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The negative absorption of radiation

In Einstein's celebrated derivation of the Planck radiation formula, an equilibrium is considered to exist between three elementary processes: (1) a spontaneous emission from the atoms, (2) an absorption of energy by the atoms proportional to the energy density in the field, and (3) an induced emission of energy from the atoms, also proportional to the energy density. The third process can be described as a negative absorption of radiation, and is quite characteristic for Einstein's theory, as the omission of it from the equations leads to Wien's radiation formula instead of to Planck's. The negative absorption of radiation also figures prominently in the Kramers–Heisenberg theory of dispersion. The physical existence of such absorption has been up to now an article of faith rather than a proved experimental fact, and indeed some writers (Ornstein and Burger, S N Bose) have been tempted to question its reality.

A definite experimental proof is now forthcoming of the reality of negative absorption. We have discovered (*Nature*, April 21, 1928, p. 619) that when a liquid, for e.g. benzene, is irradiated by monochromatic light, the radiation scattered by the molecules contains several spectral lines of modified frequencies. Careful measurements have shown that the difference between the incident and scattered frequencies is exactly equal to an infrared frequency of the molecule, so that the process of modified scattering involves the absorption of radiation by the molecule. As the molecule has several characteristic infrared frequencies, we have an equal number of modified scattered lines. This is seen in the photograph reproduced in figure 1, which is from a spectrogram of the scattering by liquid benzene, of the light of the mercury arc from which practically everything except the 4358 A group of lines had been filtered out. In the spectrogram, the wavelengths in the incident radiation are marked in A, and the modified scattered lines are indicated by arrowheads. (It may be mentioned in passing that the benzene had not been completely purified, hence a marked continuous spectrum is also present in the modified scattering). The brightest modified lines are of longer wavelength than 4358 A, and their frequencies are determined by the infrared absorption lines at $16{\cdot}55\,\mu$, $11{\cdot}78\,\mu$, $10{\cdot}10\,\mu$, $8{\cdot}51\,\mu$, $6{\cdot}27\,\mu$ and $3{\cdot}267\,\mu$. (These wavelengths can be determined more accurately in this way than with an infrared spectrometer).

An inspection of the actual spectrogram, however, shows two modified lines of shorter wavelength than the exciting 4358·3 line, and the measurements show that their frequencies *exceed* that of the latter by the infrared frequencies of the molecule, namely, those corresponding to $16{\cdot}55\,\mu$ and $10{\cdot}10\,\mu$ respectively. The

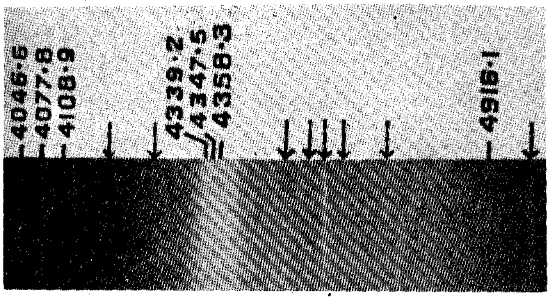

Figure 1

presence of these lines proves simultaneously the existence in the liquid of molecules at levels of energy correspondingly higher than the normal, and the fact that the incident radiation induces a return to a lower state of energy; in other words, that there is a negative absorption of the radiation. The feebleness of the modified line of enhanced frequency, in relation to the modified line of degraded frequency, is consistent with the supposition that the transitions in either direction are equally probable, if we take into account the fact that the proportion of molecules in the liquid in a higher level of energy than the normal is small at the ordinary temperatures.

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