The Transparency of the Air Between 1100 and 1300A

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It has long been predicted that the air possesses considerable transparency for light in the region between 1100 and 1300A. This paper deals with a very simple method of demonstrating this transparency by the use of a thermoluminescent screen. Secondary products of the investigation are *first*, a study of the selective sensitivity of the screen just mentioned; *second*, a determination of the nature of the so-called Entladungsstrahlen; and *third*, the description of a simple method of testing the transparency of lithium fluoride crystals.

SOME time ago Hopfield[1] pointed out that the air should possess considerable transparency between 1100 and 1218A even in a column about 4 cm thick. Later Ladenburg, Van Voorhis and Boyce[2] showed that for oxygen the gap should extend between 1100 and 1300. The most obvious method of testing the matter is to close a vacuum grating spectrograph with a window of lithium fluoride and then to photograph the spectrum of a condensed spark placed in air outside the window and a few centimeters from it.

In the actual experiment a piece of lithium fluoride was selected transparent in the extreme ultraviolet to the neighborhood of 1100A. The spectrograph was provided with a concave grating of one meter radius. The distance from the external window to the slit was about one centimeter. Condensed sparks about 3 mm in length, produced by a half kw transformer with a capacity of about 0.002 μf were employed. The potential across the gap, estimated by the sparking distance between spherical electrodes, was found to be of the order of 9000 volts. The spark was placed in air and about one and one-half to two cm from the window. Experiments were made with carbon, copper and silicon electrodes. The times of exposure varied between ten and forty minutes depending upon the width of the slit, etc. etc. Cramer Contrast plates were used treated with Cenco pump oil.

In every case the spectra were nearly independent of the material of the spark terminals. They consisted chiefly of nitrogen and oxygen lines lying between 1144 and 1311A. The wavelengths were determined by comparison with the values given in the Tables of MacInnes and Boyce.[3] Three lines are due to N_1, two to N_{11}, two to N_{111}, four to O_1; and one to hydrogen; one line was not identified. When the distance of the spark to the window was increased to about four and one-half cm, a few of the strongest lines between 1144 and 1185A were still present.

While this method is perfectly straightforward, the necessary apparatus is rather complicated. It is the chief purpose of this article to describe a much easier way of demonstrating the transparency of the air in this particular region. The simplified procedure was suggested by some old experiments of Wiedemann on what he termed "Entladungsstrahlen."[4]

The experiment is conducted as follows: A paste of calcium sulphate and water is thoroughly mixed with a little manganese sulphate. The exact amount of the second ingredient does not seem important; it may vary from one to five percent. The resulting thick broth is evaporated to dryness; the residue is ground to powder, mixed again with a little water and flowed on copper strips of suitable dimensions. The water is allowed to evaporate and the copper with its coating is heated to redness for a few minutes. The whole process is very much the same as that described by Hoffmann[5] many years ago.

The demonstration is carried out by placing one of these coated copper strips beneath a condensed spark of about 3 mm, between "V" shaped electrodes, and at a distance of two or three centimeters from the spark. Upon the surface of calcium sulphate are placed a small piece of fluorite known to be transparent to 1240A and a similar piece of the best lithium fluoride

[1] Hopfield, Phys. Rev. **20**, 587 (1922).
[2] Ladenburg, Van Voorhis and Boyce, Phys. Rev. **40**, 1018 (1932).
[3] MacInnes and Boyce, Palmer Physical Lab., Princeton, N. J., 1930.
[4] Wiedemann, Wied. Ann. **56**, 237 (1895).
[5] Hoffmann, Wied. Ann. **60**, 269 (1897).

known to be transparent to 1100A the spark is then excited for ten or fifteen seconds. The crystals are next removed and the coated copper strip is heated to a maximum temperature of about 180°. If the experiment is carried on in the dark, the calcium sulphate is seen to glow quite strongly before the maximum temperature is reached. The important facts to note are that the part of the surface which had been protected by the fluorite did not glow, while the portion which had been covered by the lithium fluoride was luminescent, though not to so great a degree as those parts of the surface which had been totally unprotected. The conclusion is clear: The observed thermoluminescence is produced by light which has passed several centimeters of air, to which fluorite is opaque and which is able to penetrate lithium fluoride at least to some degree. The luminescence is therefore due to the region of the spectrum between 1100 and 1250A.

It must be noted that if the calcium sulphate surface, part of which is protected by fluorite, be given a very long exposure to a spark; upon heating a faint luminescense appeared under the fluorite. This indicates that while the opacity of the air is considerable near the absorption limit of fluorite yet it shows some transparency, a fact which is in agreement with the results obtained with a spark in air and the vacuum spectrograph.

So much then for this simple demonstration. Next it is of interest to determine the spectral region to which the calcium sulphate-manganese-sulphate screen is sensitive.

To this end a strip of copper, properly coated, was inserted in the vacuum grating spectrograph in the position usually occupied by the photographic plate. The source was a hydrogen discharge tube. A long exposure proved necessary, the time being of the order of seven or eight hours. The spectral region covered by the plate extended from 900 to about 2100A. The calcium sulphate screen was next heated in a dark room and observed visually. The extent of the resulting luminescence indicated that the sensitivity of the thermoluminescent substance began quite abruptly near 1300A and was only limited on the side of the extreme ultraviolet by the end of the plate itself, that is by a point near 900A.

More precise measurements were made by placing an Eastman "33" photographic plate,

film side down, upon the calcium sulphate screen after it had been withdrawn from the spectrograph; strips of thin asbestos being used to keep the plate about a millimeter from the screen. On heating, the resulting luminescence was recorded on the photographic plate. The results confirmed the visual observations. The group of hydrogen lines near 1280A was reproduced in luminescence; but the strong hydrogen spectrum from 1340 to 1640A produced no effect whatever.

To test the sensitivity of the substance under examination in the region beyond that which could be conveniently covered with the concave grating instrument, a spectrograph provided with a plane grating used at grazing incidence was employed. The general arrangement being that described by Osgood.[6] The source was a hot spark between a tungsten and a tungsten carbide terminal. The resulting spectrum extended to 140A. The calcium sulphate surface was exposed in this instrument for one and a half hours. On heating, eye observations showed that the sensitivity extended to the end of the spectral range of the instrument, namely to 140A.

We may conclude therefore that the mixture of calcium sulphate with a few percent of manganese sulphate shows thermoluminescence when excited by light in the region between 140A and 1300A. It may be activated by even shorter wavelengths. It is not excited by longer wavelengths, as is demonstrated by the fact that fluorite is opaque to the radiations which produce the effect. The properties of this and of kindred substances are well worth further investigation.

We may now proceed to our second sub-topic. To those who have read the papers of Wiedemann[4] and of Hoffmann[5] already quoted, the bearing of the experiment just described upon the nature of the so-called Entladungsstrahlen will be obvious. These same Entladungsstrahlen have been defined as a radiation proceeding from a spark to which both quartz and fluorite are opaque but which can penetrate several centimeters of air. It now seems clear that a great part of the thermoluminescent action attributed to these rays is produced by the region of the spectrum between 1100 and 1300A to which the air is relatively transparent.

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[6] Osgood, Rev. Sci. Inst. 5, 368 (1934).

Miss Laird[7] has pointed out that light of even shorter wavelength may also cause some of the luminescence. From the experiment just described it seems probable that the screen is sensitive in the region of the very shortest wavelength. But what we now know of the absorption of the air makes it improbable that light between 300 and 1100A could reach the thermoluminescent surface, and the character of the spark makes it unlikely that radiations of shorter wavelength were given out in the particular experiments here described. Obviously a very powerful spark might possibly produce soft x-rays which in turn might penetrate several centimeters of air.

Finally, the calcium-sulphate-manganese sul-

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[7] Laird, J. Opt. Soc. Am. **13**, 39 (1926).

phate screen affords a simple method of testing the relative transparencies of various specimens of lithium fluoride. It is only necessary to place the unknown specimens, together with a piece of known quality, on the surface in question; expose for ten or fifteen seconds to the light from a 3 mm condensed spark at a distance of two or three centimeters, and then heat the screen in a dark room. The degree of transparency of the lithium fluoride can be quite accurately judged by the brightness of the thermoluminescence excited by the light which has passed through the specimen.

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On the Half-Lives of Potassium, Rubidium, Neodymium and Samarium

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The long apparent half-lives of K, Rb and Nd are in striking disagreement with theory. To relieve this discrepancy, at least in part, the suggestion has often been made that their activities are due to isotopes of small abundance, having half-lives small in comparison with the apparent ones. Using data on the relative abundance of the elements, it is shown that the half-life of the active fraction of K is greater than 10^7 years, and that the active fractions of Rb, Nd and Sm have half-lives greater than 10^8 years. It is pointed out that these activities may be caused by small radioactive fractions of well-known isotopes; RaD and stable Pb(210) constitute a similar case. Data are presented which show that it is possible for the active portions of Nd and Sm to be genetically connected.

1. INTRODUCTION

THE apparent decay constant, λ', of a radioactive element composed of several isotopes is the fraction of its atoms which disintegrates per unit of time. If only one isotope, whose atoms constitute a fraction A of all the atoms in the preparation, is active, then the actual decay constant is

$$\lambda = \lambda'/A, \qquad (1)$$

and the actual half-life is

$$T = AT', \qquad (2)$$

where T' is the apparent half-life. The apparent half-lives of K, Rb, Nd and Sm are of the order of 10^{12} to 10^{13} years and the question arises whether their activities are due to isotopes which have been detected with the mass spectrograph,

or to undetected isotopes for which A is very small. The case of Sm has been discussed by Hevesy, Pahl and Hosemann.[1] Its apparent half-life agrees fairly well with the value computed from the range of the alpha-particles. Therefore it is probable that the alpha-particles are emitted by one of the known isotopes. It is also probable that there is only one active isotope, for Bearden and Kanne[2] have shown that all the alpha-particles have the same range, within 2 mm. On the other hand, the situation in regard to K, Rb and Nd is unsatisfactory. The theories of Beck and Sitte and of Fermi[3] yield half-lives much

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[1] Hevesey, Pahl and Hosemann, Zeits. f. Physik **83**, 43 (1934).
[2] Bearden and Kanne, Phys. Rev. **47**, 639 (1935). See also Ortner and Schintlmeister, Zeits. f. Physik **90**, 698 (1934).
[3] Beck and Sitte, Zeits. f. Physik **86**, 105 (1933); Fermi, Zeits. f. Physik **88**, 161 (1934).