Huygens Institute - Royal Netherlands Academy of Arts and Sciences (KNAW)

Citation:

Moll, W.J.H., An investigatiopn of some ultra-red metallic spectra, in:
KNAW, Proceedings, 9 II, 1906-1907, Amsterdam, 1907, pp. 544-548

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other and to the former basepoints have not a particular position.

With the aid of this remark we can easily find the following theorems, with which we conclude:

"Both cusps of which the fourfold point of the curve c_{12} coinciding with a basepoint A'_i seems to consist and the two cusps of the curves of the system showing in this point a cusp, coincide in cuspidal tangents, but they turn their points to opposite sides."

"If the three basepoints A'_1, A'_2, A'_3 lie on a right line l, the locus proper of the cusps reduces itself to a curve c^9 touching the line l in A'_1, A'_2, A'_3. If the three remaining basepoints exist then the points of intersection of l with the sides of the triangle having those basepoints as vertices are points of c^9".

The last case answers to that of a surface S^3 with a double point; the parabolic curve having in this doublepoint a threefold point, because l separates itself three times from c^{12}, is as has been found above already a twisted curve of order nine.

Physics. — *"An investigation of some ultra-red metallic spectra."* By W. J. H. Moll. (Communicated by Prof. W. H. Julius).

(Communicated in the meeting of December 29, 1906).

Among the spectra of known elements those of the alkali-metals, by their relatively simple structure, lend themselves particularly well to an investigation of their ultra-red parts. Many observers have consequently sought for emission lines of these metals in this region.

For the first part of the ultra-red spectrum the photographic plate may be sensitised; especially Lehmann [1]) measured in this way various lines with wave-lengths ranging to almost 1 μ. By means of the bolometer Snow [2]) could advance to 1.5 μ.

For the further region, however, nothing was known about these spectra. Coblentz [3]), to be sure, was led by a series of observations in this respect, to the conclusion that the alkali-metals emit no specific radiation beyond 1.5 μ, but I had reason to doubt the validity of this conclusion.

In what follows I will briefly describe the method by which some ultra-red spectra were investigated, and the lines thus found. In an

1) H. Lehmann. D.'s Ann. 5, 633, 1901.

2) B. W. Snow. W.'s Ann. 47, 208, 1892.

3) W. W. Coblentz. Investigations of Infra-red Spectra. Carnegie Inst. Washington. 1905.

academical thesis, which will soon be published, further details will be given.

For the investigation of the alkalies, the metallic salts were volatilised in the arc in the ordinary way. The very complicated band-spectrum, emitted by the arc when no metallic vapour is present, extends far into the ultra-red. But this interferes in no way with the investigation of the metals, since it is entirely superseded when the arc contains a sufficient quantity of metal. On the other hand the continuous spectrum, emitted by the incandescent particles in the arc, makes it somewhat difficult to observe some feebler lines; besides, the radiation of carbonic acid, the product of combustion of the carbons, (with a maximum near 4,44 μ) persists with almost unchanged intensity.

The image of the arc is projected by a concave mirror on the slit of a reflecting-spectrometer; the rays are analysed by a rock-salt prism and part of the so formed spectrum falls on a linear thermopile. This thermopile, like that of RUBENS, is built up of iron and constantan; all the dimensions were chosen smaller than in the original pattern and a great sensitiveness was obtained. As well the emitting slit as the thermopile are mounted in fixed positions; in order to throw on this latter different parts of the spectrum in succession, the prism can be rotated through small angles. A WADWORTH combination of prism and plane mirror maintains minimum-deviation during rotation.

In chosing and designing the instruments, the desirability was kept in mind of replacing the very tiring reading of the galvanometer and the simultaneous noting of the corresponding position of the prism, by an automatical recording-device. I had in mind the splendid arrangement by which LANGLEY has for years recorded the intensity-curve of the ultra-red solar spectrum on a photographic plate. That this method has not been followed for recording heat-spectra instead of the time-absorbing visual observations, must be ascribed in the first place to a very complicated mechanism being required for obtaining complete correspondence between the linear displacement of the photographic plate and the rotation of the spectrometer, and secondly to the difficulty of keeping the surrounding temperature perfectly equal during the observations.

With very simple means I devised a method of recording, which avoids these two difficulties, while yet it warrants a sure "correspondence", and yields accurate results also when changes in the surrounding temperature cannot be prevented. For this purpose the continuous recording has been replaced by the marking of a series of dots, while for the continuous rotation of the spectrometer an intermittent one has been substituted. In this way for any recorded radiation-intensity the corresponding position of the prism can be found, not by *measuring* abscissae, but by *counting* dots. Since moreover not only the deflections of the galvanometer but each time also the zero-positions are recorded, it is possible to determine on the spectograms the radiation-intensities also when during the observations the surrounding temperature, and consequently the zero-position, was variable.

The principal advantages of this method of observation over the usual one are:

1. the absolute reliability of the observations,
2. the very short time required for a set of observations,
3. the accuracy with which interpolation is possible when the zero-position shifts,
4. the non-existence of disturbances, caused by the proximity of the observer,
5. the complete comparability of the different observations,
6. the possibility of estimating the probable error from the shape of the zero-line.

The short time in which a set of observations is made, is of importance when e.g. heat-sources are investigated which, like the arc, show slow changes in radiation-intensity. A spectrum, ranging from 0,7 to 6 μ was recorded with 200 displacements of the spectrometer in two hours.

In the spectrograms a spectral line is represented by 5 to 6 dots. With one displacement of the spectrometer namely the line is shifted over a distance amounting to $^2/_5$ of the breadth of the image of the slit, or of the equal breadth of the thermopile. Hence the same kind of radiation will strike the thermopile during five successive displacements. From the mutual position of the dots, the place where the radiation-intensity has its maximum may be accurately determined. In order to derive from this the place occupied by the line in the spectrum, it is sufficient to know one fixed point in the spectrum. This fixed point was as a rule taken from a comparison spectrum, for which the carbonic acid emission of a Bunsen flame was chosen, the maximum of which, according to very accurate measurements of Paschen, lies at 4.403 μ. Part of the flame spectrum was for this purpose recorded simultaneously with the spectrum to be studied.

A simple calculation then gives the refractive index for the unknown ray. In order to derive from this the wave-length of the line, a dispersion formula must be used. I became aware that the well-known dispersion curves of LANGLEY and of RUBENS show considerable differences, and although at first sight LANGLEY's determinations seem to be much preferable, yet on closer examination their excellence must be doubted, especially for the longer wave-lengths. To prefer one of the dispersion curves to the other seems to be at present a matter of arbitrary choice. So I have given in the tables besides the observed refractive indices, the wave-lengths, calculated from them as well by LANGLEY's as by RUBENS' formula. The refractive indices hold good for a temperature of 20°; their determination is based on the index 1.54429 for the *D*-line, a value, derived from very accurate determinations by LANGLEY.

The tables given below contain the lines of Na, K, Rb and Cs (I have been unable to obtain reliable results with Li in the arc) and of Hg. The results were derived from a large number of spectrograms (10 to 12 for each metal). For the investigation of the mercury spectrum a mercury arc-lamp was devised, furnished with a rock-salt window. The spectrum of mercury has been repeatedly investigated as far as 10μ; no measurable emission has been found beyond 1.7μ.

In the tables the first column gives the refractive index n of rock-salt, the second and third the wave-length μ of the line, according to the formulae of LANGLEY and RUBENS, and the fourth the approximate value I of the intensity.

For the lines of which the exact position was difficult to ascertain, the refractive index is only given in four decimals.

SODIUM.

n	μ(Langley)	μ (Rubens)	I
1.53529	0.819	0.816	240
.53062	1.14	1.13	180
.52961	1.27	1.25	15
.5286	1.44	1.42	5
.5281	1.57	1.54	5
.52711	1.85	1.80	25
.52613	2.21	2.16	45
.52589	2.31	2.25	35
.52455	2.90	2.84	20
.5234	3.42	3.36	5
1.52178	4.06	4.00	10

POTASSIUM.

n	μ(Langley)	μ (Rubens)	I
1.53654	0.771	0.768	620
.5325	0.97	0.96	10
.5310	1.11	1.10	20
.53030	1.18	1.17	320
.52972	1.25	1.24	200
.52823	1.53	1.50	95
.5261	2.24	2.18	5
.52486	2.76	2.70	20
.52401	3.14	3.08	20
.52263	3.73	3.67	15
1.52184	4.04	3.98	10

RUBIDIUM.

n	μ (Langley)	μ (Rubens)	I
1.53733	0.744	0.742	12
.53624	0.782	0.779	450
.5359	0.795	0.792	300
.5332	0.93	0.92	10
.53202	1.01	1.00	35
.5309	1.11	1.10	10
.52912	1.35	1.33	200
.52830	1.49	1.51	180
.52597	2.28	2.22	20
.52477	2.80	2.73	25
1.52186	4.03	3.97	10

CAESIUM.

n	μ (Langley)	μ (Rubens)	I
1.53566	0.803	0.801	40
.53451	0.855	0.851	250
.53375	0.895	0.891	200
.5333	0.920	0.914	75
.53202	1.01	1.00	90
.52902	1.37	1.35	70
.52846	1.48	1.45	80
.5275	1.74	1.70	5
.5264	2.08	2.03	5
.5257	2.41	2.35	5
.52433	3.00	2.93	50
.52315	3.51	3.45	30
1.52203	3 97	3.91	10

MERCURY.

n	μ (Langley)	μ (Rubens)	I*
1.53198	1.01	1.00	28
.53076	1.13	1.11	8
.52907	1.36	1.34	11
.52828	1.52	1.49	5
1.52759	1.70	1.66	5

* The intensity of the green and yellow mercury lines has been put = 10.

Mathematics. — "*On the locus of the pairs of common points and the envelope of the common chords of the curves of three pencils.*" 2nd part.: *Application to pencils of conics.* By Dr. F. Schuh. (Communicated by Prof. P. H. Schoute.)

(Communicated in the meeting of December 29, 1906).

9. If the pencils of curves are pencils of conics ($r = s = t = 2$) then in the case of there being no common base-points the locus is of order fifteen and the envelope of class six. In the following we