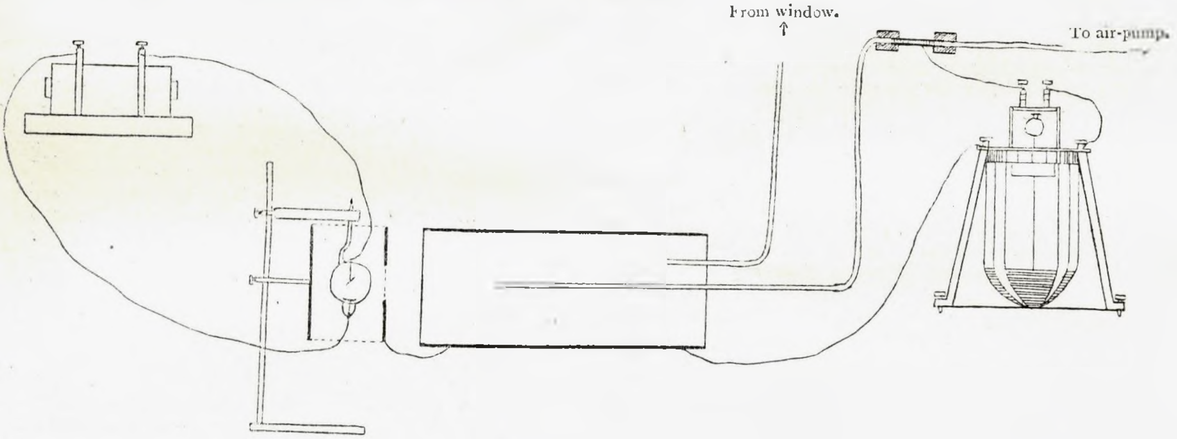
heard of the cultivation of woad, *Isatis tinctoria*; but "wood-wax" (? woad-wax), *Genista tinctoria*, which grows plentifully in that neighbourhood in pastures on marly soil, used to be collected by the peasant-women for dyeing purposes at the cloth factories in Trowbridge. The plant being very tough to pull up, "wood-waxing" was very laborious work. I am not aware whether it is still carried on there.

Croydon, December 16. H. FRANKLIN PARSONS.

ELECTRIFICATION OF AIR BY RÖNTGEN RAYS.[1]

TO test whether or not the Röntgen rays have any electrifying effect on air, the following arrangement was made.

A lead cylinder 76 cms. long, 23 cms. diameter, was constructed; and both ends were closed with paraffined cardboard, transparent to the Röntgen rays. Outside the end distant from the electrometer (see diagram) a Röntgen lamp[2] was placed. In the other end two holes were made, one in the middle, through which passed a glass tube (referred to below as suction pipe) of sufficient length to allow the end in the lead cylinder to be put into any desired place in the cylinder. By means of this, air was drawn through an electric filter[3] by an air pump. The other hole, at a little distance from the centre, contained a second glass tube by which air was drawn through indiarubber tubing from the open-air quadrangle outside the laboratory.



In one series of experiments the end of the suction pipe was kept in the axial line of the lead cylinder at various points 10 cms. apart, beginning with a point close to the end distant from the Röntgen lamp.

In every case the air drawn through the filter was found to be negatively electrified when no screen or an aluminium screen was interposed between the Röntgen lamp and the near end of the lead cylinder. The air was found not electrified at all, or very slightly negative, when a lead screen was interposed.

When the Röntgen lamp was removed or stopped, and air was still pumped through the filter, no deflection was observed on the electrometer. This proved that the air of the quadrangle was not electrified sufficiently to show any deflection when thus tested by filter and electrometer.

Similar results were obtained with the end of the suction pipe placed so as to touch the floor of the lead cylinder, or the roof, or the sides. Whether the air was pumped away from a place in the cylinder permeated, or from a place not permeated, by the Röntgen rays, it was in all cases found to be negatively electrified.

The following are some of the results obtained on December 16 and 17. The electrometer was so arranged as to give 140 scale divisions per volt.

Conditions.—Large lead cylinder metallically connected with sheath of electrometer. Röntgen lamp surrounded by a lead sheath, which latter was also connected to electrometer-sheath. There was a window in this lamp-sheath 2·5 cms. broad and 5 cms. high. This window could be screened by aluminium or by lead. These screens were always connected metallically to sheaths. During all the experiments a Bunsen lamp (not shown in the diagram) was kept constantly burning, with its flame about 30 c.m. below the Röntgen lamp.

Results.—Röntgen lamp in action; air drawn from lowest point of end of lead cylinder next to the R. lamp.

December 16:—

3·55 p.m.	– 61	scale divisions in	2 mins.	with aluminium screen.
	– 63	,,	,, 2 ,,	no screen.
	– 14	,,	,, 2 ,,	lead screen.

4.20 p.m. Air drawn from point on lowest line of lead cylinder 26 cms. distant from R. L. end.

– 14	scale divisions in	2 mins.	with lead screen.
– 78	,,	,, 2 ,,	no screen.
– 24	,,	,, 2 ,,	lead screen.
– 83	,,	,, 2 ,,	alumin. screen.
– 13	,,	,, 2 ,,	lead screen.

December 17. R.L. acting, and air drawn through filter.

10.47 a.m.				End of suction pipe kept in axial line of cylinder cms.
– 44	in 2 mins.	with alumin.	screen ...	68 from R. L. end.
0	,, ,,	lead	,, ...	68 ,, ,,
– 28	,, ,,	no	,, ...	58 ,, ,,
– 24	,, ,,	no	,, ...	48 ,, ,,
0	,, ,,	lead	,, ...	48 ,, ,,
– 23	,, ,,	alumin.	,, ...	48 ,, ,,
– 26	,, ,,	alumin.	,, ...	38 ,, ,,
– 9	,, ,,	lead	,, ...	38 ,, ,,
– 7	,, ,,	lead	,, ...	28 ,, ,,
– 26	,, ,,	alumin.	,, ...	28 ,, ,,
– 36	,, ,,	alumin.	,, ...	18 ,, ,,
– 21	,, ,,	alumin.	,, ...	8 ,, ,,

We had previously made experiments with a sheet-iron funnel 1 metre long, 14·5 cms. diameter; and with a glass tube 150 cms. long, 3·5 cms. diameter; and with an aluminium tube 60 cms. long, 4·5 cms. diameter. Air was pumped from different parts while the Röntgen rays were shining along the tube from one end, which was closed by paraffined paper stretched across it. In every case the air was found to be negatively electrified.

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[1] "Electrification of Air by Röntgen Rays." By Lord Kelvin, Dr. J. C. Beattie, and Dr. M. Smoluchowski de Smolan. (Read before the Royal Society of Edinburgh, Monday, December 21, 1896.)

[2] The Röntgen lamp was a vacuum vessel with an oblique platinum plate (Jackson pattern).

[3] Kelvin, Maclean, Galt, *Proc. R.S.*, London, March 14, 1895.

In those earlier experiments the air drawn away was replaced by air coming in from the laboratory at the open end of the tube. We found evidence of disturbance due to electrification of air of the laboratory by brush discharges from electrodes between the induction coil and Röntgen lamp, and perhaps from circuit-break spark of induction coil. These sources of disturbance are eliminated by our later arrangement of lead cylinder covered with cardboard at both ends, as described above, and air drawn into it from open-air outside the laboratory.

We have also found a very decided electrification of air—sometimes negative, sometimes positive—when the Röntgen rays are directed across a glass tube or an aluminium tube, through which air was drawn from the quadrangle outside the laboratory, to the filter.

A primary object of our experiments was to test whether air electrified positively or negatively lost its charge by the passage of Röntgen rays through it. We soon obtained an affirmative answer to this question, both for negative and positive electricity. We found that positively electrified air lost its positive electricity, and in some cases acquired negative electricity, under the influence of Röntgen rays; and we were thus led to investigate the effect of Röntgen rays on air unelectrified to begin with.

Note on Diagram.—For the sake of simplicity, the screening of the electrometer is not shown in the diagram. In carrying out the above experiments, however, we have found it absolutely necessary not only to surround the electrometer with wire gauze in the usual manner, but we have had also to place a sheet of lead below it, and to screen also the side next the Röntgen lamp by a lead screen. In some cases it was even necessary to cover up the whole with paper to prevent the electrified air of the room from disturbing the instrument.

KELVIN.
J. C. BEATTIE.
M. SMOLUCHOWSKI DE SMOLAN.

Physical Laboratory, University, Glasgow,
December 19.

ON A NEW LAW CONNECTING THE PERIODS OF MOLECULAR VIBRATIONS.

AFTER the attempts to detect harmonic ratios in the wave-lengths of the light emitted by incandescent gases had failed, Balmer led the way in a line of research which promises to furnish a rational explanation of the different periods of a vibrating molecule. If τ_0 is a constant, the frequencies of all the hydrogen lines can be represented by Balmer's formula:

$$\tau = \tau_0\left(1 - \frac{4}{m^2}\right)$$

where for m we must put successively 3, 4, &c., and lines have been observed as far as $m = 15$. We may call τ_0 the convergence frequency, as it is that to which the vibrations approach as m increases. We also call the slowest vibration of the series the "fundamental." For other spectra the relationship is not quite so simple, but confining ourselves to the alkaline metals, the spectra of which have been most carefully examined and discussed by Kayser and Runge, these authors show that the vibration frequencies may be represented by means of three series of the form

$$\tau = A - \frac{B}{m^2} - \frac{C}{m^4} \; . \; . \; . \; . \; . \; . \; . \; .$$

the fundamental in every case being given by $m = 3$. The first, or principal series, has lines which are single in the spectrum of lithium, but double in the other cases, the components separating further and further as the atomic weight increases. The two supplementary series consist of lines which easily widen and show the remarkable property that the convergence frequency A has nearly the same value for both supplementary series.

I must refer to Kayser and Runge's paper for a discussion as to how far the formula is approximate only, as well as to other details; but as the majority of physicists have not hitherto paid much attention to this subject, I may add the remark, that the division of spectra into a number of series of the above nature is by no means arbitrary, but constitutes a most important step in the simplification of a very complex problem. It is known that Runge and Paschen have shown that the constituents of cleveite gas have spectra resembling those of the alkali metals; and I hope in a future communication to show that the spectrum which I have called the compound line spectrum of oxygen also divides into three series of the same type.

As regards my new law, it is so simple that it is astonishing how it could so long have remained unnoticed. It may be enunciated as follows:

If we subtract the frequency of the fundamental vibration from the convergence frequency of the principal series, we obtain the convergence frequency of the supplementary series.

The following table shows how far the law is accurate:

	A (Principal Series)	Wave Number of Fundamental Vibration	Difference	A (Supplementary Series)
Lithium	43585	14907	28678	28667
				28587
Sodium	41537	16960	24577	24566
		16977	24560	24547
				24496
				24476
Potassium	35087	12988	22099	22077
		13045	22042	22022
				22050
				21991
Rubidium	33762	12579	21183	21179
		12802	20960	20939

The numbers given in the table are proportional to the frequencies, being inverse wave-lengths in centimetres. The two numbers given in the second column refer to the two components of the double lines. As the lines of the supplementary series are double in the spectra of sodium and potassium, there are the four convergence frequencies in these cases which are all given. In comparing the two last columns it must be remembered that the quantity denoted by A, which is the convergence frequency, cannot be determined with the highest accuracy because Kayser and Runge's formula is approximate only and fails to give accurate results for the case $m = 3$. The only serious differences between the third and fourth columns occur in the two cases in which Runge and Paschen used the case $m = 3$ in determining the constant.

In the case of cæsium, the fundamental vibration lies in the infra-red, and has not been observed, but we may use the law to forecast its position, and obtain a wave-length of 8908 for the less refrangible, and of 8518 for the most refrangible component, numbers not differing much from Kayser and Runge's estimate for the same lines. The numbers given by Runge and Paschen for the gases from cleveite are sufficient to show that the law also holds in the case of both sets of the three series into which the spectrum divides itself. In the case of oxygen, I have not obtained sufficient data as yet to determine the position of the principal series, as it lies chiefly in the ultra-violet, and the lines measured so far belong nearly all to the supplementary sets.

The supplementary series have not been observed in the spectrum of hydrogen, but the new law shows that if they exist they must lie in the infra-red, and it is with some confidence that I predict the existence of hydrogen lines in the infra-red, the convergence frequency being 1218·51 ($\lambda = 8206{\cdot}6$).