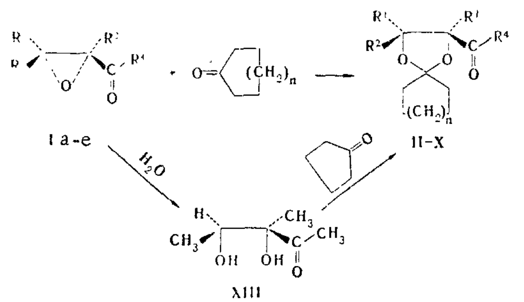
REACTION OF 2-ACYLOXIRANES WITH CYCLIC KETONES

I. G. Tishchenko, O. N. Bubel',
and G. Z. Stasevich

UDC 547.729

Acyloxiranes react with cyclopentanone and cyclohexanone in the presence of catalytic amounts of boron trifluoride etherate to give the corresponding 2-acyl-1,4-dioxaspiro[4,4]-nonanes and 2-acyl-1,4-dioxaspiro[4,5]decanes. The corresponding cis-2,3-dimethyl-2 acetyl-1,4-dioxaspiroalkanes are formed from trans-2,3-dimethyl-2-acetyloxirane.

Up until now the reaction of acyloxiranes with ketones has not been investigated. We have studied the reaction of 2-acyloxiranes (Ia-e) with cyclopentanone and cyclohexanone in the presence of catalytic amounts of boron trifluoride etherate; the reaction gives the corresponding 2-acyl-1,4-dioxaspiro[4,4]nonanes (II-V) and 2-acyl-1,4-dioxaspiro[4,5]decanes (VI-X).



Ia, II, VI $R^1=R^2=R^3=H$; $R^4=CH_3$; Ib, III, VII $R^1=R^2=H$; $R^3=R^4=CH_3$; Ic, IV, VIII $R^1=R^2=R^4=CH_3$; $R^3=H$; Id, V, IX $R^2=R^3=R^4=CH_3$; $R^1=H$; Ie, X $R^1=R^2=R^3=H$; $R^4=Ph$; II—V $n=0$; VI—X $n=1$

Acyloxirane Ib reacts readily with cyclopentanone, and acyloxiranes Ia, c react readily with cyclopentanone and cyclohexanone even at room temperature, while heating to 80°C is required in the remaining cases. The structures of II-X were established by hydrolysis in acetic acid to the corresponding ketoglycols and cyclic ketones, which were identified from their physicochemical constants and the melting points of their 2,4-dinitrophenylhydrazones; the structures were also confirmed by their IR and PMR spectra.

Absorption bands at 1090, 1115, 1150, and 1200 cm^{-1}, which are characteristic for the COCOC fragment of the 1,3-dioxolane ring [1] are observed in the IR spectra of II-X. The stretching vibrations of the carbonyl group in II-IX appear at 1710-1720 cm^{-1}, while the stretching vibrations of the carbonyl group in X appear at 1690 cm^{-1}.

Ring expansion of 2-acyloxiranes Ia-e proceeds via a known mechanism [2, 3] with inversion of the configuration of one of the ring-carbon atoms; this is confirmed by the cis structure of spirans V and IX. The configurations of spirans V and IX were established by comparison of their PMR spectra with the spectra of authentic trans-2,3-dimethyl-2-acetyl-1,4-dioxaspiro[4,4]nonane (XI) and its cis isomer. The PMR spectra of the cis isomer and of spiran V are identical and differ from the PMR spectrum of XI (Fig. 1) with respect to the position of the signals of the CH_3 groups.

V. I. Lenin Belorussian State University, Minsk. Translated from Khimiya Geterotsiklicheskikh Soedinenii, No. 7, pp. 885-888, July, 1974. Original article submitted December 7, 1972; revision submitted January 10, 1974.

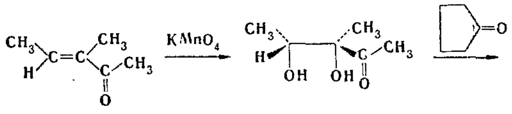
TABLE 1. Ketoglycols Obtained by Hydrolysis of II-X

Ketoglycol	Bp, °C (mm)	n_D^{20}
3,4-Dihydroxy-2-butanone [7]	66—68 (0,2)	1,4505
3-Methyl-3,4-dihydroxy-2-butanone [6]	101—102 (11)	1,4490
Erythro-3-Methyl-3,4-dihydroxy-2-pentanone	102—103 (10)	1,4520
4-Methyl-3,4-dihydroxy-2-pentanone [5]	100—102 (12)	1,4524
1-Phenyl-2,3-dihydroxy-1-propanone[*]	mp 78—79°	—

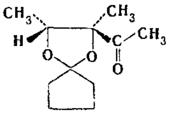
[*] Found: C 64.9; H 6.0%. $C_9H_{10}O_3$. Calculated: C 65.0; H 6.1%.

Fig. 1. PMR spectra of cis- and trans-2,3-dimethyl-3-acetyl-1,4-dioxaspiro[4,4]nonanes (V, XI): 1) cis isomer (V); 2) trans isomer (XI).

trans-Spiran XI was synthesized from cyclopentanone and threo-3-methyl-3,4-dihydroxy-2-pentanone (XII), which was obtained by hydroxylation of trans-3-methyl-3-penten-2-one with potassium permanganate.



XII



XI

Cis isomer V was similarly obtained from cyclopentanone and erythro-3-methyl-3,4-dihydroxy-2-pentanone (XIII). The latter was synthesized by acid hydrolysis of oxirane Id.

The practically complete coincidence of the chemical shifts of the signals of the 2- and 3-CH_3 groups in the PMR spectra of V and IX makes it possible to conclude that spiran IX also has the cis configuration.

EXPERIMENTAL

The IR spectra of thin layers of the compounds were recorded with a UR-20 spectrometer. The PMR spectra of CCl_4 solutions were recorded with a Varian HA-100-15D spectrometer with tetramethylsilane as the internal standard. Thin-layer chromatography (TLC) on a loose layer of activity II aluminum oxide [elution with ether—petroleum ether (1:1); the chromatograms were developed in iodine vapors] was used to evaluate the individuality of the compounds obtained. The starting acyloxiranes (Ia-e) were obtained by the methods described in [4-6].

2-Acetyl-1,4-dioxaspiro[4,4]nonane (II). A solution of 10 g (0.12 mole) of oxirane Ia in 25 g (0.3 mole) of cyclopentanone was added dropwise at 5° to a mixture of 25 g (0.3 mole) of cyclopentanone and 0.7 ml of boron trifluoride etherate. Ten minutes after the addition of the oxirane solution the reaction mixture was neutralized with methanolic potassium hydroxide and washed with water. The organic layer was dried with potassium carbonate and fractionated with a Vigreux column at reduced pressure to give 8.2 g (43%) of II with bp 109-110° (12 mm), n_D^{20} 1.4571, and d_4^{20} 1.0942. Found: C 63.4; H 8.3%; MR_D 42.48. $C_9H_{14}O_3$. Calculated: C 63.5; H 8.2%; MR_D 42.66. PMR spectrum[*]: δ 2.16 (s, CH_3), 3.82-4.30 (m, 2,3-H_3), 1.71-1.86 ppm [$(CH_2)_4$].

3,3-Dimethyl-2-acetyl-1,4-dioxaspiro[4,4]nonane (IV). A solution of 10 g (0.09 mole) of oxirane Ic in 15 g (0.18 mole) of cyclopentanone was added dropwise at 20° to a mixture of 20 g (0.24 mole) of cyclopentanone and 1 ml of boron trifluoride etherate. After 1.5 h, the reaction mixture was worked up as in the preceding experiment to give 11.2 g (55%) of IV with bp 97-98° (12 mm), n_D^{20} 1.4490, and d_4^{20} 1.0301. Found: C 66.7; H 9.2%; MR_D 51.61. $C_{11}H_{18}O_3$. Calculated: C 66.7; H 9.1%; MR_D 51.89. PMR spectrum: δ

---

[*] The following abbreviations are used here and subsequently: s is singlet, d is doublet, q is quartet, and m is multiplet.

1.04 (s, CH_3), 1.36 (s, CH_3), 2.19 (s, $COCH_3$), 3.85 (s, 2-H, and 1.68-1.89 ppm [$(CH_2)_4$].

2-Acetyl-1,4-dioxaspiro[4,5]decane (VI). A solution of 10 g (0.12 mole) of oxirane Ia in 30 g (0.3 mole) of cyclohexanone was added dropwise to a mixture of 50 g (0.5 mole) of cyclohexanone and 1.5 ml of boron trifluoride etherate, after which the temperature of the mixture was raised to 35°. It was then cooled to 20° and allowed to stand for 12 h. Workup gave 19.3 g (90%) of VI with bp 114-115° (11 mm), n_D^{20} 1.4660, and d_4^{20} 1.0798. Found: C 65.5; H 8.8%; MR_D 47.26. $C_{10}H_{16}O_3$. Calculated: C 65.2; H 8.7%; MR_D 47.26. PMR spectrum: δ 2.23 (s, $COCH_3$), 3.80-4.28 (m, 2,3-H_3), and 1.25-1.75 ppm [$(CH_2)_5$].

3,3-Dimethyl-2-acetyl-1,4-dioxaspiro[4,5]decane (VIII). The procedure used to obtain VI was used to prepare this compound from 2 mole of cyclohexanone and 0.4 mole of oxirane Ic in the presence of 1.5 ml of boron trifluoride etherate. The yield of product with bp 108-109° (12 mm), n_D^{20} 1.4540, and d_4^{20} 1.0260 was 28%. Found: C 67.9; H 9.3%; MR_D 56.04. $C_{12}H_{20}O_3$. Calculated: C 67.9; H 9.4%; MR_D 56.49. PMR spectrum: δ 1.04 (s, CH_3), 1.36 (s, CH_3), 2.20 (s, $COCH_3$), 3.97 (s, 2-H), and 1.48-1.56 ppm [$(CH_2)_5$].

2-Methyl-2-acetyl-1,4-dioxaspiro[4,5]decane (VII). A solution of 10 g (0.1 mole) of oxirane Ib in 35 g (0.35 mole) of cyclohexanone was added with stirring to a mixture of 15 g (0.15 mole) of cyclohexanone and 1 ml of boron trifluoride etherate heated to 60°, after which the mixture was heated to 80° for 30 min. Workup of the mixture gave 9.6 g (48%) of VII with bp 109-110° (11 mm), n_D^{20} 1.4584, and d_4^{20} 1.0474. Found: C 66.8; H 9.2%; MR_D 51.68. $C_{11}H_{18}O_3$. Calculated: C 66.7; H 9.1%; MR_D 51.88. PMR spectrum: δ 1.32 (s, CH_3), 2.19 (s, $COCH_3$), 3.60 (d, 3-H, J = 8.5 Hz), 4.15 (d, 3-H, J = 8.5 Hz), and 1.30-180 ppm [$(CH_2)_5$].

cis-2,3-Dimethyl-2-acetyl-1,4-dioxaspiro[4,5]decane (IX). The procedure used to synthesize VII was used to prepare this compound. Workup gave 61% of a product with bp 116-117° (12 mm), n_D^{20} 1.4620, and d_4^{20} 1.0383. Found: C 68.0; H 9.5%; MR_D 56.21. $C_{12}H_{20}O_3$. Calculated: C 67.9; H 9.4%; MR_D 56.49. PMR spectrum: δ 1.09 (d, 3-CH_3, J = 6.5 Hz), 1.28 (s, 2-CH_3), 2.16 (s, $COCH_3$), 3.99 (q, 3-H, J = 6.5 Hz), and 1.30-1.80 ppm [$(CH_2)_5$].

2-Benzoyl-1,4-dioxaspiro[4,5]decane (X). The procedure used to synthesize VII was used to obtain this compound from oxirane Ie and cyclohexanone by heating at 80° for 3 h. Workup gave 69% of a product with bp 126-127° (0.4 mm), n_D^{20} 1.5362, and d_4^{20} 1.1201. Found: C 73.4; H 7.4%; MR_D 68.52. $C_{15}H_{18}O_3$. Calculated: C 73.1; H 7.4%; MR_D 67.77.

2-Methyl-2-acetyl-1,4-dioxaspiro[4,4]nonane (III). The procedure used to synthesize IV was used to obtain this compound from 0.5 mole of cyclopentanone and 0.1 mole of oxirane Ib. The mixture was heated at 20° for 2 h. Workup gave 59% of a compound with bp 97-98° (12 mm), n_D^{20} 1.4490, and d_4^{20} 1.0527. Found: C 65.2; H 8.8%; MR_D 46.99. $C_{10}H_{16}O_3$. Calculated: C 65.2; H 8.7%; MR_D 47.26. PMR spectrum: δ 1.33 (s, CH_3), 2.19 (s, $COCH_3$), 3.59 (d, 3-H, J = 8.5 Hz), 4.16 (d, 3-H, J = 8.5 Hz), and 1.30-1.80 ppm [$(CH_2)_4$].

cis-2,3-Dimethyl-2-acetyl-1,4-dioxaspiro[4,4]nonane (V). The procedure used to synthesize III was used to obtain this compound. Workup gave 57% of a product with bp 102-103° (11 mm), n_D^{20} 1.4522, and d_4^{20} 1.0375. Found: C 66.4; H 9.2%; MR_D 51.58. $C_{11}H_{18}O_3$. Calculated: C 66.7; H 9.1%; MR_D 51.89. PMR spectrum: δ 1.12 (d, 3-CH_3, J = 6.4 Hz), 1.28 (s, 2-CH_3), 2.16 (s, $COCH_3$), 3.82 (q, 3-H, J = 6.4 Hz), and 1.72-2.05 ppm [$(CH_2)_4$].

Hydrolysis of II-X. Acetic acid was added to a mixture of 0.03 mole of the spiran and 2.5 ml of water until the spiran had dissolved completely, after which the solution was refluxed for 3-5 h and fractionated with a Vigreux column at reduced pressure. The physicochemical constants of the ketoglycols obtained are presented in Table 1. The 2,4-dinitrophenylhydrazones of the isolated cyclopentanone and cyclohexanone melted at 145 and 161° (from methanol), respectively. No melting-point depression was observed for mixtures of these hydrazones with genuine samples.

threo-3-Methyl-3,4-dihydroxy-2-pentanone (XII). A solution of 43 g (0.27 mole) of potassium permanganate in 1500 ml of acetone and 80 ml of water was added dropwise with stirring to a cooled (to −10°) mixture of 20 g (0.2 mole) of trans-3-methyl-3-penten-2-one [4] in 40 ml of acetone, after which the mixture was filtered, and the acetone was removed from the filtrate at reduced pressure. The residue was saturated with potassium carbonate and extracted repeatedly with ether. The ether extracts were dried with potassium carbonate, the ether was removed, and the residue was distilled at reduced pressure to give 24% of the ketodiol with bp 78-80° (1 mm), n_D^{20} 1.4515, and d_4^{20} 1.0901. Found: C 54.7; H 9.0%; MR_D 32.69. $C_6H_{12}O_3$. Calculated: C 54.5; H 9.1%; MR_D 32.97.

Erythro-3-Methyl-3,4-dihydroxy-2-pentanone (XIII). A mixture of 29 g (0.25 mole) of oxirane Id and 200 ml of 5% perchloric acid was stirred at 60° for 5 h. The mixture was then cooled, neutralized with potassium carbonate, and vacuum evaporated to 50 ml. This material was extracted with ether, and the extracts were dried with potassium carbonate. The ether was removed, and the residue was distilled at reduced pressure to give 31% of the ketodiol with bp 77-79° (1 mm), n_D^{20} 1.4520, and d_4^{20} 1.0912. Found: C 54.6; H 9.0%; MR_D 32.65. $C_6H_{12}O_3$. Calculated: C 54.5; H 9.1%; MR_D 32.97.

trans-2,3-Dimethyl-2-acetyl-1,4-dioxaspiro[4,4]nonane (XI). A 1-ml sample of boron trifluoride etherate was added to a mixture of 13.2 g (0.1 mole) of ketodiol XII, 63 g (0.75 mole) of cyclopentanone, and 2 g of anhydrous copper sulfate, after which the mixture was allowed to stand at room temperature for 3 days. It was then filtered, and the filtrate was neutralized with methanolic potassium hydroxide, diluted with ether, washed with water, and dried with sodium sulfate. The solvent was removed, and the residue was distilled at reduced pressure. The product was dissolved in ether–hexane (1:3), and the solution was filtered through a layer of aluminum oxide to give XI with bp 62-63° (0.3 mm), n_D^{20} 1.4515, and d_4^{20} 1.0316 in 30-35% yield. Found: C 66.6; H 8.9%; MR_D 51.79. $C_{11}H_{18}O_3$. Calculated: C 66.7; H 9.1%; MR_D 51.89. PMR spectrum: δ 1.12 (s, 2-CH_3), 1.20 (d, 3-CH_3, J = 6.3 Hz), 2.18 (s, $COCH_3$), 3.89 (q, 3-H, J = 6.3 Hz), and 1.60-1.95 ppm [$(CH_2)_4$].

The cis isomer, with bp 103-104° (12 mm) and n_D^{20} 1.4520, which was identical to spiran V, was similarly obtained from ketodiol XIII.

LITERATURE CITED

1. E. D. Bergmann and S. Pinchas, Rec. Trav. Chim., 71, 161 (1952).
2. V. N. Yandovskii and T. I. Temnikova, Zh. Organ. Khim., 4, 1758 (1968).
3. B. N. Blackett, J. M. Coxon, M. P. Hartshorn, A. I. Lewis, G. R. Little, and G. I. Wright, Tetrahedron, 26, 1311 (1970).
4. H. O. House and R. Ro, J. Amer. Chem. Soc., 80, 2428 (1958).
5. I. N. Nazarov and A. A. Akhrem, Zh. Obshch. Khim., 20, 2189 (1950).
6. I. G. Tishchenko, in: Liquid-Phase Oxidation of Unsaturated Organic Compounds [in Russian], Minsk (1961), p. 73.
7. H. O. L. Fisher, E. Baer, H. Pollock, and H. Nidecker, Helv. Chim. Acta, 20, 1213 (1937).