PHOTOCHEMISTRY OF VITAMIN B_{12} DERIVATIVES. NEW OBSERVATIONS AND CONCLUSIONS.

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Irradiation of cobalamins of the general type Co(III)(corrin)(N-base)X which contain $C(CN)_3^-$, $Pt(CN)_4^{2-}$, and $Au(CN)_2^-$ as the sixth ligand X leads to the photosubstitution of X by the solvent. The reactive excited states are most likely of the LF type. In the case of methylcobalamin the well-known photohomolysis of the Co-C bond is suggested to be induced by LLCT excitation.

The light sensitivity is one of the outstanding features of vitamin B_{12} and its derivatives such as the cobalamins of the general formula Co(III)(corrin)(N-base)X (or B_{12}-X).[1-6] While evidence has been obtained that the photoaquation of cyanocobalamin (X = CN) is initiated by LF excitation[7-9] the reactive excited states of alkylcobalamins (X = R) were not identified although it has been speculated that in this case LMCT states are responsible for the photohomolysis of the Co(III)-C bonds.

The present work was undertaken in order to study the photochemistry of new cobalamins which contain a second metal complex such as $Pt(CN)_4^{2-}$ or $Au(CN)_2^-$ as the sixth ligand X. These metallocobalamins might be useful as models for new medical applications. Another goal of our work was to reveal the nature of the reactive excited states of alkylcobalamins with X = CH_3 and $C(CN)_3$.

The metallocobalamins $[B_{12}$-μ-NCPt(II)$(CN)_3]^-$ and $[B_{12}$-μ-NCAu(I)CN] were prepared in analogy to $[B_{12}$-μ-NCFe(II)$(CN)_5]^{3-}$ [10] by the reaction of aquocobalamin $[B_{12}$-$H_2O]^+$ (B_{12a}) with $Pt(CN)_4^{2-}$ and $Au(CN)_2^-$, respectively. The absorption spectra of both metallocobalamins (Fig. 1 and 2) which are dominated by the intense ππ* intraligand bands of the corrin ligand[1,5] are very similar to that of $[B_{12}$-μ-NCFe(II)$(CN)_5]^{3-}$ [10] and thus indicative of a nitrogen-coordinating cyanide as the sixth ligand. Upon irradiation both metallocobalamins underwent a clean photosolvation as shown by the spectral variations which were observed during the photolysis (Fig. 1 and 2). The final spectra were identical with those of $[B_{12}$-$H_2O]^+$ [1,5,7] and $[B_{12}$-DMSO$]^+$, [11] respectively.

$$[B_{12}\text{-}\mu\text{-NCPt(II)}(CN)_3]^- + \text{DMSO} \xrightarrow{h\nu} [B_{12}\text{-DMSO}]^+ + Pt(CN)_4^{2-}$$

$$[B_{12}\text{-}\mu\text{-NCAu(I)CN}] + H_2O \xrightarrow[CH_3OH]{h\nu} [B_{12}\text{-}H_2O]^+ + Au(CN)_2^-$$

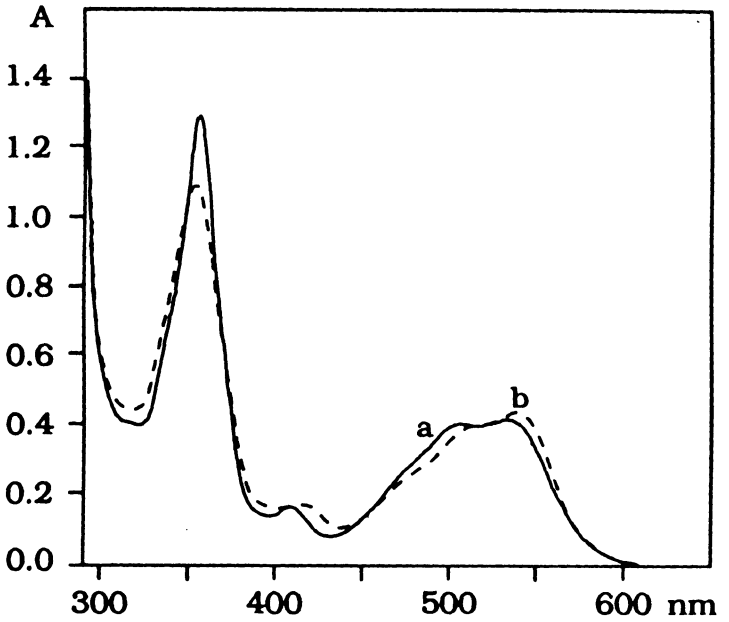

Figure 1

Spectral changes during the photolysis of 4.48×10^{-5} M $K[B_{12}\text{-}\mu\text{-}NCPt(II)(CN)_3]$ in dimethylsulfoxide at (a, —) 0, and (b, - - -) 180 min irradiation time, $\lambda_{irr} > 310$ nm (Osram XBO 450 W/4 lamp) and a 1-cm cell.

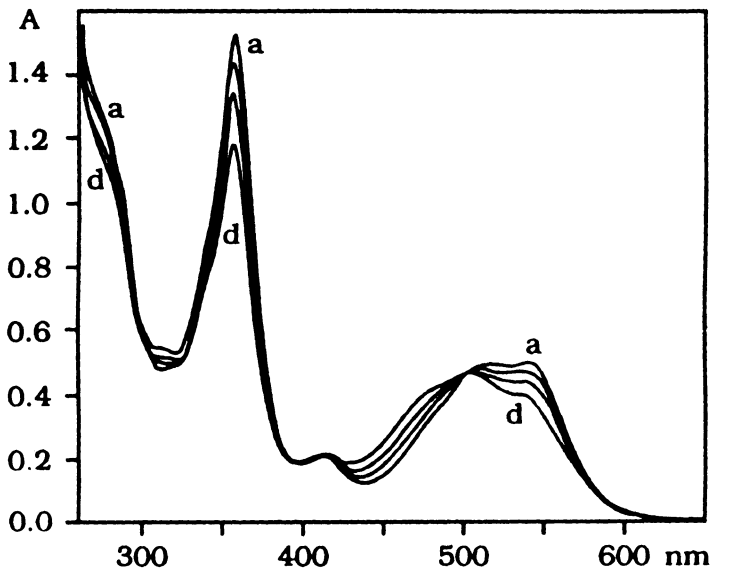

Figure 2

Spectral changes during the photolysis of 6.39×10^{-5} M $B_{12}\text{-}\mu\text{-}NCAu(I)(CN)$ in methanol/H_2O at (a) 0, 30, 70, and (d) 140 min irradiation time, $\lambda_{irr} > 310$ nm and a 1-cm cell.

As in the case of other cobalamins such as B_{12}-CN the photosubstitution of these metallocobalamins are most likely initiated by LF (Co^{III}) excited states which are populated from corrin intraligand $\pi\pi^*$ states.[7-9]

Since certain Pt(II) and Au(I) complexes are used for the chemotherapy of cancer and rheumatism, respectively, it is feasible that metallocobalamins which contain suitable Pt(II) and Au(I) complexes can serve as physiological carriers for these metals. Moreover, a controlled photochemical release of the bioactive metal complexes might lead to a new type of phototherapy.

While it seems to be rather clear that the photosubstitution of cobalamins originates from LF excited states the identity of the reactive excited states of alkylcobalamins is yet unknown. In this context it is quite interesting that tricyanomethylcobalamin which contains tricyanomethanide $C(CN)_3^-$ as the sixth ligand X undergoes also a photosolvation.

$$B_{12}C(CN)_3 + H_2O \xrightarrow{h\nu} B_{12}\text{-}H_2O^+ + C(CN)_3^-$$

The spectral changes (Fig. 3) indicate clearly the formation of B_{12}-H_2O^+. In addition, the released $C(CN)_3^-$ was identified by its emission spectrum.[12]

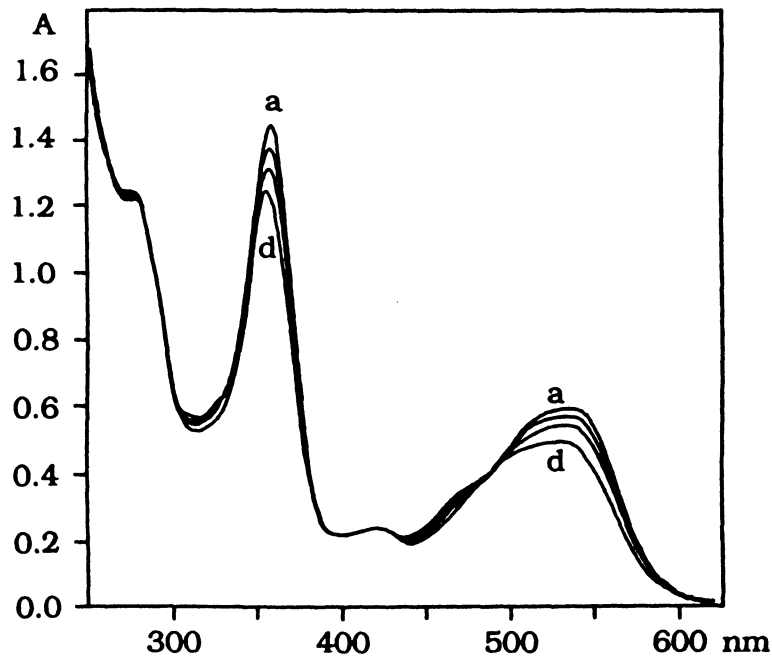

Figure 3

Spectral changes during the photolysis of 5.88×10^{-5} M B_{12}-$C(CN)_3$ in water at (a) 0, 30, 60, and (d) 120 min irradiation time,with white-light irradiation (Osram HBO 100 W/2 lamp) and a 1-cm cell.

However, tricyanomethylcobalamin which was prepared by the reaction of aquocobalamin with $KC(CN)_3$ in slightly acidic water may contain the tricyanomethanide ligand with a Co-N instead of a Co-C bond.[13,14] On the contrary, typical alkylcobalamins such as methylcobalamin, which are characterised by a Co-C σ-bond, undergo a homolytic photocleavage of this cobalt-carbon bond. [1-6] A net reaction is observed only in the presence of oxygen since the radical pair[15] regenerates methylcobalamin if O_2 is not inserted.

$$B_{12}\text{-}CH_3 + O_2 + H_2O \xrightarrow{h\nu} B_{12}\text{-}H_2O^+ + H_2CO + OH^-$$

On the basis of the wavelength-dependent quantum yields of this photolysis[16,17] it is suggested[17] that the reactive excited state of B_{12}-CH_3 is of the LLCT type.[18] Irradiation of the LLCT band (λ_{max} = 317 nm) leads to the homolysis of the Co-C bond by the promotion of a Co-C σ-bonding electron to a π* orbital of the corrin ligand.[17] However, the photosensitivity of methylcobalamin extends, but with reduced efficiency, also to longer-wavelength absorptions which are of the corrin ππ* type. We suggest[17] that these intraligand transitions are mixed with LLCT transitions by $a_{2u} \rightarrow e_g$ configuration interaction assuming a (simplified) D_{4h} symmetry for methylcobalamin.

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