Synthesis of Pyrroles with Fused Carbocycles or Heterocycles from Weinreb *N*-Vinyl-α-amino Amides

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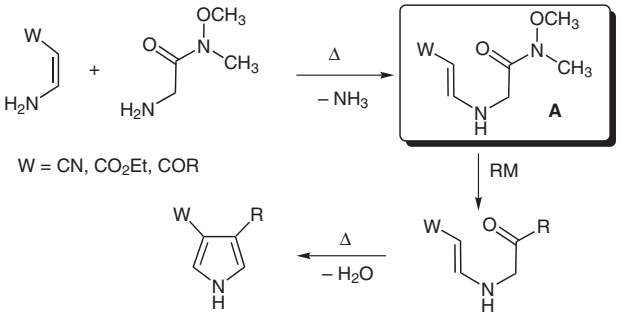
Abstract: Pyrroles fused to diverse carbocycles and heterocycles were prepared from Weinreb *N*-vinyl-α-amino carboxamides integrated in cyclic systems. The selective reaction of the carboxamide group with organometallic compounds allowed us to obtain a great variety of the carbonyl intermediates analogous to the Knorr synthesis, which were thermally cyclized. The principal limitation of the method was due to the insolubility of some metallic intermediates as well as to the low nucleophilicity and stability of the enamine during the cyclization process.

Key words: Knorr pyrrole synthesis, Weinreb amides, fused pyrroles

In a previous paper of ours, we developed a versatile variant of the Knorr synthesis for pyrroles in which Weinreb α-amino amides were used instead of the traditional α-amino ketones (Scheme 1).[1] The key intermediate of the synthetic sequence is the *N*-methoxy-*N*-methylcarboxamide derivative A, which by means of its reaction with organometallic compounds, allows us to obtain pyrrole building blocks.



Scheme 1

Initially the procedure was developed starting from acyclic enamines[1] and later it was successfully applied to the synthesis of [1]benzopyrano[4,3-*b*]pyrrol-4(1*H*)-ones[2] and pyrrolizines.[3]Now, starting from cyclic enamines we have tried to prepare 6,7-dihydro-1*H*-indol-4(5*H*)-ones, 5,6-dihydrocyclopenta[*b*]pyrrol-4(1*H*)-ones, [1]benzopyrano[2,3-*b*]pyrrol-4(1*H*)-ones, pyrano[4,3-*b*]pyrrol-4(1*H*)-ones, 1*H*-furo[3,4-*b*]pyrrol-4(6*H*)-ones and 2-acylindoles. These bi- or tricyclic moieties are interesting units that can be found in numerous compounds with a wide range of biological activity, such as antimitotic,[4] antibiotic,[5] bioluminescent,[6,7] antipsychotic[8] or plant growth regulators.[9] The keto substrates chosen **1**–**9** (Figure 1) and the intermediates derived from them show a variety of structural characteristics – carbocycles, heterocycles, five- or six-membered cycles, ketone derivatives, ester derivatives – which have allowed us to make important observations regarding the behavior of the synthetic process and, above all, concerning some limitations which had not been observed in previous studies.

In our synthetic design we can distinguish three stages: a) formation of the key intermediates **14**–**25**; b) reaction of these intermediates with organometallic compounds; and c) cyclization of the ketones **28**–**40** to the pyrroles **41**–**50** (Scheme 2).

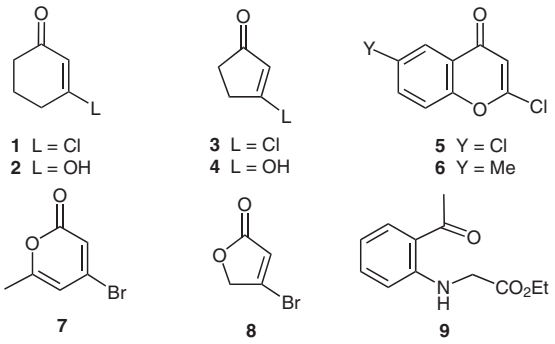
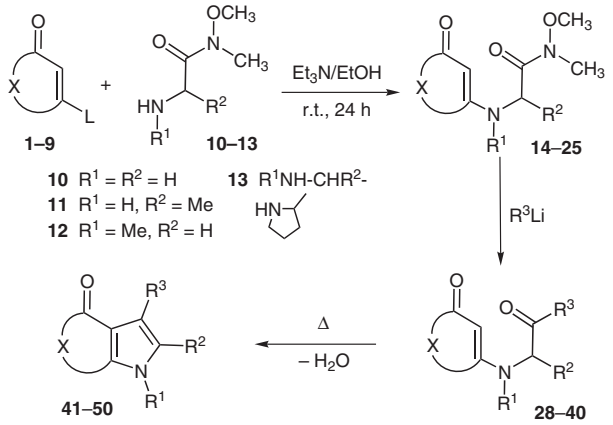


Figure 1 Precursor conjugated ketones chosen for preparing fused pyrroles



Scheme 2

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Preparation of the Key Intermediates

In general, all the key intermediates **14**–**25** were prepared by reaction of β-chlorocycloalkenyl ketones **1**, **3**, **5**, **6** or β-bromo-α,β-unsaturated esters **7**, **8** with *N*-methoxy-*N*-methyl α-amino carboxamides (hydrobromide derivatives) **10**–**13** through a conjugated addition–elimination (Scheme 2). The interchange of halogen for nitrogen substituents proceeded satisfactorily (65–89%) at room temperature in ethanol–triethylamine (Table 1). The carbocyclic intermediates **14**–**18** were also obtained, but with lower yields (55–75%), starting from a solution of the corresponding β-diketones **2** and **4** with the previous carboxamides **10**–**13** in methanol at room temperature.

Table 1 Enamines **14**–**25** Prepared

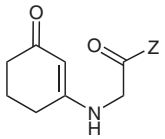
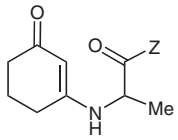
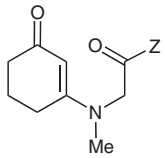
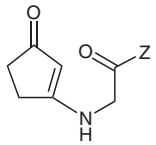
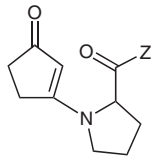
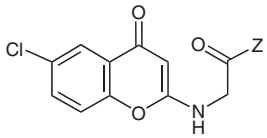
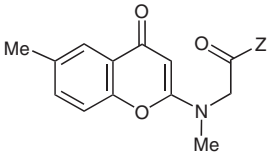
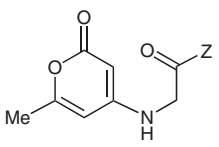
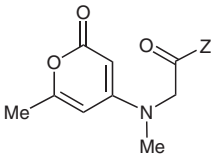
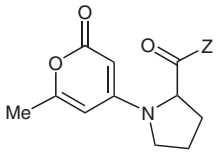
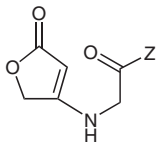
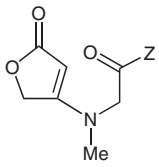
Substrates	Product	Yield (%)	Mp (°C)	^{1}H NMR ($CDCl_3$); δ, *J* (Hz)
1 + **10**	 **14**	89	117	1.79–1.83 (m, 2 H), 2.14 (t, 2 H, *J* = 6.5), 2.28 (t, 2 H, *J* = 6.2), 3.07 (s, 3 H), 3.57 (s, 3 H), 3.80 (d, 2 H, *J* = 4.1), 4.88 (s, 1 H), 5.68 (br, 1 H, NH)
1 + **11**	 **15**	81	119	1.36 (d, 3 H, *J* = 6.7), 1.94–2.00 (m, 2 H), 2.31–2.36 (m, 4 H), 3.22 (s, 3 H), 3.74 (s, 3 H), 4.41 (q, 1 H, *J* = 6.7), 5.10 (s, 1 H), 5.42 (br, 1 H, NH)
1 + **12**	 **16**	78	125	1.94–1.98 (m, 2 H), 2.22–2.26 (m, 2 H), 2.39–2.45 (m, 2 H), 2.99 (s, 3 H), 3.17 (s, 3 H), 3.71 (s, 3 H), 4.19 (s, 2 H), 5.13 (s, 1 H)
3 + **10**	 **17**	58	189	2.34–2.37 (m, 2 H), 2.58–2.61 (m, 2 H), 3.18 (s, 3 H), 3.69 (s, 3 H), 3.96 (d, 2 H, *J* = 3.3), 4.94 (s, 1 H), 7.26 (br, 1 H, NH)
3 + **13**	 **18**	56	>300	The NMR spectrum presented broad duplicated signals with a low magnetic response. The equilibrium between the two pseudo-planar conformations of the enamine group (C=CNR_2) plays an important role in the number and type of NMR signals.
5 + **10**	 **19**	86	197	3.31 (s, 3 H), 3.76 (s, 3 H), 4.23 (s, 2 H), 5.76 (s, 1 H), 6.10 (br, 1 H, NH), 7.48 (d, 1 H, *J* = 8.7), 7.66 (dd, 1 H, *J* = 2.5, 8.7), 8.21 (d, 1 H, *J* = 2.5)
6 + **12**	 **20**	85	82	2.38 (s, 3 H), 3.10 (s, 3 H), 3.19 (s, 3 H), 3.77 (s, 3 H), 4.36 (s, 2 H), 5.40 (s, 1 H), 7.12 (d, 1 H, *J* = 8.6), 7.30 (dd, 1 H, *J* = 2.1, 8.6), 7.91 (d, 1 H, *J* = 2.1)
7 + **10**	 **21**	74	148	2.15 (s, 3 H), 3.25 (s, 3 H), 3.75 (s, 3 H), 3.96 (d, 2 H, *J* = 4.0), 4.93 (s, 1 H), 5.56 (br, 1 H, NH), 5.63 (s, 1 H)

Table 1 Enamines **14**–**25** Prepared (continued)

Substrates	Product	Yield (%)	Mp (°C)	^{1}H NMR ($CDCl_3$); δ, *J* (Hz)
7 + **12**	 **22**	72	175	2.08 (s, 3 H), 2.96 (s, 3 H), 3.12 (s, 3 H), 3.68 (s, 3 H), 4.17 (s, 2 H), 4.86 (br, 1 H), 5.68 (br, 1H)
7 + **13**	 **23**	64	94	2.05-2.20 (m, 2 H), 2.23 (s, 3 H), 2.28–2.38 (m, 2 H), 3.22 (s, 3 H), 3.50–3.72 (m, 2 H), 3.81 (s, 3 H), 4.69 (s, 1 H), 4.97 (s, 1 H), 5.42 (s, 1 H)
8 + **10**	 **24**	69	169	3.25 (s, 3 H), 3.76 (s, 3 H), 4.00 (d, 2 H, *J* = 2.9), 4.70 (s, 1 H), 4.71 (s, 2 H), 5.88 (br, 1 H, NH)
8 + **12**	 **25**	77	229	2.87 (s, 3 H), 3.09 (s, 3 H), 3.63 (s, 3 H), 4.00 (s, 2 H), 4.40–4.70 (m, 3 H)

[a] Z = N(OMe)Me.

Reaction with Organometallic Compounds

While the nature of the ring substituent did not play a significant part in the previous stage, it did in the reaction of **14**–**25** with organometallic compounds and in the subsequent cyclization of the resulting ketones **28**–**40**. The secondary enaminones derived from six-membered cycles (3-aminocyclohex-2-enones **14**, **15**, 3-amino-4*H*-1-benzopyran-4-one **19** and 2*H*-pyran-2-one **21**) gave excellent yields in their reaction with organometallic compounds. As was to be expected, the ketone or ester group was completely deactivated (intermediate **26**) with the first mole of organometallic reagent,[2,3] and if an excess of reagent is used, only the Weinreb-amide was transformed into a carbonyl group. Normally a strict control of the temperature and proportion of reagents is unnecessary to obtain satisfactory yields.

Starting from the enamines **16**, **20**, **22** and **23** (also derived from six-membered cycles) as we had already shown with other tertiary enamines,[2,3] the deactivation of the carbonyl group toward the organometallic reagents is only partial (compare structures **26** and **27** in Figure 2). As a consequence, control of the selective reaction of the Weinreb amide group with organometallic reagents was less satisfactory than with the secondary enamines. Only the less basic organolithium compounds at –40 °C (e.g. MeLi and RC≡CLi) allowed us to prepare the corresponding ketones.

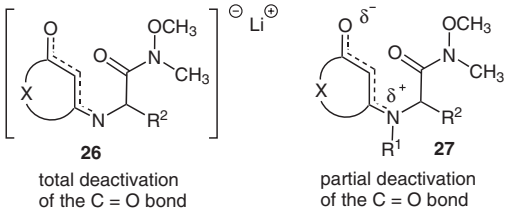


Figure 2 Intermediate structures **26** and **27** illustrating the deactivation of C=O group (cf. Scheme 2)

The most important limitations in the reaction with organometallic compounds have been found starting from the five-membered cycles, both carbocycles **17**, **18** as well as heterocycles **24**, **25**, which in general remained not transformed due to the insolubility of the metallic intermediates. Only it was possible to convert the tertiary enamine **25** to **40** (70%) in an ultrasonic bath. The failure in these cases was not, therefore, due to a lack of selectivity in the reaction of the organometallic compounds with the Weinreb amides, but rather to a problem of insolubility.

The hydrolysis of the organometallic intermediates occurs with total or partial simultaneous cyclization to pyrroles. Consequently, no attempt was made to isolate the ketones **28**–**40** from the reaction mixture and the process was continued at reflux in chloroform in the presence of silica gel in order to obtain a complete transformation to pyrroles **41**–**50** (Table 2). Only the ketones **35**, **37** and **40**, which could not be cyclized, were isolated and purified for their characterization.

Table 2 Preparation of Pyrroles **41–50** from **14–25**

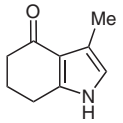
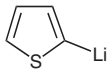
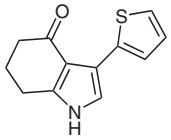
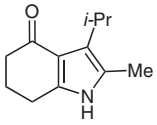
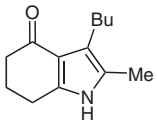
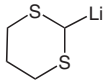
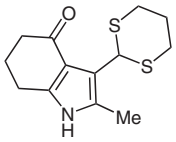
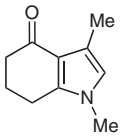
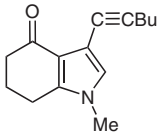
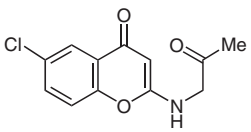
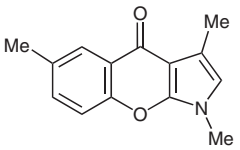
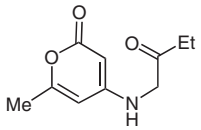
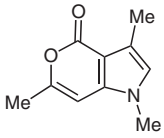
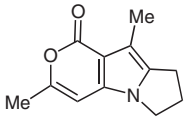
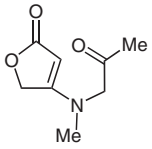
Reaction with Organometallic Compounds						Cyclization		
Amide	RM	Ratio	Temp (°C)	Time (min)	Ketone Yield (%)	Solvent (Reflux)	Time (min)	Product Yield (%)
14	MeLi	1:1.5	–40	25	**28** (75)[a]	toluene	60	 **41** (73)
14		1:2	–40	50	**29** (72)[a]	xylene	60	 **42** (53)
15	*i*-PrMgBr	1:2	–40	50	**30** (77)[a]	toluene	60	 **43** (66)
15	BuLi	1:2	–40	40	**31** (71)[a]	toluene	60	 **44** (81)
15		1:2	–40	30	**32** (68)[a]	toluene	60	 **45** (63)
16	MeLi	1:2	–40	20	**33** (68)[a]	$CHCl_3$	60	 **46** (75)
16	BuC≡CLi	1:2	–40	40	**34** (72)[a]	$CHCl_3$	60	 **47** (65)
17	–[b]				–			–
18	–[b]				–			–
19	MeLi	1:2	–40	20	 **35** (90)	–[c]		–
20	MeLi	1:2	–40	40	**36** (82)[a]			 **48** (77)

Table 2 Preparation of Pyrroles **41–50** from **14–25** (continued)

Reaction with Organometallic Compounds						Cyclization		
Amide	RM	Ratio	Temp (°C)	Time (min)	Ketone Yield (%)	Solvent (Reflux)	Time (min)	Product Yield (%)
21	EtMgBr	1:3	–30	40	 **37** (85)	–[c]		–
22	MeLi	1:2.5	–40	30	**38** (72)[a]	$CHCl_3$	3.5	 **49** (80)
23	MeLi	1:2	–40	50	**39** (70)[a]	$CHCl_3$	3	 **50** (88)
24	–[b]				–			–
25	MeLi	1:2.5	–40	60	 **40** (70)	–[c]		–

[a] Estimated from ^{1}H NMR spectra of the reaction mixture. Not isolated.
[b] Various RM and experimental conditions were tried without success.
[c] Various experimental conditions were tried without success.

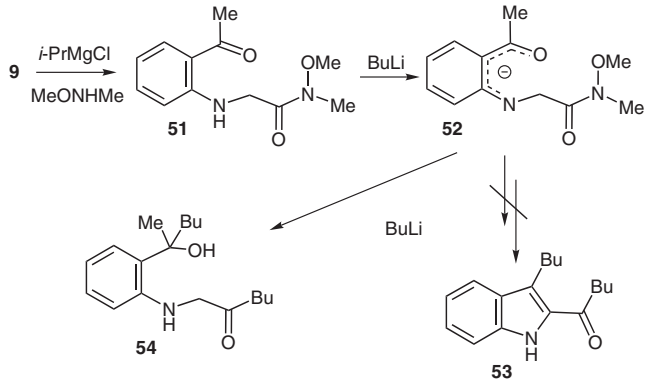
Cyclization

The easy cyclization of the ketones **28–40** to the pyrroles **41–50** not only depended on the electrophilicity of the carbonyl group (R^3: H > alkyl > aryl), but also on the nature of the initial cycle and the nature of R^1, to the point where these last two factors limited the viability of the cyclization in some cases. In general, the Knorr intermediates derived from tertiary amines **33**, **34**, **36**, **38**, **39** ($R^1 \neq$ H) were cyclized in refluxing chloroform or toluene to give the corresponding pyrroles **46–50**. Only in the specific case of the 4-[*N*-methyl-*N*-(2-oxopropyl)amino]furan-2(5*H*)-5-one (**40**) did all the attempts at cyclization failed. This abnormal behavior was attributed to the low nucleophilicity of the enamine when it was integrated in the furanone cycle.

On the other hand, the secondary enamines **28–32**, **35**, **37** (R^1 = H), thermally less reactive and less stable than the tertiary enamines, behaved differently. Thus, the intermediates derived from the carbocycles **28–32** gave good yields of pyrroles in toluene or chloroform under reflux, but their analogues derived from heterocycles **35**, **37** did not cyclize in the same conditions and were degraded when solvents with a higher boiling point were used (e.g. xylene) which required longer times to acquire higher temperature.

Attempts to prepare 2-acylindoles via the key intermediate **51** deserve a separate discussion (Scheme 3). This was obtained starting from **9** by reaction with isopropylmagnesium chloride/*N*,*O*-dimethylhydroxylamine.[10] Formally, the synthetic design shown in Scheme 3 presents the same basic principle: the deactivation by conjugation of the acetyl groups in the amide intermediates (e.g. **52**) should allow the transformation, respectively, of **9** in **51** and **51** in **52**. Unfortunately, the expected deactivation did not take place and the carboxamide **51**, which was obtained in low yield (25%)[11] afforded **54** by attack of the organolithium compound both at the carboxamide group as well as at the acetyl group. Everything indicates that the deactivation of the acetyl group in **52** is less efficient than in **26** (Figure 2), given that the resonance structure implies loss of the aromatic character.

Melting points were measured on a Reichert-Jung Thermo Galen and are uncorrected. IR spectra were obtained on a Perkin-Elmer 1720 X spectrometer. NMR spectra were recorded on a Bruker AC300 spectrometer, and chemical shifts are given downfield from $SiMe_4$ as an internal standard. ^{13}C NMR spectra were carried out



Scheme 3

with complete ^{1}H decoupling and the assignments were made by additional DEPT experiments.

The starting compounds were purchased from commercial suppliers (**2**, **4**) or prepared by literature procedures (**1**,[12] **3**,[12] **5**,[13] **6**,[13] **7**,[14] **8**,[15] **9**[16]).

Weinreb Amides 14–25 from 1–9; General Procedure

A mixture of halo derivative **1**–**9** (10.6 mmol), Weinreb α-amino amide (hydrobromide derivatives) **10**–**13** (11.6 mmol) and Et_3N (3.08 mL, 22.2 mmol) in anhyd CH_2Cl_2 (40 mL) was stirred at r.t. (ca. 24 h). At the end of the reaction, monitored by TLC, the solution was concentrated in vacuo, and the residue was dissolved in CH_2Cl_2–H_2O (1:1, 100 mL). The aqueous layer was extracted with CH_2Cl_2 (2 × 50 mL) and the combined organic layers were dried (Na_2SO_4) and evaporated to dryness. The residue was purified by chromatography on silica gel using THF (for **14**–**16**, **22**), acetone (for **18**), CH_2Cl_2–THF (5:1) (for **21**), CH_2Cl_2–Et_2O (5:1) (for **23**) as eluent, or recrystallized from CH_2Cl_2–Et_2O (for **17**, **20**, **24**, **25**) or from toluene (for **19**) (Table 1).

Ketones 28–40 and Pyrroles 41–50 from 14–25; General Procedure

To a magnetically stirred solution of amides **14**–**25** (2.22 mmol) in anhyd THF (35 mL) was added dropwise the organometallic compound under N_2 (see Table 2). At the end of the reaction (monitored by TLC), the mixture was hydrolyzed. The organic layer was separated, washed with H_2O, dried (Na_2SO_4) and evaporated. Except **35**, **37** and **40** [recrystallized from EtOAc (for **35**) or from CH_2Cl_2–Et_2O (for **37**, **40**)], the carbonyl intermediates were not isolated and the residue was carried over to cyclization treatment. Thus, the reaction mixtures of **28**–**34**, **36**, **38**, **39** (ca. 2.2 mmol) and silica gel (5 × w/w) in the appropriate solvent (50 mL) were heated in a rotary evaporator, slowly distilling the solvent (see Table 2). The silica gel was removed by filtration and washed thoroughly with hot acetone. The solvent was removed in vacuo, and the concentrate was chromatographed on silica gel using CH_2Cl_2–Et_2O (20:1) (for **42**, **44**, **45**), CH_2Cl_2–Et_2O (10:1) (for **47**) or CH_2Cl_2 (for **50**) as eluent, or recrystallized from EtOH (for **41**), from CH_2Cl_2–Et_2O (for **43**, **46**, **49**) or from toluene (for **48**) (Tables 2 and 3).

2-(2-Acetylphenylamino)-*N*-methoxy-*N*-methylacetamide (51)

To a magnetically stirred mixture of **9** (0.50 g, 2.26 mmol), *N,O*-dimethylhydroxylamine hydrochloride (3.50 g, 1.55 mmol) in anhyd THF (40 mL) at –20 °C, was added dropwise a solution of *i*-PrMgCl in THF (9.05 mmol, 2 M). The mixture was kept for 40 min at –10 °C and quenched with 20% wt aq NH_4Cl. The aqueous layer was extracted with CH_2Cl_2 (2 × 50 mL) and the combined organic layers were dried (Na_2SO_4) and concentrated. The residue was chromatographed (silica gel, CH_2Cl_2–Et_2O, 15:1) to give **51** (25%) (Table 3).

1-[2-(1-Hydroxy-1-methylpentyl)phenylamino]hexan-2-one (54)

The title compound was prepared by a procedure analogous to that described for the ketone **35**, starting from **51** (0.52 g, 2.22 mmol) and BuLi (4.16 mL, 1.6 M in toluene, 6.66 mmol) in anhyd THF (35 mL) at –40 °C. The crude product was purified by chromatography on silica gel using CH_2Cl_2–Et_2O (30:1) as eluent; yield: 53%; oil; R_f 0.35 (CH_2Cl_2–Et_2O, 35:1) (Table 3).

Table 3 Physical and Spectral Data for Compounds **35**, **37**, **40**–**51** and **54**

Product[a]	Mp (°C)	IR (KBr) (cm^{-1})	^{1}H NMR ($CDCl_3$); δ, *J* (Hz)	^{13}C NMR ($CDCl_3$), δ
35	161	1722, 1618, 1563	2.17 (s, 3 H), 4.23 (s, 2 H), 5.29 (s, 1 H), 7.45 (d, 1 H, *J* = 8.7), 7.64 (dd, 1 H, *J* = 2.1, 8.7), 7.81 (d, 1 H, *J* = 2.1), 8.27 (br, 1 H, NH)	27.0 (CH_3), 50.4 (CH_2), 84.8 (CH), 119.0 (CH), 123.8 (CH), 124.4 (C), 129.0 (C), 132.0 (CH), 151.7 (C), 163.7 (C), 173.0 (C), 203.6 (C)
37	oil	3426, 1715, 1690	1.08 (t, 3 H, *J* = 7.3), 2.09 (s, 3 H), 2.49 (q, 2 H, *J* = 7.3), 3.91 (d, 2 H, *J* = 4.3), 4.79 (s, 1 H), 5.65 (s, 1 H), 5.86 (br, 1 H, NH)	7.4 (CH_3), 19.7 (CH_3), 33.4 (CH_2), 50.9 (CH_2), 81.0 (CH), 98.9 (CH), 156.9 (C), 161.0 (C), 164.9 (C), 204.7 (C)
40	105	1716, 1619	2.13 (s, 3 H), 2.88 (s, 3 H), 3.98 (s, 2 H), 4.40–4.70 (m, 3 H)	27.1 (CH_3), 39.7 (CH_3), 61,9 (CH_2), 66.8 (CH_2), 82.1 (CH), 169.2 (C), 175.2 (C), 201.9 (C)
41	203	3210, 1627, 1481	2.12–2.16 (m, 2 H), 2.30 (s, 3 H), 2.45 (t, 2 H, *J* = 6.0), 2.78 (t, 2 H, *J* = 6.0), 6.41 (s, 1 H), 8.47 (br, 1 H, NH)	11.6 (CH_3), 22.5 (CH_2), 23.9 (CH_2), 38.4 (CH_2), 116.2 (CH), 116.7 (C), 117.8 (C), 143.4 (C), 193.8 (C)
42	155	3205, 1655, 1585	2.12–2.19 (m, 2 H), 2.47 (t, 2 H, *J* = 5.9), 2.79 (t, 2 H, *J* = 6.3), 6.43 (s, 1 H), 7.10 (dd, 1 H, *J* = 3.5, 5.2), 7.39 (d, 1 H, *J* = 3.5), 7.44 (d, 1 H, *J* = 5.2)	22.4 (CH_2), 27.9 (CH_2), 37.2 (CH_2), 122.7 (CH), 127.3 (CH), 128.2 (CH), 128.7 (CH), 142.7 (C), 152.4 (C), 199.4 (C)
43	196	3214, 1617, 1466	1.28 (d, 6 H, *J* = 7.0), 2.07–2.11 (m, 2 H), 2.21 (s, 3 H), 2.42–2.46 (m, 2 H), 2.73–2.77 (m, 2 H), 3.28–3.32 (m, 1 H, *J* = 7.0), 8.50 (br, 1 H, NH)	11.6 (CH_3), 22.1 (2CH_3), 23.1 (CH_2), 23.8 (CH_2), 25.3 (CH), 39.1 (CH_2), 118.0 (C), 123.1 (C), 124.8 (C), 142.8 (C), 194.9 (C)

Table 3 Physical and Spectral Data for Compounds **35**, **37**, **40–51** and **54** (continued)

Product[a]	Mp (°C)	IR (KBr) (cm^{-1})	^1H NMR ($CDCl_3$); δ, *J* (Hz)	^{13}C NMR ($CDCl_3$), δ
44	172	3221, 1622, 1599, 1468	0.91 (t, 3 H, *J* = 7.2), 1.32–1.39 (m, 2 H), 1.48–1.53 (m, 2 H), 2.08–2.12 (m, 2 H), 2.14 (s, 3 H), 2.43 (t, 2 H, *J* = 6.2), 2.62 (t, 2 H, *J* = 7.3), 2.74 (t, 2 H, *J* = 6.2)	10.9 (CH_3), 14.0 (CH_3), 22.6 (CH_2), 22.9 (CH_2), 24.0 (CH_2), 24.5 (CH_2), 33.1 (CH_2), 38.7 (CH_2), 118.3 (C), 119.1 (C), 124.1 (C), 142.2 (C), 194.9 (C)
45	287	3210, 1627, 1595, 1467	1.60–1.64 (m, 1 H), 1.92–2.02 (m, 2 H), 2.02–2.07 (m, 1 H), 2.24 (t, 2 H, *J* = 5.9), 2.31 (s, 3 H), 2.64 (t, 2 H, *J* = 5.9), 2.74–2.94 (m, 4 H), 6.16 (s, 1 H), 11.20 (br, 1 H, NH)	12.2 (CH_3), 22.1 (CH_2), 23.5 (CH_2), 25.1 (CH_2), 31.7 ($2CH_2$), 38.4 (CH_2), 40.9 (CH), 114.3 (C), 115.3 (C), 128.9 (C), 141.8 (C), 193.9 (C)
46	131	1639	2.10–2.16 (m, 2 H), 2.28 (s, 3 H), 2.42 (t, 2 H, *J* = 5.9), 2.69 (t, 2 H, *J* = 6.2), 3.48 (s, 3 H), 6.28 (s, 1 H)	11.3 (CH_3), 21.6 (CH_2), 23.5 (CH_2), 33.0 (CH_3), 38.2 (CH_2), 118.7 (C), 120.7 (CH), 143.5 (C), 194.9 (C)
47	155	1654, 1548	0.92 (t, 3 H, *J* = 7.2), 1.42–1.64 (m, 4 H), 2.05–2.16 (m, 2 H), 2.40–2.44 (m, 4 H), 2.68 (t, 2 H, *J* = 6.2), 3.50 (s, 3 H), 6.65 (s, 1 H)	13.6 (CH_3), 19.4 (CH_2), 21.6 (CH_2), 22.0 (CH_2), 23.2 (CH_2), 30.9 (CH_2), 33.4 (CH_3), 37.9 (CH_2), 73.3 (C), 90.9 (C), 103.0 (C), 120.9 (C), 126.7 (CH), 142.8 (C), 192.9 (C)
48	184	1640, 1609	2.44 (s, 3 H), 2.46 (s, 3 H), 3.65 (s, 3 H), 6.24 (s, 1 H), 7.33 (d, 1 H, *J* = 8.4), 7.40 (dd, 1 H, *J* = 1.9, 8.4), 8.12 (d, 1 H, *J* = 1.9)	11.6 (CH_3), 21.0 (CH_3), 31.0 (CH_3), 105.5 (C), 115.2 (C), 115.9 (CH), 116.7 (CH), 123.4 (C), 126.2 (CH), 133.3 (CH), 149.6 (C), 152.2 (C), 174.3 (C)
49	154	1711, 1633, 1501	2.26 (s, 3 H), 2.34 (s, 3 H), 3.57 (s, 3 H), 6.12 (s, 1 H), 6.45 (s, 1 H)	10.6 (CH_3), 20.0 (CH_3), 32.9 (CH_3), 93.3 (CH), 106.1 (C), 118.6 (C), 123.1 (CH), 139.9 (C), 155.5 (C), 160.9 (C)
50	168	1703, 1630	2.23 (s, 3 H), 2.27 (s, 3 H), 2.54 (q, 2 H, *J* = 6.9), 2.79 (t, 2 H, *J* = 6.9), 3.89 (t, 2 H, *J* = 6.9), 6.07 (s, 1 H)	10.0 (CH_3), 19.8 (CH_3), 22.2 (CH_2), 27.6 (CH_2), 44.0 (CH_2), 94.0 (CH), 108.4 (C), 109.3 (C), 134.6 (C), 137.1 (C), 154.2 (C), 161.2 (C)
51	111	3299, 1669, 754	2.59 (s, 3 H), 3.24 (s, 3 H), 3.76 (s, 3 H), 4.15 (d, 2 H, *J* = 5.1), 6.62–6.66 (m, 2 H), 7.37 (dd, 1 H, *J* = 1.6, 8.5), 7.77 (dd, 1 H, *J* = 1.6, 8.2), 9.34 (br s, 1 H)	27.9 (CH_3), 32.5 (CH_3), 44.0 (CH_2), 61.5 (CH_3), 111.8 (CH), 114.6 (CH), 118.3 (C), 132.7 (CH), 134.8 (CH), 149.9 (C), 171.4 (C), 200.5 (C)
54	oil	3366, 1719, 744	0.84–0.94 (m, 6 H), 1.26–1.41 (m, 6 H), 1.57–1.67 (m, 4 H), 1.65 (s, 3 H), 2.50 (t, 2 H, *J* = 7.4), 3.99 (s, 2 H), 6.47 (dd, 1 H, *J* = 0.8, 8.1), 6.66 (td, 1 H, *J* = 0.8, 6.6), 7.07–7.16 (m, 2 H)	13.8 (CH_3), 14.0 (CH_3), 22.3 (CH_2), 23.0 (CH_2), 25.8 (CH_2), 26.6 (CH_2), 28.3 (CH_3), 39.8 (CH_2), 40.3 (CH_2), 54.0 (CH_2), 111.4 (CH), 116.4 (CH), 126.7 (CH), 128.2 (CH), 129.4 (C), 146.1 (C), 208.0 (C).

[a] Satisfactory microanalyses obtained: C ±0.30, H ±0.30, N ±0.30.

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