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CONVENIENT SYNTHESIS OF VARIOUS TERHETEROCYCLIC COMPOUNDS BY Pd(0)-CATALYZED COUPLING REACTIONS

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Abstract - Various terheterocyclic compounds containing thiophene, furan, selenophene, pyridine and thiazole rings have been obtained by the $Pd(PPh_3)_4$-catalyzed coupling of dihalo-substituted heterocyclic compounds with heterocyclic boronic acids, using sodium bicarbonate as base and a 1,2-dimethoxyethane - water mixture as solvent. In cases when the boronic acids were not available or easily deboronated, and/or the heterocyclic halo derivatives were unstable in alkaline solution, trialkylstannylheterocycles were used instead of boronic acids in the coupling with dihaloheterocycles, with THF as solvent and $PdCl_2(PPh_3)_2$ as catalyst. The naturally occurring 3'-methoxy-2,2':5',2"-terthiophene was prepared by a copper-promoted nucleophilic substitution of 3'-iodo-2,2':5',2"-terthiophene, previously prepared by Pd(0)-catalyzed coupling of 2,3,5-triiodothiophene with 2-thiophene boronic acid.

RESULTS AND DISCUSSION

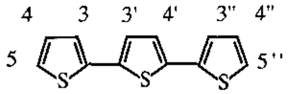
Terheterocyclic compounds are of interest in many fields[1-7]. They show biological properties, such as photo-enhanced activity against fungi, nematodes, insect larvae, algae, and human erythrocytes. They can also act as germination inhibitors and herbicides.[1] Some of them, like 2,2':5',2"-terthiophene(1)[2] and 3'-methoxy-2,2':5',2"-terthiophene,[3] are naturally occurring. Terheterocycles are also of interest as monomers for the preparation of conducting polymers, and their uv spectra and oxidation potential have been studied.[4,5] Some terheterocycles have also recently been used as precursors in the synthesis of electron-acceptor molecules,[6] which represents an interesting approach in the search for new highly conducting molecular complexes. Terheterocycles with three nitrogen-containing rings have been shown to be useful as ligands in iron(II) and nickel(II) complexes.[7]

Kagan et al. synthesized most of their terthiophenes by ring-closure of the middle ring through reaction of bis(thienyl)butadiynes with sodium sulfide[8] or cyclization of 1,4-diketones.[9] Other ring-closure reactions include the treatment of the readily accessible bis[2-oxo-2-(2-thienyl)-ethyl] sulfide with P_4S_{10} or Lawesson's reagent and then heating the resulting 2,6-diaryl-1,4-dithiin.[10] Kagan et al. also prepared terthiophene by iodine oxidation of an ate complex, obtained by stepwise reaction of 9-BBN with methanol, thienyllithium, boron trifluoride-etherate and a second equivalent of thienyllithium.[11] The method, currently most used for the preparation of terheterocycles, was developed by Kumada et al.,[12] and consists of the Ni(0)-catalyzed coupling of two equivalents of heterocyclic Grignard reagents with dihalo heterocycles.[1,4,5] By this method, almost all isomeric terthiophenes were prepared from the isomeric dibromo thiophenes and 2- or 3-thiophene magnesium bromide, using Ni(0)[13] or Pd(0)[1] as catalyst. However, for the preparation of functionalized compounds, the Grignard cross-coupling reactions are obviously limited to substrates whose functional groups do not react with the organometallic reagent. Furthermore, the heterocyclic ring must not add Grignard reagent and the halo derivatives must not be so reactive that they give halogen-magnesium exchange, which would lead to symmetrical by-products (cf.[14,15]).

Some years ago, we modified the Suzuki Pd(0)-catalyzed coupling,[16] so that it became useful in the heterocyclic series.[17,18] This cross-coupling, as well as the Pd(0)-catalyzed coupling of heterocyclic tin derivatives,[19,20] tolerates a variety of functional groups both in the organometallic reagent and in the heterocyclic halide. We were therefore interested in comparing the cross-coupling of boronic acids or tin reagents with the Kumada couplings for the synthesis of terheterocycles. We obtained (**1**) in 40 % yield by coupling 2.4 equiv. of 2-thiopheneboronic acid with one equiv. of 2,5-dibromothiophene, which was stirred under reflux in a mixture of 1,2-dimethoxyethane and aqueous sodium bicarbonate, using $Pd(PPh_3)_4$ as catalyst. An excess of 20 % boronic acid was generally used in the coupling reactions. Less excess resulted in the formation of monocoupled by-products, which were difficult to separate from the terheterocycle. The need for excess boronic acid was due to deboronation even under the weakly alkaline conditions, that were used. The tendency for deboronation was greatest with π-excessive heterocycles.

Using these conditions, 3,2':5',3"-terthiophene (**2**) was obtained from 3-thiopheneboronic acid and 2,5-dibromothiophene in 48 % yield. From 2-thiopheneboronic acid and 2,6-dibromopyridine and p-dibromobenzene, 2,6-di-(2-thienyl)pyridine (**3**) and 1,4-di-(2-thienyl)benzene (**4**) were obtained in 55 % and 39 % yield, respectively. Compound (**3**) has previously been obtained by ring-closure of 5-dimethylamino-N,N-dimethyl-1,5-bis-(2-thienyl)-2,4-pentadieniminium tetrafluoroborate,[21] by the Kumada reaction between 2-thiophenemagnesium bromide and 2,6-dichloropyridine[12] and through the reaction of 2,6-dichloropyridine with 2-thienyllithium.[22] Compound (**4**) has previously been obtained in only 14 % yield from N,N'-dinitroso-N,N'-diacetyl-p-phenylenediamine,[23] and in 22 % yield from bis-(2-thienyl)butadiyne by a Diels-Alder reaction.[24]

The coupling of 2,5-dibromothiazole with 2-thiopheneboronic acid gave 2,5-di-(2-thienyl)thiazole (**5**) only in poor yield (29 %). However, the previous method, which consisted of the reaction of 2-(2-thienyl)-5-thiazoyllithium with 2-thienyllithium and cupric chloride, gave only a 20 % yield.[25] The ^{1}H nmr data previously reported for (**5**) are not in accordance with our findings. Attempts to couple 2,5-dibromothiazole with 3-thiopheneboronic acid and 2-selenopheneboronic acid failed.



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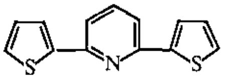

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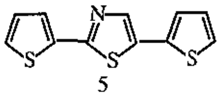

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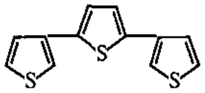

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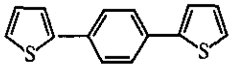

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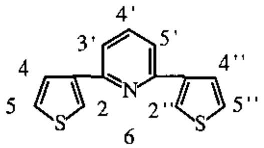
The previously unknown 2,6-di-(3-thienyl)pyridine (**6**), 2,6-di-(3-furyl)pyridine (**7**) and 2,5-di-(3-furyl)thiophene (**8**) were prepared from 2,6-dibromopyridine and 3-thiophene- and 3-furanboronic acid and from 2,5-dibromothiophene and 3-furanboronic acid in about 50 % yield.



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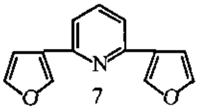

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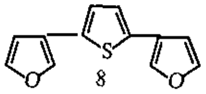

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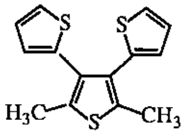
Attempts to use the easily available 3,4-dibromo-2,5-dimethylthiophene in the coupling reaction were not successful. The reaction with 2-thiopheneboronic acid was slow , and after the usual reaction time of four hours, a mixture of the starting material and of mono and dicoupled product was obtained in approximately equal proportions. After 8 h the product ratio was almost the same, due to competing deboronation. Using 3,4-diiodo-2,5-dimethylthiophene instead of the bromo derivative, coupling proceeded smoothly with 2- and 3-thiopheneboronic acids and 3-furanboronic acid to give 2,5-dimethyl-3,4-di-(2-thienyl)thiophene (**9**), 2,5-dimethyl-3,4-di-(3-thienyl)-thiophene (**10**) and 2,5-dimethyl-3,4-di-(3-furyl)thiophene (**11**) in 44-49 % yield.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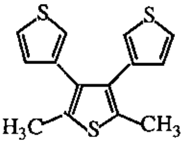
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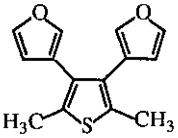
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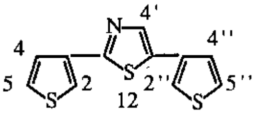
As previously mentioned, we had problems with the coupling of 2,5-dibromothiazole. Furthermore, we were unable to prepare 2-thiazoleboronic acid, which we wanted to use in the synthesis of some di-(2-thiazoyl)-substituted compounds. We therefore investigated if 2,5-dibromothiazole was more stable under the neutral conditions in the $PdCl_2(PPh_3)_2$-catalyzed coupling of heterocyclic tin derivatives, which is carried out in refluxing THF. The reaction of 3-tributylstannylthiophene and 2-tributylstannylselenophene gave 2,5-di-(3-thienyl)thiazole (**12**) and 2,5-di-(2-selenienyl)-thiazole (**13**) in 52 % and 25 % yield. In order to remove tin-containing impurities, the products had to be recrystallized from 90 % ethanol. This problem can be avoided by using the more expensive trimethylstannyl reagent.



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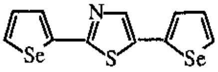
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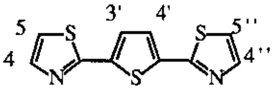
In contrast to 2-thiazoleboronic acid, 2-trimethylstanylthiazole is known.[26] Reacting 2.4 equiv. of this compound with 2,5-dibromothiophene, 2,6-dibromopyridine and p-dibromobenzene gave 2,5-di-(2-thiazoyl)thiophene (**14**), 2,6-di-(2-thiazoyl)pyridine (**15**) and 1,4-di-(2-thiazoyl)-benzene (**16**) in 52, 52 and 67 % yield, respectively. (**14**) was previously prepared by the condensation of dithiocarboxamido-2,5-thiophene and two equiv. of α-haloketone, followed by alkaline hydrolysis and decarboxylation[27] in 8 % overall yield.



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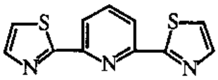
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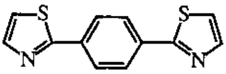
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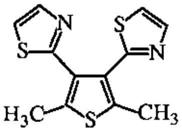
Attempts to synthesize 2,5-dimethyl-3,4-(2-thiazoyl)thiophene (**17**) from 2,5-dimethyl-3,4-diiodo-thiophene and 2-trimethylstannylthiazole failed. Only 2,5-dimethyl-3-iodo-4-thiazoylthiophene was obtained in 16 % yield. These results indicate that the steric demand is greater in couplings with tin compounds than with boronic acids. Somewhat unexpectedly, the coupling of 2-trimethylstannylthiazole with 2,5-dibromothiazole to the unknown 2,5-di-(2-thiazoyl)thiazole (**19**) also failed. The isomeric 2,4-di-(2-thiazoyl)-, 2,5-di-(4-thiazoyl)- and 2,5-di-(5-thiazoyl)thiazoles are known.[28]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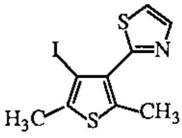
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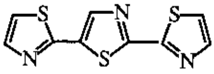
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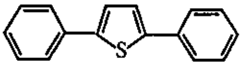
The well-known 2,5-diphenylthiophene (**20**), which has previously been prepared in good yield by treating 2,4-diphenyl-1,4-butandione with Lawesson's reagent,[29] or 1,4-diphenylbutadiyne with hydrogen sulfide,[30] could also be obtained in 61 % yield by the coupling of 2,5-di-(trimethylstannyl)thiophene[31] with 2.4 equiv. of bromobenzene. We tried to apply the same strategy to the synthesis of the naturally-occurring 3'-methoxy-2,2':5',2"-terthiophene (**22**) isolated from the Mexican species Dyssodia, closely related to Tagetes.[3] 3-Methoxythiophene was dimetalated with butyllithium and reacted with trimethylstannyl chloride to yield the 3-methoxy-2,5-di-(trimethylstannyl)thiophene (**21**). This compound was found to be highly explosive, and it destroyed the test tube upon attempted elemental analysis of carbon and hydrogen. Reaction of (**21**) with 2.4 equiv. of 2-bromothiophene using $PdCl_2(PPh_3)_2$ as catalyst resulted in a tarry mixture, from which after tedious purification through column chromatography on silica gel 60, a 6 % yield of pure (**22**) could be obtained, using 2.5:97.5 ethyl acetate:heptane as eluent, followed by hplc on nucleosil OH, using 5:95 ethyl acetate:heptane as eluent. A much better method for the preparation of (**22**) was found by reacting 3'-iodo-2,2':5',2"-terthiophene (**23**), prepared by the Pd(0)-catalyzed coupling of 2,3,5-triiodothiophene with 2-thiopheneboronic acid,[32] with sodium methoxide and cupric oxide in methanol, which gave (**22**) in 54 % yield, together with 30 % of (**1**), which could easily be separated by column chromatography.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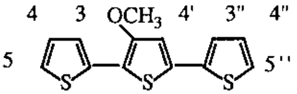

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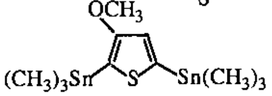
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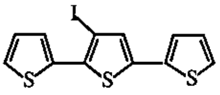
23

Compound (**22**) had the same mass spectral fragmentation as described by Bohlmann and Zdero.[3] However, they made erroneous assignments of two ^1H nmr signals. After using COSY and relating the assignments of the ^{13}C signals with the ^{1}H signals using HETCOR, correct assignments could be made (cf. Table 3).

EXPERIMENTAL

Melting points are uncorrected. The ^{1}H nmr spectra were recorded on a Varian XL-300 spectrometer. The mass spectra were recorded on a Finnigan 4021 spectrometer. Glc analyses were carried out on a Varian 3700 gas chromatograph using a Dexil 300, 3 % column.

General procedure for the $Pd(PPh_3)_4$-catalyzed coupling reaction of compounds **1, 2, 3, 4, 5, 6, 7, 8, 9, 10** and **11**

A 250 ml flask, equipped with condenser, magnetic stirrer and nitrogen inlet, was charged with 10.0 mmol of the dihaloarene, 0.60 mmol of tetrakis-(triphenylphosphine)palladium(0) and 80 ml of 1,2-dimethoxyethane. After stirring for 10 min, 24.0 mmol of the boronic acid was added, immediately followed by 60 ml of 1 M sodium bicarbonate solution. The reaction mixture was refluxed for 4 h, with vigorous stirring under nitrogen. After cooling to room temperature, insoluble traces of the catalyst were filtered off, the organic solvent was evaporated under reduced pressure, 100 ml of water were added to the residue, and the mixture was extracted with three 50 ml portion of ether. The combined ethereal phases were washed with water, and with saturated sodium chloride solution and dried over magnesium sulfate. After evaporation, the product was purified using column chromatography, by using silica gel 60 and pentane as eluent for compound **9**, **10** and **11**. The other compounds were purified in a similar way using 7:3 pentane:ethyl acetate as eluent. For the derivatives the isolated yields and melting points are given in Table 1, elemental analyses in Table 2 and the ^{1}H nmr data in Tables 3 and 4.

General procedure for the $PdCl_2(PPh_3)_2$-catalyzed coupling reaction of compounds **12, 13, 14, 15, 16** and **18**

A 50 ml flask, equipped with condenser, magnetic stirrer and nitrogen inlet was charged with 3.9 mmol of the dihaloarene (for compounds **12**, **13** and **16** twice the descirbed scale), 0.39 mmol of di(triphenylphosphine)palladium(II)dichloride, 20 ml of dry THF followed by 9.3 mmol of trialkylstannylthiophene. The reaction mixture was refluxed for 20 h with vigorous stirring under nitrogen. After cooling to room temperature, the THF was evaporated, followed by the addition of 40 ml of water. The mixture was extracted with three 20 ml portions of ether. The combined ethereal phases were washed with water, and with saturated sodium chloride solution, and dried over magnesium sulfate. Ether was evaporated and the product was purified by column chromatography using silica gel 60 and 7:3 pentane:ethyl acetate as eluent. For the derivatives, isolated yields and melting points are given in Table 1, elemental analyses in Table 2 and ^1H nmr data in Tables 3 and 4.

2,5-Diphenylthiophene (**20**)

A 100 ml flask, equipped with condenser, magnetic stirrer and nitrogen inlet was charged with 4.7 g (30.0 mmol) of bromobenzene, 0.88 g (1.25 mmol) of di(triphenylphosphine)palladium(II)dichloride, 50 ml of dry THF, followed by 5.0 g (12.5 mmol) of 2,5-di(trimethylstannyl)thiophene. The reaction mixture was refluxed for 20 h with vigorous stirring under nitrogen. After cooling to room temperature, the THF was evaporated, followed by the addition of 120 ml of water. The mixture was extracted with three 60 ml portions of ether. The combined ethereal phases were washed with water, and with saturated sodium chloride solution, and dried over magnesium sulfate. The ether was evaporated and the product was purified by column chromatography using silica gel 60 and 7:3 heptane:ethyl acetate as eluent. Isolated yield and melting point are given in Table 1, elemental analysis in Table 2, and the ^1H nmr data in Tables 3 and 4.

2,6-Dibromopyridine and 2-bromothiophene were commercial samples. 2-Trimethylstannylthiazole,[21] 2,5-di(trimethylstannyl)thiophene,[31] 3'-iodo-2,2':5',2"-terthiophene,[32] 2,5-dibromothiophene,[33] 3,4-diiodo-2,5-dimethylthiophene,[34] 3,4-dibromo-2,5-dimethylthiophene,[35] 2-thiopheneboronic acid,[36] 3-thiopheneboronic acid,[36] 3-furanboronic acid,[37] 2-selenopheneboronic acid,[38] 2-bromothiazole,[39] 2,5-dibromothiazole[40] and 3-methoxythiophene[41] were prepared according to the literature.

2-Tributylstannylselenophene

To a stirred solution of 11.8 g (90 mmol) of selenophene and 13.0 g (112 mmol) of TMEDA in 100 ml of dry ether under nitrogen, 70 ml (99 mmol) of butyllithium (1.42 M in hexane) was added dropwise at such a rate that moderate reflux was maintained. The solution was refluxed for 30 min, followed by cooling to -70 °C whereupon 32.2 g (99 mmol) of tributylstannyl chloride dissolved in 30 ml of dry etherwere added at such a rate that the temperature did not exceed -70 °C. The solution was stirred for 4 h at the same temperature, and then allowed to reach room temperature. Water was added to the mixture, the organic phase was separated and the 200 ml aqueous phase was extracted with three 50 ml portions of ether. The combined ethereal phases were dried over magnesium sulfate and the ether was evaporated, followed by distillation udner reduced presusre. Yield: 19.7 g (52 %), lit.[6] 22 %, bp 126 °C/0.6 mm Hg. ^1H Nmr ($CDCl_3$): δ 7.51 (m,1H), δ 7.52(m,1H), δ 8.37 (dd,J=1.27 and 4.64 Hz,1H) ppm.

3-Tributylstannylthiophene

To a stirred solution of 12.8 g (80 mmol) of 3-bromothiophene in 90 ml of dry ether at -70 °C under nitrogen, 62 ml (88 mmol) of butyllithium (1.42 M in hexane) were added dropwise at such a rate that the temperature did not exceed -70 °C. The solution was stirred for 30 min at -70 °C, whereupon 28.6 g (88 mmol) of tributylstannyl chloride dissolved in 30 ml of dry ether were added After stirring at -70 °C for 4 h, the work-up was performed as described above. *Yield 14.9 g* (50 %), bp 124 °C/0.6 mm Hg. ^{1}H Nmr ($CDCl_3$): δ 7.17 (dd,J=1.00 and 4.75 Hz,1H), δ 7.34 (dd,J=0.98 and 2.47 Hz,1H), δ 7.46 (dd,J=2.54 and 4.73 Hz,1H) ppm. Anal. Calcd for $C_{16}H_{30}SSn$: C, 51.5; H, 8.10; S, 8.59. Found: C,51.5; H, 7.96; S, 8.56.

3-Methoxy-2,5-di(trimethylstannyl)thiophene (**21**)

To a stirred solution of 6.8 g (60 mmol) of 3-methoxythiophene, 13.8 g (119 mmol) of TMEDA in 100 ml of dry ether under nitrogen, 83 ml of butyllithium were added dropwise at such a rate that moderate reflux was maintained. The solution was refluxed for 30 min, followed by cooling to -70 °C whereupon 24.9 g (125 mmol) of trimethylstannyl chloride dissolved in 30 ml of dry THF were added at such a rate that the temperature did not exceed -70 °C. After stirring at -70 °C for 4 h, the work-up was performed as described above. Yield: 22 %, bp 113 °C/0.9 mm Hg. ^{1}H Nmr ($CDCl_3$): δ 7.05 (s, 1H) ppm. Anal.Calcd for $C_{11}H_{22}OSSn_2$: C, 30.0; H, 5.04; S, 7.29. Found: C, 31.8; H, 5.19; S, 7.19. Correct C and H analyses could unfortunately not be correctly obtained probably due to the explosive nature of (**21**).

3'-Methoxy-2,2':5',2"-terthiophene (**22**)

In a 25 ml flask fitted with an efficient stirrer and reflux condenser with a calcium chloride tube, 0.90 g of sodium were dissolved in 11 ml of methanol. Potassium iodide (10 mg), 1.0 g of 3'-iodo-2,2':5',2"-terthiophene,[32] and 0.50 g of cupric oxide were added. The mixture was then *refluxed with efficient stirring for 100 h. The cooled mixture was filtered*, diluted with two volumes of water and extracted with ether. The combined ethereal phases were washed with water, dried over magnesium sulfate and purified by column chromatography using silica gel 60 and heptane as eluent. Yield: 0.40 g (54 %) and 0.20 g (30 %) of the by-product 2,2':5',2"-terthiophene. Elemental analysis is given in Table 2 and ^{1}H nmr data are given in Tables 3 and 4.

ACKNOWLEDGEMENT

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Table 1. Yields, melting points and molecular weights for some terheterocyclic compounds.

Compound	Yield %	mp/^{o}C	Found mwt	Lit. yield %	Lit. mp/^{o}C	Calc. mwt	Ref. No
1	40	92-93	248	84	93-94, 95	248.4	8, 30
2	48	193-195	248	100	193	248.4	8
3	55	78-80	243	11, 18	78-79, 79	243.3	12, 22
4	39	204-205	242	14, 22	208	242.4	23, 24
5	29(19)*	84-85	249	20	92	249.4	25
6	51	159-161	243	-	-	243.3	-
7	50	52-54	211	-	-	211.2	-
8	48	110-112	216	-	-	216.3	-
9	44	62-64	276	-	-	276.4	-
10	49	115-117	276	-	-	276.4	-
11	48	58-60	244	-	-	244.3	-
12	52(23)*	99-101	249	-	-	249.4	-
13	25(8)*	76-78	343	-	-	343.2	-
14	52	145-147	250	30	154	250.4	27
15	52	136-138	245	-	-	245.3	-
16	67	151-152	244	-	-	244.3	-
18	16	68-70	321	-	-	320.9	-
20	61	150-151	236	80	153, 152-3	236.3	29, 30
22	54	oil	278	-	63	278.0	3

• Isolated yields after chromatography and recrystallisation.

Table 2. Elemental analyses for some terheterocyclic compounds.

Compound	Found	% C	% H	% N	% S	Calc.	% C	% H	% N	% S
5		53.0	2.80	5.42			53.0	2.83	5.62	
6		64.2	3.70	5.80			64.2	3.73	5.76	
7		74.0	4.17	6.57			73.2	4.30	6.63	
8		67.1	3.70		15.0		66.6	3.73		14.8
9		61.3	4.44		34.2		60.8	4.38		34.8
10		61.0	4.32		34.8		60.8	4.38		34.8
11		68.8	4.97		13.0		68.3	4.95		13.1
12		52.0	2.74	5.68			53.0	2.83	5.62	
13		38.4	2.00	4.01			38.5	2.06	4.08	
15		53.7	2.91	17.2			53.9	2.88	17.1	
16		60.0	3.28	11.5			60.0	3.30	11.5	
18		34.25	2.57	4.43			33.65	2.51	4.36	
22		56.1	3.64	34.1			56.1	3.62	34.5	

Table 3. ^{1}H nmr chemical shifts (ppm) for some terheterocyclic compounds in $(CD_3)_2SO$.

Compound	H-2	H-3	H-4	H-5	H-2'	H-3'	H-4'	H-5'	H-6'	H-2"	H-3"	H-4"	H-5"
1	-	7.34	7.10	7.53	-	7.27	7.27	-	-	-	7.34	7.10	7.53
2	7.73	-	7.46	7.65	-	7.37	7.37	-	-	7.73	-	7.46	7.65
3	-	7.83	7.18	7.66	-	7.77	7.86	7.77	-	-	7.83	7.18	7.66
4*	-	7.34	7.10	7.29	7.63	7.63	-	7.63	7.63	-	7.34	7.10	7.29
5	-	7.68	7.20	7.75	-	-	8.02	-	-	-	7.44	7.16	7.63
5*	-	7.50	7.10	7.41	-	-	7.80	-	-	-	7.21	7.06	7.30
6	8.30	-	7.88	7.67	-	7.76	7.87	7.76	-	8.30	-	7.88	7.67
7	8.41	-	7.14	7.79	-	7.57	7.81	7.57	-	8.41	-	7.14	7.79
8	8.06	-	6.85	7.76	-	7.24	7.24	-	-	8.06	-	6.85	7.76
9*	-	6.80	6.98	7.25	-	-	-	-	-	-	6.80	6.98	7.25
10*	6.93	-	6.70	7.18	-	-	-	-	-	6.93	-	6.70	7.18
11*	7.26	-	6.19	7.37	-	-	-	-	-	7.26	-	6.19	7.37
12	8.14	-	7.59	7.72	-	-	8.14	-	-	7.84	-	7.53	7.71
13	-	7.82	7.41	8.33	-	-	7.96	-	-	-	7.52	7.34	8.22
14	-	-	7.89	7.82	-	7.71	7.71	-	-	-	-	7.89	7.82
15	-	-	8.05	7.95	-	8.20	8.13	8.20	-	-	-	8.05	7.95
16	-	-	7.99	7.89	8.09	8.09	-	8.09	8.09	-	-	7.99	7.89
18	-	-	-	-	-	-	-	-	-	-	-	8.00	7.92
20**	7.71	7.45	7.34	7.45	-	7.56	7.56	-	-	7.71	7.45	7.34	7.45
22***	-	7.26	6.76	6.84	-	-	6.66	-	-	-	6.96	6.64	6.71
23*	-	7.43	7.11	7.37	-	-	7.18	-	-	-	7.18	7.04	7.27

The assignments of the signals from compounds 5, 12, 13, 22 and 23 were evaluated using homonuclear correlation (COSY).

* In $CDCl_3$, ** H-6 and H-6" = H-2 and H-2", *** in C_6D_6

Table 4. Coupling constants (Hz) for some terheterocyclic compounds in $(CD_3)_2SO$.

Comp	J(2-4)	J(2-5)	J(3-4)	J(3-5)	J(4-5)	J(2"-4")	J(2"-5")	J(3"-4")	J(3"-5")	J(4"-5")
1	-	-	3.7	1.1	5.1	-	-	3.7	1.1	5.1
2	1.3	2.9	-	-	4.9	1.3	2.9	-	-	4.9
3	-	-	3.6	1.3	5.2	-	-	3.6	1.3	5.2
4*	-	-	3.6	1.2	5.1	-	-	3.6	1.2	5.1
5	-	-	3.7	1.1	5.1	-	-	3.7	1.2	5.1
6	1.4	3.1	-	-	5.0	1.4	3.1	-	-	5.0
7	0.9	1.6	-	-	1.7	0.9	1.6	-	-	1.7
8	0.9	1.4	-	-	1.9	0.9	1.4	-	-	1.9
9*	-	-	3.5	1.2	5.1	-	-	3.5	1.2	5.1
10*	1.3	3.0	-	-	4.9	1.3	3.0	-	-	4.9
11*	0.9	1.6	-	-	1.7	0.9	1.6	-	-	1.7
12	1.3	2.9	-	-	5.1	1.3	2.9	-	-	5.2
13	-	-	3.9	1.1	5.5	-	-	3.8	0.9	5.5
14	-	-	-	-	3.2	-	-	-	-	3.2
15	-	-	-	-	3.2	-	-	-	-	3.2
16	-	-	-	-	3.2	-	-	-	-	3.2
18	-	-	-	-	-	-	-	-	-	3.3
20**	-	-	7.3	-	-	-	-	7.3	-	-
22***	-	-	3.6	1.2	5.2	-	-	3.6	1.2	5.1
23*	-	-	3.7	1.2	5.1	-	-	3.6	1.1	5.1

* In $CDCl_3$, ** J(2-3)=8.4, *** in C_6D_6.

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