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Synthesis and Conformational Studies of *cis* and *trans* Condensed-Skeleton 3-Substituted-1,3-oxazine-2,4-diones

János Pintye[a], Ferenc Fülöp[a], Gábor Bernáth[a,*], and Pál Sohár[b]

[a] Institute of Pharmaceutical Chemistry, University Medical School, H-6701 Szeged, Hungary

[b] EGIS Pharmacochemical Works, Spectroscopic Department, H-1475 Budapest, Hungary

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N-Substituted-2-carboxamido-1-cycloalkanols were cyclized with 1,1′-carbonyldiimidazole to synthesize *cis*- and *trans*-*N*-alkyl-, *N*-aralkyl- and *N*-aryl-2,4-dioxo tri- and tetramethyleneperhydro-1,3-oxazines. The structures of the compounds and their *cis* or *trans* ring anellation were confirmed by IR, ^{1}H- and ^{13}C-NMR spectroscopy, and the *cis* and *trans* pairs of isomers were compared to establish the predominant conformation of the flexible *cis* isomers. It was found that—similarly to the 1,3-oxazin-2- and -4-ones studied earlier—the "*O-endo*" conformers are preferred, in which the 1-oxygen atom is *axial* to the alicyclic ring; this is independent of the number of ring atoms in the alicycle, and of the presence of an oxazinedione ring, even though this is more flexible that the ring of oxazinones.

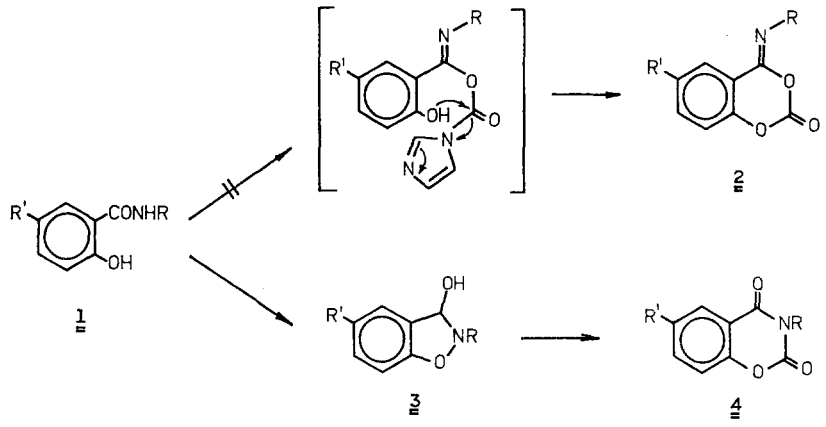
(Keywords: 1,1′-Carbonyldiimidazole; Substituted 1,3-oxazine-2,4-diones with condensed skeleton; IR; ^{1}H-NMR; ^{13}C-NMR)

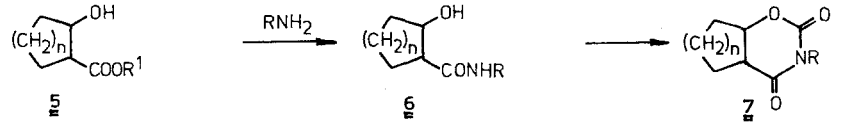
Synthese und Konformation von cis und trans 2-substituierten kondensierten 1,3-Oxazin-2,4-dionen

cis- und *trans*-*N*-Alkyl-, *N*-Aralkyl- und *N*-Aryl-2,4-dioxo-, tri- und tetramethylen-perhydro-1,3-oxazine wurden aus 2-Carboxamido-1-cycloalkanolen und 1,1′-Carbonyldiimidazol dargestellt. Mit Hilfe der IR, ^{1}H- und ^{13}C-NMR Spektroskopie wurden die Struktur, die *cis*- oder *trans*-Annellierung der Ringe und die bevorzugte Konformation der flexiblen *cis*-Isomeren im Vergleich zum *cis-trans* Isomerenpaar nachgewiesen. Ähnlich zu den früher untersuchten 1,3-Oxazin-2- und -4-onen ist hier ebenfalls das „*O-endo*" Konformere bevorzugt; in diesem ist der Sauerstoff *axial* angeordnet, und zwar unabhängig von der Zahl der alicyklischen Ringatome und dem flexibleren Oxazindionring.

Introduction

Salicylamide and its derivatives (**1**) were cyclized with 1,1′-carbonyldiimidazole to produce the isoimides **2** and isoxazoles **3**[2]. According to the postulated reaction mechanism, 1,1′-carbonyldiimidazole as an electrophilic agent attacks the hydroxy group of the iminohydrin tautomer of the acid amide **1** and the resulting intermediate undergoes cyclization to give **2**. In later studies of this reaction compounds of types **2** and **3** could not be isolated[3]; at room temperature 2*H*-1,3-benzoxazine-2,4-(3*H*)-diones of type **4** were obtained, whose structures were confirmed





cis, $n = 1, 2$
trans, $n = 2$
$R^1 = H, C_2H_5$

		n	R			n	R
a	*cis*	1	CH_3	**h**	*trans*	2	$CH_2C_6H_5$
b	*cis*	2	CH_3	**i**	*cis*	2	$CH_2C_6H_4Cl(p)$
c	*trans*	2	CH_3	**j**	*trans*	2	$CH_2C_6H_4Cl(p)$
d	*cis*	2	C_6H_5	**k**	*cis*	2	$CH_2C_6H_4Cl(o)$
e	*trans*	2	C_6H_5	**l**	*cis*	2	$CH_2C_6H_3Cl_2(o,p)$
f	*cis*	1	$CH_2C_6H_5$	**m**	*trans*	2	$CH_2C_6H_3Cl_2(o,p)$
g	*cis*	2	$CH_2C_6H_5$	**n**	*cis*	2	$CH_2CH_2C_6H_5$

by spectroscopy and by comparison with samples prepared *via* another synthetic route[3].

Similar cyclization reactions of *cis*- and *trans*-2-hydroxy-1-cyclohexanecarboxamides (**6**, $n = 2$) or of the homologues with cyclopentane skeleton (**6**, $n = 1$) have not been reported. As a continuation of our investigations on saturated bicyclic compounds containing two hetero atoms, the present work is concerned with these reactions. Syntheses of the closely analogous alicyclic stereoisomeric 1,3-oxazin-2-ones[4–6] and 1,3-oxazin-4-ones[7–8] have been described earlier. The structures of the products were confirmed by ^{1}H-NMR and X-ray diffraction analysis[6,9].

Results and Discussion

Syntheses

In this paper ring-closure reactions of *N*-substituted-2-cycloalkanol-1-carboxamides (**6**) with 1,1′-carbonyldiimidazole are reported. The starting stereohomogeneous *N*-substituted-2-hydroxy-1-cycloalkanecarboxamides (**6**) were synthesized by previously published procedures[10,11] from the appropriate 2-hydroxy-1-cycloalkanecarboxylic acids or their esters (**5**) and amines. Reaction of **6** with a four-fold molar excess of 1,1′-carbonyldiimidazole gave stereohomogeneous 2,4-dioxo-*cis*-5,6-trimethylene- and *cis*- and *trans*-tetramethylene-3,4,5,6-tetrahydro-1,3-oxazines (**7**).

The synthetic route and the structures of the products were analogous to those described by *Geffken* for the aromatic systems[3]. However, in our case the synthesis was an endothermic process, whereas with the aromatic compounds the reaction took place at low temperatures. Derivatives with an unsubstituted nitrogen atom (**7**, $R = H$) could not be isolated, probably because of their excellent solubility in water.

Spectroscopic Studies

The structures of **7 a–n** have been confirmed by IR, ^{1}H NMR and, in some cases ^{13}C NMR spectroscopy.

In the IR spectra of all compounds examined the bands of the urethane-carbonyl group can be identified between 1 745 and 1 760 cm^{-1}, the amide-I bands at 1 680–1 700 cm^{-1}, and the two or three intense C—O vibration bands of the ester group between 1 015 and 1 285 cm^{-1}; in **7 d–n**, containing aryl or aralkyl groups, the characteristic bands of the aromatic ring are also found (Table 3).

In the ^{1}H-NMR spectra of **7 b–e, g–n** (Table 3) the overlapping multiplets of the alicyclic methylene groups appear in the range 1.2–2.5 ppm with 8 H intensity, and in those of **7 a, f**, containing a cyclopentane ring, between 1.6 and 2.4 ppm, with 6 H intensity. In the spectra of the *trans* isomers **7 c, h, j, m**, the signal of H-5 is also merged with this system, whereas for **7 e** and the *cis* isomers this multiplet is

distinct at 2.4–2.9 ppm, its lines coalescing to a signal 20–25 Hz in width. The H-6 signal in the *trans* isomers is a double triplet in the range 4.04–4.30 ppm with a width of about 25 Hz. In the *cis* isomers the sharper signals of the cyclopentane derivatives **7a, f** (with $w_{1/2}$ ca. 12 Hz) can be identified at 4.90 and 4.82 ppm, respectively; for the analogue compounds with a cyclohexane ring the signals are found in the range 4.44–4.73 ppm. The aromatic hydrogens of the phenyl or substituted phenyl rings exhibit the expected multiplets with 5 H (**7d–h, n**), 4 H (**7i–k**) and 3 H (**7l, m**) intensities in the range 7.05–7.40 ppm; one can also identify the methyl singlets (**7a–c**), the methylene singlets (**7f, h, j, m**) or AB multiplets (**7g, i, k, l**) with 2 H intensity; in the case of **7n** there is an AA′BB′ multiplet with a total intensity of 4 H.

The ^{13}C-NMR spectra were recorded for the compounds **7a, f** containing a cyclopentane ring and for the three pairs of isomers **7b, c**, **7d, e** and **7i, j** (Table 4); the suggested structures were confirmed unequivocally by the spectra. The carbon signals of the amide- and urethane-carbonyl groups are found in the ranges 170.2–171.3 and 150.9–152.0 ppm, respectively. Due to the vicinity of oxygen, the C-6 signal can be identified at relatively low field, between 73.2 and 79.8 ppm; even within this range, the signal is characteristically different for the *cis* and *trans* isomers ($\sim$ 73.4 and $\sim$ 76.9 ppm, respectively), and it is also affected considerably by the number of ring atoms, for **7a, f** the chemical shift being 79.8 and 79.7 ppm. The same applies to the C-5 signal; the measured data are $\sim$ 41.9 ppm (**7b, d, i**) and $\sim$ 44.7 ppm (**7c, e, j** and **7a, f**). Reduction of the number of ring atoms is expected to cause paramagnetic shifts of about 6.5 ppm in the C-5 and C-6 signals in **7a, f**, as compared with the homologues **7b, d, i** (the chemical shifts of the anellated carbon atoms in decalin is 36.8 ppm, whereas the corresponding shift in bicyclo[3.3.0]octane is 43.3 ppm[12]). In the case of C-5, this difference is partly compensated by the steric hindrance between the carbonyl group and H-10 (which is greater here than in the cyclohexane analogues) causing increased shielding[13] (see below). In the cyclohexane derivatives the C-7, C-8, C-9 and C-10 signals are more shielded in the *cis* isomers by about 2.6, 1.4, 0.3 and 3.1 ppm, respectively. Considerably different values were measured for the cyclopentanes and, naturally, the C-10 signal was absent. The signals of the methyl (**7a, b, c**), *N*-methylene (**7f, i, j**) and aromatic carbons (**7d, e, f, i, j**) could all be assigned, in the expected numbers and chemical shift ranges.

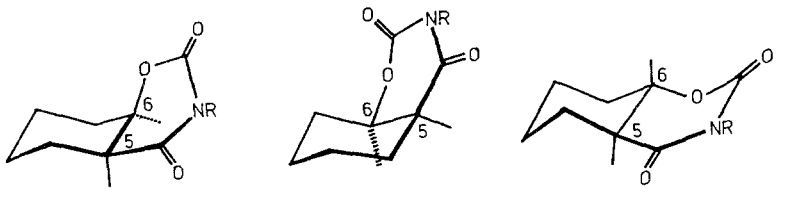
The opposite shifts of the C-4 signal in the isomers can be explained by the more delocalized electronic structure of the more planar imide group in the *trans* isomer; the —*I*-effect of the urethane group acts against the polarization of the amide-carbonyl and thus against the decrease of the electron density at C-4. Consequently, the C-4 atom is more shielded in the *trans* isomers with an average of 0.6 ppm.

In determinations of the ring anellation, the chemical shifts of the alicyclic carbons are of decisive importance, since the corresponding signals appear at higher fields in the spectra of the sterically hindered *cis* isomers, as a consequence of the steric compression shift. The field effect is known[13] to cause considerably increases in the shielding of carbon atoms carrying hindered groups.

With regard to the conformations the new compounds allow interesting comparisons with the previously described perhydro- and

dihydro-oxazines with condensed alicyclic rings, such as the 2-[14,15] and 4-oxo-oxazines[11]. The incorporation of two sp^2 carbon atoms or of the —CONRCOO— group into the ring clearly results in a greater flexibility of the heterocycle, thereby possibly affecting the conformations.

There are two possible stable conformations of the *cis*-tetramethylene isomers (one of them with *axial* 1-heteroatom and *equatorial* C-4 attached to the chair-form cyclohexane ring, and the other with the reversed situation). Our earlier results suggested that the "*O-endo*" form with *axial* heteroatom predominates and conformationally homogeneous systems are formed[14]. Exceptions are the 1-*NR*-derivatives ($R \neq H$), where the bulky *NR* group (R = Me, CH_2Ph) adopts the *equatorial* position to avoid the sterically unfavourable arrangement; thus, the system (again conformationally homogeneous) is now stable in the "*O-exo*" conformation[17,18] (*cf.* Fig. 1).



cis (*O-endo*) *cis* (*O-exo*) *trans*

Fig. 1. Conformations of 1,3-Oxazin-2,4-diones (7)

If the ring is not six-membered, a conformational equilibrium is attained, but the preferred conformer remains the same.

The principles of the conformational analysis of analogous systems have been described in detail earlier[14,16]. Data of decisive importance for the present compounds are the chemical shifts and splittings of the H-6 proton resonance signals or (in the case of coalesced lines) the halfbandwidths. In the *trans* isomers H-6 is necessarily *axial* and therefore more shielded, the coupling constants being much greater than in the case of the *equatorial* position. This follows from the empirical rule $\delta H_e > \delta H_a$, generally valid for cyclohexanes[17a], and from the *Karplus* relation ${}^3J_{a,a} > {}^3J_{a,e} \approx {}^3J_{e,e}$[19].

If the *cis* isomers exist in the *"O-exo"* conformation—or this is at least the predominant form in the conformational equilibrium—there will be no significant difference in the chemical shift and halfbandwidth of the H-6 signal between the pair of isomers. H-6 is *axial* relative to the cyclohexane ring in the *"O-exo"* form, and hence its position relative to the C(6)—O(1), C(5)—C(6) and C(6)—C(7) bonds (primarily determining the shielding) remains the same as in the *trans* form; one of its three

couplings, the H-6*a*, H-7*a* interaction, is *diaxial* as before, and thus the halfbandwidth will be only slightly reduced as compared with the *trans* isomer. In the latter, H-6 is involved in two *diaxal* couplings (H-6*a*, H-7*a* and H-5*a*, H-6*a*); considering the coupling constants obtained with the *trans* isomers (11.5, 11.5 and 4.5 Hz, *cf.* Table 3), this corresponds to a halfbandwidth of about 27.5 Hz. In the "*O-exo*" conformation this is diminished to about 20.5 Hz, whereas the expected line width for the "*O-endo*" form is < 13.5 Hz (since H-6 is *equatorial* here and the three interactions are H-5*a*, 6*e*, H-6*e*,7*a* and H-6*e*,7*e*).

From the data for the rigid *trans* isomers, it follows from Table 3 that the *cis* isomers are conformationally homogeneous systems in this case too, their "*O-endo*" conformation being the stable one. This is confirmed by the much smaller halfbandwidth (~ 12 Hz) and markedly greater chemical shift (0.3 ppm, on the average) of the H-6 signal of the *cis* isomers as compared with that of their *trans* counterparts. Since H-5 is *axial* in both the *trans* isomers and the *cis* isomers with "*O-endo*" conformation, it is reasonable that its halfbandwidth does not differ significantly for the pairs of isomers; at the same time this suggests that the assignment of the preferred conformations is correct.

The fact that the characteristics of the H-5 and H-6 signals of the cyclopentane derivatives **7 a** and **7 f** are unchanged as compared with the *cis* isomers of the six-membered homologous is an indication that the dihedral angles about C-5 and C-6 remain practically unchanged; accordingly, the alicyclic ring is preferentially present as the envelope conformer in which C-6 sticks out of the plane formed by the other carbon atoms, and the oxygen is attached to it *axially*.

From the four methylene carbon signals for the *cis*-anellated cyclohexane derivatives the steric compression shifts of C-8 and C-10 are 1.1 and 0.5 ppm, respectively, greater than those for C-9 and C-7; this is a consequence of the 1,3-*diaxial* interaction with the *axial* oxygen. Since such an interaction is only possible in the "*O-endo*" conformation, this provides additional evidence for the preference of this conformation. This conclusion is based on the unequivocal assignments of the C-7 and C-10 signals, and accordingly at least one of these assignments required special proof:

As the first step double resonance experiments were carried out to determine the chemical shifts of the ten cyclohexane protons in the ^{1}H-NMR spectrum of compound **7 e**, selected as a model. The H-5 and H-6 signals are well separated (Table 3); the other eight protons exhibit four signals at 1.35, 1.60, 1.90 and 2.35 ppm, the intensities being 3 H, 1 H, 2 H and 2 H. When the H-5 signal is saturated, not only the H-6 signal (dt $\rightarrow$ dd), but also the two multiplets at 1.45 and 2.35 ppm are simplified; similarly, irradiation of the H-6 signal reduces the H-5 doublet of triplets

to a doublet of doublets and the signals at 1.6 ppm (dqa → dt) and 2.35 ppm are also changed. Hence, with $\delta H_a < \delta H_e$, it follows for the various methylene groups that δ H-8*a*, 9*a*, 10*a* ≈ 1.35, δ H-7*a* ≈ 1.6, δ H-8*e*, 9*e* ≈ 1.9, δ H-7*e*, 10*e* ≈ 2.35 ppm.

In the second step, the off-resonance ^{13}C-NMR spectrum of isomer **7e** was recorded. The exciting frequency was selected about 2 kHz upfield from the range of the proton shifts; in this way, the decreases of the ^1J(C, H) coupling constants measured in the proton-coupled spectrum gave the carbon signals in the off-resonance spectrum in the sequence of the shielding of the protons attached to them[17b]. The average shifts of the methylene hydrogens follow the sequence $\delta H_7 > \delta H_{10} > \delta H_8 \approx \delta H_9$ and the value of the splitting of the C-7-10 signals in the off-resonance spectra decreases in the signal sequence 31.4, 23.8, 24.7, 24.4 ppm, so that the assignments δ C-7 = 31.4 and δ C-10 = 23.8 ppm can be considered as being established.

The relation δ C-7 > δ C-10 was probable because of the β-effect[17c] of the oxygen, but the assignment of the C-10 signal was uncertain, since the decreased shielding caused by the increased order of the adjacent carbon atom[17d] might be compensated by a field effect due to steric hindrance in the fused ring system; evidence for this was actually found. The assignment of the C-10 signal for the *cis* isomer **7d** was substantiated in the same way.

Despite the greater flexibility of the hetero ring, the conformational relations in these compounds are the same as in the oxazines studied earlier; the dihedral angles about C-5 and C-6 in the homologues condensed with the five-membered alicyclic ring do not differ considerably either.

Katritzky et al.[20] have interpreted their NMR data proposing a nearly 1 : 1 equilibrium ratio of the "*N-endo*" and "*N-exo*" conformers of *cis*-5,6-tetramethylenedihydrouracil with a slight preference for the "*O-endo*" conformer. However, their measurements were performed in *TFA* or in a 7 : 5 mixture of *TFA* and D_2O which could have considerably affected the tautomeric equilibrium; protonation may have occurred and the conformational relations might have been influenced by an O → NH exchange.

Experimental

IR spectra were run in KBr pellets on a Specord-75 (Jena, FRG) grating spectrometer.

^{1}H and ^{13}C NMR spectra were recorded in $CDCl_3$ solution at room temperature on a Bruker WM-250 *FT* instrument and a Bruker WP-80 SY FT spectrometer, using *TMS* as internal standard and the ^{2}H resonance of the solvent as the lock signal. The most important measuring parameters were as follows: frequency: 250.13 and 20.14 MHz; sweep width: 5 kHz; pulse width: 1 and 3 μs (~ 20 and ~ 30° flip angle); acquisition time: 1.64 s; number of scans: 8 and 1–4 K; computer memory: 16 K. Complete proton noise decoupling for the routine

Table 1. *Data of compounds* **6f, i–m**[a]

No.	M.p., °C Solvent	Yield (%)	Formula[b] M.w.
6f	91–92 benzene	69	$C_{13}H_{17}NO_2$ 219.29
6i	124–126 ethyl acetate	84	$C_{14}H_{18}ClNO_2$ 267.76
6j	169–171 ethyl acetate	90	$C_{14}H_{18}ClNO_2$ 267.76
6k	100–103 benzene	77	$C_{14}H_{18}ClNO_2$ 267.76
6l	114–115 ethanol	87	$C_{14}H_{17}Cl_2NO_2$ 302.20
6m	180–182 ethanol	95	$C_{14}H_{17}Cl_2NO_2$ 302.20

[a] Compounds **6a–e, g, h** have been described previously[6,10,11].
[b] All compounds gave satisfactory elemental analyses (C, H, N).

^{13}C-NMR spectra and *Lorentz*ian exponential multiplication for signal-to-noise enhancement were used (line width: 0.7 and 1 Hz). Convertional CW- and BB-irradiations of approx. 0.15–0.20 W and 5 W, respectively, were used in the double resonance and off-resonance experiments, the offset being 2 kHz in the latter measurements.

N-Substituted-2-hydroxy-1-cycloalkanecarboxamides **6f, i–m**

cis-2-Hydroxy-1-cycloalkanecarboxylic acid (20 mmol) and the corresponding amine (50 mmol) were heated for 2 h on an oil-bath at 170 °C. After evaporation of the excess amine, the residue crystallized on trituration.

2,4-Dioxo-cis-5,6-trimethylene- and cis- and trans-5,6-tetramethylene-3,4,5,6-tetrahydro-1,3-oxazines **7a–n**

The starting compound **6a–n** (10 mmol) and 1,1′-carbonyldiimidazole (40 mmol) were refluxed for 8 h in benzene. Water was added to the reaction mixture, and the by-product imidazole was separated from the required product (**7a–n**) contained in the benzene solution. Drying and concentration of the organic phase gave the desired compounds in crystalline form.

The physical properties of compounds **6** and **7** are listed in Tables 1 and 2.

Acknowledgements

The authors are indebted to Mr. *A. Fürjes* and Mr. *I. Pelczer* for valuable technical assistance.

Table 2. *Data of compounds* **7a–n**

No.	M. p., °C Solvent	Yield (%)	Formula[a] M. w.
7a	44–46 ethyl acetate- petrol ether	40	$C_8H_{11}NO_3$ 169.18
7b	60–62 ethanol- petrol ether	86	$C_9H_{13}NO_3$ 183.15
7c	113–115 ethanol- petrol ether	87	$C_9H_{13}NO_3$ 183.15
7d	168–170 ethanol	80	$C_{14}H_{15}NO_3$ 245.19
7e	208–210 ethanol	82	$C_{14}H_{15}NO_3$ 245.19
7f	48–50 ethanol- petrol ether	41	$C_{14}H_{15}NO_3$ 245.19
7g	61–63 ethanol	40	$C_{15}H_{17}NO_3$ 259.20
7h	130–132 ethanol	47	$C_{15}H_{17}NO_3$ 259.20
7i	119–121 ethanol	90	$C_{15}H_{16}ClNO_3$ 293.18
7j	138–140 ethanol- petrol ether	93	$C_{15}H_{16}ClNO_3$ 293.18
7k	115–117 ethanol	93	$C_{15}H_{16}ClNO_3$ 293.18
7l	124–125 ethanol	62	$C_{15}H_{15}Cl_2NO_3$ 327.15
7m	168–169 ethanol- benzene	65	$C_{15}H_{15}Cl_2NO_3$ 327.15
7n	85–87 ethanol	74	$C_{16}H_{19}NO_3$ 273.22

[a] All compounds gave satisfactory elemental analyses (C, H, N).

Table 3. *IR and* ^{1}H-*NMR data of compounds* **7 a–n**

No.	IR bands (KBr, cm^{-1})					^{1}H-NMR chemical shifts ($\delta_{TMS} = 0$ ppm) in $CDCl_3$								
	C=O (urethane)	amide-I	C—O	$C_{Ar}H$	$C_{Ar}C_{Ar}$	CH_2 m(8H)[a]	H-5 m(1H)	H-5[b]	H-6 m(1H)[c]	H-6[b]	*Ar*H			CH_3	CH_2 (2H)[d]
7a	1750	1690	1280 1035	—	—	1.7–2.4	2.90	25	4.90	12	—	—	—	3.22	—
7b	1750	1685	1285 1015	—	—	1.3–2.1	2.73	20	4.62	12	—	—	—	3.20	—
7c	1760	1700	1280 1150	—	—	1.2–2.5		—	4.11	—	—	—	—	3.19	—
7d	1760	1700	1215 1100	765	695	1.2–2.2	2.82	25	4.73	12	7.15[e]	7.44[f]		—	—
7e	1755	1700	1200 1080 1050	760	710 690	1.2–2.5	2.55	25	4.30	—	7.17[e]	7.43[f]		—	—
7f	1750	1690	1210 1150	755	725 690	1.6–2.4	2.87	25	4.82	12	7.30[e]	7.38[f]		—	4.96
7g	1750	1680	1250 1235 1125	735	725 690	1.3–2.0	2.71	20	4.53	12	7.25–7.40[g]			—	4.92 4.95
7h	1745	1685	1225	760 745	695	1.2–2.4		—	4.04	—	7.27[e]	7.39[f]		—	4.93

7i	1755	1685	1200	799	—	1.2–2.0	2.73	25	4.55	12	7.26[h] 7.33[h]	—	4.91
			1180										4.88
7j	1755	1695	1175	800	—	1.1–2.5		—	4.05	—	7.25[h] 7.35[h]	—	4.87
			1020	785									
7k	1755	1695	1200	750	—	1.2–2.1	2.76	22	4.64	12	7.1–7.4[g]	—	5.04
			1190										5.07
7l	1755	1690	1250	830	—	1.3—2.0	2.76	20	4.64	12	7.36[i] 7.18[j] 7.07[k]	—	4.97
			1230	815									5.02
				800									
7m	1755	1700	1230	855	—	1.2–2.5		—	4.14	—	7.36[i] 7.17[j] 7.09[k]	—	4.99
			1165	830									
				810									
7n	1755	1700	1200	765	710	1.2–2.0	2.63	25	4.44	12	7.15–7.30[g]	—	2.90
			1170		690								4.02

[a] Overlapping multiplets of 8 H intensity (6 H for **7a**, **f**).
[b] Half signal width in Hz.
[c] $2 \times t$ (J: 11.5, 11.5 and 4.5 Hz) for *trans* isomers **7c**, **e**, **h**, **j**, **m**.
[d] s (2 H) for **7f**, **h**, **j**, **m**; AB multiplet (**7g**, **i**, **k**, **l**), J_{AB}: 14 (**7g**), 12 (**7i**) and 17 Hz (**7k**, **l**); AA′BB′ multiplet (**7n**).
[e] m (3 H) of *meta* and *para* hydrogens of phenyl ring.
[f] m (2 H) of *ortho* protons of phenyl ring.
[g] Overlapping multiplets of ring hydrogens of 5 H (**7g**, **n**) or 4 H intensity (**7k**).
[h] A (H-2′, 6′) or B (H-3′, 5′) part of AA′BB′ multiplet (2×2 H), $\delta A < \delta B$.
[i] H-3′ d (J: 1.8 Hz), 1 H.
[j] H-5′ $2 \times$ d (1 H).
[k] H-6′ d (J: 8.3 Hz), 1 H.

Table 4. ^{13}C-*NMR chemical shifts* ($\delta_{TMS} = 0$ *ppm*) *of compounds* **7 a–f, i, j** *in* $CDCl_3$ *at 62.9 MHz*

No.	C-2	C-4	C-5	C-6	C-7	C-8	C-9	C-10	CH_3	CH_2	C-1	C-2,6	C-3,5	C-4
7a	151.2	170.6	44.6	79.8	32.8	22.1	28.1	—	28.4	—	—	—	—	—
7b	151.7	171.3	41.8	73.2	28.6[a]	23.2	24.1	20.6	28.6[a]	—	—	—	—	—
7c	152.0	170.7	44.5	76.8	31.3	24.7[b]	24.5[b]	23.8	28.7	—	—	—	—	—
7d	—	171.0	42.2	73.6	28.8	23.2		20.7	—	—	135.3	129.2	128.5	128.7
7e	151.2	170.5	44.9	77.1	31.4	24.7[b]	24.4[b]	23.8	—	—	135.4	129.2	128.5	128.7
7f	150.9	170.2	45.0	79.7	32.8	22.0	28.1[b]	—	—	44.8	137.0	128.5[b]	128.6[b]	127.6
7i	151.7	171.1	41.9	73.4	28.7	23.1	24.1	20.7	—	44.6	134.2	128.8	130.4	135.8
7j	151.5	170.3	44.7	76.8	31.2	24.3[b]	24.5[b]	23.6	—	44.5	133.8	128.7	130.4	135.5

[a] Overlapping lines.
[b] Reversed assignment is also possible.

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