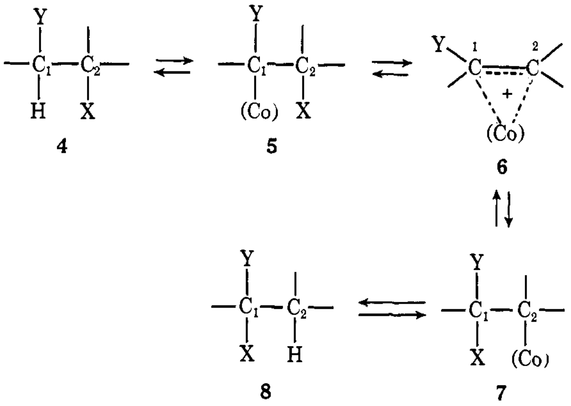
Much of the chemistry of the cobaloximes parallels that of B_{12} itself,[17] and should the converse be true, then the above results admit the plausibility of the proposal that the reactions catalyzed by coenzyme B_{12} dependent enzymes proceed *via* $\sigma \rightleftarrows \pi$ rearrangements. Such 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 X[19] 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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[17] G. N. Schrauzer, *Accounts Chem. Res.*, **1**, 97 (1968).

[18] Recent observations suggest that this is a homolytic fission.[2,7]

[19] The migration of X with its bonding electrons poses no problem when X contains an electronegative atom such as O or N. In the methylmalonyl CoA mutase reaction our mechanism requires the migration of an "acyl" group with its bonding electrons, a reaction for which there is ample precedent; R. M. Acheson, *Accounts Chem. Res.*, **4**, 177 (1971).

[20] National Institutes of Health Predoctoral Trainee.

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On the Photochemical Isotopic Exchange between Acetone-^{18}O 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 nonradiative 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-^{18}O (90.8% ^{18}O 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-^{18}O- (*m/e* 66) from acetone-^{18}O (*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-^{18}O formed relative to the total ^{18}O-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_6-^{18}O 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-^{18}O and acetone-d_6 undergo photochemical isotopic exchange to give acetone and acetone-d_6-^{18}O (Table I and Figure 1). The quantum yields given were calculated by assuming the photochemical isotopic exchange to be

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[1] E. J. Bowen and E. L. A. E. De la Praudiere, *J. Chem. Soc.*, 1503 (1934).

[2] For later works on the photochemistry of acetone see: (a) P. E. Frankenburg and W. A. Noyes, Jr., *J. Amer. Chem. Soc.*, **75**, 2847 (1953); (b) R. Picek and E. W. R. Steacie, *Can. J. Chem.*, **33**, 1304 (1955); (c) K. Pfordt and G. Leuschner, *Justus Liebigs Ann. Chem.*, **646**, 23 (1961); (d) J. T. Przybytek, S. D. Singh, and J. Kagan, *Chem. Commun.*, 1224 (1969).

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[5] S. P. Elliott, Ph.D. Thesis, University of Chicago, 1970.

[6] N. C. Yang, M. H. Hui, and S. A. Bellard, *J. Amer. Chem. Soc.*, **93**, 4056 (1971).

[7] R. R. Hautala and N. J. Turro, *ibid.*, **93**, 5595 (1971).

[8] D. R. Coulson and N. C. Yang, *ibid.*, **88**, 4511 (1966).

[9] The samples were analyzed with a Finnigan 1015 mass spectrometer with a System Industries 150 computer. Each sample was scanned ten times to assure the proper operation of the spectrometer, and the results of three of the scans were displayed. The intensity of each peak was displayed as the per cent of the intensity of the most intense peak in the region scanned. The results given are the average of the three scans. The range of deviation for the three scans was ±0.20% for low intensity peaks which corresponds to ±10% of the intensity and ±0.50% for high intensity peaks which corresponds to ±1.0% of the intensity. The authors wish to acknowledge Mr. Barry Williams for his assistance in operating the mass spectrometer.

Table I

Run no.	Sample vol, ml	Time, hr	Quencher,[a] 1 M	Water, 1 μl	$\frac{66\ (m/e)}{60\ (m/e) + 66\ (m/e)}$, %	$\phi_{[66(m/e)]}$
1[b]	0.16	5	–	–	1.96	0.11
1	0.16	70, 77	–	–	Complete[e]	
2[c]	0.16	10	–	–	3.24	0.12
2	0.20	10	+	–	3.13	0.11
2	0.16	20	–	–	9.93	0.20
2	0.16	30	–	–	15.55	0.23
2	0.16	50	–	–	29.65	0.33
2	0.20	50	+	–	15.55	0.12
3[d]	0.14	20	+	+	7.90	0.10
3	0.14	20	–	+	Complete[e]	

[a] Quencher is *trans*-1,3-pentadiene. [b] The light intensity was 3.75 × 10^{-6} einstein min^{-1} ml^{-1}. [c] The light intensity was 3.0 × 10^{-6} einstein min^{-1} ml^{-1}. [d] The light intensity was 4.46 × 10^{-6} einstein min^{-1} ml^{-1}. [e] 50 ± 1.

reversible (eq 1) and the rates of exchange to be the

$$(CH_3)_2C{=}^{18}O + (CD_3)_2C{=}O \underset{h\nu}{\overset{h\nu}{\rightleftharpoons}} (CH_3)_2C{=}O + (CD_3)_2C{=}^{18}O \quad (1)$$

same for all isotopic acetones.[10] The results of run no. 2 show that the rate of exchange does not remain constant with time and accelerates as the reaction proceeds; therefore, the exchange may be catalyzed by a photoproduct formed during the irradiation. Although we were unable to detect any products by mass spectrometry after the irradiation, any such product may still be present in trace amount.

Subsequently, we examined the effect of a trace of water on the rate of exchange (run no. 3) and found that water has a dramatic catalytic effect on the rate of exchange indicating that the reaction may be catalyzed by a trace of hydroxylic contaminant either added before or formed during irradiation. However, when a catalytic amount of water is added to the equimolar mixture of the isotopic acetones in the dark, no detectable exchange was observed by mass spectrometry even after the mixture had been allowed to stand for 24 hr in the dark. Therefore, both water (or other OH containing compounds) and uv light are needed for the catalytic exchange, and water alone cannot act as a "carrier" for ^{18}O in the exchange.

We also found that *trans*-1,3-pentadiene, a triplet quencher, had very little effect on the rate of exchange at the beginning of the irradiation (after 10 hr) but reduced the rate by about 60% after 50 hr of irradiation and the diene also completely quenched the catalytic effect of water (run no. 3). The quantum yields of isotopic exchange between acetone-d_6 and acetone-^{18}O at low conversion were found to be the same within experimental error as those in the presence of *trans*-1,3-pentadiene or in the presence of both the diene and water, 0.11 ± 0.01. Our data suggest that the isotopic exchange may occur from both the singlet excited state and the triplet state of acetone. The exchange from the singlet excited state occurs at a constant quantum yield unaffected by the presence of *trans*-1,3-pentadiene or both water and the diene, while the exchange from the triplet state is negligible unless it is catalyzed by a hydroxylic contaminant. In the presence of water, the catalyzed exchange from the triplet state may become much more rapid than that from the singlet excited state.

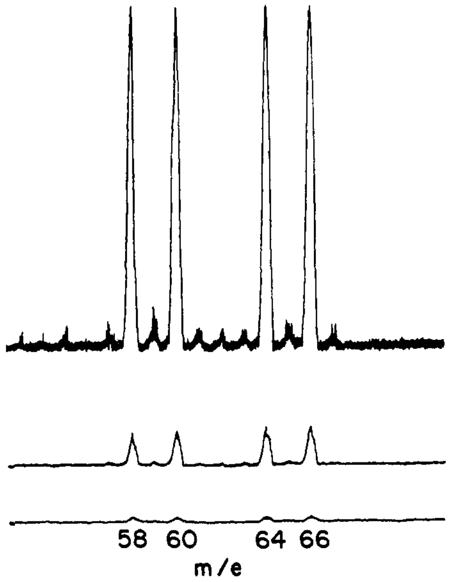
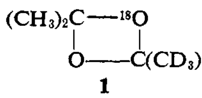
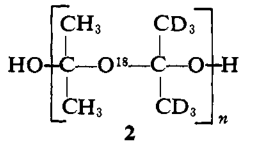


Figure 1. The mass spectrum of an equimolar mixture of acetone-d_6 and acetone-^{18}O after 70 or 77 hr of irradiation.

Since the formation of acetone-d_5 and acetone-d-^{18}O was not detected even after the oxygen isotopes had been completely equilibrated (Figure 1), polar intermediates such as enol or enolate of acetone cannot play a significant role in this exhange. Our results indicate that an excited acetone will react with acetone in the ground state to give an intermediate or intermediates which will dissociate to ground-state acetone, whereby in such an intermediate or intermediates the oxygen atoms from different molecules of acetone have become chemically equivalent. Intermediates such as 1,3-dioxetane **1** or polymeric hydrate **2** will fulfill such



1



2

a requirement. Statistically an excited labeled acetone may react with either an identical or a different labeled acetone, and the intermediate formed may dissociate in

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[10] The quantum yield was calculated to be given by the following expression, $\phi = N \ln (1 - 2\alpha)^{-1}/2It$, where N is the number of moles of ^{18}O-labeled acetone present, α is the fraction of acetone-^{18}O-d_6 formed among ^{18}O-labeled acetone, I is the light intensity in einsteins per minute, and t is the irradiation time in minutes.

two different ways yielding either the starting material or the isotopic exchanged products. Therefore, the maximum quantum efficiency for the exchange *via* a dimeric intermediate is 0.25. We have shown that the exchange may take place from both the singlet excited state and the triplet state of acetone. The very high quantum efficiency of the exchange from the triplet state in the presence of water may be explained by the formation of a polymeric intermediate such as **2**, while the exchange from the singlet excited state which is not catalyzed by water may be rationalized by the formation of a 1,3-dioxetane intermediate **1** which will dissociate back to acetone under our experimental conditions. The investigation is being continued.

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Hydrolysis and Aminolysis of Metal Ion Activated Esters. Nucleophilic Paths and Properties of the Tetrahedral Intermediate

Sir:

The occurrence of nucleophilic or general base catalyzed paths for hydrolysis of acyl-activated esters or amides is an important question in metal activated enzymes such as carboxypeptidase A[1] and leucine aminopeptidase,[2] and in serine proteinases.[3] Previously it has been shown that nitrogen bases act as nucleophiles toward the metal ion activated ester I in aqueous solution but the mechanism of catalysis by oxygen bases (Figure 1) was not established although some support for a general base catalyzed role was presented;[4] we now report that acetate ion also acts as a nucleophile toward I. The distinction between the two mechanisms occurs in the formation of an anhydride intermediate IV in the nucleophilic path, whereas the general base reaction leads directly to hydrolyzed product V, reaction 2. Although IV is much more rapidly hydrolyzed than I, its presence can be detected by competition experiments.

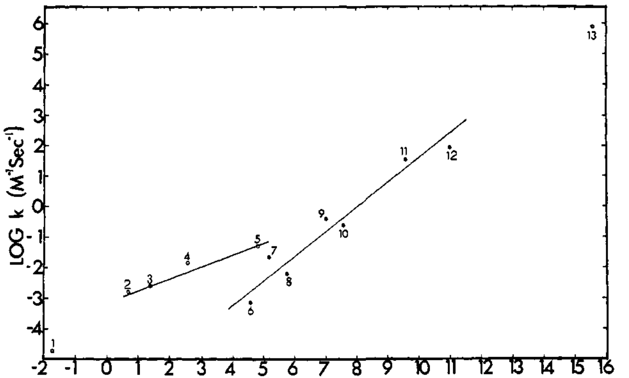
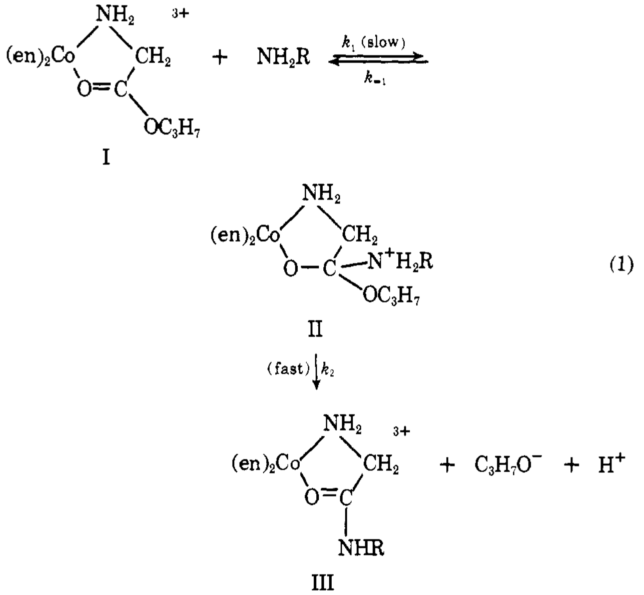


Figure 1. Plot of log k for lysis of [Co(en)$_2$(glyOC$_3$H$_7$)](ClO$_4$)$_3$ in aqueous solution *vs.* pK_a of nucleophile: 1, water; 2, trichloroacetate; 3, dichloroacetate; 4, chloroacetate; 5, acetate; 6, aniline; 7, pyridine; 8, aminoacetonitrile; 9, imidazole; 10, glycine ethyl ester; 11, ammonia; 12, dimethylamine; 13, hydroxide. β *ca.* 0.4 (oxygen anions), 0.8 (nitrogen bases).



(1)

Rate data and products for the reaction of [Co(en)$_2$(GlyOC$_3$H$_7$)](ClO$_4$)$_3$ with H$_2$O, HO$^-$, NH$_2$CH$_2$CN, and CH$_3$CO$_2^-$ are given in Table I. It is apparent that contributions to the rate of ester disappearance by k_{OAc} and k_N (N = NH$_2$CH$_2$CN) determined from the rate law

$$k_{obsd} = k_{H_2O}[H_2O] + k_{OH}[OH^-] + k_N[N] + k_{OAc}[OAc^-]$$

are unchanged by the presence or absence of aminoacetonitrile and acetate, respectively, and that when acetate is absent the k_N[N] contribution is balanced by the amount of [Co(en)$_2$(GlyNHCH$_2$CN)]$^{3+}$ found in the products. The latter experiments demonstrate that aminoacetonitrile acts entirely as a nucleophile toward I, and the independence of k_{OAc} and k_N establishes the absence of a k[AcO$^-$][N] term in the rate law. Furthermore, when both acetate and aminoacetonitrile are present under conditions where k_{OAc}[AcO$^-$] dominates k_{obsd} (~80%), the amount of [Co(en)$_2$(GlyNHCH$_2$CN)]$^{3+}$ formed remains practically unchanged. These results require aminoacetonitrile to compete for the acetate path following the rate-determining step and are consistent with the formation of the anhydride IV. Also they require aminoacetonitrile, HO$^-$, and H$_2$O to have essentially the same competition properties for

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