

Letters to the Editor.

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Negatively Modified Scattering.

IN a paper published in 1923, Einstein and Ehrenfest discussed the general problem of thermodynamical equilibrium in an assembly traversed by light, which is subjected to scattering by the particles of the assembly. They deduced, in a way (which is quite analogous to Einstein's famous deduction of the laws of black body radiation by consideration of thermodynamical equilibrium in the presence of Bohr-type of vibrators), that the excited particles of the system would give rise to a type of modified scattering analogous to Einstein's negative absorption. Smekal pointed out in a letter to *Naturwissenschaften* (1923) that if light of frequency ν is scattered by the particles of the assembly, then in addition to unmodified scattering of frequency ν , scattered light should also consist of light of frequency $\nu + \nu_k$, $\nu - \nu_k$, where $h\nu_k$ is the energy difference between the excited state and the normal state of the scattering particles ("Handbuch der Physik," Bd. 23, pp. 93-99).

This last prediction has been very brilliantly confirmed by Raman and Krishnan, who exposed liquid benzene to the monochromatic mercury radiation $\lambda 4358$, and on examining the spectrum of the scattered light found modified scattered light of frequencies $\nu + \nu_k$ where ν_k is any one of the fundamental frequencies of liquid benzene. We wish to point out that Raman and Krishnan's experiment is not, strictly speaking, a confirmation of Einstein's negative or stimulated emission, as mentioned by these authors (NATURE, June 30, 1928), but of the analogous case of negatively modified scattering (that is, scattering of light of frequency $\nu + \nu_k$) discussed by Smekal.

We wish further to point out that the theory of modified scattering affords a very simple and convincing explanation of the phenomena of resonance spectra of vapours of sodium, potassium, and the halogens discovered and so elaborately described by R. W. Wood in his numerous papers. He found that when vapour of these substances is illuminated by monochromatic light (lithium, cadmium, bismuth, or zinc arc), then the vapour emits laterally a partially polarised spectrum consisting of the original line, and a number of fine lines spaced at equal frequency intervals (of about 145 in the case of Na). The position of these excited lines in the spectrum depends upon that of the exciting light, though the frequency interval between the exciting line and its adjacent excited light is independent of the exciting frequency for the same substance. The remarkable fact is that there are also a number of lines on the shorter wavelength side of the exciting light, which have been styled by the German authors (Pringsheim and his students) the 'anti-Stokes' lines. These anti-Stokes' lines also show equal spacing, and they can be explained as being due to negatively modified scattering.

Pringsheim and his students have shown that the sodium vapour contains temporary Na_2 molecules and gives rise to banded spectra on excitation. One of the strongest vibration frequency intervals is $\Delta\nu = 145$, which may be identified with the frequency of one of the fundamental modes of vibration of the component atoms. So the explanation of Wood's resonance spectra becomes evident now. When the exciting light traverses Na_2 molecules, the light is scattered by

them, the scattered light having the frequencies $\nu \pm \nu_k$ where $h\nu_k$ is the energy difference between any excited state and the normal state of the Na_2 molecule; the excitation not involving any electron displacement, but being due only to the vibration of the component atoms which are easily produced under moderate heating. The plus sign refers to the negatively modified scattered light and accounts for the anti-Stokes' lines. Similar explanations hold good for the resonance spectra of K_2 and the halogens. These substances alone have been shown to be capable of giving rise to resonance radiation, as the molecules can be easily excited to higher vibration frequencies. But it can presumably be proved to be a general phenomenon in the case of all molecules.

We wish further to point out that though the phenomenon has been described as one of 'scattering,' it seems to be intermediate between pure scattering (as by fog-particles in which the agent responsible for scattering does suffer no physical change) and pure absorption (as, for example, the absorption of the sodium line by the sodium atom, resulting in the utilisation of the total energy of the energy-particle in lifting the electron to the higher orbit and production of a new system). This phenomenon is just intermediate between the two, as the incident light reacts on the particle, and robs it of its internal energy and is re-emitted as a new radiation of increased frequency.

It seems that the polarisation of the secondary rays is probably only a time effect, depending upon the intimacy of the reactions taking place between the incident light and the scattering particle. Therefore in pure scattering, the scattered light should be completely polarised in pure absorption and in re-emission unpolarised; and in phenomena intermediate between these two it should be partially polarised, as has been proved by Wood.

The phenomena of negative scattering should also be capable of extension to free electrons, and will thus probably afford an easy explanation of the origin of bright and broad bands in the spectra of Novæ, and of winged lines in the solar spectrum.

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The Scattering of Light by Free Electrons according to Dirac's New Relativistic Dynamics.

DIRAC and Gordon have given a quantum-dynamical treatment of the problem of the scattering of light by free electrons which seems to be in good agreement with experimental results. Since the development due to Dirac of a more rational relativistic dynamics of the electron, which automatically takes the so-called 'spin' phenomena into account, the basis of the theory of the intensity and polarisation of the Compton scattering is, however, somewhat modified. We have undertaken a calculation, based on the new theory, of the intensity of the light scattered by an electron under the influence of a plane monochromatic wave train. When the incident radiation is unpolarised—a case where the least deviation from the former theory would be expected—our result can be expressed by the following formula:

$$I = I_0 \frac{e^4}{2m^2c^4r^2} \frac{(1 + \cos^2 \theta)}{\left\{ 1 + \frac{h\nu}{mc^2}(1 - \cos \theta) \right\}^3} \left(1 + \left(\frac{h\nu}{mc^2} \right)^2 \frac{(1 - \cos \theta)^2}{(1 + \cos^2 \theta) \left(1 + \frac{h\nu}{mc^2}(1 - \cos \theta) \right)} \right) \quad (1)$$