Two other experiments were performed in compensated nematic phases at 32 and 65 °C (Table II) in order to show that the observed helical matrix effect was not a temperature effect.

If these data confirm the contribution of solute–solvent interactions to optical induction, already documentated in thermal reactions,[5] they show in addition and for the first time that the asymmetric induction is simultaneously dependent upon the handedness of the pitch. As a matter of fact, recently, Nakazaki,[7] in a mechanically twisted achiral nematic phase, pointed out that this asymmetric cyclization was controlled by the handedness of the mechanical twist.

The pitch contribution lies in our case in between 0.1 and 0.24% (the enantiomeric excess obtained in the cholesteric phase minus the one obtained in the compensated nematic). It is interesting to remark that this value (corresponding to 1 to 2 cal/mol) is of the same order of magnitude as the extent of asymmetric induction observed by Kagan[20,21] and Calvin[22–24] during the photosynthesis of hexahelicene with circularly polarized light (CPL). Such pitch contribution could also arise from the formation of CPL in the mesophase.[25]

However one could argue that intimate solute–solvent interactions are responsible for all the optical activity induced by the fact that the pitch could intervene in altering the manner in and degree to which the chiral solvent interacts with the hexahelicene precursors.

Such phenomena could have some contribution to the prebiotic generation of optical activity.[11,26]

Experimental Section

1-Phenyl-2-(2-benzo[*c*]phenanthrenyl)ethylene (1). To a stirred mixture of 0.01 mol of (2-benzo[c]phenanthrenylmethyl)triphenylphosphonium bromide[14] and 100 mL of anhydrous THF was added, at room temperature, 0.01 mol of *n*-butyllithium in hexane. Almost immediately after the addition of the base to the reaction mixture, the contents became orange and soon dark red. The solution was stirred for 2 h and 0.011 mol of freshly distilled benzaldehyde was added. The uncolored mixture was then stirred for 2 h and finally the solvent was evaporated. The residue was purified by a rapid filtration on silica gel (methylene chloride eluant) and the cis–trans isomers were separated by chromatography on silica gel (hexane–cyclohexane 1:1 as solvent) and identified by NMR[27] (total yield (cis + trans) = 90%).

Cis isomer: liquid; NMR (CCl_4) 6.40 (br s, 2 vinylic H), 6.80–7.20 (m, 14 arom H), 8.10 (d, $|J|$ = 8 Hz, H_{12}), 8.70 ppm (br s, H_1).

Trans isomer: mp, 140 °C; NMR (CCl_4) 1 7.10–7.90 (m, 16 H, 14 arom and 2 vinylic H), 8.90 (br s, H_{10}), 8.97 ppm (d, J = 8 Hz, H_{12}).

Photocyclization in a Cholesteric Liquid Crystal. Olefin 1 (20 mg; either the cis or the trans isomer or a mixture of the two isomers) was mixed with 2.5 g of a mixture of cholesteryl chloride and cholesteryl myristate (in the ratio 1.75/1.00) during 2 h at 80 °C (isotropic phase) under stirring. Then 1 to 2 mg of iodine was carefully dissolved in the mixture. The pitch of this cholesteric mixture was determined by the droplet method[29] while the handedness of the mesophase, known from literature,[8,9] was also controlled either by the droplet method[30] or the Grandjean–Cano method.[31]

The reaction mixture was introduced between two Pyrex plates separated by a 0.1-mm spacer. The planar alignment obtained by rubbing the Pyrex upper plate with a lens-cleaning tissue was checked with a polarizing microscope.

After irradiation (1.5 h with a 125-W high-pressure mercury lamp, temperature being rigorously controlled with a microthermocouple inside the preparation), the plates were washed with methylene chloride. Solvent was evaporated and the residue purified by flash chromatography[12] (eluant, hexane). Finally hexahelicene was purified by chromatography on silica gel (eluant, pentane): 85% yield; mp 229 °C;[14] NMR (CCl_4, 250 MHz)[15] 6.65 (t, $|J|$ = 7.5 Hz, 2 H, B), 7.16 (t, $|J|$ = 7.5 Hz, 2 H, C), 7.55 (d, $|J|$ = 9.0 Hz, 2 H, A), 7.79 (d, $|J|$ = 9.0 Hz, 2 H, D), 7.90 (s, 4 H, E and F), 8.05 ppm (s, 4 H, G and H).

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Registry No. (*E*)-1, 20508-12-7; (*Z*)-1, 20508-11-6; 3, 187-83-7; (2-benzo[c]phenanthrenylmethyl)triphenylphosphonium bromide, 35160-98-6; benzaldehyde, 100-52-7; cholesteryl chloride, 910-31-6; cholesteryl myristate, 1989-52-2.

(20) Moradpour, A.; Nicoud, J. F.; Balavoine, G.; Kagan, H.; Tsoucaris, G. *J. Am. Chem. Soc.* **1971**, *93*, 2353.
(21) Kagan, H.; Moradpour, A.; Nicoud, J. F.; Balavoine, G.; Martin, R. H.; Cosyn, J. P. *Tetrahedron Lett.* **1971**, 2479.
(22) Bernstein, W. J.; Calvin, M.; Buchardt, O. *J. Am. Chem. Soc.* **1972**, *94*, 494.
(23) Bernstein, W. J.; Calvin, M. *Tetrahedron Lett.* **1972**, 2195.
(24) Bernstein, W. J.; Calvin, M.; Buchardt, O. *J. Am. Chem. Soc.* **1973**, *95*, 527.
(25) De Gennes, P. G. "The Physics of Liquid Crystals"; Clarendon Press: Oxford, 1974; Chapter 6.
(26) Balavoine, G.; Moradpour, A.; Kagan, H. B. *J. Am. Chem. Soc.* **1974**, *96*, 5152.
(27) Somers, J. B. M.; Laarhoven, W. H. *Recl. J. Royal. Netherlands Chem. Soc.* **1980**, *99*, 160.
(28) Muskat, K. A.; Fischer, E. *J. Chem. Soc. B* **1967**, 662.
(29) Candau, S.; Le Roy, P.; Debeauvais, F. *Mol. Cryst. Liq. Cryst.* **1973**, *23*, 283.
(30) Seuron, P.; Solladié, G. *Mol. Cryst. Liq. Cryst.* **1979**, *56*, 1.
(31) Cano, R. *Bull. Soc. Fr. Mineral. Cristallogr.* **1968**, *91*, 20.

Alkoxide Variation in Complex Base-Promoted Syn Dehydrohalogenations

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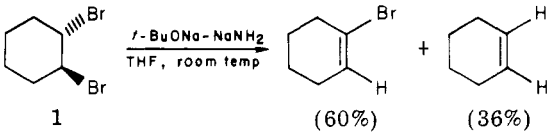
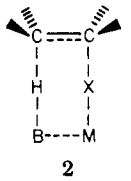
In 1972, Caubère and Coudert[1] reported a 60% yield of 1-bromocyclohexene in the reaction of *t*-BuONa–activated $NaNH_2$ with *trans*-1,2-dibromocyclohexane, 1. Under the



1 (60%) (36%)

same conditions, mostly unreacted 1 was recovered when either *t*-BuONa or $NaNH_2$ alone was the base. The unusual propensity for this complex base[2,3] to induce syn dehydrohalogenation was rationalized by Sicher's[4] transition state 2 in which interactions of the base counterion M with the leaving group X are important.



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(1) Caubère, P.; Coudert, G. *J. Chem. Soc., Chem. Commun.* **1972**, 1290.
(2) Caubère, P. *Top. Curr. Chem.* **1978**, *73*, 49.
(3) Caubère, P. *Acc. Chem. Res.* **1974**, *7*, 301.
(4) Sicher, J. *Angew. Chem., Int. Ed. Engl.* **1972**, *11*, 200.

0022-3263/80/1945-5394$01.00/0

Table I. Reactions of $R^1R^2R^3CONa$-$NaNH_2$ with *trans*-1,2-Dibromocyclohexane in THF at 25 °C

system	$R^1R^2R^3CONa$ R^1	R^2	R^3	% 1-bromocyclohexene[a]	% cyclohexene[a]	% 1-bromocyclohexene/% cyclohexene[b]	time for consumption of 1, h
1	*n*-Pr	H	H	36	45	0.8	43
2	*n*-Pen	H	H	38	46	0.8	44
3	*n*-$C_{11}H_{23}$	H	H	38	39	1.0	24
4	*i*-Pr	H	H	53	46	1.2	3
5	*t*-Bu	H	H	63	30	2.1	7.5
6	Me	Me	H	55	45	1.2	1.5
7	Me	Et	H	55	44	1.2	1
8	Me	*n*-Pr	H	64	35	1.8	1
9	Me	*n*-Hex	H	65	33	2.0	2
10	Et	Et	H	61	39	1.6	1
11	Et	*n*-Pen	H	63	36	1.8	1
12	*i*-Pr	*i*-Pr	H	35	27		4.5
13	cyclohexyl		H	30	40		24
14	Me	Me	Me	62	30	2.1	7.5
15	Me	Me	*n*-Bu	47	47	1.0	19
16	Me	Me	*n*-Oct	63	33	1.9	5.5
17	Me	Et	Et	69	29	2.4	1
18	Me	Et	*n*-Bu	64	30	2.1	3
19	Me	Et	*n*-Oct	62	33	1.9	8.5
20	*n*-Bu	*n*-Bu	*n*-Bu	62	33	1.9	5.5
21	cyclohexyl		Me	54	30	1.8	4
22	2-tetrahydrofuranyl[c]	H	H	12	trace		30
23	$PhOCH_2$	H	H	54	31	1.7	10.5
24	$EtOCH_2CH_2OCH_2$	H	H	trace	65		3.5
25	*p*-$MeOC_6H_4$[c]	H	H	24	24		6

[a] Estimated uncertainty of ±2%. [b] When yields of 1-bromocyclohexene + cyclohexene ≥ 75%. [c] Numerous unidentified side products were formed.

Subsequently, the complex base combination of *t*-BuO-Na–$NaNH_2$ in THF was shown to dehydrobrominate other *trans*-1,2-dibromocycloalkanes and produce 1-bromocyclopentene, 1-bromocycloheptene, and 1-bromocyclooctene in 47%, 90%, and 95% yields, respectively.[5,6]

Early studies of complex bases which had four different sodium oxyanion base components[6] revealed that the combination of *t*-BuONa–$NaNH_2$ produced the highest proportion of 1-bromocyclohexene in reactions with **1** in THF. In view of the remarkable propensity of RONa-activated $NaNH_2$ for inducing syn dehydrohalogenation, further investigation of the effects of varying the sodium alkoxide component of the complex base seemed warranted. We now report the results of such a study.

Reactions of **1** with RONa–$NaNH_2$ combinations were conducted under nitrogen in THF at 25 °C. The reaction mixture was periodically sampled and analyzed for unreacted **1** by using gas chromatography. This provided a qualitative measure of the time required for consumption of **1** by the heterogeneous base–solvent mixture. When all (≥99%) of the substrate had been consumed, the reaction mixture was worked up and the yields of 1-bromocyclohexene and cyclohexene[7] were determined by gas chromatographic analysis using appropriate internal standards. Product yields and the times at which complete consumption of the substrate were noted are recorded in Table I for 25 combinations of RONa–$NaNH_2$.

From the data presented in Table I, it is immediately apparent that the identity of the $NaNH_2$-activating RONa has a moderate influence upon the relative propensities for competitive dehydrobromination and debromination and a marked effect upon the reactivity of the complex base.

Examination of the data reveals that several combinations of RONa–$NaNH_2$ (systems 8–11, 14, 17) provide high yields of elimination products (92–100%), the highest proportions of dehydrobromination to debromination products (% 1-bromocyclohexene/% cyclohexene = 1.6–2.4), and the most rapid consumption of **1** (1–2 h). These systems include sodium alkoxides derived from certain secondary (2-pentanol, 3-pentanol, 2-octanol, 3-octanol) and tertiary (2-methyl-2-butanol) alcohols. Complex bases in which the sodium alkoxides were derived from the hindered primary alcohol neopentyl alcohol (system 5) or several tertiary alcohols (systems 14, 16, 18–20) also gave high conversions of **1** into unsaturated products and good regioselectivity for formation of 1-bromocyclohexene but exhibited a lower reactivity than those of the first group. Thus, this study has revealed several new complex base systems which combine enhanced reactivity with the same propensity for syn dehydrohalogenation previously observed with *t*-BuONa–$NaNH_2$.

Although the reasons for the influence of alkoxide component variation upon the products and rates of reaction of **1** with RONa–$NaNH_2$ are undoubtedly complex, it appears to be important for the alkyl group(s) of the alkoxide to possess a certain level of hydrophobic bulk. With less hydrophobic alkyl groups (such as those in alkoxides obtained from *n*-alkanols), self-association of the sodium alkoxides may be responsible for the poor activation of $NaNH_2$. On the other hand, alcohols with highly branched alkyl group structures may produce sodium alkoxides which are inefficient in disrupting the $NaNH_2$ surface for steric reasons.

Experimental Section

Materials. Degussa broken sodamide was washed several times with THF and powdered in a mortar under THF. The THF (Badische Anilin, reagent) was distilled from sodium and stored over sodium wire. All alcohols were either commercial products (Fluka or Aldrich) or were prepared by the classical condensation

(5) Caubère, P.; Coudert, G. *Bull. Soc. Chim. Fr.* **1973**, 3067.
(6) Guillaument, G.; Lemmel, V.; Coudert, C.; Caubère, P. *Tetrahedron* **1974**, *30*, 1289.
(7) Formed by anti debromination. See ref 8 and work cited therein.
(8) Collins, C. J.; Christie, J. B. *J. Am. Chem. Soc.* **1960**, *82*, 1255.

of a Grignard reagent with a suitable ketone. All the alcohols were distilled from sodium before use. *trans*-1,2-Dibromocyclohexane was prepared from cyclohexene.[9]

Complex Base Preparation. A solution of the activating alcohol (30 mmol) in THF (10 mL) was added dropwise to a suspension of $NaNH_2$ (90 mmol) in THF (20 mL) at room temperature under nitrogen. The mixture was then heated for 2 h at 45–50 °C. If during these operations a light pink color appeared the complex base gave poor results. The coloration apparently results from the presence of peroxides in the reactants or solvent.

Elimination Reactions. A solution of 1 (20 mmol) in THF (40 mL) was slowly added to the prepared complex base mixture at 25 °C under nitrogen. Small aliquots were periodically removed, hydrolyzed, extracted with Et_2O, and analyzed by gas chromatography (Girdel 75 CD/PT gas chromatograph with 5-m SE-30 columns). Upon completion of the reaction, the product mixture was quenched with ice–water and extracted with Et_2O, and the Et_2O extract was dried over $CaCl_2$. Yields of 1-bromocyclohexene and cyclohexene were measured by gas chromatography using cyclooctane and benzene, respectively, as internal standards.

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Registry No. 1, 822-86-6; 1-butanol Na, 2372-45-4; 1-hexanol Na, 19779-06-7; 1-dodecanol Na, 18888-95-4; 2-methyl-1-propanol Na, 13259-29-5; 2,2-dimethyl-1-propanol Na, 3561-85-1; 2-propanol Na, 683-60-3; 2-butanol Na, 7726-51-4; 2-pentanol Na, 75495-33-9; 2-octanol Na, 68488-95-9; 3-pentanol Na, 36402-10-5; 3-octanol Na, 75495-34-0; 2,4-dimethyl-3-pentanol Na, 67638-47-5; cyclohexanol Na, 22096-22-6; 2-methyl-2-propanol Na, 865-48-5; 2-methyl-2-hexanol Na, 75495-35-1; 2-methyl-2-decanol Na, 67638-50-0; 3-methyl-3-pentanol Na, 67638-48-6; 3-methyl-3-heptanol Na, 75495-36-2; 3-methyl-3-undecanol Na, 75495-37-3; 5-butyl-5-nonanol Na, 75495-38-4; 1-methylcyclohexanol Na, 75495-39-5; tetrahydro-2-furanmethanol Na, 59137-52-9; 2-phenoxyethanol Na, 26109-86-4; 2-(2-ethoxyethoxy)ethanol Na, 52382-21-5; 4-methoxybenzenemethanol Na, 53942-86-2; sodium amide, 7782-92-5; 1-bromocyclohexene, 2044-08-8; cyclohexene, 110-83-8.

(9) Lisher, M. W. *J. Am. Chem. Soc.* **1941**, *63*, 143.

Pyrrolo[1,2-*c*]thiazole, a Ring-Fused Nonclassical Thiazole System

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The initial report of the transient existence of 1,3-dimethylthieno[3,4-*c*]thiophene[1] has attracted the attention of several research groups to the unusual physical and chemical properties of the nonclassical condensed thiophenes. Subsequently, the number of these so-called "tetravalent sulfur" compounds has increased to include examples of a variety of condensed heterocyclic systems and stable derivatives are now known.[2] In contrast, examples of nonclassical sulfur systems containing a bridgehead nitrogen atom as part of the sulfur-containing ring are quite rare.[3] We now report evidence supporting the transient existence of the pyrrolo[1,2-*c*]thiazole system.

Reaction of commercially available thiazolidine-4-carboxylic acid (1) and acetic anhydride[4] in the presence of dimethyl acetylenedicarboxylate (DMAD) afforded 1*H*,3*H*-pyrrolo[1,2-*c*]thiazole 2 (Scheme I) which was easily converted to its corresponding sulfoxide 3 with *m*-chloroperoxybenzoic acid (MCPBA). Dehydration of 3 in refluxing acetic anhydride resulted in a complex mixture from which none of the desired pyrrolothiazole 4 could be isolated. When, however, the same dehydration was carried out in the presence of *N*-phenylmaleimide (NPM) a mixture of 1:1 cycloadducts was isolated. Chromatographic separation and subsequent characterization demonstrated these adducts to be exo and endo adducts **5a** and **5b**. The exo/endo structural assignments were based on the NMR spectra of the adducts according to the established practice of ascribing a greater deshielding effect of the sulfur bridge on the imide α-protons of the endo adduct.[5] The formation of these adducts presumably arises from the in situ generation of nonclassical thiazole 4 and subsequent 1,3-dipolar cycloaddition of the added dipolarophile across the thiocarbonyl ylide form **4a**. Treatment of the exo/endo mixture, **5a**/**5b**, with sodium methoxide[3a,5b,6] afforded indolizine 6, further supporting the thiocarbonyl ylide as the site of the previous cycloaddtion. By TLC small amounts of 6 could also be observed in the reaction mixture of the previous trapping experiment.

Dehydration of 3 in the presence of dimethyl acetylenedicarboxylate (Scheme II) was also anticipated to occur across the thiocarbonyl ylide to yield 7 which was further expected to spontaneously eliminate sulfur[5,7] to give indolizine 8. In reality, reaction of 3 and DMAD produced a complex mixture from which a colorless solid was isolated in low yield. Both the mass spectrum and the elemental analysis of this material demonstrated it to be a primary 1:1 cycloadduct of 4 and DMAD, thereby eliminating 8 as a possible structure. The NMR spectrum of the product ultimately led to its being assigned cyclazine structure 9, resulting from cycloaddition across the azomethine ylide form **4b**.[8] The chemical shift of the Δ^3-pyrroline methyl was diagnostic, occurring at δ 1.67 instead of the δ 2.2–2.6 range observed for the pyrrole methyls in this study. Similar regiochemistry has been observed in the cycloadditions of the thiazolo[3,4-*b*]indazole system[3a] with olefinic and acetylenic dipolarophiles.

Experimental Section

Dimethyl 5-Methyl-1*H*,3*H*-pyrrolo[1,2-*c*]thiazole-6,7-dicarboxylate (2). L-Thiazolidine-4-carboxylic acid (5.3 g, 40 mmol), dimethyl acetylenedicarboxylate (7.4 mL, 60 mmol), and Ac_2O (40 mL) were refluxed for 3 h. The reaction was cooled to room temperature and the excess Ac_2O was removed at reduced pressure. The resulting brown residue was triturated with CH_3OH, affording a beige solid which crystallized from CH_3OH as beige prisms: 5.0 g (49%); mp 133–135 °C; NMR ($CDCl_3$) δ 2.33 (s, 3, CH_3), 3.78 (s, 3, ester), 3.84 (s, 3, ester), 4.22 (s, 2, 1-CH_2), 4.89 (s, 2, 3-CH_2). Anal. Calcd for $C_{11}H_{13}NO_4S$: C, 51.75; H, 5.13;

(1) M. P. Cava and N. M. Pollack, *J. Am. Chem. Soc.*, **89**, 3639 (1967).
(2) (a) M. P. Cava and M. V. Lakshmikantham, *Acc. Chem. Res.*, **8**, 139 (1975); (b) C. A. Ramsden, *Tetrahedron*, **33**, 3203 (1977); (c) K. T. Potts, *Chem. Heterocycl. Compd.*, **30**, 317, (1977).
(3) (a) K. T. Potts and J. L. Marshall, *J. Org. Chem.*, **41**, 129 (1976); (b) H. Schimoharada, S. Ikeda, S. Kajigaeshi, S. Kanemasa, *Chem. Lett.*, 1237 (1977).
(4) R. Huisgen, H. Gotthardt, H. O. Bayer and F. C. Schaefer, *Chem. Ber.*, **103**, 2611 (1970).
(5) (a) M. P. Cava, M. Behforouz, G. E. M. Husbands, and M. Srinivasan, *J. Am. Chem. Soc.*, **95**, 2561 (1973); (b) K. T. Potts and D. McKeough, *ibid.*, **96**, 4298 (1974).
(6) (a) K. T. Potts and D. McKeough, *J. Am. Chem. Soc.*, **96**, 4276 (1974); (b) K. T. Potts, J. Baum, and E. Houghton, *J. Org. Chem.*, **39**, 3631 (1974).
(7) (a) R. Helder and H. Wynberg, *Tetrahedron Lett.*, 605 (1972); (b) H. Gotthardt and F. Reiter, *Chem. Ber.*, **112**, 266 (1979).
(8) The only other materials which could be isolated from this reaction were a higher R_f reddish gum, which appeared to be a multiple condensation product of DMAD, and a lower R_f, uncharacterizable material reminiscent of that formed from the reaction of 3 and Ac_2O in the absence of an added dipolarophile.

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