A NEW APPROACH TO THE SYNTHESIS OF OPTICALLY ACTIVE DISPARLURES — ATTRACTANTS OF *Porthetria dispar*

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A fairly simple and original one-stage method of obtaining optically active attractants of *Porthetria dispar* — (+)- and (—)-2-methyl-Z- and E-7,8-epoxyoctadecanes has been developed. The synthesis is based on the epoxidation of 2-methyloctadec-Z- and -E-7-enes by chiral peroxide complexes of molybdenum of the type of MoO_5 — L* in an organic solvent at room temperature. Derivatives of tartaric, lactic, β-aminopropionic, and aspartic acids have been used as the chiral ligands (L*).

According to the literature [1-5], one of the most promising methods of combating the gypsy moth is the use of an attractant of the *Porthetria dispar* male — 2-methyl-Z-7,8-epoxyoctadecane. With the aid of this substance it is possible not only to make a count but also a fairly effective and strictly selective regulation of the numbers of gypsy moths, which are the main pest of deciduous forests.

A paper has recently been published [6] in which it is shown that the attractant activity of (+)-Z-disparlure is considerably higher than that of (±)-2-methyl-Z-7,8-epoxyoctadecanes, while the (—)-enantiomer is a repellant for this insect. The synthesis of optically active (+)- or (—)-Z-disparlures is characterized by a multistage nature and the yield of desired products does not exceed 13% [7-9].

In view of the interest and promising nature that disparlure presents for the fight against the gypsy moth, we have developed a new simple and convenient method for obtaining (+)-2-methyl-Z-7,8-epoxyoctadecane by the epoxidation of 2-methyloctadec-Z-7-ene (I) with chiral peroxide complexes of molybdenum of the type of MoO_5L^* or with the reagent tert-$C_4H_9O_2$ — $MoCl_5$ in the presence of optically active ligands. The optically active peroxide complexes of Mo were obtained by methods given in the literature [10, 11]. As the chiral ligands (L*) we have used derivatives of aspartic, lactic, tartaric, and propionic acids. Oxidation was performed in CH_2Cl_2 or $CHCl_3$ solution at 20°C. At a lower temperature the rate of peroxidation by the complexes MoO_5L^* is very small and a long time is required to obtain satisfactory yields of the desired epoxides.

It has been established that in the epoxidation of (I) [12] by the complex MoO_5L^* in CH_2Cl_2 solution, 2-methyl-Z-7,8-epoxyoctadecane (II) with a specific rotation of $\sim +0.4°$ is obtained in exceptionally high yield. The conversion of the initial olefin (I) in these experiments was not less than 57%, and the optical yield of (II) amounted to 50%. The oxidation of (I) in $CHCl_3$ led not only to a fall in the total yield of (II) but also to a decrease in the optical yield of the latter to 35%. The use as chiral ligands in the complex MoO_5L^* of optically active methyl esters of morpholin-2-ylsuccinic acid ($[\alpha]_D^{20} - 0.6°$, L_2) and of 3-diethylamino-2-methylpropionic acid ($[\alpha]_D^{20} - 0.36°$, L_3) permitted (—)- enantiomers of (II) to be obtained which had specific rotations of $-0.2°$ and $-0.3°$, respectively.

It must be mentioned that in the experiments with the complex $MoO_5L_3^*$ together with the (—)- enantiomer of (II) a mixture of the C_{16} and C_{22} olefins (III and IV) and their epoxides (V and VI) was formed, the total amount of which in the reaction mixture did not, however, exceed 11%. Compounds (III) and (IV), and (V) and (VI), were identified by IR and mass spectrometry. We were unable to separate the mixture of olefins (III) and (IV) or the mixture of epoxides (V) and (VI) because of their close boiling points. The olefins (III) and (IV) are apparently the products of the disproportionation of (I) under the action of Mo ions, which

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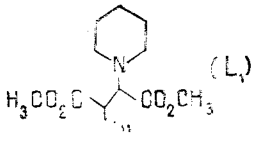
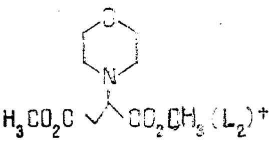
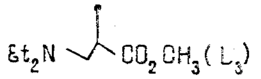
TABLE 1. Influence of the Structure of the Chiral Ligand on the Enantioselectivity of the Epoxidation of 2-Methyloctadec-Z-7-ene by the Reagent MoO_5-L^*

L^*	Yield of 2-methyl-Z-7,8-epoxyoctadecanes, %	Selectivity for (II), %	$(\alpha)_D^{20}$, deg
 (L_1)	57	100	+0,4
	29	100	+0,28
 (L_2)†	46	89	−0,2
 (L_3)	39	100	−0,3

Experimental conditions: 1.87 mmole of (I), 1.87 mmole of MoO_5L^*, 20 ml of CH_2Cl_2, 20°C.
*Epoxidation was performed in $CHCl_3$
†In addition to (II) in these experiments, a mixture of C_{16} and C_{22} olefins and epoxides in an amount of 11% was obtained.

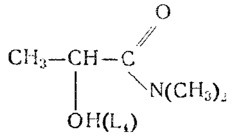
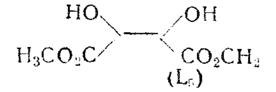
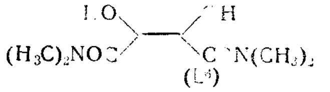
are widely used in double decomposition reactions of unsaturated compounds [13]. The subsequent epoxidation of (III) and (IV) by the complex MoO_5L^* gave the oxides (V) and (VI).

The replacement of aspartic acid esters in the complex MoO_5L^* by the dimethyl esters or diamides of tartaric and lactic acids led not only to (II) but also to a complex mixture of C_{19} olefins (VII) and optically active C_{19} epoxides (VIII), and also to the products (III-VI) which could be obtained as the result of the disporportionation of (I) followed by the epoxidation of (III) and (IV) by the complex MoO_5L^*.

The molecular weights of mixtures (VII) and (VIII) found by mass spectrometry were 266 and 282, respectively. The IR spectrum of (VII) had strong absorption bands at 975 and 3070 cm^{-1} which are characteristic for a trans-disubstituted double bond. The ozonization of (VII) in CH_3OH solution followed by the reduction of the products of ozonolysis by H_2 on Pd/C led to a mixture of C_7-C_{11} saturated aldehydes which were identified by comparison with authentic preparations [14, 15]. The experimental results obtained permitted the conclusion that (VII) was a mixture of 2-methyloctadec-E-6- and -8-enes obviously formed as the result of trans isomerization and double-bond migration in (I) under the action of the Mo complexes. The oxidation of the olefins (VII) by MoO_5L^* under the conditions of our experiment led to the corresponding oxides (VIII). As can be seen from Table 2, an increase in the time of oxidation by the complex MoO_5L^* had little effect on the overall yield and composition of the products of the epoxidation of (I).

In order to compare the enantioselective activity of the reagents MoO_5L^* and of hydroperoxide salts of MO which, according to Japanese authors [16], epoxidize olefins by the same mechanism, we investigated the oxidation of (I) with the aid of tert-BuO_2H in the presence of catalytic amounts of $MoCl_5$ and an optically active tartaric acid ester [(I) : tert-BuO_2H : $MoCl_5$: ester = 50 : 50 : 1 : 20]. It was found that at −8°C this reagent converts (I) with a total yield of 41% in 48 h into a mixture of (II), (VII), and (VIII), from which it was possible to isolate the mixture of epoxides (VIII) with a specific angle of rotation of +0.35°. A decrease in the time of epoxidation (8 h) led to an increase in the specific rotation of

TABLE 2. Influence of the Structure of the Ligand in the Complex MoO_5L^* and of the Time of Reaction on the Yield and Composition of the Products of the Epoxidation of 2-Methyloctadec-Z-7-ene

L*	Time, h	Overall yield, %	Comp. of the reaction mixture, %			
			VII	II	VIII	III–VI
 (L₄)	8	64	11	16	33	40
″ *	8	86	29	5	40	25
 (L₅)	8	61	7	20	43	30
 (L₆)	8	76	4	16	34	46
″	20	80	5	14	32	49
″	44	84	4	12	39	45
″	68	88	3	13	42	42
″	92	92	2	14	45	39
″	116	93	2	14	46	38

For the experimental conditions, see Table 1.
*The reaction was carried out at 40°C.

the VIII to + 0.5°. On the other hand, the epoxidation of (I) at 20°C with the reagent tert-$BuO_2H-MoCl_5$ in the presence of dimethyltartrate gave a racemic mixture of (II) and (VIII) with a total yield of ∿ 98%. The oxidation of (I) by the reagent tert-$BuO_2H-MoCl_5$ took place with exceptionally high selectivity when the bis-(N,N-dimethylamide of tartaric acid was used as ligand, leading only to the (+)- enantiomer of (II) with a specific rotation of +0.17°. Similar results were obtained when L_6 was replaced by L_1 (Table 3).

Having obtained the hoped-for results in the synthesis of (+)- and (−)-Z-disparlures, we investigated the oxidation of 2-methyloctadec-7E-ene (IX) with the reagents mentioned in order to obtain optically active 2-methyl-E-7,8-epoxyoctadecanes. The epoxidation of (IX) by the reagent MoO_5-L^* (−8°C, 8 h in CH_2Cl_2) led to (−)-2-methyl-E-7,8-epoxyoctadecane (X, $[\alpha]_D^{20}$ −4.9°) with a yield of 24%. When (IX) was oxidized with the reagent tert-$BuO_2H-MoCl_5-L^*$, the (+)- enantiomer (XI) was formed with a specific rotation of +5.6°.

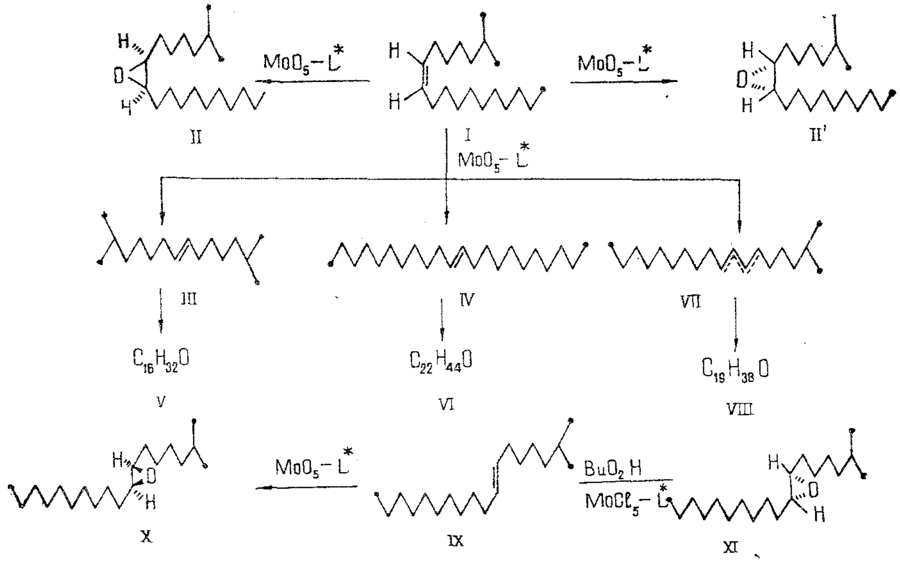
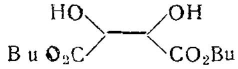


TABLE 3

L*	Yield, % (g)	Comp. of reaction mixture, %			
		II	$(\alpha)_D^{20}$,deg	VII	VIII
L_5	41(0,22)	29	+0,35	20	51
	73(0,38)	84	−0,12	16	—
L_6	8(0,04)	100	+0,17	—	—
L_1	28(0,15)	83	+0,13	—	17

Thus, we have shown for the first time the possibility of obtaining optically active (+)- or (−)-Z- and -E-disparlures from readily available reagents.

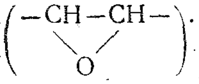
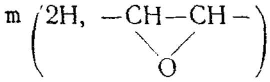
It must be mentioned that the optically active forms of Z-disparlure enriched with the (+)- enantiomer that we have obtained have been tested under field conditions and have shown a considerably higher activity than the racemic mixture of (±)-2-methyl-Z-7,8-epoxyoctadecanes.

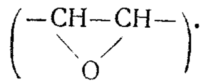
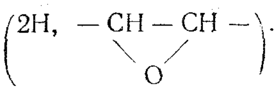
EXPERIMENTAL

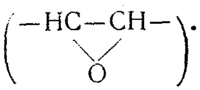
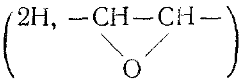
The investigation was carried out with 2-methyloctadec-Z-7-ene [12] and 2-methyloctadec-E-7-ene [17] with purities of 95-99%. As the optically active ligands we selected (−)-dimethyl piperidin-2-ylsuccinate (L_1, bp 98°C/1.33 hPa, mp 54°C, $[\alpha]_D^{20}$ −2.4°), (−)-dimethylmorpholin-2-ylsuccinate (L_2, bp 107°C/1.39 hPa, mp 59°C, $[\alpha]_D^{20}$ −0.6°), and (−)-methyl 3-diethylamino-2-methylpropionate (L_3, bp 89°C/1.33 hPa, $[\alpha]_D^{20}$ −0.36°). PMR spectra were recorded on a Tesla BS-480R spectrometer (with HMDS as internal standard and $CDCl_3$ as solvent), and IR spectra on a UR-20 instrument (film). The compounds obtained were analyzed on a Chrom-41 chromatograph with a flame-ionization detector using a 2.4 × 0.3 m column containing PEGA (15 wt. %) on Chromaton (0.2-0.25 μ) with helium as the carrier gas at the rate of 100 ml/min, temperature 160-180°C. Specific rotations were determined with the aid of a Perkin-Elmer 141 polarimeter. Mass spectra were recorded on an MKh-13-06 instrument with an energy of the ionizing electron of 70 eV and a temperature of the ionization chamber of 200°C.

General Procedure for the Epoxidation of 2-Methylocta-Z-7-ene with the Aid of MoO_5L^*. A solution of 1.87 mmole (0.5 g) of 2-methyloctadec-Z-7-ene in 20 ml of methylene chloride was treated with 1.87 mmole of the complex MoO_3L^* obtained as described by Kagan et al. [10], and the reaction mixture was stirred at 20°C for 48 h. Then the precipitate that had deposited was filtered off and the solvent was distilled off under reduced pressure at a temperature of 20°C. The residue was chromatographed on a column (0.8 m × 3 cm) filled with Al_2O_3 (activity grade II), being eluted successively with hexane and hexane−diethyl ether (10 : 1). The fractions were collected in 20-ml portions. The solvent was distilled off and the residue was analyzed by GLC. The first two fractions contained the initial olefin (I) unchanged, and the products of double decomposition (III) and (IV) and of isomerization (VII). The fourth and fifth fractions yielded the individual (+)- (when $L^* = L_1^*$) and (−)- (when $L^* = L_2^*$ or L_3^*) enantiomers of disparlure. Mixtures of C_{16}, C_{19}, and C_{22} epoxides were isolated from experiments using the activators L_4, L_5, and L_6 as chiral ligands.

The experimental results are presented in Tables 1 and 2. The compounds obtained had the following constants:

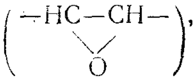
(+)-2-Methyl-7R,8S-epoxyoctadecane (II) bp 139°C (1.33 hPa), n_D^{20} 1.4472, $[\alpha]_D^{20}$ + 0.4°. IR spectrum, ν, cm^{-1}: 840, 860, 1080, 1270  $\left(-\underset{\diagdown O \diagup}{CH-CH}-\right)$. PMR spectrum (δ, ppm): 0.85 s (6H, CH_3C), 0.91 m (3H, CH_2C-), 1.29 m (26H, $-CH_2-$), 1.46 m (1H, CH<), 2.86 m  $\left(2H, -\underset{\diagdown O \diagup}{CH-CH}-\right)$; M^+ 282. Found, %: C 80, 83, H 13.44, $C_{19}H_{38}O$. Calculated, %: C 80, 85, H 13.48.

(−)-2-Methyl-7R,8R-epoxyoctadecane (II), bp 139°C (1.33 hPa), n_D^{20} 1.4472, $[\alpha]_D^{20}$ −0.3°. IR spectrum (ν, cm^{-1}): 840, 860, 1080, 1270  $\left(\underset{\text{O}}{\text{—CH—CH—}}\right)$. PMR spectrum (δ, ppm): 0.85 s (6H, CH_3C <), 0.91 m (3H, CH_3C —), 1.29 m (26H, $-CH_2-$), 1.46 m (1H, CH <), 2.86 m  $\left(2H, \underset{\text{O}}{\text{—CH—CH—}}\right)$. M^+ 282. Found, %: C 80.81, H 13.42, $C_{19}H_{38}O$. Calculated, %: C 80.85, H13, 48.

Mixture of C_{19} epoxides (VIII), bp 138°C/1.46 hPa, n_D^{20} 1.4831, $[\alpha]_D^{20}$ + 0.5°. IR spectrum (ν, cm^{-1}): 840, 860, 1080, 1270  $\left(\underset{\text{O}}{\text{—HC—CH—}}\right)$. PMR spectrum (δ, ppm): 0.85 s (6H, CH_3C <), 0.91 m (3H, CH_3C—), 1.29 m (26H, $-CH_2-$), 1.46 m (1H, CH<), 2.31–2.64  $\left(2H, \underset{\text{O}}{\text{—CH—CH—}}\right)$. M^+ 282. Found, %: C 81, H 13.2, $C_{19}H_{38}O$. Calculated %: C 80, 85, H 13,48.

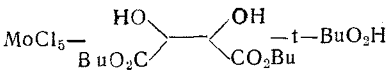
Mixture of C_{19} olefins (VII), bp 106°C/0.73 hPa. IR spectrum (ν, cm^{-1}): 975, 3030 (trans-CH=CH−). PMR spectrum (δ, ppm): 0.85 s (6H, CH_3C<), 0.91 m (3H, CH_3C−), 1.29 m (23H, $-CH_2-$, >CH−), 1.92 m (4H, $CH_2C{=}C$), 5.3 m (2H, −CH=CH), M^+ 266.

Ozonolysis of the Olefins (VII). A current of oxygen containing 6-7% of ozone was passed through a solution of 1 g of (VII) and 30 ml of methanol at 5-10°C until ozone appeared at the outlet. Then the mixture obtained was hydrogenated over Pd/C until the absorption of hydrogen ceased. The solvent was distilled off and the residue (1.3 g) was analyzed by GLC. 5-Methylhexanal, 6-methylheptanal, 7-methyloctanal, dodecanal, and undecanal were detected in a ratio of 20 : 25 : 15 ; 25 : 15, respectively; M^+ 114, 128, 142, 156, 170.

Mixture of the epoxides (V) and (VI). IR spectrum (ν, cm^{-1}): 845; 865, 1979, 1275  $\left(\underset{\text{O}}{\text{—HC—CH—}}\right)$, M^+ 240, 324.

Epoxidation of 2-Methyloctadec-Z-7-ene with the Aid of the Reagent tert-BuO_2H−$MoCl_5$−L.* To a solution of 1.87 mmole (0.5 g) of 2-methyloctadec-Z-7-ene in 20 ml of methylene chloride were added 0.037 mmole (0.01 g) of $MoCl_5$, 0.94 mmole (0.33 g) of dimethyl tartrate, and 1.87 mmole (0.17 g) of tert-BuO_2H and the mixture was stirred at −8°C for 48 h. Then it was worked up in the manner described above. This led to the isolation of 0.22 g (41%) of a mixture of compounds consisting of (II) (0.06 g, 29%), (VII) (0.04 g, 20%), and (VIII) (0.62 g, 51%).

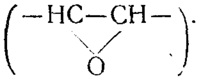
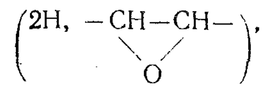
TABLE 4

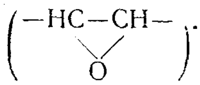
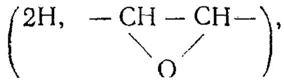
Reagent	Yield, % (g)	Comp. of reaction mixture, %		
		VIII	X	$[\alpha]_D^{20}$, deg
$MoCl_5$—L_5—t—BuO_2H	60 (1,2)	79	21	+1 2
 $MoCl_5$—(HO)(BuO_2C)CH—CH(OH)(CO_2Bu)—t—BuO_2H	63 (1.24)	19	81	+5,6
MoO_5—L_1	24 (0,48)	14	86	−4,9

The results of the experiments are given in Table 3.

Epoxidation of 2-Methyloctadec-E-7-ene (IX). The reaction of 2 g of (IX) with 1.7 g of the complex MoO_5-L_1 in 20 ml of methylene chloride under the conditions described above yielded 0.5 g of (−)-2-methyl-7S,8S-epoxyoctadecane (X)).

The epoxidation of 2 g of (IX) with the aid of the reagent tert-$BuO_2H-MoCl_5-L_5$ gave 0.23 g of (+)-2-methyl-7R,8R-epoxyoctadecane (XI). The results of the experiments are given in Table 2.

(−)-2-Methyl-7R,8R-epoxyoctadecane (X), bp 108°C (0.13 hPa, n_D^{20} 1.4830, $[\alpha]_D^{20}-4.9$. IR spectrum ν, cm^{-1}): 840, 860, 1080, 1270.  $\left(-\underset{O}{HC-CH}-\right)$. PMR spectrum (δ, ppm): 0,85 s (6H, $CH_3C<$), 0,91 m 3H, CH_3C-, 1,29 m (29H, $-CH_2-$), 1,46 m (1H, CH<), 2,64 m  $\left(2H,\ -\underset{O}{CH-CH}-\right)$, M^+ 282. Found, %: C 80,80, H 13,41. $C_{19}H_{38}O$ Calculated, %: C 80,85, H 13,48.

(+)-2-Methyl-7S,8S-epoxyoctadecane (XI), bp 108°C, (0.13 hPa) n_D^{20} 1.4830, $[\alpha]_D^{20}+5.6°$. IR spectrum (ν, cm^{-1}): 840, 860, 1080, 1270,  $\left(-\underset{O}{HC-CH}-\right)$. PMR spectrum (δ, ppm): 0,85 (6H, $CH_3C<$), 0,91 m(3H CH_3C-), 1,29 m (26H, $-CH_2-$), 1,46 m (1H, CH), 2,64 m  $\left(2H,\ -\underset{O}{CH-CH}-\right)$, M^+ 282. Found, %: C 80,82, H 13,4. $C_{19}H_{38}O$. Calculated, %: C 80,85, H 13.48.

V. N. Odinokov took part in the discussion of some of the results.

SUMMARY

A new and original method for the synthesis of the (+)- and (−)-enantiomers of 2-methyl-Z-7,8-epoxyoctadecane and 2-methyl-E-7,8-epoxyoctadecane — attractants of *Porthetria dispar* — using the readily available 2-methyloctadec-Z- and -E-7-enes and peroxide complexes of molybdenum as the starting materials has been developed.

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