term is computed as 562,600 cm^{-1} for Pb V and as 761,800 cm^{-1} for Bi VI. The ionization potentials are 69.40 volts and 93.97 volts respectively, which values are 1.3 percent and 6.6 percent higher than those obtained by the extrapolation method by Mack. In Fig. 1 a Moseley diagram is given.

The author wishes to express his appreciation to Chairman R. C. Gibbs of the Physics Department of Cornell University, where most of this work was done, and particularly to thank Professor J. E. Mack and his associates of the University of Wisconsin for their friendly and helpful correspondence.

SEPTEMBER 15, 1936 PHYSICAL REVIEW VOLUME 50

The Pressure Effect on the *C* Band of Strontium Hydride

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At low hydrogen pressures the emission spectrum of the 3808A band of SrH shows a sharp break-off at $R(18)$, while at high pressures the lines extend to $R(49)$. The presence of lines with high K values allows an accurate determination of the constants of the upper state. Analysis shows the presence of an uncoupling term $-0.1415\ (K-1)$ in the upper state. Perturbations due to resonance and predissociation are present. The electronic configurations and probable dissociation energies are considered.

OF the known five band systems which the spectrum of SrH exhibits the *C* system at 3808A is particularly interesting, because its main band, the (0,0), has a line structure that is intense and well defined to a certain point and then abruptly breaks off, leaving no further trace of lines to be found. An analysis of this band has shown it to be a $C^2\Sigma \rightarrow N^2\Sigma$ transition.[1] The only other band observed in the system is a weak (0,1) band, which permitted a sufficiently complete analysis to show the same kind of abrupt breaking-off in rotational structure. This phenomenon has been attributed[1] to predissociation of the upper ("*C*") state due to the influence of a neighboring electronic state (probably the *D* state).

An analogous situation had long been known to exist in the *C* system of CaH.[2] Later Grundström and Hulthén[3] obtained its spectrum with the pressure of the hydrogen surrounding the calcium greatly increased. The bands were no longer predissociated, but were more or less normal in appearance. Bearing in mind the close analogy between the spectrum of CaH and SrH it was thought worth while to investigate the effect of pressure on the SrH *C* band.

EXPERIMENTAL PROCEDURE

The spectrum was obtained from an arc between a copper cathode and a copper cup containing metallic strontium as an anode. The arc burned in an atmosphere of hydrogen at pressures varying from a few mm of Hg to 700 mm of Hg. The cathode was water cooled, and a continuous stream of water was directed on the glass walls of the tube containing the arc. With this arrangement it was possible to operate the arc continuously for two or three hours.

A 120-cm concave grating with a dispersion of 5A/mm in the second order was used in a Rowland mounting. Exposure times were of the order of four hours for second-order plates.

ANALYSIS

When the *C* band is photographed with a hydrogen pressure of a few mm of Hg its rotational structure breaks off at $K'=19$. When the pressure is increased to 400 mm or more the band no longer exhibits this predissociation but displays a fairly normal structure. In addition to the (0,0) very weak traces of the (1,1) and (2,2) bands appear. The assignment of the K values is given in Table I. Combination differences permit these assignments up to $K=28$, beyond which the P branch becomes too weak to observe. For $K>28$ the R lines were fitted to a Fortrat para-

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[1] W. R. Fredrickson, M. E. Hogan, Jr., and W. W. Watson, Phys. Rev. **48**, 602 (1935).

[2] Mulliken, Phys. Rev. **25**, 509 (1925).

[3] Grundström and Hulthén, Nature **125**, 634 (1930).

TABLE I. *Assignment of frequencies in the $C^2\Sigma \rightarrow N^2\Sigma$ (0,0) band of SrH (cm^{-1} units). Two lines blocked together indicate the boundary of a wide line.*

Intensity	ν (obs.)	$P(K)$	$R(K)$
2	26,245.01	9, 13	
9	[251.35 254.45]	8, 9, 10, 11, 12, 13, 14, 15, 16	
9	[257.42 259.62]	7, 9 11, 17	
8	262.45	6, 18	
3	268.18	5, 19	
7	271.98	4, 20	
3	278.13	3	
3	279.85	21	
3	284.62	2, 22	
2	291.26	1, 23	
2	298.24	24	
1	306.85	25	0
2	314.79	26	1
4	323.58	27	2
2	333.36	28	3
3	343.08		4
3	353.21		5
1	357.66*		
1	362.24		6
0	368.16		7
1	374.48		7
4	[378.73 382.49]		7
4	391.82		8
4	403.95		9
2	407.65		9
0	413.23*		
5	417.77		10
0	425.17		11
6	432.01		11
9	445.93		12
0	454.19*		
5	461.26		13
3	474.27		14
4	[494.01 497.59]		15
4	510.73		16
1	[531.13 538.95]		17
4	547.38		18
2	569.16		19
2	586.09		20
1	605.97		21
1	626.09		22
1	647.17		23
1	668.15		24
1	689.44		25
0	711.54		26
1	734.40		27
2	757.22		28
1	781.66		29
0	800.19		30
0	816.72		31
0	846.97		32
0	868.61		33
0	888.85		34
0	909.68		35
0	934.56		36
arc line	963.32		37
arc line	990.18		38
0	27,017.39		39
0	030.17		40
0	049.48		41
0	076.44		42
0	105.00		43
0	140.19		44
0	165.16		45
0	201.09		46
0	231.69		47
0	262.44		48
0	293.47		49

* Unassigned lines.

bola and thus given their K values. The resolving power of the grating was not sufficient to distinguish the spin doubling nor to resolve the abnormally broad lines in the head of the P branch and in several other places throughout the R branch.

A study of the photographic plate and of the assignments given in Table I reveals the presence of several perturbations in the band, evidenced by anomalous displacements, irregular intensity distribution and abnormal doubling of certain lines. In order to obtain information about these perturbations an attempt was made to write a theoretical equation for the lines of the R branch. A deviation of the observed position of a line from its theoretical would thus indicate a perturbation. To write such an equation necessitates the determination of the coefficients of the energy level equation

$$T(K)=T_0+B_0K(K+1)+D_0K^2(K+1)^2 \quad (1)$$

for the two states in question, and thus determining the coefficients of the line equation. For the lower state B_0'' and D_0'' have been calculated[4] (Table II). The levels of the upper state were found with the aid of combination differences and were observed to be somewhat irregular. In view of this, the procedure used by Grundström[5] for CaH bands was followed. An additional function $f(K)$ was assumed to exist, so that

$$T'(K)=T_0'+B_0'K(K+1)+D_0'K^2(K+1)^2+f(K).$$

TABLE II. *Constants for the N and C states of SrH.*

Normal state	C state
$B_0''=3.6344$	$B_0'=3.9416$
$D_0''=-1.287\times10^{-4}$	$D_0'=-1.3986\times10^{-4}$
$\omega_e=1206$ (experimental)	$\omega_e=1349$ (experimetal)
$x_e\omega_e=17$ (experimental)	$x_e\omega_e=24$ (experimental)
	$r_0=2.067$A
α(uncoupling) $=-0.1415$	

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[4] Watson, Fredrickson and Hogan, Phys. Rev. **49**, 150 (1936).

[5] Grundström, Zeits. f. Physik **95**, 574 (1935).

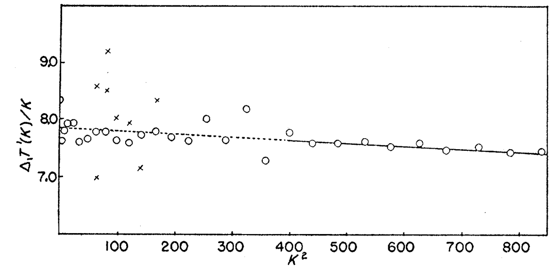

FIG. 1. $\Delta_1 T'(K)/K$ *vs.* K^2. The circles are obtained from upper state levels; the crosses represent additional levels giving rise to the anomalous doubling. The y intercept of the straight line equals $2B_0'$ and the slope equals $4D_0'$.

From this we may obtain

$$\Delta_1 T'(K)/K = [T'(K) - T'(K-1)]/K = 2B_0' + 4D_0'K^2 + [f(K) - f(K-1)]/K.$$

If $\Delta_1 T'(K)/K$ is plotted against K^2 we should expect to get a straight line only when $[f(K) - f(K-1)]/K$ is zero or negligible. Such a plot is given in Fig. 1. The straight line occurs from $K^2 = 400$ on. Therefore, by substituting the term values for levels from $K = 20$ to $K = 30$ into Eq. (1), the values of B_0' and D_0' were obtained (Table II). For points at small K^2 values in Fig. 1 there seems to be a general sinking below the straight line (except, of course, for points marked with x's, which represent anomalous doublets and thus cannot be considered). This sinking of the points suggests the possibility of an additional term, α/K, where α is a constant. Thus $[f(K) - f(K-1)]/K = \alpha/K$ or $f(K) = \alpha(K \pm n)$ + const. where n is any integer. The assumptions are made that $n = 1$, the sign is negative and the const. = 0. These assumptions are quite arbitrary and are chosen to produce the best agreement between the observed and theoretical wave numbers of the levels. The upper state, therefore, may be represented by

$$T'(K) = T_0' + B_0'K(K+1) + D_0'K^2(K+1)^2 + \alpha(K-1).$$

If we combine the values of B and D for the two states we get the following equation:

$$R(K) = 26{,}298.53 + 7.5760(K+1) + 0.3072(K+1)^2 - 2.6856 \times 10^{-4}(K+1)^3 - 11.16 \times 10^{-6}(K+1)^4 + \alpha K.$$

By substitution in several presumably unperturbed lines the average α is found (Table II). It is a measure of "uncoupling" of the orbital angular momentum in the C state. The wave numbers of the line of the R branch were calculated from the above equation and then subtracted from those of the observed lines. Perturbations were thus found to occur in four regions: $R(7)$ to $R(11)$, $R(17)$ to $R(18)$, $R(30)$ to $R(40)$ and $R(40)$ to $R(49)$. For high K values the differences between calculated and observed positions become large due to a lack of powers above the fourth in the theoretical equation, but these differences are readily distinguishable from perturbations by their uniformity in trend.

TABLE III. *Probable configurations and dissociation products.*

State	Probable Configuration	Dissociation Products	Dissociation Energy
$N-{}^2\Sigma$	$5s\sigma^2 4d\sigma$	Sr, ${}^1S$+H, ${}^2S$	12,000 cm^{-1}
$A-{}^2\Pi$	$5s\sigma^2 5p\pi$	Sr, ${}^3P$+H, ${}^2S$	13,300
$B-{}^2\Sigma$	$5s\sigma^2 5p\sigma$	Sr, ${}^3P$+H, ${}^2S$	12,300
$D-{}^2\Sigma$	$5s\sigma 5p\sigma^2$	Sr, ${}^3P$+H, ${}^2S$	10,000 (?)
$F-{}^2\Pi$	$5s\sigma 5p\sigma 5p\pi$	Sr, ${}^3P$+H, ${}^2S$	7,800
$C-{}^2\Sigma$	$5s\sigma^2 6s\sigma$	Sr, ${}^3S$+H, ${}^2S$	15,000

In the region $K = 7$ to $K = 11$, the perturbations are of the resonance type, but those in the regions following $K = 17$, 30 and 40 must be due to the overlapping of levels which are above the dissociation limit of their own state and consequently would cause predissociation of the C state if the hydrogen atmosphere were not under pressure. Unfortunately, the D state has not been sufficiently analyzed to permit a quantitative investigation of these perturbations.

DISSOCIATION PRODUCTS

In a recent paper[6] Grundström has called attention to the analogous spectra of the hydrides of the alkaline-earths. If one makes the assumption —logical by comparison with MgH and CaH— that the C state of SrH predissociates into the ${}^3P$ Sr atom (the dissociation product of the disturbing D state) and a normal ${}^2S$ H atom, then the relative positions of the levels of the SrH molecule and the Sr atom can be obtained. Again, by analogy, one would assume the product of dissociation of the C state to be a ${}^3S$ Sr atom, which would give a value of the energy of dissociation of approximately 15,000 cm^{-1}. To check this the ordinary extrapolation methods of Birge and Rydberg[7] were used. To obtain ω_e and $x_e\omega_e$

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[6] Grundström, Zeits. f. Physik **99**, 595 (1936).

[7] Jevons, *Report on Band Spectra of Diatomic Molecules*, p. 193.

for the normal state the C (0,0), (0,1) and D (v',2), (v',3), (v',4) bands[8] were used. With these and the C (1,1), (2,2) bands, with heads at 26,380 cm^{-1} and 26,495 cm^{-1}, respectively, the vibration constants of the C state were calculated (Table II). These gave for the dissociation value: by Rydberg's method, $D=10{,}000$ cm^{-1}; linear extrapolation, $D=18{,}200$ cm^{-1}. Since neither of these agrees with the position of an atomic state of Sr, one concludes that the ^3S, occurring at about the average, is more likely than any other to be the state of excitation of the atom after dissociating from the C state. This would indicate an electron configuration[9] of the molecule in the C state of $5s\sigma^2 6s\sigma$. The dissociation values for all the known states of SrH, obtained from products of dissociation, are listed in Table III.[10]

We wish to thank Dr. A. J. King for generous supplies of pure metallic strontium.

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[8] See reference 4. The (v',4) of the D system, located at 16,272 cm^{-1}, has not yet been reported.

[9] This configuration differs from that assigned by Grundström (reference 3), but the difference might possibly be due to a typographical error.

[10] These values differ somewhat from those listed by Grundström (reference 3) though the methods used were identical.

SEPTEMBER 15, 1936 PHYSICAL REVIEW VOLUME 50

Mass-Spectrograph Analysis of Beryllium

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A new source of ions suitable for positive ray analysis was developed in the form of a molecular beam from a hot oven. Ions were produced in the beam by electron impact and focused on the entrance slit of the mass spectrograph by suitable electric fields. The method was applied to the study of beryllium but only Be^9 was found. The experiment placed an upper limit on the existence of Be^8 of one part in ten thousand.

ALTHOUGH most of the lighter elements have been satisfactorily investigated, analyses of the isotopic constitution of beryllium have not yielded consistent information. Watson and Parker[1] have reported the existence of Be^8 in an intensity ratio $\text{Be}^9 : \text{Be}^8 \doteqdot 2000 : 1$ from a study of the band spectra of BeH. On the other hand, Olsson[2] failed to observe any Be^8H lines on heavily exposed photographs of the bands. Aston's[3] analysis by means of accelerated anode rays, using BeF, has given no conclusive results because of the difficulty of obtaining sufficient intensity. Furthermore, while Be^8 appears presumably as a disintegraion product of at least five nuclear reactions,[4] two, or possibly three, of these would be satisfied by the existence of a stable Be^8 nucleus, although an alternative explanation has recently been suggested.[4] From these considerations it would seem of some importance to be able to set an upper limit for the relative abundance of Be^8 in natural sources of beryllium. Our investigation was undertaken with this end in view.

The apparatus used is that described by Blewett.[5] The glass tube carrying the ionization chamber and electron filament was modified in order to permit the introduction of a small furnace in a manner shown in Fig. 1A. The furnace O can be inserted through either of the ground glass joints as indicated in the figure. It consists of a cylindrical spiral T, Fig. 1B, made from a strip of 1- or 2-mil tantalum, 2 cm long, 8 mm wide spot welded to two nickel rods which are supported by tungsten leads. The lip extending over the side serves to partially collimate the vapor stream. It has been found desirable to use a radiation shield N, usually of sheet nichrome, to protect the glass walls and to reduce sputtering as much as possible.

A 1-kw 120/20-volt transformer supplies the

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[1] Watson and Parker, Phys. Rev. **37**, 167 (1931).

[2] Olsson, Zeits. f. Physik **73**, 732 (1932).

[3] Aston, *Mass Spectra and Isotopes.*

[4] Wells and Hill, Phys. Rev. **49**, 858 (1936).

[5] Blewett, Phys. Rev. **49**, 900 (1936).