Isotope Shift in Magnesium*

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The previous investigations concerning the isotope shift of magnesium have been repeated and extended by means of an improved atomic beam source and a Perot-Fabry interferometer. The values of Meissner have been checked to within experimental error in most cases. In addition, several new lines have been resolved, and their isotope shifts determined. The $3\,^1P-m\,^1D$ series has been resolved from $m=3$ out as far as the member $m=11$. In this series the values of $\Delta\nu(=\nu_{26}-\nu_{24})$ seem to converge to a value of about 0.068 cm^{-1} rather than the value 0.056 cm^{-1} obtained by Meissner. The isotopic shifts of the members $m=5$ and $m=6$ of the series $3\,^1P-m\,^1S$ have been measured. The results obtained are discussed in connection with the theoretical work of Vinti, who assumed the splitting to be solely a mass effect. The experimental and theoretical values of $\Delta\nu$ agree in sign, but the former are usually larger by a factor of about two. The $3\,^2D-4\,^2F$ doublet of Mg II at 4481A has been measured very carefully and the separation of the two components found to be 1.000 ± 0.002 cm^{-1}.

INTRODUCTION

THE magnesium atom is ideal for the study of isotope shift. It possesses three isotopes of mass numbers 24, 25, and 26, and abundance percentages 77.4; 11.5; 11.1. Since the atomic number is even, no nuclear spin is to be expected for the isotopes 24 and 26. It can further be shown[1] that the isotope 25 is not likely to cause observable hyperfine splitting in many of the most prominent lines because of the nature of the states involved.

It may be advisable to give a brief résumé of earlier investigations of the magnesium spectrum.

Murakawa[2] investigated the problem using a water-cooled Schueler discharge tube and found all lines sharp and single.

Bacher and Sawyer[1] repeated the investigation using a liquid-air-cooled Schueler tube. Their spectral apparatus consisted of a Perot-Fabry interferometer in combination with a glass spectrograph. Values of plate separations up to 29.5 mm were used. All of the lines investigated, with the exception of the strong triplet 5183/72/67A ($3\,^3P_{2,1,0}-4\,^3S_1$), were found to possess two components, a strong one, and a considerably weaker satellite on the short wave-length side.

These observations were interpreted by Bacher and Sawyer as an isotope effect. The explanation of the structure as a pure mass effect was eliminated because of the presence of only one satellite, instead of two. It was also pointed out that the shift was in the wrong direction to be accounted for by a difference in nuclear fields caused by the fact that the nuclei with a larger number of particles have larger radii. The fact that only two components were observed was explained as directly due to perturbation effects. The splitting was found to be quantitatively related to the magnitude of the perturbation.

The investigation was extended to the resonance line by Jackson and Kuhn[3] and by Fisher[4] using the atomic beam in absorption and emission, respectively. Both investigations revealed again two components, the weaker lying on the short wave-length side. The magnitude of the splitting obtained was quite different in the two cases, however; Jackson and Kuhn obtained the value $+0.033\pm0.002$ cm^{-1}, while Fisher reported a splitting of $+0.066$ cm^{-1}.

Meissner[5] repeated the investigation employing the atomic beam as a light source. A Perot-Fabry interferometer was used with separations of 12, 36, 42, 60, and 180 mm. His spectrograms exhibit an entirely different appearance from those of earlier workers. With the exception of

* Based upon a thesis submitted by L. G. Mundie to the faculty of Purdue University in partial fulfillment of the requirements for the degree of Doctor of Philosophy in April, 1943.

[1] A. E. Bacher and R. A. Sawyer, Phys. Rev. **47**, 587 (1935).

[2] K. Murakawa, Zeits. f. Physik **72**, 793 (1931).

[3] D. A. Jackson and H. Kuhn, Proc. Roy. Soc. **A164**, 48 (1938).

[4] R. A. Fisher, Phys. Rev. **51**, 381 (1937).

[5] K. W. Meissner, Ann. d. Physik **31**, 505 (1938).

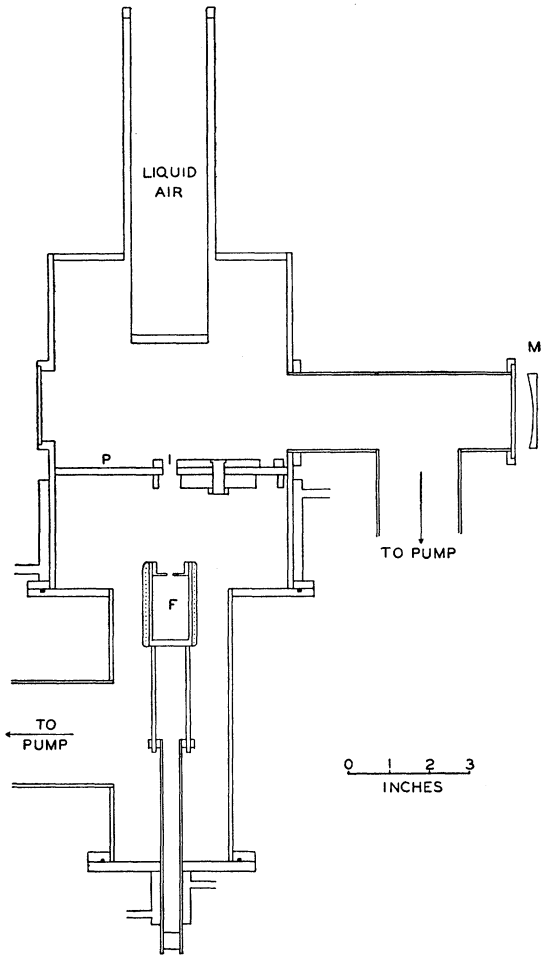

FIG. 1.

the green triplet at 5183A, all of the more intense lines were found to consist of *three* nearly equally spaced components. The strongest component was of longest wave-length; the other two were of nearly equal intensity. The explanation as a pure mass effect was of course strongly suggested, and hence proposed by Meissner. The line shifts of the $3\,^1P-m\,^1D$ series were observed from $m=3$ to $m=7$. Convergence of the latter values allowed a calculation of the isotope shift of the $3\,^1P$ term, as well as the $m\,^1D$ terms involved. The shift of the $5\,^1S$ term was also obtained. The analysis could not be pushed any further, however, because of lack of sufficient accurate experimental data.

Fisher[6] has recently repeated his work on the resonance line at 2852A. He succeeded in resolving the triplet isotope structure and found the separation from the main component of the two weaker components to be 0.030 and 0.053 cm^{-1}.

A theoretical investigation of the isotope shift in magnesium has been recently carried out by Vinti,[7] who assumes the shift to be solely a mass effect. The "specific" shift (that part of the total shift which is not accounted for by replacing m, the mass of the electron, by μ, the reduced mass, in the wave equation) is treated as a perturbation in much the same way as was done in the case of Li by Hughes and Eckart.[8] Only a first-order approximation is necessary, as the second approximation is smaller by a factor of the order m/M, where M is the mass of the nucleus. By choosing explicit radial functions, Vinti was able to calculate the splitting of several lines. The results obtained are of the right order of magnitude, but on the whole the agreement with the observed values is not particularly satisfactory. Using the observed values of $\Delta\nu$, Vinti was further able to predict the splitting of several other lines without making any explicit use of radial functions.

The present investigation was undertaken with the aim of repeating and extending the previous experimental investigations of isotope shift in magnesium. Such an undertaking is worthy of attention in view of the following facts:

(a) The results of Meissner are in complete disagreement with the results of earlier investigations; and (b) the agreement between theory and experiment is not particularly good. A confirmation of the earlier measurements was therefore desirable. Furthermore, there was hope that new and more extended experiments could give information about the isotope shift of lines which had not been investigated experimentally but which Vinti had calculated.

I. EXPERIMENTAL DETAILS

A. The Atomic Beam Apparatus

The prime requirement of an atomic beam for the present type of investigation is that it should produce a spectrum which (1) has sufficient intensity for the production of spectrograms in

[6] R. A. Fisher, Rev. Mod. Phys. **14**, 79 (1942).

[7] J. P. Vinti, Phys. Rev. **56**, 1120 (1939).

[8] D. S. Hughes and C. Eckart, Phys. Rev. **36**, 694 (1930).

reasonably short times, (2) has the freedom from Doppler broadening required in the particular case under investigation, and (3) is reasonably free from foreign lines and bands. Experimentally this means that we must have (1) the greatest possible density in both the atomic and the exciting electronic beams, (2) sufficient collimation of the atomic beam, and (3) a high vacuum in the excitation chamber.

It might be pointed out that the intensity requirements in the present case are rather high. This is seen when we consider that the intensity at the maximum of a fringe formed by a Perot-Fabry interferometer is of the order of only one percent of that of the incident light and that, furthermore, we are interested in bringing out satellites which are even many times weaker than the main component.

The vacuum requirement is also not easily fulfilled because of the enormous amounts of gas given off by the furnace, filament, anode, and the walls of the chamber which are under constant bombardment by stray electrons.

The apparatus finally evolved from a series of preliminary trials may be described in detail.

A general view of the arrangement is seen in Fig. 1. It consists of a cylindrical chamber which has been divided by the copper plate P into two parts: the furnace chamber, and the excitation chamber. Each of these is connected directly to an oil diffusion pump having a pumping speed of about 45 liters per second. The two chambers are joined only by the so-called image aperture I through which the atomic beam passes, prior to deposition on the base of the liquid air trap. With this arrangement an excellent vacuum can be maintained in the excitation chamber even while the furnace is giving off a considerable amount of gas. The furnace F consists of a steel cylinder wound with Nichrome V wire embedded in Saureisen cement. It is mounted on three long nickel-silver legs to minimize the conduction of heat to the support. The cover is recessed into the furnace cavity to ensure a high temperature of the oven aperture, and hence avoid deposition of metal upon it. The walls of the furnace chamber are water cooled. By use of the concave spherical mirror M so arranged as to form a real image of the beam at the beam itself, a considerable improvement in the intensity was obtained.

In order to avoid clogging of the image aperture I, the device shown in Fig. 2 was used. (This arrangement is also to be seen in cross section in Fig. 1.) Eleven slits 2 mm × 10 mm were cut in a circular brass plate B as indicated. These image apertures are brought into position over the oven aperture one after the other by means of a lateral motion of the lever L. Motion is allowed by the sylphon S, and restricted to the horizontal direction by the vertical pin P. The motion is transmitted to the plate by a pawl and ratchet arrangement. In order to avoid clogging of the stationary opening O in the dividing plate D, it was found necessary to introduce a second rotating plate A on the lower side of the dividing plate. The plate A is rigidly connected to B, and contains a set of corresponding slits considerably larger than those in B. It was found that about fifteen minutes were required for any appreciable clogging of an image slit. Thus the eleven slits were sufficient for even the longest exposure.

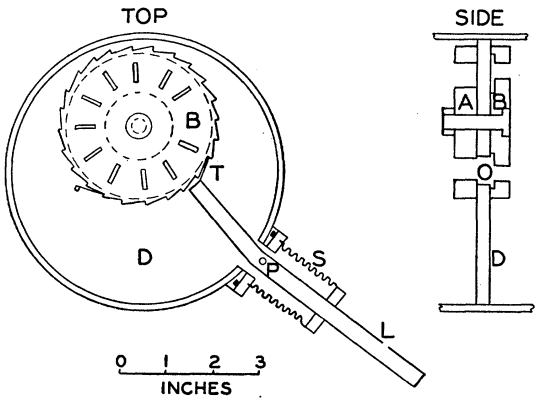

FIG. 2.

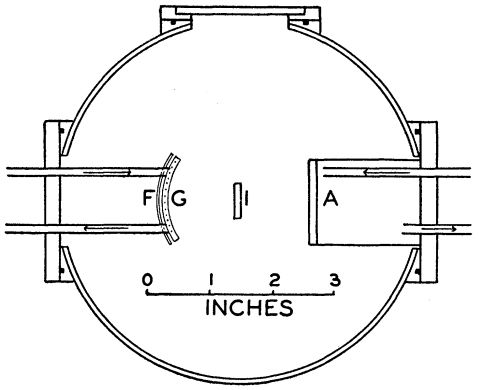

FIG. 3.

The final electron gun arrangement adopted was similar to that used by Meissner and Luft.[5,9] As a description of their arrangement has never been published, it will be described in detail here. The general arrangement is seen schematically in Fig. 3, which represents a top view of the assembled device. The filament F and grid G are in the shape of portions of concentric cylinders. The image slit I is located so as to send the atomic beam along the common axis of these cylinders. The water-cooled anode A collects the electrons that have passed through the excitation region, and assists in focusing the electrons. The leads of the filament are omitted in this sketch.

In Fig. 4 the details of the construction of the grid are shown. The grid elements consist of nickel tubes T of 0.045" O.D., and 0.009" wall thickness. Cooling is accomplished by passing distilled water along the paths indicated by the arrows. The nickel tubes are hard-soldered into the brass frame B, the profile of which is to be seen in the "front view" diagram. B is, in turn, hard-soldered between two thin copper frames C.

An Eastern centrifugal force pump was originally used for circulating the distilled water

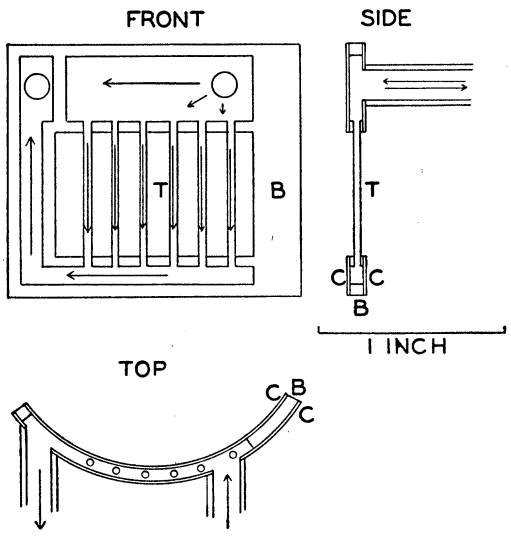

FIG. 4.

through the grid. Since the motor was found to become rather hot on continuous use, the arrangement shown schematically in Fig. 5 was finally adopted. Here A and B are two steel tanks of about 40 gallons in capacity, one of which is originally filled with distilled water. The glass tube T indicates the position of the water level in A. The tube C is connected to an air line, and

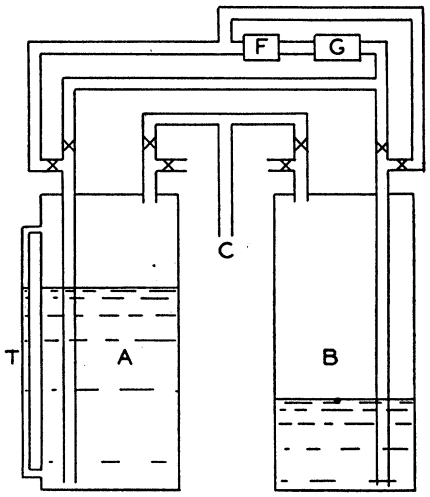

FIG. 5.

it is seen that by proper manipulation of the stopcocks X the water may be caused to pass back and forth from one tank to another through the grid G, being filtered each time by the filter F. The latter consists of a piece of tightly woven cotton cloth, with an area of about eight square inches. Water flow at a rate of about 25 gallons an hour was sufficient to prevent boiling in the grid tubes.

Details of the mounting of the filament are shown in Fig. 6. The filament itself consists of two strips of 0.001" platinum ribbon F. These strips are mounted between strips of copper C and nickel N pressed tightly together by flat-head screws as shown. Electrical current is conducted to the filament by the leads L. About 25 amperes were usually sufficient to bring the oxide coating to operating temperature. Mica strips were used for insulation.

The filament, grid, anode, and furnace were mounted on individual face plates, the vacuum seal being accomplished by the use of cylindrical rubber gaskets.

Figure 7 shows the electrical connections to the apparatus. The circuit was protected from overloading by a magnetic circuit-breaker B. This was found to be quite essential, for any

[9] K. W. Meissner and K. F. Luft, Ann d. Physik **28**, 667 (1937).

material increase in pressure in the chamber will cause arcing between the filament and grid, resulting in very high currents. The grid and anode voltages were supplied by a d.c. generator of 2-kw rating. A 1000-ohm resistance R_1 was

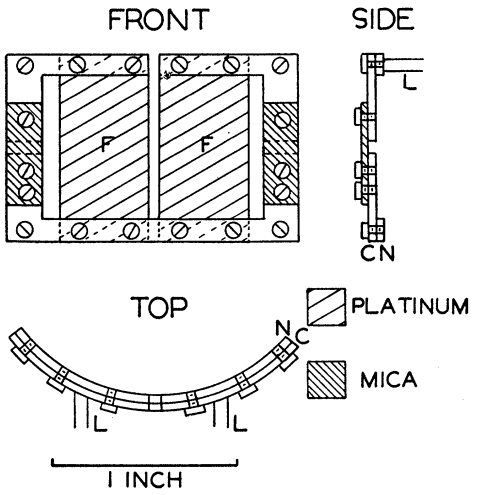

FIG. 6.

connected in series with the filament for stabilization of minor disturbances. The grid voltage may be changed relative to that of the anode by adjustment of the 900-ohm variable resistance R_2. Filament emission currents up to about 400 ma were obtained, approximately half being transmitted to the anode.

Measurement of pressure was performed with a Knudson gauge similar to that described by DuMond and Pickels.[10] This type of gauge is ideal for the present purpose, for it gives continuous readings, covers a wide range of pressures, and is extremely rigid. Its characteristics are, furthermore, not at all changed by the sudden bursts of pressure which occur because of evolution of gas from the furnace. The scale is linear at lower pressures, and nearly so at forepump pressures. Calibration was performed by using a McLeod gauge. A permanent horseshoe magnet was found to be quite sufficient for damping, and much handier than the electromagnet usually used.

The spectra obtained with this new atomic beam apparatus were practically free from a background present with earlier constructions and due to bands of gaseous impurities.

[10] J. W. M. DuMond and W. M. Pickels, Rev. Sci. Inst. **6**, 362 (1935).

B. Spectral Apparatus

A Perot-Fabry interferometer was crossed with a prism spectrograph in making the measurements of hyperfine structure. The interferometer was placed between the collimator and the prism of the spectrograph. This is the arrangement for maximum intensity, as the entire areas of the interferometer plates are utilized in parallel light. The plates must, however, be very accurately plane and parallel when this method is used.

The spectrograph employed was a Steinheil, No. 5102, furnished with three glass prisms. The aperture of the lenses was 7.0 cm. In most of the work one prism furnished sufficient dispersion, and a focal length of 64 cm for both the collimator and the camera was used. While working in the infra-red, however, it was necessary to use a camera lens of 40-cm focal length in order to obtain sufficient intensity. In the investigation of the green triplet at 5180A, all three prisms were necessary to obtain sufficient dispersion.

The interferometer plates were made of fused quartz. They were 6.6 cm in diameter, and of slightly prismatic shape, the plane surfaces making an angle of about 30′ with each other.

These plates were coated with silver by sputtering in hydrogen. To ensure a uniform coating, a cathode area considerably larger than the area of the plates was employed, and the plate being sputtered was carefully centered with respect to the cathode. Pure hydrogen was obtained by using the palladium-tube method. The best surfaces were obtained by employing small sputtering currents and rather long sputtering periods. In a typical run, for example, a current of 9

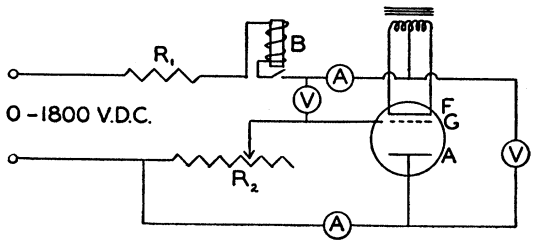

FIG. 7.

milliamperes maintained for 36 minutes produced a surface with a reflection coefficient of 0.90.

Measurements of the optical properties of the sputtered surfaces were made with a Weston photronic cell, and a wall-type galvanometer.

It was found possible to obtain surfaces for which the absorption coefficient ranged from 0.03 to about 0.06, depending on the density of the deposit used. Reflection coefficients of from 0.85 to 0.93 were employed.

The silvered surfaces of the interferometer plates were kept accurately parallel by spacers made of fused silica. The preparation of these spacers will now be described in some detail.

Opaque tubing of fused silica of 67-mm O.D. and 5-mm wall thickness was obtained from the Amersil Company, and was cut into the desired lengths with a high speed saw. Three small projections of clear fused quartz were then fused on each end, 120° apart, care being taken to have the corresponding projections of both ends accurately opposite one another. The projections were approximately hemispherical in shape, and about 3 mm in diameter. The next step was to grind the hemispheres on a flat surface of ground glass until the outer portions of their surfaces became plane circles about 2 mm in diameter. Carborundum was used for the initial rough grinding, and the finishing was accomplished using rouge.

After one set of the projections was finished, the other set had to be adjusted by careful grinding and polishing so that the planes formed by the two sets of surfaces became accurately parallel. The accomplishment of this task was very much simplified by using an interferometer, originally designed for plant physiological investigations by one of us.[11]

The interferometer housing consists of a brass cylinder which encloses the plates and spacer and is fitted with plate-springs of sheet steel for pressing the plates firmly against the spacer. This mounting, as well as the type of spring action, was adapted from the Perot-Fabry interferometer manufactured by Carl Zeiss, Jena. In order to secure absolutely reliable performance, however, it was necessary, especially for larger spacers, to provide both ends of the housing with adjusting springs. This design is similar to the one used by Meissner and Luft.[9] It may be mentioned that the original etalon of Perot and Fabry as constructed by Jobin,[12] also allowed adjustment of spring pressures from both ends.

After the interferometer is assembled, the spring pressures must be adjusted until the reflecting surfaces are accurately parallel to one another, as evidenced by the fact that the diameters of the interference rings formed by any small portion of the surfaces are exactly equal to those formed by any other portion. During the preliminary adjustment this condition is checked with the naked eye; a more accurate final adjustment is made with a telescope of small aperture but rather high magnifying power. A krypton discharge tube was used as light source for this adjustment. It was found that relatively small spring forces were required for this adjustment when the polishing was carefully performed in the manner described above. Another requirement for perfect adjustment is that the interferometer plates and the faces of the spacer projections be in optical contact. If these conditions are fulfilled a perfect adjustment can be retained for several days.

Because long exposure times were required, it was necessary to place the interferometer in a chamber that was maintained at constant temperature and constant pressure. For this purpose the chamber was equipped with a jacket through which water of constant temperature circulated. The temperature of this water was thermostatically controlled and was maintained constant to within 0.02°C. The interior of the chamber was easily reached by removing one end plate. This plate was fitted airtight to the chamber by the application of Apiezon stopcock grease. Plane parallel windows were sealed to the end plates of the chamber.

The spectra were recorded on Eastman plates; type 103 G was used for the visible region and type 1-P for the infra-red line 8806A. In the latter case the plates were hypersensitized with ammonia.

Most of the spectrograms were measured by means of an Abbe comparator (Zeiss, Jena, Model A, 1937), using magnifications ranging from six to twenty. In the case of two or three of the weakest lines, however, it was necessary to use even smaller magnifications in order to see the weak components of a line clearly. In these cases a Leiss comparator was used, set for a magnification of only three diameters. The possible

[11] K. W. Meissner, Physik. Zeits. **30**, 965 (1929); Jahrb. f. wiss. Botanik **76**, 208 (1932).

[12] Ch. Fabry and A. Perot, Ann. Chim. Phys. [7] **25**, 98 (1902).

error, of course, is increased by using such a small magnification.

II. RESULTS

A. General Features of the Lines

A large number of spectrograms were taken with interferometer spacings of 30.0, 41.7, and 60.0 mm. In agreement with the results of Meissner, it was found that whenever the hyperfine structure could be resolved, three nearly equally spaced components were present. The strongest component was always of longest wave-length, and the other two were always of nearly equal intensity.

The attribution of these components to the three isotopes of magnesium is undoubtedly justified, so in the following, we will refer to the wave numbers of the three components as ν_{24}, ν_{25}, and ν_{26}. In this investigation we have been primarily interested in the determination of the wave number differences of the various lines, given by $\Delta\nu=\nu_{26}-\nu_{24}$, and $\Delta'\nu=\nu_{25}-\nu_{24}$.

The $3\,^1P-m\,^1D$ series is very strongly developed in the atomic beam. Measurement of this series has been pushed to the member $m=11$. However, the satellites were extremely weak in the higher members, and starting with $m=7$, only one satellite could be observed. The accuracy of these measurements is naturally rather low.

Two members of the $3\,^1P-m\,^1S$ series appeared quite distinctly, and $\Delta\nu$ values were obtained in the case of the lines $m=5$ and $m=6$.

The intercombination resonance line

$$3\,^1S_0-3\,^3P_1,\ 4571\text{A},$$

appeared on a few plates, but was always too weak for the detection of any possible satellites.

In agreement with the results of previous investigations, no structure whatever could be detected in the case of the green triplet

$$5167\text{–}5184\text{A}\ (3\,^3P-4\,^3S).$$

B. Reduction of the Perot-Fabry Patterns

The quantitative evaluation of the wave number differences between the components of the lines was performed by applying Tolansky's method,[13,14] which is very convenient for close lines. This method is based on the fact that the squares of the diameters of the Perot-Fabry fringes form an arithmetical series of the first order and that the squared diameter values of the fringes of close lines show constant differences which are related to the wave number differences by a simple relation. The squares of the diameters of all the fringes measured on a compound line can be arranged in an array with horizontal and vertical rows with constant horizontal and vertical differences, from which the wave number differences can be found provided that the thickness of the spacer is known. In the case of the wave number difference between the Mg_{25} and Mg_{24} components, the relation is

$$\nu_{25}-\nu_{24}=\frac{(D_{25}^2-D_{24}^2)_{Av}}{(\Delta D^2)_{Av}}\cdot\frac{1}{2t}\ \text{cm}^{-1},$$

where $(\Delta D^2)_{Av}$ is the average value of the constant difference in D^2 between consecutive fringes of the same component, and where t is the thickness of the spacer in cm.

The value of $\nu_{26}-\nu_{24}$ is calculated in a similar manner.

C. Quantitative Results

Measurements were made on seventeen of the spectrograms taken. The values obtained from different plates agreed quite well among themselves, the mean error ranging from 0.0004 cm^{-1} for the stronger lines to about 0.005 cm^{-1} for the weakest ones.

The measured values of $\Delta\nu$ were found to fluctuate about definitely different values for different sizes of spacers. This is due to a slight "attraction" of strong spectral lines for neighboring weak ones, resulting in a "shrinking" of the observed separation.[15] The magnitude of this "attraction" depends on the distance between the two lines on the photographic plate which, in turn, depends upon the size of the spacer used. In such cases the most accurate results are obtained when the weak line being measured is (1) farthest from the neighboring strong line, or (2) midway between two strong lines. When the 60-mm spacer was used, condition (2) prevailed for the Mg^{25} components in the $3\,^1P-m\,^1D$ series, as the Mg^{26} component became super-

[13] S. Tolansky, J. Sci. Inst. **8**, 223 (1931).
[14] K. W. Meissner, J. Opt. Soc. Am. **31**, 405 (1941).
[15] O. Oldenberg, Ann. d. Physik **67**, 253 (1922).

TABLE I. Isotope shifts in Mg.

λ(A)	Transition	Mundie & Meissner	Meissner	Bacher & Sawyer
8806	$3\,^1P-3\,^1D$	0.0000 +0.0423±0.0004 +0.0851±0.0004	0.0000 +0.0412±0.0004 +0.0831±0.0004	0.0000 — +0.082
5528	$3\,^1P-4\,^1D$	0.0000 +0.0374±0.0004 +0.0709±0.004	0.0000 +0.0354±0.0004 +0.0714±0.0009	0.0000 — +0.065
4703	$3\,^1P-5\,^1D$	0.000 +0.038±0.001 +0.068±0.001	0.000 +0.034±0.002 +0.068±0.002	0.000 — +0.061
4351	$3\,^1P-6\,^1D$	0.000 +0.039±0.001 +0.070±0.001	0.000 — +0.061±0.003	— — —
4167	$3\,^1P-7\,^1D$	0.000 — +0.066±0.001	0.000 — +0.062±0.003	— — —
4057	$3\,^1P-8\,^1D$	0.000 — +0.067±0.003	Satellite present but not measurable	— — —
3986	$3\,^1P-9\,^1D$	0.000 — +0.067±0.003	— — —	— — —
3938	$3\,^1P-10\,^1D$	0.000 — +0.068±0.005	— — —	— — —
3904	$3\,^1P-11\,^1D$	0.000 — +0.069±0.005	— — —	— — —
5711	$3\,^1P-5\,^1S$	0.0000 +0.0266±0.0004 +0.0545±0.0004	0.0000 +0.0248±0.0015 +0.0543±0.0010	Asymmetry indicates structure similar to but narrower than that of 5528A
4730	$3\,^1P-6\,^1S$	0.0000 — +0.0625±0.0007	Line weak; no satellite visible	— — —

imposed on the Mg^{24} rings of next lower order number. Results obtained with the 60-mm spacer were therefore more heavily weighted in calculating the separations $\nu_{24}-\nu_{25}$ for this series.

Table I shows a complete list of measurements of $\Delta\nu$ and $\Delta'\nu$ made. For the sake of comparison, the results of Bacher and Sawyer and of Meissner have been included.

A fairly strong line at 4481A was found to be due to the Mg II transition ($3\,^2D-4\,^2F$); two components were found, with the intensity ratio of about 2 : 3. The splitting was calculated to be 1.000 ± 0.002 cm^{-1}.

III. DISCUSSION

It is seen from Table I that the observed isotope shifts are for the most part in substantial agreement with those of Meissner. The differences are in some cases larger than the combined predicted experimental errors, indicating that the true experimental error is somewhat larger than the quoted values. The latter are simply the average fluctuations of the values obtained among the different plates.

The measurement of the $3\,^1P-m\,^1D$ series has been carried to higher members. The values of $\Delta\nu(=\nu_{26}-\nu_{24})$ for the higher members of this series are found to fluctuate about an average value of 0.068 cm^{-1}. One would expect, therefore, that this value represents the (26–24) shift of the $3\,^1P$ term. This value is considerably higher than the approximate value of 0.056 cm^{-1} obtained by Meissner by extrapolation from the shift of the lower series members. Similarly, the values of $\Delta'\nu(=\nu_{25}-\nu_{24})$ seem to converge to a

value of 0.038 cm^{-1}, which may be taken as the (25–24) shift of the $3\,^1P$ term. It should perhaps be pointed out that the ground state of the singly ionized atom is considered as the level of zero energy for each isotope. Thus the shifts of the $3\,^1P$ term may be regarded as the corresponding shifts of the hypothetical "line" $(3\,^1P)_{MgI} - (3\,^2S)_{MgII}$ as has been done by Vinti.

Knowing the shift of the $3\,^1P$ term we can at once calculate the shifts of other terms involved in transitions with this term, in cases where the corresponding spectral lines have been resolved. Table II gives a list of term shifts obtained in this way. In this table

$$\Delta = T_{26} - T_{24} \quad \text{and} \quad \Delta' = T_{25} - T_{24}.$$

The analysis may be pushed further with the help of the very recent values of Fisher[6] for the shifts of the resonance line λ2852 $(3\,^1S_0 - 3\,^1P_1)$. For this line Fisher obtained values of +0.030 cm^{-1} and +0.053 cm^{-1} for $\Delta'\nu$ and $\Delta\nu$, respectively. The shifts of the $3\,^1S_0$ level are at once seen to be $\Delta' 3\,^1S_0 = 0.098$ cm^{-1} and $\Delta 3\,^1S_0 = 0.121$ cm^{-1}. Furthermore, if we accept Bacher and Sawyer's value, $\Delta\nu = +0.083$ cm^{-1}, for the intercombination line λ4571$(3\,^1S_0 - 3\,^3P_1)$, we obtain for the shift of the $3\,^3P_1$ level the value $\Delta 3\,^3P_1 = 0.038$ cm^{-1}. Finally, the sharpness of the lines $(3\,^3P_{0,1,2} - 4\,^3S_1)$ and $3\,^3P_{0,1,2} - 3\,^3D_{1,2,3})$ allow one to conclude that $\Delta 4\,^3S_1 \approx \Delta 3\,^3P_1$, and $\Delta 3\,^3D_{1,2,3} \approx \Delta 3\,^3P_1$.

In Table III a comparison is made of the theoretically predicted shifts of Vinti with the experimentally observed shifts of Meissner (M) and with those of the present investigation (MM). It is seen that the experimental results obtained in the present investigation are slightly further from the calculated values of Vinti than are the results of Meissner. The experimentally observed shift is in all cases about twice as large as the calculated value. The discrepancy between theory and experiment can be understood perhaps in view of the fact that the radial wave functions used are probably not very accurate.

Unfortunately, all of the other lines calculated by Vinti were found to be much too weak for resolution with the interferometer, and hence no check of the theory could be made from this direction.

It is interesting to note that the Mg^{26} satellite was measurable out to the member $m = 11$ of the $3\,^1P - m\,^1D$ series, while the Mg^{25} satellite could only be followed out to the member $m = 6$. A possible explanation is that the Mg^{25} line becomes "fused" with the base of the intense Mg^{24} line, although this explanation would not be valid in the case of larger plate separations.

The relative abundances of the isotopes Mg^{25}/Mg^{26} are found from the mass spectrograph to be 11.5/11.1. The difference in the abundances of these two isotopes should cause a corresponding difference in the intensities of the satellites in the spectral lines. A careful measurement of the intensities should therefore furnish a conclusive check on the order in which the satellites are assigned to the isotopes.

TABLE II. Calculated shifts.

Term	$\Delta'(cm^{-1})$	$\Delta(cm^{-1})$
$3\,^1P$	+0.038	+0.068
$3\,^1D$	−0.004	−0.017
$4\,^1D$	+0.001	−0.003
$5\,^1D$	0.000	0.000
$5\,^1S$	+0.011	+0.013
$6\,^1S$	—	+0.005

TABLE III. Comparison of calculated and observed shifts.

Transition	λ(A)	$\Delta\nu_{calc.}(cm^{-1})$	$\Delta\nu_M(cm^{-1})$	$\Delta\nu_{MM}(cm^{-1})$
$3\,^1P - 3s\,^2S$(MgII)		0.0264	0.056	0.068
$3\,^1P_1 - 3\,^1D_2$	8807	$\leqq$0.0434	0.0831	0.0851

This measurement was attempted in the present investigation. The line 8806A was chosen because this line exhibits the largest isotope shift. Furthermore, because of the high resolving power of the interferometer in this region, a very distinct separation of the components was achieved. Thus the instrumental conditions for the task were fulfilled. It was very soon found, however, that the photographic characteristics of the hypersensitized infra-red plates are not sufficiently constant for intensity measurements of the high accuracy required.

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