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Vicarious Nucleophilic Substitution of Hydrogen in Nitroderivatives of Five-Membered Heteroaromatic Compounds

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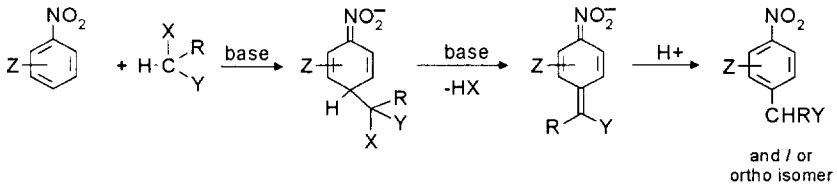
Abstract: Nitro derivatives of thiophene, furan and pyrrole react with carbanions containing leaving groups giving products of replacement of hydrogen with functionalized alkyl substituents. Many specific features of this reaction are discussed.

Vicarious nucleophilic substitution of hydrogen (VNS) in aromatic compounds is a process, by means of which hydrogen atoms in nitroarenes can be replaced with functionalized alkyl substituents.[1,2] This two step reaction proceeds *via* addition of carbanions containing leaving groups X at the carbanionic center to the nitroaromatic ring, followed by base induced ß-elimination of HX from the intermediate σ-adducts.[3] (Scheme 1).



Scheme 1

Two equivalents of base are necessary for the reaction to proceed, one for deprotonation of CH acids to form the carbanion and the second for inducing the ß-elimination of HX.

Numerous examples of the VNS reaction in nitroaromatic compounds with a variety of CH-acids prove that it is a general process in respect to the both partners.[2] There is almost no limitation concerning substituents present in the arene ring, which can be homo- or heterocyclic.[4] Practically any carbanion containing such leaving groups as halogens, OAr, SAr, SR etc. can enter this reaction.

In our preliminary communications we have reported that the VNS reaction can proceed in nitro derivatives of five-membered aromatic heterocycles, such as thiophene, furan and pyrrole.[5,6] Here we would like to present a full account of our studies on this subject. The VNS reaction in nitroimidazoles and nitropyrazoles was already reported elsewhere.[7]

RESULTS AND DISCUSSION

Thiophene, furan and pyrrole ring systems bear a strong resemblance to the fully aromatic benzene ring. There are many examples of typical nucleophilic aromatic substitution of halogen *via* the addition-elimination mechanism in various derivatives of these heterocycles containing electron withdrawing substituents.[8] Particularly abundant data are available for S_NAr reactions in nitrothiophene derivatives in synthetic as well as mechanistic aspects.[9] Nitro derivatives of these heterocycles are therefore expected to be very active partners also in the VNS reaction.

VNS reactions in nitrothiophene derivatives.

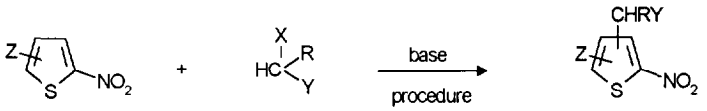
2-Nitrothiophene (**1**) in the presence of strong bases reacts smoothly with a large variety of CH-acids of general structure X-CHRY where X is a leaving group, Y - carbanion stabilizing group and R - hydrogen, alkyl or aryl, according to the VNS scheme (Table 1, entries 1-19). Usually potassium hydroxide or *tert*-butoxide in liquid ammonia or polar aprotic solvents were used in these reactions. Although nucleophilic addition to **1** can occur in two positions 3 and 5, strong preference for the substitution in position 3 has been observed. In the reaction of all secondary carbanions (R=H) with **1** 3-H was exclusively replaced (Table 1, entries 1-12). The structure of the products was determined by ^{1}H NMR spectroscopy and, in some cases, confirmed by chemical means. For example in the reaction of **1** with N,N-dimethyl-chloromethanesulfonamide (entry 1) only one substitution product was obtained (yield 81%). Its ^{1}H NMR spectrum showed signals of the thiophene ring protons as an AB spin system with δ = 7.37 and 7.88 ppm and coupling constant J = 5.8 Hz characteristic for 2,3-disubstituted thiophenes. Typical values for coupling constants of the thiophene ring protons are $J_{2,3}$ = 4.90 ÷ 5.80 Hz; $J_{3,4}$ = 2.45 ÷ 4.35 Hz.[10] The substitution in position 3 was independently confirmed in the reaction of 2-nitro-5-deuteriothiophene with the same carbanion. In the ^{1}H NMR spectrum of the product there was a singlet in the aromatic region (δ = 7.4) which beyond any doubt has proven that the substitution took place in position 3. It is interesting to compare specific "*ortho*" orientation in the VNS reaction of **1** with secondary carbanions to the analogous reactions of nitrobenzene. In the latter, secondary carbanions replace hydrogen in both positions *ortho*- and *para*- furnishing a mixture of the two isomeric products in ratio depending on the size of the carbanions and the reaction conditions.[11]

A strong tendency for the "*ortho*" substitution in **1** was observed also in its reaction with tertiary carbanions which usually gave two products of VNS at C-3 and C-5 (entries 14-19), whereas in nitrobenzene such carbanions replace practically only *para* hydrogen.[11,12] The conditions favourable for the *ortho* substitution (*tert*-BuOK, THF) are not efficient for VNS with tert. carbanions in nitrobenzene,[13] whereas such reaction in **1** proceeds readily at C-3 (entry 13).

In order to rationalize this strong preference for the "*ortho*" orientation of VNS in **1** the mechanistic scheme of the reaction should be considered. Since the VNS reaction proceeds *via* reversible addition of the carbanions followed by the base induced ß-elimination, the orientation depends on the relation of the rates and equilibrium's

Unlike that of benzene, the aromatic system of thiophene is not symmetrical, bonds C-2 - C-3 and C-4 - C-5

Table 1. Reactions of 2-Nitrothiophene and its Derivatives with Various CH-Acids.



Entry	Nitro deriv.		CH-acid			Procedure[a]	Product		
	No	Z	R	X	Y		Position of CHRY	No.	Yield %
1	**1**	H	H	Cl	SO_2NMe_2	A	3	**2**	81
2	**1**	H	H	Cl	SO_2Ph	A	3	**3**	74
3	**1**	H	H	Cl	SO_2p-Tol	A	3	**4**	76
4	**1**	H	H	Cl	SO_2OPh	A	3	**5**	59
5	**1**	H	H	PhS	COO*t*-Bu	A	3	**6**	50
6	**1**	H	H	Cl	CN	A[b]	3	**7**	55
7	**1**	H	H	PhS	CN	A	3	**7**	69[c]
8	**1**	H	H	PhO	CN	A	3	**7**	74[c]
9	**1**	H	H	PhS	2-CN-C_6H_4	A	3	**8**	43
10	**1**	H	H	PhS	4-CN-C_6H_4	A	3	**9**	70
11	**1**	H	H	PhS	4-$PhSO_2C_6H_4$	A	3	**10**	63
12	**1**	H	H	Cl	COPh	E	3	**11**	25
13	**1**	H	Me	Cl	SO_2Ph	C	3	**12**	70
14	**1**	H	Me	Cl	SO_2Ph	B	3 , 5	**12 , 13**	64 , 16
15	**1**	H	Et	Cl	SO_2Ph	B	3 , 5	**14 , 15**	39 , 28
16	**1**	H	Ph	Cl	SO_2Ph	B	5	**16**	78
17	**1**	H	Me	Cl	CN	B	3 , 5	**17 , 18**	39 , 5
18	**1**	H	*i*-Pr	Cl	CN	B	3 , 5	**19 , 20**	26 , 6
19	**1**	H	Et	Cl	NO_2	E	5	**21**[d]	52
20	**25**	5-Br	H	Cl	SO_2t-Bu	A	3	**26**	74
21	**25**	5-Br	H	Cl	SO_2NMe_2	A	3	**27**	74
22	**25**	5-Br	H	Cl	SO_2Ph	A	3	**28**	92
23	**25**	5-Br	H	Cl	SO_2Ph	C[e]	3	**28**	82
24	**25**	5-Br	Et	Cl	SO_2Ph	B	3	**29**	75
25	**25**	5-Br	Ph	Cl	SO_2p-Tol	E	3	**30**	85
26	**25**	5-Br	H	Cl	CN	A	3	**31**	36
27	**32**	5-I	H	Cl	SO_2NMe_2	A	3	**33**	80
28	**34**	5-CN	H	Cl	SO_2Ph	A	3	**35**	91

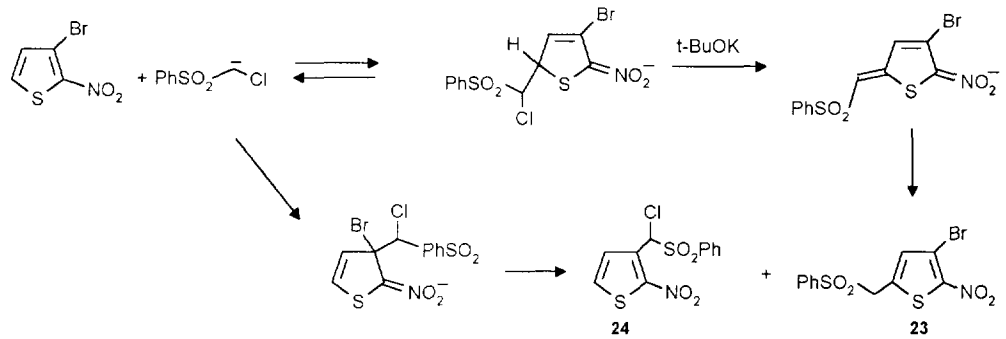
a) Procedures for all Tables: A - KOH/NH_3; B - *t*-BuOK/NH_3; C - *t*-BuOK/THF; D - *t*-BuOK/DMSO; E - KOH/DMSO; F - *t*-BuOK/DMF; G- MeONa/NH_3. b) Two-fold excess of $ClCH_2CN$ was used. c) Product was not isolated, the yield estimated on the basis of ^1H NMR spectrum. d) 2-Nitro-5-propionylthiophene. e) *t*-BuOK dissolved in THF was added dropwise to a mixture of the reagents.

have substantial double character.[14] For this reason nucleophilic addition in 2-nitrothiophene and its derivatives occurs preferentially at C-3, thus electronic effects favour the "*ortho*" orientation of VNS in **1**. On the other hand constants of the σ-adducts formation and on the relation of the rates of the elimination processesthe orientation of VNS in **1** is less affected by steric hindrances created by the nitro group than in nitrobenzene. It is reasonable to assume that rate of the elimination of HX from the σ-adduct is more sensitive to steric hindrances than the addition

process, because the elimination requires antiperiplanar configuration of H-C and C-X bonds. Such configuration in the σ-adducts of tertiary carbanions in positions *ortho* in nitrobenzene can be difficult to attain because of steric repulsion of R or Y with the vicinal NO_2 group, hence the elimination is hindered. In 5-membered rings such difficulties are less pronounced than in 6-membered rings because of the geometry of the former.[8c]

Amongst successful reactions of a variety of carbanions with 2-nitrothiophene there is an example of the VNS with ω-chloroacetophenone leading to the expected (2-nitro-3-thienyl)methyl phenyl ketone **11** (entry 12). So far attempts to use α-haloketones in the VNS reaction were seldom successful.[15] Nitronate anion generated from 1-chloro-1-nitropropane reacted satisfactorily with **1**, but instead of the expected nitroalkane 2-nitro-5-propionylthiophene (**21**) was isolated (entry 19). Apparently the VNS in position 5 of **1** was followed by the Neff reaction,[16] perhaps during the work-up procedure.

Many substituted 2-nitrothiophene derivatives entered smoothly the VNS reaction. Interesting results confirming general mechanistic scheme of the VNS process were obtained with 2-nitro-3-bromothiophene **22**. In spite of the preferred addition of nucleophiles at C-3 in 2-nitrothiophene, when this position is occupied by a halogen the addition of chloromethyl phenyl sulfone carbanion occurs at C-5 and under conditions, which assure rapid ß-elimination of HCl from the σ^H-adduct (high concentration of base) VNS at C-5 is the major process.

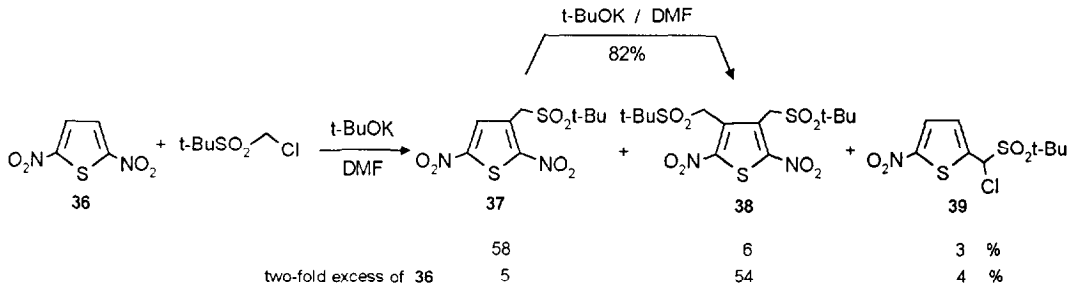


Scheme 2

The addition to C-5 bearing hydrogen is a reversible process, thus low base concentration disfavouring the elimination of HCl from the initial σ^H-adduct changes the reaction course and S_NAr of 3-Br takes place (Scheme

2). These results strongly support the general mechanistic scheme of the VNS reaction - fast and reversible addition followed by the base induceed ß-elimination.

Derivatives of 2-nitrothiophene substituted in position 5 react satisfactorily with secondary and tertiary carbanions furnishing products of VNS in position 3 (Table 1 entries 20-28), even when substituent Z at C-5 can be easily replaced *via* simple nucleophilic aromatic substitution as for example in 5-bromo or 5-iodo-2-nitrothiophenes. Even under conditions favouring this reaction (low concentration of base) no products of S_NAr of halogen have been observed (entry 23). The reaction is somewhat more complex in the case of 2,5-dinitrothiophene **36**. In this case, similarly as in the case of *m*-dinitrobenzene[17] mono- and disubstitution of hydrogen can occure. There is also a possibility of the S_NAr type substitution of one of the nitro groups. Indeed, the reaction of **36** with chloromethyl *tert*-butyl sulfone under the standard VNS conditions resulted in the formation of three compounds: products of VNS of one hydrogen atom **37** (58%), two hydrogen atoms **38** (6%), and product of S_NAr of one of the nitro groups **39** (3%) (Scheme 3). When the CH-acid was applied in a two-fold excess along with at least five-fold excess of base **38** was mainly formed (54%). In a separate experiment treatment of **37** with the chlorosulfone and an excess of base gave **38** in high yield (82%).

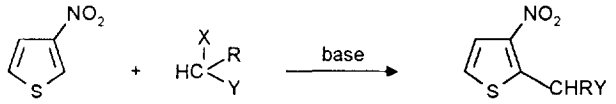


Scheme 3

Recently Bartoli has reported that addition of RMgBr to 2-nitrothiophene gave two isomeric adducts at C-3 and C-5 in ratio 1.7-6.7 depending on the size of R in RMgBr, and claimed that the reaction with MeMgBr in which the adducts C-3 and C-5 are formed in ratio equal 6.7 reflects virtual activity of these positions in **1** toward nucleophilic addition.[18] Since the VNS reaction in **1** with secondary carbanions proceeds selectively at C-3 this conclusion seems unjustified. The orientation pattern of the addition of RMgBr to nitroarenes, which proceeds apparently *via* single electron transfer and radical-radical anion coupling[19] should be a more complicated function of the reactants structure. Strong preference for the nucleophilic addition to **1** at C-3 is clearly shown also by the selective formation of 3-dihalomethylated products in the VNS reaction with CX_3^- anions.[20] In this process, due to the facile ß-elimination of HX from the corresponding σ^H-adducts, virtual orientation of the nucleophilic addition is monitored with a great deal of confidency. Similarly the VNS hydroxylation of **1** proceeds selectively at C-3.[21]

In 3-nitrothiophene (**41**) only position 2 is activated by the nitro group towards nucleophilic addition and, according to our expectations, both secondary and tertiary carbanions gave products of the VNS of hydrogen in position 2- (Table 2). When this position is occupied as in the case of 2-(2-phenylsulfonyl-2-propyl)-3-nitrothiophene, the reaction with carbanions did not take place and the starting materials were recovered.

Table 2. Reactions of 3-Nitrothiophene **41** with CH - Acids.



Entry	R	X	Y	Procedure[a]	Product	
					No.	Yield (%)
1	H	Cl	SO_2Ph	A	**42**	96
2	H	Cl	SO_2NMe_2	A	**43**	40
3	H	PhS	CN	A	**44**	9
4	Me	Cl	SO_2Ph	G	**45**	94
5	Et	Cl	SO_2Ph	G	**46**	38
6	Ph	Cl	SO_2Ph	D	**47**	93

a) See Table 1.

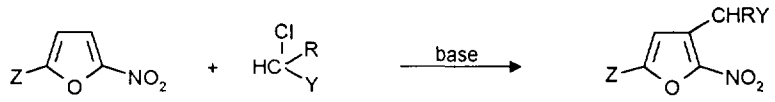
The VNS reactions in nitrofuran and nitropyrrole derivatives.

In 2-nitrofuran **48**, like in 2-nitrothiophene, there are two positions 3 and 5 susceptible to the nucleophilic attack. Many data indicate that furan is less aromatic than thiophene[22] therefore formation of the anionic σ-adducts *via* nucleophilic addition to 2-nitrofuran should proceed with higher equilibrium constant than in the case of 2-nitrothiophene. In spite of that VNS in 2-nitrofuran with chloromethyl phenyl sulfone carbanion gave only low yield (23%) of 3-substituted product, not even traces of 5-substituted product were detected (Table 3, entry 1). Structure of this product was established on the basis of ^1H NMR spectrum and by the independent synthesis. The VNS in the reaction of 5-nitro-2-furancarboxylic acid with chloromethyl phenyl sulfone proceeded similarly to such reaction of nitrobenzoic cids[23] and gave product **53** (Table 3, entry 4) which upon decarboxylation gave compound **49** identical to that obtained directly from **48**.

Low yield and the formation of only 3-substituted product in the reaction of **48** with chloromethyl phenyl sulfone does not correlate with its VNS reaction with CCl_3^- anions. In spite of intrinsic instability of these anions the dichloromethylation of **48** proceeds in good yield (78%), giving two isomeric products of the substitution in positions 5 and 3 in ratio 3:1.[20] One can suppose therefore that also the sulfone carbanion adds mainly in position 5 of 2-nitrofuran but decomposition of this σ-adduct, perhaps *via* the ring openning, occurs faster that the desired ß-elimination, whereas somewhat less favourable addition in position 3 followed by the elimination gave the VNS product. Since CCl_3^- anion contains three leaving groups its σ-adducts in both positions 5 and 3 of **48** undergo

fast ß-elimination so two isomeric dichloromethylation products are formed in good overall yield. This reasoning is supported by results of VNS in **48** with dichloromethyl phenyl sulfone carbanion. In this case, due to the presence of two leaving groups the elimination of HCl from the σ adducts proceeds much faster hence theproduct of the substitution at C-5 was obtained in good yield (Table 3, entry 3). Similarly VNS in **48** with 1-chloro-1-nitropropane anion occures in position 5 (the initial product is converted to **50** via the Neff reaction).

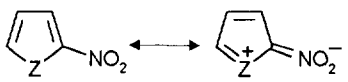
Table 3. Reactions of 2-Nitrofuran and its Derivatives with CH - Acids.



Entry	Nitrofuran derivative		R	Y	Procedure[a]	Product	
	No.	Z				No.	Yield (%)
1	**48**	H	H	SO_2Ph	A	**49**	23
2	**48**	H	Et	NO_2	E	**50**[b,c]	24
3	**48**	H	Cl	SO_2Ph	F	**51**[b]	48
4	**52**	COOH	H	SO_2Ph	A	**53**	75
5	**54**	$COOCH_3$	H	SO_2Ph	A	**55**	75
6	**56**	CN	H	SO_2Ph	A	**57**	82
7	**58**	CH=NOH	H	SO_2Ph	A	**59**	73
8	**58**	CH=NOH	Et	SO_2-*p*-Tol	B	**60**	68
9	**58**	CH=NOH	Ph	SO_2Ph	F	**61**	49

a) See Table 1. *b)* Substitution takes place in position 5. *c)* 2-nitro-5-furyl ethyl ketone.

Thus it appears that orientation of the VNS with CCl_3^- anions reflects intrinsic properties of **48** because the initially formed σ-adducts of CCl_3^- undergo fast β-elimination of HCl, whereas that with chloromethyl sulfone carbanion is an artifact in this respect. This is also in agreement with the reported orientation of the addition of RMgBr to 2-nitrofuran which occurs with slight preference in position 5.[24] Substantial differences in the course of the nucleophilic addition to 2-nitrofuran and 2-nitrothiophene, expressed in different orientation pattern of VNS should be commented. Less aromatic character of the furan ring should favour the addition across C-2 - C-3 bond in the former, contrary to what is actually observed. It appears that efficient conjugation of the donor oxygen atom with the nitro group which can be pictured by resonance structure **62** is responsible for this orientation. Such conjugation with sulfur atom in **1** is much less efficient.



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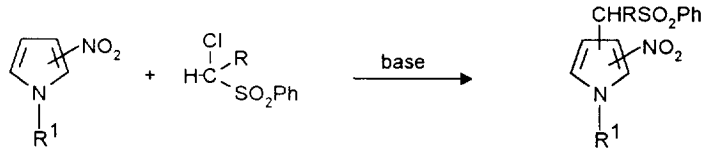
When there is a substituent in position 5 of 2-nitrofuran VNS with chloromethyl, α-chloroethyl and α-chlorobenzyl phenyl sulfones proceeded satisfactorily at C-3. Taking into account that **53** undergoes facile decarboxylation to **49** and that 5-nitro-2-furancarboxylic acid is much more available, stable and gave better results

in the VNS reaction than 2-nitrofuran this approach can be recommended for synthesis of 3-substituted 2-nitrofurans.

Nitropyrroles are strong NH-acids and under highly basic conditions, necessary for the VNS reaction, they are deprotonated to the corresponding anions which are inactive towards nucleophiles. On the other hand N-protected nitropyrroles react satisfactorily with chloromethyl phenyl sulfone carbanions (Table 4). The reaction of N-methyl-2-nitropyrrole **63** surprisingly gave product of the substitution in position 5,[6] not 3 as was erroneously reported in our preliminary communication.[5] Similar orientation pattern was observed in the reaction of N-propyl- and N-isopropyl-2-nitropyrroles. This unexpected orientation can be rationalized by taking into account efficient conjugation of the nitro group with the unshared electron pair of the ring nitrogen as shown in structure **62** (Z = NMe). Such type of the conjugation was directly observed by ^{17}O NMR spectra of **63**.[25] This explanation is strongly supported by the formation of only 3-substituted product in the reaction of N-tosyl-2-nitropyrrole, in which such conjugation is not feasible. Thus it is possible to control the orientation of the VNS reaction in 2-nitropyrrole (3- vs 5- substitution) by changing character of the N-protecting group. When this group is only

Table 4. Reactions of Nitropyrrole Derivatives with Chlorosulfones.



Entry	Nitropyrrole derivative			R	Procedure[a]	Product		
	No.	NO_2 position	R^1			$CHRSO_2Ph$ position	No.	Yield (%)
1	**63**	2	Me	H	A	5	**64**	90
2	**63**	2	Me	Me	B	5	**65**	82
3	**66**	2	*n*-Pr	H	A	5	**67**	93
4	**68**	2	*i*-Pr	H	A	5	**69**	68
5	**70**	2	SO_2p-Tol	H	A	3	**71**	83
6	**72**	2	CH_2OCH_3	H	A	3 , 5	**73 , 74**	14 , 74
7	**75**	3	Me	H	A	2	**76**	86
8	**75**	3	Me	Me	A	2	**77**	71

a) See table 1.

slightly electrophilic, as in the case of N-methoxymethyl derivatives, two isomeric VNS products were formed, isomer 5- being the major one.

Orientation of the VNS in 2-nitropyrrole derivatives differs substantially from these reported by Bartoli for the addition of the Grignard reagents to 1-methyl- and 1-benzyl-2-nitropyrroles which always produced mixtures

of isomeric adducts in positions 3 and 5 with slight preference of the latter.[18] Since it is supposed that this reaction proceeds *via* initial single electron transfer[19] such discrepancy in the orientation pattern is not surprising.

As one could expect the reaction with N-methyl-3-nitropyrrole produced only one product of the substitution at C-2 (Table 4, entry 7 and 8).

The results presented in this paper indicate that the VNS reaction is a powerful and versatile tool in synthesis of substituted derivatives of thiophene, furan and pyrrole.

EXPERIMENTAL

Melting points are uncorrected. ^{1}H NMR spectra were recorded - unless otherwise noted - on a Varian EM 360 (60 Mhz) or, in specified cases, on a Varian Gemini (200 MHz) and a Brucker AM 500 (500 MHz) instruments. The chemical shifts were measured in $CDCl_3$ (unless otherwise noted) as δ in relation to TMS as internal standard. IR spectra were recorded on a Beckmann IR 4240 spectrometer in KBr. Mass spectra were obtained on a Finnigan 8200 (70 eV) spectrometer.

The following starting materials were prepared according to the published proceedures: 2-bromo-5-nitrothiophene,[26] 3-bromo-5-nitrothiophene,[27] 3-nitrothiophene,[28] 2-iodo-5-nitro-thiophene,[29] 2,5-dinitro-thiophene,[28] 2-nitropyrrole,[30] 3-nitropyrrole,[31] 1-methyl-2-nitro- and 1-methyl-3-nitropyrrole,[31] chloro-methyl phenyl- and chloromethyl p-tolyl sulfone,[32] 1-chloroethyl phenyl sulfone,[33] 1-chloropropyl phenyl sulfone,[34] chloromethyl *tert*-butyl sulfone,[35] α-chlorobenzyl phenyl and *p*-tolyl sulfones,[36] phenyl chloromethanesulfonate,[37] *o*-cyanobenzyl, *p*-cyanobenzyl and *p*-(phenylsulfonyl)benzyl phenyl sulfides,[38] 2-chloropropionitrile,[39] 2-chloro-3-methylbutyronitrile,[40] N,N-dimethylchloromethanosulfonamide,[41] 5-nitrofurfural oxime,[42] 2-cyjano-5-nitrofuran,[43] 5-nitro-2-furanocarboxylic acid and its methyl ester.[42]

The following starting materials were prepared according to new or modified procedures:

1-n-Propyl-2-nitropyrrole (**66**). To a stirred suspension of powdered KOH (1.5 g, 27 mmol) in DMSO (25 ml), 2-nitropyrrole (1.4 g, 1.3 mmol) was added at 20-25°C After 5 min n-propyl iodide (25 g, 15 mmol) was added dropwise, the mixture stirred for 1 h, poured into water, the product extracted with ether, the solvent evaporated and the residue chromatographed. Yield of **66** 1.66 g, 83%, oil ^{1}HNMR δ 0.92 (t, J=7 Hz, 3H), 1.93 (q, J=7 Hz, 2H), 4.38 (t, J=7 Hz, 2H), 6.21 (dd, J=4.3, 2.8 Hz, 1H), 6.98 (m, 1H), 7.22 (dd, J=4.3, 2.8 Hz, 1H). Anal. calcd for $C_7H_{10}N_2O_2$ (MW 154.17) C, 54.54; H, 6.54; N, 18.17%. Found: C, 54.40; H, 6.57; N, 17.93%.

1-Isopropyl-2-nitropyrrole (**68**) was obtained in the same way as **66** using iso-propyl iodide, yield 42%, mp. 29-32°C (hexane).^{1}H NMR (CCl_4) δ = 1.48 (d, J = 7 Hz, 6H), 5.19-5.80 (m, 1H), 6.05-6.10 (m,1H), 6.92-7.21 (m, 2H). Anal. calcd for $C_7H_{10}N_2O_2$ (MW 154.17) C, 54.54; H, 6.54; N, 18.17%. Found C, 54.44; H, 6.47; N, 18.00%.

1-Methoxymethyl-2-nitropyrrole (**72**). To a stirred suspension of sodium hydride (84 mg, 3.5 mmol) in DMF (3 ml) a solution of 2-nitropyrrole (189 mg, 1.70 mmol) in DMF (2 ml) was added. After 3 min chloromethyl methyl ether (161 mg, 2.0 mmol) in THF (1 ml) was addeed, the mixture was stirred for 15 min at room temperature, poured into water and extracted with ethyl acetate. The product was purified *via* chromatography (SiO_2, hexane-ethyl acetate 6:1), yield 225 mg, 85%, pale yellow oil. ^{1}H NMR δ 3.40 (s, 3H), 5.75 (s, 2H), 6.25-6.46 (m, 1H), 7.12-7.55 (m, 2H); Anal. calcd for $C_6H_8N_2O_3$ (MW 156.14) C, 46.15; H, 5.16; N, 17.94%; Found C, 46.21; H, 5.12; N, 17.46%.

1-p-Toluenesulfonyl-2-nitropyrrole (**70**). A solution of 2-nitropyrrole (1.83 g, 15 mmol), p-toluenesulfonyl chloride (2.86 g, 15 mmol) and triethyl amine (3.03 g, 30 mmol) in methylene chloride was refluxed for 1h. Triethyl amine hydrochloride was filtered off from the cold mixture, the solvent evaporated, the residue dissolved in toluene-ethyl acetate the solution passed through silicagel the solvent evaporated and the product recrystalized from methanol, yield 3.91 g, 98%, mp. 100°C; ^{1}H NMR δ 2.49 (s, 3H), 6.38 (m,1H), 7.30-8.22 (m, 6H). Anal. calcd for $C_{11}H_{10}N_2O_4S$ (MW 266.27) C, 49.62; H, 3.79; N, 10.52%; Found C, 49.37; H, 3.68, N, 10.33%.

Reactions of carbanions with nitroheterocycles, general procedures.

A. *$KOH/NH_{3\ liquid}$*. To a stirred suspension of powdered KOH (1 g, 18 mmol) in liquid ammonia (25 ml) a solution of the nitro heterocycle (2.5 mmol) and the carbanion precursor (2.5 mmol) in tetrahydrofuran (5 ml) was added dropwise. The reaction in refluxing ammonia was carried out for 1h then ammonium chloride (1 g, 19 mmol) was added and the ammonia evaporated. The residue was treated with diluted (1:20) hydrochloric acid (100 ml) the product extracted with methylene chloride, the extract washed, dried and the solvent evaporated. The product was purified *via* column chromatography on SiO_2, using hexane - ethyl acetate as eluent.

B. *tert-BuOK/$NH_{3\ liquid}$*. To a stirred solution of the alkoxide (0.84g, 7.5 mmol) in liquid ammonia (20 ml) a solution of the nitro heterocycle (2.5 mmol) and the CH-acid (2.5 mmol) in dry THF (5 ml) was added dropwise. The reaction was carried out for 2 h then ammonium chloride (1.0 g, 19 mmol) was added and the mixture was worked-up as in the procedure **A**. The product was purified *via* column chromatography (hexane -ethyl acetate) or by recrystallization of the crude product from CCl_4 (**16**).

C. *tert-BuOK/THF*. *tert*-BuOK (0.84 g, 7.5 mmol) was dissolved in THF (20 ml) and the solution was cooled to -50°C. A solution of the nitro heterocycle (2.5 mmol) and the CH-acid (2.5 mmol) in THF (5 ml) was then added and the reaction mixture was stirred at -40 ÷ -30°C for 30 min. Acetic acid (1 ml) was added, the mixture was poured into water (150 ml) and worked-up as in the procedure **A**.

D. *tert-BuOK/DMSO*.To a stirred solution of *tert*-BuOK (0.84 g, 7.5 mmol) in DMSO (20 ml) a solution of the nitro heterocycle (2.5 mmol) and the CH-acid (2.5 mmol) in DMSO (5 ml) was then added dropwise. The reaction mixture was stirred at 20 ÷ 30°C for 15 min. then poured into diluted (1 : 20) hydrochloric acid (100 ml) and worked-up as in the procedure **A**.

E. *KOH/DMSO*. The reaction was carried out as in the procedure **D** except that KOH (1.0 g, 18 mmol) susspended in DMSO was used as a base. 2-Chloro-2-nitropropane was used in 1.2 molar excess over the nitro heterocycle and the reaction mixture was poured on ice and acidified with acetic acid. The products were isolated using benzene - chloroform (**11**, **50**) or hexane - ethyl acetate (**21**, **30**) as eluent in column chromatography.

F. *tert-BuOK/DMF*. The reaction was carried out as in the procedure **C** at -30°C for 10 min. in DMF (20 ml). The reaction mixture was poured into diluted hydrochloric acid (200 ml), extracted with ethyl acetate and worked-up as in the procedure **A**.

G: *MeONa/$NH_{3\ liquid}$*. The reaction was carried out as in the procedure **B** using MeONa instead of *t*-BuOK.

N,N-dimethyl-(2-nitro-3-thienyl)methanesulfonamide (**2**), mp 104°C (MeOH); ^{1}H NMR (CD_3COCD_3) δ 2.84 (s, 6H), 4.88 (s, 2H), 7.37 (d, J = 5.8 Hz, 1H), 7.88 (d, J = 5.8 Hz, 1H); Anal. cald for $C_7H_{10}N_2O_4S_2$ (MW 250.30) C, 33.59; H, 4.03; N, 11.19%; Found C, 33.47; H, 3.99; N, 11.30 %.

(2-nitro-3-thienyl)methyl phenyl sulfone (**3**), mp 155°C (MeOH); ^{1}H NMR (CD_3COCD_3), δ 5.08 (s, 2H), 7.20 (d, J = 5.8 Hz, 1H), 7.60-7.75 (m, 5H), 7.84 (d, J = 5.8 Hz); Anal. calcd for $C_{11}H_9NO_4S_2$ (MW 283.33) C, 46.63;

H, 3.20; N, 4.94%; Found C, 46.61; H, 3.14; N, 4.64%.

(2-nitro-3-thienyl)methyl p-tolyl sulfone (**4**), mp 183°C (MeOH); ^{1}H NMR (CD_3COCD_3) δ 2.48 (s, 3H), 5.10 (s, 2H), 7.28 (d, J = 5.8 Hz, 1H), 7.44-7.81 (m, 4H), 7.95 (d, J = 5.8 Hz, 1H); Anal. calcd for $C_{12}H_{11}NO_4S_2$ (MW 297.35) C, 48.47; H, 3.73; N, 4.71%; Found C, 48.58; H, 3.71; N, 4.52%.

phenyl (2-nitro-3-thienyl)methanesulfonate (**5**), mp 72°C (MeOH); ^{1}H NMR δ 5.27 (s, 2H), 7.30-7.63 (m, 6H), 7.70 (d, J = 5.8 Hz, 1H); Anal. calcd for $C_{11}H_9NO_5S_2$ (MW 299.33) C, 44.14; H, 3.03; N, 4.68%; Found C, 43.91; H, 2.93; N, 4.70%.

t-butyl (2-nitro-3-thienyl)acetate (**6**), mp 45°C (MeOH); ^{1}H NMR δ 1.49 (s, 9H), 4.04 (s, 2H), 7.10 (d, J = 5.8 Hz, 1H), 7.58 (d, J = 5.8 Hz, 1H). Anal. calcd for $C_9H_{13}NO_4S$ (MW 343.28) C, 49.37; H, 5.39; N, 5.76%; Found C, 49.57; H, 5.40; N, 5.80%.

(2-nitro-3-thienyl)acetonitrile (**7**), mp 64°C (MeOH); ^{1}H NMR (CD_3COCD_3) δ 4.34 (s, 2H), 7.38 (d, J = 5.8 Hz, 1H), 7.99 (d, J = 5.8 Hz, 1H); Anal. calcd for $C_6H_4N_2O_2S$ (MW 168.17) C, 42.62; H, 2.40; N, 16.66%; Found C, 42.84; H, 2.23; N, 16.69%.

2-nitro-3-(2-cyanophenylmethyl)thiophene (**8**), 100°C (heptane - AcOEt); ^{1}H NMR δ 4.71 (s, 2H), 6.48 (d, J = 5.8 Hz, 1H), 7.35-7.90 (m, 5H); Anal. calcd for $C_{12}H_8N_2O_2S$ (MW 244.27) C, 59.01; H, 3.30; N, 11.47%; Found C, 59.37; H, 3.01; N, 11.53%.

2-nitro-3-(4-cyanophenylmethyl)thiophene (**9**), 110°C (heptane - AcOEt); ^{1}H NMR δ 4.59 (s, 2H), 7.01 (d, J = 5.8 Hz, 1H), 7.40-7.80 (m, 5H); Anal. calcd for $C_{12}H_8N_2O_2S$ (MW 244.27) C, 59.01; H, 3.30; N, 11.47%; Found C, 59.31; H, 3.07; N, 11.18%.

4-[(2-nitro-3-thienyl)methyl]phenyl phenyl sulfone (**10**), mp 149°C (MeOH); ^{1}H NMR δ 4.48 (s, 2H), 6.90 (d, J = 5.8 Hz, 1H), 7.50-7.75 (m, 3H), 7.90-8.15 (m, 2H); Anal. calcd for $C_{17}H_{13}NO_4S_2$ (MW 359.43) C, 58.81; H, 3.65; N, 3.90; Found C, 56.74; H, 3.42; N, 3.78%.

(2-nitro-3-thienyl)methyl phenyl ketone (**11**), mp 104-105°C (EtOH); ^{1}H NMR δ 4.90 (s, 2H), 7.20 (d, J = 6 Hz, 1H), 7.56 - 7.87 (m, 4H), 8.14 - 8.43 (m, 2H); Anal. calcd for $C_{12}H_9NO_3S$ (MW 247.27) C, 58.29; H, 3.67; N, 5.66%; Found C, 58.00; H, 3.48; N, 5.49%.

1-(2-nitro-3-thienyl)ethyl phenyl sulfone (**12**), mp 140°C (EtOH); ^{1}H NMR (CD_3COCD_3) δ 1.79 (d, J = 7 Hz, 3H), 5.83 (q, J = 7 Hz, 1H), 7.58 (d, J = 5.8 Hz, 1H), 7.70-7.80 (m, 5H), 8.10 (d, J = 5.8 Hz, 1H); Anal. calcd for $C_{12}H_{11}NO_4S_2$ (MW 297.35) C, 48.47; H, 3.73; N, 4.71; Found C, 48.70; H, 3.62; N, 4.38%.

1-(2-nitro-5-thienyl)ethyl phenyl sulfone (**13**), mp 135°C (EtOH); ^{1}H NMR (CD_3COCD_3) δ 1.80 (d, J = 7 Hz, 3H), 5.03 (q, J = 7 Hz, 1H), 7.09 (d, J = 3.8 Hz, 1H), 7.48 (d, J = 3.8 Hz, 1H), 7.65-7.90 (m, 5H); Anal. calcd for $C_{12}H_{11}NO_4S_2$(MW 297.35) C, 48.47; H, 3.73; N, 4.71%; Found C, 48.52; H, 3.76; N, 4.66%.

1-(2-nitro-3-thienyl)propyl phenyl sulfone (**14**), mp 123°C (hexane - AcOEt); ^{1}H NMR δ 0.92 (t, J = 7 Hz, 3H), 1.95-2.70 (m, 2H), 5.71 (dd, J = 10.5 and 5.0 Hz, 1H), 7.30-7.85 (m, 7H); Anal. calcd for $C_{13}H_{13}NO_4S_2$ (MW 311.38) C, 50.15; H, 4.21; N, 4.50%; Found C, 50.34; H, 4.00; N, 4.58%.

1-(2-nitro-5-thienyl)propyl phenyl sulfone (**15**), mp 91°C (hexane - AcOEt); ^{1}H NMR δ 0.98 (t, J = 7 Hz, 3H), 1.90-2.65 (m, 2H), 4.38 (dd, J = 10 Hz and 4 Hz, 1H), 6.93 (d, J = 3.8 Hz, 1H), 7.50-7.95 (m, 6H); Anal. calcd for $C_{13}H_{13}NO_4S_2$ (MW 311.38) C, 50.15; H, 4.21; N, 4.50%; Found C, 50.28; H, 4.24; N, 4.43%.

α-(2-nitro-5-thienyl)benzyl phenyl sulfone (**16**), mp 141°C (EtOH); ^{1}H NMR δ 6.71 (s, 1H), 7.81 (m, 11H), 8.09 (d, J = 3.8 Hz, 1H); Anal. calcd for $C_{17}H_{13}NO_4S_2$ (MW 359.43) C, 56.81; H, 3.64; N, 3.90%; Found C, 56.44; H, 3.40; N, 3.84%.

2-(2-nitro-3-thienyl)propionitrile (**17**), mp 73°C (hexane); ^{1}H NMR δ 1.78 (d, J = 7 Hz, 3H), 5.04 (q, J = 7 Hz,

1H), 7.45 (d, J = 5.8 Hz, 1H), 7.73 (d, J = 5.8 Hz, 1H); Anal. calcd for $C_7H_6N_2O_2S$ (MW 182.20) C, 46.15; H, 3.32; N, 15.37%; Found C, 45.86; H, 3.31; N, 14.77%.

2-(2-nitro-5-thienyl)propionitrile (**18**), oil; ^{1}H NMR δ 1.81 (d, J = 7 Hz, 3H), 4.31 (q, J = 7 Hz, 1H), 7.30 (d, J = 3.8 Hz, 1H), 8.03 (d, J = 3.8 Hz, 1H); Anal. calcd for $C_7H_6N_2O_2S$ (MW 182.20) C, 46.15; H, 3.32; N, 15.37%; Found C, 46.06; H, 3.13; N, 14.99%.

2-(2-nitro-3-thienyl)isobutyronitrile (**19**), oil; ^{1}H NMR δ 1.20 (d, J = 7 Hz, 6H), 2.35 (m, 1H), 4.97 (d, J = 7 Hz, 1H), 7.45 (d, J = 5.8 Hz, 1H), 7.86 (d, J = 5.8 Hz, 1H); Anal. calcd for $C_9H_{10}N_2O_2S$ (MW 210.26) C, 51.41; H, 4.79; N, 13.32%; Found C, 51.59; H, 4.70; N, 13.04%.

2-(2-nitro-5-thienyl)isobutyronitrile (**20**), oil; ^{1}H NMR δ 1.24 (d, J = 7 Hz, 6H), 2.27 (m, 1H), 4.08 (d, J = 7 Hz, 6H), 2.27 (m, 1H), 4.08 (d, J = 7 Hz, 1H), 7.32 (d, J = 3.8 Hz, 1H), 8.11 (d, J = 3.8 Hz, 1H); Anal. calcd for $C_9H_{10}N_2O_2S$ (MW 210.26) C, 51.41; H, 4.79; N, 13.32%; Found C, 51.36; H, 4.78; N, 13.32%.

2-nitro-5-propionylthiophene (**21**), mp 82-84°C lit[44] 84-87°C ^{1}H NMR δ 1.30 (t, J = 7 Hz, 3H), 3.06 (q, J = 7 Hz, 2H), 7.85 (d, J = 3.8 Hz, 1H), 8.16 (d, J = 3.8 Hz, 1H); IR (cm^{-1}) 1670, 1500, 1335.

(3-bromo-2-nitro-5-thienyl)methyl phenyl sulfone (**23**), mp 201°C (hexane - EtOAc); ^{1}H NMR δ 5.00 (s, 2H), 7.41 (s, 1H), 7.58-8.30 (m, 5H); Anal. calcd for $C_{11}H_8BrNO_4S_2$ (MW 362.21) C, 36.48; H, 2.23; N, 3.87; Br, 22.06%; Found C, 36.47; H, 2.02; N, 3.78; Br, 22.86%.

chloro-(2-nitro-3-thienyl)methyl phenyl sulfone (**24**), mp 171°C (hexane - EtOAc); ^{1}H NMR δ 5.82 (s, 1H), 7.50-8.12 (m, 7H); Anal. calcd for $C_{11}H_8ClNO_4S_2$ (MW 317.8); C, 41.58; H, 2.54; N, 4.40%; Found C, 42.06; H, 2.23; N, 4.04%.

(5-bromo-2-nitro-3-thienyl)methyl t-butyl sulfone (**26**), mp 147°C (hexane - EtOAc); ^{1}H NMR δ 1.51 (s, 9H), 4.90 (s, 2H), 7.47 (s, 1H); Anal. calcd for $C_9H_{12}BrNO_4S_2$ (MW 342.23); C, 31.59; H, 3.53; N, 4.09%; Found C, 31.71; H, 3.78; N, 4.14%.

N,N-dimethyl-(5-bromo-2-nitro-3-thienyl)methanesulfonamide (**27**), mp 111°C (hexane - EtOAc); ^{1}H NMR (CD_3COCD_3) δ 2.80 (s, 6H), 4.89 (s, 2H), 7.56 (s, 1H); Anal. calcd for $C_7H_9BrN_2O_4S_2$ (MW 329.19) C, 25.54; H, 2.76; N, 8.51%; Found C, 25.48; H, 2.71; N, 8.43%.

(5-bromo-2-nitro-3-thienyl)methyl phenyl sulfone (**28**), mp 200-204°C dec. (MeOH); ^{1}H NMR (CD_3COCD_3) δ 5.16 (s, 2H), 7.31 (s, 1H), 7.69-7.88 (m, 5H); Anal. calcd for $C_{11}H_8BrNO_4S_2$ (MW 362.22) C, 36.48; H, 2.23; N, 3.87%; Found C, 36.69; H, 2.21; N, 3.65%.

1-(5-bromo-2-nitro-3-thienyl)propyl phenyl sulfone (**29**), mp 121°C (hexane - EtOAc); ^{1}H NMR (CD_3COCD_3) δ 0.97 (t, J = 7 Hz, 3H), 1.92-2.70 (m, 2H), 5.74 (dd, J = 10, 5 Hz, 1H), 7.60 (s, 1H), 7.64-8.00 (m, 5H); Anal. calcd for $C_{13}H_{12}BrNO_4S_2$ (MW 390.28) C, 40.01; H, 3.10; N, 3.59%; Found C, 39.66; H, 2.88; N, 3.65%.

α-(5-bromo-2-nitro-3-thienyl)benzyl sulfone (**30**), 130°C (hexane - EtOAc), ^{1}H NMR δ 2.39 (s, 3H), 6.78 (s, 1H), 7.10-7.75 (m, 9H), 8.17 (s, 1H); Anal calcd for $C_{18}H_{14}BrNO_4S_2$ (MW 452.35) C, 47.79; H, 3.12; N, 3.10%; Found C, 47.65; H, 2.94; N, 2.93%.

(5-bromo-2-nitro-3-thienyl)acetonitrile (**31**), 91°C (MeOH); ^{1}H NMR δ 4.26 (s, 2H), 7.51 (s, 1H); Anal. calcd for $C_6H_3BrN_2O_2S$ (MW 247.07) C, 29.17; H, 1.22; N, 11.34%; Found C, 28.97; H, 1.01; N, 11.36%.

N,N-dimethyl-(5-iodo-2-nitro-3-thienyl)methanesulfonamide (**33**), mp 139°C (hexane - EtOAc), ^{1}H NMR δ 2.93 (s, 6H), 4.82 (s, 2H), 7.63 (s, 1H); Anal. calcd for $C_7H_9IN_2O_4S_2$ (MW 376.19) C, 22.35; H, 2.41; N, 7.45%; Found C, 22.34; H, 2.38; N, 7.33%.

(5-cyano-2-nitro-3-thienyl)methyl phenyl sulfone (**35**), mp 176°C dec. (EtOH); ^{1}H NMR (CD_3COCD_3) δ 5.24 (s, 2H), 7.65-8.00 (m, 6H); Anal. calcd for $C_{12}H_8N_2O_4S_2$ (MW 308.32) C, 46.75; H, 2.62; N, 9.09%; Found C,

46.76; H, 2.53; N, 9.06%.

(2,5-dinitro-3-thienyl)methyl t-butyl sulfone (**37**), mp 171°C (acetone); ^{1}H NMR (CD_3COCD_3) δ 1.53 (s, 9H), 5.20 (s, 2H), 8.37 (s, 1H); Anal. calcd for $C_9H_{12}N_2O_6S_2$ (MW 308.33) C, 35.06; H, 3.98; N, 9.09%; Found C, 35.08; H, 3.82; N, 8.99%.

2,5-dinitro-3,4-di-(t-butylsulfonylmethyl)thiophene (**38**), mp 212°C (acetone), ^{1}H NMR(CD_3COCD_3-CD_3SOCD3) δ 1.50 (s, 18H), 5.39 (s, 4H); Anal. calcd for $C_{14}H_{22}N_2O_8S_3$ (MW 442.53) C, 38.00; H, 5.01; N, 6.33%; Found C, 37.95; H, 4.99; N, 7.03%.

chloro-(2-nitro-5-thienyl)methyl t-butyl sulfone (**39**), contaminated sample was isolated. ^{1}H NMR (CD_3COCD_3); δ 1.53 (s, 9H), 7.09 (s, 1H), 7.70 (d, J = 3.9 Hz ,1H), 8.16 (d, J = 3.9 Hz, 1H); MS (EI, 70eV) 281 (5), 265 (4), 177 (30), 160 (5), 143 (25), 130 (5), 95 (12).

2-nitro-3-(2-p-tolylsulfonyl-2-propyl)-5-phenylsulfonylmethyl thiophene (**41**), mp 137°C (MeOH); ^{1}H NMR (CD_3COCD_3) δ 1.76 (s, 6H), 2.47 (s, 3H), 4.58 (s, 2H), 7.19 (s, 1H), 7.25-8.15 (m, 9H); Anal. calcd for $C_{21}H_{21}NO_6S_3$ (MW 479.6) C, 52.59; H, 4.41; N, 2.92%; Found C, 53.38; H, 4.49; N, 2.63%.

(3-nitro-2-thienyl)methyl phenyl sulfone (**42**), mp 134°C (MeOH); ^{1}H NMR (CD_3COCD_3) δ 5.42 (s, 2H), 7.80-8.15 (m, 7H); Anal. calcd for $C_{11}H_9NO_4S_2$ (MW 283.32) C, 46.63; H, 3.20; N, 4.94%; Found C, 46.58; H, 3.01; N, 4.77%.

N,N-dimethyl-(3-nitro-2-thienyl)methanesulfonamide (**43**), mp 147°C (CCl_4); ^{1}H NMR (CD_3COCD_3) δ 2.90 (s, 6H), 5.13 (s, 2H), 7.80 (s, 2H); Anal. calcd for $C_7H_{10}N_2O_4S_2$ (MW 250.30) C, 33.59; H, 4.03; N, 11.19%; Found C, 33.34; H, 4.09; N, 11.11%.

(3-nitro-2-thienyl)acetonitrile (**44**), oil, ^{1}H NMR δ 4.76 (s, 2H), 7.08 (d, J = 5.9 Hz, 1H), 7.43 (d, J = 5.9 Hz, 1H); Anal. calcd for $C_6H_4N_2O_2S$ (MW 168.17) C, 42.85; H, 2.40; N, 16.66%; Found C, 42.70; H, 2.11; N, 17.41%.

1-[(3-nitro-2-thienyl)]ethyl phenyl sulfone (**45**), mp 152-154°C (CCl_4); ^{1}H NMR (CD_3COCD_3) δ 1.55 (d, J = 7Hz, 3H), 5.90 (q, J = 7 Hz, 1H), 7.45-7.85 (m, 7H); Anal. calcd for $C_{12}H_{11}NO_4S_2$; (MW 297.35) C, 48.47; H, 3.73; N, 4.71%; Found C, 48.45; H, 3.58; N, 4.55%.

1-(3-nitro-2-thienyl)propyl phenyl sulfone (**46**), mp 103°C (MeOH), ^{1}H NMR δ 1.00 (t, J = 7Hz, 3H), 1.90-2.80 (m, 2H), 5.98 (dd, J = 4.0, 10.4 Hz, 1H), 7.30 - 7.95 (m, 7H); Anal. calcd for $C_{13}H_{13}NO_4S_2$ (MW 311.36) C, 50.14; H, 4.21; N, 4.50%; Found C, 51.09; H, 4.56; N, 4.05%.

α-(3-nitro-2-thienyl)benzyl phenyl sulfone (**47**), mp 138°C (MeOH); ^{1}H NMR δ 7.18 (s, 1H), 7.40-7.95 (m, 12H); Anal. calcd for $C_{17}H_{13}NO_4S$ (MW 359.43) C, 56.81; H, 3.46; N, 3.90%; Found C, 56.75; H, 3.38; N, 3.97%.

(2-nitro-3-furyl)methyl phenyl sulfone (**49**), mp 151°C (MeOH); ^{1}H NMR δ 4.79 (s, 2H), 6.96 (d, J = 1.8 Hz, 1H), 7.52-7.99 (m, 6H); Anal. calcd for $C_{11}H_9NO_5S$ (MW 267.28) C, 49.44; H, 3.39; N, 5.24%; Found C, 49.18; H, 3.20; N, 5.40%.

2-nitro-5-furyl ethyl ketone (**50**), mp 64-65°C (hexane); lit.[45] mp 68-70°C ^{1}H NMR δ 1.26 (t, J = 7 Hz, 3H), 3.01 (q, J = 7 Hz, 2H), 7.27-.52 (m, 2H); IR (cm^{-1}) 1682, 1530, 1350, Anal. calcd for $C_7H_7NO_4$ (MW 169.15) C, 49.71; H, 4.17; N, 8.28%; Found C, 49.58; H, 4.07; N, 8.30%.

chloro-(2-nitro-5-furyl)methyl p-tolyl sulfone (**51**), mp 122°C (MeOH); ^{1}H NMR (200 MHz) δ .49 (s, 3H), 5.71 (s, 1H), 6.90 (d, J = 3.8 Hz, 1H), 7.30 (d, J = 3.8 Hz, 1H), 7.39 (m, 2H), 7.76 (m, 2H); Anal. calcd for $C_{12}H_{10}NO_5SCl$ (MW 315.72) C, 45.65; H, 3.19; N, 4.44%; Found C, 45.71; H, 3.19; N, 4.34%.

2-nitro-3-(phenylsulfonylmethyl)-5-furanocarboxylic acid (**53**), mp 205°C (MeOH); ^{1}H NMR (CD_3COCD_3) δ 5.00 (s, 2H), 5.95 (s, 1H), 7.55 (s, 1H), 7.70-8.00 (m, 5H); Anal. calcd for $C_{12}H_9NO_7S$ (MW 311.27) C, 46.30;

H, 2.91; N, 4.50%; Found C, 46.00; H, 2.65; N, 4.54%.

methyl 2-nitro-3-(phenylsulfonylmethyl)-5-furanocarboxylate (**55**), mp 124°C (MeOH); ^{1}H NMR δ 4.05 (s, 3H), 4.86 (s, 2H), 7.40 (s, 1H), 7.62-8.10 (m, 5H); Anal. calcd for $C_{13}H_{11}NO_7S$ (MW 325.30) C, 48.00; H, 3.41; N, 4.31%; Found C, 48.11; H, 3.30; N, 4.51%.

2-nitro-3-(phenylsulfonylmethyl)-5-furanocarbonitrile (**57**), mp 168-170°C (MeOH); ^{1}H NMR (CD_3COCD_3) δ 4.98 (s, 2H), 7.61-8.10 (m, 6H); Anal. calcd for $C_{12}H_8N_2O_5S$ (MW 292.27) C, 49.31; H, 2.76; N, 9.58%; Found C, 50.17; H, 2.81; N, 9.32%.

5-nitro-4-(phenylsulfonylmethyl)-2-furfural oxime (**59**), mp 173°C (MeOH); ^{1}H NMR (CD_3COCD_3) δ 5.04 (s, 2H), 7.62-8.18 (m, 8H); Anal. calcd for $C_{12}H_{10}N_2O_6S$ (MW 310.30) C, 46.47; H, 3.25; N, 9.03%; Found C, 46.34 H, 3.09; N, 9.06%

5-nitro-4-(1-p-tolylsulfonylpropyl)-2-furfural oxime (**60**), mp 152°C (CCl_4); ^{1}H NMR δ 0.96 (t, J = 7 Hz, 3H), 1.90-2.66 (m, 5H), 5.33 (dd, J = 11, 4.5 Hz, 1H), 7.25-8.00 (m, 6H), 8.12 (s, 1H); Anal. calcd for $C_{15}H_{16}N_2O_6S$ (MW 352.29) C, 51.14; H, 4.59; N, 7.93%; Found C, 51.25 H, 4.53; N, 7.88%.

5-nitro-4-(α-phenylsulfonylbenzyl)-2-furfural oxime (**61**), mp 169°C (CCl_4); ^{1}H NMR (CD_3COCD_3) δ 6.47 (s, 1H), 7.40-7.88 (m, 12H), 8.01 (s, 1H); Anal. calcd for $C_{18}H_{14}N_2O_6S$ (MW 386.40) C, 55.95; H, 3.65; N, 7.25%; Found C, 55.97; H, 3.39; N, 7.34%.

(1-methyl-2-nitro-5-pyrryl)methyl phenyl sulfone (**64**), mp 164°C (MeOH); ^{1}H NMR (500 MHz) δ 3.87 (s, 3H), 4.40 (s, 2H), 5.87 (d, J = 4.2 Hz, 1H), 7.10 (d, J = 4.2 Hz, 1H), 7.50-7.76 (m, 5H); Anal. calcd for $C_{12}H_{12}N_2O_4S$ (MW 280.29) C, 51.42; H, 4.32; N, 9.99%; Found C, 51.38; H, 4.24; N, 9.70%.

1-(1-methyl-2-nitro-5-pyrryl)ethyl phenyl sulfone (**65**), mp 172-173°C (MeOH); ^{1}H NMR (CD_3COCD_3) δ 1.65 (d, J = 7 Hz, 3H), 3.72 (s, 3H), 5.20 (q, J = 7 Hz, 1H), 6.42 (d, J = 4 Hz, 1H), 7.40 (d, J = 4 Hz, 1H), 7.25-8.05 (m, 5H); Anal. calcd for $C_{13}H_{14}N_2O_4S$ (MW 294.32) C, 53.05; H, 4.79; N, 9.52%; Found C, 52.76; H, 4.59; N, 9.55%.

(1-n-propyl-2-nitro-5-pyrryl)methyl phenyl sulfone (**67**), mp 127-128°C (MeOH); ^{1}H NMR (500 MHz) δ 0.90 (t, J = 7.0 Hz, 3H), 1.68 (m, 2H), 4.32 (t, J = 7.0 Hz, 2H), 4.48 (s, 2H), 5.91 (d, J = 4.2 Hz, 1H), 7.19 (d, J = 4.2 Hz, 1H), 7.62-7.90 (m, 5H); Anal. calcd for $C_{14}H_{16}N_2O_4S$ (MW 308.35) C, 54.53; H, 5.23; N, 9.08%; Found C, 54.50; H, 5.24; N, 8.93%.

(1-isopropyl-2-nitro-5-pyrryl)methyl phenyl sulfone (**69**), mp 109°C (MeOH); ^{1}H NMR (CCl_4) δ 1.47 (d, J = 7.0 Hz, 6H), 4.46 (s, 2H), 5.65-5.85 (m, 1H), 6.11 (d, J = 4.1 Hz, 1H), 6.88-7.85 (m, 6H); Anal. calcd for $C_{14}H_{16}N_2O_4S$ (MW 308.35) C, 54.53; H, 5.23; N, 9.08%; Found C, 54.52; H, 5.20; N, 9.16%.

(1-p-toluenosulfonyl-2-nitro-3-pyrryl)methyl phenyl sulfone (**71**), mp 174-176°C (EtOH); ^{1}H NMR (500 MHz) (CD_3COCD_3) δ 2.52 (s, 3H), 4.80 (s, 2H), 6.56 (d, J = 3.5 Hz, 1H), 7.47-7.49 (m, 2H), 7.58 (d, J = 8.5 Hz, 2H), 7.60-7.66 (m, 3H), 7.85 (d, J = 3.5 Hz, 1H), 7.95 (d, J = 8.5 Hz, 2H); Anal. calcd for $C_{18}H_{16}N_2O_6S_2$ (MW 420.47) C, 51.42; H, 3.84; N, 6.66%; Found C, 51.55; H, 3.81; N, 6.52%.

(1-methoxymethyl-2-nitro-3-pyrryl)methyl phenyl sulfone (**73**), mp 132-134°C (MeOH); ^{1}H NMR (500 MHz) δ 3.28 (s, 3H), 4.79 (s, 2H), 5.56 (s, 2H), 6.49 (d, J = 3.0 Hz, 1H), 6.98 (d, J = 3.0 Hz, 1H), 7.47-7.49 (m, 2H), 7.59-7.63 (m, 1H), 7.74-7.76 (m, 2H); Anal. calcd for $C_{13}H_{14}N_2O_5S$ (MW 310.32) C, 50.32; H, 4.55; N, 9.03%; Found C, 50.69; H, 4.96; N, 9.10%.

(1-methoxymethyl-2-nitro-5-pyrryl)methyl phenyl sulfone (**74**), mp 96-98°C (MeOH); ^{1}H NMR (500 MHz) δ 3.27 (s, 3H), 4.54 (s, 2H), 5.86 (s, 2H), 5.98 (d, J = 4.3 Hz, 1H), 7.15 (d, J = 4.3 Hz, 1H), 7.54-7.58 (m, 2H), 7.6-7.72 (m, 1H), 7.76-7.79 (m, 2H); Anal. calcd for $C_{13}H_{14}N_2O_5S$ (MW 310.32) C, 50.32; H, 4.55; N, 9.03%; Found

C, 50.36; H, 4.49; N, 9.03%.

(1-methyl-3-nitro-2-pyrryl)methyl phenyl sulfone (**76**), mp 153-155°C (MeOH); ^{1}H NMR (CD_3COCD_3) δ 3.90 (s, 3H), 5.23 (s, 2H), 6.75 (d, J = 4 Hz, 1H), 7.04 (d, J = 4 Hz, 1H), 7.79 (m, 5H); Anal. calcd for $C_{12}H_{12}N_2O_4S$ (MW 280.29) C, 51.42; H, 4.32; N, 9.99%; Found C, 51.41; H, 4.20; N, 10.07%.

1-(1-methyl-3-nitro-2-pyrryl)ethyl phenyl sulfone (**77**) mp 126°C (MeOH); ^{1}H NMR (200 Mhz) δ 1.93 (d, J = 7.5 Hz, 3H), 4.04 (s, 3H), 6.11 (q, J = 7.5 Hz, 1H), 6.52 (d, J = 3.4 Hz, 1H), 6.62 (d, J = 3.4 Hz, 1H), 7.4-7.7 (m, 5H); Anal. calcd for $C_{13}H_{14}N_2O_4S$ (MW 294.32) C, 53.24; H, 4.47; N, 9.55%; Found C, 53.34; H, 4.70; N, 9.47%.

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