54. *Occurrence of Harmonics in Spectral Lines.*

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Unlike sound vibrations, it is generally supposed that light waves do not contain the octaves and the higher harmonics. The series lines are given by definite formulae, which do not allow the presence of harmonic lines, in the usual sense of the word. But with lines not belonging to series, we find that there are a number for almost all elements that can be looked upon as the octaves. The number of such lines is sometimes so great that the probability of the wave-lengths observed becoming almost exactly half of those in the longer region leaves little doubt of their being the octaves, and not due to some chance coincidence. With the present aspect of the emission of light, the appearance of the octaves is not denied by the principle of correspondence, but little attention seems to have been paid to this point.

In hydrogen, the octaves of the visible region is tolerably small compared with those in the ultra-violet. The coincidence is generally to within an angstrom; in fact many show exact coincidence, assuming Lyman's values in the Schumann region. It may, however, be argued that owing to the extremely large number of lines, the intervals between successive lines are very small, so that the half values of longer waves happen to fall in nearly the exact place. There may be some lines thus coming in by chance, as the intensity relation is quite indefinite. With mercury, there are good many lines falling in groups of octaves, especially among those observed by Bloch with the electrodeless discharge. Some numbers of higher harmonics have also been noticed in the spectra of mercury. Copper and zinc show the same characteric.

The reason why this singular fact has not been noticed seems to lie in the scarcity of observations of the spectra in the extreme violet, as the octaves and the higher harmonics are generally to be found in the region of double and higher frequencies. Moreover, most spectroscopists seemed to be charmed at the appearance of the series lines, so that little

care was bestowed on the examination of the position of lines, which are more related to the acoustic spectrum than that of light.

One of us has already remarked that if we assume the presence of nuclear vibration, the appearance of the said phenomena is easy to explain on the classical theory, but there is great difficulty in discriminating these vibrations from those caused by electron movements outside the nucleus. It is further to be noticed that in the case of nuclear vibrations, the octaves are approximate, and not exact; as the vibrations must be assumed to be asymmetric. The examination of the spectra of different elements indicate the said conclusion, but many may be due to the difficulty of the measurement of the lines in the region of short wave-lengths.

For the sake of illustration, a short list of lines in the hydrogen spectra only is given in the following:—

Harmonics of Hydrogen Lines.

Wave-lengths λ	$\frac{\lambda}{2}$ (obs.)	Δ	$\frac{\lambda}{4}$ (obs.)	Δ
6249.42	3124.90	-0.2	1562.2	+0.2
6240.42	3119.73	+0.5	1560.0	+0.1
6238.57	3119.73	-0.4	1559.6	-0.4
6236.03	3117.70	+0.3	1558.7	+0.4
6233.22	3117.26	-0.7	"	-0.4
6225.02	3112.09	+0.4	1556.4	-0.1
6201.38	3100.97	-0.3	1550.6	-0.2
6174.28	3087.33	-0.2	1543.9	-0.3
6169.85	3085.25	-0.3	1541.6	+0.9
6167.07	3083.23	+0.3	1540.8	+0.2
6162.63	3081.56	-0.3	1540.6	-0.1
6159.82	3079.90	0.0	1539.9	-0.1
5942.24	2971.20	-0.1	1486.1	-0.5
5936.29	2968.44	-0.2	1483.7	-0.4
5657.57	2828.67	+0.1	1414.9	-0.5
5654.61	2827.23	+0.1	1413.0	+0.7
5610.80	2804.56	+0.8	1402.8	-0.1
4968.44	2483.95	+0.2	1241.5	+0.6
4966.13	2482.87	+0.2	1241.5	0.0

Owing to the presence of a continuous spectrum after this region, the occurrence of octaves is difficult to find out. Passing this obscure part, we arrive at another part of the spectrum, where forty more lines having the octaves are found. The lack of intensity relation leaves some doubt as to the presence of the real octaves.

In hydrogen spectrum, we found about 180 lines having the lines equivalent to *one-third of wave-lengths* and about 150 lines with lines equivalent to *one-fourth*.

In mercury, there are about 57 lines accompanied with octaves, and dozen lines with $\frac{1}{3}\lambda$; in copper, we find about 70 octave lines.

With spectra of other elements, similar relation can be found; for want of wave-lengths determinations in the extreme ultra-violet, we have to wait for some years till the literature on the subject is more complete than we have at present.