Fused Heterocycles. Part 4.[1] Synthesis and Stereochemistry of Hexahydrobenzo[6,7]cyclohepta[1,2-*c*]pyrazoles

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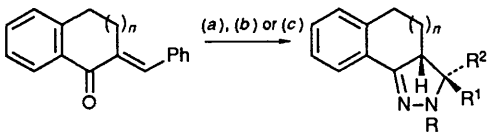
Hexahydrobenzo[6,7]cyclohepta[1,2-*c*]pyrazoles have been synthesized by treating 2-benzylidene-1-benzosuberone with hydrazine derivatives. The *cis* and *trans* isomers have been distinguished and conformational equilibria studied by NMR techniques.

Recently we reported the reaction of 2-arylidene-1-tetralones and related α,β-unsaturated ketones with hydrazines, semicarbazide and thiosemicarbazide.[1-3] It has been found that the 3-H,3a-H *cis*/*trans* isomer ratio in the condensed pyrazole derivatives obtained depends on the reaction conditions. The synthesis of the homologous hexahydrobenzo[6,7]cyclohepta-[1,2-*c*]pyrazoles has now also been accomplished. Condensed pyrazole derivatives of this type are already known,[4,5] but neither the relative configuration of the centres of the chirality nor the conformation of the seven-membered ring has been discussed. Some of these pyrazoles were found to possess anti-implantation,[4] antiarrhythmic,[6] antiinflammatory,[7] antihypertensive and abortifacient[8] activities which make them substances of interest for pharmaceutical research as well.

Results and Discussion

Synthesis.—The reaction of 2-benzylidene-1-benzosuberone (**1**) with phenylhydrazine, semicarbazide or thiosemicarbazide, refluxing in ethanol, in the presence of hydrochloric acid afforded the hexahydrobenzo[6,7]cyclohepta[1,2-*c*]pyrazoles (Scheme 1). The compounds are racemates, but only the (3a*R*) diastereoisomers are shown. (The hydrogen atoms of the seven-membered ring are depicted by applying the convention in which 3a-H is in the β-position, towards the observer). The reaction resulted in the formation of both 3-H,3a-H *cis* and *trans* diastereoisomers with all hydrazine derivatives except thiosemicarbazide where only the *cis* isomer could be isolated. Diastereoisomers *cis*-**2**, *trans*-**2**, *cis*-**4** and *trans*-**4** were separated by column chromatography. The fairly reactive methylhydrazine reacts with 2-benzylidene-1-benzosuberone even in the absence of catalyst, yielding the *trans* isomer *trans*-**5** exclusively. With hydrazine in ethanol both isomers are formed, however, they decompose in 2–3 days to form nitrogen and a tar.[9] These compounds are also unstable in solution, so that only the *trans* isomer could be studied by NMR spectroscopy. The mixture of the isomers *cis*-**6** and *trans*-**6** was allowed to react with benzenesulphonyl chloride to yield the appropriate sulphonamide derivatives, from which only the *trans*-**8** isomer could be isolated in a pure state, while *cis*-**8** was contaminated with *ca.* 15% of the *trans*-**8** isomer. The *trans*-**7** and *cis*-**7** derivatives were prepared by treatment of **1** with hydrazine in acetic acid.

Assignment and Characterization of the cis *and* trans *Isomers.*—The structure and relative configuration of the compounds prepared have been determined by means of ^1H and ^{13}C NMR spectra and homonuclear proton–proton NOE difference measurements. Assignment of the proton signals

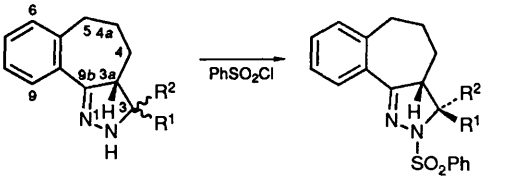


1, *n* = 2
9, *n* = 1

2–5, 7
10, 11

Compound	*n*	R	Method	R^2	R^1
cis-**2**	2	$CONH_2$	(*a*)	Ph	H
trans-**2**	2	$CONH_2$	(*a*)	H	Ph
cis-**3**	2	$CSNH_2$	(*a*)	Ph	H
trans-**3**	2	$CSNH_2$	*	H	Ph
cis-**4**	2	Ph	(*a*)	Ph	H
trans-**4**	2	Ph	(*a*)	H	Ph
trans-**5**	2	Me	(*b*)	H	Ph
cis-**6**	2	H	(*a*)	Ph	H
trans-**6**	2	H	(*a*)	H	Ph
cis-**7**	2	COMe	(*c*)	Ph	H
trans-**7**	2	COMe	(*c*)	H	Ph
cis-**10**	1	COMe	(*c*)	Ph	H
trans-**10**	1	COMe	(*c*)	H	Ph
cis-**11**	1	$CONH_2$	(*a*)	Ph	H
trans-**11**	1	$CONH_2$	(*a*)	H	Ph

* This compound was obtained by isomerization of *cis*-**3**



cis, trans - **6**

cis - **8**, R^1 = H; R^2 = Ph
trans - **8**, R^1 = Ph; R^2 = H

Scheme 1 Methods: (*a*), NH_2NHR, EtOH, HCl; (*b*) NH_2NHR, EtOH; (*c*) NH_2NH_2, AcOH

of the seven-membered ring has been performed by one-dimensional COSY spectra[10] and NOE difference experiments. For the assignment of the ^{13}C NMR signals, data for the six-membered analogues[1,2] could only be partially utilized. Therefore ^{13}C–^1H heteronuclear correlation spectra had to be measured for an unambigous assignment of the C-4, C-4a and C-5 signals. Identification of some other signals, mainly those of quaternary carbon atoms, was possible by means of the semiselective INEPT method.[11] This experiment was optimized

to 7 Hz long-range ^{13}C–^{1}H heteronuclear coupling. In our previous work[1] the COLOC[12] method was used for the same purpose but now equivalent information could be obtained more simply and quickly. ^{1}H and ^{13}C NMR spectral data are summarized in Tables 1 and 2. For *cis*/*trans* isomers of the hexahydrobenzo[6,7]cyclohepta[1,2-*c*]pyrazoles it was, in turn, possible to use the appropriate data for six-membered analogues[1] as reference. Since in the present case the reaction was less stereoselective, more isomeric pairs could be compared. By pairwise comparison of the ^{1}H NMR spectra the chemical shift of 3-H is considerably higher (by 0.5–0.7 ppm) in the *cis* than in the *trans* isomer. The chemical shift of 3-H, however, depends on the substituent R. (In the case of the models available it covers a range of *ca.* 1.05 ppm for both isomers.) It is also valid that owing to the diamagnetic effect of the 3-phenyl group, 3a-H is more shielded in the *trans* isomers by 0.5–0.7 ppm while substituent R is without influence. The only exception is the isomeric pair **8** where this difference is only 0.08 ppm.

Characteristic differences were also observed concerning the chemical shift of the proton signals of the seven-membered ring. Both the chemical shifts and the sequence of these signals are different in the *cis* and *trans* isomers. An unambiguous assignment was therefore important, especially since the signals were only partially resolved at the applied magnetic fields. In the *cis* and *trans* isomers the change in shielding of 4α-H and 4β-H is also a consequence of the diamagnetic anisotropy of the 3-phenyl group. As a result, in the *cis* isomers, chemical shifts for 4α-H and 4β-H are lower by *ca.* 0.7–1 ppm than those for the *trans* compounds. The exception is again the isomeric pair **8** for which the chemical shift difference at 4α-H is merely 0.2 ppm. This may be attributed to the influence of the bulky SO_2Ph group on the conformation of the 3-phenyl group in respect of its rotation around the C(3)–C(1′) axis and altering the diamagnetic shielding at 3-H and 4-H_2. The chemical shift difference between *geminal* methylene protons is relatively small in *trans*-**5** and *trans*-**6** where no considerable conjugation exists between the N-2 nitrogen atom and substituent R. For this reason, our estimates concerning the conformation of the seven-membered ring (see below) are mainly valid for the 2-phenyl and 2-acyl derivatives. It is noteworthy that in the *cis* compounds $J_{3\text{-H},3a\text{-H}}$ is 10.5–11.6 Hz while the value is 3.9–14.0 Hz for the *trans* compounds. Since the value appears to be highly dependent on the substituent R it is of less value for the conformational analysis and for distinguishing the *cis*/*trans* isomers.

Comparison of the ^{13}C NMR spectra provides similar results, as observed with the six-membered analogues. In the *cis* isomers the chemical shift of C-3 is significantly smaller, which is a consequence of the quasiaxial arrangement of the 3-phenyl group in the dominant conformer, while this group is quasiequatorial in the *trans* isomer (see below). The different β-substituent effect[13] of the axial and equatorial substituents in position 3 is reflected in the difference of the chemical shifts of C-3a. A further feature is that the chemical shifts of C-4 and C-1′ are smaller in the *cis* isomers as a result of their shorter distance as compared to the appropriate *trans* isomer (steric interaction). A small but significant difference was observed for the C-9b signals where the signal of the *cis* isomer appeared downfield in each case.

For the differentiation of the *cis* and *trans* isomers the homonuclear NOE difference[14] technique is the most important tool. Owing to the spatial proximity of protons 3-H and 3a-H the mutual and substantial NOE between them in the *cis* isomer and a negligible or total absence of the NOE in the *trans* isomer enables an unambiguous identification of the isomers. Difference NOE measurements are summarized in Table 3.

Conformational Analysis.—With the six-membered analogues (in some cases with oxygen or sulphur as heteroatom) of hexahydrobenzo[6,7]cyclohepta[1,2-*c*]pyrazoles,[1,2] the half-chair conformer was found to predominate in the half-chair ⇌ boat conformational equilibrium in both the *cis* and *trans* isomers. The half-chair was further stabilized by the equatorial disposition of the 4-phenyl group. At the same time, however, conformational mobility of the five-membered ring was restricted due to the conjugation of the C=N double bond with the substituent in position 2.

Conformational possibilities for the seven-membered ring are even more manifold[15] as illustrated in Fig. 1 showing that two boats, a chair and a twist-boat conformer should be taken into consideration. Maximum conjugation between the condensed aromatic ring and the C=N double bond is possible in the boat-2 conformer which is therefore the most favourable conformation in respect of conjugation. The dihedral angle of the C=N double bond and the condensed aromatic ring is *ca.* 30° in the twist-boat while it is *ca.* 80° both in the chair and boat-1 conformers, therefore practically no conjugation can be expected in the latter two conformations. The interconversion of boat-2 ⇌ twist-boat and chair ⇌ boat-1 conformers of the seven-membered ring is accompanied by the inversion of the envelope conformer of the fused pyrazole ring. The conjugation of the condensed aromatic ring and the C=N double bond is reflected both in the UV spectra (Table 4) and in the chemical shift of the *peri*-9-H proton, since in the case of a coplanar arrangement it is expected to be shifted downfield as a result of the diamagnetic anisotropy of the C=N double bond. Data in Table 1 show that, except for two compounds, *trans*-**2** and *trans*-**7**, the chemical shift value is *ca.* 7.9 ppm or higher, which corroborates the dominance of conformer boat-2. However, these exceptions also indicate that the conformational equilibrium may be different for the *cis* and *trans* isomers which should therefore be investigated in more detail. For this reason some of our compounds were subjected to NOE difference spectroscopy (Table 3).

Dreiding models show that, independently of *cis*/*trans* isomerism, 3a-H and 5β-H protons are close in space in the boat-2 conformer whereas 3a-H and 4aβ-H are close in space in the chair conformer. NOEs between 3a-H and 5β-H are reliably high in the *cis* isomers but lower for the *trans* compounds, which may be a consequence of the fact that these signals are close to each other in the spectra of the *trans* isomers. A reliable NOE effect between the 3a-H and 4aβ-H signals can be measured only in the case of the *trans* isomers since the latter is not well separated from 4aα-H in the *cis* isomers. At the same time a small but significant NOE can be observed between the 4α-H and 5α-H protons both in the *cis* and *trans* isomers which indicates some contribution of the chair conformer to the conformational equilibrium beside the predominant boat-2 conformer. It should be mentioned that owing to the spatial proximity of the 3-phenyl group and the 4a-methylene group the boat-1 conformer is very unfavourable in the *cis* isomers. Although this interaction is not present in the *trans* isomer, NOE relating to the spatial proximity of the 3-H and 4aβ-H protons is not detectable which means that the ratio of the of the boat-1 conformer is negligible.

In the boat-2 conformer of the *cis* isomer, as a result of the 1,3-allylic strain and the *peri*-effect of the N-2 acyl group, the quasiaxial arrangement of the 3-phenyl group is energetically favourable. Since the energy content of the boat-2 conformer is higher in the *trans* isomer, the percentage of twist-boat conformer (which also allows some conjugation) is higher. In this latter conformation the 3-phenyl group adopts a quasi-equatorial position. It is important to recognize that the dihedral angle between 3-H and 3a-H decreases to 90° in the twist-boat form in contrast to the value of 150° characteristic of both boat-1 and boat-2 conformers. In the *trans* isomers the

Table 1 ^{1}H NMR chemical shifts (δ/ppm) and characteristic coupling constants (*J*/Hz) for compounds **2–8**

	cis-**2**	*trans*-**2**	*cis*-**3**	*trans*-**3**	*cis*-**4**	*trans*-**4**	*trans*-**5**	*trans*-**6**	*cis*-**7**	*trans*-**7**	*cis*-**8**	*trans*-**8**
3-H	5.54	5.02	6.03	5.55	5.30	4.65	3.61	4.49	5.62	5.02	4.98	4.30
3a-H	3.78	3.12	3.88	3.19	3.72	3.18	3.15	3.21	3.77	3.04	3.28	3.20
4α-H	0.98	1.8–2.05	0.92	1.9–2.05	1.08	1.75–2.05			0.98	1.75–1.9	*ca.* 0.9	1.09
							1.96	2.0–2.2				
4β-H	1.52	2.24	1.56	2.35	1.45	2.24			1.52	2.21	1.57	1.97
4aα-H		1.8–2.05		1.9–2.05		1.75–2.05				1.75–1.9		
	1.7–1.9		1.7–1.9		1.6–1.9		1.64	1.6–1.9	1.7–1.85		1.7–1.9	1.55–1.8
4aβ-H		1.71		1.83		1.68				1.67		
5α-H	2.63		2.65		2.60	2.73	2.71		2.65		2.64	2.55
		2.7–3.0		2.8–3.0				2.7–3.05		2.7–2.95		
5β-H	2.98		2.99		2.94	2.92	2.95		3.01		2.82	2.84
9-H	7.93	7.75	8.00	7.73	7.97	7.94	7.93	7.95	8.03	7.68	7.89	7.88
$J_{3,3a}$	11.0	5.8	10.8	3.9	11.6	8.5	14.0	11.3	11.1	4.9	10.5	8.6
$J_{3a,4\alpha}$	14.0	11.8	13.3	12.1	12.8	11.8	11.5		13.0	11.9	12.5	12.2

Table 2 ^{13}C NMR chemical shifts (δ/ppm) for compounds **2–8**

	cis-**2**	*trans*-**2**	*cis*-**3**	*trans*-**3**	*cis*-**4**	*trans*-**4**	*trans*-**5**	*trans*-**6**	*cis*-**7**	*trans*-**7**	*trans*-**8**
C-3	65.2	68.0	68.5	71.3	68.9	73.1	81.4	72.7	64.8	67.9	72.5
C-3a	50.0	57.9	49.6	58.1	50.4	58.2	56.2	55.2	49.4	57.5	57.4
C-4	25.3	33.7	24.1	34.0	27.3	33.3	29.7	30.0	25.2	34.3	31.4
C-4a	24.7	25.5	23.9	25.7	25.3	25.6	25.4	25.6	24.7	25.7	24.8
C-5	33.9	35.8	33.2	35.6	34.7	35.0	35.3	35.1	33.9	37.5	34.8
C-5a	140.8	141.6	141.2	142.1	140.1	140.8	140.2	140.5	140.9	141.4	140.1
C-6	130.3	130.2	131.0	130.5	130.0	130.2	130.1	130.1	130.4	130.4	130.3
C-7	130.1	129.6	130.4	130.3	128.7	128.7	128.7	129.0	130.4	129.8	130.1
C-8	126.8	126.4	126.8	126.5	126.4	126.4	126.4	126.4	126.7	126.5	126.5
C-9	128.3	128.4	128.3	128.4	128.2	128.6	128.2	128.4	128.5	128.5	129.0
C-9a	131.3	131.9	130.3	131.3	132.9	132.9	132.5	132.7	131.2	132.1	130.7
C-9b	158.2	157.3	162.7	161.8	153.6	152.5	154.9	156.6	160.3	159.8	162.9
C-1′	137.2	142.1	136.5	141.4	136.7	142.3	139.7	141.4	136.8	141.8	141.0
C-2′,6′	128.4	125.1	128.3	125.0	128.7	125.8	127.7	126.9	128.4	125.3	126.5
C-3′,5′	126.8	128.8	126.7	128.9	127.5	129.1	128.6	128.8	126.7	128.9	128.7
C-4′	127.6	127.4	127.6	127.6	127.5	127.6	127.9	127.6	127.6	127.6	128.0
R	155.1	155.7	176.1	177.1	144.8[a]	145.1[a]	41.7		168.6	169.1	134.7[a]
					113.8[b]	113.6[b]			21.9	21.9	128.7[b]
					128.5[c]	128.8[c]					128.5[c]
					118.8[d]	119.2[d]					133.2[d]

[a] For C-1″. [b] For C-2″,6″. [c] For C-3″,5″. [d] For C-4″.

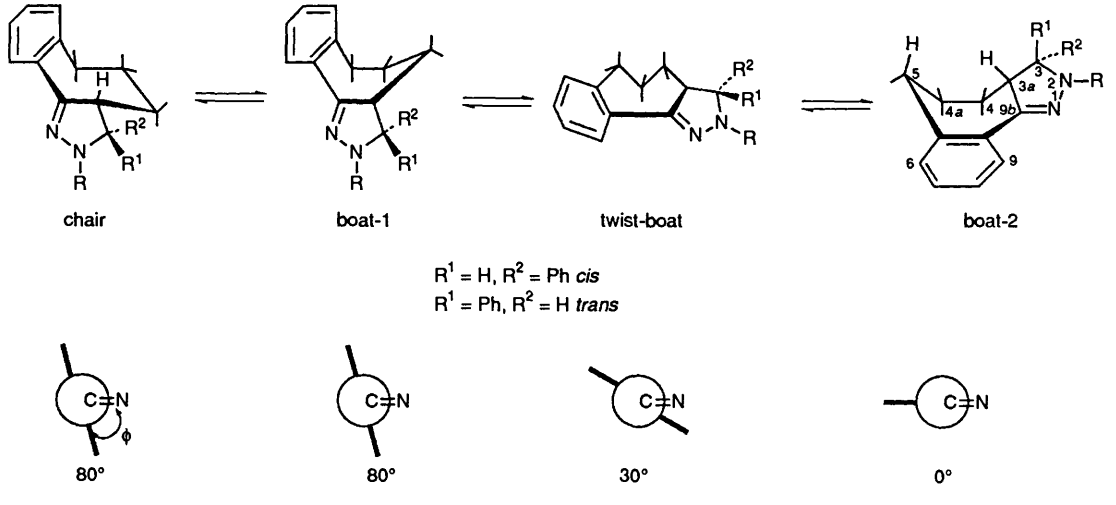


Fig. 1

decrease in the $J_{3-H,3a-H}$ coupling constant in the Me ⟶ $CONH_2$ series indicates the enhancement of the ratio of the twist-boat conformer beside the dominating boat-2 conformer. This explains the fact that the 9-H signals of both *trans* N-2-acyl derivatives show an upfield shift since the ratio of the twist-boat conformer is the highest in these cases.

In the *trans* isomers the increased percentage of the twist-boat conformer is corroborated also by the magnitude of the $J_{3a-H,4\alpha-H}$ coupling constant (13 Hz for the *cis* and 12 Hz for the *trans* isomers in each case). In conformers boat-2 and chair the dihedral angle of the coupled protons is *ca.* 180°, while in the twist-boat conformer it is 150°.

Table 3 Results of homonuclear difference NOE experiments on selected compounds

Compound	Proton irradiated	NOE observed (%)
cis-**2**	3a-H	3-H (15.9); 4β-H (6.5); 4a-H_2 (5.1); 5β-H (8.3)
	4β-H	3-H (1.6); 3a-H (5.8); 4α-H (27.2); 2′,6′-H (4.5)
	4α-H	3a-H (1.4); 4β-H (24.6); 4a-H_2 (4.9); 5α-H (2.9); 2′,6′-H (5.6)
	5α-H	4α-H (3.6); 4a-H_2 (7.4); 5β-H (30.1); 6-H (12)
	5β-H	3a-H (10.5); 4a-H_2 (3.8); 5α-H (21.0)
trans-**2**	3-H	3a-H (2.6); 4β-H (3.1); 4α-H (4.3); 2′,6′-H (7.1)
	3a-H	3-H (2.2); 4β-H (2.7); 4aβ-H (1.3)
	4β-H	3-H (5.3); 3a-H (6.3); 4α-H + 4aα-H (22.7); 4aβ-H (5.4)
	4aβ-H	3a-H (4.5); 4β-H (4); 5-H_2 (3.3)
	5α-H	4α-H + 4aα-H (10.3); 4aβ-H (3.4); 6-H (6.5)
	5β-H	3a-H (>2); 4aβ-H (5.7); 4α-H + 4aα-H (6.2); 6-H (13)
cis-**3**	3-H	3a-H (9.5); 2′,6′-H (4.4); 4β-H (1)
	3a-H	3-H (14.3); 4β-H (5.8); 4α-H (2); 4a-H_2 (6.7); 5β-H (8.8)
	4α-H	3a-H (1.8); 4β-H (30.2); 4a-H_2 (5.5); 5α-H (2.8)
	4β-H	3a-H (4.6); 4α-H (23.1); 4a-H_2 (>5); 2′,6′-H (4.5)
	5α-H	4α-H (3.2); 4a-H_2 (7.5); 5β-H (35); 6-H (10)
	5β-H	3a-H (13); 4a-H_2 (4.3); 5α-H (20.6)
cis-**7**	3-H	3a-H (10.2); 2′,6′-H (12.2); 4β-H (1); CH_3 (1.4)
	3a-H	3-H (12.0); 4β-H (4.2); 4a-H_2 (3.4); 5β-H (6.9)
trans-**7**	3-H	3a-H (2.6); 4α-H (3.7); 4β-H (2.5); 2′,6′-H (4.6)
	3a-H	3-H (2.0); 4β-H (3.9); 4aβ-H (3.2)
trans-**8**	3-H	3a-H (2.7); 4α-H (3.0); 4β-H (2.4); 2′,6′-H (9.3); 2″,6″-H (6.1)
	3a-H	3-H (2.0); 4β-H (2.7); 4aβ-H (2.1); 5β-H (3.3); 2′,6′-H (5.0)
	4α-H	3-H (4.9); 4β-H (24.3); 4a-H_2 (>3); 5α-H (2.3)
	4β-H	3-H (3.4); 3a-H (5.4); 4α-H (25.7); 4aβ-H (3.3); 2′,6′-H (1)
	5α-H	4α-H (3.4); 4a-H_2 (2.9); 5β-H (29.1); 6-H (6.5)
	5β-H	3a-H (6.6); 4aβ-H (4.0); 5α-H (24.2); 6-H (6.0)

Table 4 Comparison of characteristic UV data (solvent: ethanol) and 9-H chemical shifts for selected compounds

Compound	R	δ(9-H)/ppm	λ_{max}/nm	log ε
cis-**2**	$CONH_2$	7.93	299	4.12
trans-**2**	$CONH_2$	7.75	284	4.13
cis-**7**	COMe	8.03	294	4.10
trans-**7**	COMe	7.68	280	4.16
cis-**10**	COMe	8.07	294	4.25
trans-**10**	COMe	7.96	290	4.28
cis-**11**	$CONH_2$	8.01	297	4.20
trans-**11**	$CONH_2$	7.95	292	4.18

Since the conjugation between the condensed aromatic ring and the C=N double bond decreases with a higher ratio of the twist-boat conformer in the conformational equilibrium this phenomenon should be reflected in the UV spectra. λ_{max} values of the **2** and **7** *cis*/*trans* isomer pairs and those of their six-membered analogues **10** and **11** are shown in Table 4. It can be seen that in the case of the *cis* isomers the absorption maximum values are almost the same in the six- and seven-membered analogues. The hypsochromic shift is different for the *trans* isomers since it is 4–5 nm in the six-membered, and significantly larger, 14–15 nm, in the seven-membered series. This is in accordance with alterations of the chemical shift of 9-H.

Experimental

Synthesis.—2-Benzylidene-1-benzosuberone was prepared according to a known method.[16] Its *E*-configuration was corroborated by ^{1}H NMR spectroscopy.[17]

Method A. A mixture of α,β-unsaturated ketone (5 mmol), hydrazine derivative (10 mmol) and concentrated hydrochloric acid (5 cm^3) was refluxed in ethanol (50 cm^3). The reaction was monitored by TLC. The precipitate was filtered off, rinsed with ethanol, washed free of acid with water and recrystallized from methanol. Diastereoisomers were separated by fractional crystallization or column chromatography on silica gel or neutral aluminium oxide.

Method B. The mixture of 2-benzylidene-1-benzosuberone (1.24 g, 5 mmol) and methyl hydrazine (0.99 g, 21 mmol) in ethanol was stirred at room temperature for 2 h. After standing for one day the solvent was evaporated, and the residue was recrystallized, first from diethyl ether then from methanol.

Method C. The α,β-unsaturated ketone (10 mmol) and hydrazine hydrate (40 mmol) were dissolved in acetic acid (50 cm^3) and the mixture was refluxed for 40–50 h. The solution was poured into water, the oily product was extracted with chloroform and washed with water until neutral. The chloroform extract was dried ($MgSO_4$) and evaporated to yield a mixture of *cis* and *trans* isomers as well as some unchanged ketone. The mixture was separated by column chromatography over neutral aluminium oxide or silica gel.

2-Benzenesulphonyl-3-phenyl-2,3,3a,4,5,6-hexahyhydrobenzo-[6,7]cyclohepta[1,2-c]pyrazole (**8**). A mixture of isomers *cis*-**6** and *trans*-**6** (3.65 g, 14 mmol) and benzenesulphonyl chloride (5.31 g, 30 mmol) was refluxed in dry pyridine (100 cm^3) with the exclusion of moisture for 2.5 h. The red solution was poured into water yielding an oily material. This was extracted with chloroform, washed with water until neutral, dried (Na_2SO_4) and evaporated. The pure *trans* isomer *trans*-**8** was obtained by fractional crystallization.

Compound trans-**3**. This was synthesized by epimerization of *cis*-**3** under basic conditions. Details of the epimerization experiments will be published elsewhere.[18]

M.p.s are uncorrected. Elemental analyses were carried out

Table 5 Physical constants, analytical and IR spectral data for compounds **2–10**

Compound	M.p./°C	Yield (%)	Molecular formula	Required (%)			Found (%)			ν(amide/thioamide)/ cm^{-1}
				C	H	N	C	H	N	
cis-**2**	208–210	61	$C_{19}H_{19}N_3O$	74.73	6.27	13.76	74.80	6.37	13.56	1680
trans-**2**	165–169	30	$C_{19}H_{19}N_3O$	74.73	6.27	13.76	74.62	6.31	13.62	1675
cis-**3**	95 (dec.)	65	$C_{19}H_{19}N_3S$	71.00	5.96	13.07	70.95	6.02	13.31	1360
trans-**3**	85 (dec.)	93	$C_{19}H_{19}N_3S$	71.00	5.96	13.07	70.80	5.71	13.08	1350
cis-**4**	163–166	32	$C_{24}H_{22}N_2$	85.17	6.55	8.28	85.20	6.36	8.49	—
trans-**4**	130–132	32	$C_{24}H_{22}N_2$	85.17	6.55	8.28	85.04	6.70	8.34	—
trans-**5**	96–97	86	$C_{19}H_{18}N_2$	83.18	6.61	10.21	83.30	6.42	10.28	—
cis-**7**	oil	6	$C_{20}H_{20}N_2O$	—	—	—	—	—	—	1650
trans-**7**	128–129	20	$C_{20}H_{20}N_2O$	78.92	6.62	9.20	79.03	6.30	9.27	1655
trans-**8**	168–170	17	$C_{24}H_{22}N_2O_2S$	71.62	5.51	6.96	71.49	5.54	7.12	—
cis-**10**	148–150	15	$C_{19}H_{18}N_2O$	78.59	6.25	9.65	78.60	6.30	9.42	1660
trans-**10**	96–97	21	$C_{19}H_{18}N_2O$	78.59	6.25	9.65	78.64	6.30	9.43	1680

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Spectroscopy.—IR spectra were recorded on a Specord 75IR instrument. UV spectra were taken on a Perkin-Elmer Model 402 instrument. ^{1}H NMR spectra were recorded on Bruker AC-250 and AM-300 spectrometers at 250 and 300 MHz, respectively. ^{13}C NMR spectra were recorded at 67.2 MHz. Samples were taken in $CDCl_3$ solution and tetramethylsilane was used as internal standard.

For the homonuclear NOE experiments a delay time of 3 s and a total irradiation time of 1.5 s (*ca.* 3 × T_1) was applied. For the 1D-COSY and semiselective INEPT measurements, soft pulses from the decoupler with 25 Hz selectivity were used.

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