mixture, was added over a 15-min period. The mixture was allowed to warm to −20 °C and stirred for 24 h. At the end of this period, the dark-orange reaction mixture was poured into 10 mL of pentane and washed with four 1-mL portions of H_2O, the aqueous layer back-extracted with 10 mL of pentane, and the combined pentane solution was dried over $MgSO_4$. The pentane was distilled and the product phenylpropyne[16] was collected by preparative GC on the above column in 56% yield (104 mg).

Oxidation of Phenylpropyne to Benzoic Acid. The product phenylpropyne from each pure isomeric vinyl triflate was oxidized according to the following general procedure.[17] Into a 25-mL round-bottom flask equipped with a magnetic stirring bar and reflux condenser was added 4 mL of H_2O, 0.41 g (2.6 mmol) of $KMnO_4$, and 38 mg of Na_2CO_3 followed by 75 mg (0.65 mmol) of the phenylpropyne. The entire mixture was stirred for 1 h at room temperature and then refluxed for about 3 h until the purple color had completely vanished. After cooling, 0.5 mL of 50% H_2SO_4 was slowly added, the mixture was refluxed for 0.5 h and then cooled, and the brown MnO_2 was decomposed with $NaHSO_3$. The solution was made strongly acidic by the addition of 0.5 mL of 50% H_2SO_4 and after cooling in an ice bath the white precipitate was filtered. The filtrate was washed with cold water and the crystals allowed to air dry. The resulting benzoic acid was doubly sublimed to yield 35 mg (44%) of product which was assayed[18] for radioactivity along with each precursor phenylpropyne and vinyl triflate.

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Registry No.—6, 64188-89-2; (*E*)-7, 64162-87-4; (*Z*)-7, 64162-86-3; phenylpropyne-^{14}C, 64162-88-5; acetophenone-^{14}C, 5821-66-9; ethyl phenylmethylglyudate, 64162-89-6.

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(19) Fluorine interferes with this method of assay, hence, the lower precision and activity of the triflates.
(20) The possible rapid equilibration of (*E*)- and (*Z*)-carbenoids prior to rearrangement can not be ruled out, nor easily probed experimentally. The possibility of a *large* difference in migratory aptitude (in favor of phenyl) overwhelming any tendency toward stereochemical selectivity can be ruled out by the observation of alkyl migration and acetylene formation in certain dialkylvinyl triflates $R(CH_3)C=CHOTf$ under similar conditions.[21]
(21) Unpublished observations, D. P. Fox.

Reaction of Pentafluorosulfur Bromide with *cis*- and *trans*-1,2-Difluoroethylene

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The incorporation of pentafluorosulfur groups into hydrocarbons was first accomplished by Case et al. in reactions of pentafluorosulfur chloride with olefins and chloroolefins under free-radical conditions.[1] Similar results were later obtained by Gard and coworkers in reactions with pentafluorosulfur bromide with olefins, but under more facile conditions.[2] In some recent work in this laboratory, we have also noted a distinct difference in the reactivity of SF_5Cl and SF_5Br toward olefins,[3] as well as in the ability of SF_5Br itself to add to various substituted olefins.[4] Such behavior has prompted an investigation into the mechanism by which SF_5Br adds to unsaturated systems.

We have found that pentafluorosulfur bromide reacts with *cis*- and *trans*-1,2-difluoroethylene to give the erythro and threo forms of the addition product $SF_5CHFCHFBr$. The relative amounts of conformers produced are very similar for each olefin and are essentially identical for reactions carried out in the presence or absence of light as shown in Table I. This indicates that the reactions are not stereospecific and suggests that they are occurring via the same radical intermediate in all systems. Dehydrobromination of the addition products yields a mixture of *cis*- and *trans*-$SF_5CF=CFH$.

Structural assignments of the erythro and threo diastereomers have been made on the basis of a comparison of vicinal fluorine coupling constants obtained from proton-decoupling experiments in the C–F region of the fluorine NMR spectra. In one compound, a multiplet was found to collapse to two overlapping pentets arising from coupling between the vicinal fluorine atoms and between one of these fluorines and the SF_4 group. The second multiplet in the same spectrum collapsed to two doublets that were formed from coupling between vicinal fluorines and between one of the fluorine atoms and the axial fluorine in the SF_5 group. From these data, the vicinal fluorine coupling constant in this compound was determined to be 37 Hz. Similar proton decoupling in the second compound resulted in a vicinal fluorine coupling of 13 Hz. The larger coupling constant was assigned to the trans arrangement of the fluorine atoms found in the erythro structure **1a,** in accordance with the Karplus rule that relates the size of the coupling constant to the dihedral angle between coupled species.[5] Similarly, the smaller F–F coupling constant was assigned to the gauche arrangement of fluorine atoms in the threo compound in **1b.** Additional fluorine and proton NMR data are contained in Table II.

Dehydrobromination of the *erythro*- and *threo*-$SF_5CHFCHFBr$ diastereomers yielded mixtures of *cis*- and *trans*-$SF_5CF=CFH$. The predominant formation of the cis isomer from the erythro compound and the trans isomer from the threo compound is consistent with an antiperiplanar arrangement of the hydrogen and bromine atoms to be eliminated. The presence of a second isomer in each reaction, as indicated by a cis–trans ratio of 4:1 for erythro and 0.4:1.0 for threo, suggested that some syn elimination was occurring as well. The trans olefin underwent isomerization to the more stable cis form in good yields (77%) at 125 °C. This isomerization is consistent with previous work that has shown the *cis*-1-fluoro-2-haloolefins to be more stable than the trans isomer.[6] Structural assignments of the olefins are based on the greater intensity of the olefin-stretching vibration in the infrared spectrum, as expected, for the less symmetrical cis

Table I. Results of SF_5Br[a] Addition to Difluoroethylenes

	Registry no.	Threo:erythro	Conversion, %	Yield, %
cis-$C_2F_2H_2$, dark	1630-77-9	2.17 (2.24)	86	60
cis-$C_2F_2H_2$, $h\nu$		2.15	100	74
trans-$C_2F_2H_2$, dark	1630-78-0	1.83 (1.76)	87	66
trans-$C_2F_2H_2$, $h\nu$		1.94	100	75

[a] Registry no.: 15607-89-3.

Table II. ^1H and ^{19}F Nuclear Magnetic Resonance Data

Compound	Registry no.	Chemical shift[a]	Coupling constant,[b] J	
erythro-$FSF_4CHFCHFBr$	64282-18-4	A −70.9	A–B = 145	C–D = 37
A B C D		B −49.5	A–C = 1	C–X = 38
X Y		C +152.1	A–D = 1	C–Y = 5
		D +145.0	A–X = 4.6	D–X = 5
		X −5.49	B–D = 11	D–Y = 47
		Y −6.67	B–X = 4.5	X–Y = 5
threo-$FSF_4CHFCHFBr$	64235-94-5	A −70.6	A–B = 144	C–D = 11
A B C D		B −49.4	A–C = –	C–X = 43
X Y		C +171.7	A–D = –	C–Y = 19
		D +158.5	A–X = –	D–X = 18
		X −5.50	B–D = 11	D–Y = 46
		Y −6.77	B–X = 6	X–Y = 0
cis-$FSF_4CF{=}CHF$	64282-17-3	A −72.1	A–B = 145	C–D = 12
A B C D		B −59.5	B–C = 4	C–X = 13.5
X		C +128.2	B–D = 12	D–X = 69.3
		D +158.7		
		X −7.10		
Trans-$FSF_4CF{=}CHF$	64282-16-2	A −69.6	A–B = 146	C–D = 133
A B C D		B −56.3	B–D = 19	C–X = 4.3
X		C +153.5	B–X = 22	D–X = 69.0
		D +160.7		
		X −7.04		

[a] Proton chemical shifts in ppm relative to Me_4Si. Fluorine shifts in ppm relative to CCl_3F. [b] In Hz.

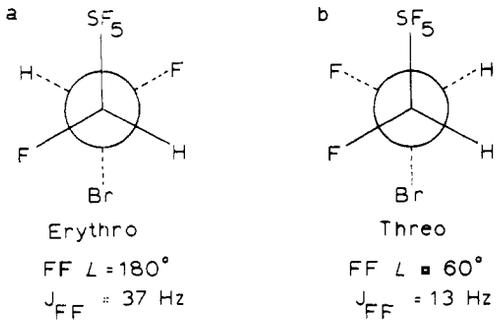


Figure 1. (a) *erythro*-$SF_5CHFCHFBr$; (b) *threo*-$SF_5CHFCHFBr$.

isomer and on proton-decoupling experiments of the C–F resonance in the fluorine NMR spectrum. The larger F–F coupling constant was assigned to the trans isomer, as in the parent compound.

From the results of the addition experiments, it is apparent that SF_5Br does not add stereospecifically to the difluoroethylenes, since only one product would have formed in each of the addition reactions. This would appear to rule out a trans addition via a configuration-holding cyclic bromonium ion, which would have resulted in stereospecificity. The possibility of this bridging bond uncoupling to form an open-chain carbonium ion, or of the direct formation of such a carbonium ion, cannot be ruled out entirely. However, the similarity of product ratios for the reactions carried out both in the presence and in the absence of light mitigates against this possibility. Furthermore, this similarity in product ratios implies that the additions in all cases are occurring via the same intermediate. The behavior of the reactions carried out in the presence of light suggests a radical mechanism and a radical intermediate species. The addition reactions are essentially complete after exposure to ambient lighting for 30 min and can be stopped effectively at partial conversion by removing them from the light, as observed in NMR measurements. The fact that the same product ratios are obtained for reactions carried out in the absence of light suggests that a radical mechanism is operating under these conditions as well, but it is initiated at a slower rate in the dark. The addition of an inhibitor to these systems in the form of hydroquinone led to inconclusive results with the recovery of SiF_4, SO_2, CF_3CFBrH, and unreacted $C_2F_2H_2$. No SF_5Br was recovered nor any addition product isolated.

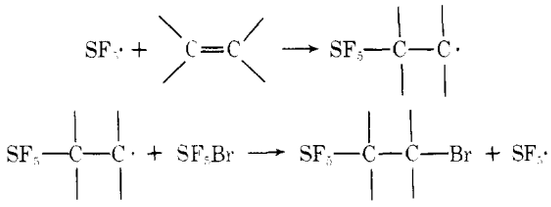
With regard to the mechanism for both reaction systems, a referee has suggested the sequence in Scheme I which is similar to that proposed by Case et al.[1] and others.[7] This route would apparently be preferred over one involving bromine atom addition to the olefin in the first propagation step, since it utilizes the more common atom transfer instead of a radical displacement in the second step. Furthermore, as pointed out in the case of SF_5Cl additions to olefins,[1] attack of a radical species on SF_5Br as shown in the propagation step would be

Scheme I

Initiation

$$SF_5Br \longrightarrow SF_5 + Br\cdot$$

Propagation



more likely to occur at the bromine atom than at the sulfur, which is highly protected by fluorine atoms.

Experimental Section

All reactant manipulations were conducted in a Pyrex system equipped with greaseless Kontes glass/Teflon valves. Infrared spectra were recorded on a Perkin-Elmer Model 567 spectrophotometer using a 10-cm cell equipped with KBr windows. NMR spectra were recorded on a JEOL PS-100 spectrometer operating at 100 MHz for proton and 94.1 MHz for fluorine resonances. Chromatographic separations were carried out using a Gow-Mac Model 69-550 gas chromatograph equipped with an 8 ft × ¼ in. SS column packed with 20% DC-QF-1 45/60 Chromosorb P, operating at 90 °C for the addition products and ambient temperatures for the olefins with a flow rate of 40 cm^3/min. Liquid injections were made at an injection port temperature of 120 °C. Analyses were performed by PCR, Inc., Gainesville, Fla.

2-Bromo-1,2-difluoroethylsulfur Pentafluoride. In a typical reaction, SF_5Br (0.207 g, 1 mmol) and $C_2F_2H_2$ (0.0649 g, 1 mmol) were condensed into a 3-mL Pyrex cell equipped with a glass/Teflon valve. Depending upon the nature of the experiment to be conducted, the reaction mixture was stored either in the dark or left under ambient lighting conditions for 1 week. The volatile materials were then transferred to a vacuum system, and a preliminary separation was made by fractional condensation through a series of traps at −78, −116, and −196 °C. Any unreacted difluoroethylene was collected at −196 °C, with the SF_5Br and small amounts of S_2F_{10} being isolated at −116 °C. The material that was not volatile at −78 °C was separated by GLC. No attempt was made to identify minor products that were formed.

***erythro*-$SF_5CHFCHFBr$:** IR 3030 (vw), 3000 (sh), 1480 (vw), 1360 (vw), 1310 (vw), 1285 (vw), 1240 (vw), 1210 (w), 1175 (w), 1150 (m), 1105 (m), 1085 (w), 1060 (w), 910 (s), 885 (vs), 770 (w), 695 (w), 665 (m), 615 (m), 575 (w), 520 (vw) cm^{-1}.

Anal. Calcd for $C_2H_2F_7SBr$: C, 8.86; H, 0.74; F, 49.07; S, 11.8. Found: C, 9.01; H, 0.90; F, 49.54; S, 12.41.

***threo*-$SF_5CHFCHFBr$:** IR 3025 (vw), 3010 (vw), 1480 (vw), 1365 (vw), 1295 (vw), 1235 (vw), 1180 (m), 1135 (w), 1095 (m), 1055 (vw), 945 (m), 885 (vs), 785 (w), 745 (w), 695 (w), 660 (m), 610 (m), 575 (w) cm^{-1}.

Anal. Found: C, 9.03; H, 0.90; F, 42.91; S, 12.58.

1-Pentafluorosulfur-1,2-difluoroethylene. *threo*-$SF_5CHFCFHBr$ (0.147 g, 0.541 mmol) was condensed into a Pyrex reactor containing powdered KOH (0.168 g, 2.98 mmol) and left at ambient temperature for 5 min. The volatile material (0.539 mmol) was dried over P_2O_5 and separated by GLC using gas injections.

***cis*-$SF_5CF{=}CFH$:** mol wt 189.6 (calcd, 190.08); IR 3150 (vw), 2900 (vvw), 1715 (w), 1355 (w), 1190 (m), 1140 (w), 900 (vs), 810 (m), 695 (w), 625 (w), 585 (vw), 550 (vw) cm^{-1}.

***trans*-$SF_5CF{=}CFH$:** mol wt 189.8 (calcd, 190.08); IR 3110 (vw), 1705 (w), 1230 (m), 1200 (m), 900 (vs), 890 (s), 835 (w), 710 (vw), 630 (w), 575 (vw), 540 (w) cm^{-1}.

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Acetylenic Nucleosides. 1. Synthesis of 1-(5,6-Dideoxy-β-D-*ribo*-hex-5-ynofuranosyl)uracil and 1-(2,5,6-Trideoxy-β-D-*erythro*-hex-5-ynofuranosyl)-5-methyluracil

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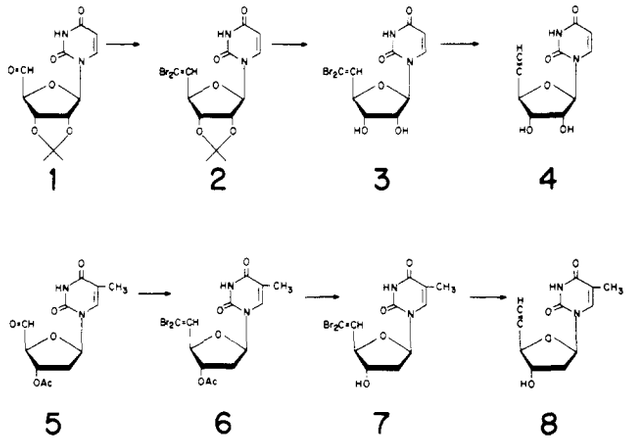
We have recently synthesized 5-ethynyluridine[1] and 5-ethynyl-2′-deoxyuridine,[2] which showed significant (50% at 2×10^{-8} M) growth inhibitory activity against L-1210 cells in vitro. This finding, and the fact that various drugs incorporating the acetylenic function can behave as specific inhibitors[3] for certain enzymatic systems, suggested that nucleosides bearing the acetylenic function at various positions in the carbohydrate moiety of pyrimidines and purines are of interest as potential antimetabolites. In this paper, we describe the synthesis of 1-(5,6-dideoxy-β-D-*ribo*-hex-5-ynofuranosyl)uracil (**4**) and 1-(2,5,6-trideoxy-β-D-*erythro*-hex-5-ynofuranosyl)-5-methyluracil (**8**).

Introduction of unsaturated groups in the sugar moiety of the pyrimidine nucleosides using the Wittig reaction has not been very useful, presumably due to the instability of the aldehyde or the product under the experimental conditions used.[4] Recently, a modified Wittig-type method for the transformation of aldehydes to dibromo olefins and their subsequent conversion to acetylenes has been developed.[5-7] We have used this procedure effectively in our previous[2] work and now explored its potential for the preparation of nucleosides modified in the carbohydrate portion.

The crude 2′,3′-*O*-isopropylideneuridine-5′-aldehyde[4] (**1**) was condensed with (dibromomethylene)triphenylphosphorane,[7] yielding 1-(5,6-dideoxy-6,6-dibromo-2,3-*O*-isopropylidene-β-D-*ribo*-hex-5-enofuranosyl)uracil (**2**). Treatment of



2 with formic acid at room temperature removed the isopropylidene group and provided 1-(5,6-dideoxy-6,6-dibromo-β-D-*ribo*-hex-5-enofuranosyl)uracil (**3**) in excellent yield. The transformation of **3** to acetylenic derivative **4** was achieved by stirring with *n*-butyllithium in tetrahydrofuran in a dry ice–acetone bath, followed by neutralization with acetic acid.

Utilizing similar experimental conditions, 3′-*O*-acetylthymidine-5′-aldehyde[8] (**5**) was condensed with (dibromomethylene)triphenylphosphorane in methylene chloride to afford 1-(2,5,6-trideoxy-6,6-dibromo-3-*O*-acetyl-β-D-*erythro*-hex-5-enofuranosyl)-5-methyluracil (**6**).

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