VARIABILITY OF SPECTRUM LINES IN THE IRON ARC

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Recent progress in the application of spectroscopy to physical and astronomical problems has depended in large measure upon the determination of very minute changes in spectrum lines, involving not only their position in the spectrum, but their variations of intensity and shape and their alteration by magnetic and electric fields. In the attempt to interpret observations upon the spectra of heavenly bodies, which in general are produced under the most complex conditions of radiation, it is therefore of prime importance to possess detailed information regarding the peculiarities of behavior of spectrum lines individually.

These considerations make clear the need for standard lines whose wavelength is accurately known when they are produced under known conditions, and whose response to definite variations in the physical conditions surrounding the source is well established. For the general purposes of precision spectroscopy, the necessity for the fixing of a complete system of working standards of wavelength extending throughout the spectrum has led to the adoption of the electric arc between iron terminals under certain specified conditions as a standard source of radiation. However, the determinations by different observers of the wavelengths of lines selected as standards do not show the accordance which would be expected, if the errors were solely those inherent in the method of observation. The suspicion thus aroused as to the constancy of these wavelengths, when the arc is employed under the specified conditions, coupled with the need for extensions to our knowledge of the character of the lines under different conditions of radiation has made necessary a careful study of the iron arc spectrum, some results of which form the substance of this paper.

A visual observation of the arc made with the help of various colored screens brings out the fact that there are considerable differences in brightness in different parts of this source. At the negative pole the vapor is in general far brighter than at the positive pole, while there is an equatorial region which is less bright than either. With a deep red screen the outer envelope of the arc appears to surround a comparatively dark core which contains two small bright brushes, one emanating from each pole. A blue screen, on the other hand, causes the outer parts to appear much fainter than the part which appeared dark in red light.

These facts and others associated with them led us to compare the spectra of different parts of the arc with apparatus of high power, and a method was developed for making studies of this kind under conditions favorable to the detection of very small variations in the spectrum. Even with very stable apparatus, considerable difficulty is found with high dispersion spectrographs in eliminating minute instrumental disturbances sufficiently large to interfere seriously with observations of quantities whose order of magnitude is a few thousandths of an angstrom, and it was not until we made our exposures to the two parts of the source simultaneous that we obtained satisfactory consistency in the results. This was accomplished by means of a pair of small total reflecting prisms arranged over the slit of the spectrograph in a 5-fold enlarged image of the arc, with a rotating sectored disk interposed in the path of the light from the brighter portion of the source. The latter adjunct serves to equalize the effective intensities so that the corresponding spectral images are practically identical in blackness—a necessary precaution when their positions on the photographic plate are to be determined by visual observations with a filar micrometer. The same auxilliary apparatus was employed for comparing the spectra of two separate arcs operated with different current strengths, and it may be applied to many comparisons requiring the highest precision. By the aid of it we have obtained photographs of the entire visible spectrum of iron and part of the ultraviolet, the spectrum of the light from near the negative pole appearing as a narrow strip extending along the center of the plate, with contiguous spectra on each side taken from the midpoint of the arc. Upon these plates we have measured for about 1600 lines the wavelength at the negative pole using the same line at the center of the arc as a reference standard. Of the lines examined about 1300 show no determinable difference in wavelength, 249 are displaced toward the red and 64 toward the violet, the larger shifts amounting to about +0.025 angstrom and −0.030 angstrom respectively. The presence upon the same photograph of lines belonging to all three of these classes establishes the fact that many lines in the spectrum are modified in some way at the pole of the arc to an extent which must be taken into account when they are involved in precise measurements. It becomes of importance, therefore, to enumerate and classify these lines and to determine under what conditions, if any, they may be used as standards of reference. Also, the question may be raised as to whether the shifts we observe are actual displacements of the maxima of the lines or are due merely to unsymmetrical widening. Concerning this latter point it should be said that especial attention was given it both in collecting and discussing our data. The equalization of the brightness of the two parts of the source by the rotating disk referred to above was always nearly complete except when the light from the pole was purposely made fainter than from the center. Under these latter conditions it was found that the displacements persisted, although if due to unsymmetrical widening they should disappear. Furthermore, a set of typical lines showing displacements in both directions were observed with two different forms of microphotometer, both of which confirmed the conclusion that the maximum of the line is actually displaced at the pole as compared to its position at the center of the arc. With either of these instruments the location of the maximum of a line is independent of any bias on the part of the observer. It is true that the shifts are often accompanied by considerable dissymmetry, though there are some exceptions.

An examination of our data brings out a partial correspondence between the effects observed at the negative pole and those known to be due to increase of pressure around the source. But we find a large number of lines whose wavelengths are unaffected at the negative pole, which should show an easily measurable increase in wavelength if there were a general increase in pressure near the pole sufficient to account for the observed displacements. This would suggest the probability that some other agency than pressure is effective, but the possibility remains of a local increase in pressure affecting only the innermost portion of the vapor in the vicinity of the pole. To determine the rôle played by pressure a fuller knowledge is required of its effect upon the wavelengths of these affected lines, a subject now under investigation at this observatory. A more complete discussion of this question and of the possible effect of density as distinguished from pressure, together with complete lists of affected lines, will appear in our more extended paper soon to be published in the *Astrophysical Journal.*

In addition to the observations discussed above, we have measured the relative intensities in different parts of the arc of a few typical lines in the green part of the iron spectrum. For this purpose still higher dispersion and resolving power were employed in the spectrograph, and the slit was placed parallel to the axis of the arc. As precautions against the numerous sources of error in such observations, may be mentioned the impression of a photometric scale upon each photographic plate used, the avoidance of overexposure, etc. The enlarged image of the arc and the long slit of the spectrograph permit an excellent analysis of the image from one pole of the arc to the other, although each line image represents an integration of all the light in the line of sight. These photographs display the differences between different classes of lines in a striking manner, showing the variations in width, intensity, dissymmetry, etc., from point to point along the arc axis. For deriving from these plates curves showing the variation of intensity *across the spectrum line* at any desired point, a registering microphotometer was employed. This instrument automatically draws a curve which can be transformed by the aid of the photometric scale into an intensity curve. By comparing these intensity curves for a given line taken at a series of points along the axis of the arc, an idea is had of the actual shape of the line in

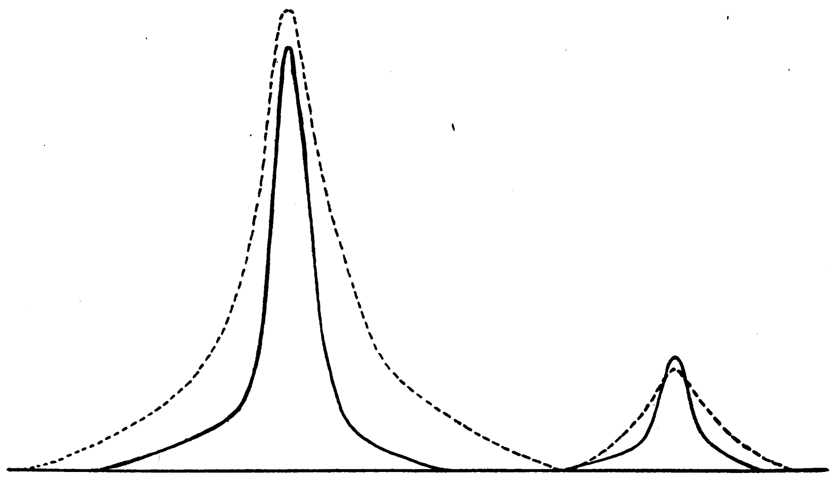

Fig. 1. Comparative intensities at pole and center.
......λ 5424 ——— λ 5434

different parts of the arc. Figure 1 shows typical intensity curves taken from near the negative pole and the center of the arc respectively for two lines. The dotted curves refer to λ 5424, which shows a large shift toward the violet at the negative pole, while the other curves belong to λ 5434, whose wavelength is unchanged. Both lines are seen to be more intense at the negative pole than at the center, but the difference is greater for λ 5424. On account of the greater widening and dissymmetry shown by this line in the vicinity of the pole, it is important to compare the total energy of radiation at center and pole for each line. This has been accomplished by taking intensity curves at short intervals along the line from one pole to the other, integrating these curves and plotting their areas as ordinates with abscissae corresponding to the points at which the intensity curves were taken. Figure 2 shows the energy curves thus obtained for the same lines. The apparent decrease in energy close to the negative pole is undoubtedly fictitious, being introduced by several causes operating during the exposure of the photographic plate. It is seen from the curves of Figure 2 that the energy of emission of λ 5424 is 6 times as great near the negative pole as it is at the center, while for λ 5434 the ratio is 3.2. Since the former line occurs chiefly in the core of the arc and the latter is strong in both inner and outer parts, viz., throughout a much greater volume of arc vapor, it is possible that the effects observed at the negative pole for lines like λ 5424 are due in

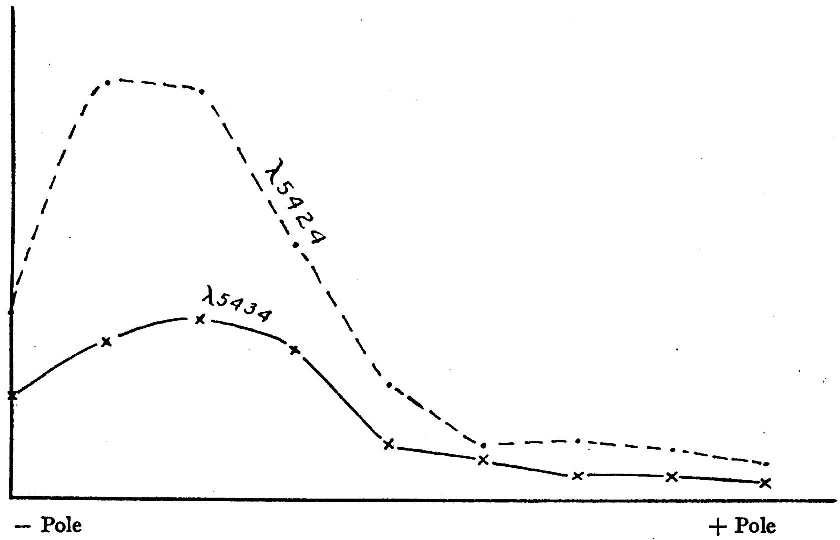

Fig. 2. Distribution of energy along the axis of the arc.

part to the greater proximity of the separate radiating centers; in other words, to an effect of density of radiating vapor as distinguished from pressure. It is by no means certain that the true pressure effect depends entirely upon increased nearness of the centers of emission and not upon changes in the surrounding medium.

From an examination of the variations of wavelength when the light is taken from points between the center and the negative pole, as well as from a comparison of spectra taken from the centers of two arcs carrying currents of different strength, we find that the most sensitive lines exhibit measurable displacements at considerable distance from the pole and are affected by changes of 40% in the current even when observed at the center. Attention is thus called to the difficulty of securing reproducible values of the wavelength for such lines when the spectrograph slit is placed parallel to the axis of the arc, especially if an astigmatic spectrograph is used. With the slit at right angles to the arc at its middle point, on the other hand, it is easy to obtain reproducible results.

Our conclusions may be summarized as follows:

1. It has been shown that the wavelengths of many lines in the iron arc spectrum depend upon the portion of the source used.

2. These variations in wavelength appear not to be due to a general increase in pressure in the vicinty of the negative pole, but the questions of a local increase in pressure and the possible effect of density are still under investigation.

3. The energy distribution in the arc has been shown for two types of lines.

4. Some working conditions whose observance favors the obtaining of reproducible values of wavelength have been quantitatively determined.

AN EXPERIMENTAL STUDY OF LIPOLYTIC ACTIONS

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Purpose of this Investigation. The chemical changes which occur in animal and vegetable growth have focused attention in recent years upon a group of catalytic agents, the enzymes, which are capable of accelerating these changes. The study of the chemical nature and behavior of enzymes is, however, extremely difficult because of the complexity of the substances which occur in living matter and which constitute in most cases the material upon which the enzymes act. Thus most enzymatic reactions involve changes in substances such as proteins or starches, which are themselves of unknown chemical structure. There are, however, some which produce changes in simpler substances. Among these are the lipases, or the ester-hydrolyzing (including the fat-hydrolyzing) enzymes. In this case the composition and structure of the initial and final substances involved in the reaction are definitely known, and the uncertain factors due to the chemical nature of the substance acted upon are eliminated.