

Table I. Tin Satellite Pmr Spectra of Neophyl Methylene Groups

Line ^a	100-MHz spectra			220-MHz spectra				
	Calcd	Energy, ^b Hz	Obsd	Calcd rel intensity	Calcd	Energy, ^b Hz	Obsd	Calcd rel intensity
1	-23.0		-22.5	1.93	-29.3		-30.0	1.44
2	+14.8		14 to 15	1.46	+6.4		+6.5	1.29
3	-36.0		Not seen	0.07	-42.3		-43.0	0.51
4	+1.8		Obscured	0.54	-6.6		-7	0.71
5	-9.0		Not seen	0.07	-2.7		~ -4	0.51
6	+43.2		Obscured	0.54	+51.6		+53.0	0.71
7	-22.0		-22.5	1.93	-15.7		-16	1.49
8	+32.2		+31.0	1.46	+38.6		+38.0	1.29

^a Labeled according to ref 6. ^b Calculated using the following parameters (relative to $1/2(\nu_A + \nu_B)$): geminal proton-proton, $J_{AB} = -13.1$ Hz, $\Delta\nu_{AB} = 0.151$ ppm; geminal tin-proton, $J_{AX} = 55 \pm 1$ Hz, $J_{BX} = 35 \pm 1$ Hz.

starting material were present; the positions of these were checked at 60 and 220 MHz.⁴

The region of interest, that of the neophyl methylene protons, is shown in Figure 1 for both the 100- and 220-MHz scans. Peak positions are labeled A₁, A₂, B₁, and B₂ for the central AB quartet of the anisochronous methylene protons, for which the tin atom has zero spin. The satellite spectra due to the tin isotopes (117 and 119) of spin one-half are the AB parts of overlapping ABX spectra. To avoid confusion, the average position of the satellite spectra has been labeled, and these positions were used to calculate tin-proton coupling. The relationship between the tin (117 and 119) couplings is simply $J(117) = 0.956 J(119)$. We observe nonequivalent coupling between the tin and the methylene protons (J_{AX} and J_{BX}), with values of 55 and 35 ± 1 Hz, respectively. The ABX line positions have been labeled from 1 to 8 to correspond to the eight possible resonances in the AB part of an ABX spectrum. It is most important to remember that the tin-proton couplings cannot be obtained directly from the spectrum.⁵ Table I contains calculated and observed line positions. The numbering refers directly to the eigenfunctions and eigenvalues obtainable from the literature.⁶ Only the relative signs of J_{AX} and J_{BX} are obtainable from the spectra. All other signs must be inferred from other data. Geminal proton-proton couplings of saturated hydrocarbons are known to be negative, and geminal tin-proton couplings across a carbon atom are known to be positive in methyltin derivatives.⁷

Addition of small amounts of pyridine causes rapid isomerization of the enantiomers of the tin compound.^{1,2} The resulting trivial AA'X spectrum of the neophyl methylene protons yields only the average value of the two geminal tin-proton spin coupling parameters. This is found to be 46 ± 1 Hz which is in good agreement with the expected value from the uncollapsed spectrum.

The large difference in coupling between tin and two chemically equivalent but anisochronous protons poses several questions, not the least of which is the significance of such coupling constants when used to infer hybridization parameters of the tin atom. Clearly, two quite different hybridization parameters

can be obtained for one tin-carbon bond in this present example. Using the collapsed and averaged tin-proton coupling of the compound would yield yet a third. Obviously angle dependence of the coupling constant is important, and the probability of contributions other than Fermi contact cannot be ignored. Both of these factors are tacitly overlooked in correlations of $^2J_{Sn-H}$ and per cent s orbital character. A correlation between $^2J_{Sn-H}$ and J_{Sn-C} has previously indicated that one of them contains contributions other than the Fermi contact term. An extrapolated value of about $+25$ Hz for $^2J_{Sn-H}$ when J_{Sn-C} approaches zero suggests an order of magnitude for these contributions.⁷ It is significant that the difference between the tin-methylene proton couplings in our compound is of the same order.

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A Model for the Mechanism of Action of Coenzyme B₁₂ Dependent Enzymes. Evidence for $\sigma \rightleftharpoons \pi$ Rearrangements in Cobaloximes

Sir:

Most vitamin B₁₂ coenzyme dependent enzymes catalyze a net substrate rearrangement in which hydrogen migrates to an adjacent carbon atom, while an alkyl, acyl, or electronegative group (X) migrates in the opposite direction (**4** \rightarrow **8**, Scheme I).¹⁻⁵ Numerous proposals have been made concerning the possible mode of migration of the X group,^{1-4,6-12}

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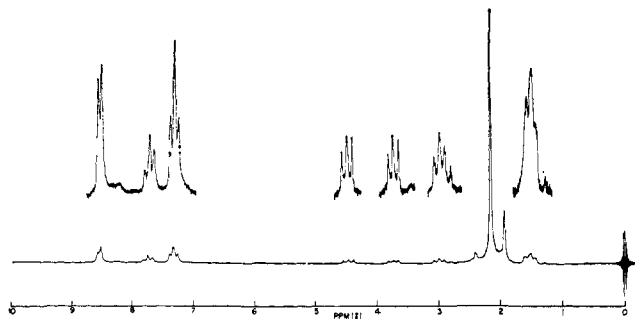


Figure 1. Nmr spectrum (100 MHz) of 2-acetoxyethyl-2-¹³C-(pyridine)cobaloxime (**1**) in CDCl₃.

but little experimental evidence has been presented to corroborate these conjectures or give information as to the specific intermediates involved. In a study on the mechanism of ethanolamine ammonia-lyase,⁷ it was suggested that the migration of X (in this case ammonia) might occur *via* the conversion of a σ complex of 2-aminoethanol (**5**, X = NH₃; Y = OH) to a π complex of enol acetaldehyde (**6**, Y = OH). Readdition of ammonia to this π complex, at the hydroxyl-bearing carbon, regenerates a new σ complex of the rearranged substrate (**7**, X = NH₃; Y = OH). While $\sigma \rightleftharpoons \pi$ rearrangements are well known in organometallic chemistry, there has been no definitive evidence that π complexes are formed by corrinoids or chemically related complexes, such as cobaloximes. We wish to report the rearrangement of a cobaloxime σ complex which proceeds *via* a Co(III) π complex (or its electronic equivalent), an observation which lends support to the hypothesis that π complexes play a role in the rearrangements controlled by the coenzyme B₁₂ dependent enzymes.

The methanolysis of 2-acetoxyethyl(pyridine)cobaloxime[2-acetoxyethyl(pyridine)bis(dimethylglyoximate)cobalt(III)] to the corresponding 2-methoxyethyl derivative has recently been reported.¹³ It was found that the methanolysis took place at a rate comparable to the rate of solvolysis of trityl acetate, and it was proposed that this reaction proceeded through an initial ionization to give acetate and one of three possible intermediates: a symmetrical π complex, or one of two variations of an unsymmetric carbonium ion. Our experiments with 2-acetoxyethyl-2-¹³C-(pyridine)cobaloxime (**1**) show that this solvolysis proceeds such that the cobalt atom is bonded equally to both C₁ and C₂ of the ionized intermediate.

Bromoacetic acid-*I*-¹³C was reduced by diborane in THF to 2-bromoethanol-*I*-¹³C, which was acetylated to give 2-bromoethyl acetate-*I*-¹³C. 2-Acetoxyethyl-2-¹³C-(pyridine)cobaloxime (**1**) (containing 65–70 atom % ¹³C) was prepared from the bromo ester by a variation of the procedure of Hill.¹⁴ The proton nmr spectrum of **1** (Figure 1) shows, *inter alia*, a triplet at 1.50 ppm ($J_{\text{H-H}} = 8$ Hz, with additional long-range coupling $J_{^{13}\text{CCH}} = 2.5$ Hz) for the C₁ protons, a triplet at 3.70 ($J_{\text{H-H}} = 8$ Hz) for the C₂ protons on ¹²C, and

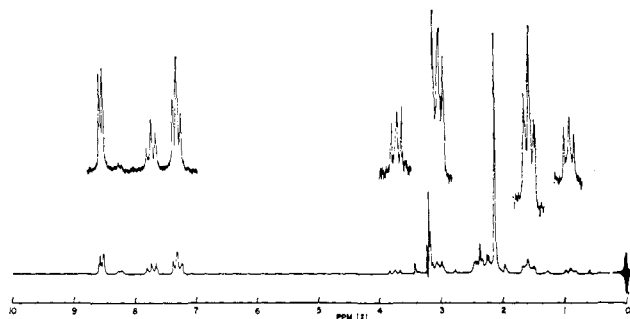
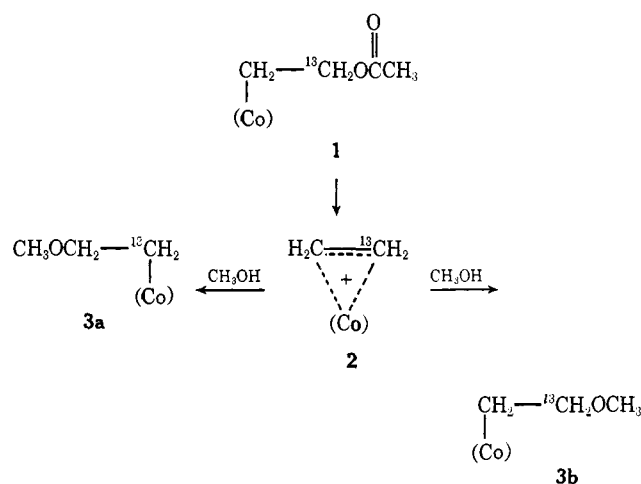


Figure 2. Nmr spectrum (100 MHz) of methanolysis product **3a,b** in CDCl₃.

two ¹³C “satellite” triplets at 2.96 and 4.44 ($J_{\text{H-H}} = 8$ Hz; $J_{^{13}\text{C-H}} = 148$ Hz) for the C₂ protons on ¹³C. Methanolysis of a suspension of **1** for a period of 14 days at room temperature gave a product (**3a,b**) whose proton nmr spectrum (Figure 2) showed a triplet at 1.58 ($J_{\text{H-H}} = 9$ Hz; $J_{^{13}\text{CCH}} = 2.5$ Hz) for the C₁ protons on ¹²C, and two triplets at 0.9 and 2.26 ($J_{\text{H-H}} = 9$ Hz; $J_{^{13}\text{C-H}} = 136$ Hz) for the C₁ protons on ¹³C. In addition to this a triplet at 3.06 ($J_{\text{H-H}} = 9$ Hz; $J_{^{13}\text{CCH}} = 2$ Hz) for the C₂ protons on ¹²C and two triplets at 2.36 and 3.76 ($J_{\text{H-H}} = 9$ Hz; $J_{^{13}\text{C-H}} = 140$ Hz) for the C₂ protons on ¹³C were observed. Moreover, while the three triplets of the C₂ protons of **1** are of equal intensity (resulting from the 2:1 ratio of ¹³C:¹²C), in the solvolyzed products (**3a,b**) each of the four ¹³C triplets are of equal intensity, but are now only one-fourth as intense as the ¹²C triplets.

All of the above data are consistent with the intervention of an intermediate during the methanolysis in which the cobalt atom is bonded equally to both carbon atoms,¹⁵ and we prefer to envisage this intermediate as π complex **2**. Quenching of such an intermediate by



methanol at either of the two equivalent carbon atoms leads to the observed distribution of ¹³C.

(15) Only two (0.9 and 3.76 ppm) of the four ¹³C triplets are completely resolved; the other two overlap at ~ 2.3 ppm. However, in a first-order spectrum of this type, the observation of one of the ¹³C triplets characterizes both of them.

(16) Randomization of label associated with exchange of methoxyl residues between product and solvent was excluded by the failure to incorporate CD₃O into 2-methoxyethyl(pyridine)cobaloxime in a reaction containing equimolar amounts of the cobaloxime and acetic acid with methanol-*d*₄ as solvent.

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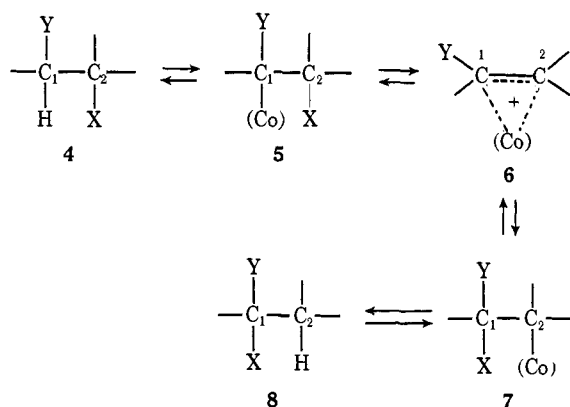
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Much of the chemistry of the cobaloximes parallels that of B_{12} itself,¹⁷ and should the converse be true, then the above results admit the plausibility of the proposal that the reactions catalyzed by coenzyme B_{12} dependent enzymes proceed *via* $\sigma \rightleftharpoons \pi$ rearrangements. Such reactions can be envisaged as shown (Scheme I).

Scheme I



Initially, the Co-C bond of the coenzyme is broken.¹⁸ This is followed by transfer of the migrating hydrogen from C_1 of the substrate to the enzyme-coenzyme complex,¹ coupled with the formation of a new cobalt-carbon bond at C_1 of the substrate to give the σ complex 5. Enzyme-assisted removal of X¹⁹ from C_2 of the substrate generates a π complex 6 of the type discussed above. Readdition of X at C_1 followed by a reversal of the hydrogen transfer with breaking and remaking of the cobalt-carbon bonds gives the rearranged substrate 8 and completes the catalytic cycle.

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(20) National Institutes of Health Predoctoral Trainee.

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On the Photochemical Isotopic Exchange between Acetone-¹⁸O and Acetone-*d*₆

Sir:

In 1934, Bowen and De la Praudiere reported that acetone is much less photoreactive in the pure liquid state than it is in solution.^{1,2} Recently, Chapman

and Wampfler found that the efficiency of photosensitization of olefins by a number of aromatic ketones decreases with increasing ketone concentration and suggested that the formation of excimers may be responsible for their observation.^{3,4} Elliott in our laboratory noted that the quantum yield of the photolysis of 2-pentanone in *tert*-butyl alcohol decreases with increasing 2-pentanone concentration.⁵ These results indicated that there is a concentration-dependent non-radiative decay process of the excited carbonyl compounds in solution. Since excited carbonyl compounds may react with olefins to give an exciplex intermediate which may deactivate to the ground state or transform into a chemical product,^{6,7} excited acetone may react with acetone in the ground state *via* an excimer in an analogous manner. We investigated the photochemistry of isotopic labeled acetone in order to explore the nature of interaction between excited acetone and ground-state acetone.

Equimolar mixtures of acetone-*d*₆ (Merck Sharp and Dohme, a mixture of 97% acetone-*d*₆ and 3% acetone-*d*₅) and acetone-¹⁸O (90.8% ¹⁸O enriched, Miles-Yeda, Ltd.) were degassed and irradiated at 313 nm concurrently with a 2-hexanone actinometer in an apparatus previously described.⁸ The samples were analyzed by mass spectrometry after the irradiation.⁹ The formation of acetone (*m/e* 58) and acetone-*d*₆-¹⁸O (*m/e* 66) from acetone-¹⁸O (*m/e* 60) and acetone-*d*₆ (*m/e* 64) may be followed by the increase in the *m/e* 66 peak in the mass spectra of the samples after the irradiation. The amount of exchange, *i.e.*, the fraction of acetone-*d*₆-¹⁸O formed relative to the total ¹⁸O-labeled acetone, may be expressed as $66(m/e)/[60(m/e) + 66(m/e)]$ after the *m/e* 66 peak has been corrected for the small amount of acetone-*d*₅-¹⁸O initially present in acetone-*d*₆. We also found that mixtures of isotopic labeled acetones did not undergo any isotopic exchange in the dark and pure liquid acetone did not exhibit any noticeable change in its mass spectrum after 24 hr of irradiation. The results are summarized in Table I.

Our results clearly demonstrated that acetone-¹⁸O and acetone-*d*₆ undergo photochemical isotopic exchange to give acetone and acetone-*d*₆-¹⁸O (Table I and Figure 1). The quantum yields given were calculated by assuming the photochemical isotopic exchange to be

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