matter. We may take λ=6Xιo\*δ cms., µ —I =0.0003; whence from (21) we obtain as the distance x, equal to I*∕h,* which light must travel in order to undergo alteration in the ratio e : I,

x = 4∙4×10"1s×n (22)

The completion of the calculation requires a knowledge of the value of *ni* the number of molecules in unit volume under standard conditions, which, according to Avogadro’s law, is the same for all gases. Maxwell estimated 1∙9×io19, but modern work suggests a higher number, such as 4∙3×1019 (H. A. Wilson, *Phil. Mag.,* 1903; see A. Schuster, *Theory of Optics,* § 178). If we substitute the latter value in (22) we find x = 19×106 cm. = 190 kilometres.

Although Mount Everest appears fairly bright at 100 miles’ distance, as seen from the neighbourhood of Darjeeling, we cannot suppose that the atmosphere is as transparent as is implied in the above numbers; and, of course, this is not to be expected, since there is certainly suspended matter to be reckoned with. Perhaps the best data for a comparison are those afforded by the varying brightness of stars at different altitudes. P. Bouguer and others estimate about 0∙8 for the transmission of light through the entire atmosphere from a star in the zenith. This corresponds to 8∙3 kilometres of air at standard pressure. At this rate the transmission through 190 kilometres would be (∙8)23 or 0∙006 in place of e-1 or 0∙37. Or again if we inquire what, according to (21), would be the trans­mission through 8∙3 kilometres, we find 1—0.044=0’956.

The general conclusion would appear to be that, while as seen from the earth’s surface much of the light from the sky is due to comparatively gross suspended matter, yet an appreciable proportion is attributable to the molecules of air themselves, and that at high elevations where the blue is purer, the latter part may become predominant.

For a further discussion founded upon the observations of Q. Majorana and A. Sella, reference may be made to Lord Kelvin’s *Baltimore Lectures,* p. 317, where a higher estimate of the value of *n* is favoured. It may be remarked that it is only the constant part of sky-light that can be due to detached molecules. Ordinary observation of the landscape shows that there is another part, highly variable from day to day, and due to suspended matter, much of which is fine enough to scatter light of blue quality.

The experiments of Tyndall upon precipitated clouds have been already referred to. So long as the precipitated particles are very fine, the light dispersed in a perpendicular direction is sky-blue and fully polarized. At a further stage of their growth the particles disperse in the perpendicular direction a light which is no longer fully polarized. When quenched as far as possible by rotation of a nicol prism, it exhibits a residue of a more intense blue colour; and further it is found that the direction of the most nearly complete polarization becomes inclined to the direction of the primary rays.

A discussion of these and other questions upon the basis of the electromagnetic theory of light is given in the *Phil. Mag.,* 1881, 12, p. 81. Here we must be content with a statement of some of the results. So long as the particles are supposed to be very small and to differ little from their environment in optical properties, there is little difference between the electric and the elastic solid theories, and the results expressing the character of the scattered light are equivalent to (5). Whatever may be the shape or size of the particles, there is no scattered light in a direction parallel to the primary electric displacements. In order to render an account of Tyndall’s “ residual blue ” it is necessary to pursue the approximation further, taking for simplicity the case of spherical shape. We learn that the light dispersed in the direction of primary vibration is not only of higher order in the difference of optical quality, but is also of order *k2c2* in comparison with that dispersed in other directions, where *c* is the radius of the sphere, and *k* = 2τr∕λ as before. The incident light being white, the intensity of the component colours scattered in this direction varies as the inverse *eighth* power of the wave-length, so that the resultant light is a rich blue.

As regards the polarization of the dispersed light as dependent on the angle at which it is emitted, we find that although, when terms of the second order are included, the scattered light no longer vanishes in the same direction as before, the peculiarity is not lost but merely transferred to another direction. The angle *0* through which the displacement occurs is measured backwards, *i.e.* towards the incident ray, and its value is given by

λ δk fc2∙2 z .

(23)

∆K being the difference of specific inductive capacities.

Experiments upon this subject are not difficult. In a darkened room a beam of sunlight (or electric light) is concentrated by a large lens of 2 or 3 ft. focus; and in the path of the light is placed a glass beaker containing a dilute solution of sodium thiosulphate (hyposulphite of soda). On the addition, well stirred, of a small quantity of dilute sulphuric acid, a precipitate of sulphur slowly forms, and during its growth manifests exceedingly well the pheno­mena under consideration. The more dilute the solutions, the slower is the progress of the precipitation. A strength such that there is a delay of 4 or 5 minutes before any effect is apparent will be found suitable, but no great nicety of adjustment is necessary.

In the optical examination we may, if we prefer it, polarize the primary light; but it is usually more convenient to analyse the scattered light. In the early stages of the precipitation the polariza­tion is complete in a perpendicular direction, and incomplete in oblique directions. After an interval the polarization begins to be incomplete in the perpendicular direction, the light which reaches the eye when the nicol is set to minimum transmission being of a beautiful blue, much richer than anything that can be seen in the earlier stages. This is the moment to examine whether there is a more complete polarization in a direction somewhat oblique; and it is found that with *θ* positive there is, in fact, a direction of more complete polarization, while with *θ* negative the polarization is more imperfect than in the perpendicular direction itself.

The polarization in a distinctly oblique direction, however, is not perfect, a feature for which more than one reason may be put for­ward. In the first place, with a given size of particles, the direction of complete polarization indicated by (23) is a function of the colour of the light, the value of *θ* being 3 or 4 times as large for the violet as for the red end of the spectrum. The experiment is, in fact, much improved by passing the primary light through a coloured glass. Not only is the oblique direction of maximum polarization more definite and the polarization itself more complete, but the observation is easier than with white light in consequence of the uniformity in the colour of the light scattered in various directions. If we begin with a blue glass, we may observe the gradually increasing obliquity of the direction of maximum polarization; and then by exchanging the blue glass for a red one, we may revert to the original condition of things, and observe the transition from perpendicularity to obliquity over again. The change in the wave-length of the light has the same effect in this respect as a change in the size of the particles, and the comparison gives curious information as to the rate of growth.

But even with homogeneous light it would be unreasonable to expect an oblique direction of perfect polarization. So long as the particles are all very small in comparison with the wave-length, there is complete polarization in the perpendicular direction; but when the size is such that obliquity sets in, the degree of obliquity will vary with the size of the particles, and the polarization will be complete only on the very unlikely condition that the size is the same for them all. It must not be forgotten, too, that a very moderate increase of dimensions may carry the particles beyond the reach of our approximations.

The fact that at this stage the polarization is a maximum, when the angle through which the light is turned *exceeds* a right angle, is the more worthy of note, as the opposite result would probably have been expected. By Brewster’s law ζsee Polarization of Light) this angle in the case of regular reflection from a plate is *less* than a right angle; so that not only is the law of polarization for a very small particle different from that applicable to a plate, but the first effect of an increase of size is to augment the difference.

The simple theory of the dispersion of light by small particles suffices to explain not only the blue of the zenith, but the com­parative absence of small wave-lengths from the direct solar rays, and the brilliant orange and red coloration of the setting sun and of the clouds illuminated by his rays. The hyposulphite experiment here again affords an excellent illustration. But we must not expect a simple theory to cover all the facts. It is obvious that the aerial particles are illuminated not only by the direct solar rays, but also by light dispersed from other parts of the atmosphere and from the earth’s surface. On this and other accounts the coloration of the sky is highly variable. The transi­tion from blue to orange or red at sunset is usually through green, but exceptional conditions may easily disturb the normal state of things. The brilliant sunset effects observed in Europe after the Krakatoa eruption may naturally be attributed to dust of unusual quality or quantity in the upper regions of the atmo­sphere (see Dust).

Related to abnormalities of colour we may expect to find corre­sponding polarization effects. Of this nature are the neutral points, where the polarization changes character, observed by F. J. D. Arago, J. Babinet and Sir D. Brewster, for an account of which reference may be made to E. Mascart, *Traité d'optique.* The normal polarization at the zenith, as dependent upon the position of the sun, was the foundation of Sir C. Wheatstone’s polar clock. (R.)