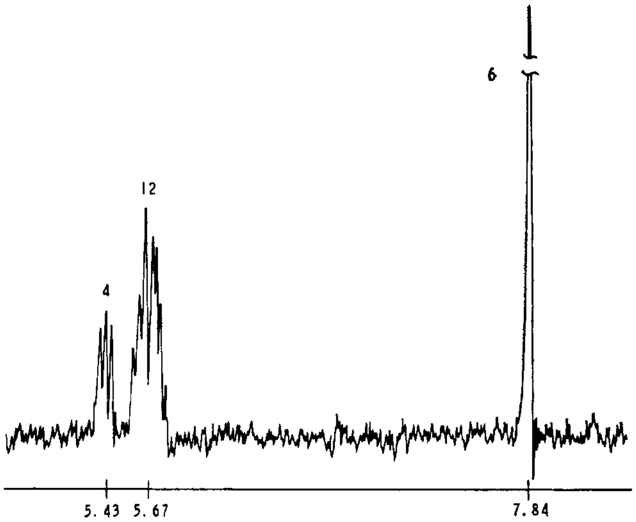
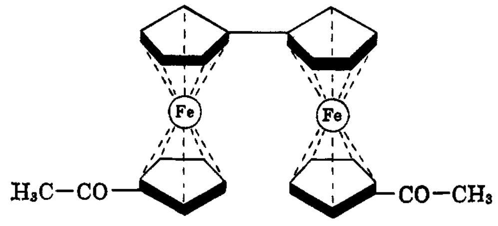


Fig. 2.—Proton n.m.r. spectrum of diacetylbiferrocenyl V.



V

Merck alumina. Elution with ether rapidly removed a broad yellow band from which 1.13 g. of an orange solid was obtained. Recrystallization of the solid produced 0.95 g. of biferrocenyl, m.p. 237–239° (nitrogen). The n.m.r. spectrum of this product exhibited a triplet at τ 5.65 due to four protons, a triplet at 5.83 due to four protons, and a singlet at 6.02 due to ten protons.[9] The n.m.r. and infrared spectra of biferrocenyl obtained from this reaction were identical with the corresponding spectra of an authentic sample. Continued elution with ether removed a faint yellow band; the latter yielded 8 mg. of red crystals, m.p. 83–85°. A mixture melting point determination of this product with acetylferrocene (m.p. 85–86°)[17] was undepressed, and the n.m.r. spectrum of the product was identical with the n.m.r. spectrum of acetylferrocene. Elution with ether next removed a faint red band. There was obtained 23 mg. of an orange solid, m.p. 153–158°. Recrystallization of the solid from *n*-heptane produced 15 mg. (1%) of acetylbiferrocenyl III, m.p. 158–159°.

Anal. Calcd. for $C_{22}H_{20}Fe_2O$: C, 64.12; H, 4.89; mol. wt., 412. Found: C, 63.96; H, 5.11; mol. wt., 417.

Elution of the final band produced 290 mg. (14%) of acetylbiferrocenyl II in the form of red crystals, m.p. 140–141°. Recrystallization of the product raised the melting point to 143°.

Anal. Calcd. for $C_{22}H_{20}Fe_2O$: C, 64.12; H, 4.89; Fe, 27.10; mol. wt., 412. Found: C, 64.04; H, 4.89; Fe, 27.34; mol. wt., 417.

Diacetylation of Biferrocenyl.—A solution of biferrocenyl (1.0 mmole, 0.370 g.) in 30 ml. of methylene chloride was added dropwise with stirring and under nitrogen to a solution of acetyl chloride (3.0 mmoles, 0.22 ml.) and anhydrous aluminum chloride (3.0 mmoles, 0.40 g.) in 20 ml. of the same solvent. Following the addition, the reaction mixture was refluxed for 1 hr. and then hydrolyzed with de-oxygenated water. The phases were separated and the aqueous phase was extracted with methylene chloride. The combined organic phases were washed several times with water and dried over anhydrous sodium sulfate. The mixture was filtered and concentrated to dryness.

The residue was dissolved in *ca.* 15 ml. of methylene chloride–benzene (1:1) and the solution was chromatographed on a 1.5 cm. × 50 cm. column of Merck alumina. Elution with benzene removed a yellow band. Recrystallization of the resulting product from *n*-heptane produced 60 mg. of biferrocenyl, m.p. 237–239° (nitrogen). Further elution removed a salmon-colored band. The product from this band was recrystallized from *n*-heptane to yield 15 mg. of crude acetylbiferrocenyl II, m.p. 137–139°. The infrared spectrum of this product was identical with the spectrum of acetylbiferrocenyl II obtained from the monoacetylation of biferrocenyl. A broad red band was next eluted with methylene chloride. Recrystallization of the resulting product from a mixture of benzene and *n*-hexane produced 180 mg. (40%) of diacetylbiferrocenyl V in the form of deep red crystals, m.p. 191–192°.

Anal. Calcd. for $C_{24}H_{22}Fe_2O_2$: C, 63.48; H, 4.88; Fe, 24.60; mol. wt., 454. Found: C, 63.85; H, 4.98; Fe, 24.20; mol. wt., 454.

A narrow red band was next eluted with 5% methanol in chloroform. The product was rechromatographed in benzene solution and a red band was eluted with mixtures of benzene and chloroform. The resulting product was recrystallized from methanol to yield 20 mg. of red crystals, m.p. 147–147.5°.

Anal. Calcd. for $C_{24}H_{22}Fe_2O_2$: C, 63.48; H, 4.88; Fe, 24.60. Found: C, 63.32; H, 5.10; Fe, 24.68.

---

[17] P. J. Graham, R. V. Lindsey, G. W. Parshall, M. L. Peterson, and G. M. Whitman, *J. Am. Chem. Soc.*, **79**, 3416 (1957).

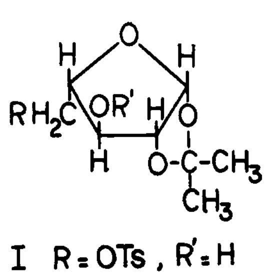
Preparation of Methyl L-Arabinothiapyranoside and Disulfide Derivatives of 5-Mercapto-L-arabinose[1]

Roy L. Whistler and R. M. Rowell

Department of Biochemistry, Purdue University, Lafayette, Indiana

Received September 16, 1963

In the preparation of analogs of natural sugars wherein sulfur replaces the normal ring oxygen, the analog of the common plant sugar, L-arabinose, is now made. As in several previous preparations[2-5] of thia sugars, sulfur is introduced by nucleophilic displacement of the tosyloxy group with the thiobenzylate anion. The starting compound is 1,2-*O*-isopropylidene-5-*O*-tosyl-L-arabinofuranose[6] (I) which is converted to II with the thiobenzylate ion. Reduction with sodium in liquid ammmonia gives 5-deoxy-1,2-*O*-isopropylidene-5-mercapto-L-arabinofuranose (III). Methanolysis produces an anomeric mixture of methyl

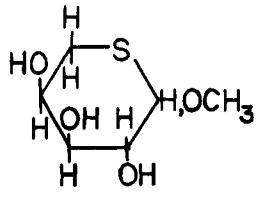


I R = OTs, R' = H

II R = SCH₂ϕ, R' = H

III R = SH, R' = H

IV R = SAc, R' = Ac



V

---

[1] Journal Paper No. 2206 of the Purdue Agricultural Experiment Station, Lafayette, Ind. Presented in part at the 145th National Meeting of the American Chemical Society, New York, N. Y., Sept., 1963.

[2] R. L. Whistler, M. S. Feather, and D. L. Ingles, *J. Am. Chem. Soc.*, **84**, 122 (1962).

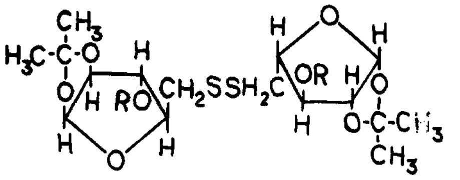
[3] R. L. Whistler and D. L. Ingles, *J. Org. Chem.*, **27**, 3896 (1962).

[4] R. L. Whistler and T. van Es, *ibid.*, **28**, 2303 (1963).

[5] V. S. R. Rao, J. F. Foster, and R. L. Whistler, *ibid.*, **28**, 1730 (1963).

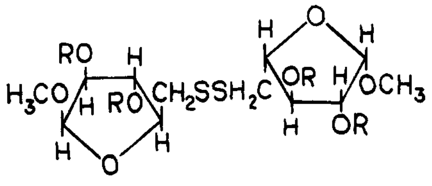
[6] P. A. Levene and J. Compton, *J. Biol. Chem.*, **116**, 189 (1936).

L-arabinothiapyranosides, in low yield with formation of a large amount of sugar disulfide (VIII). Similar results are obtained even under essentially oxygen-free conditions. Methanolysis of the thioacetate (IV) gives 27% of V and 70% of disulfide (VIII). Periodate oxidation of V produced the expected amount of formic acid. The disulfide of III is easily prepared by bubbling air through a hot ethanol solution of III. The crystalline disulfide (VI) can be converted, by acetylation in pyridine, to bis(3-*O*-acetyl-5-deoxy-1,2-*O*-isopropylidene-L-arabinofuranose) 5,5′-disulfide (VII), or by methanolysis to the crystalline bis(methyl 5-deoxy-β-L-arabinofuranoside) 5,5′-disulfide (VIII). The very high specific optical rotation of VIII is suggestive that this disulfide is in the β-L-configuration. Methanolysis of VIII in 2% hydrochloric acid in absolute methanol showed a decrease in the specific optical rotation from +404 to +194 in 36 hr. Acetylation of VIII in pyridine gives a crystalline acetate (IX).



VI R = H

VII R = Ac



VIII R = H

IX R = Ac

Experimental

5-Deoxy-1,2-*O*-isopropylidene-5-thiobenzyl-L-arabinofuranose (II).—1,2-*O*-Isopropylidene-5-*O*-tosyl-L-arabinofuranose (I, 12 g.) reacted with 12 g. of the sodium salt of benzyl mercaptan in a manner described previously,[3] except that the chloroform extracts were washed with water until neutral. After drying with sodium sulfate, the chloroform was distilled under reduced pressure. The dry product, II, was taken up in 25 ml. of chloroform, 75 ml. of petroleum ether (b.p. 66–68°) was added, and the mixture was cooled to 4° until crystallization was complete. The yield was 8.2 g. (80%), m.p. 72°, $[\alpha]^{25}D$ +29.57° (*c* 1.40, chloroform).

Anal. Calcd. for $C_{15}H_{20}O_4S$: C, 60.81; H, 6.76; S, 10.81. Found: C, 61.04; H, 6.65; S, 10.71.

5-Deoxy-1,2-*O*-isopropylidene-5-mercapto-L-arabinofuranose (III).—Compound II (10 g.) was converted to III in the manner previously described except that the product was worked up under a dry, oxygen-free nitrogen atmosphere. Titration of the product with 0.1 *N* iodine solution[7] showed that 85% of the thiol groups were free. The compound gave an immediate color at 25° with both sodium nitroprusside (SNP)[8,9] and 2,3,5-triphenyl-2*H*-tetrazolium chloride (TTC).[10]

Anal. Calcd. for $C_8H_{14}O_4S$: S, 15.53. Found: S, 15.37.

3-*O*-Acetyl-5-deoxy-1,2-*O*-isopropylidene-4-thioacetyl-L-arabinofuranose (IV).—Sirupy III (5 g.) was dissolved in 40 ml. of dry pyridine and the solution was cooled to 0°. To this was added 30 ml. of acetic anhydride with shaking. The mixture was allowed to stand at 25° overnight, under nitrogen, and then was poured into 600 ml. of ice and water. In a short time the thick sirup which separated crystallized and was removed by filtration. It was recrystallized from ethanol to give 5.65 g. (81%), m.p. 85°, $[\alpha]^{25}D$ −13.67° (*c* 1.39, chloroform). The thioacetyl derivative gave an immediate color with TTC and showed characteristic absorption for thioacetate in the ultraviolet region of 230–240 mμ.[11]

Anal. Calcd. for $C_{12}H_{18}O_6S$: C, 49.70; H, 6.20; S, 11.05. Found: C, 49.91; H, 5.89; S, 11.19.

Methyl L-arabinothiapyranoside (V).—Compound IV (3 g.) was dissolved in 100 ml. of 1% methanolic hydrogen chloride and allowed to stand at 25° for 24 hr. At the end of this time, silver carbonate was added until the solution was neutral. After filtration and concentration, the solution was applied to Whatman No. 3 MM filter paper and irrigated with 1-butanol–ethanol–water (40:11:19 v./v.). Three compounds were isolated: starting material (IV), a disulfide (VIII), and methyl L-arabinothiapyranoside (V). The product V did not crystallize and had $[\alpha]^{25}D$ +21.84° (*c* 0.87, water).

Anal. Calcd. for $C_6H_{12}O_4S$: S, 17.77; OCH_3, 17.22; Rast mol. wt., 180. Found: S, 17.92; OCH_3, 16.96; Rast mol. wt., 169.

Periodate oxidation showed 4 moles of periodate consumed, 1.7 moles of total acids produced, and 1 mole of formic acid produced per mole of V. These results indicate the presence of a pyranoside. The excess periodate consumed was probably due to the oxidation of sulfur to a sulfone or sulfoxide.[12]

Bis(5-deoxy-1,2-*O*-isopropylidene-L-arabinofuranose) 5,5′-Disulfide (VI).—A solution of 1 g. of III in 25 ml. of hot ethanol was oxygenated by bubbling air through it for 3 hr. The solution was concentrated to a sirup which crystallized. Titration of this compound with 0.1 *N* iodine solution showed no thiol activity. Reaction with TTC and SNP gave no color test until after reduction of the disulfide bond with lithium aluminum hydride[13] in diethyl ether. The compound had m.p. 160°, $[\alpha]^{25}D$ −23.53° (*c* 1.02, chloroform).

Anal. Calcd. for $C_{16}H_{26}O_8S_2$: C, 46.81; H, 6.38; S, 15.62; Rast mol. wt., 410. Found: C, 46.55; H, 6.43; S, 15.48; Rast mol. wt., 419.

Bis(3-*O*-acetyl-5-deoxy-1,2-*O*-isopropylidene-L-arabinofuranose) 5,5′-Disulfide (VII).—A solution of 2 g. of VI in 20 ml. of dry pyridine was cooled to 0°. To this was added 15 ml. of acetic anhydride, and the solution was kept at 25° overnight and then poured into 500 ml. of ice and water. The compound was extracted with two 100-ml. portions of chloroform, and the combined extracts were washed with a saturated sodium bicarbonate solution, dilute copper sulfate solution, and finally with water. The chloroform was dried over sodium sulfate and concentrated to a thick sirup which crystallized. Recrystallization from ethanol gave VII, m.p. 108°, $[\alpha]^{25}D$ +12.15° (*c* 1.81, chloroform). The compound developed no color with TTC and SNP until after reduction with lithium aluminum hydride in diethyl ether.

Anal. Calcd. for $C_{20}H_{30}O_{10}S_2$: S, 12.96; Rast mol. wt., 494. Found: S, 13.21; Rast mol. wt., 498.

Bis(methyl 5-deoxy-L-arabinofuranoside) 5,5′-Disulfide (VIII).—A solution of 1 g. of VI and 50 ml. of 1% methanolic hydrogen chloride was refluxed for 1 hr. The solution was passed through a column of Amberlite IR-45 (OH) resin to remove acids, and the effluent was concentrated under reduced pressure to dryness. The product was crystallized in ethanol to m.p. 184°, $[\alpha]^{25}D$ +403.5° (*c* 1.33, water). Reaction with TTC and SNP gave no color test until after reduction with lithium aluminum hydride in diethyl ether.

Anal. Calcd. for $C_{12}H_{22}O_8S_2$: C, 40.23; H, 6.19; S, 17.89; OCH_3, 17.32; Rast mol. wt., 358. Found: C, 40.57; H, 6.28; S, 17.81; OCH_3 17.28; Rast mol. wt., 349.

Bis(methyl 2,3-di-*O*-acetyl-5-deoxy-L-arabinofuranose) 5,5′-Disulfide (IX).—A solution of 2 g. of VIII was acetylated and

---

[7] R. M. Evans and L. N. Owen, *J. Chem. Soc.*, 244 (1949).

[8] K. A. H. Mörner, *Z. physiol Chem.*, **28**, 594 (1899).

[9] W. I. Patterson, W. B. Geiger, C. R. Mizell, and M. Harris, *J. Res. Natl. Bur. Std.*, **27**, 89 (1941).

[10] W. E. Trevelyan, D. P. Procter, and J. S. Harrison, *Nature*, **166**, 444 (1950).

[11] H. P. Koch, *J. Chem. Soc.*, 387 (1949).

[12] N. J. Leonard and C. R. Johnson, *J. Org. Chem.*, **27**, 282 (1961).

[13] R. C. Arnold, A. P. Lien, and R. M. Alm, *J. Am. Chem. Soc.*, **72**, 731 (1950).

worked up as described for VII. Recrystallization from ethanol gave product of m.p. 115°, $[\alpha]^{25}\text{D}$ +319.8° (*c* 1.26, chloroform). Reaction with TTC and SNP gave no color until after reduction with lithium aluminum hydride in diethyl ether.

Anal. Calcd for $C_{20}H_{30}O_{12}S_2$: S, 12.17; Rast mol. wt., 526. Found: S, 11.87; Rast mol. wt., 517.

Acknowledgment.—The authors gratefully acknowledge grants from the U. S. Department of Health, Education and Welfare and from the Corn Industries Research Foundation which helped support this work.

Reactions of Calcium with Organonitrogen Compounds and Aromatic Hydrocarbons[1]

ALLEN R. UTKE AND R. T. SANDERSON[2]

Department of Chemistry, University of Iowa, Iowa City, Iowa

Received December 16, 1963

In a recent note[3] we described the reaction by which calcium in liquid ammonia and pyridine and methylpyridines form highly reactive compounds. We have also conducted exploratory investigations of reactions between ammonia solutions of calcium and other organonitrogen compounds, making similar observations. Following the suggestion that these reactions may involve electron addition to the aromatic rings by the calcium–ammonia system, we extended this investigation to aromatic hydrocarbons and observed similar reactions. Evaporation of the excess ammonia led to isolation of insoluble solid products that were mostly highly colored, easily hydrolyzed, and highly reactive with air. These products have not been well-characterized, but we wish to report them here in the hope of interesting others in studying them further.

Empirical compositions of the products together with color and general order of reactivity are given in Table I for the nitrogen compounds and in Table II for the hydrocarbons. Some evidence of reaction was also noted with ethylenediamine and piperidine, but not with benzene or tetrahydrofuran.

TABLE I

CALCIUM ORGANONITROGEN COMPOSITIONS AND PROPERTIES

Reagent (R)	Empirical formula[a]	Color	Air reactivity[b]
Quinoline	$CaRA_{1.54}$	Red-brown	L
	CaRA	Black	L
	$CaR_{1.46}$	Black	L
	$CaR_2A_{0.52}$	Black	L
3-Methylisoquinoline	$CaRA_{1.88}$	Orange-brown	H
Phenanthridine	$CaRA_{1.78}$	Orange-brown	M
Acridine	$CaRA_{1.69}$	Tan	M
2,2′-Dipyridine	$Ca_2RA_{1.29}$	Violet-black	M
1,10-Phenanthroline	$CaRA_{0.74}$	Purple	M
2-Aminopyridine	$CaRA_{0.88}$	White	H
	CaR_2	White	L
2-Amino-5-methylpyridine	$CaRA_{0.72}$	White	M
2,2′-Dipyridylamine	$CaRA_{0.73}$	Yellow	H
	$CaR_2A_{0.33}$	Light green	L
Diphenylamine	$CaRA_{2.13}$	Light green	H
	$CaR_2A_{0.83}$	Tan	M
Triphenylamine	$CaRA_{1.44}$	Tan	L

[a] A = NH_3. [b] H = high reactivity, incandescence, sometimes throwing off sparks; M = medium reactivity, immediate color change with evolution of heat and smoke, sometimes setting fire to paper in contact with it; L = low reactivity, only slightly exothermic with air or water.

TABLE II

CALCIUM HYDROCARBON COMPOSITIONS AND PROPERTIES

Reagent (R)	Empirical formula[a]	Color	Air reactivity[b]
Diphenyl	$CaRA_{1.48}$	Orange-brown	L
Naphthalene	$CaRA_{2.07}$	Light red	H
	$CaRA_{1.62}$	Light red	H
Anthracene	$CaRA_{1.49}$	Light green	H
Phenanthrene	$CaRA_{1.84}$	Tan	L
Chrysene	$CaRA_{1.81}$	Violet	M
Pyrene	$CaRA_{2.04}$	Red-violet	M
Fluoranthene	$CaRA_{1.70}$	Orange-green	L
Diphenylethylene	$CaRA_{2.06}$	Green	L
Tetraphenylethylene	$CaRA_{1.44}$	Light red	L

[a] A = NH_3. [b] See footnote *b*, Table I.

Experimental

Reagents.—Calcium metal was about 98% pure electrolytic lump from Fisher Scientific Co. Spectrographic analysis showed the major impurities to be magnesium and strontium, with minor amounts of manganese, aluminum, and copper and only a trace of iron. It was granulated in an inert atmosphere immediately before use. Ammonia was commercial liquefied anhydrous dried over solid potassium hydroxide. Ethylenediamine, 98–100%, was obtained from Matheson Coleman and Bell, stored over solid potassium hydroxide, and refluxed over barium oxide prior to distillation for use. Benzene from Fisher Scientific Co. and tetrahydrofuran from Matheson Coleman and Bell were dried over sodium wire before use. Acridine and 3-methylisoquinoline, both from Eastman, were recrystallized from ether, as were pyrene and 2,6-diaminopyridine from Reilly Tar and Chemical Corp. Indene, Eastman practical, was redistilled (b.p. 181°, lit. 182.4°). Diphenylethylene was a student preparation, boiling at 114° (1 mm.), as was tetraphenylethylene, m.p. 227–228°, lit. 227°. Freshly opened samples were used of phenanthrene and diphenyl from Matheson Coleman and Bell, purified naphthalene from Fisher Scientific Co., 1,10-phenanthroline and 2,2′-dipyridylamine from Aldrich Chemical Co., and Eastman triphenylmethane and 2,2′-dipyridine. Other reagents used as obtained from the suppliers were 2-aminopyridine from Matheson Co., m.p. 58–60°, chrysene and fluoranthene (95% minimum) from Reilly Tar and Chemical Corp., Eastman 2-amino-5-methylpyridine, anthracene, fluorene (98%), triphenylamine, and Paragon Testing Laboratories diphenylamine. Other chemicals used were standard laboratory reagents.

Apparatus and General Procedure.—These were identical with those described in detail in our earlier note.[3] Briefly the nitrogen compound or hydrocarbon was added to the calcium-ammonia solution at about −70°, excess ammonia was evaporated at its boiling point, and after long evacuation of the residue at room temperature, its composition was estimated by weight difference

Quinoline–Calcium, 1:1.—Two experiments were run with similar results. Formation of a red-brown solid was observed after evaporation of the ammonia and evacuation, 39 hr. at 27° for one product and 22 hr. at 31° for the other. The compositions were $Ca(Q)(NH_3)_{1.52}$ and $Ca(Q)(NH_3)_{1.43}$ The first product did not react very obviously with air except to change to a yellowish tan. It reacted with water forming a yellow solid that dissolved in dilute hydrochloric acid. Analysis of this solution showed 48.9% of the original quinoline to be present.

---

[1] Taken from the dissertation submitted to the University of Iowa by A. R. Utke in partial fulfillment of the requirements for a Ph.D. degree, 1963.

[2] To whom communications should be addressed; during the academic year 1963–1964, Department of Chemistry, Arizona State University, Tempe, Ariz.

[3] A. R. Utke and R. T. Sanderson, *J. Org. Chem.*, **28**, 3582 (1963).