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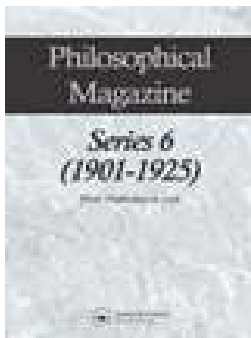
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VI. *Some Observations on the Absorption Spectra of the Vapours of Inorganic Salts.* By E. J. EVANS, B.Sc., A.R.C.S., Lecturer in Physics, Victoria University, Manchester*.

[Plate II.]

INTRODUCTION.

SOME time ago the present author† published investigations on the absorption spectra of the vapours of iodine, bromine, selenium, and tellurium at various temperatures, and later, as a continuation of the above investigations, the absorption spectra of the vapours of certain simple salts were examined. This research was not completed, as the author's attention was diverted to other problems, and the object of the present paper is to give a brief account of the results then obtained.

It is well known that the absorption spectra of the above-mentioned elementary substances show the presence of well-defined absorption bands, and it was considered of some interest to determine whether the absorption spectra of the vapours of a few inorganic salts show the presence of similar bands. For this purpose the absorption spectra of the chlorides of ammonium and mercury, and the chloride, bromide, and iodide of cadmium were examined. It was found that all the vapours examined, with the possible exception of ammonium chloride, showed evidence of a general selective absorption in the ultra-violet, and in no case could it be definitely proved that the vapours of the salts gave any well-defined absorption bands similar to those of Cl, Br, and I.

These conclusions refer to the particular region of the spectrum (λ 2500– λ 6700) which was investigated. No measurements of the variation of the general absorption with wave-length were made.

EXPERIMENTAL ARRANGEMENT.

A weighed quantity of the salt under investigation was placed in a quartz tube, which was evacuated to a low pressure through a side-tube connected to a mercury pump. The side-tube was then sealed off in the oxy-hydrogen flame. The quartz tube was afterwards placed at the centre of an

* Communicated by Sir E. Rutherford. This paper formed a portion of a thesis approved for the D.Sc. degree by the University of London.

† *Astrophys. Journal*, xxxii. pp. 1–16 (1910); xxxii. pp. 291–299 (1910); xxxiv. pp. 277–287 (1911); xxxvi. pp. 228–238 (1912).

electric furnace wound with nichrome wire, and the temperature could be adjusted to any value between that of the room and about 1200° C. The temperature was measured by a Pt, Pt-Rh thermocouple, which was connected to a direct reading instrument. When the required temperature had been attained, light from the positive pole of the carbon arc was passed through the vapour inside the quartz tube, and focussed by quartz lenses on the slit of a concave grating, having a radius of 1 metre, and ruled with 15,000 lines to the inch. The spectrum was then examined both visually and photographically.

EXPERIMENTAL RESULTS.

Ammonium Chloride.

It is well known that the vapour of this substance is dissociated into NH_3 and HCl at 350° C., and consequently the pressure of the vapour inside the quartz tube is double the amount calculated from the ordinary gas equation

$$pv = R \frac{M}{m} \theta,$$

where $R = 8.2 \times 10^7$,
 θ = absolute temperature,
 m = molecular weight of vapour,
 M = mass in grams of substance in tube,
 v = volume of tube in c.c.

From the dimensions of the tube it could readily be deduced that if .017 gram of NH_4Cl was placed in the tube, the pressure of the vapour at a temperature of 700° C. was approximately 2 atmospheres, and in the experiments under discussion this quantity of NH_4Cl was used. Photographs of the absorption spectrum were obtained at temperatures varying from 250° C. to 550° C., and visual observations were also made. As the result of a large number of experiments, it was concluded that the vapour of ammonium chloride does not give any well-defined absorption bands in the region extending from λ 2500- λ 6700, and, furthermore, there is no definite evidence that the vapour shows any general absorption in the same region. It is, however, possible that the vapour absorbs in the extreme red and infra-red regions of the spectrum, which were not examined in this research.

Mercuric and Mercurous Chloride.

Mercuric chloride is volatile even at ordinary temperatures, and its vapour pressure increases rapidly with temperature from 20.7 mm. at 200° C. to 370.7 mm. at 2,100° C. In the present experiments 10 gram of mercuric chloride was placed in an evacuated quartz tube, and by means of the gas equation it was calculated that the pressure of the vapour was approximately 1.6 atmospheres at 1000° C. Visual observations and the examination of numerous photographs taken at temperatures ranging from 20° C. to 1000° C. showed that there were no well-defined bands in the region λ 2500– λ 6700. On the other hand, there was distinct evidence of a general absorption in the ultra-violet which increased in intensity and spread towards the red end of the spectrum with rise of temperature. At 900° C. no light of shorter wave-length than λ 3400 passed through the vapour.

Mercurous chloride sublimes at about 400° C., and its vapour consists of a mixture of mercury and mercuric chloride unless special care is taken to free the salt from traces of moisture. About 0.9 gram of the salt was heated to temperatures varying from 400° C. to 800° C., and the absorption spectrum was photographed and also visually examined.

The photograph taken at 400° C. showed general absorption in the region λ 2500– λ 2800, and this increased with rise of temperature, so that at 800° C. the continuous spectrum of the carbon arc could not be photographed below λ 3200.

As in the case of mercuric chloride, the observations carried out both visually and photographically indicated that the vapour at temperatures varying from 400° C.–800° C. gave no well-defined absorption bands. In the experiments described, no special care was taken to absolutely remove all traces of moisture, and consequently the vapour probably consisted of a mixture of mercury and mercuric chloride. According to the experiments of Wood*, mercury shows an absorption band at λ 2536 which widens unsymmetrically towards the red over a range of 400 Å.U. as the pressure increases to several atmospheres. If a foreign gas is present, the line widens symmetrically at first, and afterwards unsymmetrically towards the red.

In the experiments on mercurous chloride the presence of the λ 2536 line would be difficult to detect, since the mercury

* *Astrophys. Journal*, xxvi. pp. 41–45 (1907).

would be mixed with mercuric-chloride vapour, and the continuous spectrum from the carbon arc is very faint below λ 2800.

The Bromide, Iodide, and Chloride of Cadmium.

In the experiments with cadmium bromide, which melts at 571° C. and boils at 809° C., $\cdot 07$ gram of the salt was placed in an evacuated quartz tube, and it was calculated that the pressure of the vapour was slightly in excess of 1 atmosphere at 1000° C.

Two sets of experiments were carried out at temperatures varying from 600° C. to 900° C., and several photographs of the absorption spectrum were taken. The first series of photographs showed no trace of any cadmium absorption line, but the second series even at 600° showed the presence of the cadmium absorption line at λ 3261. The line was, however, not strong on any of the films, showing that the cadmium bromide had only undergone slight decomposition at the higher temperatures. Apart from this line there were no other absorption lines or bands on the photographs. At 600° C. there was evidence of general absorption below λ 3100, and at 900° C. all wave-lengths between λ 2500 and λ 3800 were completely absorbed by the cadmium-bromide vapour. In later experiments $\cdot 065$ gram of metallic cadmium were placed in the quartz tube, and a photograph of the absorption spectrum was taken at 1000° C. The quantity of free cadmium present in this experiment was much greater than in the experiments with the cadmium bromide, but even then there was complete absorption only below λ 3000. These experiments, therefore, strongly point to the conclusion that cadmium-bromide vapour shows general selective absorption in the ultra-violet. The absorption due to the cadmium-bromide vapour is shown in Pl. II. photograph 1 (a) and (b); (a) giving the spectrum of the positive pole of the carbon arc, and (b) the same spectrum after the light has passed through the vapour at 900° C. The latter photograph shows a general absorption of light of shorter wave-length than 3800 Å.U.

Experiments were also carried out on the absorption of light by the vapour of cadmium iodide, which melts at 404° C. and boils at 714° C. The iodide was produced by the combination of metallic cadmium with iodine contained in a quartz tube, which was heated to a temperature of about

400° C. by means of an electric furnace. The quantity of each substance used was .005 gram, and it is therefore seen that the cadmium was in excess. The experiments with pure metallic cadmium previously referred to show that at 1000° C. only light of shorter wave-length than λ 3000 was completely absorbed, and in the cadmium-iodide experiments the amount of free cadmium was only $\frac{1}{30}$ that employed in the experiments on the absorption spectrum of cadmium vapour. As the temperature of the furnace was raised, the light after passing through the quartz tube was reddish in colour, and when examined with the spectroscope showed the ordinary absorption spectrum of iodine vapour. This colour, however, completely disappeared when the temperature of the furnace was approximately 400° C., showing that the iodine had combined with the cadmium. A large number of photographs were then taken at temperatures ranging from 400° C. to 1000° C., and it was found that cadmium-iodide vapour showed a decided general absorption in the ultra-violet. At 400° C. there was scarcely any evidence of absorption, as the light from the positive pole of the electric arc could be photographed in the ultra-violet as far as λ 2500. When, however, the temperature of the furnace had reached 650° C. all light of shorter wave-length than λ 3500 had been absorbed, and this absorption spread towards the red end of the spectrum as the temperature was raised to 1000° C., so that absorption could then be traced as far as λ 3800. As cadmium vapour was present in these experiments, it would be expected that the λ 3261 cadmium absorption line would be visible on the photographs, but owing to the great absorption of the iodide, this line could only be seen faintly on one of the films taken, when the temperature of the furnace was 580° C. Even at this comparatively low temperature the wave-length of the line (λ 3261) was near the limit of transmission.

Finally, the absorption of light by cadmium-chloride vapour was studied. This substance melts at 590° C. and boils at 900° C., and the absorption spectrum of its vapour was photographed at temperatures ranging from 600° C. to 1000° C. In these experiments the quartz tube was evacuated to a pressure of .01 mm. of mercury, and the quantities of the chloride used in two sets of experiments were .07 and .045 gram respectively. It was evident from the results of the first series of experiments that the cadmium-chloride vapour had been partially decomposed at high temperatures, for the 3261 line of cadmium appeared with increasing

intensity on photographs taken when the temperatures of the vapour were 650° C., 840° C., and 980° C. In addition to the 3261 absorption line, photographs taken at temperatures above 800° C. showed the presence of more diffuse absorption lines of shorter wave-length, but later experiments indicated that the lines could not possibly be attributed to the chloride. These lines became more distinct as the temperature increased, but their investigation was rendered difficult by the general absorption in the same region probably due to the chloride vapour.

In the second series of experiments, greater care was taken to remove moisture from the chloride, and two photographs taken at 700° C. and 830° C. showed no trace of the cadmium absorption line. There was, however, distinct evidence of general absorption in the ultra-violet, but it was less intense than the absorption by CdBr_2 and CdI_2 . Even in these experiments a slight decomposition of the vapour was obtained at a higher temperature (940° C.), and the 3261 absorption line together with the other lines of shorter wave-length appeared on the photographic film. At this temperature all wave-lengths between λ 3100 and λ 2500 were almost completely absorbed.

The absorption of cadmium-chloride vapour is illustrated by photograph (2) (*a*) and (*b*), where (*a*) is the continuous spectrum due to the positive pole of the carbon arc, and (*b*) the same spectrum after passing through CdCl_2 vapour at 940° C. It shows a general absorption of light of shorter wave-length than 3100 Å.U., and also the presence of absorption lines at 3261, 3171, 3162, and 3152. The 3261 line is the well-known absorption line of cadmium vapour, and the origin of the other lines will be discussed later.

EXPERIMENTS ON THE ABSORPTION OF CADMIUM VAPOUR.

The two specimens of cadmium used in these experiments were analysed spectroscopically to test their purity. The cadmium was placed in the positive pole of the carbon arc, and two photographs were taken with the concave grating. A careful examination of the photographs showed that the two specimens did not contain any impurities.

Wood* found that the absorption spectrum of cadmium vapour consisted of two lines at λ 2288.1 and λ 3261.2, which can also be obtained as emission lines. The former line,

* Wood, *Astrophys. Journal*, xxix. pp. 211-223 (1909).

which is much the more prominent, was found to broaden perfectly symmetrically when pure Cd was examined, but unsymmetrically when mercury was added. The absorption line at λ 2288 Å. attained a width of about 200 Å.U. at the highest temperatures employed, but the λ 3261 line was never very broad under these conditions. In the present experiments, only the absorption line at λ 3261 could be obtained, as the carbon arc which was the source of the continuous spectrum is not suitable for the examination of absorption lines in the neighbourhood of λ 2288 Å. These experiments on the absorption of the vapour were carried out at different temperatures with each specimen of cadmium, and the amounts of the metal used were 0.15 gram and 0.65 gram respectively. The vapour obtained from 0.15 gram of one specimen gave an absorption line at λ 3261, which broadened symmetrically with increase of temperature until its width was about 100 Å.U. at 1000° C. At the above temperature the vapour also gave additional absorption lines in the region λ 3000– λ 3200, and a general absorption in the region λ 2500– λ 3000, which is possibly due to the broadening of the λ 2288 line. These absorption lines were the same as those previously obtained when the absorption spectrum of CdCl₂ was examined, with the exception that cadmium vapour gave an extra line at 3178.

The vapour obtained from 0.65 gram of the other specimen gave practically the same absorption spectrum as the above, with the difference that the absorption lines in the region λ 3000– λ 3200 were very faint and difficult to detect with certainty. It was found, however, that these lines could be more readily obtained if cadmium vapour were mixed with hydrogen. For this purpose hydrogen was allowed to enter an evacuated quartz tube containing 0.3 gram of cadmium until the pressure was 25 cm. of mercury. Photographs taken when the temperatures of the vapour were 880° and 970° showed the presence of the absorption lines in the region λ 3000– λ 3200. The wave-lengths of some of these rather diffuse lines were measured, and the approximate values obtained were 3142, 3152, 3162, and 3171 Å.U. It therefore follows that these lines cannot be attributed to the vapour of CdCl₂, and the experiments suggest that they may possibly be due to an unstable compound of Cd and H, the lines being produced when the compound dissociates.

SUMMARY.

The absorption spectra of the vapours of ammonium chloride, mercuric and mercurous chloride, cadmium chloride, bromide, and iodide were examined, and it was found :—

- (a) That the vapours did not give any well-defined absorption lines or bands like bromine and iodine in the region λ 2500– λ 6700.
- (b) That they gave a general selective absorption in the ultra-violet (except possibly NH_4Cl) which in the case of the cadmium salts was greater for the iodide and bromide than for the chloride.

The author wishes to thank Sir Ernest Rutherford for placing the necessary facilities at his disposal, and for the kind interest he has taken in the work.

Manchester University,
Dec. 1915.

VII. *On the most Effective Primary Capacity for Tesla Coils.*
By W. MORRIS JONES, B.Sc., *Research Student of the University of Wales* *.

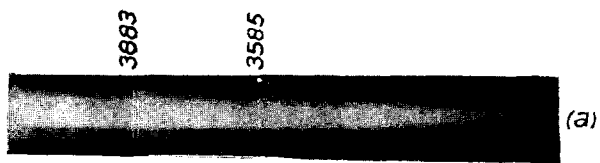
IT is generally assumed that a Tesla coil gives the best effect (*i. e.* the highest secondary potential for a given primary discharge potential) when the two circuits are so adjusted that, separated, their periods of oscillations are equal. This condition is expressed by the relation $L_1C_1 = L_2C_2$, and is commonly called the condition for “resonance” or “synchronism,” though it does not mean that the two periods of the system are equal when the circuits are closely coupled. The above condition appears to have been first arrived at by Drude † in a well known memoir on the Tesla coil, and has received general acceptance.

In a recent paper Professor Taylor Jones ‡ has shown that the above condition does not apply if the adjustment is made by varying the primary capacity alone, but that in this case the “optimum” value of C_1 is considerably greater than the resonance value. Taking the secondary potential, when the

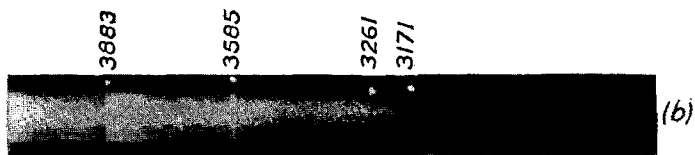
* Communicated by Prof. E. Taylor Jones, D.Sc.

† *Ann. de Physik*, xiii, p. 512 (1904).

‡ *Phil. Mag.*, xxx, p. 224 (1915).



PHOTOGRAPH I.



PHOTOGRAPH II.