concentration of THF or DME is initially too low to stabilize the radical anion and thus sodium and naphthalene are probably formed to some extent. Of particular interest in Table II is the Et_2O (THF) system at room temperature which afforded considerably more of the syn product than did the THF (THF) system under comparable conditions (Table I). Again, one can envoke steric arguments in explaining these results; however, the probably nonhomogeneous nature of these solutions precludes a detailed picture of the protonation process.

It is evident from the data presented in Tables I and II that the stereochemistry of reduction for this type of system can be controlled by appropriate choice of reaction conditions. The problem of removing naphthalene and other aromatic by-products from the reaction mixture after a reduction has been carried out makes the synthetic worth of this technique somewhat questionable. In the systems here studied this was indeed a problem. However, one can envision phenylcyclopropane systems which are amenable to separation, and for these cases the technique has merit. Yields are usually high and cyclopropane cleavage products are not obtained. This is a serious drawback in the sodium–liquid ammonia reduction of cyclopropyl halides possessing a phenyl substitutent.

Experimental Section[13]

7-Phenyl-7-chloronorcarane (1a and 1b).—The compound was prepared in a 34% yield according to the method of Closs and Coyle.[14]

***anti*-7-Phenyl-7-chloronorcarane (1a).**—A mixture of the epimers **1a** and **1b** (27.3 g, 0.132 mol; 2/1 = **1a**/**1b**) and silver nitrate (8.99 g, 0.053 mol) in 50 ml of methanol was stirred for 24 hr. The reaction mixture was filtered, water and ether were added to the resulting solution, and the organic layer was separated. The reaction mixture was then worked up in the usual manner. Compound **1a** was separated from 7-phenyl-7-methoxynorcarane and 2-phenyl-3-methoxycycloheptene by column chromatography on silica gel and elution with ligroin. After five recrystallizations from pentane, 6.96 g of a white solid (mp 36–37°) was obtained. Spectral data and melting point were in complete agreement with those previously reported.[3]

***anti*-1-Phenyl-1-chloro-*cis*-2,3-dimethylcyclopropane (3a).**—The compound was prepared as previously described.[2]

Sodium Naphthalenide.—Sodium naphthalenide was prepared in both DME and THF according to the method of Scott.[12]

Sodium Naphthalenide Reductions.[15] **Dilute Conditions.**—To a solution of compound **1a** or **3a** (50 mg) in 15 ml of freshly dried DME or THF or ether was added dropwise with stirring approximately a twofold excess of sodium naphthalenide reagent (1.0 *M*). The reaction mixture was stirred for 5 min and quenched with water. An internal standard was added and the resulting mixture was analyzed by vpc (column a for the reduction of **1a** and column b for the reduction of **3b**).

Concentrated Conditions.—To a solution of 2 ml of reagent (1.0 *M*) in 15 ml of freshly dried DMF, THF, or ether was added with stirring neat or in solution approximately 50 mg of **1a** or **3b**. The reaction mixture was then stirred for 30 min. It was worked up and analyzed as described above.

Registry No.—**1a**, 6434-79-3; **3a**, 13154-00-2; sodium naphthalenide, 12521-84-5.

Acknowledgment.—Acknowledgment is made to the donors of the Petroleum Research Fund, administered by the American Chemical Society, for partial support of this research.

(13) Infrared spectra were determined with a Perkin-Elmer Model 137 or Model 457 recording spectrophotometer. All spectra were measured in carbon tetrachloride unless otherwise stated. The nmr spectra were measured at 60 Hz with an Hitachi Perkin-Elmer R20 spectrometer using tetramethylsilane as the internal reference. Columns used for gas chromatography (vpc) were (a) 10% Carbowax 20M 8 ft × 0.25 in. and (b) 20% DCQF1 12 ft × 1/8 in. All yields were determined by vpc. Unless otherwise stated, magnesium sulfate was employed as the drying agent. All reactions involving air or moisture sensitive compounds were carried out under a nitrogen atmosphere.

(14) G. L. Closs and J. J. Coyle, *J. Org. Chem.*, **31**, 2759 (1966).

(15) The reduction products were characterized by vpc retention times and comparison of infrared spectra with authentic samples. We thank Professor G. L. Closs for supplying us with the infrared spectra of compounds **2a** and **2b**.

Synthesis and Nuclear Magnetic Resonance Investigation of Some Fluorothiophenes

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Received November 27, 1970

Some years ago, we reported[1] the general synthesis of fluorine-containing thiophenes *via* the reaction of thienyllithiums with perchloryl fluoride. Recently renewed interest[2,3] in this reaction prompts us to report further work in this area. Fluorine derivatives of five-membered heterocycles have been only slightly investigated.[4] Recent evidence has indicated[5] that fluorine in the 2 position of thiophene has a stronger electron-withdrawing effect than in fluorobenzene. For these reasons, it became of interest to us to determine the position of electrophilic substitution and lithiation of 2-fluorothiophene.

Acylation of 2-fluorothiophene (**1**) with acetyl chloride and stannic chloride gave 5-fluoro-2-acetylthiophene (**2**). This ketone gave 5-fluoro-2-thenoic acid (**3**) upon treatment with sodium hypochlorite and base. Iodination of **1** by the iodine–mercuric oxide method and nitration, using nitric acid in acetic anhydride, also gave the corresponding 5-substituted products **4** and **5**. In all three of these examples, the products were 98% isomerically pure on the basis of nmr examination of the reaction mixture work-up. The assignment of substitution position was based on a comparison with recently observed coupling constants[2] for 2-fluorothiophene. In all cases, typical $J_{F\text{-}H_3}$ values of 1.4–2.1 Hz and $J_{H_3\text{-}H_4}$ values of 4.0–4.6 Hz were recorded (Table I).

Lithiation of 2-fluorothiophene with *n*-butyllithium followed by treatment with dimethylformamide gave 5-fluoro-2-thenaldehyde (**6**). The aldehyde was readily oxidized to **3** by silver oxide in base. The formation of **3** by this route as well as the observed nmr parameters for **6** (Table I) confirm the structure of the aldehyde.

(1) R. D. Schuetz, D. D. Taft, J. P. O'Brien, J. L. Shea, and H. M. Mork, *J. Org. Chem.*, **28**, 1420 (1963).

(2) S. Rodmar, B. Rodmar, M. K. Sharma, S. Gronowitz, H. Christiansen, and U. Rosen, *Acta Chem. Scand.*, **22**, 907 (1968).

(3) H. Christiansen, S. Gronowitz, B. Rodmar, S. Rodmar, J. Rosen, and M. K. Sharma, *Ark. Kemi.*, **30**, 561 (1969).

(4) Tetrafluorofuran is known but rapidly polymerizes at room temperature: J. Burdon, J. C. Tatlow, and D. F. Thomas, *Chem. Commun.*, 48 (1966). Tetrafluorothiophene is known and stable: J. Burdon, J. G. Campbell, I. W. Parsons, and J. C. Tatlow, *ibid.*, 27 (1969).

(5) Based on the difference in p*K* between 2-thenoic and 5-fluoro-2-thenoic acid: G. P. Nilles and R. D. Schuetz, *J. Org. Chem.*, in press.

TABLE I
COUPLING CONSTANTS FOR VARIOUS 2-SUBSTITUTED 5-FLUOROTHIOPHENES

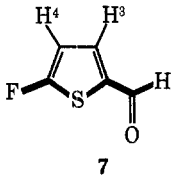
	R =	J_{FH_4}	J_{FH_3}	$J_{H_3-H_4}$
1[a]	H	1.62	3.07	3.89
2	$COCH_3$	1.4	3.6	4.2
3	COOH	1.8	4.0	4.0
4	I	2.1	3.6	4.1
5	NO_2	2.0	4.6	4.6
6	CHO	1.4	3.8	4.4

[a] Reference 2.

The $^1H-^{19}F$ coupling constant is known to increase in going from H_3 to H_5 in 2-fluorothiophene.[2] This effect is further exemplified in the quite large $^5J_{F\text{-}CHO}$ coupling constant of 4.2 Hz, determined in both the ^1H and ^{19}F nmr spectra. We therefore expected that the coupling between the fluorine and methyl protons in **2** might be observable. Indeed, this coupling was determinable and found to have a value of 0.45 Hz.

Karabatsos and Vane have shown[6] that H_3–CHO coupling in substituted benzaldehydes is observable only when the "W" effect (*i.e.*, H_3–CHO are trans–trans) is applicable. Thus, the principle rotamer in **6** would be the one in which the carbonyl function eclipses the sulfur atom. Further evidence was sought for this in the present work by variable temperature nmr observation of **6**. $J_{F\text{-}CHO}$ = 4.6 Hz for **6** in decalin between −34 and +42°. At 64°, J = 4.2 Hz, and at 89°, J = 3.9 Hz. Further increases in temperature up to 160° did not affect the coupling constant.[7,8]

These results are consistent with **7** representing the conformation of **6** and implies that **8** represents the con-



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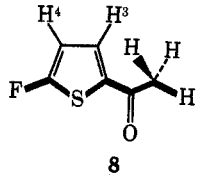

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formation of **2** at room temperature and lower. Increasing the temperature serves to decrease this rotamer population as a consequence of overcoming the rotational energy barrier about the carbonyl carbon–thiophene ring bond. This results in a decrease in $J_{F\text{-}CHO}$ since the trans–trans coupling should be larger than the trans–cis coupling.[9]

While it is possible that some contribution to the magnitude of $J_{F\text{-}CHO}$ could arise from 6-bond coupling *via* the carbon skeleton, it was noted that no additional splitting of the aldehyde proton occurred at high temperature despite the trans–trans relationship between H_3 and CHO of the higher energy rotamer.[10] It would appear that coupling occurs through the sulfur ("W" effect) in both **2** and **6**.

(6) G. J. Karabatsos and F. M. Vane, *J. Amer. Chem. Soc.*, **85**, 3886 (1963).

(7) All coupling constants were determined at least three times each; the maximum deviation was ±0.05 Hz.

(8) This corresponds to a energy barrier (ΔEa^*_{298}) to rotation of ~16 kcal/mol. Other representative energy barriers for rotation about an sp^2–sp^2 single bond following: 2-furanaldehyde, 10–11 kcal; *p*-methoxybenzaldehyde, 9.2 kcal [J. P. Lowe, *Progr. Phys. Org. Chem.*, **6**, 1 (1968)].

(9) It was not possible to determine temperature effects on the nmr of **2** since the coupling approaches the limit of resolution of the instrument.

(10) This coupling is also absent in 2-thenaldehyde: S. Gronowitz and R. A. Hoffman, *Acta Chem. Scand.*, **13**, 1687 (1959).

Experimental Section

Melting points were determined on an Electrothermal melting point apparatus calibrated with furnished standards. Infrared spectra were recorded on a Perkin-Elmer 237B spectrophotometer between NaCl plates for liquids and as KBr disks for solids. The nmr spectra were recorded on a Varian A-56/60 instrument at ambient probe temperature and with Freon 112 as solvent and internal standard but referred to CCl_3F (Φ scale) and with TMS as internal standard for the proton spectra. Variable temperature nmr spectra were run in decalin. Analyses were by Galbraith Laboratories, Knoxville, Tenn.

5-Fluoro-2-thenaldehyde (6).—A solution of 70 ml of 1.6 *N* *n*-butyllithium (Foote Chemical Co.) was cooled to 3° and treated dropwise over a period of 1 hr with 10.2 g (0.100 mol) of 2-fluorothiophene in 50 ml of ether. To this 8.0 g (0.11 mol) of dimethylformamide in 40 ml of ether was added in 30 min. After an additional 1 hr of stirring, the mixture was poured into 100 g of ice and 50 ml of 6 *N* HCl. The organic layers were separated, and the aqueous layer was extracted with four 100-ml portions of ether. The combined, dried (Na_2SO_4) ether solutions were distilled to give 8.2 g (0.063 mol, 63%) of aldehyde: bp 60–61° (63 Torr); $n^{23}D$ 1.5482; ir 1680 cm^{-1} (C=O); pmr τ 0.18 (d, J = 4.2 Hz, CHO), 2.32 (d of d, J = 4.4, 3.8 Hz, H^3), 3.22 (d of d, J = 4.4, 1.4 Hz, H^4); fmr Φ 116.7 (m, J = 4.2, 3.8, 1.4 Hz).

A 2,4-dinitrophenylhydrazone prepared in the usual manner was recrystallized twice from ethanol for analysis, mp 257–258° dec.

Anal. Calcd for $C_{11}H_7O_4FN_4S$: C, 42.72; H, 1.96; N, 18.12; S, 10.37. Found: C, 42.64; H, 2.01; N, 17.96; S, 10.44.

5-Fluoro-2-thenoic Acid (3). A.—A mixture of 3 g of silver oxide and 2 g of sodium hydroxide in 40 ml of water was stirred and 1.30 g (0.0100 mol) of 5-fluoro-2-thenaldehyde was added in one portion. The mixture was stirred for 30 min and filtered. The filtrate was acidified to congo red with concentrated HCl. The precipitate of 5-fluoro-2-thenoic acid was collected and recrystallized from hot water: mp 146–148°; yield 0.70 g (0.0048 mol, 48%); ir 1680 cm^{-1} (C=O); pmr τ 0.52 (s, COOH), 2.83 (t, J = 4.0, 4.0 Hz, H^3), 3.31 (d of d, J = 4.0, 1.8 Hz, H^4).

Anal. Calcd for $C_5H_3FO_2S$: C, 41.08; H, 2.07; S, 21.94. Found: C, 41.14; H, 1.98; S, 21.77.

B. By the Haloform Reaction.—A mixture of 30 ml of 6% sodium hypochlorite, 20 ml of 5 *M* NaOH, and 1.30 g (0.0100 mol) of 5-fluoro-2-acetylthiophene was heated on the steam bath for 2 hr. The solution was cooled and acidified to congo red with concentrated HCl. The collected acid was recrystallized from water, yield 0.42 g (0.0029 mol, 29%). This material was identical by melting point, mixture melting point, and infrared spectra with that prepared in A.

5-Fluoro-2-acetylthiophene (2).—A mixture of 1.02 g (0.0100 mol) of 2-fluorothiophene and 0.87 g (0.011 mol) of acetyl chloride in 15 ml of CS_2 was cooled to 15° and treated dropwise with 2.87 g (0.011 mol) of stannic chloride with stirring in 1 hr. After an additional 1 hr of stirring, the mixture was poured into 10 ml of water. The organic layer was separated and the aqueous layer was extracted with two 20-ml portions of carbon disulfide. The combined, dried (Na_2SO_4) organic phases were stripped of solvent and the residue was vacuum distilled to give 1.15 g (0.0072 mol, 72%) of ketone: bp 80° (15 Torr); ir 1670 cm^{-1} (C=O); pmr τ 2.73 (d of d, J = 4.2, 3.6 Hz, H^3), 3.63 (d of d, J = 4.2, 1.4 Hz, H^4), 7.63 (d, J = 0.45 Hz, CH_3); fmr Φ 119.5, (m, J = 3.6, 1.4, 0.45 Hz).

A 2,4-dinitrophenylhydrazone prepared in the usual manner was recrystallized from ethanol for analysis, mp 246–248°.

Anal. Calcd for $C_{12}H_9FN_4O_4S$: C, 44.58; H, 2.49; N, 17.33; S, 9.92. Found: C, 44.46; H, 2.54; N, 17.21; S, 9.84.

5-Fluoro-2-iodothiophene (4).—A solution of 0.64 g (6.3 mmol) of 2-fluorothiophene in 5 ml of ether was treated with alternate portions of 1.1 g of yellow mercuric oxide and 1.6 g (6.3 mmol) of iodine with vigorous stirring, during 20 min, about 10% of each reagent being added at one time. The suspension of mercuric iodide was filtered off and washed with several portions of ether. The combined filtrate and washings were distilled to remove the solvent. The residue was subjected to micro molecular distillation at 60° (20 Torr) to give 0.88 g (3.9 mmol, 62%), of product: pmr τ 3.18 (d of d, J = 4.1, 3.6 Hz, H^3), 3.90 (d of d, J = 4.1, 2.1 Hz, H^4).

5-Fluoro-2-nitrothiophene (5).—A solution of 0.57 g (5.6 mmol) of 2-fluorothiophene in 5 ml of acetic anhydride was cooled to

0° with stirring. To this a solution of 0.77 g (1.0 mmol) of 90% nitric acid in 5 ml of acetic anhydride was added during 30 min. The reaction mixture was then stored at 0° for 24 hr and then poured into 50 g of ice and set aside at 0° for 24 hr. The solution was extracted with ether (two 25-ml portions) and the combined dried (Na_2SO_4) extracts were stripped of solvent. The residue was distilled at 80° (15 Torr) to give 0.72 g (4.9 mmol, 87%) of product: pmr τ 2.40 (t, J = 4.6, 4.6 Hz, H^3), 3.47 (d of d, J = 4.6. 2.0 Hz, H^4).

Anal. Calcd for $C_4H_2FNO_2S$: C, 32.63; H, 1.37; N, 9.52; S, 21.80. Found: C, 32.90; H, 1.61; N, 9.55; S, 22.01.

Registry No.—**2**, 29669-44-1; 2 2,4-DNP, 29669-45-2; **3**, 4377-58-6; **4**, 29669-47-4; **5**, 29669-48-5; **6**, 29669-49-6; 6 2,4-DNP, 29669-50-9.

Condensed 1,3-Benzothiazines. A Facile Rearrangement of 3-Alkyl-8-nitro-*s*-triazolo-[3,4-*b*](1,3,4)benzothiadiazepine

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Contribution No. 213 from the CIBA Research Centre, Goregaon, Bombay 63, India

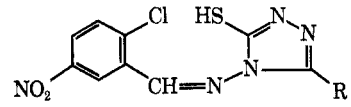
Received October 26, 1970

The fission of an N–N or of an N–O bond with formation of a cyano group under the influence of nucleophilic agents is well documented in five- and six-membered systems.[1] This note describes a novel example of a rearrangement in a seven-membered heterocyclic system involving fission of an N–N bond.

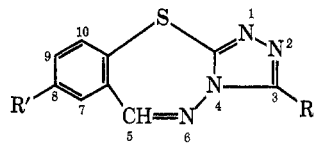
In connection with the synthesis of condensed *s*-triazole heterocycles described earlier,[2] 3-alkyl-4-(2-chloro-5-nitro)benzalamino-5-mercapto-*s*-triazoles were prepared by condensation of 3-alkyl-4-amino-5-mercapto-*s*-triazoles[3] with 2-chloro-5-nitrobenzaldehyde. It was reported earlier[2] that refluxing the sodium salt of the ethyl analog **1a** in dioxane gave 3-ethyl-8-nitro-*s*-triazolo[3,4-*b*](1,3,4)benzothiadiazepine (**2a**) as a yellow compound which showed in the nmr spectrum in DMSO-d_6 the azomethine proton as a singlet at δ 8.86. **2a** was also obtained by refluxing **1a** with 1 equiv of sodium ethoxide in ethanol.

In the presence of 1.3–2.0 equiv of sodium ethoxide, **1a** gave a new product isomeric with **2a** as shown by analytical values and spectral data. The nmr spectrum showed no signal at δ 8.86 corresponding to the azomethine proton of **2a**; the ir spectrum contained an NH band at 3350 and 3260 cm^{-1} but no nitrile band. From these data, the product can be formulated as 3-ethyl-5-imino-7-nitro-5*H*-*s*-triazolo[3,4-*b*]-1,3-benzothiazine (**3a**). The course of the reaction from **1a** can be envisaged as involving the formation of **2a** which in the presence of base undergoes scission of the N–N bond to form the nitrile **2'a** which undergoes facile intramolecular ring closure to form **3a**. An alternative structure, 3-ethyl-5-imino-7-nitro-5*H*-*s*-triazolo[5,1-*b*]-1,3-benzothiazine (**3'a**) cannot be ruled out. Treatment of **2a** in presence of 0.3–1 equiv of sodium ethoxide in ethanol gave **3a** in 68% yield, showing that the reaction from **1a** proceeds through **2a** as an intermediate.

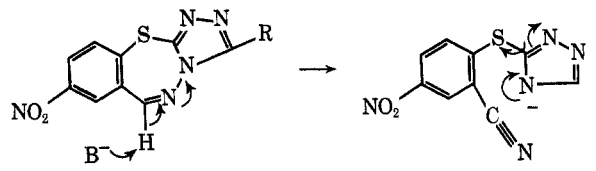
Confirmation of the product as **3a** or **3'a** was obtained by establishing its identity with the condensation product of 2-chloro-5-nitrobenzonitrile[4] (**4a**) and 3-ethyl-5-mercapto-*s*-triazole[3] (**5**) in presence of sodium ethoxide. Under carefully controlled conditions of hydrolysis, **3a** gave **3d**, the corresponding oxo compound which showed the carbonyl band at 1710 cm^{-1} in the ir spectrum. This is in agreement with the reported values for fused cyclic lactams.[5] The chloroacetyl derivative **3c** and the oxo compound **3d** can have the alternative structures **3'c** and **3'd**.



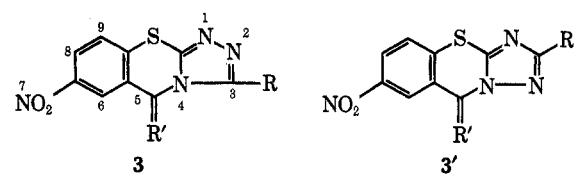
1a, R = C_2H_5
b, R = CH_3



2a, R = C_2H_5; R' = NO_2
b, R = CH_3; R' = NO_2
c, R = C_2H_5; R' = NH_2

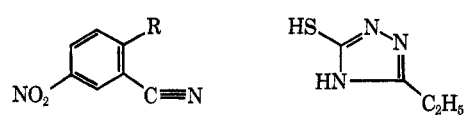


2 **2'a**, R = C_2H_5 **2'**
b, R = CH_3

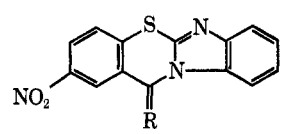


3 **3'**

3a, 3'a; R = C_2H_5; R' = NH
3b, 3'b; R = CH_3; R' = NH
3c, 3'c; R = C_2H_5; R' = NC(=O)CH_2Cl
3d, 3'd; R = C_2H_5; R' = O



4a, R = Cl **5**
b, R = OC_2H_5



6a, R = NH
b, R = O

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(5) L. J. Bellamy, "The Infrared Spectra of Complex Molecules," Wiley, New York, N. Y., 1957, p 205.