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James R. Hauske and Henry Rapoport

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4 A NEW AND CONVENIENT SYNTHESIS OF 2-DEOXY-D-RIBOSE
5 FROM 2,4-O-ETHYLIDENE-D-ERYTHROSE.
6

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8

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11

12 Abstract: A new synthesis is described of 2-deoxy-D-erythro-
13 pentose [2-deoxy-D-ribose, 2-deoxy-D-arabinose (1)], starting
14 from D-glucose. The synthesis proceeds through direct olefination
15 of 2,4-O-ethylidene-D-erythrose (2) by addition of the stabilized
16 ylides generated from dimethylphosphorylmethyl phenyl sulfide
17 (4) and the corresponding sulfoxide 5. These afford the key
18 intermediates, thio-enol ether 7 and α,β -unsaturated sulfoxide 8,
19 which when subjected to mercuric ion-assisted hydrolysis gave
20 high yields of 2-deoxy-D-ribose (1). This facile chain extension
21 of 2 required its existence as a monomer, and conditions effective
22 for obtaining the monomer have been developed. Detailed ^1H - and
23 ^{13}C -NMR studies of these compounds are presented.
24
25
26
27

1 Introduction

2 The synthesis of 2-deoxy sugars is an active area of
3 investigation, since these compounds are frequent constituents of
4 biologically important molecules. Specifically, our attention
5 was drawn to the synthesis of 2-deoxy-D-ribose (1), a necessary
6 intermediate in nucleoside synthesis. Previously reported
7 syntheses of 1 appeared unattractive due to relatively poor yields
8 (10-35%) as well as numerous and tedious purifications. The
9 strategies common to essentially all these methods was either a
fn 1 10 one-carbon degradation of D-glucose,¹ or deoxygenation of an
fn 2 11 appropriately substituted sugar derivative² that is less accessible
12 than glucose. An elegant example of the latter strategy is the
fn 3 13 recent synthesis³, which proceeds via the deoxygenation of the
14 pentose arabinose. It occurred to us that a more convenient
15 procedure might be evolved from a two-carbon degradation of
16 glucose with subsequent chain elongation.

17 A useful intermediate readily applicable to this approach is
fn 4 18 2,4-O-ethylidene-D-erythrose (2).⁴ However, since it has been
fn 5,6 19 reported^{5,6} that 2 exists primarily as a dimer 3, its usefulness for
20 chain elongation was in doubt. Thus, for 2 to serve as an efficient
21 intermediate for the synthesis of 1, two questions had to be answered:
22 (1) is it possible to prepare monomer 2; (2) would 2 be amenable to
23 nucleophilic addition and chain elongation via reaction with an ylide
24 in view of the free hydroxyl group, or would an attenuating
25 blocking-deblocking routine be necessary?

26 Although we were unable to find any reports which unequivocally
27 detail the preparation of monomer 2, a mixture of monomer 2 and

1 dimer 3 has been reported to react with certain nucleophilic reagents
2 under carefully controlled conditions of solvent and temperature.
3 Unfortunately, olefination proceeded in only about 30% yield. The
4 limited nucleophilic additions were rationalized by presuming that
5 some concentration of monomer 2 existed, however, no spectroscopic
fn 7,8 6 evidence for monomer formation was presented.^{7,8} Despite poor over-
7 all yield of olefin, these results are significant, since they
8 illustrate that 2,4-O-ethylidene-D-erythrose (2) is a potentially
9 suitable substrate for nucleophilic additions. Its potential
10 rests on the ability to prepare essentially pure monomer and its
11 reaction with an appropriately substituted ylide, which upon
12 hydrolysis would directly afford 1. This report details the
13 successful implementation of this strategy.

14 Results and Discussion

15 Preparation of 2,4-O-Ethylidene-D-erythrose and Its NMR

16 Evaluation. The synthesis of 2,4-O-ethylidene-D-erythrose (2)
17 proceeded via the very efficient periodate degradation of 4,6-O-
18 ethylidene-D-glucose 4.⁴ Recrystallization of the crude residue
19 afforded crystalline material which exhibited the ¹³C- and ¹H-NMR
20 spectra shown in Figures 1 and 2, respectively. No aldehydic
21 resonance appears in either Figures 1 or 2, which is consistent
22 with earlier reports of no aldehydic absorption either in its
23 infrared spectrum⁹ or in the ¹H-NMR spectrum of its acetates.⁷
fn 9 24 This lack of aldehydic resonance as well as the complexity of the
25 ¹³C-NMR spectrum, leaves no doubt that the product initially isolated
26 is essentially 3.
27

Place structures 2, 3, 9 here

Presumably, there is an equilibrium between dimer 3 and monomer 2, and one might expect ylide addition to shift the equilibrium as monomer is consumed. However, addition of the ylides generated from either phosphonium salt 6 or phosphonates 4 and 5 did not afford olefin, but rather resulted for the most part in the recovery of starting material 3. Although the ethylidene erythrose (2/3) has not previously served as a substrate for the synthesis of 2-deoxy-D-ribose (1), it has been reported^{5,6} to afford low yields of olefins upon treatment with certain phosphonate ylides. In a parallel fashion, we also obtained olefins 7 and 8 in poor yield upon treatment of the ethylidene erythrose with the phosphonate ylides 4y and 5y.

In contrast, treatment of crystalline 3 with ethyl acetate containing a catalytic amount of anhydrous acid¹⁰ afforded, after solvent removal, a solid residue which underwent olefin formation in excellent yield. Thus exposure of 3 to catalytic, anhydrous acid resulted in transformation to the monomeric ethylidene erythrose, 2. Removal of all traces of acid by continuous azeotropic distillation with either benzene or toluene restored the original dimeric structure, 3. When this material was then resubmitted to the ylide reaction, it was essentially inactive. Although ylide would be expected to destroy the residual acid and re-establish dimer 3, dimerization under these conditions is much slower than reaction of the ylide with the monomer aldehyde 2 and high yields of olefins result.

1 The ^{13}C - and ^1H -NMR spectra of monomeric 2,4-O-ethylidene-D-
2 erythrose (2) are shown in Figures 3 and 4. The aldehydic resonance
3 now is clearly evident in both spectra. The ^{13}C -NMR spectrum is
4 much simpler and indicates that less than 5% of dimer 3 is
5 present. However, it is complicated by an extra absorption, seven
6 carbon resonances appearing instead of the anticipated six. This
7 cannot be due to any diastereomers since such an explanation would
8 result in nonequivalence for more than one carbon resonance. We
9 attempted, therefore, to resolve this apparent anomaly by first
10 reducing 2 with sodium borohydride to the crystalline diol 9,
11 obtained in 96% yield.^{4,6}

12 The ^{13}C -NMR spectrum of diol 9 appears in Figure 5. Along with
13 the lack of an aldehydic resonance one sees the appearance of the
14 new exocyclic hydroxymethyl absorption at 62.4ppm. More significant,
15 however, is the absence of the extra resonance which is present in
16 the spectrum of 2 (Fig. 3). The six signals corresponding to the
17 six carbon nuclei were readily assigned as shown on the basis of
18 chemical shift correlations as well as off-resonance decoupling
19 experiments. On the basis of this spectrum, diol 9 does not
20 evidence nonequivalence; that is, 9 is either diastereomerically
21 pure, or alternatively, the diastereomers have fortuitously
22 coincident chemical shifts. In order to test this latter possibility,
23 we attempted to induce nonequivalence in 9 by incremental addition
24 of a lanthanide shift reagent. When 9 was treated with $\text{Eu}(\text{fod})_3$ all
25 diol resonances shifted downfield in both the ^1H - and ^{13}C -NMR
26 spectra and there was no induced nonequivalence. Therefore, we
27 conclude that 9 is a single diastereomer which has an equatorial

1 ethylidene methyl. A similar conclusion was reached⁶ for 4-O-
 2 acetyl-1,2-di-deoxy-3,5-O-ethylidene-1-nitro-D-erythro-pent-1-
 3 enitol, prepared from 2. Since 9 is a single diastereomer, 2
 4 must also be diastereomerically pure; therefore, the extra resonance
 5 appearing in Figure 3 must arise from another source. Although the
 6 spurious resonance may arise from an impurity, this seems unlikely
 7 in view of the Eu(fod)₃ results; further a dynamic conformational
 8 effect may be similarly ruled out.

9 Examination of the off resonance decoupled ¹³C-NMR spectrum of
 10 3 in D₂O exhibited doublets for all absorptions in the range of
 11 80-100 ppm. It would be reasonable to expect the monomeric material
 12 to form a hemi-acetal and this would account for the absorption
 13 appearing at 89 ppm. A ¹³C-NMR spectrum of 2 in dried dioxane
 14 did display seven absorptions; however the resonance at 89 ppm was
 15 markedly diminished (<15%) but still present, probably due to
 16 residual moisture. This result provides support for the hemiacetal
 17 hypothesis.

18 Ylide Generation and Olefin Formation. Scheme I outlines
 19 the synthesis of 2-deoxy-D-ribose (1). The olefination sequence
 20 proceeded in moderate to high yield via either the phosphorane 6y
 21 or the phosphonate ylides 4y and 5y. The success of the reaction
 22 is critically dependent upon the relative basicity of the ylide
 23 as well as on the previously described method of preparation of
 24 2,4-O-ethylidene-D-erythrose (2).

fn 11 25 It has been demonstrated¹¹ that stabilized ylides of type 4y
 26 and 5y add to a variety of hydroxy-substituted carbonyl substrates
 27 to afford either thioenol ethers or α,β -unsaturated sulfoxides.

fn 12 1 Although stabilized ylides have been applied to the synthesis of
 2 sugar moieties, they typically have been used to prepare phosphoryl-
 3 ated sugars.⁵ One exception, however, is the recent report¹² of
 4 the preparation of some deoxyhexoses via the stabilized ylide which
 5 was generated from phenylthiomethyltriphenylphosphonium chloride (6).
 6 When applied to 2, one equivalent of this ylide, 6y, afforded olefin
 7 7 in a modest 27% yield; further, the addition of two equivalents
 8 did not significantly improve the yield.

9 In an effort to improve this yield, we synthesized the
 10 stabilized phosphonate ylides 4y and 5y. The addition of trimethyl
 11 phosphite to α -chloromethyl phenyl sulfide afforded phosphonate 4,
 12 which upon subsequent oxidation with either sodium metaperiodate or
 13 peroxybenzoic acid was converted to dimethylphosphorylmethyl phenyl
 14 sulfoxide (5). Sequential treatment of either 4 or 5 with n-butyl-
 15 lithium at -30° and -70° , respectively, and then with a dry tetra-
 16 hydrofuran solution of 2,4-O-ethylidene-D-erythrose (2), furnished
 17 olefins 8 and 9, typically in 70-90% yields. Although the formation
 18 of E and Z isomers was possible for both 7 and 8, no effort was
 19 made to separate them since any mixture of geometric isomers was
 20 suitable for the next step of the synthesis. However, a qualitative
 21 assessment of the isomeric (E/Z) composition was determined by
 fn 13,14 2 ¹H-NMR. Use was made of the established^{13,14} coupling constant for
 23 the trans-vicinal protons in similar systems of 15-16 Hz, whereas,
 24 the cis-vicinal protons evidence a coupling constant of 10-11 Hz.
 25 Further, there are well defined chemical shift differences for the
 26 E and Z isomers of similar thioenol ethers¹³ as well as α,β -unsatur-
 27 ated sulfoxides.¹⁴ Typically, the proton vicinal to the cite of

1 functionality appears at higher field for the E isomer of thioenol
2 ethers and at lower field for the E isomer of α,β -unsaturated
3 sulfoxides. We noted a similar trend, that is, the chemical shift
4 differences were on the order of 0.20 to 0.40 ppm between the E and
5 Z isomers and the respective coupling constants were approximately
6 15-16 Hz and 10-11 Hz. Utilizing these data as well as the tables
fn 15 7 of chemical shifts for olefinic substituents,¹⁵ we determined that
8 the E isomer was in excess by at least a 2/1 ratio.

9 Although n-butyllithium proved to be a convenient base, we also
10 assayed a variety of other reagents and conditions for ylide
fn 16,17 11 generation. For example, there have been several reports^{16,17,18}
18 12 describing the utility of phase transfer catalysts for ylide
13 formation. These were applied in attempted ylide formation from 2.
14 With a large variety of phase transfer catalysts, ylide formation
15 did not proceed significantly with our substrates. Variations in
16 solvent, temperature, and time as well as base all resulted in
17 essentially no reaction. Also, addition of a mixture of 18-crown-6,
18 either catalytically or stoichiometrically, and potassium-t-butoxide
19 in tetrahydrofuran to a tetrahydrofuran solution of phosphonate 4 or
20 6 and the ethylidene erythrose 2, resulted in no detectable
21 reaction. Finally, alkoxide proved unsatisfactory (<10% yield);
22 however, lithium diisopropyl amide at -70°, and sodium hydride or
23 potassium hydride, both at -20°, all gave satisfactory results. All
24 of these procedures are inferior to ylide generation by addition of
25 n-butyllithium to either phosphonates 4 or 5 at -30° and -70°,
26 respectively.

1 Conversion of Thio-substituted Olefins to 2-Deoxy-D-ribose (1).

2 All that remained to complete the synthesis of 2-deoxy-D-ribose (1)
3 was the hydrolyses of thioenol ether 7 and α,β -unsaturated sulfoxide
4 8 (Scheme II). We found that treatment of thioenol ether 7 with
5 aqueous sulfuric acid did not afford 1 in satisfactory yields.
6 However, when the hydrolysis was conducted in a stepwise fashion, 1
7 was obtained in excellent yields. Treatment of 7 first with
8 mercuric chloride in acetonitrile-water, or alternatively with a
9 mercuric oxide-mercuric chloride mixture in acetonitrile-water
10 afforded, after mild aqueous acid hydrolysis, 2-deoxy-D-ribose (1)
11 in greater than 75% yield. The α,β -unsaturated sulfoxide 8 was
12 converted to 1 by exposure to aqueous sulfuric acid; however, this
13 conversion did not proceed as readily as the thioenol ether pro-
14 cedure and afforded 1 in about 30% yield from 8.

15 Alternate Synthesis of 2-Deoxy-D-ribose. Since 2, containing
16 a free hydroxyl group, had been successfully converted into 1, we
17 considered the possibility of converting D-erythrose (11) into 1. The
18 utility of such an alternate approach stems from the added flexi-
19 bility of performing the ylide addition in the absence of blocking
20 groups and would provide a model for olefination of underivatized
21 polyhydroxy aldehydes. Thus, hydrolysis of 2 with aqueous sulfuric
22 acid and subsequent treatment with the ylide 4y generated from
23 dimethylphosphorylmethyl phenyl sulfide (4) afforded the triol thio-
24 enol ether 12, which was not isolated but directly treated with a
25 mercuric oxide-mercuric chloride mixture in acetonitrile-water
26 (Scheme III). The resulting crude product was recrystallized from
27 isopropanol to afford colorless, crystalline 1 in greater than 45%
 yield.

1 In summary, we have described a convenient method for the
2 preparation of 2-deoxy-D-ribose (1) starting with D-glucose. Our
3 synthesis proceeds via monomeric 2,4-O-ethylidene-D-erythrose (2)
4 as a key intermediate, and affords enhanced overall yields and
5 simplified isolation.

fn 19

Experimental Section¹⁹

2 2,4-O-Ethylidene-D-erythrose was prepared from D-glucose via
 3 periodate oxidation of 4,6-O-ethylidene-D-glucose.⁴ Its properties
 4 were in agreement with those reported^{4,5,6} and established that the
 5 crystallized material was primarily dimer 3 with less than 5% of
 6 monomer 2. ¹H NMR (D₂O) δ 1.37 (d, CCH₃), 3.35-3.95 (m, OCH), 4.25
 7 (td, OCH₂), 4.75-5.50 (m, HO and O₂CH); ¹³C NMR (dioxane) δ 20.13
 8 (CH₃), 61.19 (CHOH, d in the off-resonance spectrum), 67.04, 67.88,
 9 68.32 (CH₂O, t in the off-resonance spectrum), 70.29, 71.50, 75.89,
 10 78.44, 80.59, 90.62, 91.68 (CHO), 95.85, 97.42, 100.23, 101.2
 11 [HC(CH₃)O₂]; IR 3435 (OH) cm⁻¹; mp 150-151° (lit.⁴ mp 149-150°);
 12 [α]_D²⁵ -36.2° (equilibrium, c 8.2, H₂O) [lit.⁴ [α]_D²⁰ -36.8°
 13 (equilibrium, c 8.25, H₂O)].

14 The dimer 3, prepared above was dissolved in ethyl acetate
 15 (20 mL/g) and several drops of glacial acetic acid or 100% phosphoric
 16 acid were added.¹⁰ The resulting solution was heated at 90° for
 17 20 min, after which it was quickly cooled to 25° and the ethyl
 18 acetate was evaporated at this temperature. The solid residue thus
 19 obtained was used without further treatment in the olefination
 20 reactions. Its properties indicated that it was primarily the
 21 monomeric 2,4-O-ethylidene-D-erythrose (2): ¹H NMR (D₂O) δ 1.25
 22 (d, CCH₃), 3.47-3.83 (m, OCH), 4.17 (dd, OCH₂), 4.86-5.28 (m, HO
 23 and O₂CH), 8.47 (s, CHO); ¹³C NMR (dioxane) δ 20.32 (CH₃), 62.09
 24 (CHOH, d in off-resonance spectrum), 70.21 (CH₂O, t in off-resonance
 25 spectrum), 82.65 (OCH, d in off-resonance spectrum), 89.0, 99.88
 26 (O₂CH, d in off-resonance spectrum), 171.45 (CHO, d in off-resonance
 27 spectrum); IR 3433 (OH), 1718 (C=O) cm⁻¹.

1 α -Chloromethyl Phenyl Sulfide. A solution of sulfuryl
2 chloride (0.21 mol, 28.4 g) in CH_2Cl_2 was slowly added over a 2 h
3 period to a heated (reflux) solution of methyl phenyl sulfide
4 (0.20 mol, 25 g) in CH_2Cl_2 . After addition was complete, the
5 mixture was heated at reflux for another hour and allowed to stand
6 at room temperature overnight. The major portion of the solvent
7 was evaporated and the residue distilled at reduced pressure: yield,
fn 20 8 92%; bp 110-115°C (20 mm) [lit.²⁰ bp 104°C (12 mm)]; NMR (CDCl_3)
9 δ 4.75 (s, ClCH_2), 7.25 ppm (m, C_6H_5).

10 Dimethylphosphorylmethyl Phenyl Sulfide (4). A mixture of
11 α -chloromethyl phenyl sulfide (41 g, 0.26 mol) and trimethyl
12 phosphite (4 mL/g of sulfide) was heated at 150-160°C for 36 h. The
13 reaction mixture was allowed to cool to room temperature and the
14 unreacted trimethyl phosphite was evaporated (40-50 mm) with heating.
15 The residue was then fractionally distilled through a 7 in. vigreux
16 column at high vacuum to afford a colorless liquid: yield, 83%;
17 bp 140-143°C (0.5 mm); NMR (CDCl_3) δ 3.5 [d, $\text{CH}_2\text{P}(\text{O})$], 3.71 [d,
18 $(\text{CH}_3\text{O})_2\text{P}$], 7.29 ppm (multiplet, C_6H_5).

19 Dimethylphosphorylmethyl Phenyl Sulfoxide (5). To a solution
20 of dimethylphosphorylmethyl phenyl sulfide (4, 23.2 g, 0.10 mol)
21 in acetone (130 mL) and water (70 mL), cooled to -5°C, was added
22 dropwise a solution of sodium metaperiodate (22.5 g, 0.11 mol, in
23 enough water to dissolve the periodate) over 1 h at -5 to 0°C. The
24 solution was stirred at 0°C for 4 hr and allowed to stand at 5°C
25 for 24 h, the precipitated sodium iodate was removed, and after
26 evaporation of the acetone, the solution was extracted with CHCl_3 .
27 Drying over magnesium sulfate and evaporating the CHCl_3 gave sulfoxide

5 as a liquid, which was purified by column chromatography on silica,
 eluting with $\text{CHCl}_3/\text{CH}_3\text{OH}$, 9/1: yield, 95%; NMR (CDCl_3) δ 3.29
 and 3.5 [AB part of an ABX system, $\text{CH}_2\text{P}(\text{O})$] 3.72 [overlapping
 doublets, $(\text{CH}_3\text{O}_2\text{P})$], 7.51 ppm (multiplet, C_6H_5).

fn 21

5 Phenylthiomethyltriphenylphosphonium Chloride (6).²¹ To
 6 triphenylphosphine (200 g, 0.76 mol) dissolved in benzene (400 mL)
 7 was added dropwise α -chloromethyl phenyl sulfide (122 g, 0.78 mol)
 8 with stirring at room temperature. After addition was complete,
 9 the mixture was heated at reflux with stirring for 10 days. Cooling
 10 to room temperature and standing gave the crystalline phosphonium
 11 salt 6 in 43% yield: mp 154-156°.

12 Thioenol Ether 7 via Phosphonate 4. To a tetrahydrofuran
 13 (12.5 mL) solution of dimethylphosphorylmethyl phenyl sulfide (4,
 14 2.32 g, 0.01 mol), cooled to -70°C , was added over 2 h a hexane
 15 solution of n-butyllithium (0.011 mol). The mixture was stirred
 16 for 1 hr at -70°C and additionally for 2 h at -40°C , then a tetra-
 17 hydrofuran (16 mL) solution of 2,4-O-ethylidene-D-erythrose (2,
 18 2g, 0.01 mol), prepared as described, was added dropwise to the
 19 mixture maintained at -40°C . After addition was complete, the
 20 contents were stirred at -40°C for 2 h, then allowed to slowly warm
 21 to room temperature and stirred at room temperature overnight. The
 22 residue after evaporation of the solvents was treated with water
 23 (25 mL) and extracted with CHCl_3 (5x15 mL) and the CHCl_3 was washed
 24 with water (15 mL), dried over magnesium sulfate and evaporated
 25 to afford thioenol ether 7 in 70-75% yield: NMR (CDCl_3) δ 1.37 (bd,
 26 CHCH_3), 3.52-4.31 [$\text{OCHCH}(\text{OH})\text{CH}_2\text{O}$], 4.75 (bqt, CH_3CH), 6.15 (d of d,
 27 $\text{C}_6\text{H}_5\text{SCHCH}$), 6.72 (d, $\text{C}_6\text{H}_5\text{SCHCH}$), 7.35 (m, C_6H_5); HRMS, calcd. for

1 $C_{13}H_{16}O_3S$ (M^+), 252.0815, found 252.0798.

2 α,β -Unsaturated Sulfoxide 8. To a dry tetrahydrofuran (20 mL)
3 solution of dimethylphosphorylmethyl phenyl sulfoxide (5, 2.48 g,
4 0.01 mol), cooled to -70°C , was slowly added over 3 h a hexane
5 solution of n-butyllithium (0.011 mol). The mixture was stirred
6 for 4 h at -70°C , after which a dry tetrahydrofuran (25 mL) solution
7 of 2,4-O-ethylidene-D-erythrose (2, 2 g, 0.01 mol) was added.
8 After addition was complete, the contents were stirred for 2 h at
9 -70°C , then allowed to slowly warm to room temperature and stirred
10 at room temperature overnight. The reaction mixture was treated
11 exactly as in the isolation of thioenol ether 7 and resulted in a
12 75-87% yield of α,β -unsaturated sulfoxide 8: NMR ($CDCl_3$) δ 1.35
13 (d of d, $CHCH_3$), 3.40-4.25 [m, $OCHCH(OH)CH_2O$], 4.80 (b q, CH_3CH),
14 6.55 [d, $S(O)CH$], 7.00 [d of d, $S(O)CHCH$], 7.55 (m, C_6H_5); HRMS,
15 calcd. for $C_{13}H_{16}O_4S$ (M^+), 236.0866, found 236.0861.

16 Thioenol Ether 7 via Phosphonium Salt 6. To a solution of
17 phenylthiomethyltriphenyl phosphonium chloride (6, 4.20 g, 0.01 mol)
18 in tetrahydrofuran (75 mL), cooled to -25°C , was added dropwise over
19 3 h a hexane solution of n-butyllithium (0.011 mol). Stirring was
20 continued for 2 h with the temperature maintained at -25°C , after
21 which a tetrahydrofuran (30 mL) solution of 2,4-O-ethylidene-D-
22 erythrose (2, 2 g, 0.01 mol) was slowly added over 2 h. The con-
23 tents were stirred an additional 2 h at 25°C , allowed to warm to
24 room temperature and stirred at room temperature overnight. The
25 reaction mixture was treated exactly as above and afforded a 27%
26 yield of thioenol ether 7, identical with material prepared from
27 phosphonate 4.

1 2,4-Ethylidene-D-erythritol (9) was prepared in 96% yield from
 2 3 in a similar fashion to that reported^{4,6} for the preparation of 9
 3 from 2: mp 100° (lit. mp 99.5-100.5°, ⁴ 98.5-100.5°⁶); $[\alpha]_D^{22}$ -54.3
 4 (c 2.0, H₂O) [lit. $[\alpha]_D^{24}$ -54.7 (c 2.0, H₂O)⁴, $[\alpha]_D^{25}$ -51.1 (c 0.67, H₂O)⁶].

5 2-Deoxy-D-erythro-pentose (2-Deoxy-D-ribose, 1). Procedure A.

6 To a solution of thioenol ether (7, 1 g, 3.96 mmol) in acetonitrile/
 7 water (3/1, 35 mL) was added a solution of mercuric chloride
 8 (2.14 g, 7.92 mmol) in acetonitrile/water (4/1, 35 mL) and the
 9 resulting cloudy mixture was stirred at 50°C for 30 h. The mixture
 10 was filtered through Celite, the insoluble portion was washed
 11 thoroughly with warm pyridine, and the filtrate was evaporated to
 12 a crude residue which was treated with trifluoroacetic acid (0.01M,
 13 10 mL) at 6°C for 36 h. The remaining acid was removed by repeated
 14 azeotropic distillation with water at reduced pressure, and the
 15 residue, upon recrystallization from isopropanol, afforded colorless,
 fn 22 16 crystalline 1 in 92% yield: mp 92-94° (lit. mp 95-98°, ¹ 96-98°²²);
 17 $[\alpha]_D^{25}$ -57.2° (c 0.5, H₂O) [lit. $[\alpha]_D^{20}$ -57.6° (c 1.1, H₂O)¹, -58°
 fn 23 18 (c 1.6, H₂O)²²]; ¹H and ¹³C NMR identical to those reported.^{3,23}

19 Procedure B. To a solution of thioenol ether (7, 1 g, 3.96
 20 mmol) in acetonitrile/water (4/1, 50 mL) was added with stirring
 21 a mixture of yellow mercuric oxide (1.07 g, 3.46 mmol) and mercuric
 22 chloride (0.86 g, 3.96 mmol). The contents were heated to 35°C for
 23 16 hr, cooled to room temperature, and the product was isolated
 24 exactly as in procedure A. The yield of pure 2-deoxy-D-ribose (1)
 25 was 88%.

26 Procedure C. via D-Erythrose (11). To a vigorously stirred
 27 solution of D-erythrose (11, 120 mg, 1 mmol, prepared as described⁴)

1 in DMF (15 mL) or in DMSO (15 mL) at -40° was added dropwise a
2 THF solution, also at -40° , of the ylide 4y [prepared by the
3 addition of n-butyllithium (2 mmol, in hexane) to a THF solution
4 (7 mL) of dimethylphosphorylmethyl phenyl sulfide (4, 0.46 g, 2 mmol)].
5 After addition was completed, the mixture was stirred for 2 h at -40° ,
6 allowed to warm to 20° , and stirred at 20° overnight. The mixture
7 was concentrated and treated with mercuric chloride, and the product was
8 isolated as described in Procedure A, affording crystalline 1 in
9 45% yield.

10
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27

Scheme I. Reaction of 2,4-O-Ethylidene-D-erythrose (2) with
Various Ylides 4y, 5y and 6y.

Scheme II. Conversion of Thioenol Ether 7 to 2-Deoxy-D-ribose (1).

Scheme III. Conversion of 2,4-O-Ethylidene-D-erythrose (2) to 2-Deoxy-D-ribose (1) via D-Erythrose (11).

2

II

4y

12

I

Figure 1. The ^{13}C NMR spectrum of 2,4-O-ethylidene-D-erythrose dimer (3).

Figure 2. The ^1H NMR spectrum of 2,4-O-ethylidene-D-erythrose dimer (3) in D_2O (external TMS).

3

Figure 3. The ^{13}C NMR spectrum of 2,4-O-ethylidene-D-erythrose
(2) resulting from acid-ethyl acetate treatment.

Figure 4. The ^1H NMR spectrum at 180 MHz in D_2O of 2,4-O-ethylidene-D-erythrose (2) resulting from acid-ethyl acetate treatment.

Figure 5. The ^{13}C NMR spectrum of 2,4-O-ethylidene-D-erythritol (9).

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