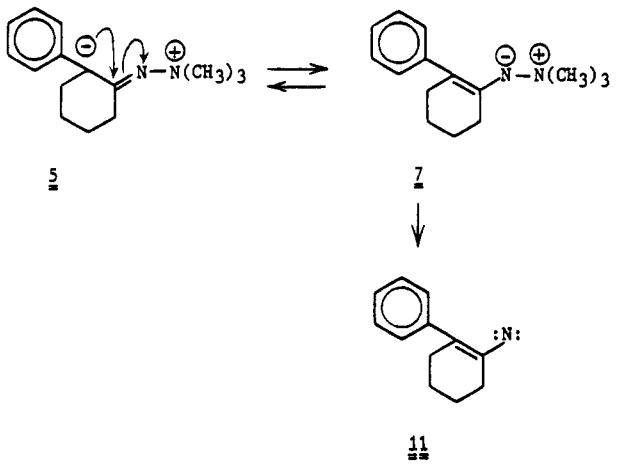
Scheme III



from the anion **5** in the anti configuration or via an intermediate vinyl nitrene **11** (Scheme III). The abstraction of a proton from one of the quaternary methyls by the anion **5**, in the syn configuration, would proceed as in Scheme II to produce the Mannich products. It is evident from the conditions necessary to produce the two synthetic sequences (Schemes I and II) that the concerted elimination of the neutral nucleophile, trimethylamine, is a higher energy process than the proposed route which produces the Mannich products.

Experimental Section

1,1,1-Trimethyl-2-(2-phenylcyclohexylidene)hydrazinium Iodide (1). To a solution of 389 g (1.8 mol) of 2-phenylcyclohexanone dimethylhydrazone[8] in 450 mL of CH_3CN was added 300 g (2.11 mol) of CH_3I. The reaction was exothermic to 43 °C over 2 h and was then heated to 70 °C for 3 h and cooled to room temperature. The crystalline mixture was diluted with 2 L of anhydrous Et_2O and cooled to 5 °C. The solid was removed by filtration, washed with Et_2O/CH_3CN (5:1), and dried to give 489 g (76%) of **1**, mp 165–167 °C. One recrystallization from $MeOH/Et_2O$ afforded the analytical sample, mp 166–167 °C. Anal. Calcd for $C_{15}H_{23}N_2I$: C, 50.28; H, 6.47; N, 7.82. Found: C, 50.39; H, 6.40; N, 7.85.

2-Phenylcyclohexanone (2). To a 5 °C suspension of 200 g (0.56 mol) of **1** in 400 mL of MeOH was added portionwise 0.56 mol of NaOMe in 150 mL of MeOH with the temperature maintained below 10 °C. After the addition was complete, the suspension was allowed to come to room temperature and then heated to 40 °C to complete solution. The solution was then recooled to 5 °C, and 400 mL of 3.0 M HCl was added, keeping the temperature below 10 °C. The MeOH was removed in vacuo, and the aqueous acid layer was extracted with Et_2O (3 × 250 mL). The combined Et_2O layers were dried, filtered, and evaporated to give 35.8 g (37%) of **2**, mp 54–55 °C. The IR and ^1H NMR were identical with those of an authentic sample.[9]

2-[(Dimethylamino)methyl]-6-phenylcyclohexanone (4). The aqueous acid fraction from the isolation of **2** was made basic with 50% NaOH and extracted with Et_2O (3 × 250 mL). The combined Et_2O layers were washed with H_2O, dried, and concentrated, and the residue was converted to its hydrochloride salt by using 2-propanolic hydrogen chloride. The yield of **4** was 54 g (36%), mp 164–168 °C. One recrystallization from $MeOH/Et_2O$ afforded the analytical sample, mp 165–168 °C. The IR and ^1H NMR were identical with those of an authentic sample prepared by the Mannich reaction of **2**.[6] Anal. Calcd for $C_{15}H_{21}NO\cdot HCl$: C, 67.27; H, 8.28; N, 5.23. Found: C, 67.01; H, 8.39; N, 5.07.

2-Phenylcyclohexanamine (12). The reaction was run in a manner identical with that for the preparation of **2** to the point where the reaction was recooled to 5 °C. At this point, 21 g (0.56 mol) of $NaBH_4$ was added portionwise, with the temperature kept below 10 °C. The reaction mixture was stirred for 2 h, poured into 500 mL of 5% NaOH, and extracted with Et_2O (2 × 500 mL). The combined Et_2O layers were extracted with 5% HCl (3 × 100 mL). The neutral Et_2O layer was dried, filtered, and evaporated to give 10 g of an inseparable mixture of five compounds as indicated by TLC. The aqueous acid layers were made basic with 50% NaOH and extracted with Et_2O (4 × 150 mL). The combined Et_2O layers were washed with H_2O, dried, filtered, and evaporated, and the residue was distilled to give 46.5 g (48%) of a mixture of the cis and trans isomers of **12**, bp 70–73 °C (0.12 mm). A sample was converted to the hydrochloride salt by using 2-propanolic hydrogen chloride, mp 225–230 °C. No effort was made to separate the isomers, but two recrystallizations (from MeOH/*i*-PrOH afforded the analytical sample: mp 237–240 °C;[7] IR (KBr) 3420 cm^{-1} ($NH_2\cdot HCl$); NMR (Me_2SO-d_6) δ 1.16–2.31 (m, 8 H), 2.65–3.51 (m, 2 H), 7.10–7.28 (m, 5 H), 7.62–7.93 (s, 3 H). The broad singlet at δ 7.62–7.93 (s, 3 H) could be exchanged with deuterium oxide. Anal. Calcd for $C_{12}H_{17}N\cdot HCl$: C, 68.09; H, 8.57; N, 6.61. Found: C, 67.79; H, 8.43; N, 6.31.

2-Amino-2-phenylcyclohexanone (3).[10] To a solution of 0.66 mol of NaOEt in 500 mL of EtOH at 80 °C was added portionwise as a dry powder 209 g (0.58 mol) of **1**. The mixture was refluxed for 1 h, cooled to 15 °C, and treated portionwise with 250 mL of 4.0 M HCl, with the temperature kept below 25 °C. The reaction was concentrated in vacuo, and the residue diluted with H_2O and extracted with Et_2O. The Et_2O layer was dried, filtered, and evaporated, with the crystalline residue being recrystallized from petroleum ether to give 15.8 g (16%) of **2**, mp 54–55 °C. The aqueous acid layer was made basic with 50% NaOH and extracted with Et_2O (2 × 500 mL). The combined Et_2O layers were washed with H_2O, dried, filtered, and concentrated, and the residue was distilled to give 82 g (74%) of **3**: bp 107–110 °C (1.3 mm); IR (film) 3300, 3360 cm^{-1} (NH_2), 1716 cm^{-1} (C=O); NMR ($CDCl_3$) δ 1.44–2.17 (m, 5 H), 1.87 (s, 2 H), 2.26–2.59 (m, 2 H) 2.65–3.06 (m, 1 H), 7.14–7.58 (m, 5 H). A sample converted to its hydrochloride salt by using 2-propanolic hydrogen chloride and recrystallized from *i*-PrOH/MeOH had a melting point of 233–234 °C. Anal. Calcd for $C_{12}H_{15}NO\cdot HCl$: C, 63.85; H, 7.15. Found: C, 63.56; H, 6.96.

Registry No. **1**, 56062-76-1; **2**, 1444-65-1; **3**, 7015-50-1; **3**·HCl, 7015-20-5; **4**·HCl, 52955-93-8; **12**·HCl, 22720-50-9; *cis*-**12**, 22147-09-7; *trans*-**12**, 1011-11-6; 2-phenylcyclohexanone dimethylhydrazone, 5758-09-8.

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(9) Newman, M. S.; Farbman, M. D. *J. Am. Chem. Soc.* **1944**, *66*, 1550.
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Ring Opening of Oxiranes by *I,I*-Bis(trifluoroacetoxy)iodobenzene

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The propensity of oxiranes to undergo ring-opening reactions is well-known.[1] We report here on the reaction of *I,I*-bis(trifluoroacetoxy)iodobenzene[2] (**2**, abbreviated

(1) Gritter, R. J. In "The Chemistry of the Ether Linkage"; Patai, S., Ed.; Wiley-Interscience: New York, 1967; Chapter 9.
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Table I. Reaction Products[a] of Oxiranes with BTI

no.	 1	products (% yield) C–O cleavage (6)	C–C cleavage (8 and 9)	rearrangement and C–C cleavage (13)
1a	$R_1 = R_4 = H$, R_2-$R_3 = (CH_2)_4$			
1b	$R_1 = R_2 = H$, $R_4 = n$-C_5H_{11}	n-$C_5H_{11}CH(OH)CHO$ (40), n-$C_5H_{11}COCH_2OH$ (40)		
1c	$R_1 = R_2 = Me$, $R_3 = H$, $R_4 = CMe_3$	$Me_2C(OH)COCMe_3$ (60)		
1d	$R_1 = R_2 = H$, $R_3 = R_4 = Ph$	$Ph_2C(OH)COH$ (73)		
1e	$R_1 = H$, $R_2 = R_3 = R_4 = Ph$	$Ph_2C(OH)COPh$ (80)		
1f	$R_1 = R_2 = R_3 = H$, $R_4 = Ph$		PhCHO (42) + CH_2O (37)	
1g (trans)	$R_1 = R_3 = H$, $R_2 = Me$, $R_4 = Ph$	PhCH(OH)COMe (15),[c] PhCOCH(OH)Me (60)[c]	PhCHO (13)	
1h (trans)[b]	$R_1 = R_3 = H$, $R_2 = R_4 = Ph$	PhCOCH(OH)Ph (18)	PhCHO (10)	Ph_2CO (17)
1i (cis)	$R_1 = R_3 = H$, $R_2 = R_4 =$ p-NO_2Ph	p-$NO_2PhCOCH(OH)PhNO_2$-p (25)	p-NO_2PhCHO (5)	(p-$NO_2Ph)_2CO$ (32)
1j (trans)	$R_1 = R_3 = H$,	p-$NO_2PhCOCH(OH)PhNO_2$-p (22)	p-NO_2PhCHO (5)	(p-$NO_2Ph)_2CO$ (47)
1k (trans)	$R_1 = R_3 = H$, $R_2 = p$-NO_2Ph, $R_4 = m$-NO_2Ph		p-NO_2PhCHO (3) + m-NO_2PhCHO (4)	p-$NO_2PhCOPhNO_2$-m (63)
1l (trans)	$R_1 = R_3 = H$, $R_2 = p$-NO_2Ph, $R_4 = p$-MeOPh		p-NO_2PhCHO (73) + p-MeOPhCHO (36)	[d]
1m	$R_1 = R_2 = R_3 = R_4 = Ph$	no reaction		

[a] All products were isolated in pure form, except for 6g. [b] Other products from this reaction are PhCH(OH)CH(OH)Ph (18%) and Ph_2CHCHO (a trace). [c] This mixture was not separated; relative yields were estimated from the NMR signal of the Me group. [d] Some p-benzoquinone was also isolated.

BTI) with oxiranes, where not only the usual patterns of ring opening are observed but also a new kind of product has been detected and attributed to a ring-opening–closure–opening sequence with rearrangement. In Table I the reaction products of 13 substituted oxiranes are collected.

It can be seen that 2-alkyl-, 2,3-dialkyl-, and trialkyl-substituted as well as 2,2-diphenyl- and triphenyl-substituted oxiranes undergo C–O cleavage and give α-hydroxy ketones as the sole products in satisfactory yields. The reaction is analogous to the cleavage of benzyl ethers by BTI,[3] and the normal product is the trifluoroacetate, which usually hydrolyses during workup. In the case of 2-n-pentyloxirane it is noted that the two possible products are produced in equal amounts, suggesting complete lack of steric implications.

2-Phenyloxirane undergoes exclusively C–C cleavage, and the reaction products are benzaldehyde and formaldehyde.

With 2,3-diaryloxiranes both types of products resulting from C–O and C–C cleavage are produced, but the main products are now benzophenones. We believe that this unexpected kind of product is the result of initial C–O ring opening, followed by rearrangement; ring closure then takes place to a new oxirane, which with C–C cleavage gives the benzophenone. The missing product from this sequence of reactions is formaldehyde, which is usually "lost" during workup. However, it is possible to also isolate formaldehyde in the form of its 2,4-dinitrophenylhydrazone. This diversity of behavior depending on the substituents is visualized in Scheme I, along with some mechanistic points. There is little doubt that initially an oxonium salt, 3, is formed. In the first case it is opened by proton removal to compound 4 (with iodonium-like character), which expels iodobenzene and is transformed to the trifluoroacetate 5. In some cases 5 may be isolated, but in any case the α-hydroxy ketone 6 is the final stable product. This mechanism has been shown to operate in the reaction between BTI and dibenzyl ethers.[3]

When the oxiranes bear one or two aryl groups, the oxonium salt 3 may be in equilibrium with its ring–chain tautomer 3′, where the carbonium ion is stabilized and has two possibilities: either it combines with CF_3COO^- to give the ester 7 or it rearranges to 8. The ester 7 is split under expulsion of iodobenzene into an aldehyde, 9, and an acylal, 10, the latter being hydrolyzed during workup and isolated as an aldehyde. The other ester 8 is presumably cyclized to the oxirane 11, which either is split by trifluoroacetic acid (produced also during formation of 4) into 12, which is oxidized further by BTI, or hydrolyses during workup to benzophenone and formaldehyde. Alternatively, 12 might spontaneously split into 13 and 14. Oxiranes like 11 are known to be fairly stable in the absence of acids,[4] but it was not possible to detect 11 by NMR spectroscopy, even by removal of CF_3COOH, because its hydrogen signal is probably masked by the aromatic protons. In the case of *trans*-2,3-diphenyloxirane (1h) the NMR spectrum during the reaction revealed the formation of ester 7 or 8. The singlet of the two equivalent protons of oxirane at δ 3.82 becomes two doublets of equal area at δ 4.98 and 5.99 (J = 8 Hz). Since the racemic ester PhCH-

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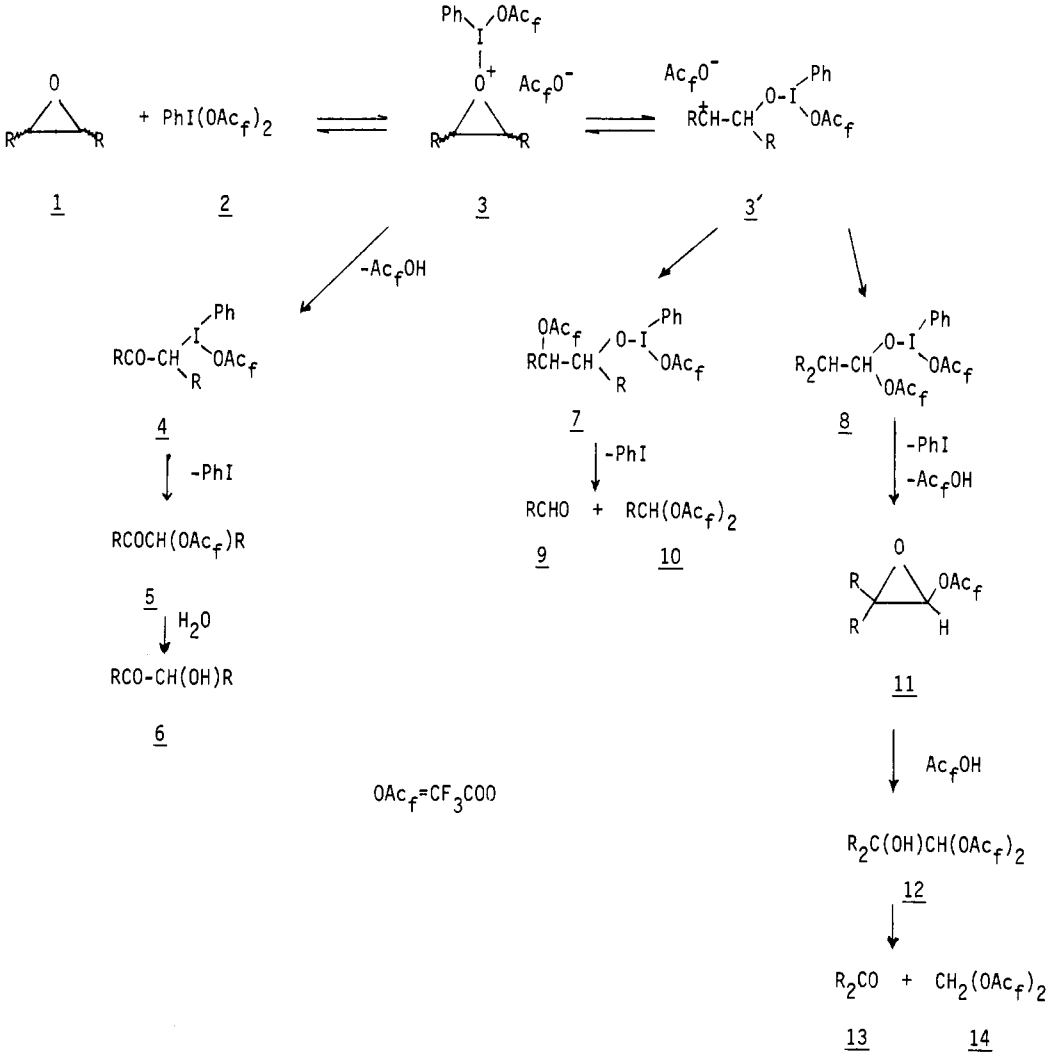
Scheme I



$(OCOCF_3)CH(OCOCF_3)Ph$ has a singlet at δ 5.98 for its methinic protons, it is probable that the observed two doublets belong to **7** rather than **8**.

Attempts to trap the oxirane **11** with added nucleophiles before the reaction was completed were unsuccessful. When **1b** was allowed to react with (diacetoxyiodo)-benzene, it remained unaltered after 3 h of heating at 60 °C. A point of interest is that the yield of 4,4′-dinitrobenzophenone was significantly higher from *trans*-oxirane **1j** than from *cis*-**1i**. Inspection of models showed clearly that it is easier during opening of **3** to **3′** for the *trans*-4-nitrophenyl group to migrate than for the cis. Finally, as expected, tetraphenyloxirane was totally inert in its reaction with BTI.

Experimental Section

^{1}NMR spectra were recorded with a Varian A-60A spectrometer. Data are given in parts per million (δ) relative to internal Me_4Si (in $CDCl_3$ solution). All oxiranes were known compounds and were prepared by standard methods.

Equimolecular quantities (usually 0.3 mmol) of the oxirane and BTI in dry CH_2Cl_2 or $CHCl_3$ were allowed to stand at room temperature for approximately 24 h or until the reaction was completed. A small amount of CF_3COOH was added to compounds **1i,j,k,l** to decrease the reaction time. Evaporation of the solvent normally led to removal of CF_3COOH and CH_2O, unless it was desirable to obtain the latter; in that case the reaction mixture was repeatedly extracted with water, and the aqueous extracts were treated with 2,4-dinitrophenylhydrazine, so that the 2,4-dinitrophenylhydrazone of formaldehyde was isolated. The residue after evaporation of the organic solvent was chromatographed with hexane–$CHCl_3$ mixtures of increasing polarity in a silica gel column. The compounds were generally eluted in the order iodobenzene, benzaldehyde, benzophenone, and α-hydroxy ketone. All products were known compounds and were identified by their physical and spectroscopic properties, which were compared with those of authentic samples.

Registry No. 1a, 286-20-4; **1b**, 5063-65-0; **1c**, 96-06-0; **1d**, 882-59-7; **1e**, 4479-98-5; **1f**, 96-09-3; **1g**, 23355-97-7; **1h**, 1439-07-2; **1i**, 14688-37-0; **1j**, 968-01-4; **1k**, 77133-16-5; **1l**, 14985-27-4; **1m**, 470-35-9; C-(O)-$(CH_2)_4$-CH-OH, 533-60-8; *n*-$C_5H_{11}CH(OH)CHO$, 17046-02-5; *n*-$C_5H_{11}COCH_2OH$, 17046-01-4; $Me_2C(OH)COCMe_3$, 546-95-2; $Ph_2C(OH)COPh$, 4237-46-1; PhCH(OH)COMe, 90-63-1; PhCOCH-(OH)Me, 5650-40-8; PhCOCH(OH)Ph, 119-53-9; *p*-NO_2PhCOCH-(OH)PhNO_2-*p*, 36898-62-1; PhCHO, 100-52-7; CH_2O, 50-00-0; *p*-NO_2PhCHO, 555-16-8; *p*-MeOPhCHO, 123-11-5; Ph_2CO, 119-61-9; (*p*-NO_2Ph)$_2$CO, 1033-26-7; *p*-NO_2PhCOPhNO_2-*m*, 1469-74-5; BTI, 2712-78-9.