in an apparatus previously described.[9] When the spectrum of 0.3 m*M* *o*-benzylbenzophenone in cyclohexane is measured several minutes after the flash excitation, it deviates only to a small extent from the initial absorption (λ_{max} 338 and 342 mμ, ϵ 140).[10] However, 50 μsec. after the flash excitation the absorption spectrum is markedly different with a new maximum at 500 mμ and a minimum at 344 mμ (Fig. 1). By studying the optical density at various wave lengths with kinetic spectrophotometry two transient intermediates were identified separately. A fast transient, the absorption maximum of which at 500 mμ is very similar to the triplet–triplet absorption of benzophenone,[11] was assigned as the n → π* triplet of *o*-benzylbenzophenone (II). Its rate of decay measured at 436 mμ and 480 mμ follows first-order kinetics with $k = 1.9 \pm 0.2 \times 10^3$ sec.$^{-1}$ which further substantiates the triplet assignment.[11] The slow transient, detected by the decay of optical density at 405 mμ, is tentatively identified as the enol (III). The decay is also of first order with $k = 9.4 \pm 0.6 \times 10^{-2}$ sec.$^{-1}$.

The interconversion relationship of the two intermediates was established by following the variation of the optical density at 345 mμ. The optical density at 345 mμ decreases to a minimum value immediately after the flash (Fig. 1), then it increases rapidly to a maximum a few msec. thereafter with a first-order rate constant, $k = 3.2 \times 10^3$ sec.$^{-1}$ (±50%), which is of the same order of magnitude as that of the triplet decay. The maximum optical density attained at this wave length is approximately 0.1 unit higher than the final absorption. The decay of this maximum absorption to the final value also follows first-order kinetics with $k = 8.7 \times 10^{-2}$ sec.$^{-1}$, which is the same as the decay of the slow transient within experimental error. The above observations establish that (1) the fast transient is converted into the slow transient, *i.e.*, the n → π* triplet is the precursor of the enol, and (2) the enol is not formed directly from the n → π* singlet. If the n → π* singlet were the immediate precursor of the enol, there would be a strong absorption at 345 mμ immediately after the flash.

Our observations demonstrate that photoenolization of *o*-benzylbenzophenone, an intramolecular photochemical reaction analogous to the type II process, involves a reaction triplet intermediate. Although the enolization may occur theoretically within the lifetime of the singlet excited state, it is actually slower than the interstate crossing of the singlet to the triplet (reaction 3). This work supports the theory that the triplet state may be a reactive state in other similar intramolecular photochemical reactions.[12,13]

(9) E. F. Zwicker and L. I. Grossweiner, *J. Phys. Chem.*, **67**, 549 (1963); L. I. Grossweiner and E. F. Zwicker, *J. Chem. Phys.*, **34**, 1411 (1961).

(10) After several flash irradiations or a prolonged irradiation with a high intensity light source, the solution acquired a yellow tint with a blue fluorescence. From the reaction medium there was isolated a small yield of a dimer whose structure is being elucidated.

(11) D. S. McClure and P. Hanst, *J. Chem. Phys.*, **23**, 1772 (1955).

(12) P. Ausloos and R. E. Rebbert, *J. Am. Chem. Soc.*, **83**, 4897 (1961).

(13) W. H. Urry and D. J. Trecker, *ibid.*, **84**, 118 (1962).

(14) The work at the Illinois Institute of Technology is supported by the United States Public Health Service, Department of Health, Education and Welfare.

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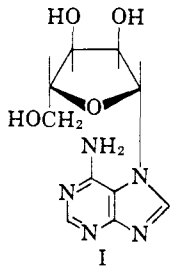
The Synthesis of the Anomeric 7-D-Ribofuranosyladenines and the Identification of the Nucleoside from Pseudovitamin B_{12}[1]

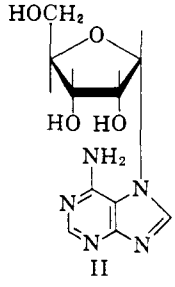
Sir:

The final identification of the nucleoside moiety of vitamin B_{12} as 1-α-D-ribofuranosyl-5,6-dimethylbenzimidazole was achieved by comparing its picrate with a synthetic specimen.[2] Later a nucleoside was isolated from pseudovitamin B_{12} and identified as 7-D-ribofuranosyladenine.[3] Although the configuration of the glycosyl linkage of this nucleoside was thought to be α,[4] this point has not been established by chemical means in the years since the isolation of the nucleoside.

Using a recently developed method[6] for the synthesis of 7-glycosylpurines, we have now synthesized both 7-β-D-ribofuranosyladenine (I) and 7-α-D-ribofuranosyladenine (II) and established the identity of the nucleoside from pseudovitamin B_{12} and II.

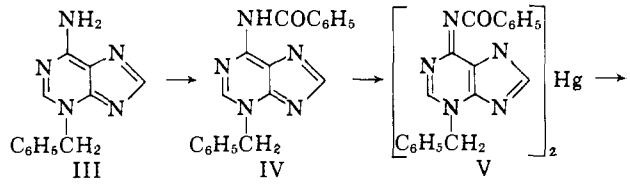


I

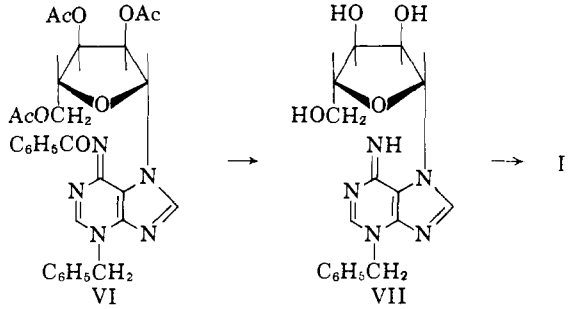


II

3-Benzyladenine (III), prepared by the benzylation of adenine in N,N-dimethylacetamide in the absence of base,[7] was allowed to react with benzoic anhydride to give N^6-benzoyl-3-benzyladenine (IV), which was converted to its mercury derivative (V) in the usual manner.[8] The mercury derivative V was coupled with tri-O-acetyl-D-ribofuranosyl chloride by refluxing a xylene suspension of the two materials for 1 hr. Removal of the acyl groups from the blocked nucleoside VI was accomplished by refluxing for 30 min. a methanol solution of it containing sodium methoxide. A 51% yield



III IV V



VI VII

(1) This work was supported by funds from the C. F. Kettering Foundation and the Cancer Chemotherapy National Service Center, National Cancer Institutes, National Institutes of Health, Contract No. SA-43-ph-1740.

(2) F. W. Holly, C. H. Shunk, E. W. Peel, J. J. Cahill, J. B. Lavigne, and K. Folkers, *J. Am. Chem. Soc.*, **74**, 4521 (1952).

(3) W. Friedrich and K. Bernhauer, *Chem. Ber.*, **89**, 2507 (1956).

(4) X-Ray analysis of the structure of the B_{12} vitamins suggests the α-configuration as well as attachment at N-7.[5]

(5) D. C. Hodgkin, *Biochem. Soc. Symp.* (Cambridge, England), **13**, 28 (footnote) (1955).

(6) J. A. Montgomery and H. J. Thomas, *J. Org. Chem.*, **28**, 2304 (1963).

(7) J. W. Jones and R. K. Robins, *J. Am. Chem. Soc.*, **84**, 1914 (1962).

(8) J. J. Fox, N. Yung, I. Wempen, and I. L. Doerr, *ibid.*, **79**, 5060 (1957).

TABLE I

Compound[a]	M.p., °C.[b]	$[\alpha]^{26}D$ (g./100 ml. H_2O)	R_f[c]	Ultraviolet spectra[d] 0.1 HCl λ_{max}, mμ	0.1 HCl $\epsilon \times 10^{-3}$	0.1 NaOH λ_{max}, mμ	0.1 NaOH $\epsilon \times 10^{-3}$
I	246	−84.9 ± 0.2 (0.351)	0.19	272	13.6	270	9.8
II	220–222	0 (0.397)	.15	273	13.3	271	9.9
Nucleoside from ψ-B_{12}[e]	218–222	0[f] (0.262)	.15[g]	273	13.6	271	9.8
Adenosine[h]	233	−60.4 (0.7)	.20	260	14.2	260	14.3
9-α-D-Ribofuranosyladenine[h]	201	+24 (0.65)	.17	257			
III	275–277		.75	275	17.5	272	12.2
IV	216		.89	300	28.2	231[h]	17.0
						333	17.9
V[i]	278						
VII			.31	278	14.3	281	11.5

[a] Satisfactory elemental analyses (C, H, N) were obtained for each compound except VII, which was not analyzed. [b] Melting points below 260° were determined on a Kofler Heizbank; those above 260° were determined in a capillary and are uncorrected. [c] Whatman No. 1 paper, water-saturated butanol. [d] Determined with a Cary Model 14 spectrophotometer. [e] Data from ref. 3. [f] Temperature not specified. [g] Calcd. from $R_{adenosine}$. [h] Data from ref. 14. [i] Elemental analyses show that V is a dipurinylmercury.

of crude 3-benzyl-7-β-D-ribofuranosyladenine (VII) was obtained as a brown glass. The benzyl group of this nucleoside VII was removed by hydrogenolysis using 5% palladium-on-charcoal catalyst in a mixture of ethanol and water at 80° and 47 p.s.i. of hydrogen. The resulting nucleoside, obtained in 31% yield, was identified as 7-β-D-ribofuranosyladenine (I) by its ultraviolet spectrum (showing sugar attachment at N-7) and application of the *trans* rule[9] (indicating the configuration of the glycosyl linkage formed by this coupling must be β[10]).

Coupling of the same dipurinyl mercury V with 5-O-benzoyl-D-ribofuranosyl bromide 2,3-cyclic carbonate[13] followed by deblocking of the resultant nucleosides with methanolic sodium methoxide gave a mixture of 3-benzyl-7-β-D-ribofuranosyladenine (VII) and 3-benzyl-7-α-D-ribofuranosyladenine (VIII) which could not be separated but could be debenzylated catalytically as described earlier for the β-anomer. Partition chromatography of the resulting mixture, using a cellulose powder column and butanol–water (86:14), gave first 7-β-D-ribofuranosyladenine (I), which crystallized on seeding with a crystal of material obtained from the first coupling described earlier, and then 7-α-D-ribofuranosyladenine (II), purified through its picrate.

Properties of the anomeric nucleosides and some of their precursors are given in Table I, along with those of the nucleoside from pseudovitamin B_{12}, adenosine, and its α-anomer. The samples of the β-anomer I prepared by the two different coupling reactions were identical, whereas the properties of the α-anomer II are in good agreement with those reported for the nucleoside from pseudovitamin B_{12}.[3] The optical rotations of the anomers (β, −84.9 ± 0.2°; α, 0°) confirm the assignment of α- and β-configurations and agree well with the relative values for adenosine and its α-anomer (−60.4° and +24°).

(9) B. R. Baker, *Ciba Found. Symp., Chem. Biol. Purines*, 120 (1957).

(10) No true exceptions to the *trans* rule have been reported in the synthesis of purine nucleosides.[11] In rare instances a minor amount of α-anomer has been detected[12] but the β-anomer is always the principal product of the reaction. In our reaction only one anomer could be detected.

(11) J. A. Montgomery and H. J. Thomas, *Advan. Carbohydrate Chem.*, **17**, 301 (1962).

(12) B. R. Baker, R. E. Schaub, and H. M. Kissman, *J. Am. Chem. Soc.*, **77**, 5911 (1955); H. M. Kissman and B. R. Baker, *ibid.*, **79**, 5534 (1957).

(13) This ribose derivative, which contains no acyloxy group at C-2 to cause stereospecific entry of a purine at C-1[9] giving rise to a β-ribonucleoside only, has been used to prepare a mixture of adenosine and its α-anomer.[14]

(14) R. S. Wright, G. M. Tener, and H. G. Khorana, *J. Am. Chem. Soc.*, **80**, 2004 (1958).

It is now possible to state with certainty that the nucleoside moiety of pseudovitamin B_{12} is in fact 7-α-D-ribofuranosyladenine. Synthesis of the nucleosides from other B_{12} vitamins is in progress.

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A Two-Stage, Two-Center Decarboxylation[1]

Sir:

The elusive question of simultaneity in multicenter-type reactions continues to receive its most critical examination in studies of Diels–Alder reactions.[2] Suggestions that a range of transition state structures might be accessible[2b,c] are supported by results which clearly demonstrate the polar ambivalence of such states[3] and warn that classical elucidative techniques might well distort the very phenomena they seek to measure.[4] The dilemma can be avoided by isotopic substitution, preferably at the reaction sites but also[2d,5] at adjacent atoms. Interpretations of these latter, α-hydrogen isotope effects have been rendered ambiguous by the discovery[6a] of one clear exception to what had been regarded[6b] as a universal, though necessarily empirical pattern. Less equivocal decisions should follow from determination of *primary* isotope effects at *both* reaction sites and we here report the first such investigation in this area.[7]

Thermal decarboxylation of the α-pyrone–maleic anhydride adduct[8] was chosen for study assuming (a) that this might legitimately be regarded as a Diels–Alder retrogression and (b) that the structural sim-

(1) The study was supported by the Air Force Office of Scientific Research, under Contract No. 49(038)-942 and Grant No. 142–63.

(2) (a) R. B. Woodward and T. J. Katz, *Tetrahedron*, **5**, 70 (1959); (b) J. A. Berson and A. Remanick, *J. Am. Chem. Soc.*, **83**, 4947 (1961); (c) C. Walling and H. J. Schugar, *ibid.*, **85**, 607 (1963); (d) S. Seltzer, *ibid.*, **85**, 1360 (1963).

(3) J. Sauer and H. Wiest, *Angew. Chem.*, **74**, 353 (1962).

(4) This has been clearly recognized in the study of rate dependence on pressure (C. Walling and D. D. Tanner, *J. Am. Chem. Soc.*, **85**, 612 (1963)).

(5) (a) D. E. Van Sickle, *Tetrahedron Letters*, 687 (1961); (b) S. Seltzer, *ibid.*, 457 (1962).

(6) (a) R. E. Weston, Jr., and S. Seltzer, *J. Phys. Chem.*, **66**, 2192 (1962); (b) S. Seltzer, *J. Am. Chem. Soc.*, **83**, 2025 (1961); *ibid.*, **85**, 14 (1963).

(7) (a) G. A. Ropp, V. F. Raen, and A. J. Weinberger, *ibid.*, **75**, 3697 (1953); (b) R. F. W. Bader and A. N. Bourns, *Can. J. Chem.*, **39**, 348 (1961), are the most closely related studies in object (a) and approach (b).

(8) (a) O. Diels and K. Alder, *Ann. Chem.*, **490**, 257 (1931); (b) B. R. Landau, Ph.D. Thesis, Harvard University, 1950.