Double Orange.

THE abnormality in a Maltese orange described in NATURE of April 7 (p. 534) would appear of common occurrence in the Queensland or South Australian fruit. A friend assures me that in a case recently received from Australia, 80 per cent. of the contents showed small oranges, more or less perfect, either embedded in the pulp or in the rind. The quality of the fruit I observed was in no way affected. It would, however, be interesting to obtain further testimony. Although the small oranges may not affect the commercial value of the fruit, their presence must be undesirable in the groves where perfection is sought.   GERALD B. FRANCIS.
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ON THE LINE SPECTRA OF THE ELEMENTS.

THE distribution of the lines in the spectra of the elements is by no means so irregular as it might seem at first sight. Since Lecoq de Boisbaudran, in 1869, discovered the general plan in the spectra of the alkali metals, a number of interesting facts have been brought to light, which will probably one of these days find their mechanical explanation, and will then greatly advance our knowledge of the molecules.

Mechanical explanations of some of the facts have been attempted already. Lecoq de Boisbaudran explains the fact that the rays of the alkali metals are, on the whole, less refrangible the greater the atomic weight, by observing that the oscillations of a body suspended in a given elastic medium will become less frequent when the mass of the body is increased. This explanation, however, seems to me to remain rather vague and unsatisfactory as long as it does not lead to any numerical results that agree with the observations. Taken literally, it makes the oscillation-frequency inversely proportional to the square root of the atomic weight, which is far from being the case.

A second well-established fact has received different explanations by Julius [1] and by Johnstone Stoney.[2] It has long been observed by Hartley that in the spectrum of several elements a number of doublets or triplets of lines appear, the oscillation-frequencies in each doublet or triplet differing by the same amount. Recent measurements by Prof. Kayser and myself have confirmed this observation. Julius believes that this phenomenon is due to a cause analogous to the combination tones in the theory of sound.

If two rays, with oscillation-frequencies a, β, combine with other rays, p, q, r, s, to oscillation-frequencies

$$\begin{array}{cccc} p + a & q + a & r + a & \quad + a \\ p + \beta & q + \beta & r + \beta & s + \beta, \end{array}$$

the same difference $a - \beta$ will occur several times. That the doublets under consideration are in many cases remarkably strong is accounted for by the fact that the intensity of the combination tone is proportional to the product of the intensities of the primary tones, so that it must become very strong when the amplitude of the primary tones is sufficiently increased.

Johnstone Stoney gives a different explanation of the doublets. He supposes that the path of the molecule from which light emanates is an ellipse, which by disturbing forces is gradually changed, and he shows that on this supposition, instead of one ray, two rays or more would originate, and the oscillation-frequencies of these rays would differ by an amount depending on the rate of change of the ellipse. If now, instead of the ellipse, the path of the molecule is any other curve, it can be considered as consisting of a number of superposed ellipses, all of which change in the same way on account of the disturbing forces. To each of the ellipses a doublet of lines corresponds, and the oscillation-frequencies of each

doublet differ by the same amount. In this explanation I do not understand the decomposition of the arbitrary curve in a series of superposed ellipses. For the movement is supposed not to be periodical, and Fourier's theorem then would not apply, at least the periods of the superposed ellipses would not be definite, as long as there are no data except the arbitrary curve itself.

Besides, both Johnstone Stoney and Julius only try to explain one of a number of regularities that have been observed in the spectra of the elements. A plausible suggestion about the movement of the molecules ought to explain more than one of the observed phenomena. I think it may be useful to point out the other regularities that have been observed in the distribution of lines, and for which as yet no mechanical explanation has been attempted.

(1) The doublets and triplets existing in the spectrum of an element can be arranged in series which show an appearance of great regularity. These series seem to be analogous to the over-tones of a vibrating body. But they possess a remarkable peculiarity, which, as far as I know, is without analogy in the theory of sound. The difference of two consecutive oscillation-frequencies decreases as these increase, and there seems to exist a finite limit to the oscillation-frequencies of a series. If n represents integer numbers, the oscillation-frequencies of a series may with great accuracy be represented by the formula—

$$A - Bn^{-2} - Cn^{-4},$$

where A, B, C are positive constants. B has nearly the same value for all the series of the different spectra. A is the limit towards which the oscillation-frequency tends, when n increases.

(2) For elements that are chemically related, the series are distinctly homologous, both in appearance of the lines and in the values of A, B, C, and with increasing atomic weight shift towards the less refrangible end of the spectrum. Homologous series have been observed in the following groups of elements :—

> Lithium, sodium, potassium, rubidium, cæsium ;
> Copper, silver ;
> Magnesium, calcium, strontium ;
> Zinc, cadmium, mercury ;
> Aluminium, indium, thallium.

In the first two and in the last group the series consist of doublets,[1] while in the remaining two groups they consist of triplets. Thus we may say that the spectrum shows a relationship between the elements similar to that between their chemical properties. It is interesting to note that magnesium forms a group with calcium and strontium, and appears more nearly related to them than to zinc, cadmium, and mercury.

(3) The doublets and triplets in each group broaden as the atomic weight increases. In the first group the difference of oscillation-frequencies is nearly proportional to the square of the atomic weight. The constant difference of the oscillation-frequencies in the doublets and triplets may also be noted in the values of A, B, C. For a series of doublets or triplets we have two or three different values of A, but only one value of B and one value of C.

(4) In each of the spectra of sodium, potassium, rubidium, and cæsium, a series of doublets has been observed, in which the oscillation-frequencies do not differ by a constant amount, the difference diminishing inversely proportional to n^4. For these series A and B have only one value each. The least refrangible doublet of the series has the same difference of oscillation-frequencies as the doublets in the other series of the same element. In the spectrum of lithium there is a homologous series of single lines. All the lines of these series have the same

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[1] Julius, *Annales de l'École Polytechnique de Delft*, tome v. (1889).
[2] Stoney, Trans. of the Roy. Dublin Soc., vol. iv. (1891).

[1] Lithium has here to be excepted, whose lines are all single.