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A determination of the wave lengths of some lines in the molecular spectrum of hydrogen

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A DETERMINATION OF THE WAVE LENGTHS OF SOME LINES
IN THE MOLECULAR SPECTRUM OF HYDROGEN

by

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(S.B., Harvard, "1924)

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Historical

The experimental study of spectra has furnished the material for the investigation of the complex nature of atomic structure. The colors of the rainbow, peacock feathers and soap films, had been noticed for many centuries. In 1665, Grimaldi noticed that a ray of light in passing by the edge of an opaque object was bent, giving colored fringes. This phenomenon was called "diffraction." He also noticed that light waves could produce darkness by "interference." In 1678, Huygens developed what is known as the "principle of Huygens," by which he analyzed wave propagation and interference. According to his principle, light consisted of vibrations in the ether. Ether particles in the same phase would produce reenforcement, while those of an uneven number would be in opposite phase at certain times, and produce interference. He explained diffraction, or bending around a sharp edge, by assuming that each vibrating particle became a new source of a wave front, or a secondary wave. Huygens could not explain polarization, because of the false assumption that the wave motion was longitudinal instead of transverse.

Young, Fresnel and Arago were the prominent exponents of the undulatory theory of light. Fresnel
showed that the colored bands noticed by Grimaldi, could be explained by Huygens' principle. If monochromatic light is used, the series of dark and light bands represent alternate interference and reinforcement. If white light is used, consisting of many colors, a series of colored fringes is obtained, arranged according to the different wave lengths present.

Newton was the most prominent exponent of the emission or corpuscular theory of light. The colored fringes on the edges of a mirror, and around a prism, had been noticed previously, but until Newton's explanation 250 years ago, the source of color was placed in the object and not in the light source. Newton showed that white light was composed of many colors, the various components being refracted by different amounts; the violet rays the most, the red rays the least. He let a pencil of sunlight pass through a prism and be dispersed, and then recombined the colored beams, by means of small prisms, into a beam of white light. If the source of color had been in the glass, obviously the same glass could not take single colors and recombine them to make white light. Newton termed this colored band or rainbow of light, a "spectrum." The interference rings, formed when a plane surface and a convex surface are pressed
together and sunlight allowed to pass through, were explained as "fits" of alternate easy reflection and transmission.

The seventeenth century was a period of great conflict between the rival theories of light. These two great men, Newton and Huygens, held entirely opposite views. Newton's reputation and influence was the greater, and therefore the false tenets of his theory became incorporated into the scientific thought of his time. His views as to the material or corpuscular nature of light were perniciously applied to radiant energy in general, so that for many years heat was considered a material substance. When Fresnel and Young proved that light vibrations were transverse and not longitudinal, the problem was solved, (at least for a time) and the undulatory theory gained in popularity.

It is remarkable to note that Newton, studying and experimenting on light, had never noticed the dark lines in the solar spectrum. It may be that Wollaston profited by the mechanical improvements that Newton made in the spectroscope. Newton added a lens between the source and the prism, and reduced the size of the opening from a round hole to the present form of narrow slit. He thus obtained sharper definition and less overlapping.
William Wollaston, an English chemist, first noticed the dark lines in the solar spectrum. In 1802, he saw seven lines, which he thought were boundary lines between the various colors. The true significance of these lines remained a mystery, until Kirchhoff's explanation in 1859.

Joseph Fraunhofer, optician, glass grinder, and physicist, may be called the first of the founders of the modern science of spectroscopy. He developed, at an early age, achromatic lenses for telescopic work, even making an object glass, for Sir David Brewster, 18 inches in diameter; then a remarkable achievement. While working on the indices of refraction for glass for certain colors, he noticed the double bright yellow lines in sodium. He tried to see if the same lines existed in sunlight, and found, much to his surprise, an almost countless number of strong and feeble dark lines. Wollaston's work was unknown to him. Fraunhofer constructed a map of 576 of these lines, naming the principal ones by letters of the alphabet, so that the well known term, "Fraunhofer lines" is properly applied as a testimonial to his work. The fact that bright lines of the spectra of the elements, correspond exactly with dark lines in the solar spectrum, and that this is an
indication of the presence of various elements in the hot gases around the sun, was due to Kirchhoff and Bunsen in 1859. We now know that the black lines are absorption lines, or images of the slit, where the energy radiated by the sun has been absorbed by the cooler gases surrounding it. While Fraunhofer did not realize all this, his work was not without value, because he realized the fixed nature of these lines and used them as known positions or "standards" to make accurate measurements of the indices of refraction of the various colored radiations. The black lines were shown to have a fixed position, because they maintained the same relative place when different prisms were used.

Fraunhofer's early apprenticeship under his father, as a glazier, resulted in the development of an extremely practical and ingenious type of inventive ability. His work on light resulted in the application of his ideas on "interference" to the making of a grating, the first ever made. He constructed his first grating by carefully winding fine silver wire on a brass frame, making sure that the winding was evenly spaced. These were replaced with a type fundamentally the same as in use today; fine, parallel, evenly spaced lines ruled on a sheet of plate glass, crude, when compared with today's work; but in
the hands of Fraunhofer, a measurement of the D line, in sodium was made with surprising accuracy. Fraunhofer's important work received very little attention for forty years, or until the explanation of Kirchhoff stimulated interest anew.

Certain substances strongly absorb light corresponding to a particular part of the spectrum. Kirchhoff noticed that sodium vapor absorbed the two adjacent (D lines) of incandescent sodium. He formulated this important law: A substance which emits waves of definite periods when heated, will selectively absorb waves of the same period when cool. This explanation was the key to the mystery of the Fraunhofer lines. Many of these lines coincided with bright lines in the spectra of the elements. The vapors of the elements surrounding the hotter nucleus of the sun, absorb the rays that they themselves would emit if incandescent. We therefore know that the chemical composition of the sun is very closely like that of the earth.

The spectrum extends far beyond its visible portion, at both ends; in fact, the eye can only see that portion between the wave lengths 3900 A.U. (violet) and 7600 A.U. (red). The short waves, or ultra-violet, may be determined in several ways. They are very active in decomposing silver salts, and can therefore be photographed, but a
prism must be used which does not absorb them. With a quartz prism, and in vacuo, it has been shown that the ultra-violet spectrum of the sun is continuous, and that it also contains Fraunhofer lines.

Herschel, in 1800, found that the sun's maximum heating effect was in a region beyond the visible red. He noticed, by using lampblack and alcohol, that the dark lines also extended into the infra-red. The American physicist, Langley, using a bolometer and rock salt crystals, has investigated the infra-red spectrum between 7600 A.U. and 53,000 A.U.

Spectroscopy took its place as an exact science when Cornu, in 1874, published part of the Angstrom Map of the solar spectrum. Rowland made a very accurate screw, and with a ruling engine fitted with this screw, made some very excellent gratings. Because of his skill, and because of a new determination of the D lines of sodium, Rowland's map of the solar spectrum became the standard in spectroscopic work.

If a polished concave surface of a mirror of speculum metal, is ruled with fine parallel lines, diffraction effects take place by reflection from the sides of the scratches. No lens is needed as the light is focused by the concave mirror. Rowland devised a mount for this instrument, which will be described.
The Rowland Mount

The diagram on page 9 gives the geometrical construction to illustrate the method of use of the grating. NML is a concave surface of speculum metal, ruled with parallel equidistant lines, with its center of curvature at K. A circle is drawn on the perpendicular line KM, with D as the center, so that it passes through K and M. Let a slit S be placed anywhere on the circle KMS, and determine the nature of the diffracted rays AO, CO, A'O and C'O. The distance (a+b) comprising one space and one ruling, is termed a grating element. If AC = A'C' = (a+b), the relative retardation between the waves arriving at O along the paths SCO and SAO is equal to (a+b) (sin i - sin θ). Whatever the position of A'C', i' = i and θ' = θ. This may be proved as follows. Join KA and KA'. Then angle SAK = i and angle KAO = θ; angle SA'K = i', and KA'O = θ'. The points A, C, A' and C' almost lie on the circle KSM, when only a small portion of the arc is considered. Then, since the angles SAK and SA'K are subtended by the same arc SK, these angles are equal, or i = i'. Similarly θ = θ'.

Thus, a number of images of the slit S, may be focused on the same circle, and if white light is used, a number of spectra will be formed on the circle KSM.
NML = Concave grating
K = Center of curvature
S = Slit
O = Camera
This arrangement was used by Rowland to obtain a spectrum in which equal distances on the photograph correspond to equal changes in wave length. (1)

The Rowland mounting (page 11), consists of two rails mounted on girders at right angles to each other. CG is an iron beam which rests on carriages on the rails. According to the geometrical relationship of right triangles, S will always be on the circumference of the circle of which CG is the diameter. When a slit is mounted at S, and the grating at G, the following conditions are fulfilled, and we should get a normal spectrum at C. 

\[
\sin i = (a + b) \frac{SC}{CG} = NA. 
\]

CG does not change in length, unless affected by temperature, so that as C moves from S to B, we get the first, second, third, and so on, order of diffraction images. The wave length of the spectrum lines is proportional to the distance moved along SB. A camera box, holding a plate of about 20 inches, may be put at C. The plate should be bent so that it coincides with the circle GSC, which is the locus of the equidistant points. The diameter of the circle GSC is the radius of curvature of the spherical grating surface. Overlapping of orders does not occur until we reach the second and third order.

**Methods of Producing Spectra.**

The spectrum emitted by an element or substance depends not only on the nature of the substance, but also upon the

(1) Edser, E., Light for Students, Page 460. 1902.
G = Grating
GB = Wrought iron beam
BS = Iron track
SA = Iron track
S = Slit
C = Camera plate
conditions which excite the molecules. The same substance can give entirely different spectra under different conditions. The four general methods of excitation are: (a) flame, (b) arc, (c) spark, (d) discharge in a partial vacuum or tube. When the salts of the alkali metals, and the alkaline earths are introduced into a flame on a platinum wire, definite and characteristic colorations are produced. The use of the spectroscope and a flame test gives us a very simple and quick means of identifying small traces of metals like potassium, lithium, and barium. Bunsen discovered caesium and rubidium by this method.

When more lines are desired, the arc may be used. The metallic salt is contained in carbon electrodes, but with the resulting objection that the spectrum will contain lines and bands due to carbon, impurities, and chemical compounds formed by the carbon and the air.

If a purer spectrum is desired, an induction coil may be used, discharging between terminals of the metals to be studied. Particles of the metal are torn off by the disruptive discharge and give a characteristic series of radiations. If especially vigorous action is desired, Leyden jars may be used to condense the spark. The conditions existing in the flame and arc are comparatively mild as compared with the spark. The spark usually enhances lines
in the arc spectra, and brings out new lines. When only one electron is removed from a neutral atom, the arc spectrum results, while the spark spectrum is the result of the passing of an electron from one orbit to another in an atom from which more than one electron has been removed. As hydrogen has only one electron to lose, the arc and spark spectra are identical.

The vacuum tube method consists of an evacuated tube, containing the gas to be studied, two terminals, and a window or end plate through which the characteristic radiations may be projected. This method is of great importance in determining the spectra of gases, such as in this experiment.

**Standards used in Spectroscopy.**

An Angstrom unit is \(10^{-10}\) meter. Fraunhofer determined the fixed position of the dark lines in the solar spectrum, and noticed that they were often very fine and sharply defined. Angstrom measured the visible spectrum from "A" to "H", using an accurate glass grating, and in 1868, published his map of the "Normal Solar Spectrum." The wavelengths were expressed in Angstrom units. Any system of measurement finally depends in accuracy upon the standard used. The standard meter is the distance, measured at the temperature of melting ice, between two transverse parallel lines ruled on a bar of platinum, which is kept in
the Palace of Archives in Paris. Copies of this have been distributed over the world. The standard meter, at Upsula, was used by Angstrom for his first map. A mistake had been made in comparing it with the standard at Paris, and therefore, a slight, but constant error remained. Thalen revised Angstrom's map after Angstrom's death, using the proper correction for the length of the meter. This corrected map remained the standard, until the publication of Rowland's results.

Rowland used the best measurements obtainable of the D1 line of sodium (5896.156), as his standard. He used a grating about 6 inches wide, with 10,000 lines to the inch, and a radius of curvature about 21.5 feet. As Rowland says, "We put in the sensitive plate and move to the part we wish to photograph. Having exposed that part, we move to another position, and expose again. Thus, we can photograph the whole spectrum in a few minutes, from the F line to the extreme violet, in several strips, each 20 inches long. Thus, the work of days with any other apparatus becomes the work of hours with this. Furthermore, each plate is to scale, an inch on any one of the strips representing exactly so much difference in wave-length." (1)

In 1894, Michelson made very accurate determinations

(1) H.A. Rowland, Phil. Mag. page 197, Sept., 1883.
of the number of wave lengths of the red cadmium line, in terms of the standard meter. According to his results, the wave length of the red cadmium line is 6438.5722 Angstrom Units. Michelson's values, obtained with his interferometer, are lower than those of Rowland, by an amount greater than the experimental error. Michelson found the red cadmium ray to be highly monochromatic. The D lines of sodium are quite monochromatic, but not sufficiently so for accurate work.

The International Union for Solar Research was formed, to clarify the matter of standards and methods. The first meeting was held at St. Louis, in 1904, followed by a meeting at Oxford the next year, where two important resolutions were adopted as follows:

1. The wave length of a suitable spectroscopic line shall be adopted as the primary standard, and that all wave lengths be measured in the unit thus defined. (Angstrom).

2. Secondary standards shall be measured by means of the interferometer in reference to the primary standard, and that secondary standards shall not be more than 50 units apart.

At Mendon, 1907, the Union adopted the red cadmium line as the primary standard, assigning to it the wave length of 6438.4696 Angstroms measured in dry air at 15 degrees Centigrade and 760 millimeters pressure of mercury. The error
between this new value and the original Angstrom unit is not more than one part in ten million.

In 1910, the fourth meeting was held at Mount Wilson. The following provisions were adopted:

1. It was decided to use certain lines in the arc spectrum of iron as secondary standards, and from these, derive in turn a series of tertiary standards.

2. The tertiary standards were to be obtained by interpolation in photographs of secondary standards, by the use of concave gratings.

3. To prevent confusion between the Angstrom unit used by Rowland, the symbol "I.A." was adopted, to indicate the standard of the International Union.

The most important result of the next meeting, at Bonn, in 1913, was the adoption of a standard iron arc. The following procedure was outlined:

1. Arc should be 6 millimeters in length.

2. A current of 6 amperes to be used for wave lengths greater than 4000 Angstroms; for less than 4000 Angstroms, a current of 4 amperes.

3. The positive pole to be above the negative; the diameter of the rods to be 7 millimeters, and 220 volt direct current to be used.

4. The middle 2 millimeters of the arc to be used.

5. Only lines of the groups a, b, c, and d, of the Mount Wilson classification to be used.
With the outbreak of the war in 1914, public and scientific attention was focused on troop lines instead of spectroscopic ones. The next meeting took place at Rome, in 1922, where a list of standard iron lines was approved. A few minor changes were made in the conditions for the proper use of the iron or Pfund arc. It was recommended that only a small portion of the central zone be used, not to exceed 1.5 mm. The current to be 5 amperes at 110-250 volts, a bead of iron oxide to be used as the lower pole. (1)

In 1927, at Sévres, the International Conference of Weights and Measures adopted the red cadmium radiation as the fundamental primary standard. (2)

In 1928, at Leyden, the International Union adopted a list of seven figure secondary standards.

Recent Determinations.

The spectrum of a metal like iron may appear to vary widely when different methods of excitation are used. The standardization (3) of the Pfund arc (4) insures that the standards used by different observers

are comparable. Even with a standard arc, the variation in current and voltage, and in photographic technique, makes it a difficult matter to assign a definite intensity to a certain line. In the multitude of fine distinct lines in the iron spectrum, certain of them may be chosen, at a convenient interval, that may be used as secondary standards. Recent papers on secondary standards are those of St. John and Babcock (1921), (1) and Meggers (1924), (2). Upon these standards are based the wave length of lines in the secondary in the secondary spectrum of hydrogen, the spectrum under investigation.

Deodar, (3) Gale-Monk and Lee, (4) and Finkelnburg, (5) have published important papers dealing with the secondary hydrogen spectrum. Gale-Monk and Lee, used a 21 foot Rowland convex grating, with a dispersion of 2.63 Angstroms a millimeter. The results obtained by Gale-Monk and Lee, and those of Finkelnburg, are given in Table 2, where they may be compared with the results obtained in the present investigation.

The Work of Professor Kent.

The experimental part of Professor Kent's work was done in Pasadena, at the California Institute of Technology.

The diagram of the lens and arc system on page 21 represents a front view; a top view is given on page 22. The schematic drawing on page 23 gives an idea of the arrangement. To produce a simultaneous exposure of both arc and tube, for long periods of time, the apparatus must be very stable, and the intensity of the light source must not vary (between appreciable limits.) The molecular spectrum of Hydrogen was produced by a vacuum tube. It has been noticed that certain metals tend to enhance the molecular spectrum, and overcome the Balmer Series. For this purpose molybdenum or tungsten, may be used. The hydrogen used, was prepared electrolytically, and was dried by passing it over phosphorus pentoxide. A constant small current of hydrogen was kept running through the tube. The tube was connected to the terminals of a high tension transformer of 10,000 to 20,000 volts. The intensity of the tube source was much less than that of the arc. The evening out of the difference in intensity, so that they both could be photographed simultaneously, was done by an ingenious device.
The apparatus consisted of a Pfund arc, P, placed at a distance. As the arc was many times more brilliant than the tube, the following method was used to obtain light of comparable intensity on the photographic plate. The light from the arc was partly refracted by the quartz plate, Q2, and then focused on the slit S1, by the lens, L1. Some light was thrown away at Q1. The slit was about one centimeter high by several centimeters broad. Its main purpose was to pick out from the arc image only the central portion. The ratio of the object distance, LiP, to the image distance, LiS1, was one to ten. The image of a 15 mm. arc would therefore be 150 mm. or ten times as large. As the slit S1, only allowed one cm. of the central part of the image to pass through, only the central portion of the arc, 1 mm. in height was used. This eliminated the irregularities in the arc caused by the poles. A quartz plate Q2, was so placed in front of the tube that it prevented very little of the tube light from passing through, yet reflected only a small portion of the light from the iron arc; allowing the greater part to be refracted as shown on page 22. A system of quartz lenses then carried the arc and tube radiations to a place mirror, M, mounted at 45 degrees. The reflected beam was focused on the slit of the spectroscope by the lens, L4, and then passed to the grating.

To eliminate as much as possible, temperature changes and the resulting convection currents, the grating was
ARC AND TUBE SYSTEM.
(Front view)

T = Vacuum tube
Q₂ = Quartz plate
L₁ = Lenses
M = Mirror
S₂ = Slit
ARC AND TUBE
SYSTEM
(Top view)

$L_1$ = Lenses
$M$ = Mirror
$P$ = Pfund arc
$Q_1$ = Quartz plate
$Q_2$ = Quartz plate
$S_1$ = Slit for arc
$S_2$ = Slit of spectroscope
$T$ = Tube
Lenses
Mirror
Pfund arc
Quartz plate
Slit for arc
Slit of spectroscope
Tube

$P = P_{f und \text{ arc}}$

$Q_1 = \text{Quartz plate}$

$Q_2 = \text{Quartz plate}$

$S_1 = \text{Slit for arc}$

$S_2 = \text{Slit of spectroscope}$

$T = \text{Tube}$
mounted in a well sunk in the floor. With a 21 foot wrought iron beam as the fixed member, a temperature rise of only 10 degrees Centigrade would produce an elongation of 0.0025 feet. When light passes through media of different densities, its direction is changed by refraction. Convection currents of air might tend to cause a "fuzziness" in the photographs.

Great care was used in focusing the light on the slit of the spectroscope. The arc and tube were started, and the plates were exposed for a period of from three to nine hours. The camera has many advantages over the eye for spectrographic work. First of all, we are not limited to what the eye can see, but can use sensitive plates which are affected by ultra-violet and infra-red rays. Long exposure makes lines visible which can not be seen by the eye. The camera plate may be accurately measured, at a later time, while actual observation is slow and tedious, and the conditions are difficult to approximate for reexamination. Professor Kent's plates were very fine, clear and sharply defined.

A diagram of the apparatus used to measure the plates is shown on the following page. The comparator consisted of a very accurately cut screw operating a plate carriage. The eye piece contained one cross hair, and was mounted so that the plate carriage moved under it. This arrangement permitted the plate to be completely enclosed in a heat insulating case. The case consisted of a wooden box, with
A = Ammeter
B = Current for relay
C = Heating coil
D = Condenser
L₁ = Light for vernier
L₂ = Light for eye-piece
R₁₀ = Rheostat
R₁₂ = Rheostat
S₁ = Switch for L₁
S₂ = Switch for L₂
S₃ = Switch for 220 V. line
Th₁, Th₂ = Thermostatic regulators
TR₁, TR₂ = Thermostats
#₁ = Current for L₁ and L₂
a removable top so that the plate might be adjusted or
turned. The opening around the eye piece was closed with
wool felt, and covered with a protecting oil cloth. The
vernier scale at one end of the screw, could be read
through a glass window. A small light, L1, and a magni-
ifying lens facilitated reading.

The heating coil, J, used to maintain a constant
temperature, was controlled by two thermostats, so arrang-
ed that if one failed to work, the other would prevent
overheating. Two thermostatic regulators, T.R1, and T.R2,
were connected with their respective thermostats, TH1, and
TH2. TH1 was set at 29.5 Centigrade, and TH2, at 34.1
Centigrade. The temperature during a run was read from
thermometers inserted in the top cover of the case.

Before taking a set of readings, the plate was placed
in its holder and adjustments for leveling and position
were made. The eye-piece was adjusted for a sharp image,
and to eliminate parallax. The switch closing the heating
circuit was turned on, and readings were not taken until
the temperature became constant. Certain lines, at short
intervals, were chosen as standards. By means of a hand
crank at the end J, of the comparator, the standard line
was set on the cross hair. The usual precaution in measur-
ing with such an instrument was used, that of always ap-
proaching a fixed point from the same direction. The ap-
proximate position of the line was taken from the position
of a pointer fastened to the carriage. The pointer moved
over a meter scale fastened to the inside of the case.

The cross hair was set on the middle of the line chosen as a standard, ten times, and the ten corresponding vernier readings were averaged. Five settings were sufficient to get an average of the intervening lines. The center of intense lines was more easily determined by making the light, L2, brighter, by cutting out resistance in the switch, S2. The standard had to be redetermined for each new set of readings on different days. This method of using standards at short intervals has the advantage that it gives practically a normal spectrum. Eye fatigue and the attendant error was minimized, because an observer did not have to read the whole plate at one sitting. One man set on the lines, while another read and recorded the vernier. Then the men exchanged positions. A comparison of the results detected any personal error. The plate was read moving right, then reversed and read moving right, thereby the line was really read from both directions.

The results obtained by the writer are given in Table I, compared with those of Professor Kent, Gale-Monk and Lee, and Finkelburg. Whole numbers of wave lengths are given in the first column. Decimal parts only are given in the remaining columns. In Table II, the variations between the results of the above named investigators is given. For example, the difference between the published value for line 4188, obtained by Professor Kent and Gale-Monk and Lee is 0.021 Angstrom Units. Professor Kent's result is lower than that of Gale-Monk and Lee.
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TABLE II
Variation between Standards

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Net Variation  - .008  - .236  - .135  + .116
Average Net Variation  - .0003  - .008  - .005  + .004
Discussion of Results.

The results of the different investigators show a wider variation than seems desirable, for work of this nature. The results of Finkelnburg are nearer to those of Professor Kent, than are those of Gale-Monk and Lee. In several cases the discrepancies are so large as to make one suspect that a different line is under consideration. Different observers often fail to agree on the intensity of a line. Some lines are broad and faint, others are thin and indistinct.

The real source of error seems to be in the method and apparatus used for measuring. The close agreement between the values determined by Professor Kent, and the writer, shows that the apparatus for measuring gives consistent results. At no time did the temperature during a set of readings vary more than 0.1 degree Centigrade. Finkelnburg and Gale-Monk and Lee, make no mention of temperature control in their report.

Another source of error was minimized by using a method of standards at short intervals. The necessity for this lies in the fact that the Rowland Grating does not give a perfectly normal spectrum. The equation for the dispersion is \[ D = \frac{n}{b \cos \theta} \] where \( D \) = dispersion, \( n \) = order of spectrum, \( b \) = grating aperture and \( \theta \) the angle.
of reflection. The Rowland mount used has a radius of curvature of 21 feet, and the plate is 41 cm. long. At the end of the plate \( \sin \theta = \frac{20.5}{21} = 0.032 \) radians or \( 1^\circ 50' \). The cosine is 0.9995. For half the plate the error would be between .002 and .003 Angstroms in the first order or about .001 to .0015 in the second order.
Summary.

The development of the prism spectroscope substituted scientific measurement for observation, and was a powerful weapon in disclosing the secrets of solar radiation. The development of the grating by Fraunhofer and its improvement by many others, led to Rowland's achievement. With a finely ruled grating of speculum metal, mounted so that a nearly normal spectrum is obtained, the standards of spectroscopic measurement have been established. The red cadmium line has been agreed upon as the primary standard, measured by the interferometer. For secondary standards, certain lines in the arc spectra of Iron are used. The Pfund arc has been standardized, and the conditions for its use so limited that in the hands of different observers, it gives comparable results. For many parts of the spectrum other standards are desirable. The great number of lines in the molecular spectrum of Hydrogen and their sharpness and definition, has lead to their use as secondary standards.

The most recent measurements of the lines in the molecular spectrum of Hydrogen have been made by Gale, Monk and Lee, and by Finkelnburg. The work done by Professor Kent, was carefully carried out and many ex-
cellent plates obtained. The writer has measured some of these lines, under Professor Kent's supervision, and is indebted to him for a glimpse of the source, methods, and achievements of spectroscopic work.
Bibliography


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