have two types of secondary X-radiation, one of intensity proportional to Z^2 which corresponds to the normal or stationary state of the atom, and the other proportional to Z produced by the thermal fluctuations of the internal structure of the atom. The former is a stationary or diffraction effect, and the latter is of a highly fluctuating type, the intensity of which has no fixed values at any time or place and the laws of which can only be formulated as statistical relationships. This type of scattering is identifiable with the Compton effect, and the observed variations of the latter with direction of observation, atomic weight of scattering atoms and wavelength of X-rays, and the observed fluctuations with respect to time and direction, are all satisfactorily explained.

In addition to these, the theory indicates that as the Compton effect is essentially a thermodynamic phenomenon involving degradation of energy, it should show a marked dependence on temperature. Experiments to verify this are in progress at Calcutta, but there are already sufficient indications in the literature of X-ray scattering and absorption and their variations with temperature to indicate that the success of the experiments is a foregone conclusion. The results of the experimental work will also be published in the *Indian J. Phys.*

C V RAMAN

210 Bowbazaar Street
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