JOURNAL OF THE COLLEGE OF SCIENCE, TOKYO IMPERIAL UNIVERSITY.
VOL. XLI., ARTICLE 8.

Magnetic Separations of Iron Lines in Different Fields.

By

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With 13 Plates.

Introduction.

As a recent development of the atomic theory, various hypotheses have been proposed to illustrate the atomic structure from the point of view as revealed by radiation. In spite of the divergence of the various theories, they all agree in attributing the origin of the spectrum lines to the moving electrons in the atom. Prof. Nagaoka has suggested that, if such an atom is placed in a magnetic field, the mutual influence between the electrons may give rise to the separation of some spectrum line, which is not proportional to the magnetic field.

In some series lines with complex structure many investigators[1] have observed anomalous Zeeman separations, and it is known as a general rule that each component, showing its own Zeeman separation in weak fields, either disappears or unites with others when the field is increased, and as a whole tends to the normal triplet in a sufficiently strong field ; consequently the separation is not generally proportional to the field. But to

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[1] Paschen u. Back, Ann. d. Physik, **39** (1912) p. 897 ; **40** (1913) p. 960.
Fortrat, C. R., **156** (1913) p. 1607 ; **157** (1913) p. 636.
Nagaoka and Takamine, Proc. Tokyo Math.-Phys. Soc., [2], **7** (1913) p. 188 ; (1914) p. 331 ; Phil. Mag., **27** (1914, p. 333 ; **29** (1915) p. 241.
Wood and Kimura, Astrophys. Jour. **46** (1917) p. 197.

make exact measurements of such lines seems to be very difficult. As for the single lines, Reese[1] and Kent[2] found that the separations of λλ 4680, 4722 and 4810 of zinc are not proportional to the field, but Cotton and Weiss[3] showed that proportionality holds good for these lines. The deviations from the proportionality given by Reese and Kent for other lines are much smaller than those for the above lines. Several investigators showed that magnetic separations of single lines are in general nearly proportional to the field. So far, however, as the present writer is aware, those lines for which the separations are accurately measured over a wide range of magnetic fields are very few, so that it requires more extended experiments covering a wide range of magnetic fields as well as numerous spectrum lines to ascertain whether a linear relation between the separation and the magnetic field exists or not, which seems to be very interesting inasmuch as it may throw some light on the structure of the atom. The following investigation was undertaken with this object in view. For this purpose, elements rich in lines are convenient, as the chance of coupling among the electrons may be large in such an atom, for it is not probable that these lines are emitted from separate atoms each by itself; indeed they give many Zeeman triplets having divergent values of separations,[4] which might be the result of coupling.

Iron, manganese, calcium and titanium were examined, but the experiments with the latter three elements being yet incomplete, only the results obtained with the first are given in the present report.

Besides the fact that iron is rich in lines which give divergent values of magnetic separations, its ferromagnetic property—though we do not know the property at the temperature of the spark—may show some special character in its magnetic spectrum,

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1) Reese, Astrophys. Jour., **12** (1900) p. 120.

2) Kent, Astrophys. Jour., **13** (1901) p. 289.

3) Cotton et Weiss, Jour. de Phys., [4], **6** (1907) p. 429.

4) Zeeman, Magnetooptics, (1913) p. 157.

and a comparison with other para-or diamagnetic elements, when sufficient data are obtained, will be interesting.

Source of Light.

The source of light used was the spark discharge between 25 percent nickel-steel terminals excited by an induction coil, the primary circuit being fed with 6 amperes of alternating current of 110 volts, 50 cycles, obtained from the city main. 4 Leyden jars were connected parallel to the spark gap directly between the poles of the induction coil to obtain a condensed discharge. An adjustable inductance and auxiliary spark gap with small capacity were inserted in the spark circuit in series; the increase of the inductance, giving the spark the character of an arc, made the spectrum lines sharper and put out the air lines, with, however, a considerable sacrifice in the intensity of the iron lines also; the auxiliary spark gap served to control the spark under examination in a favourable state for various magnetic fields. It is desirable to give the spark sonorous character with steady greenish appearance. When the magnetic field was not strong the spark continued in a favourable state for a long time, but in a strong field the terminals soon became dark red and the spark formed an arc of violet tint, making the iron lines weaker and increasing the luminosity of the continuous spectrum in the back ground, —this was especially remarkable in the green region—, so that it was necessary to polish the tips of the terminals every 5 or 10 minutes. The terminals, on being polished, recovered their ferromagnetic property, and it was very troublesome to place them in proper position between the poles of the strong electromagnet, which was, however, overcome by heating the polished terminals with a Bunsen burner.

Small cylinders about 1 mm. thick attached to brass rods were used as terminals for most of the experiments, and wedge shaped ones were used with the strongest fields to prevent the current from passing through the poles of the magnet.

During the whole course of the experiment, it was desirable to regulate the length of the spark gap, which was adjusted by clamping the terminals to the poles provided with an arrangement like a spark micrometer, by which the distance between the sparking terminals was changed so as to obtain a spark best suited for the exferiment.

Electromagnet.

The electromagnet used was so constructed that the cores with the coils can be displaced along their common axis and rotated as a whole about the vertical axis, which enabled us to bring the middle of the magnetic field on the line of collimation of the optical system, keeping this line and the magnetic lines of force at right angle with each other.

A current of 1·5 to 23 amperes from the secondary battery was used according to the magnetic field desired, and its constancy was carefully observed by means of a small adjustable resistance and an ammeter by Siemens & Halske.

Conical pole pieces ending in circular sections were used during the whole course of the experiments, the diameter of the faces and the air gap between them were 2 cm. and 1 cm. respectively for weak fields, and 0·3 cm. and 0·12 cm. for the strongest ones, the diameter and the gap being changed between these limits.

For the purpose of examining the character of the magnetic separation, it was desirable to extend the range of the magnetic field as wide as possible, but it was difficult to apply a field stronger than 37230 gauss with the electromagnet in our laboratory for the spark gap giving a source of light of considerable intensity, the diameter of the faces of the pole pieces and the air gap between them being limited as mentioned above, for further approach of the pole faces caused short-circuit of the sparking current through them, and further diminution of the diameter might have disturbed the uniformity of the magnetic field in the spark. An electromagnet with water-cooling arrangement and ferro-cobalt pole pieces would have been more suitable for experiments in stronger fields.

Echelon Grating.

The echelon grating by Hilger, frequently used by Prof. Nagaoka[1] in the study of the structure of mercury lines and other works, was used in the present research also. The constants of this instrument are as follows:—

Thickness of plate	9·350 mm.,
Number of plates	35,
Steps	1·0 mm.,
Length	32·73 cm.,

$A=1{\cdot}555055$,
$B=5{\cdot}9595\times10^{5}$,
$C=1{\cdot}9514\times10^{12}$;

where A, B, C are the constants in Cauchy's formula for the index of refraction

$$\mu=A+\frac{B}{\lambda^2}+\frac{C}{\lambda^4},$$

λ being expressed in Å.U.

The wave number intervals corresponding to the distance of two successive orders were calculated from the usual formula

$$\frac{\delta\lambda_{max}}{\lambda^2}=\frac{1}{t\,\{(\mu-1)-\lambda\frac{d\mu}{d\lambda}\}}$$

for the wave lengths of constant intervals of 50 Å.U., and their values are given in Table I.

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[1] Nagaoka and Takamine, Memoir of the Imperial Academy, Sec. II, Vol. I., No. 1, 1913.

TABLE I.

$\lambda\times10^8$	$\frac{\delta\lambda_{max}}{\lambda^2}$	$\lambda\times10^8$	$\frac{\delta\lambda_{max}}{\lambda^2}$	$\lambda\times10^8$	$\frac{\delta\lambda_{max}}{\lambda^2}$
3800	1·4739	4550	1·6103	5300	1·6948
3850	1·4853	4600	1·6172	5350	1·6992
3900	1·4963	4650	1·6239	5400	1·7035
3950	1·5070	4700	1·6304	5450	1·7077
4000	1·5172	4750	1·6367	5500	1·7117
4050	1·5272	4800	1·6428	5550	1·7157
4100	1·5368	4850	1·6487	5600	1·7195
4150	1·5460	4900	1·6545	5650	1·7233
4200	1·5551	4950	1·6600	5700	1·7269
4250	1·5637	5000	1·6655	5750	1·7305
4300	1·5722	5050	1·6707	5800	1·7339
4350	1·5803	5100	1·6758	5850	1·7373
4400	1·5882	5150	1·6808	5900	1·7406
4450	1·5958	5200	1·6856	5950	1·7438
4500	1·6031	5250	1·6902	6000	1·7469

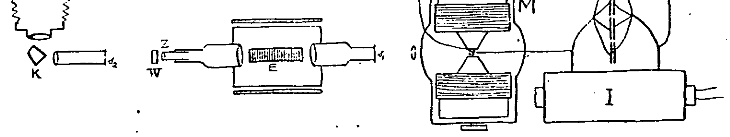
Actual values of $\frac{\delta\lambda_{max}}{\lambda^2}$ for iron lines were obtained by interpolation, and, if desired we can get the wave length intervals by multiplying by λ^2; this is unnecessary, as it is more rational to express the Zeeman separation in change of frequency than in wave length.

The chief advantage of using the echelon spectroscope consists in its high resolving power, the great intensity of light and the comparatively large value of $\frac{\delta\lambda_{max}}{\lambda^2}$. The first allows us to observe fine separations in weak fields, the second is convenient especially in investigations with strong fields, and the last is important in the investigation of spark spectra, for the lines in such spectra have considerable widths. Fabry-Perot's interferometer and Lummer Gehrcke's plate satisfy the first and the second, but not the third condition. Even with the echelon grating $\frac{\delta\lambda_{max}}{\lambda^2}$ is not sufficiently large to enable us to measure the separation in some fields when one component falls upon or close by the other. Complex separations giving more than four components with the same polarization were not measured in different fields. Though the appearance of the components belonging to the next order is troublesome in the measurement of complex separations, it has some advantage. Irregular contraction of the gelatine film of a photographic plate may cause some displacement of the silver deposit, and the error coming from this may be proportional to the separation, giving a large error for a strong field. With echelon spectra we need not measure a separation larger than $\frac{\delta\lambda_{max}}{\lambda^2}$, but may simply add the multiple of this quantity to the measured fraction, and can thus get an accurate value for the separation, provided that $\frac{\delta\lambda_{max}}{\lambda^2}$ is calculated with sufficient accuracy.

Apparatus and Method of the Experiment.

The spark placed between the magnet poles was focused by a lens on the horizontal slit s_1 of the echelon spectroscope, and the image formed by the echelon was projected on the vertical slit s_2 of a Hilger constant deviation spectroscope by means of a Rudolph's planar of 5 cm. focus. The telescope of this spectroscope was removed and its place was taken by a photographic camera with an objective of 65 cm. focus. The rough sketch is given in Fig. 1.

Fig. 1.



I induction coil
C Leyden jars
L adjustable inductance
S spark under examination
S' auxiliary spark gap

M electromagnet
s_1 horizontal slit
E echelon grating
Z Rudolph's planar
W Wollaston prism

s_2 vertical slit
K constant deviation prism
P photographic camera.

When the horizontal slit was opened wide only the prism spectrum was observed at the camera, and then the slit was slowly closed until the vertical lines contracted to dots of echelon spectra. Thus many lines were photographed at a juxtaposition, admitting exact comparison of the magnetic separations among these lines. Proper adjustment of the inclination and position of the photographic plate and the position of the planar behind the echelon spectroscope made it possible to photograph green lines in one and the same exposure with violet lines, if we allowed the disturbing of the sharpness of the prism spectrum, but the difference in the intensity and the photographic sensitivity made it convenient to separate the exposure into several steps, each lasting 10 to 360 minutes according to the magnetic field and the lines to be photographed. In some plates I have photographed the echelon spectra of the whole region in one focus with disturbed prism spectrum, and in other plates with sharp prism spectrum, changing the position of the planar from exposure to exposure. For the larger part of the experiment a Wollaston prism W was inserted between the planar and the vertical slit, by which it was possible to photograph both the parallel and perpendicular Zeeman components at once. For some exposures the Wollaston prism was removed and a nicol was placed in front of the horizontal slit. Some photos were taken without separating the polarized components to see if any dissymmetry of the resolution exists, but without any conclusive result. The others were photographed without the planar to shorten the time of exposure at the cost of small magnification.

In order to make the apparatus free from mechanical and thermal disturbances, the whole arrangement was placed in a cellar, and the box containing the echelon grating was protected by cork plates. On fine days, dry air was allowed to enter the room through the windows; then shutting the windows and the door tightly, the temperature in the room was kept as constant as possible, and the image of the echelon spectra did not suffer any sensible disturbance even if the exposure was continued during the whole day.

In order to eliminate errors arising from irregular contraction of the gelatine film of the photographic plate and other sources, photos were taken repeatedly, increasing and decreasing the magnetic field. The photographic plates mostly used were the panchromatic and process plates by Wratten & Wainwright. Wratten double instantaneous and Ilford proces plates were used occasionally for the stronger and the weaker fields respectively.

Result.

In the earlier course of the experiment it was my chief object to study the behavior of the nine strong lines in the violet region λλ 4415·13, 4404·75, 4383·55, 4325·78, 4307·92, 4271·75, 4071·75, 4063·61, 4045·82[1] over a wide range of magnetic fields. Three of these lines are arranged in a particular spacing, thus, || |, the distance between the second and the third lines being twice as large as that between the first and the second. Another aim of the investigation was to observe the separations of the principal lines in the green region, as former results in this region showed some discrepancies, which may have been due partly to experimental errors and partly to the difference of the magnetic fields. In the course of the experiment it seemed to me important to study the separations of weak lines, for a weaker line may be affected more than a stronger by mutual action, though we do not know the mechanism of radiation in the atom. Thus the resolutions of the weak lines, so far as observed with the present instrument, are also here given. Many weak lines lost their intensity with the increase of the magnetic field and became very diffuse, some showing complicated resolutions. Especially in the green region the increase of the intensity of the back ground disturbed the echelon spectra so much that they appeared to melt into it,— this phenomenon is somewhat due to the character of these lines, whose components are diffuse or complex and one falling close by

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[1] The wave lengths of these lines and the others given in the present report were first identified in the map of the iron spectrum by Buisson and Fabry in "Recueil de Constantes Physiques," and then the exact numbers were taken from the international in Kayser's „Handbuch der Spectroscopie."

the other in the increased field—, and the separations of these lines were not measured for strong fields.

As 4404·75 came out most sharply in many plates, its separation was taken as the standard, and the separations of the other lines were compared with it, without any anticipation of the absolute value of the magnetic field. The magnetic fields given in the following were calculated from the separation of the above line assuming the specific separation

$$\frac{\Delta\lambda}{\lambda^2 H} = 1{\cdot}064 \times 10^{-4},$$

which was borrowed from the result of Mr. Yamada[1] who found that the separation is proportional to the magnetic field by comparing the separation of this line with that of the zinc line 4680. As my observation extends both in weak and strong fields beyond the limits in his experiment, it may be objected that the calculation of the field for these portions is an extrapolation, but the linear relation between the magnetic field and the separations of many sharp lines shows that the separation of 4404·75 is proportional to the magnetic field.

I. *Nine Strong Lines in the Violet Region.*

λ **4415·13,** at the end of the first three lines toward the red, appears as a triplet in weak fields. The intensity of this line is comparable with that of 4404·75 in the spark spectrum without or with a weak magnetic field, but, when the field is increased, all the three components become diffuse and weak, so that it is difficult to study the behavior fully in strong fields with the echelon spectroscope. On Wratten double instantaneous plates photographed with fields of 35650 and 37230 gauss I have observed its fine resolution, giving at least $3p$-and $4n$-components. King[2] also assumes the line to be septuple from the broadening of the

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[1] Yamada, Jour. Sci. Coll., Imperial University, Tokyo, Vol. XLI., Art. 7.

[2] King, The Influence of a Magnetic Field upon the Spark Spectra of Iron and Titanium; Papers of the Mt. Wilson Solar Observatory, Vol. II., Part I.

components, though van Bilderbeek-van Meurs[1] and Graftdijk[2] found this to be triple even in a field as strong as 32040 gauss.

TABLE II.[3]

$\lambda = 4415{\cdot}13$, $3p$-and $4n$-comps. or more.

H	$\frac{\Delta\lambda}{\lambda^2}\times 10^3$	$\frac{\Delta\lambda}{\lambda^2 H}\times 10^4$	H	$\frac{\Delta\lambda}{\lambda^2}\times 10^3$	$\frac{\Delta\lambda}{\lambda^2 H}\times 10^4$
37230	n 4730 (outer) n 3780 (inner)	1·270 = 5 × 0·254 1·015 = 4 × 0·254	7690	754	0·980
	p 980	0·263	7580	807	1·064
35650	n 3660 (inner)	1·027 = 4 × 0·257	6880	725	1·053
	p 928	0·261	6850	764	1·115
20100	2280	1·134	6820	716	1·050
18690	2104	1·126	„	715	1·049
18070	2072	1·147	6770	693	1·023
10980	1251	1·140	6750	700	1·037
10510	1155	1·099	6670	715	1·071
10200	1039	1·019	6500	649	0·998
9130	979	1·071	6450	678	1·051
9060	964	1·064	6300	664	1·054
8830	884	1·001	5910	666	1·128
8800	878	0·998	5670	592	1·044
8580	940	1·095	5590	572	1·023
8410	935	1·111	5260	552	1·050
8350	870	1·042	5000	556	1·112
8230	873	1·061	4730	484	1·022
8180	855	1·045	4650	502	1·080
7810	810	1·038	1350	474	1·090
7740	792	1·023	4110	417	1·015

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1) Van Bilderbeek-van Meuss, Arch. Néerl., (2), **15** (1911). p. 353.

2) Graftdijk, Arch. Néerl., (3), **2** (1912) p. 192.

3) In this and the following tables the separation is for the pair of components symmetrically situated about the initial line. In the case of an ordinary triplet no remark with regard to polarization is given.

TABLE III.[1]

Comparison with former results.

	H	$\frac{\Delta\lambda}{\lambda^2 H} \times 10^4$
Takahashi	H<11000	1·056
van Bilderbeek-van Meurs	32040	1·06
Graftdijk	,,	1·095
King (7 comps. ?)	16000	1·084
Hartmann		1·048

In Table II. and Fig. 2 it can be seen that the specific separation measured as a triplet increases with the magnetic field, which may be attributed to the complicated separation.

λ **4404·75,** the middle line of the first group, is resolved into a sharp triplet. The separation of this line, being measured most accurately, is taken as the standard of the separation, so that neither table nor diagram of the separation is given for this line. But the linear relation between the separations of the principal lines in the following and the magnetic field—separation of 4404·75—shows that the separation of this line is exactly proportional to the magnetic field. According to Mr. Yamada, the separation of this line is given by

$$\frac{\Delta\lambda}{\lambda^2 H} = 1{\cdot}064 \times 10^{-4}.$$

As the absolute magnitude of the specific separation is not the chief object of the present research, I have calculated the magnetic field from the separation of this line by means of the above value for the specific separation, without any absolute determination of the magnetic field.

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[1] The magnetic fields applied by former investigators are not clear, as the separations of some lines, being measured at different fields, are reduced to correspond to their standard fields under the assumption that the separation is proportional to the magnetic field. But, as the difference between the standard and the observed fields may probably not be large, the standard fields are here quoted. As Hartmann's original paper is inaccessible, his result is taken from Lütig's paper in Ann. d. Physik, **38** (1912) p. 43; the magnetic field is therefore unknown.

The mean specific separation is here obtained from

$$\text{mean}\frac{\Delta\lambda}{\lambda^2 H} = \sum\frac{\Delta\lambda}{\lambda^2} \Big/ \sum H.$$

λ 4383·55, at the end of the first group toward the violet, is resolved into a sharp triplet. The result is given in Table IV. and Fig. 3.

Table IV.

λ=4383·55, triple.

H	$\frac{\Delta\lambda}{\lambda^2}\times 10^3$	$\frac{\Delta\lambda}{\lambda^2 H}\times 10^4$	H	$\frac{\Delta\lambda}{\lambda^2}\times 10^3$	$\frac{\Delta\lambda}{\lambda^2 H}\times 10^4$
37230	3982	1·070	9010	965	1·071
36330	3879	1·068	8590	919	1·069
35650	3830	1·074	8580	913	1·064
,,	3814	1·070	8520	900	1·055
34830	3696	1·061	8410	910	1·081
34490	3669	1·064	8350	895	1·071
25960	2781	1·071	8270	880	1·064
25350	2745	1·083	8260	884	1·070
25140	2688	1·069	8250	888	1·076
24870	2692	1·082	8180	875	1·069
24350	2639	1·084	8040	867	1·079
24040	2580	1·073	7830	827	1·056
23840	2560	1·074	7810	838	1·073
23600	2541	1·077	7740	815	1·052
23160	2498	1·079	7690	830	1·079
22660	2451	1·082	7580	849	1·120
22090	2355	1·066	7170	795	1·109
21940	2366	1·079	7150	774	1·081
21360	2303	1·078	6850	730	1·066
20880	2246	1·075	6820	729	1·069
20760	2229	1·074	6770	754	1·114
20550	2208	1·074	6700	710	1·060
19860	2147	1·081	,,	704	1·051
19510	2134	1·094	6670	716	1·074
18860	2032	1·077	6560	702	1·071
18800	2019	1·074	6470	675	1·043
18690	2030	1·086	6300	674	1·070
18540	1990	1·073	5910	623	1·054
18070	1960	1·085	5890	637	1·081
11050	1170	1·059	5670	601	1·060
10640	1143	1·075	5330	575	1·078
10600	1143	1·079	5250	562	1·070
10580	1127	1·065	5000	562	1·124
10330	1130	1·093	4730	480	1·014
10180	1108	1·089	4650	515	1·108
9730	1046	1·075	4590	493	1·074
9620	1005	1·045	4520	492	1·088
9590	1011	1·055	4350	507	1·165
9420	992	1·053	4020	467	1·161
9130	978	1·071	3900	463	1·187

TABLE V.

Comparison with former results.

	H	$\frac{\Delta\lambda}{\lambda^2 H} \times 10^4$
Takahashi	mean	1·075
van Bilderbeek-van Meurs	32040	1·110
Graftdijk	,,	1·095
King	16000	1·078
Hartmann		0·998

It can be observed that the specific separation is a little larger at about 25000 gauss and a little smaller in the strongest fields than the mean value, but the discrepancy is within the limits of experimental errors, and we may consider the separation of this line to be exactly proportional to the magnetic field within the range between 3900 and 37230 gauss.

λ **4325·78,** at the end of the second group toward the red, appears as a sharp triplet in weak fields and becomes diffuse with the increase of field. Though the broadening of the n-components is not so remarkable, the p-component becomes so broad in strong fields that we may expect some fine resolution of this component. This resolution was not actually observed, but the distance between the two successive apparent maxima, when the echelon grating was adjusted in its double order position for this component, was much shortened and the decrement in the field of 36330 gauss was nearly $\frac{1}{4}\delta\lambda_{max}$ corresponding to the separation of 0·068 Å.U.; moreover this component was almost resolved in a field of 37230 gauss. Judged from appearance, this line seems to be split into a quintuplet (or septuplet) with $3p$-and 2 (or 4) n-components. The result obtained with this line is given in Table VI. and Fig. 4.

TABLE VI.

$\lambda = 4325{\cdot}78$, 3*p*-, 2*n*-comps. ?

H	$\frac{\Delta\lambda}{\lambda^2}\times 10^3$	$\frac{\Delta\lambda}{\lambda^2 H}\times 10^4$	H	$\frac{\Delta\lambda}{\lambda^2}\times 10^3$	$\frac{\Delta\lambda}{\lambda^2 H}\times 10^4$
37230	3500	0·940	8750	806	0·921
36330	3384	0·931	8580	746	0·870
34830	3230	0·927	8410	706	0·840
34490	3279	0·951	8350	749	0·896
33440	3142	0·940	8270	708	0·856
25960	2330	0·898	8260	706	0·855
24870	2232	0·897	8250	690	0·836
24040	2130	0·886	8180	684	0·836
11120	990	0·890	8040	720	0·895
11050	970	0·877	7810	675	0·865
10980	962	0·876	7740	707	0·914
10660	944	0·885	7710	651	0·845
10640	944	0·887	7170	594	0·828
10630	942	0·886	6850	616	0·899
10600	956	0·902	6810	578	0·849
10580	924	0·873	6800	573	0·842
10510	899	0·855	6770	616	0·910
10330	922	0·892	6750	583	0·864
10200	836	0·820	6700	580	0·866
10180	876	0·860	,,	571	0·852
9900	881	0·890	6300	542	0·860
9760	863	0·884	5910	530	0·897
9620	812	0·844	5890	486	0·825
9610	812	0·845	5670	488	0·861
9590	828	0·863	5260	457	0·869
9420	754	0·800	5230	445	0·850
9280	765	0·824	4650	398	0·855
9250	781	0·844	4610	378	0·820
9130	810	0·887	4590	389	0·846
9010	746	0·828	4520	349	0·772
8830	787	0·891	4020	386	0·960
8800	778	0·884	3900	304	0·779

TABLE VII.

Comparison with former results.

	H	$\frac{\Delta\lambda}{\lambda^2 H}\times 10^4$
Takahashi	H>11120	0·865
van Bilderbeek-van Meurs	32040	0·873
Graftdijk	,,	0·874
King	16000	0·817
Hartmann		0·862

As may be seen in the above table and in Fig. 4, the separation is proportional to the magnetic field below 11000 gauss, showing good agreement with Hartmann's result. Though King gives a considerably smaller value of the specific separation, the result of van Bilderbeek-van Meurs, of Graftdijk and of the writer show that the specific separation is larger in the stronger field. The separation of the n-components in the strongest field obtained by the writer is equal to that of the normal triplet, though the measurement is not accurate. The character of this line somewhat resembles that of 4415·13.

λ 4307·92, middle line of the second group, is resolved into a sharp triplet.

TABLE VIII.

$\lambda=4307{\cdot}92$, triple.

H	$\frac{\Delta\lambda}{\lambda^2}\times 10^3$	$\frac{\Delta\lambda}{\lambda^2 H}\times 10^4$	H	$\frac{\Delta\lambda}{\lambda^2}\times 10^3$	$\frac{\Delta\lambda}{\lambda^2 H}\times 10^4$
37230	3958	1·063	25350	2667	1·052
36330	3869	1·065	25140	2599	1·034
35650	3744	1·050	24870	2630	1·057
,,	3729	1·046	24350	2558	1·051
34830	3640	1·045	24040	2536	1·055
34490	3605	1·045	23840	2510	1·053
26230	2742	1·045	23600	2467	1·045
25960	2690	1·036	23160	2443	1·055

H	$\frac{\Delta\lambda}{\lambda^2}\times 10^3$	$\frac{\Delta\lambda}{\lambda^2 H}\times 10^4$	H	$\frac{\Delta\lambda}{\lambda^2}\times 10^3$	$\frac{\Delta\lambda}{\lambda^2 H}\times 10^4$
22660	2410	1·064	8250	859	1·041
22220	2340	1·053	8180	867	1·060
22090	2308	1·045	,,	866	1·059
21960	2304	1·049	8040	868	1·079
21940	2308	1·052	7830	844	1·077
21600	2261	1·047	7810	818	1·048
20880	2206	1·057	7740	818	1·056
20760	2173	1·047	7710	800	1·038
20550	2132	1·038	7690	839	1·090
19860	2109	1·062	7580	813	1·072
19640	2060	1·049	7300	760	1·041
19510	2061	1·056	7170	758	1·057
18860	2020	1·071	7150	774	1·082
18800	2017	1·073	6850	706	1·030
18690	1983	1·061	6820	697	1·022
18540	1981	1·069	6800	695	1·022
11120	1176	1·058	6770	732	1·081
11050	1161	1·051	6750	723	1·071
10640	1137	1·069	6700	709	1·058
10600	1094	1·032	,,	706	1·054
10580	1130	1·068	6670	700	1·050
10510	1114	1·060	6650	728	1·094
10330	1111	1·075	6560	670	1·021
10200	1088	1·066	6300	667	1·059
10180	1083	1·064	,,	655	1·040
9730	1019	1·047	5910	622	1·052
9620	1001	1·042	5890	620	1·052
9590	988	1·030	5670	592	1·044
9420	982	1·042	5590	584	1·044
9130	956	1·047	5260	565	1·075
9010	965	1·070	5230	558	1·067
8830	907	1·027	5000	561	1·122
8800	924	1·050	4790	536	1·119
8590	897	1·044	4730	477	1·007
8580	876	1·021	4650	492	1·058
8490	912	1·074	4610	469	1·018
8480	871	1·027	4590	485	1·055
8410	876	1·042	4520	470	1·040
8350	896	1·073	4350	447	1·028
8270	866	1·047	4020	442	1·099
8260	880	1·065	3900	452	1·159

TABLE IX.

Comparison with former results.

	H	$\frac{\Delta\lambda}{\lambda^2 H}\times 10^4$
Takahashi	mean	1·054
van Bilderbeek-van Meurs	32040	1·080
Graftdijk	,,	1·081
King	16000	1·078
Hartmann		1·012

Table VIII. and Fig. 5 show that the separation is proportional to the magnetic field.

λ **4271·75,** at the end of the second group toward the violet, is resolved into a sharp triplet, the specific separation being the largest of the nine lines.

TABLE X.

λ=4271·75, triple.

H	$\frac{\Delta\lambda}{\lambda^2}\times 10^3$	$\frac{\Delta\lambda}{\lambda^2 H}\times 10^4$	H	$\frac{\Delta\lambda}{\lambda^2}\times 10^3$	$\frac{\Delta\lambda}{\lambda^2 H}\times 10^4$
35650	4173	1·171	19640	2268	1·155
34830	4065	1·167	19510	2252	1·154
34490	4030	1·168	18860	2188	1·160
34110	3973	1·165	18800	2160	1·149
33440	3910	1·169	18660	2192	1·175
32800	3838	1·170	18540	2200	1·187
22660	2668	1·177	18070	2080	1·151
22090	2593	1·174	18000	2076	1·153
21940	2602	1·186	17420	2049	1·176
21360	2480	1·161	17340	1994	1·150
20880	2418	1·158	16910	1980	1·171
20760	2396	1·154	10640	1239	1·164
20550	2316	1·127	10630	1233	1·160
19860	2315	1·166	10600	1249	1·178

H	$\frac{\Delta\lambda}{\lambda^2}\times 10^3$	$\frac{\Delta\lambda}{\lambda^2 H}\times 10^4$	H	$\frac{\Delta\lambda}{\lambda^2}\times 10^3$	$\frac{\Delta\lambda}{\lambda^2 H}\times 10^4$
10200	1190	1·167	6770	804	1·188
9730	1130	1·161	6750	806	1·193
9590	1112	1·160	6700	754	1·125
9420	1088	1·155	6670	774	1·160
9130	1070	1·171	6560	739	1·126
9010	1042	1·157	6470	760	1·175
8800	1046	1·189	6300	729	1·157
8590	966	1·124	,,	722	1·146
8580	989	1·151	5910	699	1·182
8520	1001	1·175	5890	678	1·151
8490	1000	1·178	5670	652	1·151
8350	962	1·151	5590	651	1·164
8270	985	1·190	5230	614	1·173
8260	959	1·161	5000	610	1·219
8250	961	1·165	4790	582	1·214
8180	967	1·181	4730	546	1·154
8040	970	1·206	4650	548	1·179
7810	899	1·151	4610	540	1·171
7300	825	1·130	4590	530	1·154
7170	832	1·160	4520	489	1·082
6850	793	1·157	4350	539	1·239
6820	786	1·152	4020	468	1·165
6800	764	1·123	3900	469	1·202

TABLE XI.

Comparison with former results

	H	$\frac{\Delta\lambda}{\lambda^2 H}\times 10^4$
Takahashi	mean	1·164
van Bilderbeck-van Meurs	32040	1·193
King	16000	1·168
Hartmann		1·088

Table X. and Fig. 6 show that the separation is proportional to the magnetic field.

λ 4071·75, end line of the third group toward the red, is resolved into a sharp triplet, the specific separation being the smallest of the nine lines.

Table XII.

λ=4071·75, triple.

H	$\frac{\Delta\lambda}{\lambda^2}\times 10^3$	$\frac{\Delta\lambda}{\lambda^2 H}\times 10^3$	H	$\frac{\Delta\lambda}{\lambda^2}\times 10^3$	$\frac{\Delta\lambda}{\lambda^2 H}\times 10^4$
37230	2288	0·615	10580	666	0·629
34890	2156	0·618	10330	648	0·327
34110	2120	0·622	9420	587	0·323
18860	1185	0·628	,,	584	0·620
18000	1142	0·634	8260	521	0·631
17420	1072	0·615	8040	500	0·621
17340	1086	0·626	7160	468	0·654
16910	1061	0·627	6820	430	0·631
15120	935	0·618	,,	424	0·622
14770	909	0·615	6700	430	0·642

Table XIII.

Comparison with former results.

	H	$\frac{\Delta\lambda}{\lambda^2 . I}\times 10^4$
Takahashi	mean	0·623
van Bilderbeek-van Meurs	32040	0·645
King	16000	0·641

In Table XII. and Fig. 7 some systematic deviation of the specific separation may be observed, but it lies within the errors of experiment, and the separation may be considered proportional to the magnetic field.

λ 4063 61, middle line of the third group, is resolved into a sharp triplet, and the separation is proportional to the magnetic field as may be seen in Table XIV. and Fig 8.

TABLE XIV.

$\lambda=4063{\cdot}61$. triple.

H	$\frac{\Delta\lambda}{\lambda^2}\times 10^5$	$\frac{\Delta\lambda}{\lambda^2 H}\times 10^4$	H	$\frac{\Delta\lambda}{\lambda^2}\times 10^5$	$\frac{\Delta\lambda}{\lambda^2 H}\times 10^4$
37230	3796	1·020	10640	1118	1·051
34890	3538	1·014	10630	1090	1·025
26230	2659	1·014	10600	1098	1·035
25960	2588	0·997	10330	1046	1·013
25350	2540	1·002	9420	945	1·003
25140	2504	0·996	,,	944	1·002
24870	2520	1·013	8590	907	1·056
24350	2467	1·013	8260	849	1·028
24040	2480	1·032	,,	840	1·017
23840	2400	1·007	8250	825	1·000
23600	2380	1·008	8180	845	1·032
23160	2340	1·010	8040	821	1·021
22660	2340	1·033	7300	763	1·045
22220	2286	1·029	7170	762	1·063
22090	2256	1·021	6820	685	1·004
21960	2276	1·036	,,	678	0·994
21940	2244	1·023	6700	699	1·043
21600	2152	0·996	,,	698	1·042
21360	2148	1·006	6300	640	1·015
20880	2101	1·006	5890	589	1·000
20550	2084	1·014	5670	545	0·961
20100	2048	1·019	5590	576	1·030
19860	1990	1·002	5230	535	1·022
19660	1986	1·010	4590	436	0·949
18800	1950	1·037	4520	423	0·936
18540	1916	1·033	3900	437	1·120

TABLE XV.

Comparison with former results.

	H	$\frac{\Delta\lambda}{\lambda^2 H}\times 10^4$
Takahashi	mean	1·016
van Bilderbeek-van Meurs	32040	1·037
King	16000	1·017

λ 4045·82, end line of the third group toward the violet, is resolved into a sharp triplet, the separation being proportional to the magnetic field as may be seen in Table XVI. and Fig. 9.

TABLE XVI.

λ=4045·82, triple.

H	$\frac{\Delta\lambda}{\lambda^2}\times10^3$	$\frac{\Delta\lambda}{\lambda^2 H}\times10^4$	H	$\frac{\Delta\lambda}{\lambda^2}\times10^3$	$\frac{\Delta\lambda}{\lambda^2 H}\times10^4$
34890	4015	1·151	8590	968	1·127
34110	3912	1·147	8260	947	1·147
33440	3900	1·166	,,	929	1·124
32800	3770	1·149	8250	985	1·193
22090	2580	1·168	8180	929	1·135
21360	2500	1·170	8040	950	1·181
20880	2415	1·157	7300	838	1·148
20550	2339	1·138	7170	891	1·242
20100	2316	1·152	6820	767	1·125
19860	2359	1·188	,,	766	1·124
19640	2299	1·171	6700	771	1·151
18800	2174	1·156	6300	719	1·141
18660	2179	1·168	5890	675	1·145
18540	2138	1·153	5670	636	1·122
18000	2052	1·140	5590	654	1·170
17420	2022	1·161	5230	612	1·170
17340	2008	1·158	4590	492	1·071
16910	1975	1·168	4520	481	1·064
10640	1228	1·154	3900	486	1·246
9420	1088	1·154			

TABLE XVII.

Comparison with former results.

	H	$\frac{\Delta\lambda}{\lambda^2 \Delta}\times10^4$
Takahashi	mean	1·156
van Bilderbeek-van Meurs	32040	1·196
King	16000	1·138

II. Other less Strong Lines.

λ **5615·661** is separated into a sharp triplet.

TABLE XVIII.

λ=5615·661, triple.

H	$\frac{\Delta\lambda}{\lambda^2}\times10^3$	$\frac{\Delta\lambda}{\lambda^2 H}\times10^4$	H	$\frac{\Delta\lambda}{\lambda^2}\times10^3$	$\frac{\Delta\lambda}{\lambda^2 H}\times10^4$
8350	944	1·130	6300	721	1·144
8230	904	1·098	4730	534	1·128
7560	849	1·123	4240	478	1·127
6880	753	1·094			

TABLE XIX.

Comparison with former results.

	H	$\frac{\Delta\lambda}{\lambda^2 H}\times10^4$
Takahashi	mean	1·120
Graftdijk	32040	1·170
King	16000	1·161
Hartmann		1·052

King's value of the specific separation is a little larger than the writer's, Graftdijk's being still larger; the discrepancy may be due to the difference of the magnetic field applied. If so, the curve in Fig. 10 must turn upwards, but, so far as my experiment goes, the separation is proportional to the magnetic field as shown in Table XVIII and Fig. 10. The above discrepancy is probably due to experimental errors.

λ **5586·772** appears as a diffuse triplet.

Table XX.

$\lambda=5586{\cdot}772$, triple.

H	$\frac{\Delta\lambda}{\lambda^2}\times10^3$	$\frac{\Delta\lambda}{\lambda^2 H}\times10^4$
8230	862	1·047
6300	677	1·074
4240	465	1·096

Table XXI.

Comparison with former results.

	H	$\frac{\Delta\lambda}{\lambda^2 H}\times10^4$
Takahashi	mean	1·068
Graftdijk	32040	1·19
King (7 comps. ?)	16000	1·021
Hartmann		0·901

As may be seen in Table XX., XXI. and Fig. 11, my points lie with King's on a straight line, which intersects the line of separation slightly above the origin, but the deviation is too small to assume that this is not due to experimental errors. Graftdijk gives a much larger specific separation.

λ **5572·86** appears as a diffuse triplet.

Table XXII.

$\lambda=5572{\cdot}86$, triple ?

H	$\frac{\Delta\lambda}{\lambda^2}\times10^3$	$\frac{\Delta\lambda}{\lambda^2 H}\times10^4$
8350	588	0·704
7560	541	0·716
4730	382	0·807

TABLE XXIII.

Comparison with former results.

	H	$\frac{\Delta\lambda}{\lambda^2 H}\times 10^4$
Takahashi	mean	0·732
King (7 comps. ?)	16000	0·945

The points by the writer lie on a straight line as may be seen in Fig. 12, King's value of the separation being much larger.

λ **5455·614** is separated into $2p$- and $3n$-components.

TABLE XXIV.[1]

$\lambda=5455·614$, $2p$-, $3n$-comps.

H	$\frac{\Delta\lambda}{\lambda^2}\times 10^3$		$\frac{\Delta\lambda}{\lambda^2 H}\times 10^4$	
	n	p	n	p
9690	1608		1·659	
8350	1148	1145	1·374	1·371
8230	1160	1170	1·409	1·421
6880	910	932	1·322	1·355
6300	884	853	1·402	1·353
4730	724	638	1·530	1·350
4450	712	619	1·600	1·391
4240		584		1·377

TABLE XXV.

Comparison with former results.

	H	$\frac{\Delta\lambda}{\lambda^2 H}\times 10^4$	
		n	p
Takahashi	mean	1·469	1·376
King	16000	1·452	1·429

---

[1] The separation of the outer pair is given for the n-components.

In Table XXIV. and Fig. 13 it may be observed that the separation of the p-components is proportional to the magnetic field, though that by King is a little larger. One half of the separation of the outer n-components—the separation between the undisturbed and one of the displaced components—is given in Fig. 14 to prevent confusion, which shows that the separation curve is concave upward between 5000 and 9000 gauss, but, if we take King's point into consideration, it must go down again, showing a wavy form.

λ 5446·92 appears as a quadruplet in weak fields. The n-components become very diffuse when the magnetic field is increased, which may be considered as the result of complex separation as observed by King. King gives 4 p-components in his table, but only two sharp p-components are observed on my plates, the specific separation being a little smaller between 5500 and 8000 gauss and a little larger above 10000 gauss than King's for the outer pair, as may be seen in Table XXVI. and Fig. 14.

TABLE XXVI.

λ=5446·92, 2p-, 2n-comps.

H	$\frac{\Delta\lambda}{\lambda^2}\times10^3$ p	$\frac{\Delta\lambda}{\lambda^2 H}\times10^4$ p	H	$\frac{\Delta\lambda}{\lambda^2}\times10^3$ p	$\frac{\Delta\lambda}{\lambda^2 H}\times10^4$ p
10760	1109	1·030	6400	545	0·851
10510	1072	1·020	„	531	0·830
9880	953	0·965	6300	561	0·890
„	928	0·939	5520	510	0·924
9690	941	0·971	„	484	0·877
9390	878	0·935	4940	446	0·901
„	870	0·926	4730	428	0·905
8860	778	0·878	4480	412	0·919
8350	773	0·926	4450	383	0·861
8230	775	0·941	„	n 567	n 1·274
7560	682	0·903	4240	391	0·921
6880	561	0·815	4110	374	0·910
6690	573	0·856	„	361	0·879

Table XXVII.

Comparison with former results.

	H	$\frac{\Delta\lambda}{\lambda^2 H}\times 10^4$	
		n	p
Takahashi	mean	1·274	0·921
King (8n-, 4p-comps.)	16000	1·841 1·480 1·004 0·461	0·942 0·476

λ **5429·70** appears as a quadruplet in weak fields.

Table XXVIII.

$\lambda = 5429{\cdot}70$, 2p-, 2n-comps.

H	$\frac{\Delta\lambda}{\lambda^2}\times 10^3$		$\frac{\Delta\lambda}{\lambda^2 H}\times 10^4$	
	n	p	n	p
11630		850		0·731
10760		803		0·746
10510		789		0·750
9690		727		0·750
9390		591		0·629
8860		558		0·630
8350		508		0·608
8230		520		0·631
7560		501		0·663
6880	774	429	1·125	0·624
6670		449		0·674
6400		425		0·664
6300		414		0·657
4940	520		1·052	
4730	515		1·089	
4480	560	301	1·249	0·671

TABLE XXIX.

Comparison with former results.

	H	$\frac{\Delta\lambda}{\lambda^2 H}\times 10^4$	
		s	p
Takahashi	$H<9500$ $H>9500$	1·126	0·744 0·645
Graftdijk	32040	1·54	0·0
King (6 or 8 n-, 4 p-comps.?)	16000	1·286	0·636
Hartmann		0·981	0·0

The separation of the n-components was not measured accurately owing to the broadening, but the discrepancy among the above four results in Table XXIX seems to be too large, giving greater specific separation for the stronger field, to attribute it to an error of measurement. This may be due to the complicated resolution, though Graftdijk has not observed any further resolution with a field of 32040 gauss. The separation of the p-components increases suddenly at about 9500 gauss, for each side of this field the observed points in Fig. 15 lie on a separate line which does not pass through the origin.

λ 5397·12 appears as a quadruplet.

TABLE XXX.

$\lambda=5397{\cdot}12$, $2p$-, $2n$-comps.

H	$\frac{\Delta\lambda}{\lambda^2}\times 10^3$		$\frac{\Delta\lambda}{\lambda^2 H}\times 10^4$	
	n	p	n	p
11630		675		0·580
10760		588		0·546
10510		621		0·590
9880		478		0·484
8230	1120	451	1·360	0·548
6880	833		1·210	
4730	575		1·215	
4450	601		1·351	

TABLE XXXI.

Comparison with former results.

	H	$\frac{\Delta\lambda}{\lambda^2 H}\times 10^4$	
		n	p
Takahashi	mean	1·288	0·551
Graftdijk	32040	1·46	0·0
King (6 comps.?)	16000	1·352	0·476

The measurement is not quite accurate, but the separation of the n-components agrees with that of King. The p-components indicate a wavy fluctuation of the specific separation, though the data are too scanty for minute discussion.

λ **5371·495** is separated into a sharp triplet.

TABLE XXXII.

$\lambda=5371{\cdot}495$, triple.

H	$\frac{\Delta\lambda}{\lambda^2}\times 10^3$	$\frac{\Delta\lambda}{\lambda^2 H}\times 10^4$	H	$\frac{\Delta\lambda}{\lambda^2}\times 10^3$	$\frac{\Delta\lambda}{\lambda^2 H}\times 10^4$
9880	898	0·909	6500	555	0·854
9690	885	0·913	6400	581	0·908
9610	903	0·940	6300	575	0·912
9390	787	0·838	5520	501	0·908
9250	825	0·891	5490	496	0·903
8860	723	0·816	5080	435	0·856
8410	664	0·790	4940	396	0·801
8350	724	0·866	4730	392	0·829
8230	708	0·860	4650	350	0·753
7830	649	0·829	4480	372	0·830
7690	649	0·844	4450	426	0·957
7560	607	0·803	4240	362	0·853
6880	576	0·838	4110	365	0·889
6690	553	0·826	3580	282	0·788
6670	517	0·775	2480	222	0·895
6560	543	0·828			

TABLE XXXIII.

Comparison with former results.

	H	$\frac{\Delta\lambda}{\lambda^2 H}\times 10^4$
Takahashi	mean	0·855
Graftdijk (p-comp. prob. decomposed)	32040	0·80
King (9 comps. ?)	16000	0·890

Fig. 17 shows that the specific separation suddenly falls at about 7000 gauss.

λ **5328·06** appears as a sharp triplet.

TABLE XXXIV.

λ=5328·06, triple.

H	$\frac{\Delta\lambda}{\lambda^2}\times 10^3$	$\frac{\Delta\lambda}{\lambda^2 H}\times 10^4$	H	$\frac{\Delta\lambda}{\lambda^2}\times 10^3$	$\frac{\Delta\lambda}{\lambda^2 H}\times 10^4$
9880	1093	1·106	6670	645	0·967
9830	1060	1·079	6650	700	1·052
9690	1009	1·040	6560	687	1·048
9610	994	1·034	6500	659	1·013
9390	990	1·054	6450	646	1·001
9280	1022	1·101	6400	698	1·091
9250	989	1·069	6300	735	1·166
9060	876	0·968	5520	576	1·043
8860	904	1·021	5490	580	1·056
8790	994	1·130	5060	496	0·980
8480	936	1·103	4940	490	0·991
8410	869	1·033	4790	511	1·065
8350	910	1·090	4730	521	1·101
8230	863	1·048	4480	496	1·105
7830	820	1·046	4450	513	1·153
7690	811	1·055	4240	428	1·010
7670	840	1·095	4110	460	1·120
7560	805	1·065	3920	415	1·059
7150	752	1·051	3580	352	0·983
6880	677	0·984	2950	280	0·949
6690	722	1·079	2480	282	1·137

TABLE XXXV.

Comparison with former results.

	H	$\frac{\Delta\lambda}{\lambda^2 H}\times 10^4$
Takahashi	mean	1·057
Graftdijk (p-comp. prob. decomposed)	32040	1·03
King (9 comps. ?)	16000	1·034

The separation is proportional to the magnetic field as may be seen in Fig. 18.

λ **5269·53** is separated into a sharp triplet.

TABLE XXXVI.

$\lambda=5269{\cdot}53$, triple.

H	$\frac{\Delta\lambda}{\lambda^2}\times 10^3$	$\frac{\Delta\lambda}{\lambda^2 H}\times 10^4$	H	$\frac{\Delta\lambda}{\lambda^2}\times 10^3$	$\frac{\Delta\lambda}{\lambda^2 H}\times 10^4$
9880	1130	1·144	6670	677	1·015
,,	1125	1·139	6650	698	1·050
9830	1104	1·123	6540	781	1·194
9690	1093	1·128	6500	655	1·007
9610	1101	1·147	6450	706	1·095
,,	1040	1·082	6400	700	1·093
9390	1057	1·126	6300	726	1·152
9280	1060	1·142	5680	676	1·190
9250	1033	1·117	5520	584	1·058
8860	980	1·106	5490	615	1·119
8790	991	1·128	5060	535	1·058
8490	915	1·077	4960	545	1·099
8480	906	1·069	4790	517	1·079
8410	916	1·089	4730	544	1·150
,,	915	1·088	4650	447	0·961
8350	939	1·124	4480	505	1·127
8230	910	1·105	4450	514	1·155
7830	829	1·058	4240	458	1·080
7690	837	1·088	4110	475	1·156
7670	826	1·077	3920	453	1·155
7560	786	1·040	3580	388	1·084
7150	746	1·043	2950	342	1·159
6880	708	1·029	2480	316	1·274
6690	700	1·045			

TABLE XXXVII.

Comparison with former results.

	H	$\frac{\Delta\lambda}{\lambda^2 H} \times 10^4$
Takahashi	mean	1·101
Graftdijk (p-comp. prob. decomposed)	32040	1·166
King	16000	1·128

It may be observed in Table XXXVI. and Fig. 19 that the specific separation suddenly falls at about 6500 gauss, which may be the result of the superposition of the faint component of λ 5270·35 on the measured one. This line appears in the natural state as if it were the satellite of the line in question, and, in a magnetic field, one of the n-components is masked by a component of the line in question and the other n-component, which is expected to appear, is not found, though the p-component is clearly observed. These n-components seem to be very faint in a weak field, but one of them can be observed in my photograms taken with sufficiently long exposure applying a field near 10000 gauss. If we assume the result of King, the separation of this line is nearly one half that of 5269·53, and the red component of the former just overlaps with the violet component of the latter at 4800 gauss, so that the separation of the latter must appear too large below the field and too small above it. The first appearance of the fall at 6500 gauss seems to be too late to be considered merely as the effect of the superposed line, and it comes too suddenly compared with the slow recovery in the stronger field, the reverse being expected in the above case. It seems necessary to study with an instrument of different constants to decide the behavior of the line 5269·53.

λ **5232·957** appears as a triplet.

TABLE XXXVIII.

$\lambda = 5232{\cdot}957$, triple.

H	$\frac{\Delta\lambda}{\lambda^2}\times 10^3$	$\frac{\Delta\lambda}{\lambda^2 H}\times 10^4$	H	$\frac{\Delta\lambda}{\lambda^2}\times 10^3$	$\frac{\Delta\lambda}{\lambda^2 H}\times 10^4$
8350	1046	1·252	6300	758	1·203
8230	985	1·196	4730	528	1·116
7560	859	1·136	4450	539	1·211

TABLE XXXIX.

Comparison with former results.

	H	$\frac{\Delta\lambda}{\lambda^2 H}\times 10^4$
Takahashi	mean	1·190
Graftdijk	32040	1·24
King (7 comps. ?)	16000	1·158
Hartmann		1·106

Though the measurement is not accurate, it may be seen that the separation is approximately proportional to the field.

λ **5227·20** appears as a triplet.

TABLE XL.

$\lambda = 5227{\cdot}20$, triple.

H	$\frac{\Delta\lambda}{\lambda^2}\times 10^3$	$\frac{\Delta\lambda}{\lambda^2 H}\times 10^4$	H	$\frac{\Delta\lambda}{\lambda^2}\times 10^3$	$\frac{\Delta\lambda}{\lambda^2 H}\times 10^4$
10760	1117	1·038	6880	591	0·859
10510	1149	1·092	6690	595	0·889
9880	962	0·974	6400	576	0·900
,,	945	0·956	6300	621	0·986
9690	959	0·990	5520	562	1·019
9390	868	0·924	4940	465	0·941
9250	826	0·893	4730	470	0·993
9060	765	0·845	4480	394	0·879
8860	772	0·871	4450	425	0·955
8350	765	0·916	4240	368	0·867
8230	761	0·925	4110	398	0·969
7560	752	0·995			

TABLE XLI.

Comparison with former results.

	H	$\frac{\Delta\lambda}{\lambda^2 H}\times 10^4$
Takahashi	mean	0·947
Graftdijk (p-comp. decomposed)	32040	1·01
King	16000	0·946
Hartmann		1·202

As may be seen in Fig. 21, the separation curve is concave upward between 8000 and 10000 gauss. Though King's result coincides with the mean value of the writer, Graftdijk and Hartmann give larger values.

λ **5167·492** appears as a triplet.

TABLE XLII.

$\lambda=5167{\cdot}492$, triple.

H	$\frac{\Delta\lambda}{\lambda^2}\times 10^3$	$\frac{\Delta\lambda}{\lambda^2 H}\times 10^4$	H	$\frac{\Delta\lambda}{\lambda^2}\times 10^3$	$\frac{\Delta\lambda}{\lambda^2 H}\times 10^4$
10760	1119	1·040	6650	725	1·090
9880	1042	1·055	6450	725	1·124
,,	997	1·009	6400	675	1·054
9610	1006	1·047	6300	701	1·112
9390	940	1·000	4940	504	1·020
9060	906	1·000	4730	509	1·076
8350	849	1·016	4480	480	1·070
8230	869	1·055	4450	531	1·192
7560	767	1·015	4240	457	1·077
6880	689	1·001	4110	457	1·112

TABLE XLIII.

Comparison with former results.

	H	$\frac{\Delta\lambda}{\lambda^2 H}\times 10^4$
Takahashi	mean	1·050
Graftdijk (p-comp. prob. decomposed)	32040	1·027
King	16000	1·081

It will be observed that the specific separation slightly falls at 7000 gauss, the points on each side of this field lie on a different line passing through the origin, but the amount of the fall is not distinct enough to show it.

λ **5018·45** appears as a triplet.

TABLE XLIV.

$\lambda=5018{\cdot}45$, triple.

H	$\frac{\Delta\lambda}{\lambda^2}\times10^3$	$\frac{\Delta\lambda}{\lambda^2 H}\times10^4$	H	$\frac{\Delta\lambda}{\lambda^2}\times10^3$	$\frac{\Delta\lambda}{\lambda^2 H}\times10^4$
6300	1148	1·822	4240	732	1·725
4730	803	1·696	4110	684	1·664
4450	741	1·665			

TABLE XLV.

Comparison with former results.

	H	$\frac{\Delta\lambda}{\lambda^2 H}\times10^4$
Takahashi	mean	1·724
Graftdijk	32040	1·833
King (4 comps. ?)	16000	1·840

It may be seen in Fig. 23 that the points obtained by the writer lie on a straight line which does not pass through the origin, and the point corresponding to the strongest field lies on the straight line connecting those given by King and Graftdijk with the origin. We may consider that the separation is proportional to the magnetic field above 6000 gauss and curves downwards in the vicinity.

λ **4957·62** is resolved into a triplet.

TABLE XLVI.

$\lambda = 4957{\cdot}62$, triple.

H	$\frac{\Delta\lambda}{\lambda^2} \times 10^3$	$\frac{\Delta\lambda}{\lambda^2 H} \times 10^4$	H	$\frac{\Delta\lambda}{\lambda^2} \times 10^3$	$\frac{\Delta\lambda}{\lambda^2 H} \times 10^4$
9880	1071	1·085	6690	773	1·155
9610	1027	1·069	6670	734	1·100
9390	1022	1·089	6650	714	1·073
9280	975	1·050	6500	677	1·041
9250	999	1·080	6450	669	1·037
9060	930	1·027	6400	727	1·135
8860	924	1·042	6300	716	1·137
8410	893	1·061	5520	645	1·169
8350	924	1·106	5490	610	1·110
8230	943	1·145	5060	514	1·015
7830	878	1·121	4730	526	1·111
7670	862	1·124	4550	456	1·001
7560	827	1·094	4480	490	1·091
6880	765	1·111	4450	506	1·138
6750	757	1·121	4240	481	1·133

TABLE XLVII.

Comparison with former results.

	H	$\frac{\Delta\lambda}{\lambda^2 H} \times 10^4$
Takahashi	mean	1·091
Graftdijk	32040	1·144
King	16000	1·441
Hartmann		1·112

The apparent separation may be affected by the neighbouring line 4957·31, but the results of Graftdijk and Hartmann agree with the mean value here obtained, though King gives a much larger separation.

λ **4920·52** appears as a triplet.

TABLE XLVIII.

$\lambda = 4920{\cdot}52$, triple.

H	$\frac{\Delta\lambda}{\lambda^2} \times 10^3$	$\frac{\Delta\lambda}{\lambda^2 H} \times 40^4$	H	$\frac{\Delta\lambda}{\lambda^2} \times 10^3$	$\frac{\Delta\lambda}{\lambda^2 H} \times 10^4$
9880	1148	1·161	6670	667	1·000
9390	1019	1·084	6540	679	1·038
9060	910	1·004	6400	671	1·049
8860	913	1·031	6300	674	1·070
8410	882	1·049	5680	587	1·032
8350	889	1·064	5490	581	1·058
8230	930	1·129	4550	428	0·942
7690	787	1·023	4450	463	1·041
7560	749	0·991	4240	437	1·030
6750	672	0·995			

TABLE XLIX.

Comparison with former results.

	H	$\frac{\Delta\lambda}{\lambda^2 H} \times 10^4$
Takahashi	mean	1·047
Graftdijk	32040	1·065
King (prob. complex)	16000	1·154

The apparent separation may be affected by λ 4919·007, though the mean value here obtained agrees with Graftdijk's result. If we accept King's result, the specific separation in a field stronger than 9000 gauss is greater than that in a weaker field.

λ **4891·51** appears as a triplet.

TABLE L.

$\lambda=4891{\cdot}51$, triple.

H	$\frac{\Delta\lambda}{\lambda^2}\times 10^3$	$\frac{\Delta\lambda}{\lambda^2 H}\times 10^4$	H	$\frac{\Delta\lambda}{\lambda^2}\times 10^3$	$\frac{\Delta\lambda}{\lambda^2 H}\times 10^4$
9880	877	0·888	6690	582	0·870
9390	892	0·950	6670	618	0·926
9280	821	0·884	6400	618	0·966
8860	808	0·911	6300	568	0·902
8410	780	0·927	5520	540	0·978
8350	783	0·937	4240	392	0·924
8230	771	0·936	4110	392	0·954
7690	740	0·962			

TABLE LI.

Comparison with former results.

	H	$\frac{\Delta\lambda}{\lambda^2 H}\times 10^4$
Takahashi	mean	0·925
Graftdijk	32040	1·06
King	16000	1·012

The apparent separation may be affected by the neighbouring line 4891·78.

λ **4583·83** is separated into a triplet.

TABLE LII.

$\lambda=4583{\cdot}83$, triple.

H	$\frac{\Delta\lambda}{\lambda^2}\times 10^3$	$\frac{\Delta\lambda}{\lambda^2 H}\times 10^4$	H	$\frac{\Delta\lambda}{\lambda^2}\times 10^3$	$\frac{\Delta\lambda}{\lambda^2 H}\times 10^4$
8230	954	1·159	6450	716	1·110
6880	751	1·091	4450	523	1·175
6820	725	1·063			

TABLE LIII.

Comparison with former results.

	H	$\frac{\Delta\lambda}{\lambda^2 H}\times 10^4$
Takahashi	mean	1·118
Graftdijk	32040	1·168
King	16000	1·118

The separation is approximately proportional to the magnetic field.

λ **4528·622** appears as a triplet.

TABLE LIV.

$\lambda = 4528{\cdot}622$, triple.

H	$\frac{\Delta\lambda}{\lambda^2}\times 10^3$	$\frac{\Delta\lambda}{\lambda^2 H}\times 10^4$
9280	994	1·070
9060	924	1·020
8860	974	1·099
8410	915	1·087
8350	902	1·080
8230	916	1·113
8180	880	1·075
7690	857	1·115
6880	765	1·111
6820	773	1·134
6750	813	1·204
6670	715	1·072
6540	742	1·135
6450	733	1·136
6400	747	1·167
6300	761	1·208
5590	683	1·221
5520	643	1·164
4730	568	1·200
4650	580	1·247
4480	510	1·138
4450	533	1·198
4240	499	1·176
4110	458	1·115

TABLE LV.

Comparison with former results.

	H	$\frac{\Delta\lambda}{\lambda^2 H}\times 10^4$
Takahashi	mean	1·127
van Bilderbeck-van Meurs	32040	1·16
Graftdijk	,,	1·213
King (7 comps. ?)	16000	1·090

Fig. 28 shows that the separation curve is convex upward between 4000 and 8000 gauss. If we accept the results of van Bilderbeek-van Meurs and Graftdijk, it must turn upwards at a still stronger field showing a wavy form.

λ **4494·572** appears as a triplet.

Table LVI.

λ=4494·572, triple.

H	$\frac{\Delta\lambda}{\lambda^2}\times 10^3$	$\frac{\Delta\lambda}{\lambda^2 H}\times 10^4$	H	$\frac{\Delta\lambda}{\lambda^2}\times 10^3$	$\frac{\Delta\lambda}{\lambda^2 H}\times 10^4$
9880	980	0·991	6450	663	1·028
9060	816	0·901	6300	725	1·150
8230	805	0·978	4730	545	1·151
8180	811	0·991	4650	546	1·175
7690	785	1·020	4450	466	1·047
6880	682	0·991	4240	466	1·099
6750	695	1·030	4110	430	1·047
6540	714	1·091			

Table LVII.

Comparison with former results.

	H	$\frac{\Delta\lambda}{\lambda^2 H}\times 10^4$
Takahashi	mean	1·032
Graftdijk	32040	1·28
King (7 comps. ?)	16000	0·935

The separation curve of this line quite resembles that of λ 4528·63.

λ **4476·03** appears as a triplet.

TABLE LVIII.

$\lambda=4476{\cdot}03$, triple.

H	$\frac{\Delta\lambda}{\lambda^2}\times 10^3$	$\frac{\Delta\lambda}{\lambda^2 H}\times 10^4$	H	$\frac{\Delta\lambda}{\lambda^2}\times 10^3$	$\frac{\Delta\lambda}{\lambda^2 H}\times 10^4$
9880	891	0·902	6540	640	0·979
8230	818	0·994	6450	661	1·025
8180	798	0·976	4450	435	0·978
6880	648	0·942	4250	375	0·882

TABLE LIX.

Comparison with former results.

	H	$\frac{\Delta\lambda}{\lambda^2 H}\times 10^4$
Takahashi	mean	0·960
Graftdijk	32040	0·950
King (7 comps. ?)	16000	0·955

It may be seen in Fig. 30 that the separation curve is slightly convex upward between 4000 and 10000 gauss, but the deviation is too small to warrant the drawing of any definite conclusion, and the separation is nearly proportional to the magnetic field

λ **4466·556** appears as a triplet.

TABLE LX.

$\lambda=4466{\cdot}556$, triple.

H	$\frac{\Delta\lambda}{\lambda^2}\times 10^3$	$\frac{\Delta\lambda}{\lambda^2 H}\times 10^4$	H	$\frac{\Delta\lambda}{\lambda^2}\times 10^3$	$\frac{\Delta\lambda}{\lambda^2 H}\times 10^4$
9060	916	1·011	6450	748	1·160
8230	925	1·123	5490	593	1·080
8180	858	1·049	4650	497	1·069
7690	838	1·090	4450	536	1·204
6880	758	1·101	4240	516	1·216
6820	717	1·051	4110	503	1·224
6750	734	1·087			

TABLE LXI.

Comparison with former results.

	H	$\frac{\Delta\lambda}{\lambda^2 H}\times 10^4$
Takahashi	mean	1·101
Graftdijk	32040	1·189
King (6 comps. ?)	16000	1·074

As the points in Fig. 31 are scattered, we can say nothing about this line except that the separation is approximately proportional to the magnetic field.

λ 4447·72 seems to be separated into a sextuplet, but, the n-components being too diffuse to be separated sufficiently, this line was measured as a quadruplet.

TABLE LXII.

$\lambda=4447{\cdot}72$, $2p$-, $4n$-comps., measured as a quadruplet.

H	$\frac{\Delta\lambda}{\lambda^2}\times 10^3$		$\frac{\Delta\lambda}{\lambda^2 H}\times 10^4$	
	n	p	n	p
9690		993		1·024
8180	1890	798	2·308	0·976
7530	1584		2·102	
6880	1205	637	1·751	0·926
6020	1108		1·840	
4730	743	502	1·570	1·060
4450	677	413	1·521	0·929

TABLE LXIII.

Comparison with former results.

	H	$\frac{\Delta\lambda}{\lambda^2 H}\times 10^4$	
		n	p
Takahashi	mean	1·907	0·985
King (6 comps.)	16000	2·280 1·419	0·971

Fig 32 shows that the separation of the p-components is approximately proportional to the magnetic field, but that of the n-components is concave upward. Judged from the broadening, further resolution of these n-components is probable, and, if we accept King's result, the measured mean position moves from the inner component to the outer with the increased field. Though the curvature is clear, it can be accounted for, if we assume that the relative intensity of the components changes with the magnetic field.

λ **4442·34** appears as a quadruplet.

TABLE LXIV.

$\lambda=4442{\cdot}34$, $2p$-, $2n$-comps.

H	$\frac{\Delta\lambda}{\lambda^2}\times10^3$		$\frac{\Delta\lambda}{\lambda^2 H}\times10^4$	
	n	p	n	p
11630		827		0·711
10760		808		0·750
10510		745		0·708
9690		681		0·703
8230		597		0·726
8180	1325		1·620	
7530		538		0·715
4730	811	401	1·713	0·847
4450	812		1·824	
4240	721		1·700	

TABLE LXV.

Comparison with former results.

	H	$\frac{\Delta\lambda}{\lambda^2 H}\times10^4$	
		n	p
Takahashi	mean	1·699	0·729
King ($6n$-, $4p$-comps. ?)	16000	1·533	0·583

In Fig. 33 it may be observed that the separation of the *p*-components is proportional to the magnetic field, but, if we take King's result into consideration, the specific separation must be smaller for the stronger field. The straight line connecting King's point for the *n*-component with those of the writer does not pass through the origin. The apparent separation may be affected by the neighbouring line 4443·19.

λ **4427·314** appears as a triplet.

TABLE LXVI.

λ=4427·314, triple.

H	$\frac{\Delta\lambda}{\lambda^2}\times10^3$	$\frac{\Delta\lambda}{\lambda^2 H}\times10^4$	H	$\frac{\Delta\lambda}{\lambda^2}\times10^3$	$\frac{\Delta\lambda}{\lambda^2 H}\times10^4$
8230	1190	1·445	6020	879	1·459
7530	1155	1·533	4730	685	1·447
6880	910	1·322	4650	661	1·421
6750	930	1·377	4450	661	1·485

TABLE LXVII.

Comparison with former results.

	H	$\frac{\Delta\lambda}{\lambda^2 H}\times10^4$
Takahashi	mean	1·436
King	16000	1·371

It may be seen that the separation is approximately proportional to the magnetic field.

λ **4375·934** is resolved into a triplet.

TABLE LXVIII.

λ=4375·934, triple.

H	$\frac{\Delta\lambda}{\lambda^2}\times10^3$	$\frac{\Delta\lambda}{\lambda^2 H}\times10^4$	H	$\frac{\Delta\lambda}{\lambda^2}\times10^3$	$\frac{\Delta\lambda}{\lambda^2 H}\times10^4$
8230	1165	1·415	6020	825	1·370
7530	1068	1·416	4650	684	1·470
6820	1008	1·477			

TABLE LXIX.

Comparison with former results.

	H	$\frac{\Delta\lambda}{\lambda^2 H}\times 10^4$
Takahashi	mean	1·429
King	16000	1·384

The separation is proportional to the magnetic field.

λ **4337·04** is resolved into a quadruplet.

TABLE LXX.

$\lambda=4337{\cdot}04$, $2p$-, $2n$-comps.

H	$\frac{\Delta\lambda}{\lambda^2}\times 10^3$		$\frac{\Delta\lambda}{\lambda^2 H}\times 10^4$	
	n	p	n	p
10510	984	388	0·935	0·569
8230	825		1·002	
6820	668		0·980	
4650	413		0·888	

TABLE LXXI.

Comparison with former results.

	H	$\frac{\Delta\lambda}{\lambda^2 H}\times 10^4$	
		n	p
Takahashi	mean	0·957	0·569
King	16000	0·878	0·512

Though the number of the observed points is not sufficient to infer anything from them, the separation curve of the n-components seems to turn downwards at about 8000 gauss to reach the point given by King, and the line connecting the lower 3 points does not pass through the origin, as shown in Fig. 36.

λ **4315·089** is resolved into a quadruplet.

TABLE LXXII.

$\lambda=4315{\cdot}089$, $2p$-, $2n$-comps.

H	$\frac{\Delta\lambda}{\lambda^2}\times10^3$ n	$\frac{\Delta\lambda}{\lambda^2 H}\times10^4$ n	H	$\frac{\Delta\lambda}{\lambda^2}\times10^3$ n	$\frac{\Delta\lambda}{\lambda^2 H}\times10^4$ n
21960	p 557	p 0·254	5590	964	1·722
20880	p 540	p 0·258	4650	835	1·795
7530	1397	1·852	,,	805	1·730
6850	1112	1·623	4460	776	1·740
6820	1162	1·704	4350	760	1·747
6020	1074	1·783	3580	626	1·750

TABLE LXXIII.

Comparison with former results.

	H	$\frac{\Delta\lambda}{\lambda^2 H}\times10^4$	
		n	p
Takahashi	mean	1·745	0·256
van Bilderbeek- van Meurs	32040	1·77	0·0
King	16000	1·735	0·302

The separation of the n-components is proportional to the magnetic field. The straight line connecting the points for the p-components does not pass through the origin, but we cannot say much about this.

λ **4299·26** is resolved into a triplet.

TABLE LXXIV.

$\lambda=4299{\cdot}26$, triple.

H	$\frac{\Delta\lambda}{\lambda^2}\times10^3$	$\frac{\Delta\lambda}{\lambda^2 H}\times10^4$	H	$\frac{\Delta\lambda}{\lambda^2}\times10^3$	$\frac{\Delta\lambda}{\lambda^2 H}\times10^4$
11120	1525	1·371	6300	835	1·325
8350	1064	1·274	6020	844	1·401
6880	945	1·372	5910	785	1·329
6850	909	1·327	5590	757	1·352
6820	949	1·390	5490	692	1·259
,,	932	1·367	4730	621	1·312
6750	965	1·429	4650	687	1·478
6540	848	1·296	4360	600	1·377

TABLE LXXV.

Comparison with former results.

	H	$\frac{\Delta\lambda}{\lambda^2 H}\times 10^4$
Takahashi	mean	1·353
van Bilderbeek-van Meurs	32040	1·37
King	16000	1·372

The separation is proportional to the magnetic field.

λ **4294·13** appears as a quadruplet.

TABLE LXXVI.

$\lambda = 4294{\cdot}13$, $2p$-, $2n$-comps.

H	$\frac{\Delta\lambda}{\lambda^2}\times 10^3$ n	$\frac{\Delta\lambda}{\lambda^2 H}\times 10^4$ n	H	$\frac{\Delta\lambda}{\lambda^2}\times 10^3$ p	$\frac{\Delta\lambda}{\lambda^2 H}\times 10^4$ p
9150	1058	1·156	21960	1083	0·493
8580	907	1·056	20880	979	0·468
8350	999	1·196	18690	850	0·455
8230	872	1·060	18660	953	0·511
7690	826	1·074	18070	785	0·434
6880	707	1·027	11120	533	0·479
6850	754	1·100	10980	561	0·511
6820	708	1·039	10660	498	0·467
6750	753	1·115	10200	495	0·485
6670	777	1·165	9730	490	0·503
6540	761	1·163	9150	439	0·480
6300	723	1·147	8800	408	0·464
5910	669	1·132	8580	387	0·451
5590	608	1·087	8350	369	0·442
5490	655	1·192			
4730	536	1·133			
4350	543	1·249			

TABLE LXXVII.

Comparison with former results.

	H	$\frac{\Delta\lambda}{\lambda^2 H}\times 10^4$	
		n	p
Takahashi	mean	1·119	0·475
van Bilderbeek-van Meurs	32040	1·15	decomposed
King (6 comps. ?)	16000	1·081	0·468

The n-components become diffuse when the magnetic field is increased, indicating further resolution; the separation of the p-components shows slightly wavy fluctuation.

λ **4282·408** appears as a triplet.

TABLE LXXVIII.

$\lambda = 4282{\cdot}408$, triple.

H	$\frac{\Delta\lambda}{\lambda^2}\times 10^3$	$\frac{\Delta\lambda}{\lambda^2 H}\times 10^4$	H	$\frac{\Delta\lambda}{\lambda^2}\times 10^3$	$\frac{\Delta\lambda}{\lambda^2 H}\times 10^4$
7690	855	1·111	5910	740	1·252
6880	820	1·191	5680	701	1·234
6850	817	1·192	5590	664	1·187
6820	788	1·155	4730	559	1·181
"	783	1·149	4650	616	1·325
6750	749	1·110	4460	509	1·141
6540	774	1·182	4350	524	1·204

TABLE LXXIX.

Comparison with former results.

	H	$\frac{\Delta\lambda}{\lambda^2 H}\times 10^4$
Takahashi	mean	1·182
van Bilderbeck-van Meurs	32040	1·173
King (7 comps. ?)	16000	1·058

Fig. 40 shows that the separation curve is slightly convex upward between 4000 and 8000 gauss.

λ **4260·48** is resolved into a triplet.

TABLE LXXX.

λ=4260·48, triple.

H	$\frac{\Delta\lambda}{\lambda^2}\times 10^3$	$\frac{\Delta\lambda}{\lambda^2 H}\times 10^4$	H	$\frac{\Delta\lambda}{\lambda^2}\times 10^3$	$\frac{\Delta\lambda}{\lambda^2 H}\times 10^4$
8580	1316	1·532	5590	815	1·456
8180	1208	1·475	5230	752	1·437
6850	1000	1·460	5060	745	1·472
6820	1000	1·466	4730	686	1·450
6750	1002	1·482	4650	689	1·481
6670	1020	1·529	4520	614	1·359
6300	965	1·531	4350	605	1·390
„	935	1·483	4020	598	1·488

TABLE LXXXI.

Comparison with former results.

	H	$\frac{\Delta\lambda}{\lambda^2 H}\times 10^4$
Takahashi	mean	1·475
van Bilderbeek-van Meurs	32040	1·526
King	16000	1·458
Hartmann		1·436

The separation is proportional to the magnetic field.

λ **4250·79** appears as a quadruplet.

TABLE LXXXII.

λ=4250·79, 2p-, 2n-comps.

H	$\frac{\Delta\lambda}{\lambda^2}\times 10^3$	$\frac{\Delta\lambda}{\lambda^2 H}\times 10^4$	H	$\frac{\Delta\lambda}{\lambda^2}\times 10^3$	$\frac{\Delta\lambda}{\lambda^2 H}\times 10^4$
	p	p		p	p
10980	879	0·800	6850	616	0·899
10660	816	0·765	6300	532	0·845
9130	735	0·805	5910	n 690	n 1·168
8350	646	0·774			

TABLE LXXXIII.

Comparison with former results.

	H	$\frac{\Delta\lambda}{\lambda^2 H}\times 10^4$	
		n	p
Takahashi	mean	1·168	0·808
van Bilderbeek-van Meurs	32040	0·97	0·713
King (12 comps. ?)	16000	0·851	0·730

The n-components are too diffuse to be measured accurately. The points for the p-components lie on a straight line, which does not pass through the origin. The apparent separation may be affected by the neighbouring line λ 4250·15.

λ **4235·94** is resolved into a triplet.

TABLE LXXXIV.

$\lambda=4235{\cdot}94$, triple.

H	$\frac{\Delta\lambda}{\lambda^2}\times 10^3$	$\frac{\Delta\lambda}{\lambda^2 H}\times 10^4$	H	$\frac{\Delta\lambda}{\lambda^2}\times 10^3$	$\frac{\Delta\lambda}{\lambda^2 H}\times 10^4$
6300	965	1·531	4730	693	1·464
5590	853	1·525	4650	696	1·496

TABLE LXXXV.

Comparison with former results.

	H	$\frac{\Delta\lambda}{\lambda^2 H}\times 10^4$
Takahashi	mean	1·508
van Bilderbeek-van Meurs	32040	1·62
King	16000	1·572

The straight line connecting the observed points with King's does not pass through the origin, but we may consider the separation to be proportional to the magnetic field, as the deviation is very small.

λ **4219·36** is resolved into a triplet.

Table LXXXVI.

$\lambda=4219·36$, triple.

H	$\frac{\Delta\lambda}{\lambda^2}\times 10^3$	$\frac{\Delta\lambda}{\lambda^2 H}\times 10^4$	H	$\frac{\Delta\lambda}{\lambda^2}\times 10^3$	$\frac{\Delta\lambda}{\lambda^2 H}\times 10^4$
21960	2150	0·979	6820	715	1·048
10660	1049	0·984	,,	,,	,,
8180	790	0·966	5590	503	0.900

Table LXXXVII.

Comparison with former results.

	H	$\frac{\Delta\lambda}{\lambda^2 H}\times 10^4$
Takahashi	mean	0·987
van Bilderbeek-van Meurs	32040	0·959
King	16000	0·996

The separation is proportional to the magnetic field.

λ **4202·04** appears as a quadruplet.

Table LXXXVIII.

$\lambda=4202·04$, $2p$-, $2n$-comps.

H	$\frac{\Delta\lambda}{\lambda^2}\times 10^3$	$\frac{\Delta\lambda}{\lambda^2 H}\times 10^4$	H	$\frac{\Delta\lambda}{\lambda^2}\times 10^3$	$\frac{\Delta\lambda}{\lambda^2 H}\times 10^4$
	n	n		p	p
8350	941	1·126	20880	964	0·461
8040	918	1·141	20100	916	0·456
6820	767	1·124	10660	488	0·458
,,	760	1·114	10330	464	0·449
6700	751	1·121	8350	410	0·491
6300	731	1·161	8040	377	0·469
,,	703	1·116			
5590	617	1·103			
5230	564	1·078			
4730	507	1·071			
4520	440	0·973			
4020	413	1·028			

TABLE LXXXIX.

Comparison with former results.

	H	$\frac{\Delta\lambda}{\lambda^2 H}\times 10^4$	
		n	p
Takahashi	mean	1·105	0·462
van Bilderbeek-van Meurs	32040	1·098	0·383
King (10 comps. ?)	16000	1·142	0·52

The separation of the n-components and that of the p-components are both proportional to the magnetic field above 6000 gauss, while the diagram for the former components curves downwards at the weaker field, as can be seen in Fig. 45.

λ **4199·09** is resolved into a triplet.

TABLE XC.

λ=4199·09, triple.

H	$\frac{\Delta\lambda}{\lambda^2}\times 10^3$	$\frac{\Delta\lambda}{\lambda^2 H}\times 10^4$	H	$\frac{\Delta\lambda}{\lambda^2}\times 10^3$	$\frac{\Delta\lambda}{\lambda^2 H}\times 10^4$
21960	2168	0·988	6300	599	0·950
10660	1050	0·985	,,	590	0·936
8350	808	0·967	5590	558	0·999
8180	770	0·941	5230	497	0·950
8040	799	0·994	4730	419	0·886
6820	662	0·971	4520	443	0·980
6700	675	1·008			

TABLE XCI.

Comparison with former results.

	H	$\frac{\Delta\lambda}{\lambda^2 H}\times 10^4$
Takahashi	mean	0·971
van Bilderbeek-van Meurs	32040	1·010
King	16000	0·978

The separation is proportional to the magnetic field.

λ **4181·76** is resolved into a triplet.

Table XCII.

$\lambda=4181{\cdot}76$, triple.

H	$\frac{\Delta\lambda}{\lambda^2}\times10^3$	$\frac{\Delta\lambda}{\lambda^2 H}\times10^4$	H	$\frac{\Delta\lambda}{\lambda^2}\times10^3$	$\frac{\Delta\lambda}{\lambda^2 H}\times10^4$
21960	2612	1·189	8180	982	1·200
20880	2470	1·182	6820	807	1·183
20100	2348	1·168	5590	680	1·215

Table XCIII.

Comparison with former results.

	H	$\frac{\Delta\lambda}{\lambda^2 H}\times10^4$
Takahashi	mean	1·185
van Bilderbeek-van Meurs	32040	1·225
King	16000	1·210

The separation is proportional to the magnetic field.

λ **4143·88** has at least $3p$-and $4n$-components.

Table XCIV.

$\lambda=4143{\cdot}88$, at least $3p$-, $4n$-comps.

H	$\frac{\Delta\lambda}{\lambda^2}\times10^3$	$\frac{\Delta\lambda}{\lambda^2 H}\times10^4$	H	$\frac{\Delta\lambda}{\lambda^2}\times10^3$	$\frac{\Delta\lambda}{\lambda^2 H}\times10^4$
21960	$n\left\{\begin{array}{l}3820\ (2380)\\3103\end{array}\right.$ p 692	$n\left\{\begin{array}{l}1{\cdot}739=5\times0{\cdot}348\\1{\cdot}413=4\times0{\cdot}353\end{array}\right.$ p 0·315	5590	768	1·373
			5230	673	1·287
6810	915	1·343	4730	662	1·400
6700	1004	1·499	4520	588	1·301
6300	905	1·436	4020	542	1·349
,,	856	1·360			

TABLE XCV.

Comparison with former results.

	H	$\frac{\Delta\lambda}{\lambda^2 H}\times 10^4$
Takahashi	$H<7000$	1·377
van Bilderbeek-van Meurs	32040	1·435
King (7 comps. ?)	16000	1·43

Appearing as a triplet in a weak field the separation is approximately proportional to the magnetic field. When the magnetic field is increased, both *p*-and *n*-components become diffuse, indicating further resolution. On a few plates photographed with the field above 22000 gauss, 3*p*-and 4*n*-components were observed, though it was difficult to measure them accurately, as they were faint and diffuse.

λ **4132·08** has at least 5*p*-and 4*n*-components.

TABLE XCVI.[1]

λ=4132·08, at least 5*p*-, 4*n*-comps.

H	$\frac{\Delta\lambda}{\lambda^2}\times 10^3$	$\frac{\Delta\lambda}{\lambda^2 H}\times 10^4$	H	$\frac{\Delta\lambda}{\lambda^2}\times 10^3$	$\frac{\Delta\lambda}{\lambda^2 H}\times 10^4$
21960	*n* 4000 3085 *p* 390	*n* 1·821=5×0·364 1·404=4×0·352 *p* 0·178=½×0·356	6820 5590	1000 824	1·466 1·473
20880	*n* 3620 3000 *p* 387	*n* 1·732=5×0·346 1·436=4×0·360 *p* 0·185=½×0·370	5230 4020	713 610	1·363 1·518
20100	*n* 3450 2735 *p* 390	*n* 1·716=5×0·343 1·360=4×0·340 *p* 0·194=½×0·388			

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1) The interval between two adjoining *p*-components is given in the table.

TABLE XCVII.

Comparison with former results.

	H	$\frac{\Delta\lambda}{\lambda^2 H}\times 10^4$
Takahashi	mean $H<7000$,, $H>7000$	n 1·453 $n\begin{cases}1·760=5\times 0·351\\ 1·400=4\times 0·351\end{cases}$ p $0·186=\frac{1}{2}\times 0·371$
van Bilderbeek-van Meurs	32040	1·62
King (13 comps. ?)	16000	1·869 (outer)

Though this line appears as a triplet in a weak field, both p-and n-components become diffuse when the magnetic field is increased, and finally they are resolved into many fine components. I have measured 5 p-components in equal spacing and 4 (or more?) n-components.

λ **4118·552** is resolved into a triplet.

TABLE XCVIII.

$\lambda=4118·552$, triple.

H	$\frac{\Delta\lambda}{\lambda^2}\times 10^3$	$\frac{\Delta\lambda}{\lambda^2 H}\times 10^4$	H	$\frac{\Delta\lambda}{\lambda^2}\times 10^3$	$\frac{\Delta\lambda}{\lambda^2 H}\times 10^4$
21960	2174	0·989	8180	793	0·969
20880	2056	0·984	6820	634	0·930
10660	984	0·922	5590	533	0·953

TABLE XCIX.

Comparison with former results.

	H	$\frac{\Delta\lambda}{\lambda^2 H}\times 10^4$
Takahashi	mean	0·968
van Bilderbeek-van Meurs	32040	1·024
King	16000	0·998

The separation is proportional to the magnetic field.

λ 4005·26.

TABLE C.[1)]

$\lambda=4005{\cdot}26.$

H	$\frac{\Delta\lambda}{\lambda^2}\times10^3$	$\frac{\Delta\lambda}{\lambda^2 H}\times10^4$	H	$\frac{\Delta\lambda}{\lambda^2}\times10^3$	$\frac{\Delta\lambda}{\lambda_2 H}\times10^4$
20250	*p* 303	0·150	5670	*n* 772	1·362
6820	*n* 1000	1·467	5590	*n* 771	1·379

TABLE CI.

Comparison with former results.

	H	$\frac{\Delta\lambda}{\lambda^2 H}\times10^4$
Takahashi	mean	*n* 1·407 *p* 0·150
van Bilderbeek-van Meurs	32040	1·55
King	16000	1·797

Though this line appears as a triplet in a weak field, the components become diffuse when the magnetic field is increased until they are resolved into many components. 5 *p*-components in equal spacing were measured, though the corresponding *n*-components were not measured. The resolution of this line quite resembles that of λ 4132·08 as King has noted in his report.

Those lines for which either the measurements were not accurate or the photos were taken with only one or two fields are given in the following table. The fields applied are between 5000 and 1000 gauss, most of the photos being taken with 8200 gauss. The specific separations reduced from King's results are given in the same table for comparison.

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1) The interval between two adjoining *p*-components is given in the table.

TABLE CII.

λ	$\frac{\Delta\lambda}{\lambda^2 H} \times 10^4$		
	Takahashi	King	Graftdijk
			van Bilderbeek-van Meurs
5434·527	unaffected	unaffected	
5341·03	n diffuse $2p$ 0·86	n 1·703 p 0·939	
5192·363	1·57	n 1·738 p 0·494	
5169·03	1·44	1·317	
4736·786	1·15	1·185	
4647·439	1·09	1·139	
4549·47	1·01	0·964	0·974
4482·27	4 n 1·56 0·49 2 p 0·97	n 0·433 p 0·712	
4469·39	1·01	1·37	
4461·65	1·31	1·366	
4459·12	4 n 1·67 1·30 2 p 0·44	n 1·410 p 0·397	
4422·57	2 n 1·40 2 p 0·86	n 1·380 0·492 p 0·895	
4369·77	0·93	0·923	
4352·741	1·58	n 1·371 p 0·466	
4233·615	6 n 3·04 2·05 0·94 3 p 1·04	n 2·720 1·921 0·923 p 0·974	
4227·44	1·01	1·080	1·120
4210·36	2·81	2·841	
4191·442	4 n 1·91 0·89 3 p 1·04	n 1·921 0·940 p 0·989	
4175·64	1·04	1·06	
4172·13	1·10	1·101	
4156·81	1·14	n 1·328 p 0·437	
4134·685	1·08	1·109	
4021·872	1·05	1·051	
4014·53	0·98	0·970	
3997·41	1·04	1·04	
3969·26	1·37	1·405	1·472
3956·67	1·08	1·154	
3930·30	1·41	1·424	1·429
3927·94	1·40	1·428	1·427
3922·92	1·39	1·428	1·412
3920·26	1·34	1·420	1·444

III. Nickel Lines.

As the source of light was the spark between nickel-steel terminals, some nickel lines were photographed on the same plates with iron lines.

λ **5477·12** is resolved into a triplet.

Table CIII.

$\lambda = 5477{\cdot}12$, triple.

H	$\frac{\Delta\lambda}{\lambda^2}\times 10^3$	$\frac{\Delta\lambda}{\lambda^2 H}\times 10^4$	H	$\frac{\Delta\lambda}{\lambda^2}\times 10^3$	$\frac{\Delta\lambda}{\lambda^2 H}\times 10^4$
10760	1181	1·097	6400	607	0·949
10510	1141	1·086	6300	600	0·952
9880	1036	1·049	5520	521	0·944
9690	985	1·016	4940	421	0·852
9390	862	0·918	4730	432	0·913
8860	798	0·901	4450	444	0·998
8350	806	0·965	4240	409	0·965
8230	820	0·996	4110	410	0·998
7560	690	0·913	mean		0·976
6880	599	0·871	$H<9400$		0·936

The specific separation increases with the magnetic field. We must not, however, forget that there is a weak iron line 5476·57, which is expected to appear 0·08 $\delta\lambda_{max}$ apart from the nickel line, though only a sharp line is observed in my photogram. In Fig. 51, it may be seen that the separation curve turns towards the point given by King¹⁾ for the above iron line, and the lower portion agrees approximately with Hartmann's result for the same line. But, as Hartmann²⁾ used nickel-steel terminals, we cannot say that the line observed by him is not the nickel line. On the other hand the separation given by Graftdijk³⁾ for the nickel line agrees quite well with the mean value by the writer.

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1) l. c.
2) l. c.
3) l. c.

Moreover the observed line is too strong to be taken for the iron line. I think that the line, which I have measured, is the nickel line, and the apparent separation may be somewhat disturbed by the superposition of the iron components.

λ **4714·68** appears as a triplet.

TABLE CIV.

$\lambda=4714{\cdot}68$, triple.

H	$\frac{\Delta\lambda}{\lambda^2}\times10^3$	$\frac{\Delta\lambda}{\lambda^2 H}\times10^4$	H	$\frac{\Delta\lambda}{\lambda^2}\times10^3$	$\frac{\Delta\lambda}{\lambda^2 H}\times10^4$
9880	1120	1·134	6400	749	1·170
9690	1120	1·156	6300	785	1·246
9060	932	1·029	5520	614	1·112
8860	911	1·029	4730	541	1·144
8350	920	1·101	4480	515	1·148
8230	902	1·096	4450	501	1·125
7560	772	1·021	4240	480	1·131
6880	718	1·043	4110	515	1·254
6670	767	1·150	Mean		1·114

It may be seen in Fig. 52 that the specific separation suddenly falls at 7000 gauss.

λ **4401·77** is resolved into a triplet.

TABLE CV.

$\lambda=4401{\cdot}77$, triple.

H	$\frac{\Delta\lambda}{\lambda^2}\times10^3$	$\frac{\Delta\lambda}{\lambda^2 H}\times10^4$	H	$\frac{\Delta\lambda}{\lambda^2}\times10^3$	$\frac{\Delta\lambda}{\lambda^2 H}\times10^4$
9880	1214	1·229	4450	440	0·988
8230	941	1·144	mean		1·133
6820	735	1·078			

Fig. 53 shows that the observed points lie on a straight line which does not pass through the origin. We can see a slight curvature of the separation curve, but it is within the errors of experiment.

Discussion of the Results.

Examining the preceding results, we find some similarity and regularity among many lines. Of the nine strong violet lines, the specific separation increases in each group with decreasing wave length,[1] the rate of the increase being larger for the more refrangible group, and the separation of the first line larger for the less refrangible. The lines 4415·13 and 4325·78, forming the first of the first and the second group respectively, give diffuse components, and the separations are not proportional to the magnetic field, but the broadening and the loss of intensity in strong fields are more conspicuous for the former line. On the plates photographed with the strongest fields 3*p*-and 4*n*-components are found for 4415·13, and the *p*-component of 4325·78 indicates some fine resolution which, I think, consists of three components, while 4071·75, the first line of the third group, appears as a sharp triplet of the separation proportional to the magnetic field. These lines seem to have 7, 5 (or 7) and 3 components respectively. The rest of these nine lines give sharp triplets, the separations being exactly proportional to the magnetic field.

Of the nine strong lines, seven, which were measured most accurately, give the separations proportional to the magnetic field as if no mutual influence existed between the radiating electrons, yet the divergent values of the specific separations show that Runge's rule does not hold among these lines. The ratios of these separations to the normal value are given in the following table.

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[1] For the line 4415·13, the specific separation of the *n*-components in a weak field is taken.

TABLE CVI.

λ	$\frac{\Delta\lambda}{\text{normal }\Delta\lambda}$ [1]	$\frac{p}{q}$	$\frac{\Delta\lambda}{\Delta\lambda\text{ of }4404{\cdot}75}$	$\frac{p}{q}$
4404·75	1·132 (1·135)	$\frac{8}{7}=1{\cdot}143$ $\frac{17}{15}=1{\cdot}133$ $\frac{9}{8}=1{\cdot}125$	1·000	1
4383·55	1·144 (1·147)	$\frac{8}{7}=1{\cdot}143$	1·010	$\frac{91}{90}=1{\cdot}011$ $\frac{101}{100}=1{\cdot}010$ $\frac{111}{110}=1{\cdot}009$
4307·92	1·122 (1·125)	$\frac{9}{8}=1{\cdot}125$	0·991	$\frac{120}{121}=0{\cdot}992$ $\frac{110}{111}=0{\cdot}991$ $\frac{100}{101}=0{\cdot}990$
4271·75	1·239 (1·243)	$\frac{5}{4}=1{\cdot}250$ $\frac{21}{17}=1{\cdot}235$	1·094	$\frac{11}{10}=1{\cdot}100$ $\frac{23}{21}=1{\cdot}095$ $\frac{12}{11}=1{\cdot}091$
4071·75	0·663 (0·665)	$\frac{2}{3}=0{\cdot}667$ $\frac{53}{80}=0{\cdot}663$	0·586	$\frac{10}{17}=0{\cdot}588$ $\frac{17}{29}=0{\cdot}586$ $\frac{7}{12}=0{\cdot}583$
4063·61	1·081 (1·084)	$\frac{13}{12}=1{\cdot}083$ $\frac{27}{25}=1{\cdot}080$	0·955	$\frac{22}{23}=0{\cdot}957$ $\frac{21}{22}=0{\cdot}955$ $\frac{20}{21}=0{\cdot}952$
4045·82	1·230 (1·234)	$\frac{5}{4}=1{\cdot}250$ $\frac{21}{17}=1{\cdot}235$ $\frac{43}{35}=1{\cdot}229$	1·086	$\frac{12}{11}=1{\cdot}091$ $\frac{25}{23}=1{\cdot}086$ $\frac{13}{12}=1{\cdot}083$

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1) The values given in brackets are those obtained by assuming the specific separation of λ4383·55 is 1·078 × 10^4, as given by Mr. Yamada, in stead of taking that of λ4404·75.

We find in the table that the ratios cannot be expressed in simple fractions. p and q are not small enough except for the case of 4071·75, and we can not find the unit of separation common to these lines. When the ratios between one of these separations and the rests are taken, the fractions are less simple as shown in the last two columns.

The fact that iron and other elements rich in lines give divergent values of the specific separations seems to require some consideration. That $\frac{e}{m}$ is different for electrons radiating lines of different wave lengths is not plausible, at least for those which emit radiations of nearly equal wave lengths. I think it is more reasonable to attribute the divergent values of the specific separations to the change of the atomic field. If we accept the saturnian atom, it may be considered that the strong magnetic field, which is usually supposed to be present in the atom, originates in the electrons in their orbital motions. When the external magnetic field is applied, the orbit may be changed, giving rise to the change of the atomic field, which possibly amounts to a magnitude comparable with the external field. This change of the atomic field may affect the magnetic separation, and divergent values of the separations proportional to the magnetic field may appear, if the change of the atomic field is proportional to the external field applied. Those elements rich in lines must be rich in electrons with orbital motions, whose radii are considerably large even in the non-radiating state. The peculiar positions occupied by them in the periodic table and the low electro-potentials among others seem to support the assumption. It is natural that the change of the atomic field is large for those elements rich in electrons with orbital motions, and the divergent values of the specific separations obtained with the elements rich in lines can be explained. Besides the atomic magnetic field, the change of the electric field caused by the change of the orbits may play an important rôle.

For the other lines the measurements are not so accurate as for the seven lines above related, but many of them give separations proportional to the magnetic field so far as the present experiment goes, and some others, giving complicated or diffuse resolutions, show deviations from the proportionality.

5615·661, 5328·06, 4375·934, 4299·26, 4260·48, 4235·94, 4219·36, 4199·09, 4181·76, 4118·552 appear as sharp triplets, the separations being proportional to the magnetic field, but the values of the specific separations are different. The results with 5232·957, 4957·62, 4920·52, 4891·51, 4583·83, 4476·03, 4466·556, 4427·314, are not as exact as for the lines mentioned above, but the separations are approximately proportional to the magnetic field notwithstanding some possible disturbances of the neighbouring lines, or probably complicated separations measured as triplets may be expected for some lines.

5371·495, 5269·53 and 5167·492 show some sudden fall of the specific separation at about 7000 gauss. Though the fall of the first is considerable, that of the last is only slightly noticeable. The fall of 5269·53 may be caused by the disturbance of the neighbouring line 5270·35, so that it needs more experiments with different instruments to decide its character.

5586·772, 5572·86, 4143·88, 4132·08 and 4005·26, appear as diffuse triplets in weak fields. In the field above 20000 gauss, three of them are resolved into many components, the type of resolution of 4132·08 and 4005·26 being similar, though the latter was not measured exactly. Judged from their similar appearance, the first two lines also may give some complicated separations in strong fields.

The broadening of the components of 4528·622, 4494·572 and 4282·408 also seems to indicate some complicated resolutions. The curvatures in the separation diagrams may be due to the complicated resolutions, but the result of van Bilderbeek-van Meurs and of Graftdijk show that they are triplets even in the field of 32040 gauss.

5455·614 (quintuplet) and 5227·20 (triplet) show wavy fluctuations in the specific separations of the *n*-components, the separation of the *p*-components of the former being proportional to the magnetic field. *p*-components of 5446·92 and 5397·12 also show wavy fluctuations of the separations, though the measurement of the last is not sufficient.

5429·70 gives *p*-components whose separation suddenly increases at about 9500 gauss and the observed points on each side of the field lie on a separate straight line as if the measurements were made for different components. King is of opinion that they are possibly four *p*-components, but the specific separation given by him for the outer pair is nearly equal to that at the weaker field as obtained by the writer. The separation curve of this component somewhat resembles that of the *n*-component of 4325·78.

The separations of the *n*-components of 5018·45 (triplet), 4337·04 and 4202·04 (both quadruplet) curve more or less downwards at weaker fields.

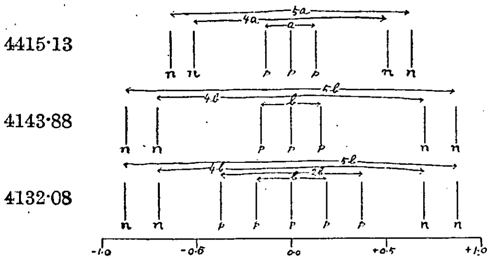
p-components of 4315·089 and 4250·79 indicate that the separations do not tend to zero when the magnetic field vanishes, though the *n*-components of the former give a separation proportional to the magnetic field. The separation of the *n*-components of 4442·34 also does not seem to vanish when the magnetic field vanishes, but that of the *p*-components is proportional to the field so far as my experiment goes.

The scattered points at the stronger fields in the separation curve of 4294·13 indicate that further resolution is possible if we increase the magnetic field or the resolving power of the instrument.

It seems that many iron lines are resolved in complicated manner, the components being spaced not in equal intervals, but they crowd together at their mean positions, so that we cannot resolve them without a strong magnetic field and an instrument of high resolving power. 4415·13 was resolved into 7-components with the strongest fields applied, but the *p*-component of 4325·78 was not resolved into fine components even with 37230 gauss, though its broadening and fringed appearance indicate the existence of a complicated resolution. 4132·08 and 4005·26 were observed to be resolvable at least into 11-components in a field stronger than 20000 gauss, and the diffuse components of many other lines also indicate further resolutions. Especially in the green region, many lines became so diffuse, when the magnetic field was increased, that I could not observe the separations in a strong field, owing partly to the increase of the luminosity of the continuous spectrum in the back ground and the decrease of the intensities of the iron lines, and partly to disturbances during the long exposure, but it seems to me that the complicated resolutions of many lines are the principal cause of failure.

The specific separation of 4415·13 seems to have a unit $a=0{\cdot}255\times10^{-4}$; the distance between the outer n-components and that between the inner are $5a$ and $4a$ respectively, and the distance between the outer pair of the p-components is a. The specific separations of 4143·88 and 4132·08 seem to have their common unit, namely $b=0{\cdot}351\times10^{-4}$, the distances between the n-components being $5b$ and $4b$ for both lines. Though we find considerable deviations for the separations of the p-components, *i. e.* the distance between the outer p-components of the former line is $0{\cdot}315\times10^{-4}$, and those between the outer and inner pairs of the latter are $2\times0{\cdot}371\times10^{-4}$, and $0{\cdot}371\times10^{-4}$, respectively, the discrepancy can be accounted for by the errors of measurements, as these separations are too small to be measured accurately. Hence we may take $0{\cdot}351\times10^{-4}$ as the unit of the separations of these two lines. But we can find no relation between a and b.

Fig. 54.



As for the nickel lines, the curvature in the separation curve of 5477·12 is clearly marked, but we must study the separation with the spark between pure nickel terminals or with concave grating to be able to fix it definitely. 4714·68 shows a separation curve similar to the iron line 5371·495, but the measurement is not so accurate. 4401·77 shows a smooth curvature in the separation curve, but the observed points are not numerous enough and the deviations are too small to speak of its existence; in fact, we can connect them by a straight line which does not pass through the origin.

Of the separations which are not proportional to the magnetic field, some may be caused by true coupling between radiating or non-radiating electrons, and others by experimental errors. Among the conditions giving rise to the appearance of false coupling, we may count the following :—

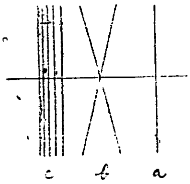
1. Errors in the determination of the magnetic field.
2. Apparent displacement of the mean position of a broad line in the double order position.
3. Errors in measuring the broad line.
4. Disturbance by other coincident or neighbouring lines known or unknown.
5. Complicated separation whose components are not thoroughly resolved.
6. Irregular contraction of the photographic film.

Those lines photographed on one plate with the same exposure as the standard line are free from the first error, as the standard line was measured most accurately. For those which were not photographed with the same exposure as the standard line, we can determine the field by measuring the photos of the standard line taken before and after the exposure for those in question without breaking the current through the electromagnet and carefully observing the constancy of the current. The separation of the standard line measured on the former agreed well with that on the latter in almost all cases, so that we may rely on the determination of the relative field.

The second is important for broad lines. This can be eliminated by taking the photos in different positions of the echelon spectra, bringing the undisturbed line in single order for some exposures and in double order for others.

The third is unavoidable, but the use of different types of cross wire somewhat improved the result. The cross wire of the micrometer used by the writer was constructed as shown in Fig. 55. *a* was mostly used for sharp lines to bisect the line in the

Fig. 55.



mean position, *b* was used for broad lines bringing the point of intersection of the wire on the mean position, and *c* was used for those which were photographed with the narrow second slit s_2 bringing the spot in the middle of the two adjacent wires.

The fourth is unavoidable, unless we use other instruments with different constants, or by crossing them. Plane grating crossed with echelon or other interferometer seems to be most convenient for such an element rich in lines as iron, though the experinent failed in the present work owing to insufficient intensity. While 4957·62, 4920·52 and 4891·51, which may be disturbed more or less by neighbouring lines, show separations approximately proportional to the field, 5477·12 (Ni), 5269·53, 4442·34 and 4250·79 give separations which are not proportional to the field with some indication of the disturbance caused by the neighbouring line.

In order to overcome the fifth difficulty, an instrument of high resolving power with considerably large value of $\delta\lambda_{max}$ is necessary, for we have to resolve the components in different positions. If $\delta\lambda_{max}$ is small, many components fall close to the others, and it is difficult to study their behavior with a sufficient number of fields. It is also necessary to apply a strong magnetic field. In the present experiment 4415·13, giving a separation which is not proportional to the magnetic field in weak fields, is resolved into seven components in fields above 35000 gauss. The separation of the n-components of 4447·72, given in Fig. 32, also shows false curvature, the mean position of the two components moving from the inner to the outer. The separations of other diffuse components may be subject to the same error, if they are formed of assemblages of several lines, and the measured positions correspond to the means.

To overcome the last difficulty it is necessary to measure the separation on different plates and increase the number of the observed points. In the present investigation I took great care to avoid these errors.

In conclusion the writer wishes to tender his coordial thanks to Prof. Nagaoka, at whose suggestion the present experiment was undertaken.

Summary.

1. The light emitted by the spark between non-magnetic nickel-steel terminals has been examined in different magnetic fields.

2. Many lines photographed at a juxtaposition with a prism spectrograph placed behind an echelon spectroscope have enabled us to compare their relative separations exactly.

3. The separations of the lines photographed were compared with that of the line 4404·75, and, assuming the latter to be proportional to the magnetic field, the behavior of the others was studied. The assumption is verified by the fact that the separations of many sharp lines are proportional to the separation of the standard line.

4. The magnetic fields are calculated assuming the specific separation of the standard line 4404·75 given by Mr. Yamada.

5. Nine strong lines in the violet region being studied carefully, the separations of seven of them were found to be exactly proportional to the magnetic field, while the others gave larger specific separations for stronger fields, the components appearing more and more diffuse with the increase of the field, and the line 4415·13 was resolved into seven components in strong fields.

6. Other less strong lines were also studied. Some of them give different types of separations, which are not proportional to the magnetic field, and the others show that their separations are proportional to the field. Specific separations are given for those measured with less accuracy or with only one or two fields.

7. Nickel lines photographed on the same plate as the iron lines are also given.

8. Many sharp lines give separations proportional to the magnetic field as if there was no mutual influence between the

radiating electrons, but the divergent values of the specific separations seem to indicate the existence of coupling. Moreover the separations of a number of lines which are not proportional to the magnetic field, seem to indicate the existence of some mutual influence, though the measurements are not sufficiently accurate.

9. Many iron lines apparently show simple resolutions into diffuse components, which are likely to be resolved again into fine components, if they are examined in stronger magnetic fields with an instrument of higher resolving power.

Published December 30th, 1920.

Fig. 2.

λ=4415·13, 3*p*-, 4*n*-comps.

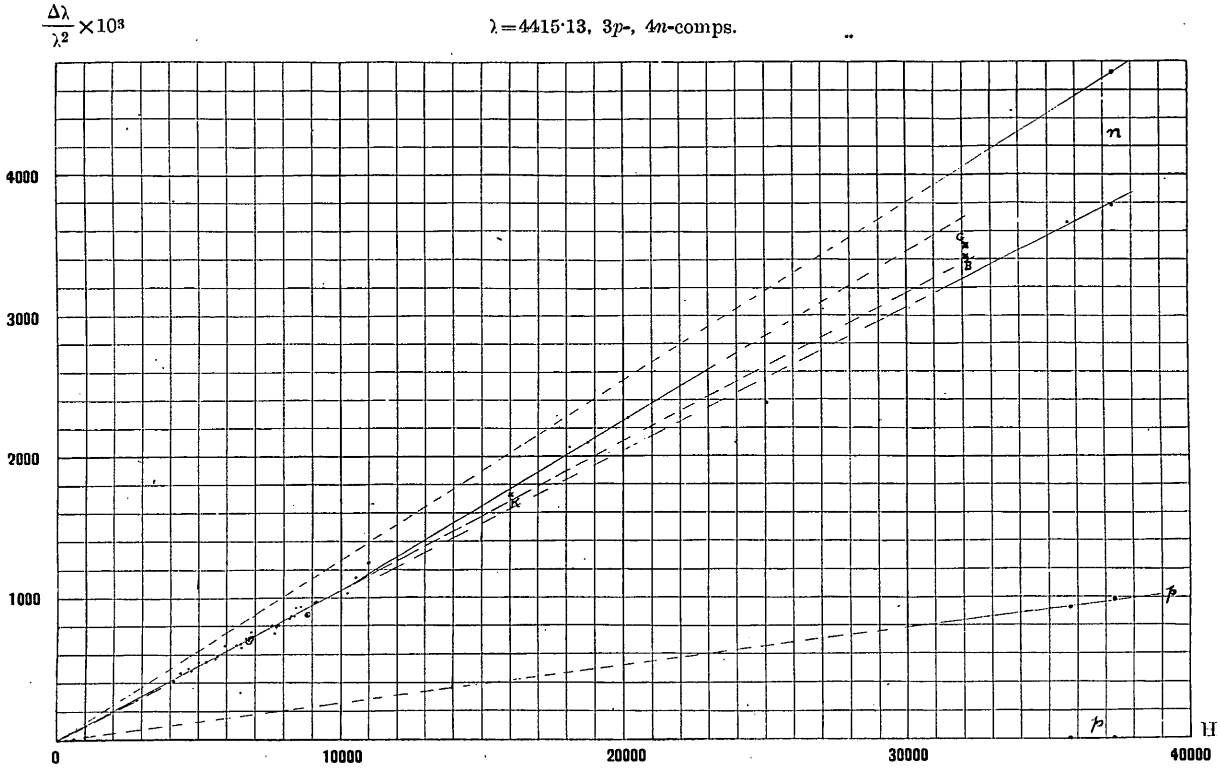
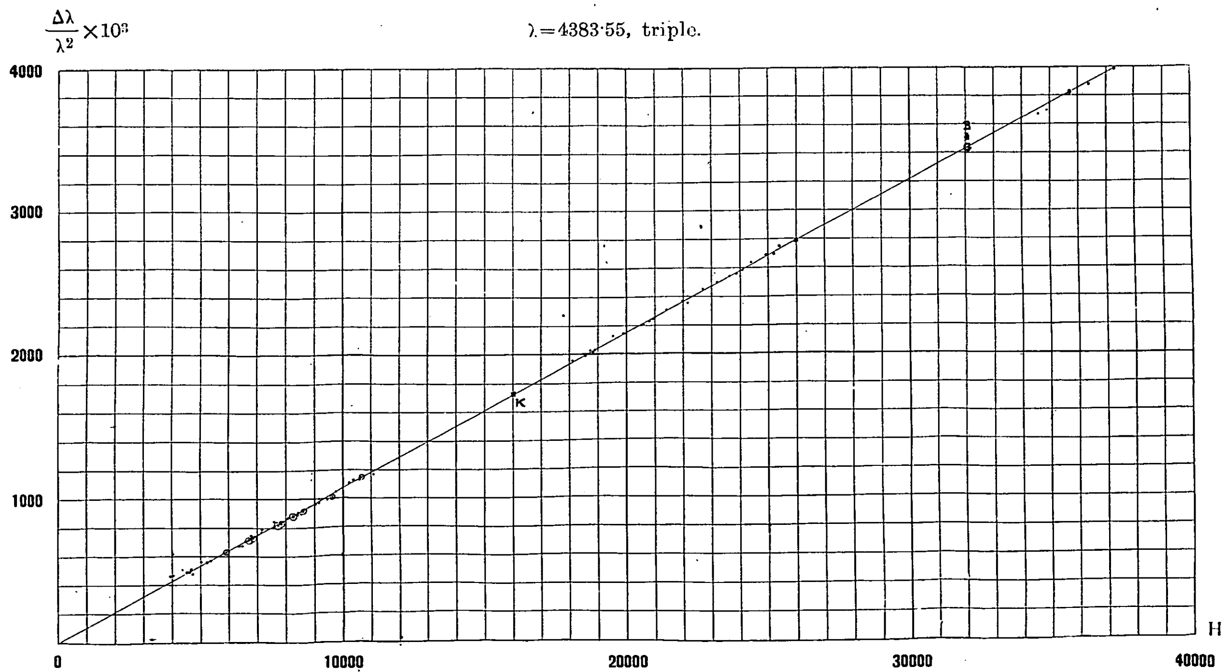


Fig. 3.

λ=4383·55, triple.



⦿ denotes an assemblage of two or more points.
B, *G* and *K* denote the points taken from the results of van Bilderbeek-van Meurs, Graftdijk and King respectively.

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Fig. 4.

λ=4325·78, quintuple ?

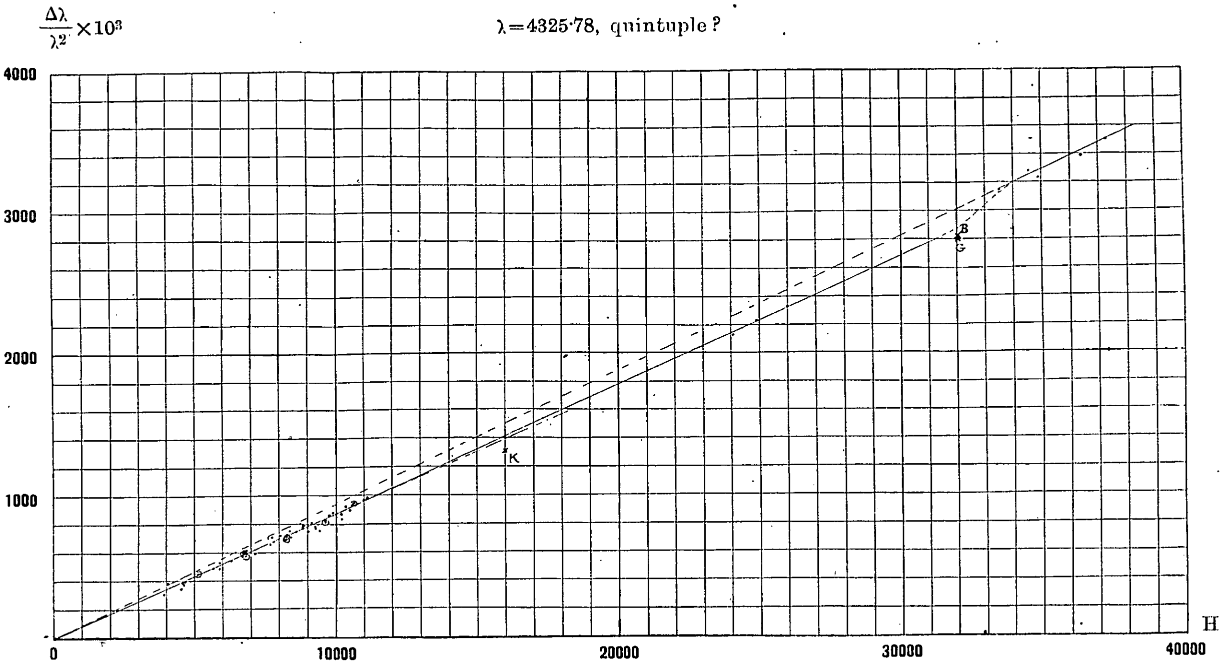

Fig. 5.

λ=4307·92, triple.

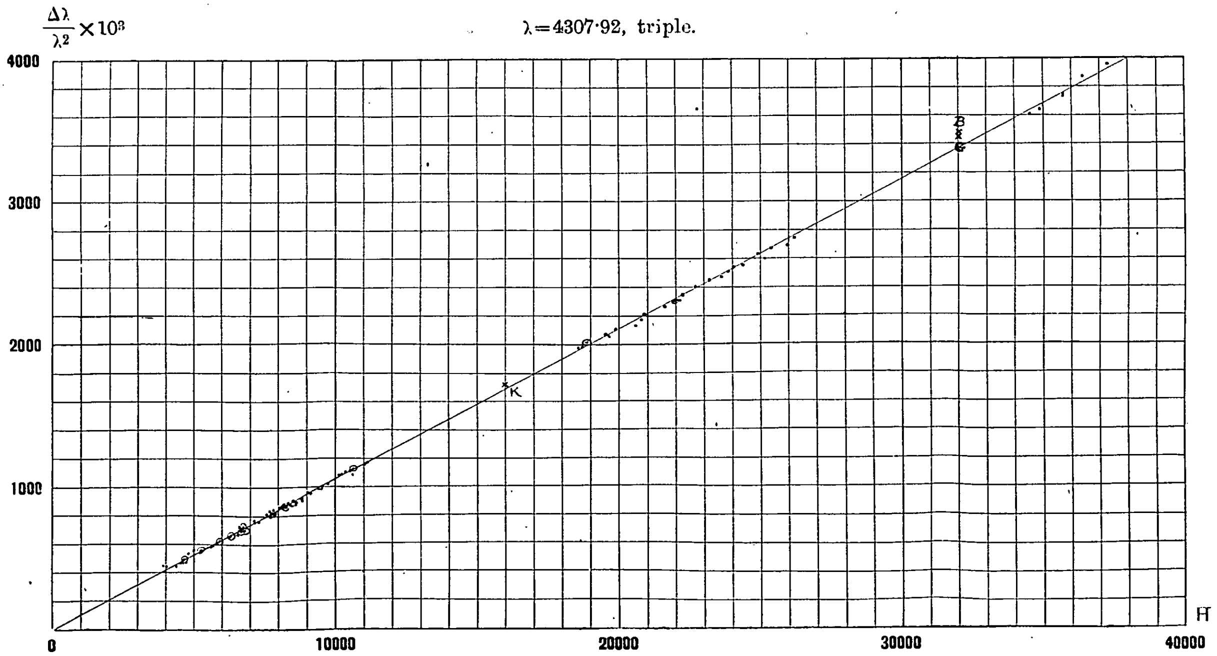

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Fig. 6.

λ=4271·75, triple.

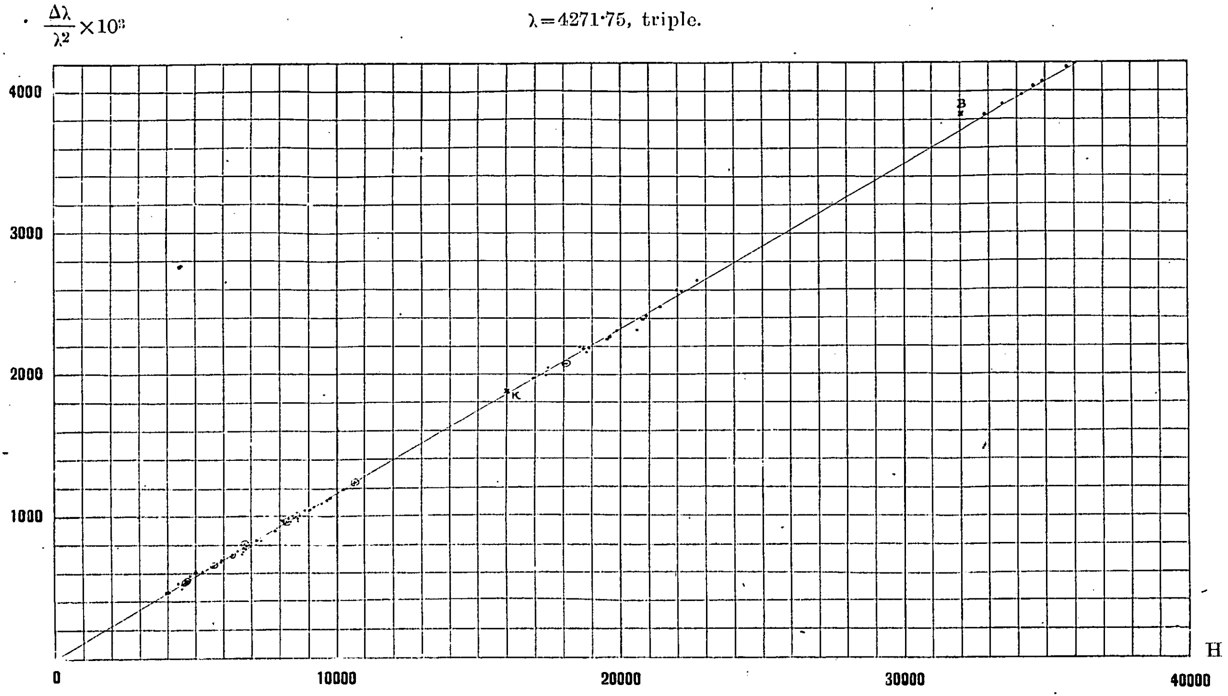

Fig. 7.

λ=4071·75, triple.

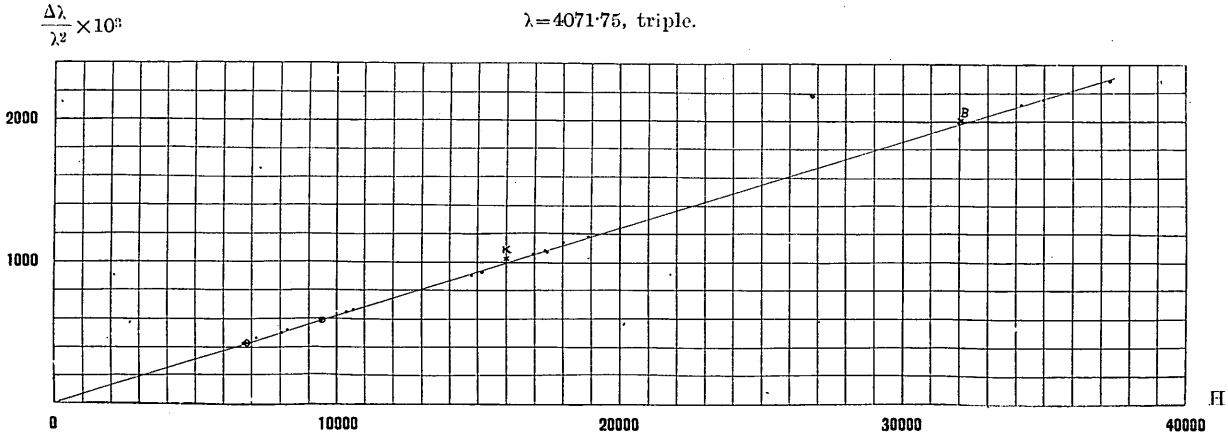

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Fig. 8.

$\lambda=4063{\cdot}61$, triple.

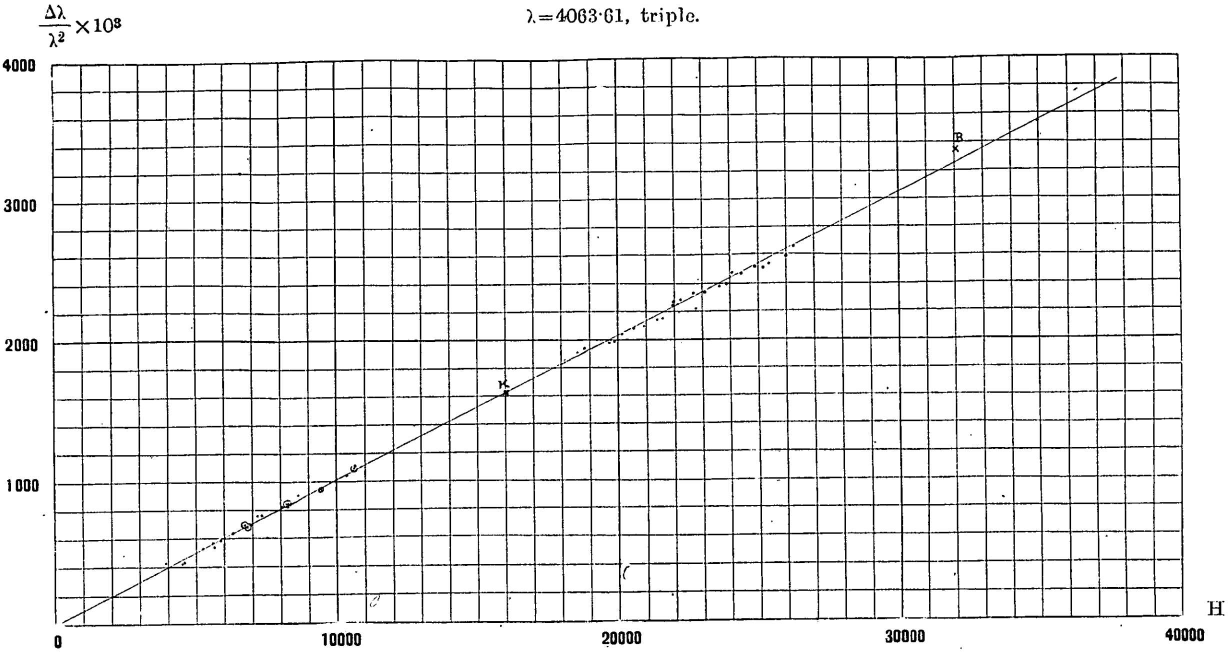

Fig. 9.

$\lambda=4045{\cdot}82$, triple.

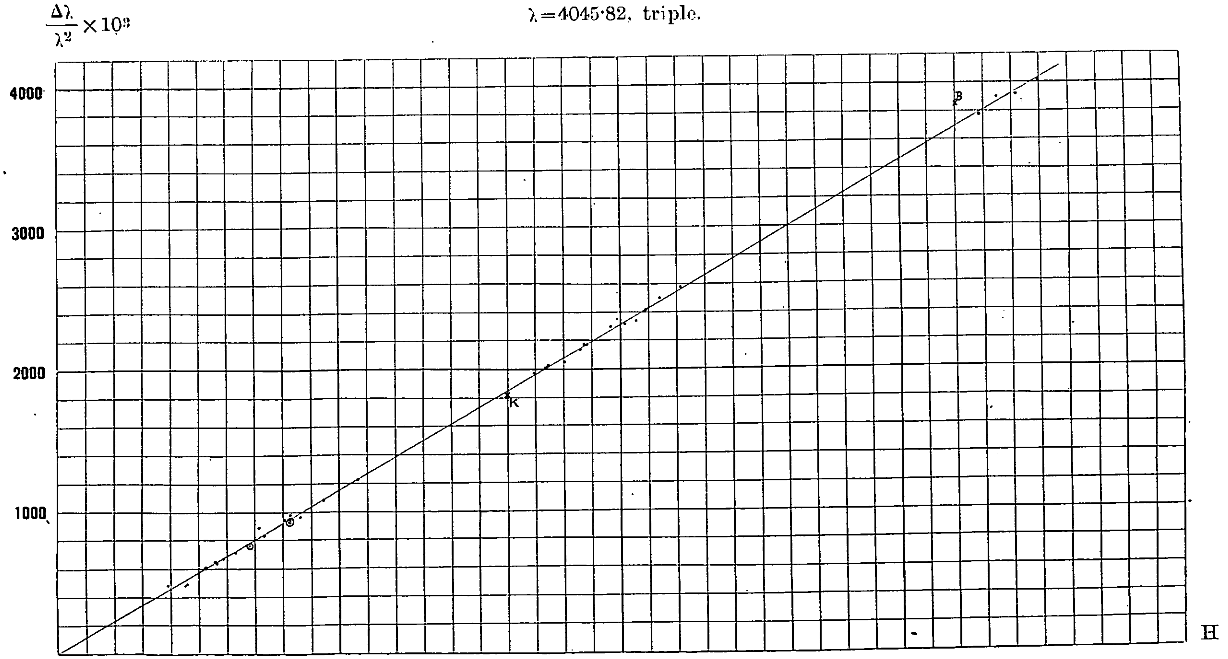

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Fig. 10.

$\lambda = 5615{\cdot}661$, triple.

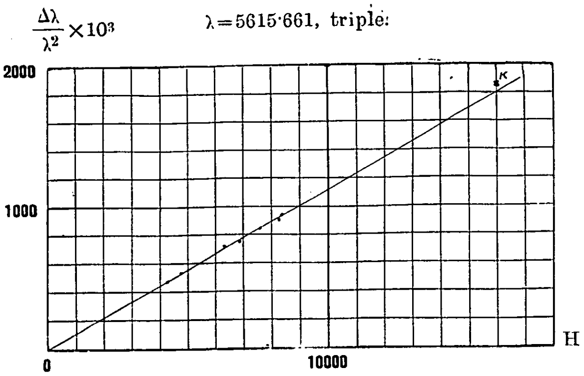

Fig. 11.

$\lambda = 5586{\cdot}772$, triplet?

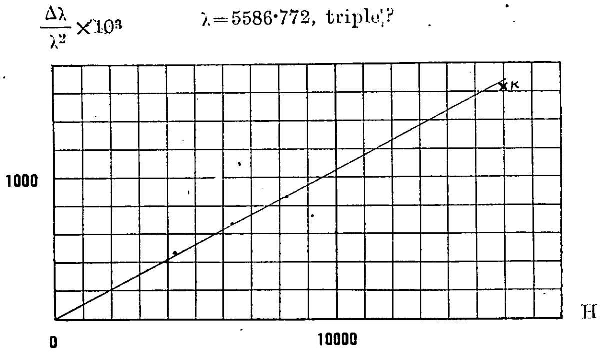

Fig. 12.

$\lambda = 5572{\cdot}86$, triple ?

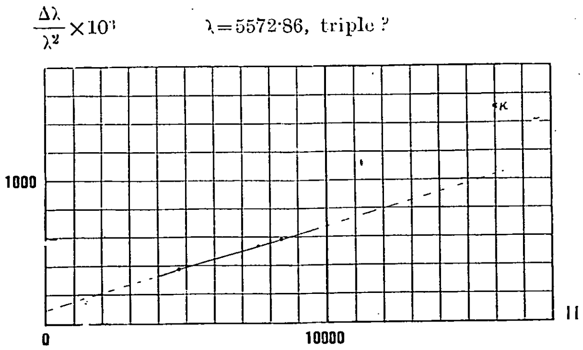

Fig. 13.

$\lambda = 5455{\cdot}614$, $2p$-, $3n$-comps.

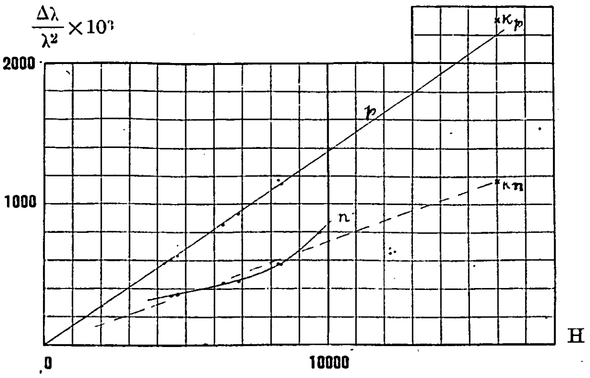

Fig. 14.

$\lambda = 5446{\cdot}92$, $2p$-, $2n$-comps.

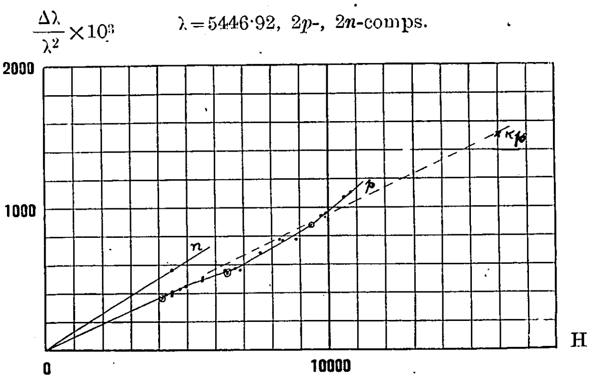

Fig. 15.

$\lambda = 5429{\cdot}70$, $2p$-, $2n$-comps.

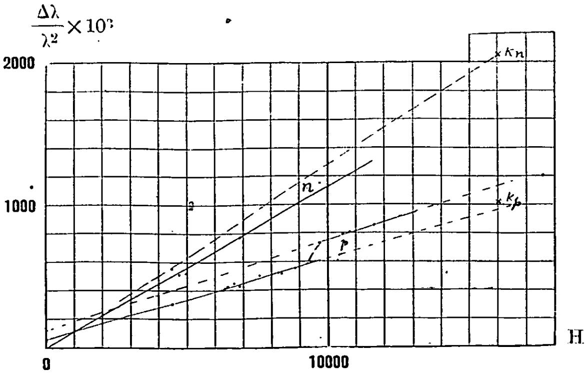

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Fig. 16.

$\lambda = 5397{\cdot}12$, $2p$-, $2n$-comps.

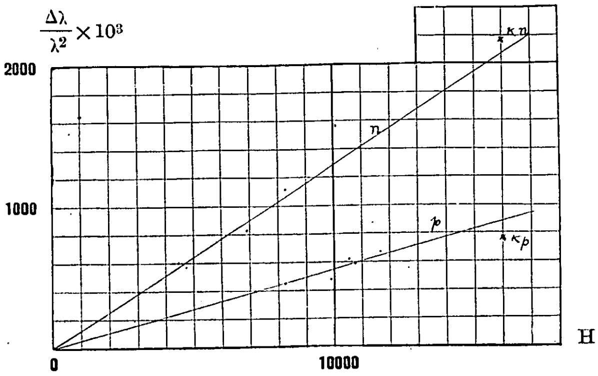

Fig. 17.

$\lambda = 5371{\cdot}495$, triple.

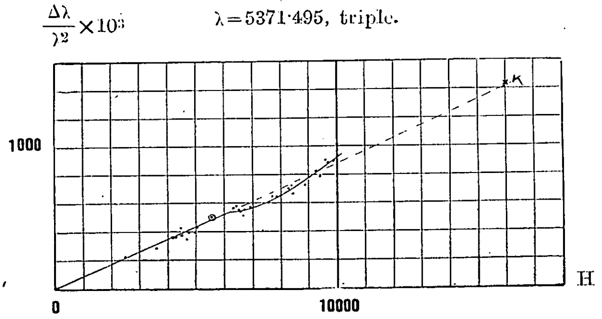

Fig. 18.

$\lambda = 5328{\cdot}06$, triple.

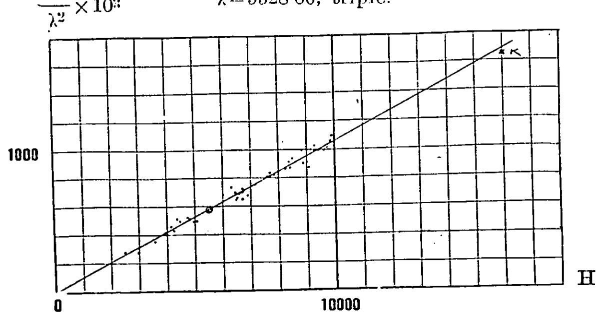

Fig. 19.

$\lambda = 5269{\cdot}53$, triple.

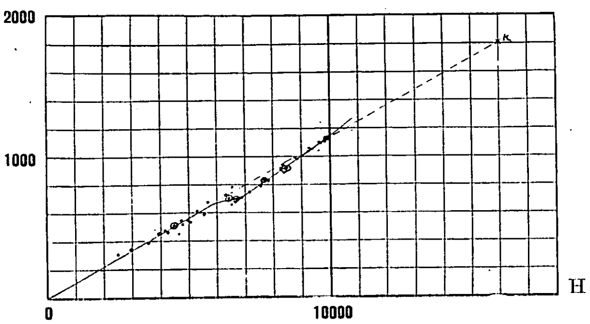

Fig. 20.

$\lambda = 5232{\cdot}957$, triple.

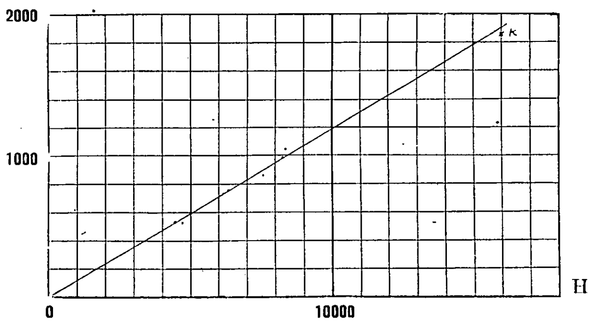

Fig. 21.

$\lambda = 5227{\cdot}20$, triple.

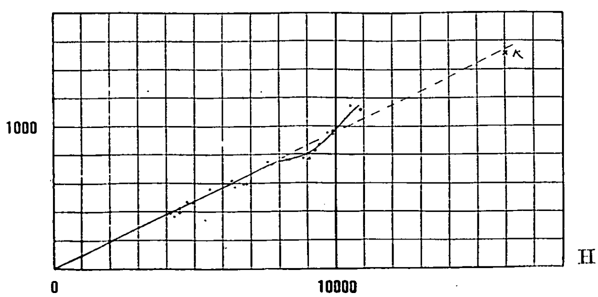

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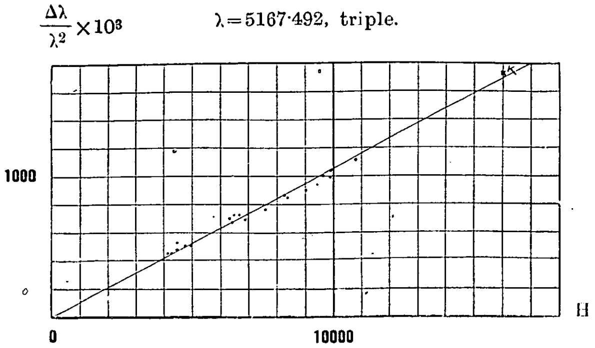
Fig. 22.



λ=5167·492, triple.

Fig. 23.

λ=5018·45, triple.

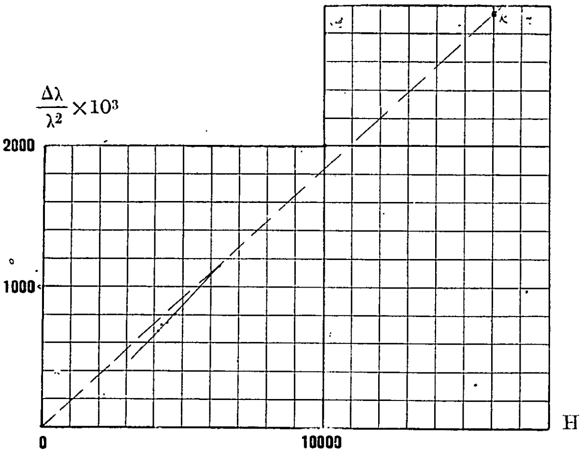


Fig. 24.

λ=4957·62, triple.

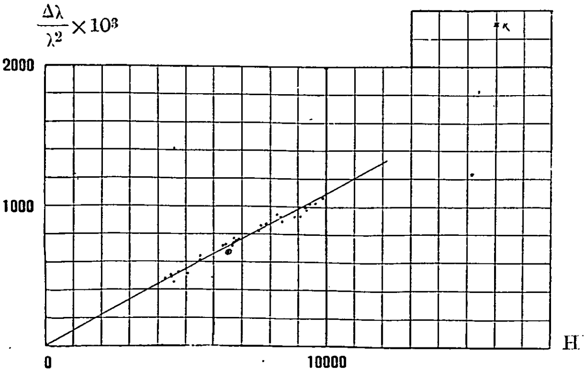
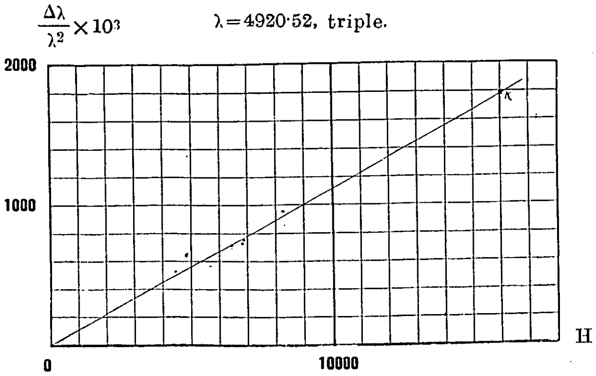
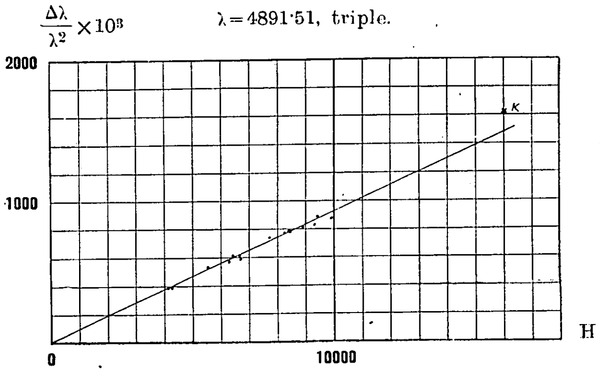


Fig. 25.



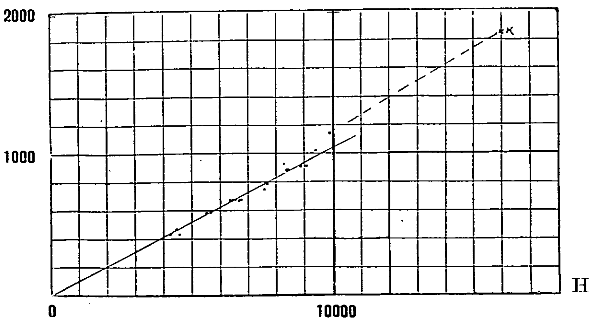
λ=4920·52, triple.

Fig. 26.



λ=4891·51, triple.

Fig. 27.



λ=4583·83, triple.

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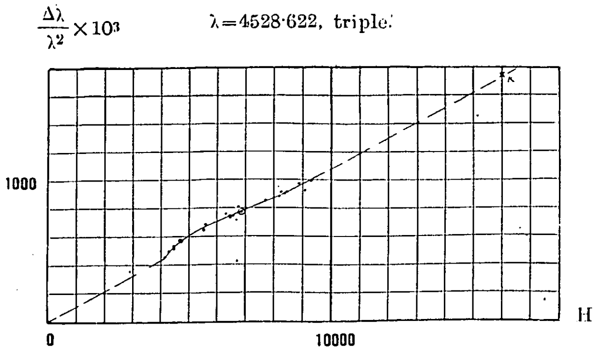
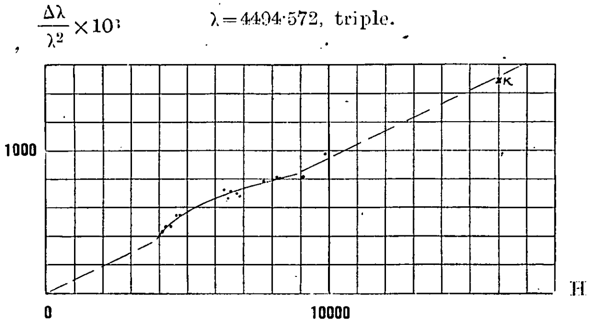
Fig. 28.



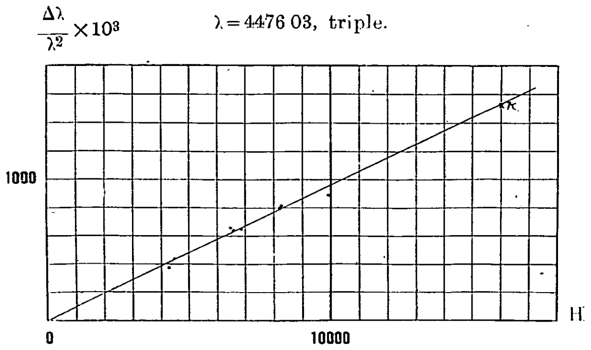
λ=4528·622, triple.

Fig. 29.



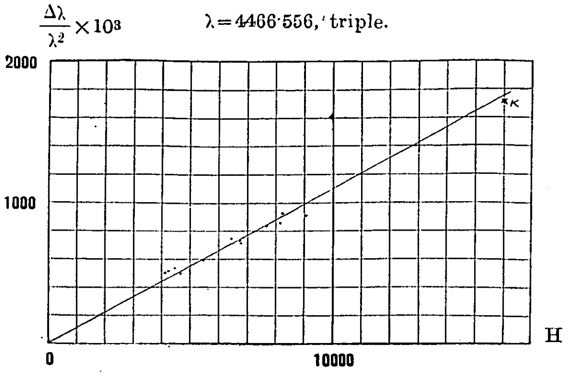
λ=4494·572, triple.

Fig. 30.



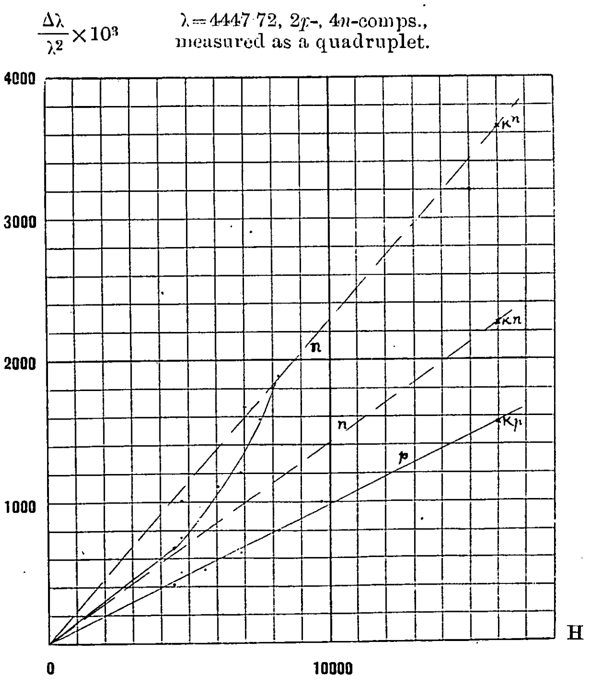
λ=4476·03, triple.

Fig. 31.



λ=4466·556, triple.

Fig. 32.



λ=4447·72, 2p-, 4n-comps., measured as a quadruplet.

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Fig. 33.

λ=4442·34. 2p-, 2n-comps.

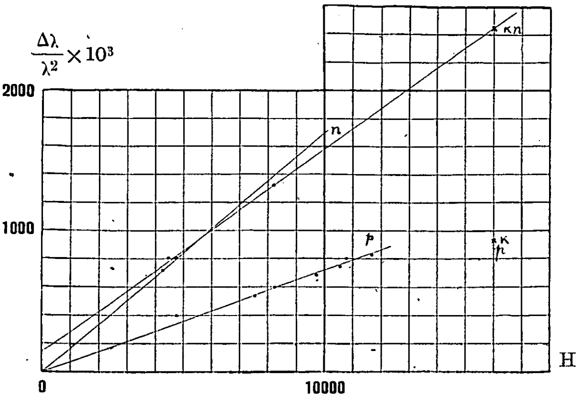

Fig. 34.

λ=4427·314, triple.

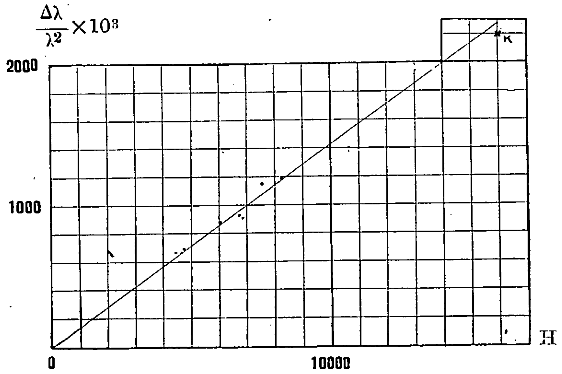

Fig. 35.

λ=4375·934, triple.

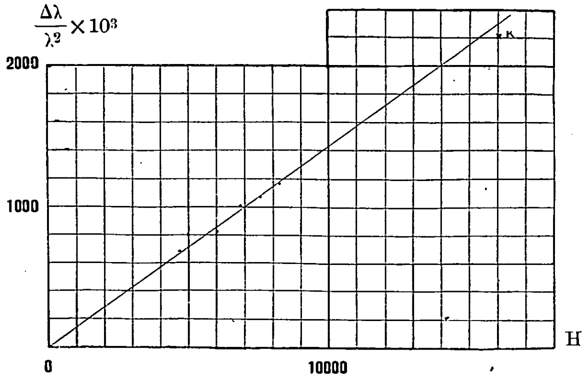

Fig. 36.

λ=4337·04, 2p-, 2n-comps.

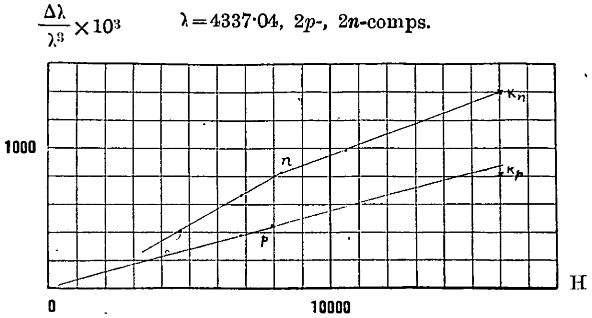

Fig. 37.

λ=4315·089, 2p-, 2n-comps.

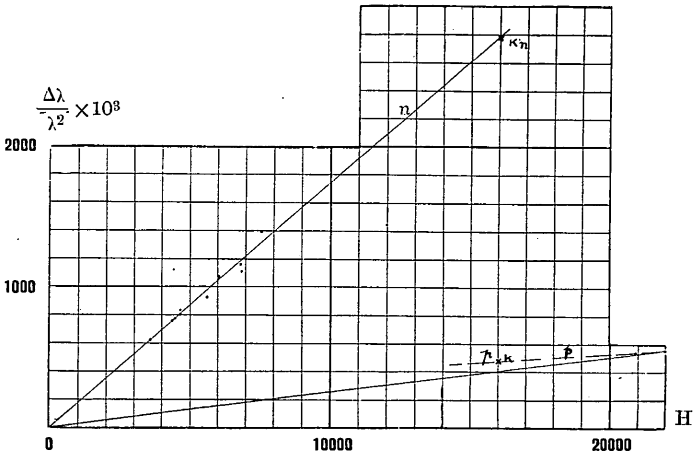

Fig. 38.

λ=4299·26, triple.

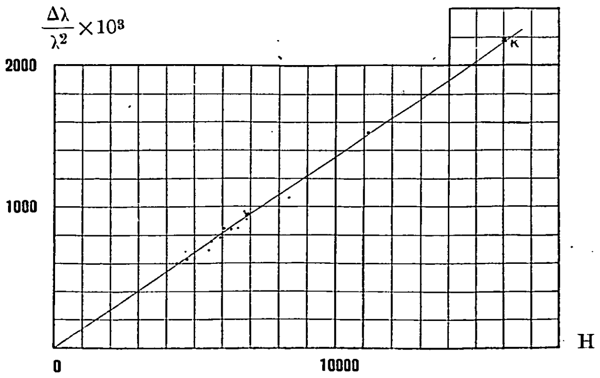

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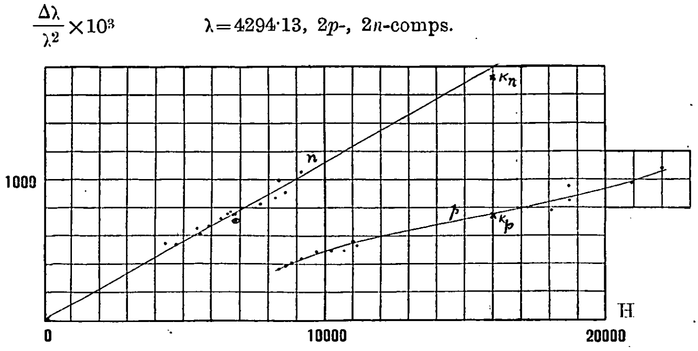
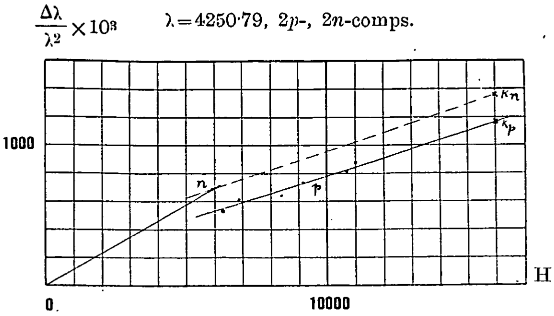
Fig. 39.



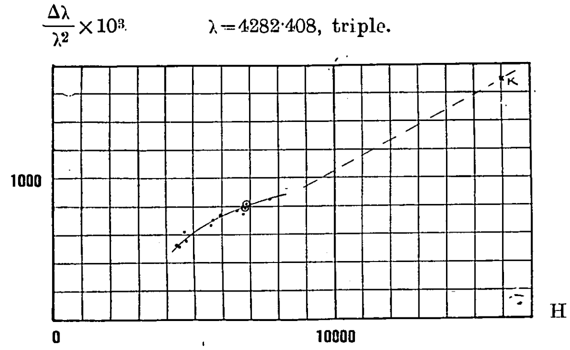
$\lambda=4294{\cdot}13$, $2p$-, $2n$-comps.

Fig. 42.



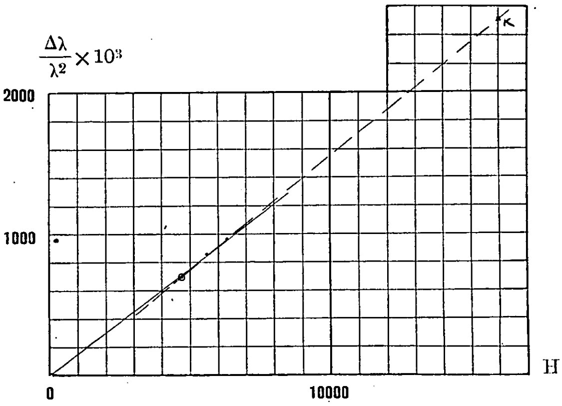
$\lambda=4250{\cdot}79$, $2p$-, $2n$-comps.

Fig. 40.



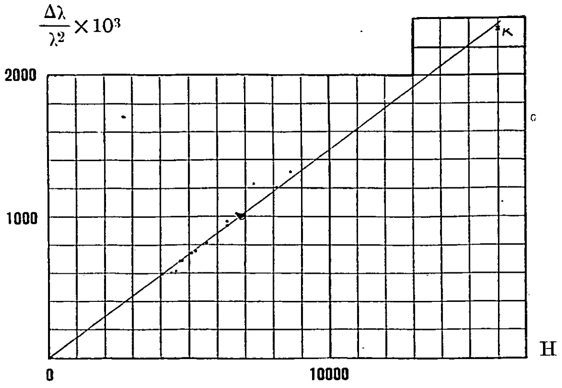
$\lambda=4282{\cdot}408$, triple.

Fig. 43.



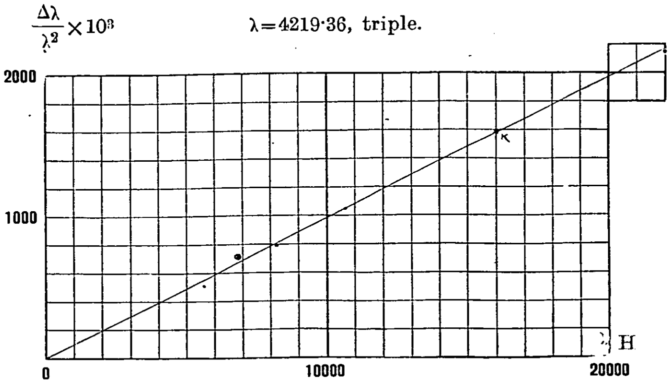
$\lambda=4235{\cdot}94$, triple.

Fig. 41.



$\lambda=4260{\cdot}48$, triple.

Fig. 44.



$\lambda=4219{\cdot}36$, triple.

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Fig. 45.

λ=4202·04, 2p-, 2n-comps.

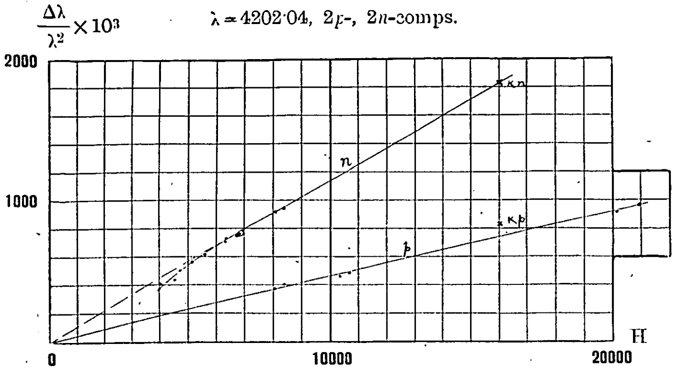

Fig. 48.

λ=4143·88, at least 3p-, 2n-comps.
The separation at 2196 gauss is not given in the figure.

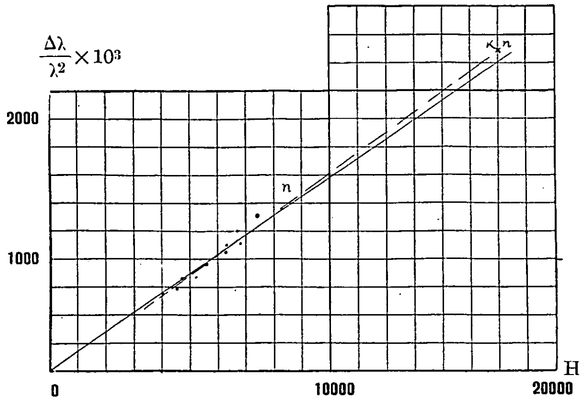

Fig. 46.

λ=4199·09, triple.

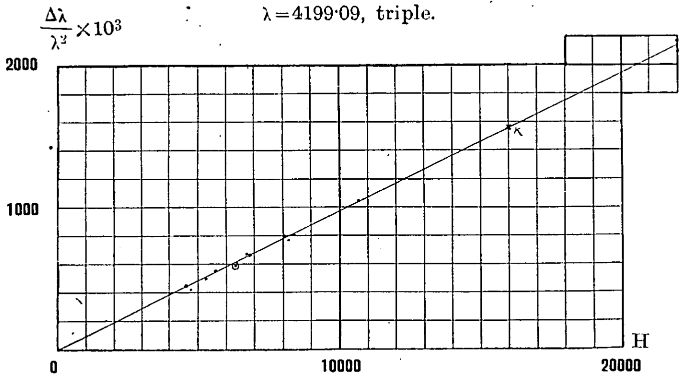

Fig. 47.

λ=4181·76, triple.

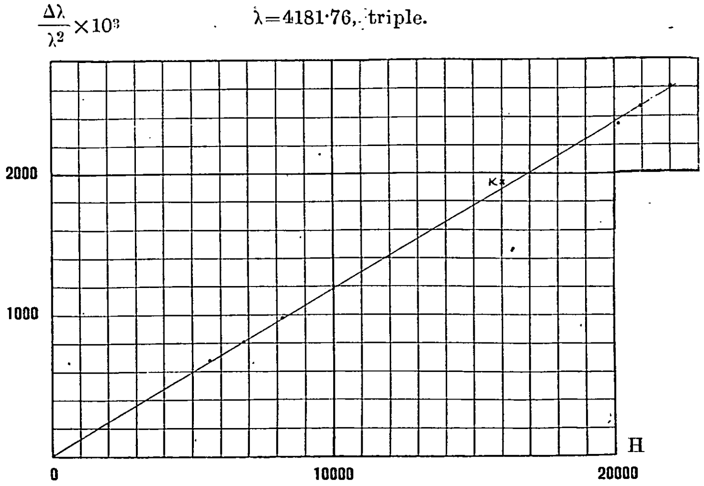

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Fig. 49.

λ=4132·08, at least 5p-, 4n-comps.

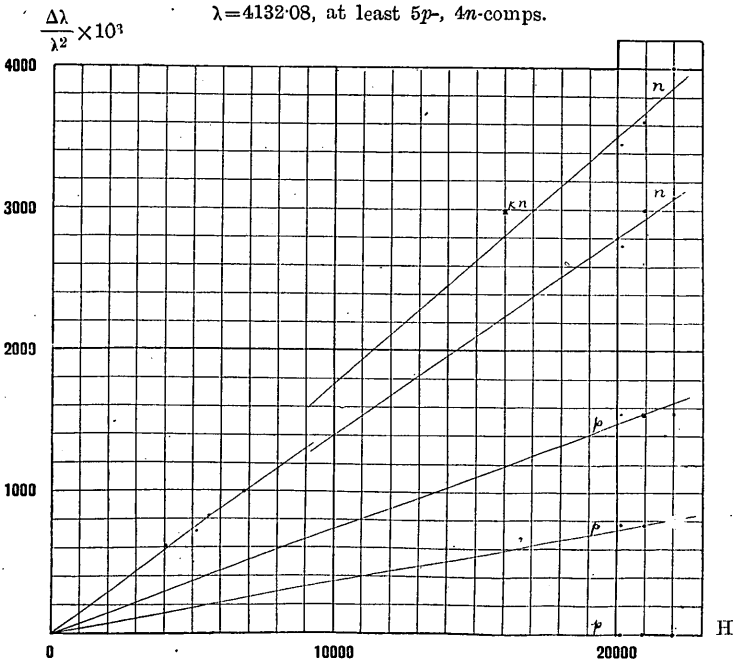


Fig. 50.

λ=4118·552, triple.

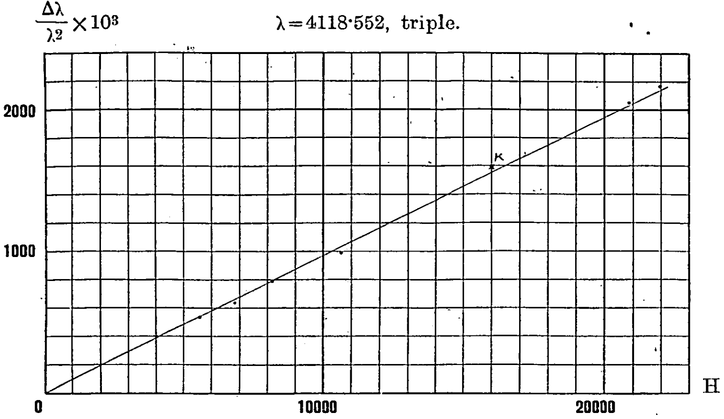


Fig. 52.

λ=4714·68 (Ni), triple.

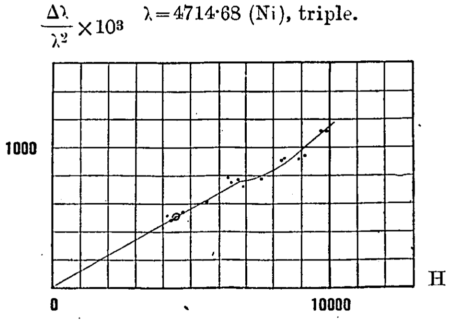


Fig. 51.

λ=5477·12 (Ni), triple.

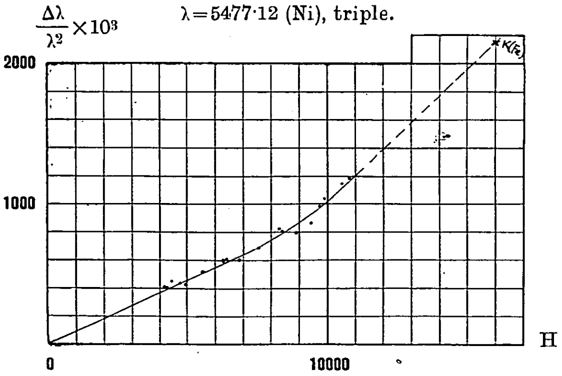
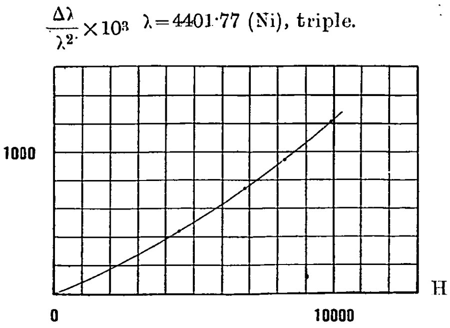


Fig. 53.

λ=4401·77 (Ni), triple.



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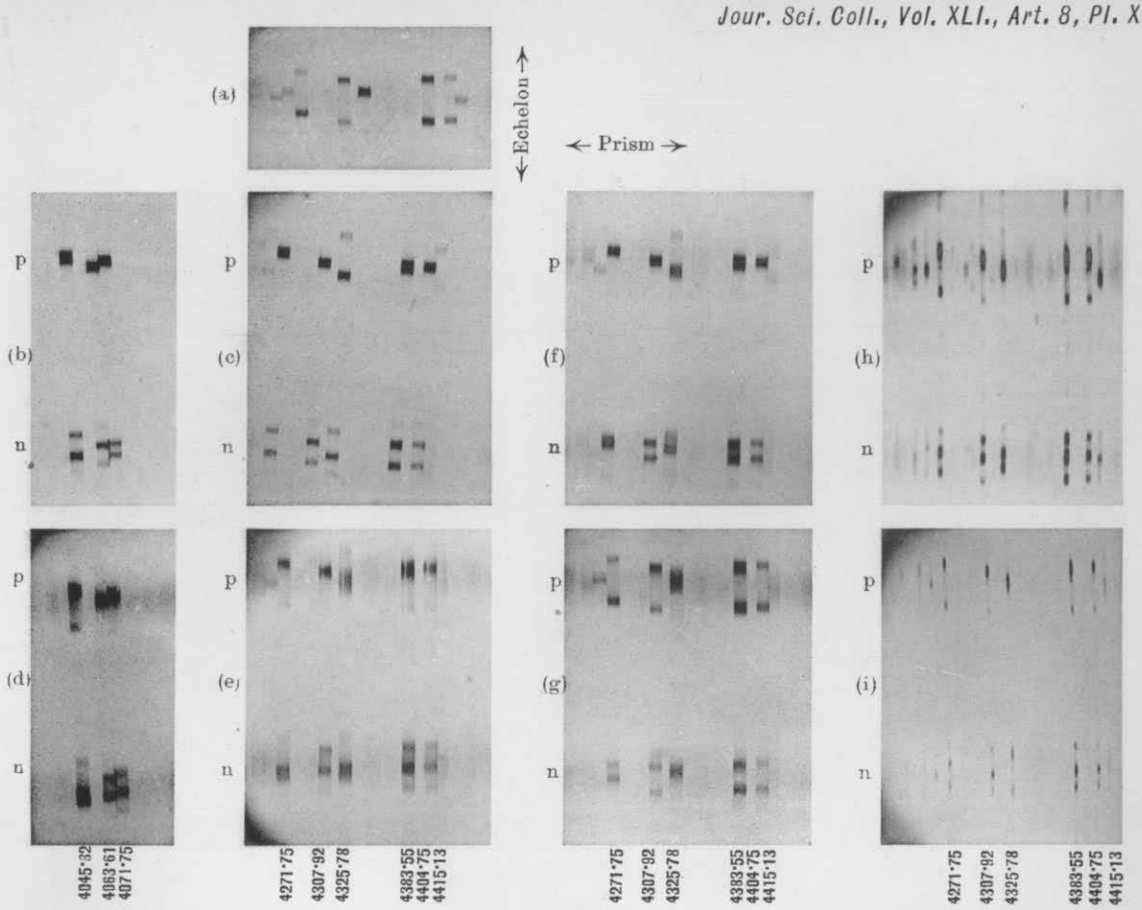
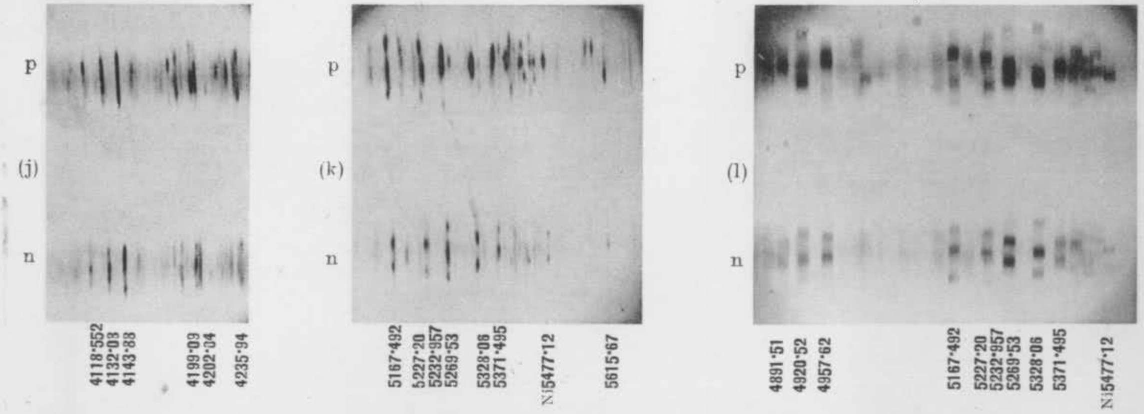


(a), $H=0$.
(b), (c), $H=7170$, each line is resolved into a sharp triplet.
(d), (e), $H=37230$, both p-and n-comps. of 4415·13 are resolved into 3 and 4 lines respectively. p-comp. of 4325·78 is fringed.
(f), $H=24040$, p-comp. of 4325·78 is diffuse.
(g), $H=35650$, both p-and n-comps. of 4415·13 are resolved. p-comp. of 4325·78 is diffuse.
(h), $H=6820$, both p-and n-comps. of 4415·13 are sharp.
(i), $H=20880$, ,, ,, ,, diffuse.



(j), $H=21960$, p-and n-comps. of 4143·88 and 4132·08 are resolved into many lines.
(k), $H=8230$.
(l), $H=6400$.

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