Tetrahedron. Vol. 34, pp. 371 to 378. Pergamon Press 1978. Printed in Great Britain

STUDIES OF POLARIZED ETHYLENES—VIII†
CONFORMATIONAL ANALYSIS OF TWISTED ETHYLENES

J. SANDSTRÖM* and U. SJÖSTRAND
Division of Organic Chemistry 1, Chemical Center, University of Lund, P.O.B. 740, S-220 07 Lund 7, Sweden

(*Received in the UK* 11 *July* 1977; *Accepted for publication* 19 *August* 1977)

Abstract—Push-pull ethylenes have been prepared, which in the ground state are twisted around the double bond, and the barriers for passage through a planar transition state have been measured with DNMR. The influence of steric and electronic factors on the rotational barriers has been investigated. Compounds have also been prepared where two barriers could be measured, one for passage through the planar state, and the other for passage through a 90° twisted state.

The potential energy curve for the rotation around a double bond in an olefin can be regarded as the sum of two potential energy curves, one for the π-electron energy and the other for the steric strain[1] (Fig. 1). The former has its maximum at the dihedral angle $\theta = 90°$, where the lack of overlap between the two ethylenic p orbitals destabilizes the system, while the latter has its maximum at $\theta = 0°$ and is due to non-bonded repulsion between the substituents on the two C atoms. We call the corresponding potential energy curves E_π and E_s, respectively. The ground state will be found at the minimum of the sum of these potential energy curves. The position of this minimum is dependent not only upon the energy maxima but also upon the shapes of the potential energy curves. E_π will probably be nearly cosine-shaped, and the depth of the energy well will to a large extent depend on the steepness of E_s. The passage between two energy minima may occur via a 90° twisted or via a planar transition state. The barriers to these two processes are called E_{90} and E_0 respectively.

In a simple ethylene, such as 1,2-dideuterioethylene or 2-butene there is a high π-barrier but little steric inter-

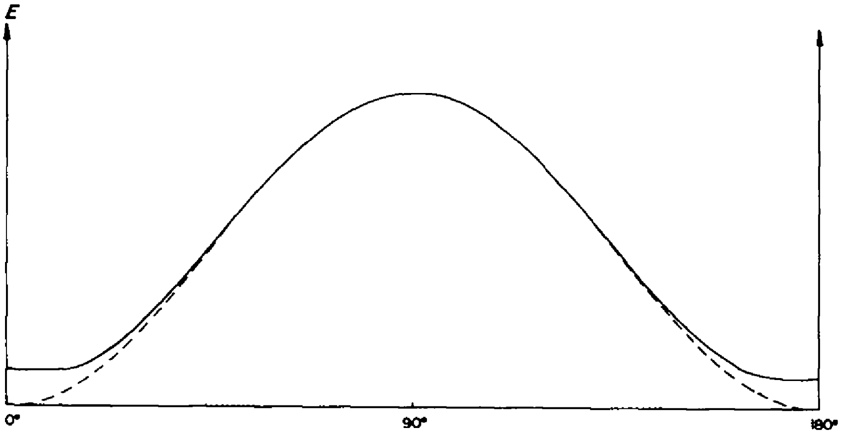


Fig. 1(a).

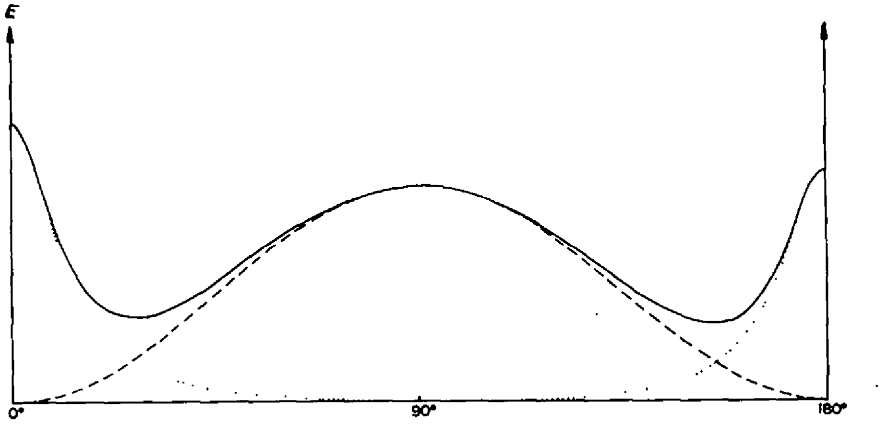


Fig. 1(b).

---

†Part VII is Ref. 18.

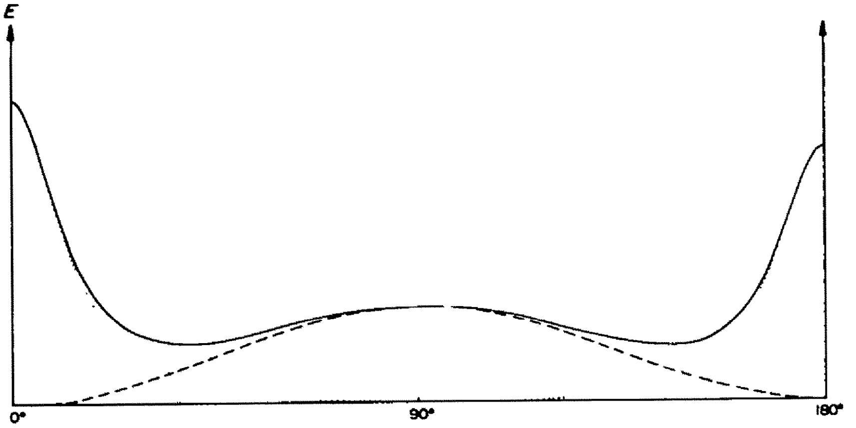


Fig. 1(c).

Fig. 1. Potential energy curves, E_s (····), E_π (----), and total energy (——). (a) Small steric and large π-electronic effect. (b) Intermediate steric and π-electronic effects. (c) Large steric and small π-electronic effect.

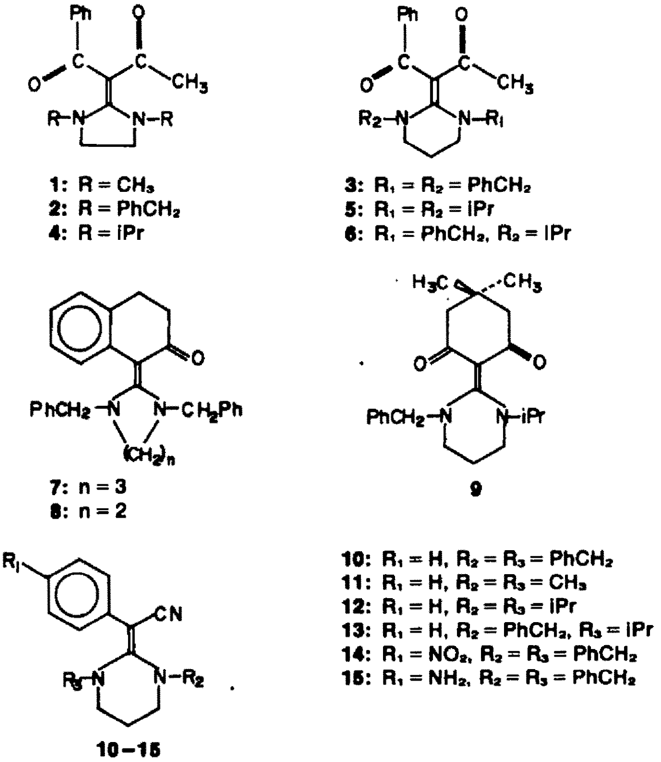
action, giving rise to a barrier separating the E and Z forms in the order 60–65 kcal/mol.[2,3] Much lower barriers can be obtained by lowering E_π. In push–pull ethylenes strong acceptors on one carbon and strong donors on the other lower E_π due to stabilization of a zwitterionic transition state by these groups.[4,5]

Lower E_{90} can also be obtained by increasing E_s. This corresponds to an increased ground state energy. If E_s is large enough the molecule will be strongly twisted in the ground state[6,7] (Fig. 1b). Overcrowded ethylenes with low E_{90} are known.[8]

When the steric interactions between the donor and the acceptor groups in push–pull ethylenes are strong enough, permanently twisted ethylenes result with a barrier for passage through a planar transition state which can be measured with DNMR (Fig. 1c).[1] We have investigated the rotational processes around the double bond in some systems of this kind (Scheme 1).

RESULTS AND DISCUSSION

The 270 MHz ^{1}H NMR spectrum of **1** at 290 K shows a singlet for the N-Me groups, while the protons in the imidazolidine ring give an AA'BB' pattern. There are two possible explanations for this. The molecule may be planar in the time average, in which case the singlet resonance for the N-Me protons is due to accidental equivalence. Then $J_{AA'}$ (Fig. 2) will be a geminal coupling constant, which can be assumed to be of opposite sign to the vicinal coupling constants J_{AB} and $J_{AB'}$.[9] If on the other hand the molecule is permanently twisted about the double bond and the passage past E_0 is slow but that past E_{90} is fast on the NMR timescale, an AA'BB' system will



1: R = CH$_3$
2: R = PhCH$_2$
4: R = iPr

3: R$_1$ = R$_2$ = PhCH$_2$
5: R$_1$ = R$_2$ = iPr
6: R$_1$ = PhCH$_2$, R$_2$ = iPr

7: n = 3
8: n = 2

9

10–15

10: R$_1$ = H, R$_2$ = R$_3$ = PhCH$_2$
11: R$_1$ = H, R$_2$ = R$_3$ = CH$_3$
12: R$_1$ = H, R$_2$ = R$_3$ = iPr
13: R$_1$ = H, R$_2$ = PhCH$_2$, R$_3$ = iPr
14: R$_1$ = NO$_2$, R$_2$ = R$_3$ = PhCH$_2$
15: R$_1$ = NH$_2$, R$_2$ = R$_3$ = PhCH$_2$

Scheme 1.

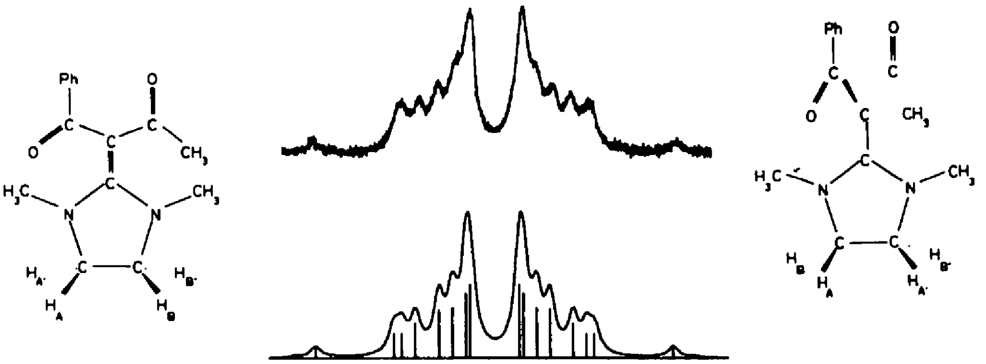


Fig. 2. Experimental and calculated spectra (100 MHz) of the imidazolidine ring protons in **1** (solvent deuteriochloroform). $\Delta\nu_{AB} = 16.5$ Hz, $J_{AB} = \mp 11.0$ Hz, $J_{AB'} = \pm 8.1$ Hz, $J_{AA'} = \pm 12.0$ Hz.

also arise but now with the geminal coupling between two nuclei with different chemical shifts (J_{AB}). The equivalence of the N-Me signals is then a consequence of a time-average perpendicular arrangement of PhCO–C–COMe with respect to the imidazolidine ring. An analysis of the spectrum with the UEAITR program[10] showed that the latter case was at hand. The parameters obtained were in agreement with the perpendicular structure.

To check the analysis, the 100 MHz spectrum was recorded and simulated using the same coupling constants and the appropriately scaled shift. The agreement was excellent (Fig. 2).

At lower temperatures first the high-field and then the low-field part of the spectrum was broadened due to slow rotation of the acetyl group, and at higher temperatures it coalesced to a singlet due to fast rotation around the double bond.

The fact that the spectral parameters fit a perpendicular structure does not mean that the ground state of the molecule has a dihedral angle $\theta = 90°$ about the double bond. The molecule is probably oscillating between two degenerate ground states with dihedral angles around 45° and 135°, and with a low barrier separating them. On the NMR timescale, however, when the exchange between these two sites is fast, this corresponds to an effectively perpendicular structure.

In **2** the Me groups have been replaced by prochiral benzyl groups. In the slow exchange region the benzylic protons give an AB pattern in agreement with a twisted structure, whereas a planar structure requires two singlets. The fast exchange spectrum shows one singlet. A complete bandshape analysis of 12 spectra in the temperature range 293 K to 353 K gave $\Delta H^{\ddagger} = 19.2 \pm 0.5$ (3σ) kcal/mol and $\Delta S^{\ddagger} = +7.7 \pm 1.5$ cal/mol·K.

The twisted ground state in this molecule will have a charge separation with a negative charge localized over $PhCOCCOCH_3$ and a positive charge over N–C–N. This zwitterionic ground state can be assumed to be strongly solvated by polar solvents, i.e. surrounded by a shell of well ordered solvent molecules. However, the planar transition state has less charge separation, causing a diminished order of the solvent molecules and therefore a positive entropy of activation, in agreement with our result.

In planar polarized ethylenes, on the other hand, we have a more polar transition state and would expect a negative entropy of activation. This has been confirmed in several works.[4,11,12]

For **3**, a complete bandshape analysis of the NMR spectra at 11 temperatures in the range 403–447 K, with the inclusion of a long-range coupling to the ring protons, gave the activation parameters: $\Delta H^{\ddagger} = 26.4 \pm 0.9$ kcal/mol, $\Delta S^{\ddagger} = +10.2 \pm 2.2$ cal/mol·K.

Enlargement of the electron-donating ring increases the steric strain in the transition state, since the benzyl groups now come closer to the acceptors, whereas the increase of strain in the ground state is less pronounced, giving a difference in $\Delta H^{\ddagger}$ of 7.2 kcal/mol between the 6- and 5-membered ring.

The slightly more positive value for $\Delta S^{\ddagger}$ for the 6-membered ring is in agreement with a more twisted and therefore more polar ground state.

In **4** and **5** the benzyl groups have been replaced by isopropyl groups. For these compounds only $\Delta G^{\ddagger}$ was determined. The values $\Delta G^{\ddagger}_{348} = 18.0$ kcal/mol and $\Delta G^{\ddagger}_{429} = 23.7$ kcal/mol for **4** and **5** respectively can be compared with the calculated $\Delta G^{\ddagger}_{348} = 16.5$ kcal/mol for **2** and $\Delta G^{\ddagger}_{429} = 22.0$ kcal/mol for **3**. The difference between the effects of two isopropyl groups and two benzyl groups on E_0 is 1.5 kcal/mol in the 5-membered ring and 1.7 kcal/mol in the 6-membered ring. This can also be expressed so that the barrier difference between a 5- and a 6-membered ring is fairly constant and independent of the size of R_1 and R_2. For **6** the value $\Delta G^{\ddagger}_{412} = 23.1$ kcal/mol lies between the values for **3** and **5**.

A model of **7** shows very strong steric interaction between the peri hydrogen and the benzylic protons. The value $\Delta G^{\ddagger}_{441} = 23.2$ kcal/mol is, however, somewhat lower than for **5**. Since the phenyl group is a less efficient electron acceptor than the benzoyl group, **7** will have a higher E_{π} than **5**. This increases the ground state energy and thus lowers E_0 (Fig. 1). In **8** the shifts were too small and it was not possible to make an accurate determination of $\Delta G^{\ddagger}$.

In **9** the two Me groups in the dimedone ring gave two sharp singlets up to above 465 K indicating that $\Delta G^{\ddagger} > 25$ kcal/mol. In this molecule we have combined a very low E_{π}, resulting from the two CO groups, which are good acceptors, with the high E_s resulting from the strong interaction with the fairly rigid dimedone ring.

A compound like **6** with four different groups attached to the double bond can exist in two enantiomeric forms due to the twist. This is analogous to the stereoisomerism in the biphenyl series. With $\Delta G^{\ddagger} > 25$ kcal/mol it should be possible to resolve the enantiomers. Such an attempt is now in progress. Resolution of chiral olefins where the chirality is due to twisting around a double bond has just been reported.[13]

A point of interest is whether it is possible to measure both E_0 and E_{90} in the same molecule. In **10** we have a system with a moderate steric interaction between the donors and the acceptors, and the combination of a phenyl and a cyano group is not very effective for stabilizing a negative charge.

The NMR spectrum of **10** shows an AB quartet below −54°, corresponding to a steric barrier of 10.7 kcal/mol.[14] Below −90° first the high-field part and then also the low-field part of the AB spectrum undergo selective broadening, and at −130° two new AB spectra have emerged. By use of the DNMR-3 program[15] the spectrum can be satisfactorily simulated assuming exchange between two AB systems, the passage through the plane being slow on the NMR timescale. From the rate constants a barrier of 7.0 kcal/mol could be evaluated, which corresponds to a $\theta = 90°$ twisted transition state. The signals are very broad at −135° and it is difficult to measure accurately the chemical shifts, which are temperature-dependent. A precise determination of T_2 is also difficult.

The ^{13}C NMR spectrum of **10** shows below −100° a non-selective broadening of all useful carbon resonances except for the quaternary ring carbon in the benzyl groups. This signal, however, is split into a doublet with $\Delta\nu = 15.0$ Hz below −127°. With the usual approximation[16] this corresponds to $\Delta G^{\ddagger} = 7.3$ kcal/mol. This is probably more reliable than the value from ^1H NMR.

The extreme broadness of the bands at low temperature, which is also observed in the ^1H NMR spectra, especially at not very low concentrations, is probably due to an association of the dipolar solute molecules. This association increases with decreasing temperature with concomitant increase in the correlation time. This decreases T_2 for proton-bearing carbon atoms but has much less effect on non-proton bearing ones.[17]

In **11** the benzyl groups have been replaced by Me groups, and only the π-barrier can be measured. This was 7.0 kcal/mol, which is in the same order as for **10**, whereas in the corresponding 5-membered rings the π-barriers are 9.5 kcal/mol and 8.5 kcal/mol for the benzyl and Me compounds, respectively.[14] The low π-electron barriers for the 6-membered compounds compared to the 5-membered ones can be explained in terms of increased steric strain in the ground state, which can also explain the lower barrier for the 5-membered benzyl compound compared to the same Me compound. This explanation does not hold for a comparison between **10** and **11**. Different abilities to stabilize the zwitterionic transition state may play a more important role here, as may also different shapes of the potential energy curves.

For **12** and **13** the ^1H NMR gave $\Delta G^{\ddagger}_{220} = 11.2$ kcal/mol and $\Delta G^{\ddagger}_{230} = 11.4$ kcal/mol (E_0) respectively. At temperatures below −70° the signals from these compounds broadened strongly while the solvent signal, which was used as a reference, did not. The association invoked to explain the broad ^{13}C resonances of **10** is probably at work here as well. This made a precise determination of T_2 difficult, which also affects the accuracy in the determination of the rate constants. We have no explanation for the unexpected higher E_0 for **13** than for **12**. This is contrary to all other results in these systems, where the isopropyl group always gives a stronger steric interaction than the benzyl group.

It was not possible to measure E_{90} in **12** or **13**, neither by ^1H NMR nor by ^{13}C NMR. It is likely that E_{90} is lower in **12** and **13** than in **10** due to higher ground state strain in the former compounds.

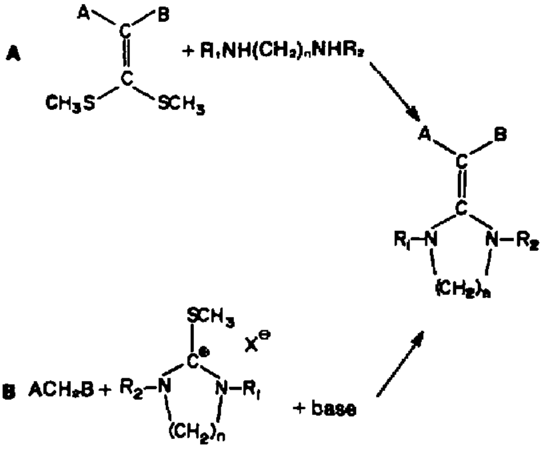
In the transition state to passage of E_0, the aryl group on the acceptor side must be almost orthogonal to the double bond, since otherwise the steric crowding would be too severe. Therefore, a substituent in the *para* position must influence the steric barrier through a change of the conjugation. An electron-accepting group increases the double-bond character of the bond between the phenyl ring and the double bond, thus making a rotation out of the plane of the phenyl ring energetically disfavoured. The opposite holds for an electron-donating group. E_0 should thus be increased by an acceptor group in the *para* position of the phenyl ring and decreased by a donor group. For the E_{90} the opposite should hold. The better conjugation with an electron-accepting *para* substituent stabilizes the transition state by delocalization of the negative charge, making E_π lower.

In **14** the nitro group raises the steric barrier to 13.9 kcal/mol, whereas the π-barrier was too low to be measured. The exchange system for **15** is similar to that for **10**, but since E_0 and E_{90} are more similar in the former compound, the spectrum is simultaneously affected by the two processes. The general band-broadening below −100° makes it difficult to evaluate the individual chemical shifts, but the coalescence of the AB spectrum can be observed between −70° and −75°. An approximative free activation energy of 9.7 kcal/mol for E_0 can be obtained by band-fitting on the low-field part of the AB spectrum, which is less affected by the passage over E_{90}. The amino group thus lowers the steric barrier by *ca.* 1.0 kcal/mol. In the ^{13}C NMR spectrum the quaternary benzylic carbons were split below −108° to a doublet, $\Delta\nu = 15.0$ Hz, corresponding to a π-barrier of 8.3 kcal/mol, which is *ca.* 1.0 kcal/mol higher than for **10**.

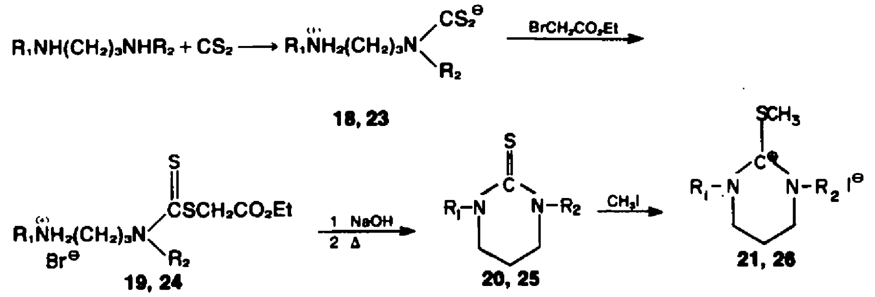
Conclusion: Our model for the potential energy curve for rotation around the double bond in polarized ethylenes can explain the experimental results, and by a careful choice of substituents it is possible to vary the relation between the steric and the π-barrier between wide limits.

SYNTHETIC PART

There are two general ways for preparing these push–pull ethylenes. One way is to treat a 1,1-bis-methylthioethylene with a dialkyldiamine and the other is to treat the appropriate methylene compound with a base and a cyclic methylthiouronium salt (Scheme 2). Both methods have been described earlier.[18]



Scheme 2.



Scheme 3.

The thioureas used as precursors for the thiouronium salts were prepared by reaction between the appropriate N,N'-disubstituted 1,2-diaminoethane or 1,3-diaminopropane and carbon disulphide in boiling pyridine. This reaction failed, however, when the N-substituents were large, and an alternative method was worked out (Scheme 3). The success of this method (which, however, fails when R_1 or R_2 = t-Bu) is due to the fact that $^-SCH_2CO_2C_2H_5$ is a much better leaving group than HS^- or S^{2-}.

There are two possible structures for the unsymmetrical dithiocarbamate 23. The carbon disulphide may attack either the nitrogen with an isopropyl group or the nitrogen with a benzyl group. Ring-closure of both dithiocarbamates gives the same product. To elucidate the structure of 23, it was treated with methyl iodide. As evidenced by the ^1H NMR spectrum, the methyl analogue of 24 formed shows a restricted rotation around the dithiocarbamate C–N bond. At room temperature the benzyl group gives rise to a doublet with unequal intensities, which collapses to a singlet at higher temperatures, whereas the doublet for the protons from the isopropyl group does not show temperature-dependence. Thus it is obvious that the attack of carbon disulphide has occurred on the benzylamino group.

EXPERIMENTAL

Most of the ^1H NMR spectra were recorded on a Jeol Model JNM-MH 100 NMR spectrometer, equipped with a standard variable temp. attachment (VT 3-c). The temp. was measured by monitoring the voltage of the internal thermocouple of the instrument, which was subsequently calibrated with an external thermocouple placed at the height of the receiver coil in a dummy tube containing 0.5 ml of the solvent.

The AA'BB' spectrum of 1 and the spectrum of 14 were recorded on a Bruker Model HX-270 spectrometer, and the ^{13}C spectra were recorded on a Varian Model XL-100-15 spectrometer. For the high temp. spectra hexamethyldisiloxane or octamethylcyclotetrasiloxane was used to provide the internal lock signal, while TMS was used for the low temp. spectra. The ^{13}C spectra were recorded with ^{19}F lock on solvent $CHCl_2F$. The determination of T_2 was performed as described earlier.[19]

Table 1.

Compound	Solvent	Δν Hz	J Hz	T K	ΔG* (E_0) kcal/mol	ΔG* (E_{90}) kcal/mol
2	ODC	30.5	14.6	349	16.5	
3	ODC	20.1	14.8	424	22.0	
4	ODC	19.0	6.7	348	18.0	
5	ODC	3.7	6.6, 6.8	424	23.8	
6 [a]	ODC	3.8	6.7, 6.8	412	23.1	
7	ODC	26.0	14.8	441	23.2	
9	ODC	7.8		>465	>25	
10 [b]	$CHCl_2F$				10.7	7.0
10 [c]	$CHCl_2F$	15.0		146		7.3
11	$CHCl_2F$	40		148		7.4
12	$CHCl_2F$	13.9	6.7	220	11.2	
13	$CHCl_2F$	17.6	6.4, 6.6	230	11.4	
14 [d]	$CDCl_3$-toluene-d_8	20.0	14.8	270	13.9	
15	$CHCl_2F$	50	14	203	9.7	
15 [c]	$CHCl_2F$	15.0		165		8.3

[a] The isopropyl group was used for evaluation of the rate constant. [b] See Ref. 14 for spectral parameters. [c] From ^{13}C NMR. [d] At 270 MHz. ODC = o-dichlorobenzene.

Dimethyl phthalate was added to provide a resolution standard for the samples which did not contain $CHCl_2F$ as a solvent, otherwise one of the solvent resonances was used.

In the spectra of 3 (but not of 2) it was not possible to obtain acceptable agreements between the experimental and simulated spectra of benzylic AB quartets without inclusion of a small long-range coupling. This was performed so that three spectra with the intensity ratio 1:2:1 and with the shifts $\nu_0 - J$, ν_0, $\nu_0 + J$ but with all other parameters the same, were added. The parameter J was then varied so that the slow-exchange spectrum could be simulated. The best fits were obtained with J = 0.5 Hz. This value was then used also in the fast-exchange region.

The diamines

N,N'-Dimethylethylenediamine and N,N'-dimethyl-1,3-diaminopropane were commercial products.

N,N'-*Diformylethylenediamine.* Ethyl formate (227 g, 3.7 mol) was added dropwise to ethylenediamine (60.0 g, 1.0 mol) and the mixture was refluxed for 2 hr. Upon cooling colourless crystals (108.1 g, 93%) precipitated, m.p. 109° (lit. 109–110°).[20]

N,N'-*Dibenzyl*-N,N'-*diformylethylenediamine.* A soln of N,N'-diformylethylenediamine (96.4 g, 0.83 mol) in DMF (350 ml) was added dropwise with stirring to a suspension of 50% NaH (84 g, 1.75 mol) in DMF (250 ml). The mixture was stirred for 1 hr. Benzyl chloride (212 g, 1.67 mol) was added dropwise with gentle warming. After 2 hr the mixture was allowed to cool, the precipitated NaCl was removed and water was added. Extraction with chloroform, drying and evaporation yielded an oil (138 g, 56%) which crystallized on standing, m.p. 100–101°.

N,N'-*Dibenzylethylenediamine.* To a soln of N,N'-dibenzyl-N,N'-diformylethylenediamine (135 g, 0.46 mol) in EtOH (350 ml) was added conc HCl (200 ml). The mixture was refluxed for 2 hr. Upon cooling and addition of ether a colourless ppt (120 g) of the hydrochloride of the desired amine was obtained. This was dissolved in M NaOH and the amine was extracted with ether. Drying and evaporation yielded the amine (84 g, 75%), which was used without further purification.

N,N'-*Dibenzyl*-1,3-*diaminopropane.* The same procedure as for N,N'-dibenzylethylenediamine was used, substituting 1,3-diaminopropane for ethylenediamine, b.p. 160°/0.4 mm.

N,N'-*Diisopropylethylenediamine.* Isopropylamine (100 g, 1.7 mol) was added dropwise to 1,2-dibromoethane (75.2 g, 0.4 g) which had been heated to 110°. The mixture was refluxed for 1 hr and solidified on subsequent cooling. Addition of a soln of NaOH (40 g) in water (60 ml) caused the separation of an oil, which after several distillations gave the product in low yield, b.p. 60°/15 mm (lit. 84°/37 mm).[21]

N,N'-*Diisopropyl*-1,3-*diaminopropane.* 1,3-Diaminopropane (74 g, 1.0 mol), acetone (174 g, 3.0 mol) and abs EtOH (50 ml) were mixed in a Parr bottle to which was added 10% Pd/C catalyst (0.8 g). Hydrogenation at 50 psi, removal of the catalyst and destillation gave the product (115.5 g, 86%), b.p. 76–77°/14 mm.

N-*Benzyl*-N'-*isopropyl*-1,3-*diaminopropane.* N-Isopropyl-1,3-diaminopropane[22] (34.8 g, 0.3 mol) was dissolved in abs EtOH (200 ml) in a Parr bottle to which was added benzaldehyde (31.8 g, 0.3 mol). The bottle was cooled with ice to moderate the reaction. To the mixture was added 10% Pd/C catalyst (1.0 g). Hydrogenation at 50 psi for 24 hr completed the reaction. Removal of the catalyst and distillation yielded the desired product (45 g, 72%), b.p. 116°/1.7 mm.

These amines gave ^1H NMR spectra in agreement with the expected structure. They are otherwise regarded as characterized by the derivatization to thioureas and ethylenes as described below.

The thioureas and thiouronium salts (Scheme 4)

1,3-*Dibenzylimidazolidine*-2-*thione* (16). To a cold (0°) soln of N,N'-dibenzylethylenediamine (77 g, 0.32 mol) in pyridine (300 ml) CS_2 (37 g, 0.49 mol) was added with stirring. The mixture was allowed to come to room temp. A colourless ppt was dissolved by refluxing the mixture for 24 hr. Evaporation of excess CS_2 and pyridine left a dark red oil, which crystallized on standing. The crude product (90.5 g, 100%) was recrystallized from MeOH to give colourless prisms (93%), m.p. 91–92°.

1,3-*Dibenzylhexahydropyrimidine*-2-*thione* (17). The same procedure as for 16 but with N,N'-dibenzyl-1,3-diaminopropane as starting material. Recrystallization from toluene, yield 81%, m.p. 133°.

1,3-*Dibenzyl*-2-*methylthioimidazolidinium perchlorate* (27). A soln of 16 (5.6 g, 0.02 mol) in Me_2SO_4 (20 ml, 0.21 mol) was heated to 100° on a water bath for 1 hr. A soln of sodium perchlorate (4.8 g, 0.04 mol) in EtOH (80 ml) was added. Addition of ether gave colourless crystals. They were filtered off, dissolved in chloroform and precipitated with ether, yielding the desired product (6.7 g, 85%), m.p. 141°.

1,3 - *Dibenzyl* - 2 - *methylthiohexahydropyrimidinium iodide* (22). To a soln of 17 (22 g, 74 mmol) in acetone (500 ml) was added MeI (21 g, 0.15 mol). After 3 days crystals had precipitated. Ether was added and more crystals were formed, which were filtered off, yielding the colourless product (25.8 g, 79%), m.p. 119–129°. (Found: C, 52.2; H, 5.31; N, 6.28. $C_{19}H_{23}N_2SI$ (438.377) requires: C, 52.1; H, 5.29; N, 6.39%).

N - (3 - *Isopropylammoniopropyl*) - N - (*isopropyl*) - *dithiocarbamate* (18). To a cold soln (0°) of N,N' - diisopropyl - 1,3 - diaminopropane (31.6 g, 0.2 mol) in dry ether (100 ml) was added dropwise with stirring CS_2 (30 g, 0.39 mol). A colourless powder precipitated immediately and was filtered off, yield 47.6 g (100%), m.p. 142–143°.

Ethoxycarbonylmethyl N - (3 - *isopropylammoniopropyl*) - N - (*isopropyl*) - *dithiocarbamate* (19). To a suspension of 18 (47.6 g, 0.20 mol) in abs EtOH (200 ml) was added ethyl bromoacetate (35.0 g, 0.21 mol) and the mixture was heated to 70° for 1/2 hr. The dark red soln was evaporated, and the remaining oil crystallized on standing. The crude product (77 g, 96%) was washed with ether, m.p. 114°.

1,3 - *Diisopropylhexahydropyrimidine* - 2 - *thione* (20). Na_2CO_3 (20 g) was added to a soln of 19 (77 g, 0.19 mol) in water (250 ml). A semi-solid substance was formed, which was extracted with toluene. The toluene layer was dried over $MgSO_4$ and refluxed for 6 hr. After evaporation the remaining oil solidified on standing. Recrystallization from ligroin yielded colourless prisms (25 g, 69%), m.p. 107°.

1,3 - *Diisopropyl* - 2 - *methylthiohexahydropyrimidinium iodide* (21). The same procedure as for 22, but with 20 as starting material, yield 92%, m.p. 185° (dec). (Found: C, 38.6; H, 6.78; N, 8.12. $C_{11}H_{23}N_2SI$ (342.288) requires: C, 38.6; H, 6.77; N, 8.18%).

N - (3 - *Isopropylammoniopropyl*) - N - *benzyl* - *dithiocar-*

16: $R_1 = R_2 = PhCH_2$, n = 2
17: $R_1 = R_2 = PhCH_2$, n = 3
20: $R_1 = R_2 = iPr$, n = 3
25: $R_1 = PhCH_2$, $R_2 = iPr$, n = 3

27: $R_1 = R_2 = PhCH_2$, n = 2, $X = ClO_4$
22: $R_1 = R_2 = PhCH_2$, n = 3, X = I
21: $R_1 = R_2 = iPr$, n = 3, X = I
26: $R_1 = PhCH_2$, $R_2 = iPr$, n = 3, X = I

Scheme 4.

bamate (**23**). The same procedure as for **18**, but with N - benzyl - N′ - isopropyl - 1,3 - diaminopropane as starting material, yield 98%.

Ethoxycarbonylmethyl N - (3 - *isopropylammoniopropyl*) - N - *benzyl - dithiocarbamate* (**24**). The same procedure as for **19**, but with **23** as starting material, yield 96%, m.p. 131–132°.

1 - *Benzyl* - 3 - *isopropylhexahydropyrimidine* - 2 - *thione* (**25**). The same procedure as for **20**, but with **24** as starting material, yield 91%, m.p. 118–119°.

1 - *Benzyl* - 3 - *isopropyl* - 2 - *methylthiohexahydropyrimidinium iodide* (**26**). The same procedure as for **22**, but with **25** as starting material, yield 72%, m.p. 119–129°. (Found: C, 46.2; H, 5.95; N, 7.19. $C_{15}H_{23}N_2SI$ (390.332) requires: C, 46.2; H, 5.94; N, 7.18%).

The ethylenes—Method A

2 - (1 - *Phenylbutane* - 1,3 - *dion* - 2 - *ylidene*) - 1,3 - *dimethylimidazolidine* (**1**) was prepared by Eriksson *et al.*[18]

2 - (1 - *Phenylbutane* - 1,3 - *dion* - 2 - *ylidene*) - 1,3 - *dibenzylimidazolidine* (**2**). 1,1 - bis - Methylthio - 2 - acetyl - 2 - benzoylethylene[11] (5.32 g, 0.020 mol) was dissolved in dry benzene (25 ml), to which was added N,N′-dibenzylethylenediamine (4.8 g, 0.020 mol) in dry benzene (25 ml). The soln was refluxed for 10 hr and the benzene evaporated off. The oily residue crystallized on standing. Recrystallization from xylene yielded colourless crystals (2.70 g, 33%), m.p. 131–133°. (Found: C, 79.1; H, 6.49; O, 7.92; N, 6.70. $C_{27}H_{26}N_2O_2$ (410.520) requires: C, 79.0; H, 6.38; O, 7.79; N, 6.82%).

2 - (1 - *Phenylbutane* - 1,3 - *dion* - 2 - *ylidene*) - 1,3 - *dibenzylhexahydropyrimidine* (**3**) was prepared as described for **2**, but with N,N′ - dibenzyl - 1,3 - diaminopropane as amine. Recrystallization from chloroform–heptane, yield 47%, m.p. 178–179°. (Found: C, 78.8; H, 6.56; N, 6.36; O, 7.59. $C_{28}H_{28}N_2O_2$ (424.548) requires: C, 79.2; H, 6.65; N, 6.60; O, 7.54%).

2 - (1 - *Phenylbutane* - 1,3 - *dion* - 2 - *ylidene*) - 1,3 - *diisopropylimidazolidine* (**4**) was prepared as described for **2**, but with toluene as solvent and N,N′-diisopropylethylenediamine as amine. The crude product (31% yield) was recrystallized from xylene–ligroin (2:1), m.p. 231–233°.

2 - (1 - *Phenylbutane* - 1,3 - *dion* - 2 - *ylidene*) - 1,3 - *diisopropylhexahydropyrimidine* (**5**) was prepared as described for **2** but with xylene as solvent and N,N′ - diisopropyl - 1,3 - diaminopropane as amine. The crude product (58% yield) was recrystallized from xylene, m.p. 183–185°.

2 - (1 - *Phenylbutane* - 1,3 - *dion* - 2 - *ylidene*) - 1 - *benzyl* - 3 - *isopropylimidazolidine* (**6**) was prepared as described for **2** but with xylene as solvent and N - benzyl - N′ - isopropyl - 1,3 - diaminopropane as amine. The crude product (90% yield) was recrystallized from xylene–ligroin (2:1) to give colourless prisms, m.p. 188–192°.

2 - *bis* - *Methylthiomethylene* - 5,5 - *dimethylcyclohexane* - 1,3 - *dione* (**28**) was prepared by the procedure described by Gompper and Töpfl,[23] starting with dimedone and with DMF as the only solvent. The crude product (63% yield) was recrystallized from ligroin, giving yellow prisms, m.p. 86–87°.

2 - (5,5 - *Dimethylcyclohexane* - 1,3 - *dion* - 2 - *ylidene*) - 1 - *benzyl* - 3 - *isopropylhexahydropyrimidine* (**9**) was prepared as described for **2**, with **28** and N - benzyl - N′ - isopropyl - 1,3 - diaminopropane and with xylene as solvent. Column chromatography on silica with MeOH and recrystallization from ligroin–toluene (7:3) gave the desired product (56% yield), m.p. 191–193°.

Method B

2 - (2 - *Tetralon* - 1 - *ylidene*) - 1,3 - *dibenzylhexahydropyrimidine* (**7**). 50% NaH (2.0 g, 0.042 mol) was suspended in dry DMF (25 ml), to which was added 2-tetralone (2.92 g, 0.020 mol) in DMF (25 ml). The mixture was stirred for 10 min and a soln of **22** (8.76 g, 0.020 mol) in DMF (50 ml) was added. The mixture was kept at 70° for 3 hr and then poured into water. Extraction with chloroform and evaporation gave a dark oil. Column chromatography on silica with first acetone and then MeOH as eluent gave the desired product. It was dissolved in acetone, and ligroin was added. On cooling yellow prisms of undefined m.p. were obtained (3.3 g, 16%), m.p. for the picrate 230°.

2 - (2 - *Tetralon* - 1 - *ylidene*) - 1,3 - *dibenzylimidazolidine* (**8**). The same procedure as for **7**, yield 44%, m.p. for the picrate 242°. (Found for picrate: C, 63.4; H, 4.78; N, 11.1. $C_{33}H_{29}N_5O_8$ (623.628) requires: C, 63.6; H, 4.69; N, 11.2%).

1,3 - *Dibenzyl* - 2 - (*α* - *cyanobenzylidene*) - *hexahydropyrimidine* (**10**) was prepared as described for **7**, starting from **22** and benzyl cyanide. Recrystallization from 96% EtOH gave colourless plates (32% yield), m.p. 178–180°. (Found: C, 82.0; H, 6.68; N, 11.0. $C_{26}H_{25}N_3$ (379.509) requires: C, 82.3; H, 6.64; N, 11.1%).

1,3 - *Dimethyl* - 2 - (*α* - *cyanobenzylidene*) - *hexahydropyrimidine* (**11**) was prepared as described for **7**, starting from 1,3 - dimethyl - 2 - methylthio - hexahydropyrimidinium iodide[24] and benzyl cyanide. The crude product (55% yield) was recrystallized from cyclohexane–benzene, m.p. 99°. (Found: C, 73.3; H, 7.57; N, 18.2. $C_{14}H_{17}N_3$ (227.312) requires: C, 74.0; H, 7.54; N, 18.5%).

1,3 - *Diisopropyl* - 2 - (*α* - *cyanobenzylidene*) - *hexahydropyrimidine* (**12**) was prepared as described for **7**, starting from **21** and benzyl cyanide. The crude product (22% yield) was recrystallized from cyclohexane, giving colourless plates, m.p. 121–122°.

1 - *Benzyl* - 2 - (*α* - *cyanobenzylidene*) - 3 - *isopropylhexahydropyrimidine* (**13**) was prepared as described for **7**, starting from **26** and benzyl cyanide. The crude product (21% yield) was recrystallized from toluene–cyclohexane (1:1), giving colourless crystals, m.p. 182–183°.

1,3 - *Dibenzyl* - 2 - (*α* - *cyano* - p - *nitrobenzylidene*) - *hexahydropyrimidine* (**14**) was prepared as described for **7**, starting from **22** and *p*-nitrobenzyl cyanide, and with sodium t-amylate as the base. The reaction was carried out under N_2. The crude product (40% yield) was recrystallized from toluene–cyclohexane (1:1) to give red prisms, m.p. 135–137°. The compound formed a crystalline 1:1 complex with diethyl ether, which tenaciously retained the ether.

1,3 - *Dibenzyl* - 2 - (*α* - *cyano* - p - *aminobenzylidene*) - *hexahydropyrimidine* (**15**). A soln of the ether complex of **14** (2.0 g, 4.0 mmol) in MeOH (50 ml) was hydrogenated in a Parr apparatus under 50 psi for 10 min with Raney nickel (2 g) as catalyst. The catalyst was removed by filtration, and the MeOH evaporated. The crude product (1.3 g, 82%) was recrystallized several times from toluene–ligroin to give the desired product, m.p. 182–184°.

Acknowledgements—We are grateful to the Swedish Natural Science Research Council and to the Royal Physiographic Society of Lund for financial support. We also thank F. K. Marita Bengtsson for valuable experimental assistance. We are also grateful to Dr. Kjeld Schaumburg from the H.C. Oersted Institute in Copenhagen for recording the 270 MHz spectrum of **1**.

REFERENCES

[1] J. Sandström and I. Wennerbeck, *J. Chem. Soc. Chem. Comm.* 1088 (1971).
[2] J. E. Douglas, B. S. Rabinovitch and F. S. Looney, *J. Chem. Phys.* **23**, 315 (1955).
[3] B. S. Rabinovitch and K. W. Michel, *J. Am. Chem. Soc.* **81**, 5065 (1959).
[4] I. Wennerbeck and J. Sandström, *Org. Magn. Reson.* **4**, 783 (1972).
[5] H. O. Kalinowski and H. Kessler, *Topics in Stereochemistry*, Vol. 7, p. 295. Interscience, New York (1973).
[6] H. L. Ammon and G. L. Wheeler, *J. Am. Chem. Soc.* **97**, 2326 (1975).
[7] S. Abrahamsson, G. Rehnberg, T. Liljefors and J. Sandström, *Acta Chem. Scand.* **B28**, 1109 (1974).
[8] I. Agranat and Y. Tapuhi, *J. Am. Chem. Soc.* **98**, 615 (1976).
[9] F. Kaplan and J. D. Roberts, *Ibid.* **83**, 4666 (1961).
[10] R. B. Johannesen, J. A. Ferretti and R. K. Harris, *J. Magn. Reson.* **3**, 84 (1970).
[11] J. Sandström and I. Wennerbeck, *Acta Chem. Scand.* **24**, 1119 (1970).

[12] H.-O. Kalinowski, H. Kessler and A. Walter, *Tetrahedron* **30**, 1137 (1974).

[13] B. Feringa and H. Wynberg, *J. Am. Chem. Soc.* **99**, 602 (1977).

[14] J. Sandström, U. Sjöstrand and I. Wennerbeck, *Ibid.* **99**, 4526 (1977).

[15] D. A. Kleier and G. J. Binsch, *J. Magn. Reson.* **3**, 146 (1970).

[16] H. S. Gutowsky and C. H. Holm, *J. Chem. Phys.* **25**, 1228 (1956).

[17] T. C. Farrar and E. D. Becker, *Pulse and Fourier Transform NMR*, p. 56. Academic Press, New York (1971).

[18] E. Ericsson, J. Sandström and I. Wennerbeck, *Acta Chem. Scand.* **24**, 3102 (1970).

[19] A. Lidén and J. Sandström, *Tetrahedron* **27**, 2893 (1971).

[20] G. M. Badger, N. Kowanko and W. H. F. Sasse, *J. Chem. Soc.* 440 (1959).

[21] R. A. Donia, J. A. Shotton, L. O. Bentz and G. E. P. Smith, *J. Org. Chem.* **14**, 946 (1949).

[22] E. D. Pearsson, W. H. Jones and A. C. Cope, *J. Am. Chem. Soc.* **68**, 1225 (1946).

[23] R. Gompper and W. Töpfl, *Chem. Ber.* **95**, 2861 (1962).

[24] E. Ericsson, T. Marnung, J. Sandström and I. Wennerbeck, *J. Mol. Struct.* **24**, 273 (1975).