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The angular momentum of light

The work of Compton on X-ray scattering led to the general acceptance of the idea that the scattering of radiation by a material particle is a unitary process in which energy and linear momentum are conserved. A molecule is, however, a much more complicated structure than an electron, and the conservation principles by themselves would give us an erroneous idea of what we should expect in light-scattering. This follows from the fact that a molecule has in general three degrees of freedom of rotation, several degrees of freedom of vibration according to its complexity, and various possible modes of electronic excitation, and that each of these may correspond to one or other of an extended series of quantum numbers. Restricting ourselves to the cases in which the molecule takes up a part of the energy of the quantum, the conservation principles would indicate that the spectrum of the scattered light should contain an immense number of new lines.

Actually, a remarkable simplicity characterises the observed spectra of the light scattered by polyatomic molecules, a simplicity which is in striking contrast with the complexity of their absorption and emission spectra. It is clear that the Compton principles cannot be regarded as capable of *predicting* the observed phenomena of light-scattering, and that their utility lies solely in the *interpretation* of results discovered by experiment. These remarks seem necessary to correct an impression to the contrary which finds expression in some recent publications.

We may extend Compton's principle and add angular momentum to the quantities which we should expect to find conserved in the collision between a light-quantum and a molecule. The fact that, in liquids and solids, the mutual influence of the material particles is very considerable, attaches some uncertainty to the interpretation of the results obtained with them. The recent success of Bhagavantam at Calcutta in measuring the polarisation and intensity of light scattered by gases, however, opens up new possibilities for the development of the subject.

As a working hypothesis, we may follow Dirac and assume that the angular momentum of a photon is *plus* or *minus* $h/2\pi$, intermediate values being inadmissible. This supposition enables us to interpret very simply the known selection rule $\Delta m = 0$ or ± 2 for the change of rotational quantum number of a diatomic molecule in light-scattering, which follows as a natural consequence of it. Further, it follows[1] that a change in rotational quantum number of the molecule should be accompanied by a reversal in the sign of circular polarisation of the photon, when the latter is scattered in the forward direction. This reversal has been actually observed by Bär and by Bhagavantam with the rotational wings accompanying the original mercury lines scattered in liquids, and the data obtained by Bhagavantam with hydrogen gas may also be interpreted as a confirmation of the same result.

It is remarkable that the latter result is also predicted by the classical electromagnetic theory of light for the case of a rotating anisotropic particle scattering circularly polarised radiation. Nevertheless, it is clear that the observed phenomena may be regarded as an experimental proof that radiation has angular momentum associated with it, and that it has the values $\pm h/2\pi$ for each quantum.

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[1] *Nature* (1931) **128**, 114.