azido complex (yield 0.12 g). The azido chloride was converted to the perchlorate by treating it with an equivalent amount of $AgClO_4$ in water. The AgCl was removed and the complex precipitated by adding excess solid $NaClO_4$. The molar absorptivity of the isolated salt, $[Co(NH_3)_4(^{15}NH_3)N_3](ClO_4)_2$, was ϵ_{518} 270. The filtrate (ice cold) was treated with cold concentrated HBr, and the aquo bromide salt which crystallized was collected, dissolved in water, and adsorbed on an ion-exchange column. Traces of the azido complex were removed by eluting with 1 *M* $NaClO_4$, and the aquo complex was then taken off the column with 3 *M* $HClO_4$. The solution was taken down to a small volume on a vacuum evaporator and the precipitated $[Co(NH_3)_4(^{15}NH_3)H_2O](ClO_4)_3$ was collected.

The pmr spectra of the complexes were obtained using a Varian HA-100 spectrometer. The samples (~0.2 g/ml) were dissolved in dimethyl-d_6 sulfoxide acidified with a trace of D_2SO_4 (98%).

D. A. Buckingham, I. I. Olsen, A. M. Sargeson
Research School of Chemistry
Australian National University, Canberra, Australia
Received August 26, 1968

Epimerization about Unactivated Tertiary Carbon Atoms in Substituted Cyclopentane Derivatives

Sir:

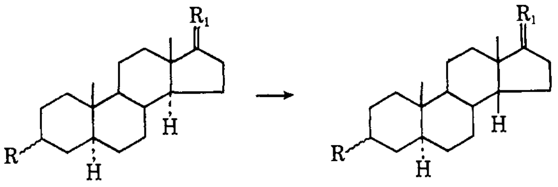
This report discloses a novel radical epimerization at a tertiary carbon atom in cyclopentane derivatives.

We have observed a slow decrease of the Cotton effect amplitude in the ORD spectrum of a cyclohexane solution of (+)-3-methylcyclopentanone when irradiated with 253.7-mμ light in the presence of mercuric bromide.[1] After irradiation for 48 hr the amplitude had decreased to 10% of its initial value. The ketone was isolated as its dinitrophenylhydrazone whose $[\alpha]_D$ value indicated 90% racemization.

On the other hand, almost no racemization was detected when optically active 3-methylcyclohexanone was treated under identical conditions.

Preferential epimerization of a tertiary hydrogen atom bound to a cyclopentane ring was observed on analogous treatment of the steroidal hydrocarbon, 5α-androstane (**1a**).[2] The only product, the 14β,5α-androstane (**2a**), was isolated in *ca.* 80% yield.[3]

Similar epimerizations at C-14 took place in 5α-androstane derivatives substituted by acetoxy or carbomethoxy functions in either five- or six-membered rings; *e.g.*, 17β-acetoxy-, 3β,17β-diacetoxy-, 3α,17β-diacetoxy-, and 3β-acetoxy-17β-carbomethoxy-5α-androstanes **1b–e** gave after irradiation in cyclohexane in the presence of mercuric bromide the corresponding 14β derivatives **2b–e**[4-6] in *ca.* 80–90% yield.



1 **2**

a, R = H; $R_1 = \,<^{H}_{H}$

b, R = H; $R_1 = \,<^{OAc}_{H}$

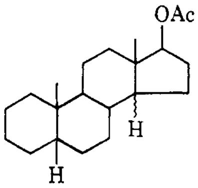
c, R = β-OAc; $R_1 = \,<^{OAc}_{H}$

d, R = α-OAc; $R_1 = \,<^{OAc}_{H}$

e, R = β-OAc; $R_1 = \,<^{COOMe}_{H}$

f, R = H; R_1 = O

g, R = β-OAc; R_1 = O



3a, 14α-H
b, 14β-H

Under the same conditions, both 5α-17-ketones **1e** and **1f** resulted in the 14β-17-ketones **2f** and **2g**[5,6] (*ca.* 90%). Furthermore, similar irradiation of 17β-acetoxy-5β-androstane (**3a**), possessing hydrogen atoms in both *trans*-hydrindan and *cis*-decalin ring junctions, yielded the 5β,14β derivative **3b**, indicating a preferential epimerization at the former junction.

The reversibility of the C-14 epimerizations was proved by irradiation of the 14β steroid **2a**, which gave *ca.* 5% of the 14α derivative **1a**. The >9:1 ratio may thus reflect the relative stability of the two C-14 epimers in androstane and 17-substituted androstane systems.[7] We assume that these epimerizations are radical induced, the radicals being formed on irradiation of mercuric bromide in cyclohexane solution.

Mercuric bromide, which is soluble in cyclohexane to the extent of ~120 mg/l. at ambient temperature, has absorption maxima at 198 and 236 mμ (ε 15,000 and 2400).[8] On irradiation with 253.7-mμ light it slowly decomposes to mercurous bromide and subsequently to mercury metal.

Neither irradiation in the presence of mercurous bromide nor irradiation in the presence of mercury metal (or cyclohexylmercuric bromide) affected the C-14 position of a 14α steroid. Similarly, irradiation of the 14α compounds with light of longer wavelength in the presence of mercuric bromide is ineffective.

Thus it appears that the direct excitation of the latter compound released bromine radicals which are capable of preferential extraction of tertiary hydrogen atoms of substituted cyclopentanes.

A complete suppression of the epimerizations in the presence of oxygen, cyclohexane, or phenol[9] indicated

---

(1) A solution of the ketone (100 ml, 30 m*M*) in cyclohexane containing 20 m*M* mercuric bromide was used.

(2) Generally 100 ml of a solution 3 m*M* in steroid and 3 m*M* in mercuric bromide was irradiated. Smaller quantities of mercuric bromide were also employed; the minimal concentration which led to the same yield of **2a** was 0.1 equiv with respect to the steroid.

(3) Satisfactory analyses and ir, nmr, and mass spectra were obtained for all new compounds reported.

(4) The characteristic feature in the nmr spectrum of the 17β-acetoxy derivatives in the 14β series is the doublet at 4.8 ppm (*J* = 5 cps) of the 17α proton; the corresponding proton in the 14α series appears as an ill-defined triplet at 4.6 ppm.

(5) The identity of **2c** and **2g** with the authentic samples was proven; *cf.* A. F. St. Andre, H. B. McPhiliamy, J. A. Nelson, A. C. Shabica, and C. R. Scholtz, *J. Amer. Chem. Soc.*, **74**, 5506 (1952).

(6) Irradiation of **1f** and **1g** gave in addition small amounts of 17-oxo-13α-5α-androstanes and 17-oxo-13α-3β-acetoxy-5α-androstane, respectively.

(7) For a discussion of the relative stability relationship of the C/D *trans* and *cis* rings in steroids, *cf.* M. Hanack, "Conformation Theory," Academic Press, New York, N. Y., 1965, pp 216–225, and references cited therein.

(8) The reported uv values for mercuric bromide in ethanol solution are λ_{max} 206, 234 mμ (log ε 3.64, 3.79): B. G. Gowenlock and J. Trotman, *J. Chem. Soc.*, 1454 (1955).

that a radical mechanism is operative in these reactions.

No isomerization at C-14 occurred when the solvent, cyclohexane, was replaced by *t*-butyl alcohol or methyl alcohol. Other hydrocarbon solvents, capable of dissolving mercuric bromide (*e.g.*, hexane) could however replace cyclohexane.

Since we assumed that the bromine radicals were responsible for the epimerization reaction, we have tried to use other sources of these radicals. A cyclohexane solution of 14α steroid **1b** was thus irradiated in the presence of bromine and of bromotrichloromethane. No more than 10% of the epimerized 14β derivative **2b** was formed. However, irradiation with the same light source in the presence of 0.15 equiv of N-bromosuccinimide resulted in a 50% conversion of 17β-acetoxy derivative **1b** to its 14β epimer **2b**, and in the presence of 1 equiv in a 90% conversion. The 17-ketone **1f** was also epimerized to the 14β-17-ketone **2f** in 50% yield when irradiated in cyclohexane solution in the presence of 1.5 equiv of N-bromosuccinimide.

Work on further applications and on the mechanism of this isomerization reaction is now in progress.

Acknowledgment. This work was supported by a grant of the Ministry of Commerce and Industry of Israel.

(9) The solution irradiated contained equivalent concentrations of the phenol and of the 14α-steroid **1b** (3 m*M* each). The phenol did not act as a uv filter as indicated by irradiation of the same compound, **1b** (3 m*M*), in the presence of much higher concentrations of benzene (30 m*M*) which resulted in 80% epimerization to **2b**.

Malka Gorodetsky, Yehuda Mazur
Department of Chemistry, The Weizmann Institute of Science
Rehovoth, Israel
Received May 24, 1968

The Molecular and Electronic Structure of Vitamin B_{12r}, Cobaloximes(II), and Related Compounds

Sir:

Vitamin B_{12r} is of interest as a low-spin Co(II) d^7 complex in which the cobalt ion could be five coordinated owing to the attachment of 5,6-dimethylbenzimidazole to the corrin ligand by the peculiar sugar phosphate "loop." However, it is possible that the interaction of this ligand with the metal is sufficiently strong only in Co(III) derivatives of the vitamin, and that in vitamin B_{12r} solutions four-coordinated species may also be present. To establish the molecular structure of vitamin B_{12r} in solution, esr spectroscopy was applied. Several authors[1-3] have previously reported esr measurements on vitamin B_{12r}. However, thus far no definite conclusions concerning the molecular or electronic structure were possible, primarily because of the low resolution of the spectra obtained.

Solutions of vitamin B_{12r} were prepared, *e.g.*, by reducing pure vitamin B_{12a} with $NaBH_4$ in water or water–methanol at pH 2.2.[4] Most measurements were performed in neutralized solutions under argon at 90°K. A spectrum of vitamin B_{12r} is shown in Figure 1. The g tensor is axially symmetrical with $g_\perp = 2.24$ and $g_\parallel = 2.014$. The high-field signal is split due to the interaction of the electron with ^{59}Co ($I = {}^7/_2$), with $\langle A_{Co}\rangle = 108$ G. Six of the eight expected lines are observed. The remaining two are hidden under the intense low-field signal. The latter is not well resolved and consists of a superposition of absorptions due to nuclear transitions belonging to $g_\perp$.

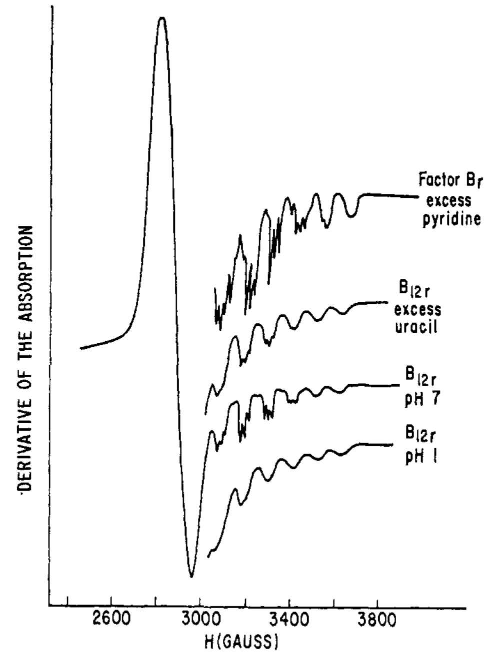


Figure 1. Esr spectra of vitamin B_{12r} under various conditions in frozen aqueous solutions at 90°K. Note the different ^{14}N shf splitting multiplicity of Factor B_r in the presence of excess of pyridine, consistent with the formation of 1:1 and 1:2 adducts of Factor B_r with pyridine.

The observed axial symmetry and the g values are very similar to those found[5] for cobalt phthalocyanine (Table I). Accordingly, vitamin B_{12r} must possess a similar electronic ground state. From the observed axial symmetry of the g tensor the placement of the unpaired electron can be limited to either the d_{z^2} or the $d_{x^2-y^2}$ orbital. Of these two the latter is eliminated in view of the absence of shf splitting due to the in-plane nitrogen atoms of the corrin system. The unpaired electron consequently must be in the $3d_{z^2}$ orbital just as in the case of cobalt phthalocyanine.[5] This conclusion becomes unambiguous in view of the observed sensitivity of the esr signal to changes in the axial environment and, more specifically, the observation of the shf splitting due to the axial ligand. Thus, the cobalt components of $g_\parallel$, particularly those with $M_I = +{}^3/_2, +{}^1/_2$, and $-{}^1/_2$, are split into three lines through the interaction with ^{14}N ($I = 1$), with $\langle A_N\rangle = 17.5$ G (Figures 1 and 2). This shf structure diminishes in solutions of pH 1 due to the protonation of the axial ligand and is absent in the esr spectrum of reduced "Factor B," which does not contain benzimidazole. The Co(II) ion in vitamin B_{12r} thus is essentially five coordinated under our conditions of measurement (Figure 2). The addition of excess of pyridine, benzim-

---

[1] H. P. C. Hogenkamp, H. A. Barker, and H. S. Mason, *Arch. Biochem. Biophys.*, **100**, 353 (1963).

[2] H. A. O. Hill, J. M. Pratt, and R. J. P. Williams, *Proc. Roy. Soc.* (London), **A288**, 352 (1965).

[3] R. H. Yamada, S. Shimizu, and S. Fukui, *Arch. Biochem. Biophys.*, **117**, 675 (1966).

[4] Well-resolved esr spectra were also obtained by reducing vitamin B_{12a} with mercaptans at neutral pH. Concerning the esr spectrum of vitamin B_{12a} in solution due to self-reduction, see L. P. Lee and G. N. Schrauzer, *J. Am. Chem. Soc.*, **90**, 5274 (1968).

[5] J. M. Assour, *ibid.*, **87**, 4701 (1965).