

1-(5-Nitro-2-furyl)-2-propenylation of Aromatic Derivatives under Friedel—Crafts Conditions

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Utilization of 1-(5-nitro-2-furyl)-2-bromopropene for propenylation of electron-rich aromatics in the presence of AlCl_3 is described. ^1H NMR spectroscopy was used to monitor the complex-forming equilibrium substrate— AlCl_3 . ^{13}C NMR spectra of the prepared 2-aryl-1-(5-nitro-2-furyl)propenes are analyzed.

Alkenylations of a limited number of electron-rich aromatic derivatives by vinyl halides in the presence of strong Lewis acids (Friedel—Crafts alkenylations) have been described. Such are, for instance, alkenylations with β -, or β,β -substituted vinyl halides with strong activating substituents [1—4]. Conversely, electron-donating groups in α -position of vinyl halide exhibit a strong inhibitory effect [5]. Such reactions allow direct alkenylation of activated aromatic substrates.

In our earlier papers we have described the activating effect of 5-nitro-2-furyl [6—8] and 5-nitro-2-thienyl [9] moiety in reactions of the Friedel—Crafts type. Thus the data gathered from the reactions with 2-(5-nitro-2-furyl)vinyl bromide allowed us to suggest a tentative Ad_E — E mechanism of 2-(5-nitro-2-furyl)vinylation of aromatic derivatives in the presence of AlCl_3 [10]. Now we present another study of the above reaction, using vinyl bromide substituted in α -position by an electron-donating group. Special attention was paid to the properties of the substrate— AlCl_3 complex, which were studied by ^1H NMR spectroscopy.

The starting 1-(5-nitro-2-furyl)-2-bromopropene (*I*) was prepared as pure (*Z*)-*I* and (*E*)-*I* isomers either by a debrominative decarboxylation of the corresponding 2-methyl-3-(5-nitro-2-furyl)-2,3-dibromopropanoic acid [11], or by treating the po-

Table 1. ^1H NMR Spectral Data (δ) of (*Z*)-*I* and its Complex with AlCl_3 in C_2HCl_3

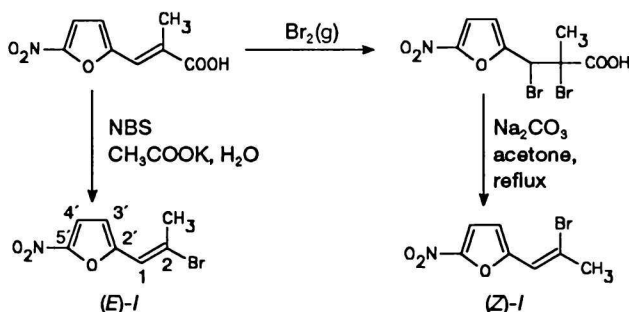
Compound	H-4' (d)	H-3' (d)	H-1	CH_3
(<i>Z</i>)- <i>I</i>	7.35	7.23	6.78	2.57
(<i>Z</i>)- <i>I</i> · AlCl_3	8.31	7.72	7.10	2.77
$\Delta\delta$	0.96	0.49	0.32	0.20

tassium salt of 2-methyl-3-(5-nitro-2-furyl)propenoic acid with *N*-bromosuccinimide (NBS) (Scheme 1).

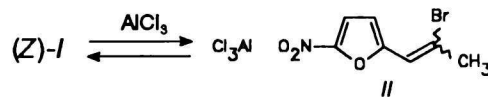
The complex-forming reaction of *I* with AlCl_3 was studied in dry C_2HCl_3 , under argon atmosphere and at 25 °C. ^1H NMR spectra were taken within 5 min from mixing the components. Under the above conditions (*E*)-*I* was found to undergo a rapid isomerization, which resulted in a mixture in which (*Z*)-*I* prevailed.

A gradual addition of AlCl_3 to (*Z*)-*I* causes a monotonous rise in chemical shifts of protons; the maximum values of chemical shifts reached are given in Table 1.

For a given mole ratio $\text{AlCl}_3/(\text{Z})\text{-I}$ $\Delta\delta$ values decrease in the order $\Delta\delta(\text{H-4}')$, $\Delta\delta(\text{H-3}')$, $\Delta\delta(\text{H-1})$, $\Delta\delta(\text{CH}_3)$. Thus the highest values of chemical shifts belong to H-4' proton of the furan ring. This observed effect on chemical shifts tallies well with the notion of primary attack of AlCl_3 on the nitro group in (*Z*)-*I* (Scheme 2).

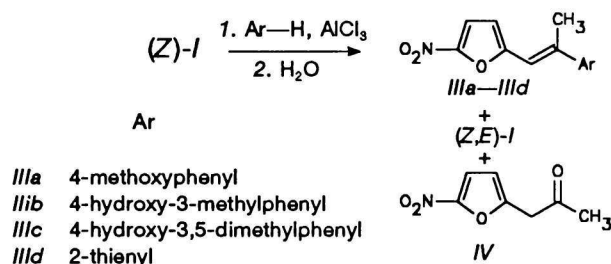


Scheme 1



Scheme 2

In the presence of excess AlCl_3 the complex *II*, a strongly activated vinyl halide, reacts with selected aromatic and heterocyclic derivatives to give 2-aryl- or heteroaryl-1-(5-nitro-2-furyl)propenes *IIIa*—*III d* (Scheme 3). Because a 2-methyl group was present in (*Z*)-*I*, the reaction gave lower yields and the range of possible substrates was narrower



Scheme 3

than in reactions with (*Z*)-2-(5-nitro-2-furyl)vinyl bromide [8].

In addition to derivatives IIIa–IIIc the reaction mixture always contained 20–30 % of *I* (a mixture of *E* and *Z* isomers with the latter predominating) and the product of hydrolysis of (*Z*)-*I* 1-(5-nitro-2-furyl)-2-propanone (*IV*) [12]. The isomer (*E*)-*I* furnished a similar distribution of products. Only stable *E* isomers of III were isolated; *Z* isomers of III (monitored by ¹H NMR spectroscopy) were not found in the reaction mixture.

The structures of the starting materials and of reaction products were confirmed by IR, UV, ¹H NMR and ¹³C NMR spectroscopy. The configuration at the double bond in IIIa–IIIc was determined from the NMR spectra containing proton coupling information, further from the measured direct coupling constants *J*(C, H), as well as from the characteristic splitting pattern resulting from the long-range coupling.

The signal of C-5' appears in ¹³C NMR spectra as a broad, low-intensity multiplet owing to the effect of the quadrupole moment of the nitro group [13, 14]. No signal of C-5' atom was observed in the spectrum of IIIb. The assignment of C-3', C-4' signals was done on the basis of direct and geminal coupling constants *J*(C, H) and the relationship [13, 15]

$$^1J(\text{C-4}', \text{H-4}') > ^1J(\text{C-3}', \text{H-3}') \\ ^2J(\text{C-4}', \text{H-3}') > ^2J(\text{C-3}', \text{H-4}')$$

The geminal interaction with H-3' causes a split of the signal of C-4' to doublet of doublets, the interaction with H-4' and H-1 splits the signal of C-3' to a doublet of triplets. The signal of C-1 in the spectra without proton decoupling appears as a double quartet, this being a consequence of long-range coupling with a CH₃ group; no interactions with protons of the furan ring were observed. Signals of carbon atoms in thiophene derivative IIIc were assigned by comparison of *J*(C, H) data with pertinent data from the literature [16].

The determination of configuration of compounds IIIa–IIIc was made on the basis of the interaction, expressed as ³*J*(C, H), between the C-3 of the methyl group and ethylenic H-1 [17–19]. In one of our previous papers we published the ³*J*(C, H)

values for some trisubstituted 1-(5-nitro-2-furyl)ethylenes [14]. These values, together with the characterized, separable (*E*)-*I* and (*Z*)-*I* isomers enabled the structure assignment of derivatives IIIa–IIIc. Thus in (*E*)-*I* the ³*J*(C-3, H-1) constant was 6.8 Hz, whereas in (*Z*)-*I* ³*J*(C-3, H-1) = 4.9 Hz. Although the measured coupling constant for (*E*)-*I* was smaller than in other derivatives [14, 18, 19], we assigned to derivatives IIIa–IIIc, in which ³*J*(C-3, H-1) = 8.5–8.7 Hz, an *E*-type of structure.

EXPERIMENTAL

Melting points were determined with a Kofler hot block. Ultraviolet spectra of methanolic solutions ($\epsilon/\text{m}^2 \text{mol}^{-1}$) were measured with a spectrophotometer UV–VIS (Zeiss, Jena). Infrared spectra of KBr discs were taken with the Specord IR 71. ¹H NMR spectra of C²HCl₃, or hexadeuteroacetone solutions were measured with an 80 MHz spectrometer, model BS 487 C (Tesla), using tetramethylsilane as internal standard. ¹³C NMR spectra were taken in 10 mm tubes at 25 °C with a 25.05 MHz spectrometer, model FX 100 (Jeol).

(*Z*)-1-(5-Nitro-2-furyl)-2-bromopropene ((*Z*)-*I*)

The 2-methyl-3-(5-nitro-2-furyl)propenoic acid (4 g; 0.02 mol) was brominated in solid phase, kept over concentrated sulfuric acid, by bromine vapours in a closed desiccator. After completion of the reaction (monitored by mass growth) the crude product was dissolved in acetone (150 cm³), Na₂CO₃ (5 g) was added and the mixture was refluxed for 4 h with the exclusion of moisture. The bromopropene (*Z*)-*I* was obtained by chromatography of the concentrated mixture on a silica gel column, eluted by benzene. Yield 2.3–2.5 g (50–54 %), m.p. = 70–72 °C. For C₇H₅BrNO₃ (*M_r* = 232.0) *w_i*(calc.): 36.2 % C, 2.6 % H, 6.0 % N, 34.4 % Br; *w_i*(found): 36.4 % C, 2.6 % H, 6.0 % N, 33.8 % Br. IR spectrum, $\tilde{\nu}/\text{cm}^{-1}$: 1480, 1471, 1356, 838. UV spectrum, $\lambda_{\text{max}}/\text{nm}$ (log { ϵ }): 353 (3.26). For ¹H NMR spectrum see Ref. [14].

(*E*)-1-(5-Nitro-2-furyl)-2-bromopropene ((*E*)-*I*)

The 2-methyl-3-(5-nitro-2-furyl)propenoic acid (1 g; 5.1 mmol) was dissolved in a warm solution of potassium acetate (1 g; 5.1 mmol) in water (150 cm³). Small portions of *N*-bromosuccinimide were added to the stirred solution at 60–70 °C during 1 h. The reaction mixture was then cooled to laboratory temperature, extracted by ethyl acetate, and

Table 2. ^{13}C NMR Spectral Data (δ) of Substituted 1-(5-Nitro-2-furyl)propenes I, IIIa—III d

Compound	C-1	C-2	C-3	C-2'	C-3'	C-4'	C-5'	C_{arom}
(E)-I	119.3	121.0	26.6	153.1	111.9	113.2	151.0	
(Z)-I	117.2	128.9	31.0	153.5	112.2	113.1	150.4	
IIIa	112.4	144.3	18.6	156.8	111.6	114.0	150.7	134.5 (C-1'), 127.4 (C-2'), 114.0 (C-3'), 160.1 (C-4'), 55.4 (OCH ₃)
IIIb	112.4	144.6	18.7	156.3	111.6	114.1	b	134.9 (C-1'), 125.2 (C-2'), 124.1 (C-3'), 154.6 (C-4'), 115.1 (C-5'), 129.0 (C-6'), 16.0 (CH ₃)
IIIb ^a	112.7	145.0	18.2	156.5	112.0	114.8	b	134.0 (C-1'), 125.5 (C-2'), 124.0 (C-3'), 157.6 (C-4'), 115.3 (C-5'), 129.4 (C-6'), 15.9 (CH ₃)
IIIc ^a	112.6	145.0	18.2	154.8	111.8	114.8	152.3	133.7 (C-1'), 127.0 (C-2'), 124.5 (C-3'), 157.5 (C-4'), 16.4 (CH ₃)
III d	112.3	146.2	18.4	156.0	111.7	114.1	150.9	137.6 (C-2'), 125.7 (C-3'), 128.6 (C-4'), 126.5 (C-5')

a) Measured in hexadeuteroacetone; b) unidentified.

Table 3. Coupling Constants $J(\text{C}, \text{H})/\text{Hz}$ in ^{13}C NMR Spectra of Trisubstituted Propenes I, IIIa—III d

Compound	C-1, H-1	C-3, H-3	C-3, H-1	C-3', H-3'	C-4', H-4'	C-3', H-4'	C-4', H-3'
(E)-I	165.0	129.8	6.8	183.6	186.5	2.9	3.9
(Z)-I	158.2	131.3	4.9	183.6	185.5	2.9	3.9
IIIa	156.8	127.9	8.5	184.1	184.6	2.9	3.8
IIIb	157.2	127.6	8.6	181.1	185.2	a	3.8
IIIc	156.7	127.8	8.7	181.2	185.4	a	3.6
III d ^b	156.8	128.9	8.8	181.7	184.7	a	3.8

a) Unidentified; b) $J(\text{C}, \text{H})$ of 2-thienyl group: 168.5 (C-4'', H-4''), 4.4 (C-4'', H-3''), 189.0 (C-5'', H-5''), 7.3 (C-5'', H-4''), 10.7 (C-5'', H-4''), 167.0 (C-3'', H-3'').

Table 4. Physicochemical Characteristics, IR and UV Spectral Data of the Derivatives IIIa—III d

Compound	Formula M_r	$w_i(\text{calc.})/\%$ $w_i(\text{found})/\%$			Yield/%	M.p./°C	$\tilde{\nu}/\text{cm}^{-1}$	$\lambda_{\text{max}}/\text{nm}$ $\log \{\epsilon\}$
		C	H	N				
IIIa	$\text{C}_{14}\text{H}_{13}\text{NO}_4$	64.9	5.05	5.40	23	84.5—85.5	1465, 1450, 1355, 1030	403 3.31
	259.3	65.2	5.11	5.31				
IIIb	$\text{C}_{14}\text{H}_{13}\text{NO}_4$	64.9	5.05	5.40	35	169—171	1512, 1460, 1351, 1034	416 3.34
	259.3	65.3	5.09	5.23				
IIIc ^b	$\text{C}_{15}\text{H}_{15}\text{NO}_4$	65.9	5.53	5.13	24	154—156	1478, 1355, 1222, 1208	415 3.18
	273.3	66.5	5.62	5.26				
III d	$\text{C}_{11}\text{H}_9\text{NO}_3\text{S}^a$	56.2	3.86	5.95	31	124—126	1466, 1360, 1340, 1031	411 3.31
	235.3	56.3	3.90	5.80				

a) $w_s(\text{calc.})$ 13.6%; $w_s(\text{found})$ 13.2%. b) IR spectrum measured in CHCl_3 solution.

the concentrated extract chromatographed on a silica gel column, eluant benzene—cyclohexane ($\varphi_r = 5:3$). Yield 0.24—0.3 g (20—25%). After crystallization from toluene—heptane m.p. = 52—56 °C. For $\text{C}_7\text{H}_5\text{BrNO}_3$ ($M_r = 232.0$) $w_i(\text{calc.})$:

36.2% C, 2.6% H, 6.0% N, 34.4% Br; $w_i(\text{found})$: 36.6% C, 2.7% H, 6.13% N, 33.9% Br. IR spectrum, $\tilde{\nu}/\text{cm}^{-1}$: 1483, 1575, 1360, 858. UV spectrum, $\lambda_{\text{max}}/\text{nm}$ ($\log \{\epsilon\}$): 363.5 (3.24). For ^1H NMR spectrum see Ref. [14].

Table 5. ^1H NMR Spectral Data (δ) of Substituted 1-(5-Nitro-2-furyl)propenes IIIa—III d

Compound	H-3' (d)	H-4' (d) ^a	H-1 (s)	CH_3 (d) ^b	Others
IIIa	6.77	7.54	6.70	2.46	3.81 (s, 3H, O—CH ₃), 6.95 (d, 2H, $J = 9.1$ Hz, H-3'', H-5''), 7.57 (d, 2H, $J = 9.1$ Hz, H-2'', H-6'')
IIIb	6.76	7.54	6.68	2.47	7.39 (s, 1H, H-2''), 7.31 (dd, 1H, $J = 8$ Hz, $J = 2.5$ Hz, H-6''), 6.86 (d, 1H, $J = 8$ Hz, H-5''), 2.24 (s, 2H, CH ₃), 8.50 (s, 1H, OH)
IIIc	6.72	7.52	6.65	2.44	7.24 (s, 2H, H-2'', H-6''), 7.55 (s, 1H, OH), 2.27 (s, 6H, 2 x CH ₃)
III d ^c	6.53	7.36	6.73	2.52	7.04 (dd, 1H, $J = 4$ Hz, H-4''), 7.23—7.33 (m, 2H, H-3'', H-5'')

a) $J(3,4) = 3.8$ Hz; b) $J(\text{H}-1, \text{H}-3) = 1.2$ Hz; c) measured in C^2HCl_3 .

2-Aryl-1-(5-nitro-2-furyl)propenes IIIa—III d

To the stirred solution of (*Z*)-I (0.5 g; 2.1 mmol) in dry CH₂Cl₂, kept at -10 °C—0 °C, AlCl₃ (0.4 g; 3 mmol) was added in one portion. After a 5 min period the solution of the respective aromatic amine (3 mmol) in dichloroethane (10 cm³) was added within 30 min. The reaction mixture was then stirred for another 3 h at -10 °C—0 °C, then poured onto the crushed ice—water mixture (300 cm³) and extracted with dichloroethane. The concentrated extract was chromatographed on a silica gel column, eluted with a toluene—ethyl acetate ($\varphi_r = 3 : 1$) mixture. The crude product was crystallized from a toluene—heptane mixture. The physicochemical properties and the spectral data of the derivatives IIIa—III d are summarized in Tables 2—5.

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