The Spark Spectrum of Nickel under Moderate Pressures

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XI. *The Spark Spectrum of Nickel under Moderate Pressures.*

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[PLATES 6–7.]

1. *Introductory.*

THE work of HUMPHREYS, DUFFIELD, GALE and ADAMS, ROSSI and others has shown that an increase of pressure round a source of light results in a general small displacement of the spectrum lines in the direction of longer wave-length, together with striking changes in the character of the lines themselves. Thus all lines have been found to broaden to a greater or less extent, either symmetrically or unsymmetrically, and many lines are reversed. In the present investigation the effect of pressures up to ten atmospheres above the normal atmospheric pressure, on the spark spectrum of nickel, has been studied with a view to obtaining accurate measurements of the displacements over that range of pressure which has been found to possess the greatest interest from an astrophysical standpoint. The chief problem which has to be considered in this connection is that of the pressure of the solar reversing layer. It is well known that wave-lengths of spectrum lines, determined from measurements in the solar absorption spectrum, exhibit small discrepancies when compared with the same lines derived from terrestrial sources. The solar wave-lengths are in general slightly greater than the terrestrial.

Ascribing the solar displacements to a difference of pressure, HUMPHREYS, MOHLER, and JEWELL* deduced a mean pressure of seven to eight atmospheres in the reversing layer. Later determinations of wave-lengths by FABRY and BUISSON† using the interferometric method have indicated a somewhat lower figure, namely five to six atmospheres.

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* 'Astrophysical Journal,' III. (1896), p. 138.

† 'Astrophysical Journal,' XXXI. (1910), p. 97.

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These conclusions have recently been strongly questioned by EVERSHED[*] who has deduced a zero pressure and ascribes the solar displacements to Döppler effects. The elucidation of the problem depends upon the comparison of the solar displacements with pressure displacements of comparable magnitude. It was felt, therefore, that a study of the effect of pressures up to about ten atmospheres above the normal was likely to yield the most useful results in relation to solar problems.

2. *Apparatus and Method.*

The Pressure-Chamber.—This was made from a T-shaped piece of steam-piping, 4 inches in external, and 2½ inches in internal diameter. The three limbs terminated in flanges to which the covers were bolted, leather washers being interposed to make the joints airtight. One of the electrodes was fixed in position and well insulated by means of a cylindrical block of ebonite. The other electrode was movable so that the spark-gap could be adjusted to any desired distance, by turning a nut attached to the outside of the cylinder. A thick leather collar acted as a substitute for a stuffing box and worked very satisfactorily under the pressures employed.

The vertical limb of the T was closed by a cover having a glass window 1 inch in diameter. The cover could be easily removed and replaced, and was always removed while the exposures on the normal spark at atmospheric pressure were being made. The apparatus was further provided with a safety valve and pressure-gauge, and the pressure was applied by means of a cylinder of compressed nitrogen. The nickel rods were cut from sheet nickel, and were held in clips attached to the electrodes. The pressure-chamber was supported in a horizontal position on a wooden stand provided with levelling-screws.

Method of Excitation.—In order to obtain a spark of sufficient brilliancy to keep the exposures within reasonable limits, a Resonance Transformer, designed by Mr. A. EAGLE, was used. A motor-alternator supplies an alternating E.M.F. of 50 cycles per second to the primary coil, at any desired voltage up to 200, and produces a potential difference up to about 100,000 volts at the spark-gap. A large adjustable parallel-plate condenser is connected in parallel with the secondary. Since the movable electrode was in metallic connection with the case of the pressure-chamber and the gas-holder the corresponding secondary terminal was carefully earthed. In air at atmospheric pressure a very brilliant spark is produced with a spark-gap of two or three millimetres. Under a pressure of eleven atmospheres a gap of about one millimetre gave the best results. The behaviour of the nickel spark under pressure displayed some points of interest. Although such a small spark-gap was employed, the spark was exceedingly brilliant and noticeably whiter in colour than the normal spark. The electrodes were rapidly disintegrated, and although the design of the

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[*] 'Kodaikanal Obs. Bulletin,' No. 36.

pressure-chamber was such that the window was seven inches from the spark-gap the window soon became clouded and had to be cleaned after each exposure. This effect was still more strongly marked when the nickel electrodes were replaced by others of a nickel-steel containing 25 per cent. of nickel.

The Spectrograph.—The 10 ft. 6 in. Rowland concave grating spectrograph in the Spectroscopic Laboratory of the Imperial College of Science and Technology was used for this work. The grating is mounted in the Littrow manner described by EAGLE.*

One of the greatest advantages of this method of mounting is that the whole apparatus is completely enclosed in a double-walled box, so that spurious shifts due to temperature variations are much less likely to give trouble than would be the case with the usual Rowland mounting. The importance of this feature in work involving the measurement of very small displacements will be sufficiently obvious.

The method of taking the photographs was as follows :—A horizontal spark was employed, as it was found that in this position the wandering of the spark seldom caused the image to leave the slit, thus effecting a considerable economy in the time of exposure. The astigmatism of the grating served to give sufficient length to the spectrum lines. In all the plates intended for measurement, the third order spectrum was employed, giving a linear dispersion of about 1·7 Å.U. per millimetre.

Each plate was exposed in three strips, the pressure spectrum being in the middle with a normal comparison spectrum just touching it on either side. One of the comparison spectra was photographed before the pressure spectrum and one after, so that temperature-shifts, if any, could be easily detected and allowed for. An iron arc spectrum was also photographed on the same plate for purposes of identification and for convenience in determining the dispersion-factor of the measuring apparatus.

The region investigated for purposes of measurement was included between λ 3450 and λ 4600, the exposures ranging from 5 to 20 minutes on Lumière ultra-rapid plates. The changes in the character of the lines have been investigated as far as λ 6100 in the first order.

3. *The Measuring Apparatus.*

A Hilger measuring-machine, of the usual type in which the microscope is driven forward by means of a finely cut screw, was employed. The ordinary eyepiece was, however, replaced by one in which the cross-wires could be made to travel across the field of view by means of a micrometer screw.

The arrangement of cross-wires is shown in fig. 1. Three parallel wires, a, b_1, b_2 are attached to the sliding frame, the two latter being at such a distance apart that the image of a line of average intensity nearly fills the space between them. The third wire a is about four times as far away and is only used when measurements are

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* 'Astrophysical Journal,' XXXI. (1910), p. 120.

being made on lines which reverse under pressure. The head of the micrometer screw is divided into 60 divisions, and whole turns are read off on the comb d.

In measuring displacements the following procedure was adopted. The micrometer was first adjusted so that the wires a, b_1, b_2 were at right angles to the direction of travel of the microscope. The plate was then placed on the stage of the measuring machine so that the line of separation of the pressure spectrum and one of the normal comparison spectra bisected the field of view, and so that the spectrum lines were parallel to the cross-wires. Having brought the line to be measured into the middle of the field of view, the final settings were made by means of the eye-piece micrometer. The normal and displaced lines were made to bisect the space between the wires b_1 and b_2 alternately, six settings being made on each. In the case of reversed lines greater precision is obtained by using a single thread. Consequently, in such cases, the wire a was brought into requisition, the normal line being measured as before. A constant difference is, of course, introduced corresponding to the distance in scale divisions between a and a line midway between b_1 and b_2.

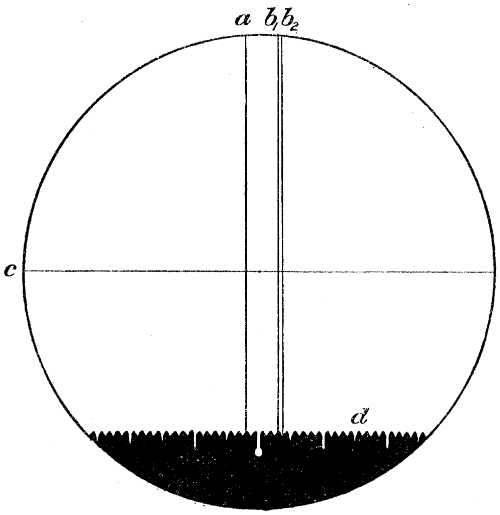

Fig. 1.

Determinations were made using each comparison spectrum and measuring in both directions. Four sets of readings were thus obtained from each plate. The mean displacement determined in this way had to be multiplied by a dispersion-factor to convert scale divisions into Ångström units. The factor was obtained by measuring the separation of suitable lines in the iron arc spectrum on the same plate, using Dr. K. BURNS' values for the wave-lengths. One division of the micrometer head corresponded to about 0·0027 Å.U., the factor varying slightly in different parts of the spectrum, being smaller towards the red. Readings were taken to tenths of a division, but the final results are only expressed to 0·001 Å.U. In the case of good lines the error is probably not more than two units in the third place of decimals.

It will be seen that the constant difference, say D, referred to above, does not affect the final result. Thus if d_1, d_2, d_3, d_4 are the means of the differences between the settings for the normal and displaced lines in the four positions, the corresponding shifts are given by

$$\left.\begin{aligned} s_1 &= d_1 - \mathrm{D} \\ s_2 &= d_2 - \mathrm{D} \end{aligned}\right\} \text{plate direct,}$$

$$\left.\begin{aligned} s_3 &= \mathrm{D} - d_3 \\ s_4 &= \mathrm{D} - d_4 \end{aligned}\right\} \text{plate reversed,}$$

whence the mean shift

$$= \frac{s_1+s_2+s_3+s_4}{4} = \tfrac{1}{4}\{(d_1+d_2)-(d_3+d_4)\}.$$

The value of D need not therefore be determined.

4. *Changes in Character of the Lines.*

One of the most obvious results of the increase of pressure is the very striking alteration which takes place in the character of the lines. A great variety of behaviour is to be observed, and it has been found convenient to divide the lines into five groups following the classification of GALE and ADAMS* :—

Class I.—Lines which reverse symmetrically.

Class II.—Lines which reverse unsymmetrically.

Class III.—Lines which remain bright and fairly narrow.

Class IV.—Lines which remain bright but are very much broadened symmetrically.

Class V.—Lines which become very much broadened unsymmetrically towards the red.

All the stronger arc lines of wave-length shorter than λ 3900 are included in classes I. and II., the majority being unsymmetrically reversed. In all cases in which the reversal is unsymmetrical, the reversal lies on the violet side of the middle of the emission line, at least so far as nickel lines are concerned. The same conclusion has been reached by DUFFIELD in the case of the iron arc. The rule does not appear to be universally true, however, for the K and H lines of calcium which appear on some plates as impurity lines, are unsymmetrically reversed in the opposite sense. The enhanced lines of nickel all belong to class IV. and exhibit no tendency to reverse.

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* 'Astrophysical Journal,' XXXV. (1912), p. 15.

For most of the lines of wave-length shorter than λ 3600 it is impossible to tell from examination of the eleven-atmosphere plates whether they belong to classes I. or II. The appearance of these lines under pressure is such that this region looks like a continuous spectrum crossed by absorption lines. On the six-atmosphere plates, however, the emission lines are visible.

Class V. displays the most striking features. The lines of this type become broad bands under pressure, with wings extending considerable distances towards the red. A width of ten to twenty Å.U. is not uncommon. A large proportion of the lines of wave-length greater than λ 4400 behave in this way, so that a curious fluted appearance is imparted to the spectrum. On some plates the strongest lines of class V. are faintly reversed, so that they qualify for class II. The appearance is, however, radically different from the ordinary members of that class.

In addition to the five well-defined classes described above, there is some indication of a sixth, analogous to the fifth, except that the winging extends towards the violet. The lines 4752·58 and 5035·55 appear to behave in this way.

5. *Modifications in Intensity.*

The radical changes in the appearance of the lines, produced by increase of pressure, make it a difficult matter to draw any conclusions with regard to changes of intensity. In the case of the stronger lines there seems to be very little alteration. An examination of the fainter lines, however, has yielded the following conclusions :—

(1) Enhanced lines are decreased in intensity. In some cases very little trace of the enhanced line is to be seen in the pressure-spectrum. This is particularly noticeable for a group of enhanced manganese impurity lines in the region λ 3400 to λ 3560. The strong nickel enhanced lines 3576·91 and 3769·62, however, are not greatly affected.

(2) Lines which are relatively stronger in the arc than in the spark are increased in intensity.

(3) Lines due to oxygen and nitrogen are completely eliminated. These results bear a striking analogy to the effects of including self-induction in an ordinary spark circuit. The general conclusion is that in the spark under pressure we get an approach to the arc condition.

The following lines are also greatly reduced under pressure: 3668·35, 3744·75, 4437·17, 4437·75. The line 4520·16 is notably strengthened.

6. *Results of Measurements.*

Two series of measurements have been made upon plates taken under total pressures of eleven and six atmospheres respectively. Those at the higher pressure are probably the more reliable. Since the absolute wave-lengths of the lines are not concerned in this work the numbers quoted are taken from the tables published by Exner and Haschek, and Hasselberg, and merely serve for purposes of identification. The wave-lengths are referred to Rowland's system.

Enhanced lines are indicated by the letter E.

Table I.

Wave-length.	Intensity.	Class.	+ 10 atmospheres.		+ 5 atmospheres.	
			$\Delta\lambda$ in $\frac{1}{1000}$ Å.U.	No. of plates.	$\Delta\lambda$ in $\frac{1}{1000}$ Å.U.	No. of plates.
3446·41	6	I.	17	1	—	—
3453·06	4	I.	13	1	—	—
3454·29 E.	2	IV.	15	1	—	—
3458·62	10	I.	18	1	—	—
3461·84	10	I.	25	1	—	—
3472·71	6	II.	14	1	—	—
3483·95	6	II.	15	1	—	—
3493·13	10	I.	15	1	—	—
3501·01	3	II.	15	1	—	—
3510·52	8	I.	22	1	17	1
3515·21	10	I.	27	1	14	1
3519·90	3	II.	19	1	10	1
3524·69	15	I.	30	1	14	1
3528·10	3	II.	18	1	—	—
3548·32	3	II.	21	2	25	1
3561·92	2	I.	11	2	—	—
3566·55	10	I.	20	2	15	1
3572·06	6	II.	18	2	12	1
3576·91 E.	6	IV.	82	1	51	1
3588·07	2	II.	14	2	—	—
3597·86	6	II.	21	3	—	—
3602·44	2	II.	16	3	—	—
3609·49	2	I.	16	3	—	—
3610·68	4	II.	26	3	13	1
3612·91	3	II.	16	3	14	1
3619·54	15	I.	18	2	13	1
3624·89	2	I.	7	3	—	—
3635·07	1	III.	51	2	—	—
3662·11	1	III.	35	2	—	—
3664·26	3	II.	22	3	18	1
3669·39	1	II.	12	3	—	—
3670·59	2	II.	25	3	—	—
3674·29	3	II.	19	2	13	2
3688·57	2	II.	20	3	—	—
3694·07	2	III.	25	3	—	—
3722·62	3	II.	29	3	—	—
3736·96	3	II.	10	3	—	—
3739·38	2	I.	10	2	—	—

TABLE I (continued).

Wave-length.	Intensity.	Class.	+ 10 atmospheres.		+ 5 atmospheres.	
			Δλ in $\frac{1}{1000}$ Å.U.	No. of plates.	Δλ in $\frac{1}{1000}$ Å.U.	No. of plates.
3769·62 E.	5	IV.	77	3	55	2
3775·74	5	II.	22	3	12	2
3783·67	5	I.	16	3	12	2
3807·29	7	II.	18	3	9	2
3831·87	2	I.	36	2	—	—
3849·70 E.	5	IV.	149	1	—	—
3858·50	8	I.	21	3	12	2
3889·80	3	IV.	—	—	—	—
3972·32	2	III.	28	1	28	1
3973·75	3	V.	58	1	82	1
4015·65	3	IV.	—	—	91	1
4121·48 ? Co.	2	III.	26	1	48	1
4142·47	1	III.	32	1	—	—
4288·20	5	V.	121	1	—	—
4331·83	4	III.	44	2	—	—
4359·76	2	III.	106	2	—	—
4401·77	6	V.	102	2	—	—
4459·25	6	V.	93	2	—	—
4462·65	3	V.	99	2	—	—
4470·70	6	V.	89	2	—	—
4592·76	5	V.	118	1	—	—

7. *Comparison with Previous Measurements.*

HUMPHREYS* has measured the displacements of ten nickel lines in the arc spectrum at pressures of $9\frac{3}{4}$, $12\frac{1}{2}$, and $14\frac{1}{2}$ atmospheres. The mean shifts per atmosphere of those lines which have also been measured at South Kensington have been calculated. The results are given in Table II.

TABLE II.

Wave-length.	Mean shift per atmosphere in $\frac{1}{1000}$ Å.U.	
	HUMPHREYS (Arc).	BILHAM (Spark).
3458·62	2·08	1·80
3461·84	1·74	2·50
3501·01	2·17	1·50
3515·21	2·67	2·75
3524·69	2·40	2·90
Means . .	2·21	2·29

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* 'Astrophysical Journal,' VI., p. 204.

A few iron lines occurring as impurity in the nickel have been measured with a view to comparing the shifts with the determinations of GALE and ADAMS, and of DUFFIELD.

The following results (Table III.) have been obtained for six lines particularly suitable for measurement.

TABLE III.

Wave-length.	Mean shift per atmosphere in $\frac{1}{1000}$ Å.U.		
	GALE and ADAMS (Arc).	DUFFIELD (Arc).	BILHAM (Spark).
* 4045·98	2·9	3·0	3·6
4063·76	2·5	2·5	3·2
4071·91	2·6	2·6	2·3
4308·08	2·6	2·1	4·3
4325·94	2·5	2·3	3·9
4383·72	3·4	2·3	4·2
Means . .	2·8	2·5	3·6

The mean of all DUFFIELD's values, set B,* has been taken, assuming proportionality of displacement to increase of pressure. The values in the second column have been obtained from GALE and ADAMS' main series of measurements at nine atmospheres.†

It will be observed that the values given in the last column are, on the average, higher than the other two. This is to be expected from the fact that all the lines referred to are reversed in the arc under eleven-atmospheres pressure, but bright in the spark under the present experimental conditions. It has been found‡ that if a line is reversed at a given pressure its shift is very much smaller than when it is unreversed.

8. *Classification of Shifts.*

As the measured lines belonging to each class are mostly comprised between somewhat narrow limits of wave-length, no attempt has been made to investigate the law of variation of displacement with wave-length. Consequently the shifts have not been reduced to a standard wave-length, which is desirable in discussing their relative magnitudes.

Some light is, however, thrown on this subject by averaging the shifts of lines belonging to the same class. The results are given in Table IV. The line 4121·48, doubtfully due to nickel, has been omitted in making the calculation.

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* 'Phil. Trans.,' A, vol. 208, p. 138.

† *Loc. cit.*, p. 17.

‡ DUFFIELD, *loc. cit.*, p. 155.

TABLE IV.

Class.	Number of lines.	Average shift in $\frac{1}{1000}$ Å.U. (11 atmospheres).	Ratios.
I.	17	18·9	1
II.	21	18·6	1
III.	7	45·9	2·4
IV.	4	80·8	4·3
V.	7	97·1	5·1

There appears to be some evidence that symmetrical and unsymmetrical reversed lines give the same average shifts. The ratios of the average shifts for the different classes are of interest in connection with the fact, first noted by HUMPHREYS, that for some metals the lines tended to form three groups in which the ratios of the pressure-shifts were approximately 1 : 2 : 4, when reduced to a standard wave-length. Later work has confirmed HUMPHREYS' view to a certain extent, notably in the case of the iron arc. The ratios, however, do not appear to be integral, and the grouping according to pressure-shifts is, to a great extent, independent of the classification according to behaviour. Under these circumstances it seems doubtful whether the phenomenon is anything more than a chance arrangement such as would follow from considering "small," "average," and "large" shifts. On the other hand, the relative shifts of lines whose behaviour justifies the supposition that they are of radically different types is a question of more direct interest, and the results are more likely to be capable of theoretical interpretation. Following out this view, and retaining our five original classes, we get the ratios in the last column of Table IV. Adopting a more general grouping by combining classes I. and II., IV. and V., we arrive at three main divisions, viz. :—

(*a*)	Reversed lines	38 lines
(*b*)	Unreversed lines (narrow)	7 ,,
(*c*)	Unreversed lines (broad)	11 ,,

giving the displacement ratios,

a.		*b.*		*c.*
1	:	2·4	:	4·6.

If we neglect the enhanced lines and consider only arc lines we obtain

a.		*b.*		*c.*
1	:	2·4	:	5·1

9. *The Apparent Violet Shift of the Line* 3514.

An interesting case is furnished by the line λ 3514·10. At eleven-atmospheres pressure this line appears as a very narrow reversal superimposed upon a broad bright line (see Plate 7, fig. 2c). Under the microscope the reversal shows a pronounced displacement towards the violet, amounting to 0·023 Å.U. at eleven atmospheres and 0·035 Å.U. at six atmospheres. As this was the only violet shift observed, further investigation seemed desirable. It was found that the spark line showed a displacement of 0·035 A.U. towards the red with respect to the corresponding line in the arc (Plate 7, fig. 1). This fact, and the anomalous behaviour under pressure, may be co-ordinated if we suppose that in the spark spectrum the line is really a doublet consisting of the arc line λ 3514·10 together with an enhanced line, the mean wave-length of the doublet being 3514·10 *plus* 0·035. Under pressure, we should expect the arc line to reverse and the enhanced line to broaden without reversal, a conclusion in entire agreement with the appearance actually observed. Moreover if the pressure displacement of the arc line was less than 0·035 Å.U., the reversal should exhibit a violet displacement with respect to the normal spark line. On this theory the arc line behaves in a perfectly normal fashion, giving a red displacement of 0·035 − ·023, *i.e.*, 0·012 Å.U. at eleven atmospheres.

10. *Abnormal Shift of Line* 3609.

A somewhat similar example is furnished by a line of wave-length 3609·02 in the arc (possibly due to iron). This line gives a very narrow reversal under pressure which shows an abnormally large shift (0·055 Å.U. at eleven atmospheres) towards the red. (Plate 7, fig. 4.)

A comparison of the arc and spark spectra (Plate 7, fig. 3) shows that the spark line is displaced towards the violet by 0·040 Å.U. with respect to the arc line.

Assuming as before that the spark line is really a doublet, the more refrangible component of which is, in this case, an enhanced line we get a true shift of 0·015 for the arc line, which is of about the right order.

11. *Qualitative Observations.*

A large number of lines have been investigated qualitatively with a view to observing their behaviour under pressure. In some cases, where the lines are very close together, such as in the doublet 4732·00 and 4732·66, it is impossible to examine the behaviour of the individual lines. Such groups have therefore been bracketed together and treated collectively.

TABLE V.

Wave-length.	Intensity.	Class.	Wave-length.	Intensity.	Class.
3467·63	2	II.	5035·55	7	[VI.]
3469·61	2	II.	5080·70	5	IV.
3471·50 E.	2	IV.	5081·30	5	
4067·20 E.	6	IV.	5099·50	3	V.
4520·16	2	III.	5100·13	3	
4547·16	2	V.	5115·55	6	V.
4600·58	3	IV.	5137·23	4	III.
4605·20	6	V.	5142·96	2	IV.
4648·89	8	V.	5146·64	4	IV.
4667·95	6	V.	5155·92	4	IV.
4686·41	4	III.	5168·83	4	IV.
4714·59	10	V.	5265·89	1	V.
4732·00	3	V.	5268·59	2	V.
4732·66	3		5371·64	4	V.
4752·58	3	[VI.]*	5411·50	2	IV.
4756·70	8	V.	5424·85	4	III.
4764·07	5	V.	5436·10	2	III.
4786·66	9	V.	5477·13	10	II.
4807·17	6	V.	5510·28	3	[VI.] ?
4829·18	3	V.	5578·98	2	III.
4831·30	3		5588·12	2	III.
4832·86	1		5592·44	4	V.
4855·57	6	IV.	5615·00	3	V.
4866·42	6	V.	5709·80	3	III.
4873·60	6	V.	5712·10	2	III.
4887·16	2	V.	5715·31	5	V.
4904·56	6	IV.	5748·57	1	III.
4918·53	6	V.	5754·86	4	III.
4936·02	4	V.	5761·10	3	V.
4953·34	4	V.	5805·45	2	IV.
4980·36	6	IV.	5858·03	3	IV.
4984·30	6	IV.	5893·13	3	III.
5017·75	6	V.	6116·34	4	III.

* Shaded to violet.

12. *Summary.*

1. The nickel spark spectrum has been investigated under pressures up to eleven atmospheres.

2. The lines exhibit a remarkable variety of behaviour and may be divided into five classes, according to their types of reversal or broadening.

3. With increase of pressure the enhanced lines decrease in intensity and broaden symmetrically.

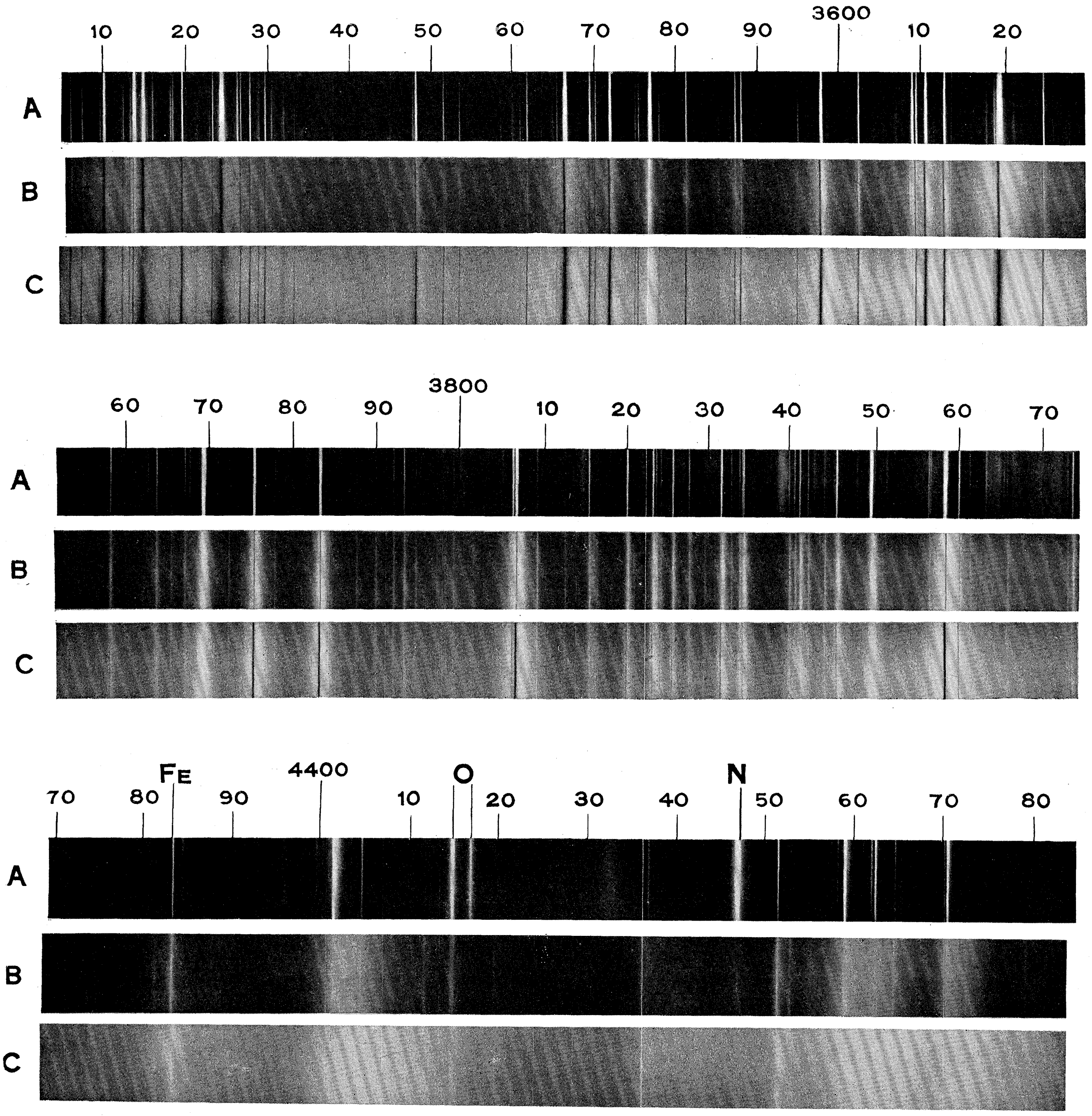
4. Gas lines disappear under pressure.

5. The general effect of pressure on the relative intensities of the lines is similar to that of including self-induction in a spark circuit.

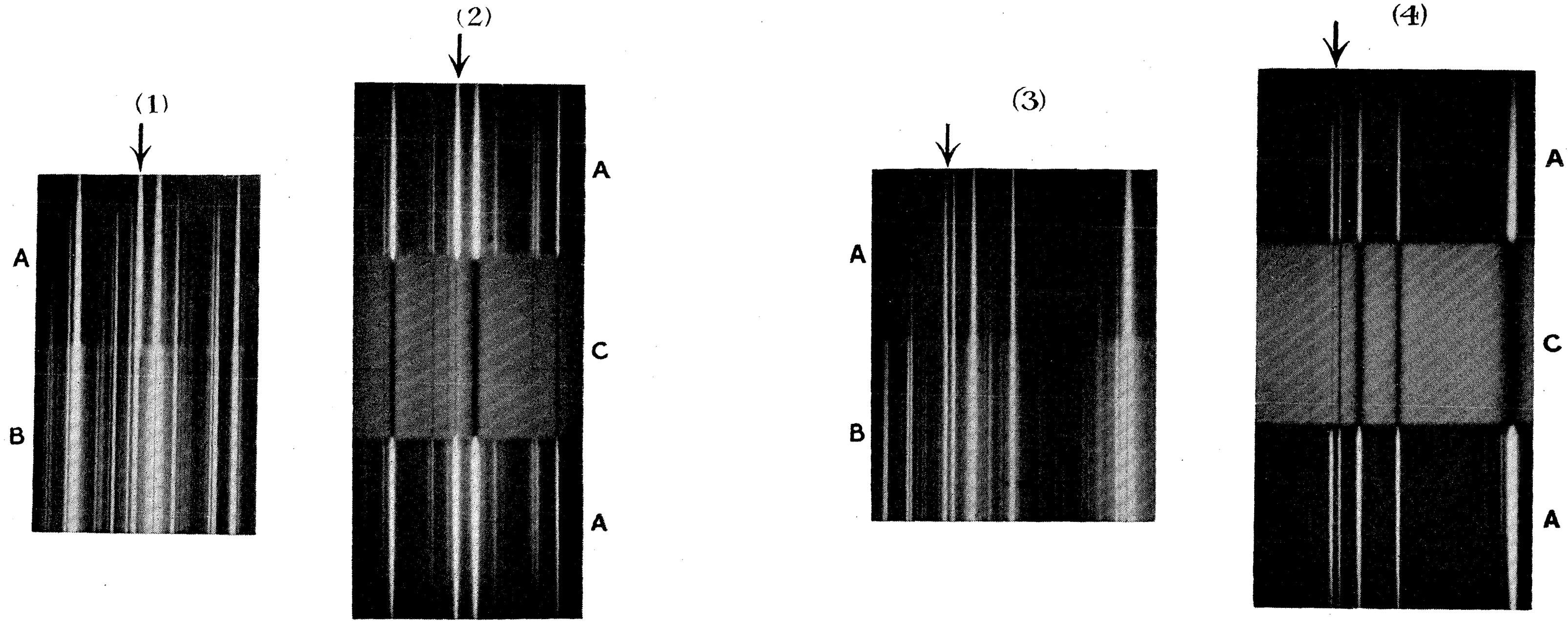
6. All lines are displaced towards the red end of the spectrum.

7. The average shifts are the same for symmetrical and unsymmetrical reversals.

NICKEL SPARK UNDER PRESSURE



A, PRESSURE 1 ATMOSPHERE,
B, PRESSURE 6 ATMOSPHERES,
C, PRESSURE 11 ATMOSPHERES.



ABNORMAL BEHAVIOUR OF LINES λ3514 AND λ3609 IN NICKEL SPARK UNDER PRESSURE.

8. The shifts are larger for unreversed than for reversed lines and are greatest for lines broadening unsymmetrically towards the red.

9. Certain abnormalities in the behaviour under pressure indicate the existence of enhanced lines, having wave-lengths 3514·14 and 3608·98 (approximately) almost coincident with two nickel arc lines.

In conclusion I wish to express my gratitude to Prof. A. FOWLER for his helpful interest in this research, and also to Mr. COLEBROOK, under whose supervision almost the whole of the apparatus was constructed in the workshops of the Imperial College.

DESCRIPTION OF PLATES.

Plate 6.

Changes in character of lines in the spark spectrum of nickel under pressure—

A. Pressure, 1 atmosphere.
B. ,, 6 atmospheres.
C. ,, 11 ,,

Plate 7.

Apparent violet displacement of λ 3514—

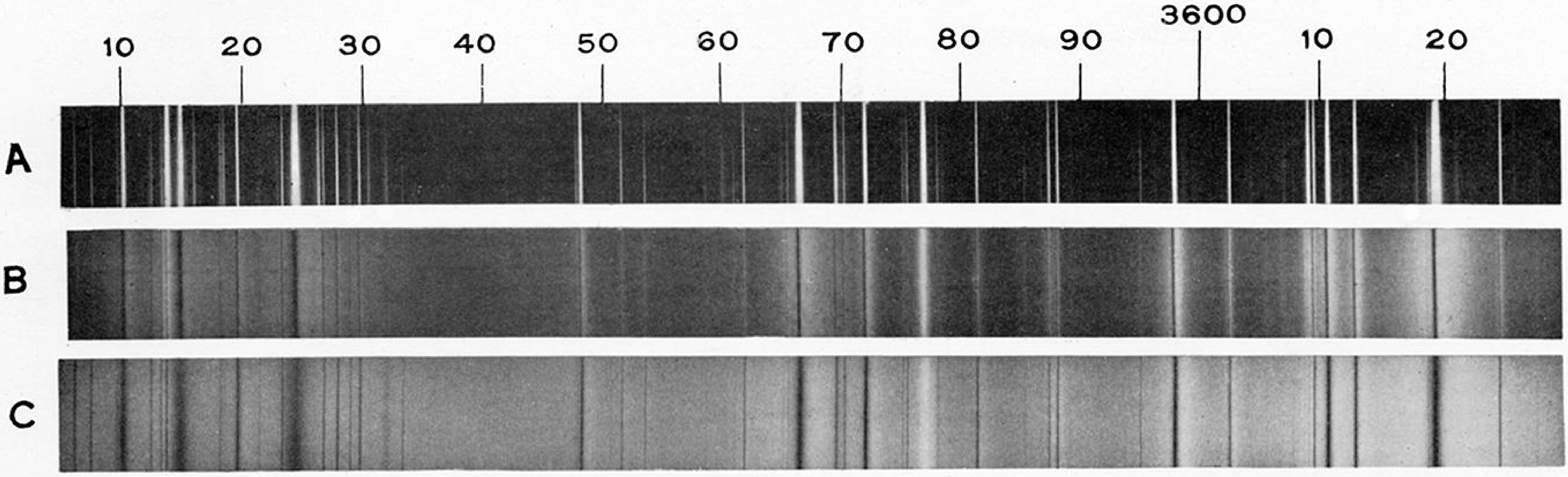
(1) Spark and arc comparison.	(2) Spark under pressure.
A. Spark.	A. Normal spark.
B. Arc.	C. Pressure, 11 atmospheres.

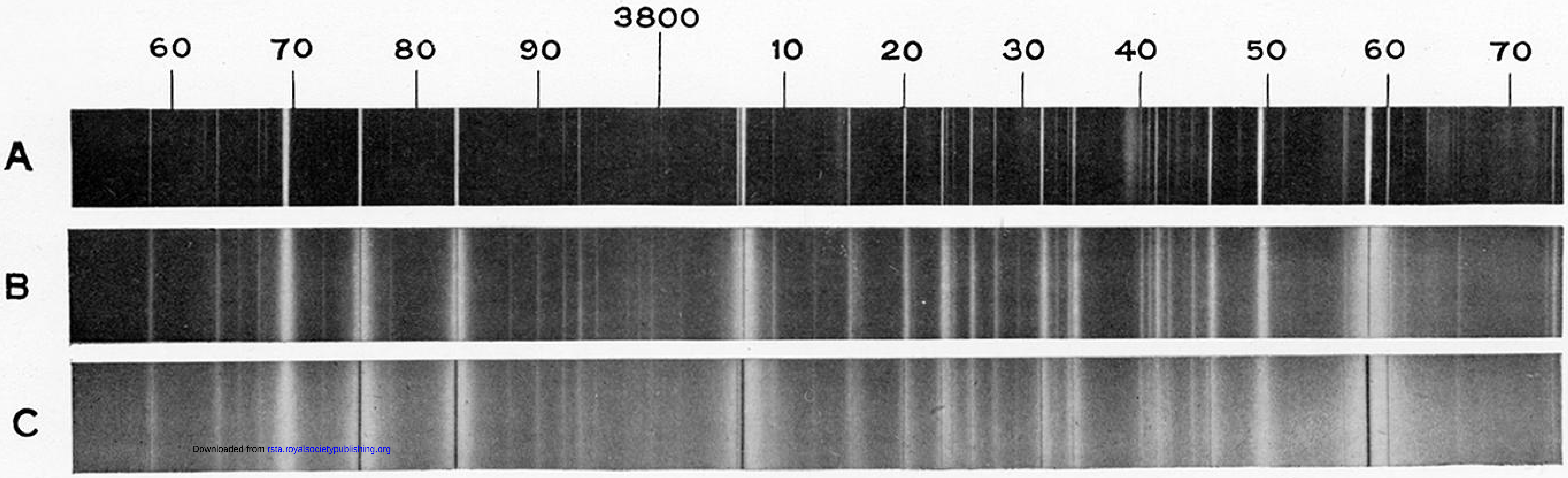
Abnormal shift of λ 3609.

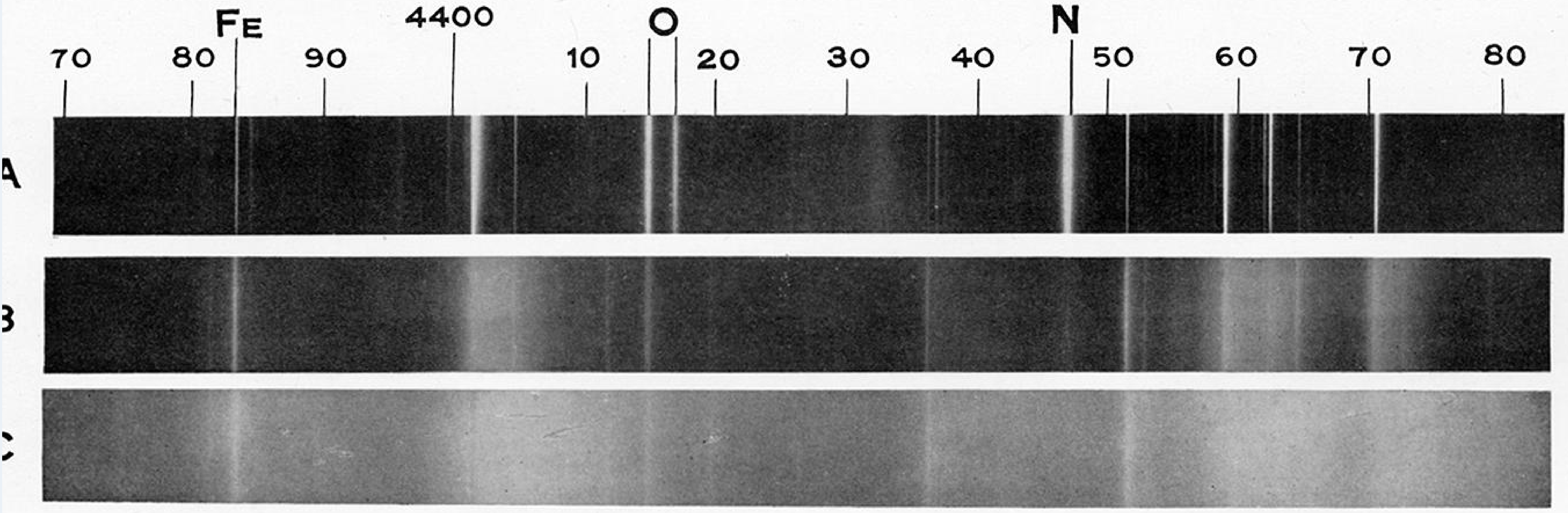
(3) Spark and arc comparison.	(4) Spark under pressure.
A. Spark.	A. Normal spark.
B. Arc.	C. Pressure, 11 atmospheres.

(Scale of reproduction :—1 mm. = 0·43 Å.U.)

NICKEL SPARK UNDER PRESSURE



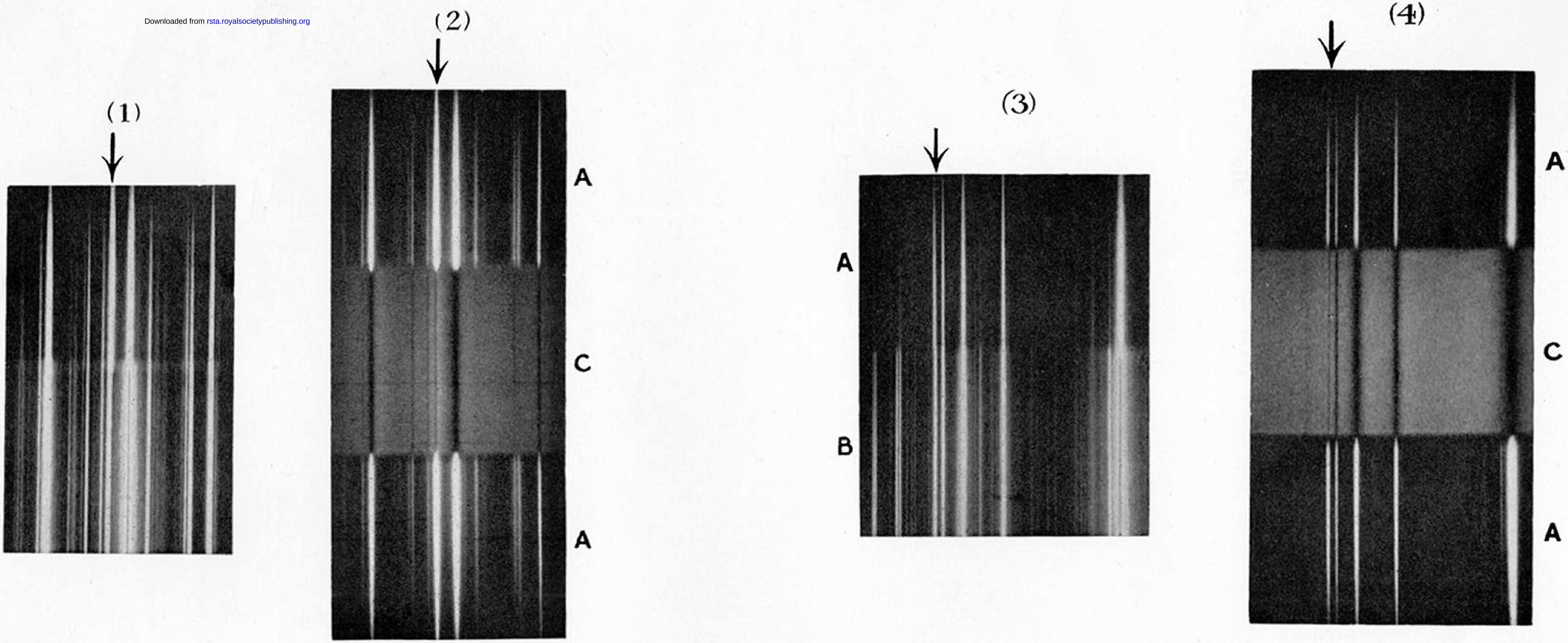




A, PRESSURE 1 ATMOSPHERE,

B, PRESSURE 6 ATMOSPHERES,

C, PRESSURE 11 ATMOSPHERES.



ABNORMAL BEHAVIOUR OF LINES λ 3514 AND λ 3609 IN NICKEL SPARK UNDER PRESSURE.