Reactions of αα'-Dibromocycloalkanones with Bases

By **Kikumasa Sato,*** **Seiichi Inoue,** and **Shin-ichi Kuranami,** Department of Applied Chemistry, Faculty of Engineering, Yokohama National University, Ooka, Minami-ku, Yokohama 233, Japan
Masao Ōhashi, Chemical Laboratory, Seimi Chemical Co., Ltd., Chigasaki, Chigasaki-shi, Kanagawa 253, Japan

Reactions of αα'-dibromocycloalkanones [(1) and (2)] with various bases in several solvents have been studied. Treatment of 2,5-dibromocyclopentanone (1) with bases such as sodium hydrogen carbonate, sodium acetate, sodium phenoxide, and secondary amines afforded the corresponding 2-substituted cyclopent-2-enones [(3), (4), (5), and (8)]. Similar treatment of 2,6-dibromocyclohexanone (2) with weak nucleophilic bases gave 2-substituted cyclohex-2-enones (9) and (10), but reactions with secondary amines possessing both strong basicity and high nucleophilicity gave 2-aminocyclohex-2-enones (13a—c) and cyclopent-1-enecarboxamides (14a—c). The ratio of (13) to (14) is strikingly affected by the reaction solvent: (13) or (14) was obtained selectively when hexamethylphosphoramide or chloroform was used, respectively. Allied reactions are described and mechanisms are suggested.

In the course of studies on the synthesis of alicyclic α-diketones, we have previously reported[1] that the reaction of 2,5-dibromocyclopentanone with morpholine in ether afforded 2-morpholinocyclopent-2-enone without any Favorskii rearrangement product. On the other hand, similar treatment of 2,6-dibromocyclohexanone with morpholine resulted in ring contraction to produce *N*-cyclopent-1-enylcarbonylmorpholine.

We now report further investigations on the reactions of the αα'-dibromocycloalkanones (1) and (2) with various bases. The reactions were carried out in several solvents, and the products were isolated and characterized (Table 1).

The reaction of the dibromo-ketone (1) with 2 equiv. of sodium hydrogen carbonate in dimethylformamide (DMF) at 0 °C for 4 h afforded 2-bromocyclopent-2-enone (3) in high yield. A similar reaction of (1) with sodium acetate or sodium phenoxide gave the corresponding 2-substituted cyclopent-2-enone (4) or (5). Treatment of (1) with 3 equiv. of morpholine gave 2-morpholinocyclopent-2-enone (8). However, when (1) was treated with 2 equiv. of sodium benzenethiolate, a strong nucleophile, 2,5-bisphenylthiocyclopentanone (6) was obtained as major product along with 2-phenylthiocyclopentanone (7). Compound (7) is presumably derived from reduction of (6) by benzenethiolate ion.[2] In no case was a Favorskii rearrangement product detected. Thus the dibromo-ketone (1) underwent monosubstitution and/or 1,4-elimination through enoliz-

[1] K. Sato, Y. Kojima, and H. Sato, *J. Org. Chem.*, 1970, **35**, 2374; K. Sato, S. Inoue, T. Kitagawa, and T. Takahashi, *ibid.*, 1973, **38**, 551.

[2] M. Oki, W. Funakoshi, and A. Nakamura, *Bull. Chem. Soc. Japan*, 1971, **44**, 808.

ation by base to produce the α-diketone derivatives (3), (4), (5), and (8).

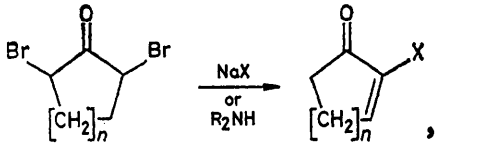
The reaction of the dibromo-ketone (2) (*cis*-isomer) with bases (NaOAc and NaOPh) of weak basicity in a similar manner also provided only α-diketone derivatives, (9) and (10), without ring contraction. The reaction of (2) with 2 equiv. of sodium benzenethiolate also gave the disubstituted compound (11). However the reaction of (2) with a strong nucleophilic base such as sodium methoxide has been shown to afford the Favorskii rearrangement product in low yield.[3] We re-examined this reaction and isolated only 2-hydroxy-6-methoxycyclohexanone dimethyl acetal (12), presumably formed by addition of methanol to the carbonyl group and substitution of one bromine atom with methoxide ion, followed by elimination of hydrogen bromide to produce the epoxide, which is cleaved by methanol. Compound (12) at room temperature was transformed into the dimer (12a).

TABLE 1

Reactions of the dibromo-ketones of (1) and (2) with various bases [a]

Compound	Base [b]	Solvent	Product(s) (% yield) [c]
(1)	$NaHCO_3$	DMF	(3) (90.6)
(1)	NaOAc	DMF	(4) (98.2)
(1)	NaOPh	MeOH	(5) (31)
(1)	NaSPh	MeOH	(6) (62.7), (7) (35.7)
(1)	Morpholine [d]	Et_2O	(8) (50)
(1)	Morpholine [d]	CH_2Cl_2	(8) (52.5)
(2)	NaOAc	DMF	(9) (41.8)
(2)	NaOPh	DMF	(10) (53.2)
(2)	NaSPh	MeOH	(11) (83.5)
(2)	NaOMe	MeOH	(12) (68.4) [h]
(2)	Morpholine [d]	Et_2O	(13a) (27), (14a) (48)
(2)	Pyrrolidine	Et_2O	(13b) (17.8), (14b) (41.5)
(2)	Piperidine	Et_2O	(13c) (12.3), (14c) (28.7).

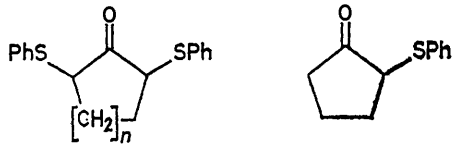
[a] Reaction carried out at 0 °C. [b] Two equiv. of base used. [c] Of isolated material. [d] Three equiv. of secondary amine used. [e] *cis*-Isomer used. [f] Reaction carried out at 80—90 °C. [g] Reaction carried out at 20—25 °C. [h] No Favorskii rearrangement product [3] detected; (12) was changed into 1,5a,6,10a-tetramethoxyperhydrodibenzo-*p*-dioxin at room temperature.



(1) $n = 1$
(2) $n = 2$

(3) $n = 1$, X = Br
(4) $n = 1$, X = OAc
(5) $n = 1$, X = OPh
(8) $n = 1$, X = Morph
(9) $n = 2$, X = OAc
(10) $n = 2$, X = OPh
(13a) $n = 2$, X = Morph
(13b) $n = 2$, X = Pip
(13c) $n = 2$, X = Pyrr

Morph = morpholino
Pip = piperidino
Pyrr = pyrrolidino



(6) $n = 1$
(11) $n = 2$

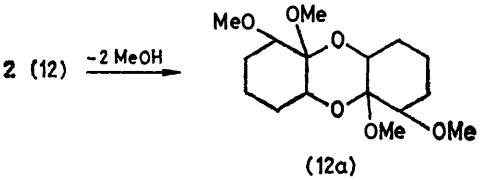
(7)

(12)

(14)a; R = Morph
b; R = Pip
c; R = Pyrr

The reactions of (2) with secondary amines of comparatively strong basicity and high nucleophilicity in ether gave moderate amounts of Favorskii rearrangement products, cyclopent-1-enecarboxamides (14a—c), together with 2-aminocyclohex-2-enones (13a—c). These results show that the occurrence of Favorskii rearrangement depends on the basicity and nucleophilicity of the reagent, and may be considerably influenced by steric effects.

The effects of various solvents on the reaction of (2) with morpholine were studied. The results are shown in Table 2. Both *cis*- (2a) and *trans*- (2b) isomers [4] gave the same results. Solvents of high basicity tend to afford (13a) as the major product. In the case of hexamethylphosphoramide the enamino-ketone (13a) was obtained selectively, and when chloroform or dichloromethane was used, the amide (14a) was obtained exclusively. From the limited data for aprotic solvents, the ratio of (13a) to (14a) appear to correlate better with basicity than with dielectric constant or dipole moment. In particular in a polar aprotic solvent such as hexamethylphosphoramide possessing high co-ordinating power (basicity), the formation of a hydrogen-bonded complex [5] between morpholine and the amino nitrogen in the solvent would be expected to enhance the nucleophilicity of morpholine towards the substrate. Further-



(12a)

more we examined the reaction of (2a) with morpholine in several CH_2Cl_2–DMF mixtures (Table 3). The data indicated that the formation of (13a) depends linearly

[3] M. Mousseron, R. Jacquier, and A. Fontaine, *Compt. rend.*, 1951, **232**, 1562.

[4] O. Wallach, *Annalen*, 1918, **414**, 314; E. J. Corey, *J. Amer. Chem. Soc.*, 1953, **75**, 3297.

[5] H. Normant, *Angew. Chem. Internat. Edn.*, 1967, **6**, 1046; *Bull. Soc. chim. France*, 1968, 791.

on the proportion of DMF. Although this effect cannot be explained only in terms of the basicity of the solvent,

TABLE 2

Reaction of the dibromo-ketone (2) with morpholine [a]

Solvent	Donor no.[b]	Substrate	Yield (%)	(13a) : (14a)
$PO(NMe_2)_3$	38.8	(2a)	75.1	97.4 : 2.6
DMF	26.6	(2a)	76.0	74.1 : 25.9
		(2b)	66.3	74.4 : 25.6
Pyridine	33.1	(2a)	80.3	70.6 : 29.4
n-Hexane		(2a)	69.0	63.3 : 36.7
Me_2SO	29.8	(2a)	85.2	50.6 : 49.4
Me_2CO	17.0	(2a)	53.5	43.9 : 56.1
Et_2O	19.2	(2a)	79.9	38.7 : 61.3
		(2b)	70.5	39.1 : 60.9
C_6H_6		(2a)	65.7	33.0 : 67.0
		(2b)	56.6	36.2 : 63.8
MeCN	14.1	(2a)	84.7	25.7 : 74.3
$MeNO_2$	2.7	(2a)	78.5	10.9 : 89.1
CH_2Cl_2		(2a)	87.8	5.5 : 94.5
$CHCl_3$		(2a)	83.1	3.9 : 96.1
H_2O	18.0	(2a)	49.7	97.0 : 3.0
MeOH		(2a)	85.6	46.5 : 53.5
EtOH		(2a)	87.4	18.3 : 81.9

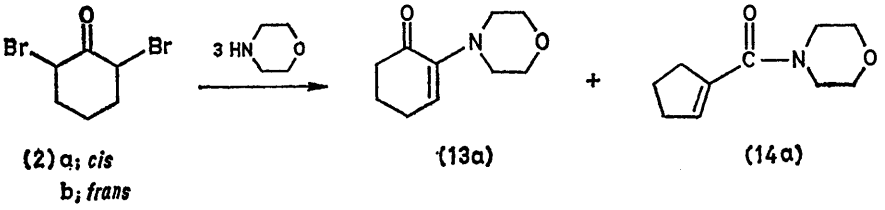
[a] Reactions carried out at 0° C; 3 equiv. of morpholine used. [b] Data in part from V. Gutmann, 'Co-ordination Chemistry in Non-aqueous Solutions,' Springer Verlag, Wien, 1968, p. 19. [c] Determined by g.l.c.

the results imply that (2a) suffers nucleophilic attack by morpholine rather than abstraction of the proton α to the carbonyl group at high DMF concentrations, and at low DMF concentration Favorskii rearrangement occurs preferentially.

As to the reaction mechanism, the amide (14) is presumably formed by Favorskii rearrangement [6] [Scheme (A); a semibenzilic type reaction mechanism cannot be excluded], and the formation of the enamino-ketone (13) can be tentatively explained by monosubstitution followed by 1,4-elimination of hydrogen bromide [Scheme (B)]. In order to clarify the mechanism, we examined the reactions of 2,6-dibromo-4-methylcyclohexanone (15) and 2,6-dibromo-2-methylcyclohexanone (16) [7] with morpholine. The dibromides (15) and (16) were obtained from bromination of corresponding ketones with dioxan dibromide.

The reaction of (15) with morpholine in ether gave the Favorskii rearrangement product, 4-methylcyclopent-1-enylcarbonylmorpholine (17), and two enamino-ketones, 4-methyl-2-morpholinocyclohex-2-enone (18) and 5-methyl-2-morpholinocyclohex-2-enone (19), in 72.5% yield [(17) : (18) : (19) 73.4 : 18.2 : 8.4 by g.l.c.]. Similar treatment [8] of (16) provided a trace of 2-methylcyclopent-1-enylcarbonylmorpholine (20), 6-methyl-2-morpholinocyclohex-2-enone (21), and the substituted product, 6-bromo-2-methyl-2-morpholinocyclohexanone (22). These reactions were attempted in various solvents; the results are summarized in Table 4. Interconversion of (18) and (19) under these conditions was not observed.

The results imply that there should be two reaction paths for the formation of the enamino-ketones. Compound (18) is formed by monosubstitution with morpholine, followed by 1,4-elimination [Scheme (B)], and the formation of (19) can be postulated as shown in Scheme (C): nucleophilic addition of morpholine to the carbonyl group followed by elimination of hydrogen bromide to form an epoxide,[9] which undergoes subsequent elimination of hydrogen bromide; alternatively after monodisplacement of bromine by morpholine, nucleophilic addition of morpholine to the carbonyl group is followed by the elimination of hydrogen bromide to form an



(2) a; *cis*
b; *trans*

(13a) (14a)

TABLE 3

Reaction of the *cis*-dibromo-ketone (2a) with morpholine

Solvent vol % DMF : CH_2Cl_2	Yield (%)	(13a) : (14a)
0 : 100	87.8	5.5 : 94.5
20 : 80	77.5	15.6 : 84.4
40 : 60	82.5	45.0 : 55.0
60 : 40	94.4	53.5 : 46.5
80 : 20	84.4	67.7 : 32.3
100 : 0	76.0	74.1 : 25.9

TABLE 4

Reactions of the dibromo-ketones (15) and (16) with morpholine [a]

Dibromide	Solvent	Yield (%)	Products (% yield) [b]
(15)	CH_2Cl_2	82.0	(17) (95.6), (18) (3.2), (19 (1.2)
(15)	Et_2O	72.5	(17) (73.4), (18) (18.2), (19) (8.4)
(15)	$PO(NMe_2)_3$	54.4	(17) (7.4), (18) (26.9), (19) (65.7)
(16)	CH_2Cl_2	94.6	(20) (trace), (21) (56.0), (22) (44.0)
(16)	Et_2O	83.7	(20) (trace), (21) (12.0), (22) (88.0)
(16)	$PO(NMe_2)_3$	87.4	(20) (61.0), (21) (trace), (22) (39.0)

[a] Reactions carried out at 0 °C. [b] Determined by g.l.c.

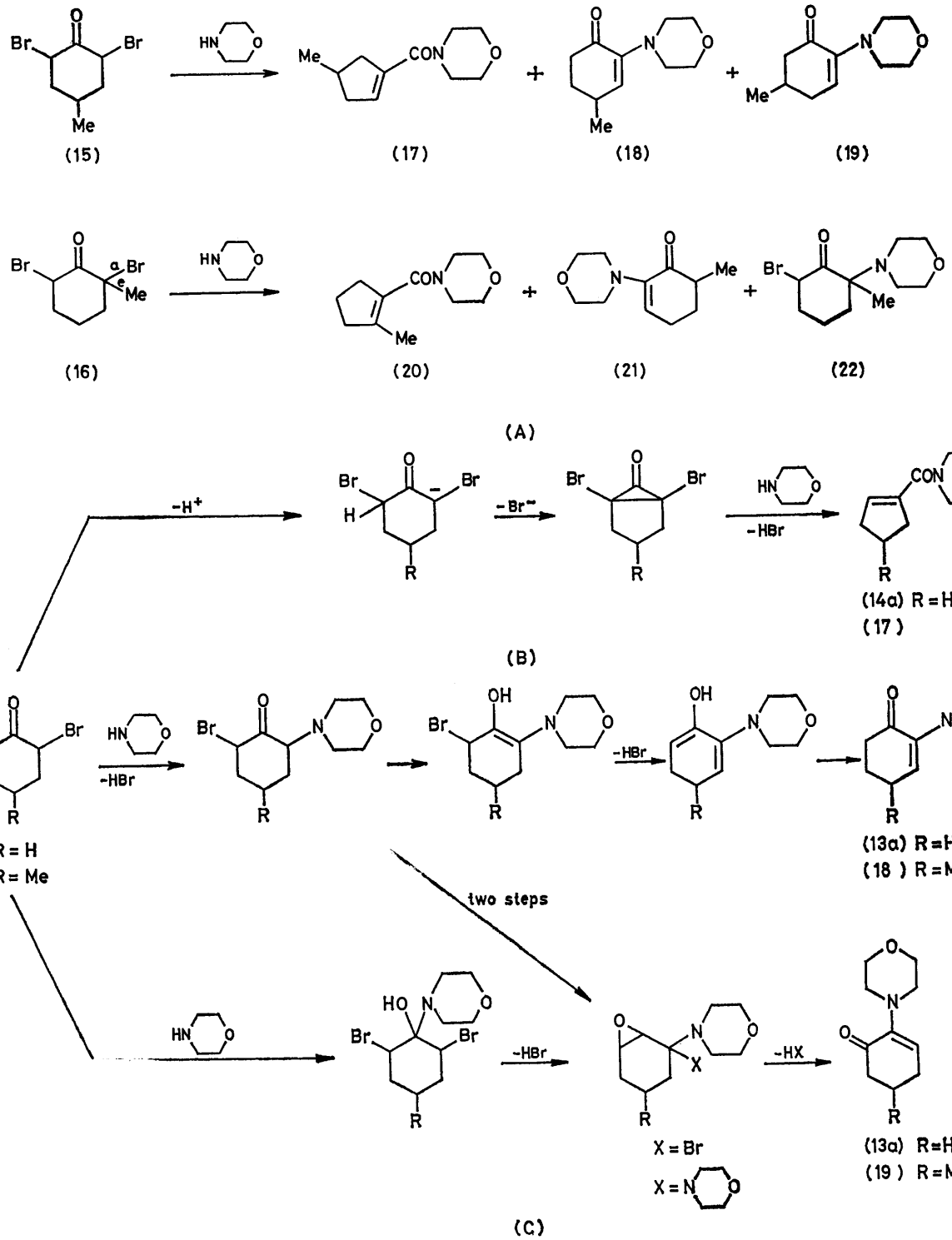
[6] A. S. Kende, *Org. Reactions*, 1960, **11**, 261; A. A. Akhrem, T. K. Ustynyuk, and Yu. Titov, *Uspekhi Khim.*, 1970, **39**, 1560; K. Sato and M. Ohashi, *J. Synth. Org. Chem. Japan*, 1974, **32**, 435.

[7] E. J. Corey, T. H. Topie, and W. A. Wozniak, *J. Amer. Chem. Soc.*, 1955, **77**, 5415.

[8] O. Walach and A. Weissenborn, *Annalen*, 1924, **437**, 148.

[9] J. G. Aston and R. Greenburg, *J. Amer. Chem. Soc.*, 1940, **62**, 2590.

epoxide,[10] which also gives (19) on subsequent deamination.



The isolation of the products (21) and (22) proves the existance of the reaction path (B): the enamino-ketone (21) is furnished by monosubstitution of the C-6 bromine atom with morpholine followed by elimination of hydrogen bromide, and compound (22) by monosubstitution of the C-2 bromine atom with morpholine.

In the case of (16), the fact that the solvent effect is the reverse of that with (15) may be due to a substituent

[10] F. G. Bordwell and K. M. Wellman, *J. Org. Chem.*, 1966, **31**, 351; 1963, **28**, 1347.

effect of the methyl group but the details are uncertain at present.

In the foregoing reactions, a polar and high basic solvent such as hexamethylphosphoramide might be expected to favour nucleophilic attack at >C:O or at >CHBr, with a corresponding increase in the amount of enamino-ketone (13) formed, whereas in solvents of low polarity and basicity such as dichloromethane, an increase in the proportion of Favorskii rearrangement product such as (14) might be expected.

EXPERIMENTAL

I.r. spectra were determined with a Hitachi 215 spectrophotometer, n.m.r. spectra with a JEOL C-60 spectrometer (tetramethylsilane as internal standard), and mass spectra with a Hitachi RMU-6E instrument (at an ionization potential of 70 eV). All g.l.c. was performed on a Shimadzu GC-4A instrument [20% Silicone DC-200 on 60—80 mesh Celite (3 m × 3 mm)]. Column chromatography was carried out with Wakogel C-200. *trans*-2,5-Dibromocyclopentanone (1) was prepared by the reported method; m.p. 70° (lit.,[11] 68—69°).

cis- *and* trans-2,6-*Dibromocyclohexanones* (2a *and* b).—Bromine (41.1 g) was stirred into dioxan (39.6 g) over 1 h. The mixture was then diluted with ether (50 ml), and cyclohexanone (12.3 g) in ether (20 ml) was dropped in at 0 °C over 30 min. After stirring for 1 h, the slightly yellow solution was poured into ice–water (60 ml). The ethereal layer was well washed with water, dried ($MgSO_4$), and evaporated. The resulting oil was distilled to give the liquid *trans*-bromide (2b) (24.0 g, 75.2%), b.p. 110—115° at 0.23 mmHg, $\nu_{max.}$ (neat) 1 725 cm^{-1} (C=O); which solidified spontaneously in an ice box; m.p. 34—35° (lit.,[4] 36°), $\nu_{max.}$ (KBr) 1 725 cm^{-1} (C=O), δ ($CDCl_3$) 2.35 (6 H, m) and 4.90 (2 H, m). The liquid *trans*-bromide at room temperature was isomerized to the *cis*-bromide (2a), m.p. 109—110° (lit.,[4] 110°), $\nu_{max.}$ (KBr) 1 740 cm^{-1} (C=O), δ ($CDCl_3$) 2.02 (4 H, m), 2.61 (2 H, m), and 4.66 (2 H, m).

Reactions of the Dibromo-ketone (1) *with Bases.*—A typical procedure is described for the synthesis of 2-bromocyclopent-2-en-1-one (3). To sodium hydrogen carbonate (3.4 g, 0.04 mol) in DMF (20 ml) was added the ketone (1) (4.84 g, 0.02 mol)in DMF (30 ml) at 0 °C, and the mixture was stirred for 4 h. DMF was removed *in vacuo*, and the residue was poured into a small amount of water. Extraction with ether–hexane (1 : 1), washing with water, drying ($MgSO_4$), and evaporation gave a residue, which was chromatographed on a silica gel column (benzene as eluant) to give the ketone (3) (2.92 g, 90.6%), b.p. 65—67° at 0.6 mmHg (lit.,[12] 52—56° at 0.3 mmHg), $\nu_{max.}$ (neat) 1 700 (C=O) and 1 580 cm^{-1} (C=C), δ (CCl_4) 2.45 (2 H, m), 2.67 (2 H, m), and 7.77 (1 H, t, *J* 3.4 Hz), M^+ 162/160.

The following compounds were prepared similarly: 2-acetoxycyclopent-2-enone (4) (2.75 g, 98.2%) [from (1) (4.84 g) and sodium acetate (3.28 g)], b.p. 79—83° at 0.6 mmHg (lit.,[13] 75—82° at 0.6 mmHg), $\nu_{max.}$ (neat) 1 760, 1 710 (C=O), and 1 620 cm^{-1} (C=C), δ (CCl_4) 2.17 (3 H, s) 2.2—2.8 (4 H, m), and 7.33 (1 H, t, *J* 3.4 Hz); *2-phenoxycyclopent-2-one* (5) (1.8 g, 31%) [from (1) (4.84 g) in methanol (30 ml) and sodium phenoxide (from 0.92 g of sodium and 3.76 g of phenol in 20 ml of methanol)], n_D^{20} 1.5718, $\nu_{max.}$ (neat) 3 060 (=C–H), 1 760 (C=O), 1 600, and 1 490 cm^{-1} (C=C), δ (CCl_4) 2.0—2.3 (4 H, m), 6.98 (1 H, t, *J* 3.4 Hz), and 7.14 (5 H, m) (Found: C, 75.6; H, 6.3%; M^+, 174. $C_{11}H_{10}O_2$ requires C, 75.8; H, 5.8%; *M*, 174); 2,5-bisphenylthiocyclopentanone (6) (3.77 g, 62.7%) and 2-phenylthiocyclopentanone (7) (1.36 g, 35.7%) [by use of benzenethiol (4.40 g) instead of phenol], (6) m.p. 60—61° (from ether), $\nu_{max.}$ (KBr) 1 740 cm^{-1} (C=O), δ ($CDCl_3$) 2.20 (4 H, m), 3.63 (2 H, m), and 7.33 (10 H, m), M^+ 300, (7) n_D^{20} 1.6188, $\nu_{max.}$ (neat) 1 735 cm^{-1} (C=O), δ (CCl_4) 1.6—2.4 (4 H, m), 3.48 (1 H, m), and 7.32 (5 H, m), M^+ 192; and 2-morpholinocyclopent-2-enone (8) (1.67 g, 50%) [from (1) (4.84 g) and morpholine (5.22 g, 0.06 mol), m.p. 63—63.5° (from methanol) (lit.,[1] 63°).

Reaction of the Dibromoketone (2) *with Bases.*—A typical procedure is described for the synthesis of 2-acetoxycyclohex-2-enone (9). To sodium acetate (3.28 g) in DMF (20 ml) was added the *cis*-dibromoketone (2a) (5.12 g, 0.02 mol) in DMF (30 ml) at 0 °C, and the mixture was stirred for 2 h. After work-up, the resulting oil was chromatographed on a silica gel column (benzene as eluant) to give the ketone (9) (1.29 g, 41.8%), b.p. 70—73° at 0.25 mmHg (lit.,[14] 129—130° at 12 mmHg), n_D^{20} 1.4825.

The following compounds were prepared similarly: *2-phenoxycyclohex-2-enone* (10) (2.0 g, 53.2%), n_D^{20} 1.5502, $\nu_{max.}$ (neat) 1 725 cm^{-1} (C=O), δ (CCl_4) 1.5—2.2 (2 H, m), 2.2—2.8 (4 H, m), 6.78 (1 H, t, *J* 4.5 Hz), and 7.13 (5 H, m) (Found: C, 76.3; H, 6.75%; M^+, 188. $C_{12}H_{12}O_2$ requires C, 76.55; H, 6.5%; *M*, 188); and *2,6-bisphenylthiocyclohexanone* (11) (5.25 g, 83.5%), m.p. 118—120° $\nu_{max.}$ (KBr) 1 682 cm^{-1} (C=O), δ ($CDCl_3$) 1.5—2.4 (6 H, m), 3.97 (2 H, m), and 7.33 (10 H, m) (Found: C, 68.9; H, 5.6%; M^+, 314. $C_{18}H_{18}OS_2$ requires C, 68.8; H, 5.8%; *M*, 314).

Reaction of the cis-*Dibromoketone* (2a) *with Sodium Methoxide.*—To a solution of sodium methoxide (from 0.92 g of sodium and 20 ml of methanol) was added the ketone (2a) (5.12 g) in methanol (30 ml) at 0 °C, and the mixture was stirred for 2 h. After work-up, the resulting oil was distilled to afford 2-hydroxy-6-methoxycyclohexanone dimethyl acetal (12) (2.60 g, 68.4%), n_D^{20} 1.4645, $\nu_{max.}$ (neat) 3 475 (O–H) and 1 095 cm^{-1} (C–O–C), δ (CCl_4) 1.53br (6 H, s), 2.47 (1 H, s), 3.28 (3 H, s), 3.32 (6 H, s), 3.37 (1 H, m), and 3.6—3.9 (1 H, m), M^+ 190. Compound (12) slowly solidified at room temperature to give 1,5a,6,10a-*tetramethoxyperhydrodibenzo*-p-*dioxin*, m.p. 146—147°, $\nu_{max.}$ (KBr) 2 950, 2 930, 2 870, 2 815, 1 460, 1 085 (C–O–C), and 1 035 cm^{-1} (C–O–C), δ ($CDCl_3$) 1.62br (12 H, s, ring CH_2), 3.22 (6 H, s, OMe), 3.35 (6 H, s, OMe), 3.50br (2 H, s, CH), and 4.13 (2 H, m, CH) (Found: C, 60.6; H, 9.0%; M^+, 316. $C_{16}H_{28}O_6$ requires C, 60.7; H, 8.9%; *M*, 316).

Reactions of the Dibromo-ketone (2) *with Secondary Amines: Typical Procedure for the Synthesis of Compounds* (13a) *and* (14a).—Morpholine (5.22 g, 0.06 mol) in ether (20 ml) was added over 30 min to the *cis*-dibromide (2a) (5.12 g, 0.02 mol) in ether (30 ml) with stirring at 0 °C, and the mixture was stirred for a further 7 h at 0 °C. The precipitated morpholine hydrobromide was filtered off, and the filtrate was distilled (b.p. 118—123° at 0.35 mmHg) to give the enamino-ketone (13a) and the amide (14a) as a mixture

[11] I. V. Machinskaya and A. S. Podberezina, *Zhur. obshchei Khim.*, 1958, **28**, 1501.

[12] G. L. Dunn, V. J. DiPasquo, and R. E. Hoover, *J. Org. Chem.*, 1968, **33**, 1454.

[13] G. Hesse and H. Friedrich, *Annalen*, 1970, **736**, 134.

[14] K. W. Rosenmund and G. Kositzke, *Chem. Ber.*, 1959, **92**, 486.

[2.90 g, 79.9%; (13a) : (14a) 38.9 : 61.1 by g.l.c.], which could be separated by silica gel column chromatography with benzene as eluant. The enamino-ketone (13a) had m.p. 51—52.5° (lit.,[15] 53—54°), $\nu_{max.}$ (KBr) 1 665 (C=O) and 1 605 cm^{-1} (C=C), δ (CCl_4) 1.92 (2 H, m), 2.38 (4 H, m), 2.77 (4 H, m), 3.67 (2 H, m), and 5.75 (1 H, t, *J* 3.9 Hz). The amide (14a) had n_D^{20} 1.5268 (lit.,[1] 1.5254), $\nu_{max.}$ (neat) 1 605 cm^{-1} (C=O and C=C), δ (CCl_4) 1.94 (2 H, m), 2.48 (4 H, m), 3.52br (8 H, s), and 5.73 (1 H, t, *J* 1.8 Hz) (Found: C, 66.0; H, 7.6. $C_{10}H_{15}NO_2$ requires C, 66.3; H, 7.7%). Similarly, the following compounds were prepared: (13b), b.p. 70—72° at 0.3 mmHg (lit.,[16] 90° at 3 mmHg), n_D^{20} 1.5242, $\nu_{max.}$ (neat) 1 670 (C=O) and 1 605 cm^{-1} (C=C), δ (CCl_4) 1.55br (6 H, s), 1.93 (2 H, m), 2.30 (4 H, m), 2.67 (4 H, m), 5.70 (1 H, t, *J* 4.5 Hz); (14b), b.p. 94—98° at 0.35 mmHg, n_D^{20} 1.5413, $\nu_{max.}$ (neat) 1 595 cm^{-1} (C=O and C=C), δ (CCl_4) 1.60br (6 H, s), 1.95 (2 H, m), 2.48 (4 H, m), 3.45 (4 H, m), and 5.80 (1 H, t, *J* 1.8 Hz), M^+ 179; (13c), b.p. 68—70° at 0.3 mmHg (lit.,[16] 83° at 3 mmHg), $\nu_{max.}$ (neat) 1 680 (C=O) and 1 603 cm^{-1} (C=C), δ (CCl_4) 1.82 (6 H, m), 2.34 (4 H, m), 3.09 (4 H, m), and 5.30 (1 H, t, *J* 4.7 Hz); N-*cyclopent-1-enylcarbonylpyrrolidine* (14c), n_D^{20} 1.5201, $\nu_{max.}$ (neat) 1 600 cm^{-1} (C=C and C=O), δ (CCl_4) 1.87 (6 H, m), 2.47 (4 H, m), 3.47 (4 H, m), and 5.95 (1 H, t, *J* 1.8 Hz) (Found: C, 72.4; H, 9.3%; M^+, 165. $C_{11}H_{15}NO$ requires C, 72.7; H, 9.2; *M*, 165).

cis-2,6-*Dibromo*-4-*methylcyclohexanone* (15).—The preparation was carried out according to the procedure for (2). In place of cyclohexanone 4-methylcyclohexanone (14.0 g) was used and the resulting oil was distilled to give the *ketone* (15) (25.1 g, 74.3%), m.p. 110—111°, $\nu_{max.}$ (KBr) 1 733 cm^{-1} (C=O), δ ($CDCl_3$) 1.10 (3 H, d, *J* 6.0 Hz), 2.00 (3 H, m), 2.70 (2 H, m), and 4.93 (2 H, m, $W_{\frac{1}{2}}$ 18 Hz) (Found: C, 31.2; H, 3.7; Br, 59.4%; M^+, 272/270/268. $C_7H_{10}Br_2O$ requires C, 31.1; H, 3.7; Br, 59.2%; *M*, 270).

2,6-*Dibromo*-2-*methylcyclohexanone* (16).—This compound was similarly obtained (28.0 g, 82.9%) from 2-methylcyclohexanone (14 g); m.p. 41.0—41.5° (lit.,[7] 43—45°), $\nu_{max.}$ (KBr) 1 723 cm^{-1} (C=O), δ (CCl_4) 1.80 (3 H, s), 1.9—2.8 (6 H, m), and 5.50 (1 H, m, $W_{\frac{1}{2}}$ 18.0 Hz).

Reaction of the Dibromo-ketone (15) *with Morpholine.*—Morpholine (5.22 g, 0.06 mol) in ether (20 ml) was added over 30 min to the ketone (15) (5.4 g, 0.02 mol) in ether (30 ml) with stirring at 0 °C, and the mixture was stirred for 7 h at 0 °C. The precipitated morpholine hydrobromide was filtered off, and the filtrate was distilled (b.p. 105—109° at 0.23 mmHg) to give the amide (17) and the enamino-ketones (18) and (19) as a mixture [2.83 g, 72.5%; (17) : (18) : (19) 73.4 : 18.2 : 8.4 by g.l.c.] which was chromatographed on a silica gel column to give 4-methylcyclopent-1-enylcarbonylmorpholine (17) (1.96 g) and the mixed enamino-ketones (18) and (19). The latter mixture was subjected to preparative g.l.c., and the pure components were isolated. The *amide* (17) had n_D^{20} 1.5069, $\nu_{max.}$ (neat) 1 607 cm^{-1} (C=O and C=C), δ (CCl_4) 1.13 (3 H, d, *J* 6.0 Hz), 2.43 (5 H, m), 3.53br (8 H, s), and 5.75br (1 H, s) (Found: C, 67.8; H, 8.85; N, 7.1%; M^+, 195. $C_{11}H_{17}NO_2$ requires C, 67.7; H, 8.8; N, 7.1%; *M*, 195). 4-*Methyl*-2-*morpholinocyclohex*-2-*enone* (18) had n_D^{20} 1.5187, $\nu_{max.}$ (neat) 1 669 (C=O) and 1 600 cm^{-1} (C=C), δ (CCl_4) 1.13 (3 H, d, *J* 6.0 Hz), 1.93 (2 H, m), 2.36 (3 H, m), 2.77 (4 H, m), 3.70 (4 H, m), and 5.60 (1 H, d, *J* 3.0 Hz) (Found: C, 67.4; H, 8.7%; M^+, 195. $C_{11}H_{17}NO_2$ requires C, 67.7; H, 8.8%; *M*, 195). 5-*Methyl*-2-*morpholinocyclohex*-2-*enone* (19) had n_D^{20} 1.5211, $\nu_{max.}$ (neat) 1 665 (C=O) and 1 602 cm^{-1} (C=C), δ (CCl_4) 1.05 (3 H, d, *J* 6.0 Hz), 2.55br (5 H, s), 2.80 (4 H, m), 3.72 (4 H, m), and 5.76 (1 H, t, *J* 4.0 Hz), M^+ 195.

Reaction of the Dibromoketone (16) *with Morpholine.*—The reaction was carried out according to the procedure for (15) (above), but with the ketone (16) (5.40 g), and the resulting oil was chromatographed on a silica gel column (benzene as eluant) to give compounds (21) (0.38 g, 9.7%), (22) (4.09 g, 74%), and (20) (<1%). N-2-*Methylcyclopent*-1-*enylcarbonylmorpholine* (20) had n_D^{20} 1.5713, $\nu_{max.}$ (neat) 1 625 cm^{-1} (C=O and C=C), δ (CCl_4) 1.68 (3 H, s), 1.97 (2 H, m), 2.47 (4 H, m), and 3.51br (8 H, s) (Found: C, 67.4; H, 8.8; N, 7.05%; M^+, 195. $C_{11}H_{17}NO_2$ requires C, 67.7; H, 8.8; N, 7.15%; *M*, 195). 6-*Methyl*-2-*morpholinocyclohex*-2-*enone* (21) had n_D^{20} 1.5178, $\nu_{max.}$ (neat) 1 680 (C=O) and 1 615 cm^{-1} (C=C), δ (CCl_4) 1.07 (3 H, d, *J* 6.0 Hz), 1.95 (2 H, m), 2.43 (3 H, m), 2.76 (4 H, m), 3.65 (4 H, m), and 5.78 (1 H, t, *J* 4.0 Hz) (Found: C, 67.4; H, 8.7%; M^+, 195. $C_{11}H_{17}NO_2$ requires C, 67.7; H, 8.8%; *M*, 195). 6-*Bromo*-2-*methyl*-2-*morpholinocyclohexanone* (22) had m.p. 163—164°, $\nu_{max.}$ (KBr) 1 726 cm^{-1} (C=O), δ ($CDCl_3$) 1.07 (3 H, s), 1.56 (2 H, m), 2.20 (4 H, m), 2.70 (4 H, m), 3.75 (4 H, m), and 5.50 (1 H, m, $W_{\frac{1}{2}}$ 19.0 Hz) (Found: C, 47.6; H, 6.4; Br, 28.8; N, 5.1. $C_{11}H_{18}BrNO_2$ requires C, 47.8; H, 6.6; Br, 28.9; N, 5.1%).

[6/2306 *Received*, 20*th December*, 1976]

[15] J. C. Sheehan, R. C. O'Neill, and M. A. White, *J. Amer. Chem. Soc.*, 1950, **72**, 3376.

[16] K. J. Klabunde and D. J. Burton, *J. Org. Chem.*, 1970, **35**, 1709.