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Note

Synthesis of 2-deoxy-1- and -6-thio-D-*arabino*-hexose and several *S*-dialkylarsino derivatives

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Compounds of the type $GXAsR_2$, where G is a conventional metabolite or analog and X is sulfur or selenium, have been prepared in these laboratories[1–4] and 22 have been found active in the P-388 *in vitro* test-system of the National Cancer Institute. Group G is intended to be a carrier for the dialkylarsino group to the physiological site of action. Group G has been varied to include such components as thioamino acids, thiocholesterol, thio- and seleno-purines, pyrimidines, and monosaccharides. The thio compounds have consistently shown higher levels of activity than the seleno analogs. Protected-sugar derivatives have afforded compounds having greater carcinostatic activity than those containing free sugars. As-Methyl substituents have been used in most of the compounds thus far prepared; other R groups, such as ethyl, propyl, (2-hydroxyethyl)methyl, and di(hexadecyl), have afforded compounds having acceptable levels of activity. The mode of action of these compounds seems to be related to their ability to react with thiol groups. It is well known that arsenic reacts with thiols in biological systems and inactivates them for normal biochemical functions. As thiol levels increase, especially in rapidly growing tissues, it is not unreasonable to assume that thiols are the target of these arsenicals.

The work reported here was undertaken to obtain additional information on the effect, on carcinostatic activity, of changing the monosaccharide group as well as the organic substituent on the arsenic atom. Synthetic routes to 3,4,6-tri-*O*-benzoyl-2-deoxy-1-thio-β-D-*arabino*-hexopyranose and 1,3,4-tri-*O*-acetyl-2-deoxy-6-thio-β-D-*arabino*-hexopyranose have been established and several dialkylarsino derivatives have been synthesized. Preliminary results of screening tests in the P-388 test-system are also reported.

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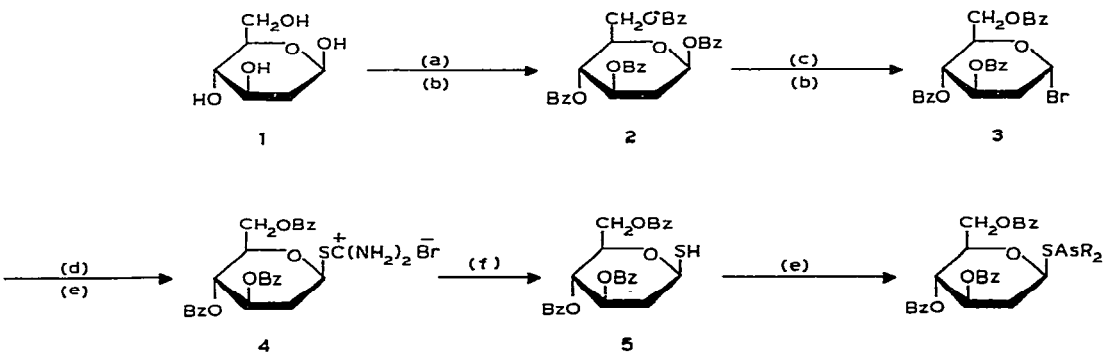
DISCUSSION

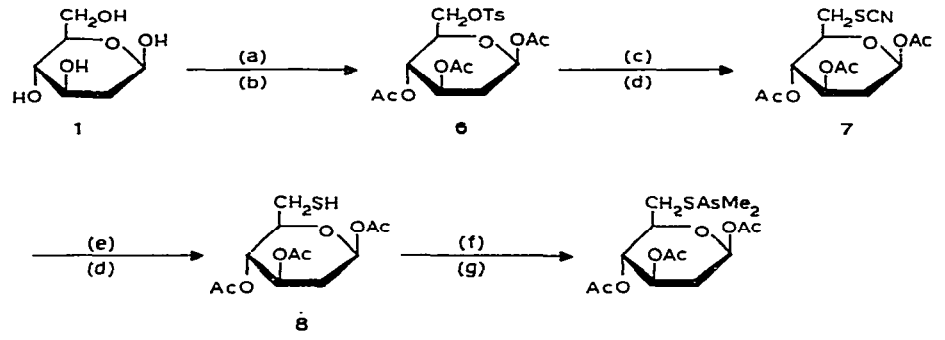
Scheme I depicts the route to 2-deoxy-1-thio-D-*arabino*-hexose and the corresponding dialkylarsino derivatives. Because 2-deoxy-D-*arabino*-hexose and its derivatives are acid-labile, the benzoyl protecting-group was used. The procedure of Bergmann *et al.*[5] was used, but at a lower temperature (0°) throughout the addition of benzoyl chloride. The tetrabenzoate (**2**) was obtained as an anomeric mixture, with the β anomer predominating. Comparison of the chemical-shift data for **2** with those reported for D-glucose[6], 2-deoxy-D-*arabino*-hexose[7], and peracetylated glucose derivatives[4,8], indicates that **2** favors the anticipated $^4C_1$ conformation. One of the H-1 signals showed $J_{1,2}$ coupling of >6.5 Hz, indicative of the β anomer. The H-2 resonances are observed as broad multiplets having values within δ 2–3. The resonances observed for the other ring-protons compare closely with those reported for the glucose analogs[4,8]. For the benzoyl groups, two sets of resonances are observed, at δ 8.0 and 7.15. The tetrabenzoate was converted into the α-bromide **3** as described by Zorbach and Payne[9], with hydrogen bromide (49%) in dichloromethane at <5°. The tetrabenzoate was isolated as yellow, hygroscopic crystals that are quite unstable when exposed to air. The H-1 resonance of **3** is observed at δ 5.1, indicative* of the α-anomeric configuration[7], as favored by the anomeric effect. Compound **3** reacted with thiourea to give the pseudothioureide (**4**), characterized by its ^{13}C-n.m.r. spectrum which shows a resonance at 171.4 p.p.m. downfield from signals of the carbonyl groups in the molecule. Conversion of **4** into the thiol by treatment with potassium carbonate caused this resonance to disappear. The product, 3,4,6-tri-*O*-



(a) BzCl
(b) CH_2Cl_2
(c) HBr
(d) $SC(NH_2)_2$
(e) Me_2CO
(f) $NaHCO_3$
(g) R_2AsI

Scheme 1

*Assignment of the α-anomeric configuration is not incontrovertible and is subject to confirmation.



(a) TsCl
(b) Ac_2O
(c) KSCN
(d) $HCONMe_2$
(e) $NaBH_4$
(f) Me_2AsI
(g) CH_2Cl_2

Scheme II

benzoyl-2-deoxy-1-thio-β-D-*arabino*-hexopyranose (**5**), was obtained in 72.5% yield. The ^{1}H-n.m.r. spectrum of **5** shows a resonance at δ 5.7 for the anomeric proton, shifted upfield from H-1 of the tetrabenzoate; it had $J_{1,2}$ coupling of 6.8 Hz, also indicative of the β configuration.

Several dialkylarsino derivatives of 2-deoxy-1-thio-D-*arabino*-hexose tribenzoate were synthesized by methods analogous to those used for the glucose derivatives[4,8]. The products, which were hygroscopic, low-melting solids, were shown from their ^{1}H-n.m.r. spectra to retain the β configuration. The resonances for the alkyl protons were readily assigned; in all cases it was found that the methyl or methylene groups are shifted upfield when they are bonded directly to arsenic[4]. Scheme II outlines the synthesis of 1,3,4-tri-*O*-acetyl-2-deoxy-6-thio-β-D-*arabino*-hexopyranose and its dimethylarsino derivative.

2-Deoxy-D-*arabino*-hexose (**1**) was converted into the 6-*O*-tosyl triacetate (**6**) by the method used for the glucose analog[10]. The product was obtained as an anomeric mixture, and separation of the β anomer was accomplished by recrystallization from abs. ethanol. This compound was then treated with potassium thiocyanate[11] in *N*,*N*-dimethylformamide. The ^{1}H-n.m.r. spectral data show an H-1 resonance at δ 5.6 with a coupling constant of 6.9 Hz. All other ring-resonances were shifted slightly downfield as compared with values observed for the 2-deoxy-1-thio-D-*arabino*-hexose tribenzoates. The ^{13}C-n.m.r. spectrum of this compound displays resonances that can be assigned to the several, ring carbon atoms by comparison with literature values[12] and with those obtained from the 2-deoxy-1-thio-D-*arabino*-hexose derivatives. The resonance for the thiocyanate carbon atom appears at 145.1 p.p.m., well-isolated from all other resonances. This fact was helpful in assessing the formation of the compound and the subsequent removal of the cyano group to obtain the thiol. This was accomplished by reduction with sodium borohydride in *N*,*N*-dimethyl-

formamide. It is essential to avoid higher than stoichiometric amounts of sodium borohydride in the reduction, as this results in loss of the protective groups. The thiol (**8**) was obtained as the β-anomer as revealed by the H-1 shift at δ 5.7 and $J_{1,2}$ of 6.9 Hz. A slight upfield shift of the C-6 protons of this compound is observed, compared with the *p*-toluenesulfonate and the thiocyanate, probably because of decreased electronegativity of the substituent group. The same effect is observed on the ^{13}C chemical shift for C-6. The dimethylarsino derivative was prepared conventionally[4,8].

Mass spectroscopy was also used for characterization. With the 2-deoxy-1-thio-D-*arabino*-hexose benzoates, thermal fragmentation resulted in loss of the heavier ions, especially the molecular ion, but it is possible to outline a fragmentation process from the data observed. The first step in the breakdown of the molecular ion involves cleavage of the C–S bond, yielding the thiodialkylarsino fragment, which is observed in all instances, and the pyranosyl cation. The breakdown of the latter then proceeds according to the previously described *A* process[13] and its variations, as reported for the glucose analogs[4,8]. 1,3,4-Tri-*O*-benzoyl-2-deoxy-6-*S*-dimethylarsino-6-thio-β-D-*arabino*-hexopyranose undergoes a fragmentation which parallels that observed for the 1-substituted derivatives.

Of the compounds prepared in this study, only 3,4,6-tri-*O*-benzoyl-2-deoxy-1-*S*-(2-hydroxyethyl)methylarsino-1-thio-β-D-*arabino*-hexopyranose displayed activity *in vivo* in the P-388 test system. The T/C value was 127 at a dose of 100 mg/kg body weight. It appears that the deoxy sugar derivatives are not as active as the glucose analogs.

EXPERIMENTAL

Materials. — 2-Deoxy-D-*arabino*-hexose was purchased from Sigma Chemical Co. Thiourea, reagent grade, was obtained from Matheson, Coleman and Bell Chemicals, and potassium thiocyanate from Fisher Scientific Co. Acetic anhydride (Fisher) was stored over molecular sieve. Benzoyl chloride (Eastman Kodak Co.) was used without further treatment. Pyridine (Fisher) was dried over sodium hydroxide pellets, distilled over phosphorus pentaoxide, and stored over molecular sieve. All solvents used were reagent grade and were dried and distilled as required. Dialkyl arsines were prepared by conventional methods[4,8].

General methods. — Solvents were evaporated with a Büchi Rotavapor-R under diminished pressure at various bath temperatures. Melting points were determined with a Büchi-SMP-20 melting-point apparatus and are not corrected. The ^1H-n.m.r. spectra were recorded at 60 MHz with a Varian T-60 instrument. All spectra were measured relative to tetramethylsilane. Chemical shifts are given in p.p.m. on the δ scale. The solvent was $CDCl_3$ and 5-mm (o.d.) Wilmad sample tubes were used. The ^{13}C spectra were recorded by Steven N. Rosenthal, Chemistry Department, Texas A & M University with a Jeol PS-100 PFT spectrometer equipped with a Nicolet 1080 computer and disc. The natural-abundance ^{13}C-n.m.r. spectra

were obtained at 25.03 MHz in the Fourier-transform mode and at a magnetic field-strength of 23 Kg. All spectra were proton-decoupled. Mass spectra were recorded in Dr. R. Grigsby's laboratory, Biochemistry Department, Texas A & M University. A DuPont CEC 21-110 high-resolution spectrometer operating at an ionizing potential of 70 eV and ion current of 200 μA was used. The accelerating potential was 8 kV. Carbon and hydrogen analyses were performed by Galbraith Analytical Laboratories, Inc., Knoxville, TN.

*Preparation of 3,4,6-tri-*O*-benzoyl-2-deoxy-1-thio-β-*D*-*arabino*-hexopyranose and its derivatives. — 1,3,4,6-Tetra-*O*-benzoyl-2-deoxy-β-*D*-glucopyranose* (**2**). Compound **2** was prepared by a modification of the method described by Bergmann *et al.*[5] 2-Deoxy-D-*arabino*-hexose (1 g) was suspended in dry pyridine (2.9 g) and kept in an ice bath. While cooling and stirring, 4.3 g of benzoyl chloride dissolved in chloroform (10 mL) was added dropwise to the mixture, which was kept at 0–2°. The resulting yellow solution was then stirred for an additional 15 min and then refrigerated for 24 h. Diethyl ether (20 mL) was then added and the flask was vigorously shaken for 0.5 h. Crystals formed upon standing, that were separated by filtration, rinsed with ether, and dried under vacuum. The crude material was an anomeric mixture that melted over the range 125–142°. Successive recrystallizations from diethyl ether gave the two anomers in overall yield of 87%; the α anomer had m.p. ~125°, and the β, 145°, in agreement with previously reported values[5]; ^{1}H-n.m.r.: δ 6.3 (d, 1 H, H-1β), 2.7 (m, 2 H, H-2), 4.6–3.8 (m, 3 H, H-3,4,5), 2.9 (m, 2 H, H-6), and 8.0 and 7.4 (m, 5 and 15 H, Bz); ^{13}C-n.m.r.: δ 166.0, 165.6, 165.4, 164.4 (C=O), 130.0–127.0 (Bz), 91.7 (C-1), 34.8 (C-2), 70.9 (C-3), 69.2 (C-4), 73.0 (C-5), and 63.2 (C-6).

*3,4,6-Tri-*O*-benzoyl-2-deoxy-α-*D*-arabino-hexopyranosyl boromide* (**3**). The tetrabenzoate **2** (2 g) was dissolved in dichloromethane (50 mL) and the flask was placed in an ice bath. To this solution was added 49% hydrobromic acid (15 mL) dropwise at a low rate so as to maintain the temperature at 0–5°. The two-phase system was separated; the aqueous layer was rinsed with dichloromethane, the organic fractions combined and, after drying over molecular sieve, the solvent was removed. The product, a yellow, hygroscopic syrup, was not very stable and it was found best to proceed directly to the next step from the crude bromide. The yield of crude product was 95%; ^{1}H-n.m.r.: δ 5.1 (d, 1 H, H-1), 2.6 (m, 2 H, H-2), 4.5–3.6 (m, 3 H, H-3,4,5). 2.9 (m, 2 H, H-6), and 8.0 and 7.4 (m, 15 H, Bz).

*(3,4,6-Tri-*O*-benzoyl-2-deoxy-1-thioureido-β-*D*-arabino-hexopyranosyl)pseudothiourea hydrobromide* (**4**). To the bromide **3** (1.5 g) dissolved in dry acetone (20 mL) was added 0.5 g of recrystallized thiourea. The mixture was boiled for 1 h under reflux, the solvent was then removed, and the resulting yellow syrup dried to give crystals, m.p. 175°. Recrystallization from 1-propanol afforded a product melting at 192.5°; yield 95%; ^{13}C-n.m.r.: δ 166.1, 166.3, 165.1 (C=O), 130.0–126.9 (Bz), 93.0 (C-1), 30.3 (C-2), 71.4 (C-3), 69.0 (C-4), 75.8 (C-5), 63.4 (C-6), and 171.4 [-$SC(NH_2)_2Br$].

*3,4,6-Tri-*O*-benzoyl-2-deoxy-1-thio-β-*D*-arabino-hexopyranose* (**5**). The crude thioureide **4** was converted quantitatively into the thiol **5** by treating 1.2 g of **4**,

suspended in water, with 10 mL of a saturated solution of potassium carbonate in water. After stirring for 0.5 h at room temperature the mixture was extracted with dichloromethane. Removal of the solvent and drying gave fine, yellow needles of product formed having m.p. 71.5°; yield 72.5%; ^{1}H-n.m.r.: δ 5.7 (d, 1 H, H-1), 2.3 (m, 2 H, H-2), 4.3 (m, 1 H, H-3), 3.7 (m, 1 H, H-4), 4.8 (m, 1 H, H-5), 2.7 (m, 2 H, H-6), 8.0 and 7.5 (m, 15 H, Bz), and 1.4 (s, 1 H, SH); ^{13}C-n.m.r.: δ 165.8 165.2, 164.8 (C=O), 132.8–126.6 (Bz), 93.1 (C-1), 29.8 (C-2), 70.6 (C-3), 68.8 (C-4), 74.0 (C-5), and 63.1 (C-6).

Anal. Calc. for $C_{27}H_{24}O_7S$: C, 65.84; H, 4.91. Found: C, 65.93; H, 5.11.

*3,4,6-Tri-*O*-benzyl-2-deoxy-1-*S*-dibutylarsino-1-thio-β-*D*-*arabino*-hexopyranose.* A solution of 3,4,6-tri-*O*-benzoyl-2-deoxy-1-thio-β-D-*arabino*-hexopyranose (7.3 g, 2 mmol) in chloroform (100 mL) was treated with 5 ml (~2 mmol) of dibutyliodarsine. Pyridine was added to maintain the pH at 7. The mixture was boiled for 1 h under reflux, cooled, and filtered through Celite. Evaporation of the solvent gave hygroscopic crystals having m.p. 45°; yield 90%; ^{1}H-n.m.r.: δ 5.7 (m, 2 H, H-6), 2.3 (m, 2 H, H-2), 4.0 (m, 1 H, H-3), 3.7 (m, 1 H, H-4), 4.8 (m, 1 H, H-5), 2.7 (m, 2 H, H-6)*, 8.1 and 7.5 (m, 15 H, Bz), 1.6 (m, 4 H, CH_2-As), 2.0 (m, 8 H, CH_2), and 1.15 (t, 6 H, CH_3); ^{13}C-n.m.r.: δ 166.4, 165.9 (C=O), 133.4–128.2 (Bz), 91.7 (C-1), 35.8 (C-2), 70.0 (C-3), 68.3 (C-4), 75.4 (C-5), 63.1 (C-6), 24.3 (CH_2-As), 29.5 (-CH_2-), and 13.7 (CH_3).

Anal. Calc. for $C_{35}H_{42}AsO_7S$: C, 61.75; H, 6.01. Found: C, 61.88; H, 6.19.

*3,4,6-Tri-*O*-benzoyl-2-deoxy-1-*S*-dipropylarsino-1-thio-β-*D*-*arabino*-hexopyranose.* 3,4,6-Tri-*O*-benzoyl-2-deoxy-1-thio-β-D-*arabino*-hexopyranose (4 g, 11 mmol) was dissolved in dichloromethane and the solution heated to boiling. Iododipropylarsine (1.5 mL, 10 mmol) was then added. The pH was adjusted to 7 by the addition of pyridine, and the mixture was boiled under reflux for 45 min. It was then cooled to room temperature and filtered through Celite. The solvent was removed to give a yellow syrup that solidified *in vacuo*. The crystals were hygroscopic and had m.p. 51.5°; yield 95%; ^{1}H-n.m.r.: δ 5.5 (m, 1 H, H-1), 2.4 (m, 2 H, H-2), 3.8 (m, 1 H, H-3), 3.4 (m, 1 H, H-4), 4.7 (m, 1 H, H-5), 2.7 (m, 2 H, H-6), 8.0 and 7.2 (m, 15 H, Bz), 2.1 (q, 4 H, CH_2-As), and 1.4 (t, 6 H, CH_3); ^{13}C-n.m.r.: δ 171.3–166.4 (C=O), 133.4–127.1 (Bz), 91.3 (C-1), 35.4 (C-2), 70.1 (C-3), 69.4 (C-4), 74.3 (C-5), 63.6 (C-6), 22.0 (CH_2As), and 11.7 (CH_3).

Anal. Calc. for $C_{31}H_{33}AsO_7$: C, 59.61; H, 5.32. Found: C, 59.61; H, 5.34.

*3,4,6-Tri-*O*-benzoyl-2-deoxy-1-*S*-dimethylarsino-1-thio-β-*D*-*arabino*-hexopyranose.* A solution of 3,4,6-tri-*O*-benzoyl-2-deoxy-1-thio-β-D-*arabino*-hexopyranose (3.8 g, ~10 mmol) in dichloromethane (150 mL) was heated to boiling and iododimethylarsine (1.2 mL, 10 mmol) was added. Pyridine was then added until the pH

*Although this resonance is further upfield from that usually observed for C-6 protons, it is not unreasonable. All other ring-protons could be assigned with considerable confidence, and the relative locations and intensities of these proton resonances are reasonable. Absolute assignments will depend on deuterium-labeling experiments.

reached 7. The mixture was boiled under reflux for 1 h and then cooled, filtered through Celite, and the solvent evaporated off. The resulting syrup crystallized upon being kept; m.p. ~44°, yield 90%; ^{1}H-n.m.r.: δ 5.6 (d, 1 H, H-1), 2.3 (m, 2 H, H-2), 3.7 (m, 1 H, H-3), 3.4 (m, 1 H, H-4), 4.4 (m, 1 H, H-5), 2.6 (m, 2 H, H-6), 7.9 and 7.3 (m, 15 H, Bz), and 1.15 (s, 6 H, CH_3); ^{13}C-n.m.r.: δ 171.0–166.8 (C=O), 133.4–128.3 (Bz), 91.7 (C-1), 35.5 (C-2), 70.3 (C-3), 69.5 (C-4), 74.1 (C-5), 63.5 (C-6), and 15.3 (CH_3).

Anal. Calc. for $C_{29}H_{29}AsO_7S$: C, 58.39; H, 4.89. Found: C, 58.41; H, 5.02.

*3,4,6-Tri-*O*-benzoyl-2-deoxy-1-*S*-(2-hydroxyethyl)methylarsino-1-thio-β-*D*-arabino-hexopyranose.* 3,4,5-Tri-*O*-benzoyl-2-deoxy-1-thio-β-D-*arabino*-hexopyranose (5 g, ~20 mmol) was dissolved in dichloromethane (100 mL) and (2-hydroxyethyl)iodomethylarsine (4 mL, ~20 mmol) was added. This was followed by the addition of diethylamine until the pH reached 7. The mixture was boiled under reflux for 1 h, allowed to cool, and filtered through Celite. Evaporation of the filtrate gave hygroscopic, yellow crystals, m.p. 51°; yield 90%; ^{1}H-n.m.r.: δ 5.7 (m, 1 H, H-1), 2.3 (m, 2 H, H-2), 3.8 (m, 1 H, H-3), 3.6 (m, 1 H, H-4), 4.9 (m, 1 H, H-5), 2.6 (m, 2 H, H-6), 8.2 and 7.5 (m, 15 H, Bz), 2.0 (m, 2 H, CH_2As), 4.2 (m, 2 H, CH_2OH), and 1.7 (s, 3 H, CH_3); ^{13}C-n.m.r.: δ 171.3–166.8 (C=O), 133.5–128.4 (Bz), 91.3 (C-1), 35.3 (C-2), 70.0 (C-3), 69.7 (C-4), 74.8 (C-5), 63.7 (C-6), 24.7 (CH_2As), 41.7 (CH_2OH), and 13.0 (CH_3).

Anal. Calc. for $C_{30}H_{31}AsO_8S$: C, 57.51; H, 4.98. Found: C, 57.62; H, 5.01.

*Preparation of 1,3,4-tri-*O*-acetyl-2-deoxy-6-thio-β-*D*-arabino-hexopyranose and its derivatives. — 1,3,4-Tri-*O*-acetyl-2-deoxy-6-*O*-tosyl-β-*D*-arabino-hexopyranose* (**6**). To prepare this compound, 3.28 g (20 mmol) of 2-deoxy-D-*arabino*-hexose was dissolved in dry pyridine (50 mL) and 3.81 g (20 mmol) of *p*-toluenesulfonyl chloride was added. The mixture was stirred for 24 h at ~25° and then acetic anhydride (6.6 mL, 60 mmol) was added. The temperature of the mixture increased slightly upon addition of the latter reagent. The solvent was removed immediately following addition of the acetic anhydride. A light-brown syrup separated. Abs. ethanol was added and the solution was kept in a freezer. After 3 days, a light-yellow solid separated that was rinsed with cold ethanol and dried; m.p. 101.5°; ^{1}H-n.m.r. and t.l.c. data indicated it to be an anomeric mixture. Successive recrystallizations from ethanol separated the two anomers; m.p. 105° (β) and 109.5° (α). The yield of β anomer was about 3 times that of the α. ^{1}H-n.m.r. data: δ 5.8 (m, 1 H, H-1), 2.3 (m, 2 H, H-2), 4.3 (m, 1 H, H-3), 3.7 (m, 1 H, H-4), 5.0 (m, 1 H, H-5), 2.8 (m, 2 H, H-6), 2.1–2.05 (m, 9 H, OAc), and 7.8 (m, 5 H, Ts); ^{13}C-n.m.r.: δ 170.0–168.7 (C=O), 91.5 (C-1), 35.3 (C-2), 70.0 (C-3), 68.0 (C-4), 72.2 (C-5), 66.8 (C-6), 20.5 (OAc), 132.5 (CH of Ts), and 21.7 (CH_3 of Ts).

*1,3,4-Tri-*O*-acetyl-2,6-dideoxy-6-thiocyanato-β-*D*-arabino-hexopyranose* (**7**). The β anomer of compound **6** (2.5 g, 5 mmol) was dissolved in 300 mL of dried and redistilled *N,N*-dimethylformamide. Potassium thiocyanate (5 g, 5 mmol) was added and the mixture was boiled for 24 h under reflux. Upon heating, the transparent mixture became dark brown. The mixture was filtered and the solvent removed to

give a dark-brown syrup that was redissolved in chloroform, treated with activated charcoal, and filtered through Celite. The solution was then rinsed with water several times until a light-yellow solution was obtained. The solvent was removed to give 7 as yellow crystals; m.p. 97.5°; yield 45–50%; ^{1}H-n.m.r.: δ 5.6 (m, 1 H, H-1), 2.4 (m, 2 H, H-2), 4.3 (m, 1 H, H-3), 3.8 (m, 1 H, H-4), 4.9 (m, 1 H, H-5), 2.8 (m, 2 H, H-6), and 2.1–2.0 (m, 9 H, OAc); ^{13}C-n.m.r.: δ 169.8–168.5 (C=O), 90.8 (C-1), 35.8 (C-2), 71.0 (C-3), 69.6 (C-4), 73.9 (C-5), 66.5 (C-6), 20.7 (OAc), and 145.1 (SCN).

Anal. Calc. for $C_{13}H_{17}NO_7S$: C, 47.18; H, 5.17; S, 9.68. Found: C, 48.62; H, 5.50; S, 8.46.

*1,3,4-Tri-*O*-acetyl-2-deoxy-6-thio-β-*D-arabino-*hexopyranose* (**8**). This compound was prepared by dissolving 2 g (~6 mmol) of compound 7 in 50 mL of *N,N*-dimethylformamide. Sodium borohydride (0.227 g, ~6 mmol) was added and the mixture was stirred for 8 h at room temperature. The solvent was evaporated off and the resulting syrup dissolved in chloroform. The solution was treated with activated charcoal and filtered through a mixture of Celite, silica gel, and silicic acid. The solvent was removed to give yellow crystals; m.p. 70.5°; yield 50%; ^{1}H-n.m.r.: δ 5.7 (m, 1 H, H-1), 2.4 (m, 2 H, H-2), 4.2 (m, 1 H, H-3), 3.8 (m, 1 H, H-4), 5.0 (m, 1 H, H-5), 2.6 (m, 2 H, H-6), 2.1–2.0 (m, 9 H, OAc), and 1.0 (s, 1 H, SH); ^{13}C-n.m.r.: δ 169.8 (C=O), 90.6 (C-1), 33.2 (C-2), 74.9 (C-3), 68.3 (C-4), 75.7 (C-5), 64.9 (C-6), and 21.0 (OAc).

Anal. Calc. for $C_{12}H_{18}SO_7$: C, 47.05; H, 5.92. Found: C, 47.30; H, 6.01.

*1,3,4-Tri-*O*-acetyl-2-deoxy-6-*S*-dimethylarsino-6-thio-β-*D-arabino-*hexopyranose*. This compound was prepared by dissolving 3.4 g (~1 mmol) of 1,3,4-tri-*O*-acetyl-2-deoxy-6-thio-β-D-*arabino*-hexopyranose in toluene (100 mL). Iododimethylarsine (1.5 mL, ~1 mmol) was added, followed by pyridine until the pH reached 7. The mixture was boiled for 1 h under reflux, allowed to cool, filtered, and the filtrate evaporated. The resultant, impure crystals were redissolved in dichloromethane and purified by column chromatography (silica gel, dichloromethane). The crystals obtained were hygroscopic and melted at 48°; yield 65%; ^{1}H-n.m.r.: δ 5.6 (m, 1 H, H-1), 2.5 (m, 2 H, H-2), 4.1 (m, 1 H, H-3), 3.7 (m, 1 H, H-4), 4.9 (m, 1 H, H-5), 2.8 (m, 2 H, H-6), 2.0–1.7 (m, 9 H, OAc), and 1.8 (s, 6 H, CH_3); ^{13}C-n.m.r.: δ 169.6–168.4 (C=O), 90.8 (C-1), 34.4 (C-2), 70.9 (C-3), 67.6 (C-4), 72.0 (C-5), 66.0 (C-6), 20.7 (OAc), and 15.8 (CH_3).

Anal. Calc. for $C_{14}H_{23}AsO_7S$: C, 40.98; H, 5.68. Found: C, 40.89; H, 5.68.

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