Self Reversal Lines of Lead in Explosion Spectrum and the Series Relations in Them.

By

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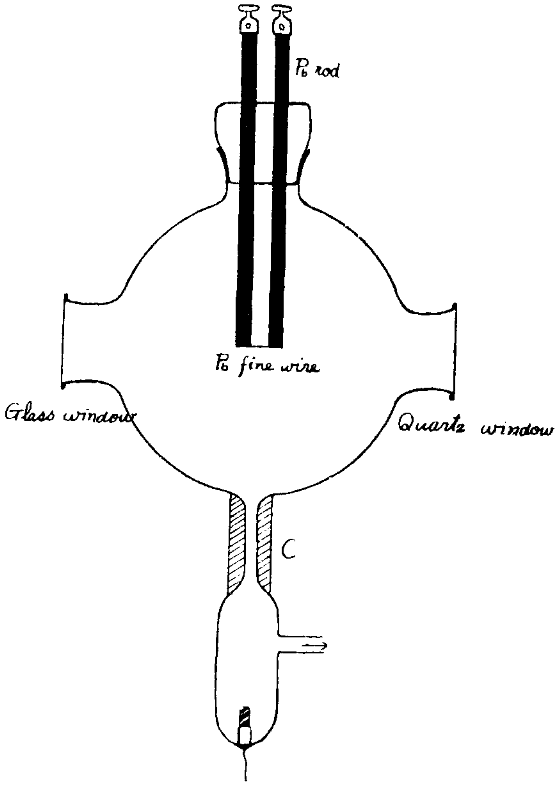
(Received November 25, 1925)

The method of exploding wire first employed by Anderson has opened a new field of research in spectroscopy. In his method, the current was supplied from a condenser of large capacity charged by a rectified current from a high tension transformer. The present author, instead of employing such a high tension source, exploded fine wires by short circuiting A. C. 110 or 200 volts circuits, and examined the light emitted at that instant. It was found that certain lines show self reversal. In the present paper the results obtained for lead are given.

As the source of the low tension cirucit, a 10 k W autotransformer giving a maximum voltage of 220 V, and a 5 k W 150 V. D. C. generator were used. The terminals of one of these circuits were directly connected to a fine lead wire to be exploded through a key, and the wire was exploded instantly by switching it. In order to study the influence of pressure and the nature of the surrounding gasses and vapours on the explosion spectrum, the wire was placed in a glass bulb as shown in Fig. 1, the pressure of the gas in the bulb being properly reduced by connecting the side tube C to a pump. This bulb has glass and quartz windows and the light emitted at the instant of explosion was photographed simultaneously through glass and quartz spectrographs. The former instrument has one constant deviation prism for the dispersing system, and the photograph was taken by a 21 inch focus camera, and the latter is a small quartz spectrograph made by Hilger.

When a fine lead wire having a diameter of about 0 75 mm. and a length of 3 cm. was exploded in air at one atmosphere by sending the

Fig. 1.



current from a 220-volt A. C. circuit, a number of lines lying especially in the ultra-violet region showed a clear reversal, this is seen in the photograph reproduced in Fig. 2, Pl. I. But when the air pressure was reduced, the reversed lines got gradually sharper and then changed to fine emission lines at a pressure of less than 10 cm. Thus by changing the pressure of the surrounding atmosphere the order with which the lines show self-reversal could be studied. Photographs given in Fig. 3, Pl. II show the series of spectra taken at the pressures of 76, 40, 30, 10, and 5 cm. Consequently the self-reversed lines were classified into groups as shown in the accompanying tables. Table I gives the lines reversed in the explosion spectrum taken at the pressure of 10 cm. Table II the ones reversed in the explosion at 30 cm. pressure, and Table III the list of such lines in the spectrum of explosion taken at one atmospheric pressure.

Thus we see that in the light from explosions taking place in air at one atmospheric pressure all the lines of diffuse series and some of sharp series were found to be reversed.

The above tables show further that the lines relating to the $2p_4$ term first reversed and the reversal proceeded to those relating to the $2p_3$ and then to the $2p_2$ term. This is quite in harmony with the results obtained by Grotrian[1] and also by Kimura[2]. Among the lines relating to the $2p_1$ term, the reversal of the line λ 2833 ($2p_1-2s$) was observed more easily than that of the line λ 2170 ($2p_1-3d_2$) while the width of the reversed line was much greater in the latter case than in the former, and of those ralating to the $2p_3$ term, the lines $\lambda\lambda$ 2614 ($2p_3-3d_2$), 2246 ($2p_3-4d_2$), 2115 ($2p_3-5d_2$) reversed before the lines $\lambda\lambda$ 2657 ($2p_3-3d_3$), 2257·5 ($2p_3-4d_1$), 2476·5 ($2p_3-X_2$) 2402 ($2p_3-X_1$) and λ 2446 ($2p_3-3s$) showed the phenomena.

The most easily reversed line relating to the $2p_2$ term is λ 2802 ($2p_2-3d_1$), the next ones are $\lambda\lambda$ 2663 ($2p_2-X_2$), 2577 $2p_2-X_1$), 2873 ($2p_2-3d_3$), 2412 ($2p_2-4d_3$) while the reversal of $\lambda\lambda$ 2823 ($2p_2-3d_2$), 2399·7 ($2p_2-4d_2$), 2628 ($2p_2-3s$), 2333 ($2p_2-4s$) took place after all the above lines were reversed. The non-series lines $\lambda\lambda$ 2394, 2088, 2059 reversed at the same stage as the lines relating to the $2p_3$ term, but those of the $2p_2$ term remained unreversed.

It was difficult to observe the reversals of the lines $2p_5-2s$, $2p_3-2s$, $2p_2-2s$ in the plate taken by the small quartz spectrograph when the explosion took place in the atmosphere, but they were found to be reversed when the explosion took place in a stream of a hot steam, or in an electric field of the strength of about 40 k V/cm. in air at one atmosphere. The reversal of the line 4058 ($2p_2-2s$) is easily observed on the plate taken by the constant deviation prism system and those of the line $2p_5-2s$, $2p_3-2s$, are observed on the plates taken by spectrographs of larger type even when the explosion took place in air.

None of the lines relating to the $2p_1$ term could be reversed in our experiment.

It is here to be remarked that the reversed lines belonging to sharp series accompany emission lines on the red side of the reversed ones.

Lastly it is desirable to notice that the line λ 2203·5 reversed in our spectrograms. According to Steinhausen this is one of the enhanced lines of lead. Quite recently Mclennan expressed the wave number of this line as the difference of arc terms as $2p_5-4s$. In our explosion spectrum reversal of this line first appeared in such a stage that lines relating to $2p_3$ reversed but those relating to $2p_2$ did not. If the line reversed by our

1 Zeits. f. Physik, **18**, 3 (1923).

2 Prof. M. Kimura's results are not yet published.

experiments be really a spark line, this is the one of the spark lines reversed most easily and this should be one of the chief lines emitted by Pb^{+}.

DISCUSSION OF THE EFFECT OF PRESSURE ON THE EXPLOSION SPECTRUM.

The broadening of the emssion as well as of the absorption lines in the explosion spectra resemble the Stark effects. The widths of the reversals of the lines $2p_3 - md_2$ increase with the term number. A Similar aspect is also observed for the diffuse series in the explosion spectrum of Al.

It may be interesting to mention here that in the explosion spectra many spark lines are observed and that in some cases they are intense and broadened while the arc lines are very feeble and sharp compared with them (Fig. 4, PL. I), and moreover that the spark line λ 2203·5 A represents strong white reversals in the broadening black back ground.

Thus we see that at the instant of explosion the great majority of metallic atoms are in an ionized state and that therefore the interatomic electric field is great enough to affect the widths of the emission and absorption lines.

The stages of the reversals found by us may be taken to represent the stages of the interatomic electric field intensity in the aggregation of the ionized vapour produced by sudden heating.

If this consideration be correct, the effects of pressure on our stages would be due to the rapidity of the expansion of the ionized vapour.

If the pressure be low the vapour which is produced by sudden heating rapidly expands to the surrounding space. and gives the vapour later produced sufficient space to come and keeping the density relatively low. The mean distances of the atoms are then sufficiently great and the interatomic electric field will be too weak to affect the widths of the lines, which results in the sharpness of the emitted lines and also in the disappearance of the reversals.

As the pressure of the surrounding gases increases the rapidity of the expansion of the evaporated vapour decreases and therefore all the evaporated atoms at successive times aggregate in a tolerably small space, their emitting and absorbing conditions being affected by their interatomic electric field.

In conclusion, the author wishes to express his cordial thanks to Prof. M. Kimura who kindly gave much valuable advices and shewed great interest throughout this work.

The author's thanks are due also to the members of the physical department of Kyoto Imperial University and the director of Konan College for their kind permission to work in the laboratories under their care.

Table I.

Reversal appearing at the 1st stage
(Explosion took place at the air press. of 10 cm.)

λ	Thorson–Grotrian's Series	Nature of the Reversal	Order of Reversal
2833·2	$2p_4-2s$	Easily seen reversed.	1
$26^{14\cdot3}_{13\cdot7}$	$2p_3-3d_2$	Faint	2_1
2393·9	?	Very faint (in some plates shows no reversal)	2_2
2247·0	$2p_3-4d_2$	Faint	2_1
2170·0	$2p_4-3d_2$	Easily seen reversed	1

Table II.

Reversal appearing at the 2nd stage
(Explosion took place at the air press. of 30 cm.)

λ	Thorsen–Grotrian's Series	Nature of the Reversal	Order of Reversal
2833·2	$2p_4-2s$	Clear Reversal	1
2802·1	$2p_2-3d_1$	Reversed	3
$26^{14\cdot3}_{13\cdot7}$	$2p_3-3d_2$	Clear	2_1
2393·9	?	〃	2_2
2247·0	$2p_3-4d_2$	〃	2_1
2203·5	Spark Line	Reversed	3
2170·0	$2p_4-3d_2$	Clear	1

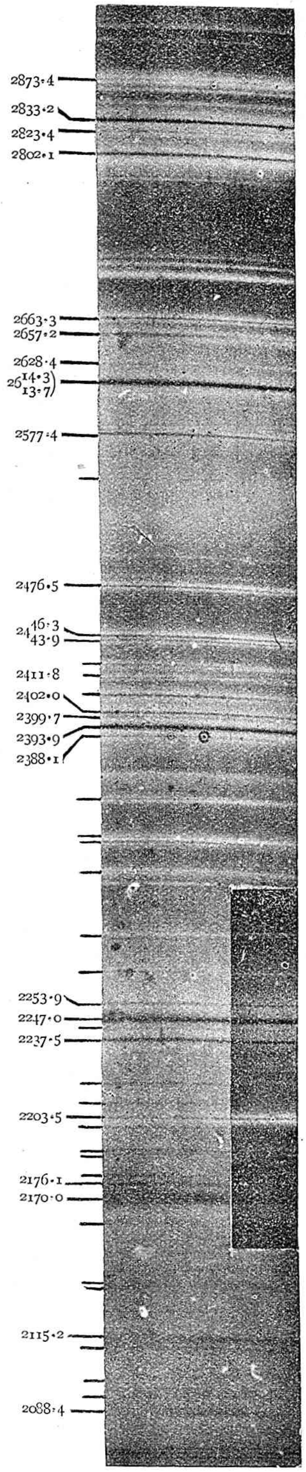
Table III.

Reversal appearing at the 3rd stage
(Explosion took place at pressure of one atmosphere)

λ	Thorsen–Grotrian's Series	Nature of the Reversal	Order of Reversal
4058·0	$2p_2-2s$	Clear Reversal on the plate taken by const. deviation prism spectrograph	
3683·6	$2p_5-2s$		
3639·7	$2p_3-2s$	Reversed when the explosion took place in electric field or in steam of hot steam	
2873·4	$2p_2-3d_3$	Reversed	4
2833·2	$2p_4-2s$	Clear	1
2823·4	$2p_2-3d_2$	Reversed	4
2802·1	$2p_2-3d_1$	Clear	3
2663·3	$2p_2-X_2$	Reversed	4
2657·2	$2p_3-3d_3$	Reversed	4

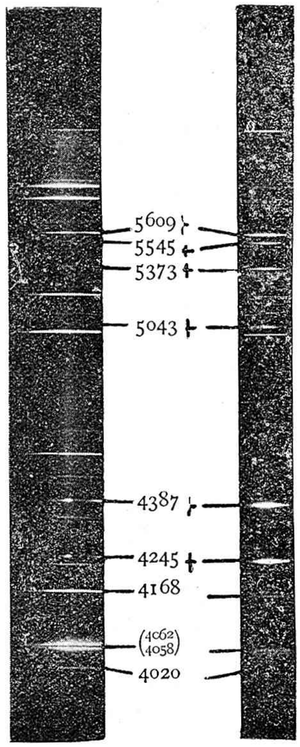
λ	Thorsen-Grotrian's Series	Nature of the Reversal	Order of Reversal
2628·4	$2p_2-3s$	Very faint (Emission appears on the red side of the reversal)	5
2614·3	$2p_3-3d_2$	Clear	2_1
2577·4	$2p_2-X_1$	Reversed	4
2476·5	$2p_3-X_2$	Reversed	4
2446·3	$2p_3-3s$	Very faint (Emission red side)	4
2443·9		Reversed	4
2411·8	$2p_2-4d_3$	Reversed	4
2402·0	$2p_3-X_1$	Reversed	4
2399·7	$2p_2-4d_2$	Faint	5
——	——	Faint	
2393·9	?	Clear	2_2
2388·1	$2p_2-4d_1$	Faint	5
2332·5	$2p_2-4s$	Reversed (Emission red side)	4
2254·0	$2p_2-5d_3(2p_5-4d_1)$	Reversed	4
2249·0	$2p_3-4d_2$	Clear	2_1
2237·5	$2p_3-4d_1$	Reversed	4
2218·7	$2p_2-5s$	Faint (Emission red side)	5
2203·5	Spark line($2p_5-4s$)	Clear	3
2200·0	?	Faint	5
2190·1	($2p_3-4s$?)	Faint (Emission red side)	5
2185·5	?	Faint	5
2181·3	?	Faint	5
2179·5	$2p_2-6d_3$	Faint	5
2176·1	$2p_2-6d_1$	Faint	5
2170·6	$2p_1-3d_2$	Clear	1 ?
2141·0	?	Faint	5
2138·0	$2p_2-7d_3$	Faint	5
2135·5	$2p_2-7d_1$	Faint	5
2115·1	$2p_3-5d_2$	Clear	2 ?
2112·0		Faint	?
2094·0	?	Faint	?
2088·4	?	Clear	2 ?
2059·5	?	Clear	2 ?
2053·2	$2p_1-3s$	Faint	?
2050·8	$2p_3-6d_2$	Faint	?

PL. I.



Self Reversal Lines of Lead in the Explosion Spectrum in one Atmospheric Pressure of Air.

Fig. 2.



Explosion Spectrum of Lead. II. (Visible Region)

Fig. 4.

PL. II.

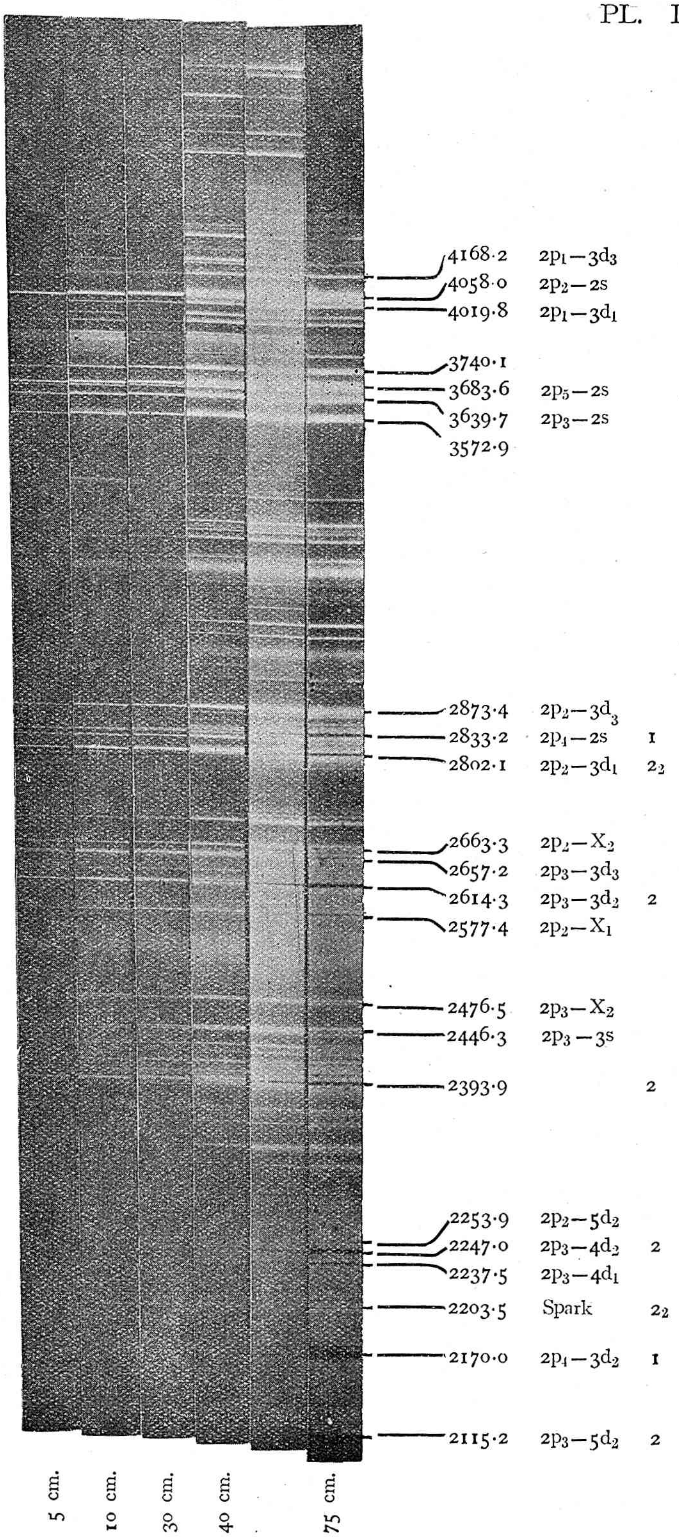


Fig. 3.

Explosion Spectrum of Pb at various Stages.