energy is roughly $6\times10^{-27}Z^2/E$ cm². (3) is the product of the number N of nuclei per cm³ and the effective range R of the recoil electron. This range will be either a typical linear dimension of the scattering sample, or the distance in which the electron loses about 1 Mev of its energy, whichever is smaller. The latter is about $0.23A/\rho Z$, where ρ is the density, and hence is of the order of a few mm. Thus for samples of reasonably large size, NR is a constant equal to about $1.4\times10^{23}/Z$. The angular spreads of both the energetic recoil electrons and the bremsstrahlung are of the order of a few degrees for the conditions of interest here. Thus (4) must be caused either by deflection of the recoil electron by multiple Coulomb scattering before it loses 1 Mev of its energy, or by large angle bremsstrahlung (because of the conservation laws, a recoil electron of definite energy has a definite direction). Both of these are improbable, but the latter much less so than the former at such a large angle as 90°. The fraction of the total number of energetic gamma-quanta radiated per unit solid angle at 90° may be estimated[3] to be $1/16\pi E^2$. Thus the cross section for such double processes is about $3\times10^{-30}Z^2/E^4$.

Comparison between the formulas given above for the resonance and the background cross sections indicates that the resonance should stand out clearly against the background. Thus for the 6.2-Mev oxygen state, the integrated resonance cross section per unit solid angle at 90° is about 1 to 2×10^{-29} cm²-Mev; the background cross section for production of scattered gamma-rays within 1 Mev of the resonance if the betatron is run at a slightly higher energy is about 10^{-30} cm². Since the background cross section does not increase with sample size when it is more than a few mm in linear dimensions, it is desirable to use as large a sample as is otherwise convenient in order to increase the over-all intensity.

[3] A. Sommerfeld, *Atombau und Spektrallinien* (Vieweg, Braunschweig, 1939), Vol. 2, p. 551.

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On the High Pressure Bands of Carbon and the Formation of C_2 Molecules

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IN several previous publications[1–3] it was stated that the so-called high pressure bands of carbon belong to the Swan bands of the C_2 molecule. In view of several recent inquiries concerning this matter it appears desirable to amplify the previous statements.

It has been shown by Johnson and Asundi[4] that the high pressure carbon bands represent a $^3\Pi-{}^3\Pi$ transition just as the Swan bands and that the two band systems have the lower state (presumably the ground state of the C_2 molecule) in common. Using Jevons' formula[5] for the band heads of the Swan system (in which a term in $v'v''$ takes account of the rather large change of the distance between head and origin) one obtains for $v'=6$ and $v''=0$, 1, $\cdots$11 the wave numbers given in the second column of Table I

TABLE I. High pressure bands of carbon.

v''	ν_{head}(calculated)	ν_{head}(observed)	Estimated intensity
0	29164	(29241)*	1
1	27560	(27620)*	1
2	25977	—	1
3	24417	24426	2
4	22879	22883	7
5	21362	21361	15
6	19867	—	1
7	18395	18394	5
8	16944	16946	10
9	15515	15518	8
10	14108	14114	6
11	12723	12731	4

* These values are band centers whereas all others are band heads.

[1] J. G. Fox and G. Herzberg, Phys. Rev. **52**, 638 (1937).
[2] G. Herzberg, Astrophys. J. **89**, 290 (1939).
[3] G. Herzberg, *Molecular Spectra and Molecular Structure I. Diatomic Molecules* (New York, 1939), p. 472.
[4] R. C. Johnson and R. K. Asundi, Proc. Roy. Soc. **A124**, 668 (1929).
[5] W. Jevons, *Report on Band Spectra of Diatomic Molecules* (London, 1932), p. 61.

which should be compared to Johnson and Asundi's wave numbers of the heads of the high pressure bands given in the third column. Except for the first two very faint bands (for which band centers rather than band heads were measured and for which a large separation head-origin is expected) the agreement with the values calculated on the assumption that the high pressure bands represent the $v'=6$ progression of the Swan system is just as good as can be expected particularly if it is remembered that the term in $v'v''$ does not completely account for the variation of the distance head-origin, and that the position of the vibrational level $v'=6$ may well be a few cm^{-1} off the extrapolated value.

A further strong argument, if such were needed, for the proposed identity is supplied by the intensity distribution. The intensities of the high pressure bands as estimated by Johnson and Asundi are given in column 4 of Table I. The two intensity maxima occur precisely at the places where they would be expected by extrapolating the Condon parabola of the observed Swan bands to $v'=6$, namely at $v''=5$ and 8. Even apart from this agreement the presence of two intensity maxima, according to well-established principles, excludes the possibility that the upper state is a $v'=0$ level of a different electronic state.

Johnson and Asundi have measured the fine structure of only the R branches of the high pressure bands. Therefore a precise determination of the rotational constants is not possible. However, a rough determination using the data for the lower state from the bands of Fox and Herzberg[1] yields $B'=1.59$ cm^{-1} for the upper state of the high pressure bands, a value that fits well into the B' *versus* v' curve of the Swan bands.

According to all these arguments the identity of the high pressure bands with the $v'=6$ progression of the Swan bands must be considered as proven. It is well known that the high pressure bands may occur when no trace of the ordinary Swan bands is observed.[6-8] Asundi and Pant[8] have considered this as conclusive evidence against our assumption. However other cases of selective excitation of certain band progressions are known, for example the excitation of certain progressions of the first positive group of nitrogen in the afterglow of active nitrogen or the excitation of a single progression of H_2 bands in a discharge through argon and hydrogen.[9,10] The question is what is the mechanism of the selective excitation in the present case.

Since the high pressure bands are observed in carbon monoxide and since the other Swan bands do not simultaneously appear it seems certain that the selective excitation is connected with the formation of C_2 molecules from carbon atoms which in turn are formed by the dissociation of CO in the discharge. This is confirmed by the observation that the bands occur usually outside the direct path of the discharge. In a previous publication[2] it was suggested that the recombination is one by triple collision, the dissociation energy being used to excite the newly formed molecule to the $v'=6$ level. However it is difficult to account in this way for the great selectivity of the excitation. It seems much more likely that the mechanism consists in an inverse predissociation leading to a recombination in a two-body collision. Indeed the observation that the Swan bands ordinarily break off with $v'=5$ suggests strongly that the $v'=6$ level is predissociated. Therefore an inverse predissociation is also possible, that is, two C atoms colliding with the proper kinetic energy on the potential curve of the state that causes the predissociation may jump over to the potential curve of the upper $^3\Pi_g$ state of the Swan bands. Only the predissociating vibrational level $v'=6$ can be formed in this way. Once in this state the molecule may go over into the ground state with emission of the high pressure bands or it may predissociate again, and the process will repeat itself until a stable molecule is formed. On this basis the selectivity in the excitation of the Swan bands is immediately accounted for at least if the lifetime of the $v'=6$ state is sufficiently small that collisions during the lifetime are unimportant.

[6] T. R. Merton and R. C. Johnson, Proc. Roy. Soc. **A103**, 383 (1923).
[7] G. Herzberg, Zeits. f. Physik **52**, 815 (1929).
[8] R. K. Asundi and D. D. Pant, Curr. Sci. **10**, 520 1941).
[9] E. E. Witmer, Phys. Rev. **28**, 1223 (1926).
[10] H. Beutler, Zeits. f. Physik **50**, 581 (1928).

The only other well-established case of inverse predissociation is the observation by Stenvinkel[11] of the emission of the predissociated lines of AlH under conditions that strongly favor formation of AlH molecules from Al and H atoms in two-body collisions.

Independent of the specific mechanism of the recombination process it follows that the dissociation energy of the C_2 molecule is less than the excitation energy of the $v'=6$ level and larger than that of the $v'=5$ level that is between the limits 3.4 and 3.6 volts—probably closer to the upper limit. This value depends of course on the correctness of the assumption of a recombination process for the explanation of the selective emission of the $v'=6$ progression of the Swan bands (i.e., the high pressure carbon bands).

[11] G. Stenvinkel, Zeits. f. Physik **114**, 602 (1939).

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Racetrack Stability*

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IN a recent Letter to the Editor, Serber[1] has pointed out that the existence of the straight, field-free sections of the racetrack synchrotron introduces a condition for the stability of the orbits which depends upon (a) the ratio of the length of a straight section to the radius of curvature of the circular portions of the orbit and (b) upon the frequencies of oscillation in the circular portions. These latter, the frequencies of the Z and of the radial motion, are proportional to $(n)^{\frac{1}{2}}$ and to $(1-n)^{\frac{1}{2}}$, respectively, where n is the coefficient determining the fall-off law for the magnetic field.

The calculation made by Serber was for a racetrack with two equal straight sections, and it was found that the proposed dimensions of the Michigan racetrack, while leading to stable orbits, were uncomfortably close to a region of instability.

We have reexamined the problem and have extended the formulas to include the case of N equal straight sections, each of length L, connected by N circular arcs of length $2\pi r/N$. The method of solution was as follows. Consider the mth passage of the electron through a circular portion of the orbit. Let the coordinate describing the particle motion within the tube be x and let the frequency of oscillation be ω. (x may be identified with either the Z or the radial displacement from equilibrium.)

$$x=A_m \sin\omega t+B_m \cos\omega t.$$

At the end of the mth circular portion of the orbit the electron enters the mth straight section. Throughout this section $\dot{x}$ remains constant but the particle has received a displacement of amount Lx/v where v is its forward velocity. The particle now enters the $(m+1)$th circular portion and will again be described by

$$x=A_{m+1} \sin\omega t+B_{m+1} \cos\omega t.$$

Recursion formulas connecting A_{m+1} and B_{m+1} with A_m and B_m may be easily found and solved.

$$A_m=A \sin m\pi\mu+B \cos m\pi\mu,$$
$$B_m=C \sin m\pi\mu+D \cos m\pi\mu,$$

where A, B, C, and D are constants which are related through recursion formulas.

It is thus seen that the amplitudes vary sinosoidally and that the motion of the x coordinate approximates to that of a modulated wave. This statement would be rigorously correct if m increased uniformly with the time. Actually m is an integer and therefore discontinuous. However the orbit, which is in reality composed of short sinusoidal arcs connected by straight lines, will closely resemble a modulated sine

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[1] R. Serber, Phys. Rev. **70**, 434 (1946).