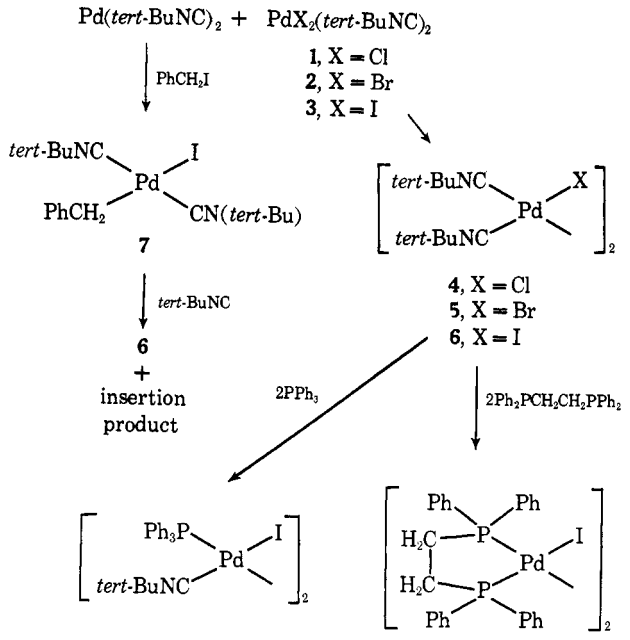
Scheme I



bands. The appearance of one NC band could be a fortuitous consequence derived from a combination of two force constants, *i.e.*, the NC stretching and the interaction force constant. The ir spectrum measured in benzene shows a slight broadening of the NC stretching absorption. In view of the valence of the metal, the NC stretching frequency (Table I) is reasonably low compared to that of the corresponding halogenopalladium(II) complex (Table I).

Unexpectedly, the Pd–**X** bond was inert to attack by tertiary phosphines. Thus, **6** was treated with 1 mol of PPh_3 in toluene at room temperature for 2 hr to give, upon chilling at −78°, orange crystals[10] of formula $[PdI(PPh_3)(tert\text{-BuNC})]_2$, dec 115–117°, ir (Nujol) 2165 cm^{-1} (N≡C). Similarly, treatment with an excess of a chelating diphosphine, $Ph_2PCH_2CH_2PPh_2$, in toluene yielded an extremely stable (no decomposition below 300°) dimer complex, $[PdI(Ph_2PCH_2CH_2PPh_2)]_2$, as orange crystals[10] (recrystallized from benzene–*n*-hexane). The remarkable stability of the dimer structure contrasts the facile bridge cleavage observed for bis(halogeno-π-allylpalladium) $[\pi\text{-}C_3H_5PdCl]_2$.[13]

Attempts were made to find chemical behavior characteristic of a d^9 ion. No reaction took place between **6** and hexaphenylethane (hence, trityl radical) in boiling ether. The reaction of **6** with bis(decanoyl) peroxide, $[CH_3(CH_2)_8COO]_2$, produced 1-nonene. Since 1-nonene was also obtained in the reaction with **3**, the reaction does not necessarily provide a diagnosis for one-electron oxidation of alkyl radical.[14] Complexes **4** and **5** failed to show the catalytic activity that $Pd(tert\text{-BuNC})_2$ displays for air oxidation of *tert*-BuNC.[15]

A characteristic reaction was observed when **5** was treated with nitric oxide in ether. A very facile reaction takes place at room temperature, producing a monomeric, diamagnetic complex, *trans*-$PdBr(NO_2)(tert\text{-BuNC})_2$, as pale yellow crystals:[10] dec 86–88°; ir (Nujol) 2235 (N≡C), 1321, and 820 cm^{-1} (NO_2). From **4** was obtained the chloro analog, *cis*-$PdCl(NO_2)(tert\text{-BuNC})_2$, as yellow needles:[10] dec 180°; ir (Nujol) 2235 and 2250 (sh) cm^{-1} (N≡C). Since these reactions were carried out under careful exclusion of air, the results imply a disproportionation of NO facilitated by the Pd(I) species. The disproportionation has been observed for reaction with complexes of Rh(I)[16] and Ni(0),[17] but not for reaction with Pd(II) complexes.[18,19] Attempted preparation of a Pd(III) complex by oxidation of **6** with iodine merely yields **3** in a high yield.

The diamagnetism, as exhibited by the sharp ^1H nmr resonances, suggests strong magnetic exchange intereactions between the two d^9 nuclei, possibly through the bridging halogen ligands and through space. The latter mechanism, however, must be confirmed by an X-ray structural analysis.

(13) M. L. H. Green in "Organometallic Compounds," Vol. 2, G. E. Coates *et al.*, Ed., Methuen, London, 1968, p 52.
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(15) S. Otsuka, A. Nakamura, and Y. Tatsuno, *Chem. Commun.*, 836 (1967).
(16) W. B. Hughes, *ibid.*, 1126 (1969).
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(18) W. P. Griffith, J. Lewis, and G. Wilkinson, *J. Chem. Soc.*, 1775 (1959).
(19) W. Manchot and H. Waldmuller, *Ber.*, **59**, 2363 (1926).

Sei Otsuka,* Y. Tatsuno, K. Ataka
Department of Chemistry, Faculty of Engineering Science
Osaka University, Toyonaka, Osaka, Japan
Received August 5, 1971

Total Synthesis of *dl*-Y Base from Yeast Phenylalanine Transfer Ribonucleic Acid and Determination of Its Absolute Configuration

Sir:

Structure **1** was recently proposed[1] for the fluorescent Y base which is obtained from baker's yeast phenylalanine tRNA upon submitting the latter to mild acid treatment.[2] In view of the scarcity of material available (300 μg), structural studies were based on interpretation of spectroscopic data, syntheses of model compounds[3] having fully substituted aromatic nuclei, and a separate synthesis of the side chain. The proposed structure has since been supported by independent physical data and results of microchemical and enzymatic reactions.[4] Recently, we have assigned to the fluorescent bases isolated from various liver $tRNA^{phe}$'s the peroxy-Y base structure **2**,[5] which also appears to account for results published by Yoshikami and Keller.[6] On the other hand, structure **3** without the side chain has been established for the Y-like base isolated from brewer's yeast $tRNA^{phe}$.[7] In the following we report the total synthesis of *dl*-Y base, thus con-

(1) K. Nakanishi, N. Furutachi, M. Funamizu, D. Grunberger, and I. B. Weinstein, *J. Amer. Chem. Soc.*, **92**, 7617 (1970); *cf. Nature (London), New Biol.*, **230**, 196 (1971).
(2) R. Thiebe and H. G. Zachau, *Eur. J. Biochem.*, **5**, 546 (1968).
(3) A. Feinberg, M. Funamizu, N. Furutachi, A. Terahara, and K. Nakanishi, manuscript in preparation.
(4) R. Thiebe, H. G. Zachau, L. Baczynsky, K. Biemann, and J. Sonnenbichler, *Biochem. Biophys. Acta*, **240**, 163 (1971).
(5) K. Nakanishi, S. Blobstein, M. Funamizu, N. Furutachi, G. Van Lear, D. Grunberger, K. W. Lanks, and I. B. Weinstein, *Nature (London)*, in press.
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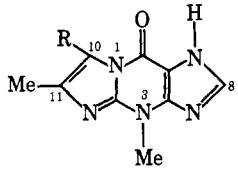
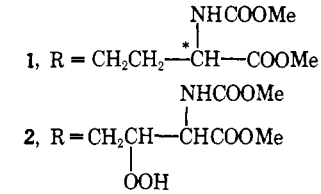
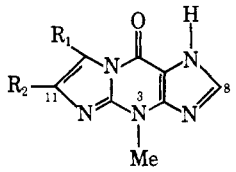




1, R = CH_2CH_2—CH(NHCOOMe)—COOMe

2, R = CH_2CH(OOH)—CH(NHCOOMe)COOMe

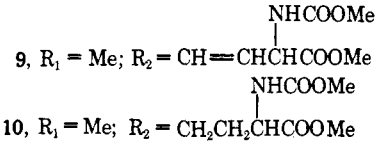
3, R = H



4, R_1 = *n*-Bu; R_2 = Me

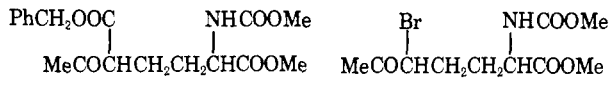
5, R_1 = Me; R_2 = —CH=CHCH_2CH_3

6, R_1 = Me; R_2 = *n*-Bu



9, R_1 = Me; R_2 = CH=CHCH(NHCOOMe)COOMe

10, R_1 = Me; R_2 = CH_2CH_2CH(NHCOOMe)COOMe



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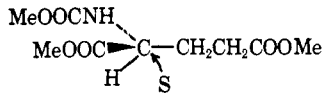

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firming its proposed structure; furthermore, we assign an *S* configuration to its single chiral center (1-C*) by correlation with an authentic material.

The model **4** having the exact Y base nucleus was first synthesized by treating 3-methylguanine[8] with 3-bromoheptan-2-one in DMSO–H_2O at 60° overnight. This afforded in 5% yields, respectively, the expected **4**[9] (mp 270° (sealed tube); uv (MeOH) 313 (ε 5000), 260 (ε 5300), 235 nm (ε 33,500); nmr ($CDCl_3$) 11-Me, 2.31 (s), N^3-Me, 4.00 (s), 8-H, 7.89 ppm (br s)), and unexpectedly **5** (mp 271–273°; uv (MeOH) 323 (ε 1050), 261 (ε 26,300), 242 (ε 37,300), 227 nm (ε 31,000); nmr ($CDCl_3$ containing 1 drop of DMSO-d_6) side-chain Me, 1.08 (t, J = 7 Hz); allylic CH_2, 2.25 (m); 10-Me, 2.75 (s); N^3-Me, 3.96 (s), α-olefinic CH, 6.35 (d, J = 17 Hz); β-olefinic CH, 6.60 (m); 8-H, 7.80 ppm (s)). Compound **5** was readily hydrogenated to yield **6**: mp 283–285°; uv (MeOH) 313 (ε 5500), 258 (ε 6750), 234 nm (ε 34,700); nmr ($CDCl_3$) 10-Me, 2.71 (s); N^3-Me, 3.96 (s); 8-H, 7.86 ppm (s); isomeric with **4**. Differentiation between the two structures **4** and **6** was based on the chemical shifts of the two olefinic methyl groups, assuming that **6** with its signal at the lower field of 2.71 ppm, in contrast to the 2.31-ppm signal in **4**, is under the anisotropic influence of the peri-oxygen function. The same assumption was made during previous structural studies[1] and, moreover, has been fully corroborated by independent synthesis during the course of structural studies of **3**.[7] By-product **5** was also formed in aqueous dimethylformamide, dioxane, and *tert*-butyl alcohol[10] in an atmosphere of nitrogen, and hence is presumably due to a disproportionation reaction; in support of this, **5** was formed in 50% yield upon reaction of heptane-2,3-dione with 3-methylguanine.

The synthesis of racemic Y base was carried out in essentially the same manner. Thus, methyl 2-amino-4-iodobutyrate hydrochloride,[11] mp 125°, was treated overnight with 1.1 mol of methyl chloroformate and 2.2 mol of triethylamine in ether at room temperature to give methyl 2-methylcarbamoyl-4-iodobutyrate, mp 55–56° (ether–hexane) (80%), which in turn was refluxed for 20 hr with 1 mol each of benzyl acetoacetate[12] and sodium hydride in dioxane–benzene (2:5, v/v) to yield methyl benzyl 2-methylcarbamoyl-5-acetyladipate (**7**), oil. The adipate was then: (i) hydrogenated over 10% palladized charcoal in methanol for 20 min; (ii) brominated with 1 mol of bromine for 2–4 hr at 0° in methanol–chloroform; and then (iii) decarboxylated by heating for 1–2 hr at 55–60° in water. This afforded in 45% yield methyl 2-methylcarbamoyl-5-bromo-6-oxoheptanoate (**8**), mp 72–73° (ether–*n*-hexane).

The heptanoate **8** was finally treated with 3-methylguanine for 20 hr at 55–60° in dimethyl sulfoxide–water (10:1, v/v) under adjustment of pH in the range of 4.5–6 by the addition of sodium hydrogen carbonate. The solvent was removed by lyophilization, the residue was extracted with ethyl acetate, and the extract was fractionated by preparative tlc [Analtech silica plate, infinite development with upper layer of ethyl acetate–*n*-propanol–water (6:1:3, v/v)]. This gave *dl*-Y base **1**, mp 204–206°, 20% yield based on reacted 3-methylguanine,[13] and, as in the case of model synthesis, a smaller amount of by-product **9**: mp 360°; uv (H_2O, pH 6.8) 325 (ε 8120), 264 (ε 23,700), 243 nm (ε 25,500); nmr ($CDCl_3$–DMSO-d_6), 11-Me, 2.73 (s); COOMe, 3.86 (s); N^3-Me and COOMe, 3.96 (6 H, s); α-olefinic CH, 6.41 (d, J = 14 Hz); β-olefinic CH, 6.74 (d of d, J = 14, 4 Hz); 8-H, 7.84 ppm (s). Hydrogenation of **9** afforded the base **10**: mp 233–234°; uv (H_2O, pH 6.6) 312 (ε 5100), 263 (ε 7010), 233 nm (ε 30,500); nmr ($CDCl_3$) 11-Me, 2.66 (s); COOMe, 3.70 and 3.74 (s); N^3-Me, 3.91 (s); 8-H, 7.76 ppm (s). Again the nmr

(8) L. B. Townsend and R. K. Robins, *J. Amer. Chem. Soc.*, **84**, 3008 (1962).

(9) Analytical and spectroscopic data of all synthetic compounds were in agreement with their structures.

(10) In 100% DMSO, **5** was the exclusive product (*ca.* 40% yield); oxidation of the bromo ketone is probably the cause of this result.

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(12) R. B. Baker, R. Schaub, M. Guerry, and J. H. Williams, *J. Org. Chem.*, **17**, 90 (1952).

(13) The yield based on total 3-methylguanine is 2%. In spite of numerous attempts to increase the reaction yield, 90% of the starting 3-methylguanine remained unreacted (not extracted by ethyl acetate), and was recovered. The low yield is either due to sluggish reactiviy of 3-methylguanine with heptanoate **8** or rather to side reactions of **8** itself. The minor fluorescent contaminants which were formed in this condensation were also formed when only **8** was submitted to the same reaction conditions; this shows that bromo ketone **8** self-condenses to give fluorescent products. The recovery of unreacted 3-methylguanine was high in the synthesis of model **4** as well.

olefinic methyl peaks at 2.26 ppm in **1** and 2.66 ppm in **10** clearly differentiated the two isomers.

The ir spectra of natural Y base (KBr, 1725, 1700, 1690, 1570 cm^{-1}) and synthetic Y base (KBr, 1726, 1698, 1583, 1568 cm^{-1}) were very similar except for minor differences. Synthetic and natural Y base both emitted at 445 nm (in H_2O) when excited at 320 nm. The uv and pK_a' of natural Y base were previously measured in 10% methanol for solubility reasons. However, as it was found that methanol was not a suitable solvent,[14] the data were remeasured in water. The uv data of synthetic (Table I) and natural Y base

Table I. Uv Data of Synthetic Y Base

Solvent	nm (ε) Peak A	Peak B	Peak C
Water[a]	235 (32,000)	263 (5800)	313 (5000)
Water (pH 2.0)	233 (35,600)	286 (7600)	
Water (pH 10.0)	236 (32,800)	265 (6800)	304 (7200)
100% MeOH	235 (48,100)	263 (8200)	310–315 (7400)

[a] The data were obtained after stirring for 24 hr because of the insolubility of Y base in water.

were in complete accord excepting for the uniformly smaller ε values (*ca.* 90%) of the latter due to purification difficulties arising from the minute amount available. The dissociation constants were 3.70 and 8.60 (±0.05) with both specimens. The nmr and mass spectral data of *dl*-Y and natural Y[1] were also in complete agreement, including the appearance of a set of mass spectral peaks 14 mass units higher when the sample was injected into the spectrometer as a methanol solution. This is a unique feature of the Y base structure and, as interpreted previously,[1] is due to reaction of methanol with the Y nucleus[14] (*i.e.*, CO or C–OH → C–OMe).

(*S*)-(+)-Glutamic acid was converted into (*S*)-dimethyl 2-methylcarbamoylglutarate (**11**), oil,[9] CD (MeOH) $\Delta\epsilon$ −0.14 (232 nm) and −0.76 (206), by carbamoylation (with methyl chloroformate–magnesium oxide, under conditions employed for N-benzoylation[15]) and dimethylation with diazomethane. Exhaustive microozonolysis[16] of natural Y base in ethyl acetate, removal of solvent, decomposition of the ozonide with hydrogen peroxide–aqueous sodium bicarbonate, extraction of acidic product with ethyl acetate, methylation with diazomethane, and tlc purification of product afforded **11** with negative and positive CD Cotton effects, respectively, at 232 and 207 nm. The structure of baker's yeast $tRNA^{phe}$ Y base, the most modified of the numerous minor bases playing important roles in codon–anticodon recognitions,[17] can thus be fully represented by **1** with an *S* configuration.[18]

Acknowledgments. We acknowledge Professors Zachau,[4] Keller,[6] and Takemura[7] for sending us preprints prior to publication. The work was supported by Public Health Service Grant No. CA 11572 and the Hoffmann-La Roche Company.

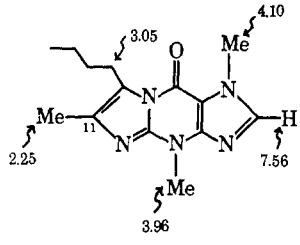
(14) It has been found that shapes of uv curves change considerably with methanol content and time, presumably due to tautomeric equilibria and/or addition of methanol (see below); the Y base kept in methanol, however, could be readily recovered by tlc. Comparison of the uv spectra of natural Y base and synthetic models employed in structural studies[1] were all carried out in 10% MeOH. Both natural and synthetic Y base described in the present communication displayed identical behavior in all respects under these conditions.

(15) M. Bergmann and L. Zervas, *Chem. Ber.*, **65**, 1192 (1932).

(16) The microozonizer was purchased from Supelco, Inc., Bellefonte, Pa.

(17) J. Eisinger, B. Feuer, and T. Yamane, *Nature (London), New Biol.*, **231**, 126 (1971).

(18) Errata for ref 1: (i) Structure **1**, place N in position 9 of nucleus; (ii) structure **11**, the 3.96-ppm Me should be attached to N^3; also C-2 should be tetravalent; (iii) structure **12**, C-2 should be tetravalent; (IV) in discussion on biogenesis (end of paper) glutaric acid should be glutamic acid.



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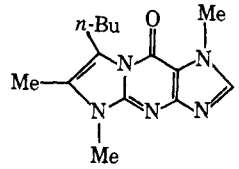

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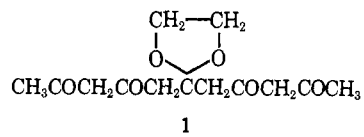
Makoto Funamizu, Akira Terahara
Aaron M. Feinberg, Koji Nakanishi*
Department of Chemistry, Columbia University
New York, New York 10027
Received August 18, 1971

Synthesis of 1,3,5,7,9-Pentacarbonyl Compounds

Sir:

Oligo-β-carbonyl compounds have long attracted attention because of their apparent involvement in the biosynthesis of phenolic natural products,[1] but investigations have been hindered by inaccessibility of the carbonyl compounds, Recently a versatile synthesis of 1,3,5,7-tetracarbonyl compounds was developed in this laboratory.[2] The synthesis involves treatment of 2,4,6-triketones with lithium diisopropylamide or other strong bases to give 1,3,5-trianions which undergo acylation or carboxylation at the 1 position. 1,3,5,7,9-Pentacarbonyl compounds have remained inaccessible. Birch and coworkers prepared ketal-protected pentaketone **1** but were unable to remove the protective group selectively.[3] Trislactone **2**, which is a derivative of 3,5,7,9-tetraoxodecanoic acid, was studied by Scott and coworkers.[4] Under basic conditions **2** underwent cleavage and recyclization to give phenolic products; however, the acyclic intermediates were not detected.



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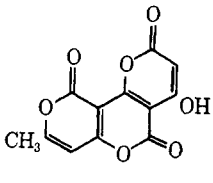

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(1) See J. H. Richards and J. B. Hendrickson, "Biosynthesis of Terpenes, Steroids, and Acetogenins," W. A. Benjamin, New York, N. Y., 1964.

(2) T. T. Howarth, G. P. Murphy, and T. M. Harris, *J. Amer. Chem. Soc.*, **91**, 517 (1969); T. M. Harris and R. L. Carney, *ibid.*, **89**, 6734 (1967).

(3) A. J. Birch, F. Fitton, D. C. C. Smith, D. E. Steere, and A. R. Stelfox, *J. Chem. Soc.*, 2209 (1963).

(4) T. Money, F. W. Comer, G. R. B. Webster, I. G.Wright, and A. I. Scott, *Tetrahedron*, **23**, 3435 (1967); F. W. Comer, T. Money, and A. I. Scott, *Chem. Commun.*, 231 (1967).