Seventy years have passed since the discovery of the Raman effect. February 28 marks the anniversary of the observation of the line spectrum of Raman's 'new radiation' and is observed as the national 'Science Day' every year. To commemorate the passage of seven decades since Raman's spectacular discovery, we reproduce three of the early reports on the Raman effect.

– Editors

A new type of secondary radiation

[Reproduced from *Nature*, 1928, **121**, 501–502]

If we assume that the X-ray scattering of the 'unmodified' type observed by Prof. Compton corresponds to the normal or average state of the atoms and molecules, while the 'modified' scattering of altered wavelength corresponds to their fluctuations from that state, it would follow that we should expect also in the case of ordinary light two types of scattering, one determined by the normal optical properties of the atoms or molecules, and another representing the effect of their fluctuations from their normal state. It accordingly becomes necessary to test whether this is actually the case. The experiments we have made have confirmed this anticipation, and shown that in every case in which light is scattered by the molecules in dust-free ligands or gases, the diffuse radiation of the ordinary kind, having the same wavelength as the incident beam, is accompanied by a modified scattered radiation of degraded frequency.

The new type of light-scattering discovered by us naturally requires very powerful illumination for its observation. In our experiments, a beam of sunlight was converged successively by a telescope objective of 18 cm aperture and 230 cm focal length, and by a second lens of 5 cm focal length. At the focus of the second lens was placed the scattering material, which is either a liquid (carefully purified by repeated distillation *in vacuo*) or its dust-free vapour. To detect the presence of a modified scattered radiation, the method of complementary light-filters was used. A blue-violet filter, when coupled with a yellow-green filter and placed in the incident light, completely extinguished the track of the light through the liquid or vapour. The reappearance of the track when the yellow filter is transferred to a place between it and the observer's eye is proof of the existence of a modified scattered radiation. Spectroscopic confirmation is also available.

Some sixty different common liquids have been examined in this way, and every one of them showed the effect in greater or less degree. That the effect is a true scattering and not a fluorescence is indicated in the first place by its feebleness in comparison with the ordinary scattering, and secondly by its polarisation, which is in many cases quite strong and comparable with the polarisation of the ordinary scattering. The investigation is naturally much more difficult in the case of gases and vapours, owing to the excessive feebleness of the effect. Nevertheless, when the vapour is of sufficient density, for example with ether or amylene, the modified scattering is readily demonstrable.

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16 February

A change of wavelength in light scattering

[Reproduced from *Nature*, 1928, **121**, 619]

Further observations by Mr Krishnan and myself on the new kind of light-scattering discovered by us have been made and have led to some very surprising and interesting results.

In order to convince ourselves that the secondary radiation observed by us was a true scattering and not a fluorescence, we proceeded to examine the effect in greater detail. The principal difficulty in observing the effect with gases and vapours was its excessive feebleness. In the case of substances of sufficient light-scattering power, this difficulty was overcome by using an enclosed bulb and heating it up so as to secure an adequate density of vapour. Using a blue-violet filter in the track of the incident light, and a complementary green-yellow filter in front of the observer's eye, the modified scattered radiation was observed with a number of organic vapours, and it was even possible to determine its state of polarisation. It was found that in certain cases, for e.g. pentane, it was strongly polarised, while in others, as for example naphthalene, it was only feebly so, the behaviour being parallel to that observed in the liquid state. Liquid carbon dioxide in a steel observation vessel was studied, and exhibited the modified scattering to a notable extent. When a cloud was formed within the vessel by expansion, the modified scattering brightened up at the same time as the ordinary or classical scattering. The conclusion is thus reached that the radiations of altered wavelength from neighbouring molecules are coherent with each other.

A greater surprise was provided by the spectroscopic observations. Using sunlight with a blue filter as the illuminant, the modified scattered radiation was readily detected by the appearance in the spectrum of the scattered light of radiations absent from the incident light. With a suitably chosen filter in the incident light, the classical and modified scatterings appeared as separate regions in the spectrum separated by a dark region. This encouraged us to use a mercury arc as the source of light, all radiations of longer wavelength than 4358 Å being cut out by a filter. The scattered radiations when examined with a spectroscope showed some sharp bright lines additional to those present in the incident light, their wavelength being longer than 4358 Å; at least two such lines were prominent and appeared to be accompanied by some fainter lines, and in addition a continuous spectrum. The relation of frequencies between the new lines and those present in the incident light is being investigated by photographing and measuring the spectra. The preliminary visual observations appear to indicate that the position of the principal modified lines is the same for all substances, though their intensity and that of the continuous spectrum does vary with their chemical nature.

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8 March

A new radiation*

[Reproduced from *Indian J. Phys.*, 1928, **2**, 387–398]

C. V. Raman, F.R.S.
[Plate 1]

1. Introduction

I propose this evening to speak to you on a new kind of radiation or light-emission from atoms and molecules. To make the significance of the discovery clear, I propose to place before you the history of the investigations made at Calcutta which led up to it. Before doing so, however, a few preliminary remarks regarding radiation from atoms and molecules will not be out of place.

Various ways are known to the physicist by which atoms or molecules may be caused to emit light, as for instance, heating a substance or bombarding it with a stream of electrons. The light thus emitted is usually characteristic of the atoms or molecules and if referred to as *primary* radiation. It is also possible to induce radiation from atoms and molecules by illuminating them strongly. Such light-emission is referred to as *secondary* radiation. The familiar diffusion of light by rough surfaces may be cited as an example of secondary radiation, but strictly speaking, it hardly deserves the name, being an effect occurring at the boundaries between media of different refractive indices and not a true volume-effect in which all the atoms and molecules of the substance take part. The first case discovered of secondary radiation really worthy of the name was the phenomenon of fluorescence whose laws were elucidated by the investigations of Sir George Stokes. This is a familiar effect which is exhibited in a very conspicuous manner in the visible region of the spectrum by various organic dry-stuffs. I have here a bottle of water in which an extremely small quantity of fluorescein is dissolved. You notice that when placed in the beam of light from the lantern, it shines with a vivid green light, and that the colour of the emission is not altered, though its brightness is changed, by placing filters of various colours between the bottle and the lantern. A violet filter excites the green flurorescence strongly, while a red filter has but little effect.

Another kind of secondary radiation whose existence has been experimentally recognized more recently is the scattering of light by atoms and molecules. It is this scattering that gives us the light of the sky, the blue colour of the deep sea and the delicate opalescence of large masses of clear ice. I have here a large bottle of a very clear and transparent liquid, toluene, which as you notice contains hardly any dust-particles, but the track of the beam from the lantern passing through it is visible as a brilliant blue cone of light. This internal opalescence continues to be visible even after the most careful purification of the liquid by repeated distillation in vacuo. A similar opalescence is shown, though much less brightly, by dust-free gases and vapours, and also by solids. A large clear block of ice shows a blue colour in the track of the beam when sunlight passes through it. The blue opalescence of blocks of clear optical glass is also readily demonstrable. The molecular scattering of light is thus a phenomenon common to all states of matter.

During the past seven years, the scattering of light in transparent media has been the subject of intensive experimental and theoretical investigation at Calcutta, and it is the researches made on this subject that have led to the discovery which I shall lay before you this evening. One important outcome of our researches has been to show that while light-scattering is in one sense a molecular phenomenon, in another sense it is a bulk-effect having a thermal origin. It is the thermal agitation of the molecules which causes them to be distributed and oriented in space with incomplete regularity, and it is the local fluctuations in the properties of the medium thus arising which give rise to optical heterogeneity and consequent diffusion of light. The subject of light-scattering is thus a meeting ground for thermodynamics, molecular physics and the wave-theory of radiation. That the combination of theories in such diverse fields of physics give us predictions which have been experimentally verified, is one of the triumphs of modern physics.

*Inaugural Address delivered to the South India Science Association on Friday, the 16th March 1928, at Bangalore.