SYNTHESIS OF RACEMIC SUGARS AND THEIR ANALOGS FROM DIHYDROPYRANS (REVIEW)

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New methods for the synthesis of glycosides of racemic sugars and some of their derivatives from various dihydropyran compounds are discussed. The problems involved in the preparation of 2-alkoxydihydropyrans with multiple bonds in various positions of the ring and problems of the stereospecificity of the epoxidation and hydroxylation of substituted dihydropyrans are examined. The stereospecificity and regiospecificity of opening of the epoxide ring of a large number of epoxytetrahydropyrans were studied in detail. It is shown that dihydropyran compounds are convenient substrates for the preparation of various racemic deoxy sugars, amino deoxy sugars, and their derivatives.

The tetrahydropyran ring is the foundation of pyranose forms of sugars; however, synthetic methods for the conversion of compounds of the pyran series to sugars have been developed only recently. This is explained, on the one hand, by the lack, until recently, of effective methods for the synthsis of substituted dihydro- and tetrahydropyrans and, on the other, by the small amount of study that has been devoted to the methods of dynamic stereochemistry and conformational analysis as applied to compounds of this series.

The development of research on the synthesis of racemic sugars from oxygen-containing heterocycles not only surmounts the unique barrier that separates the chemistry of sugars from the chemistry of heterocyclic compounds but also makes it possible to study, in the case of the simplest subjects, the conditions for conformational stability of pyranose, the physicochemical characteristics of the compounds obtained, the stereospecificity of some reactions, and other theoretical and synthetic problems in the chemistry of carbohydrates.

The development of simple and effective methods for the synthesis of sugars and their derivatives, many of which are the components of various antibiotics, is stimulating the creation of new physiologically active compounds, including nucleosidelike compounds. Data on the development of methods for the synthesis of racemic sugars and their derivatives from dihydropyrans chiefly for the last 10 years are summarized in the present communication. The principal substrates for most of the syntheses are 2-alkoxydihydropyrans with multiple bonds in various positions in the ring.

It should be emphasized that two systems of nomenclature are used in the review: the nomenclature of the pyran series for the simplest compounds, and the nomenclature of natural sugars for derivatives with several chiral centers.

Synthesis of Alkoxydihydropyrans

2-Alkoxy-5,6-dihydro-2H-pyrans and Their Derivatives. Some of the most convenient substrates in the total synthesis of racemic sugars and 4-deoxy sugars are 2-alkoxy-5,6-dihydro-2H-pyrans and their homologs. Several methods for the synthesis of compounds of this series are presently known.

Thus a mixture of spatial isomers II and III was obtained by cyclization of the acetal (I) of an unsaturated δ-hydroxy aldehyde [1, 2]:

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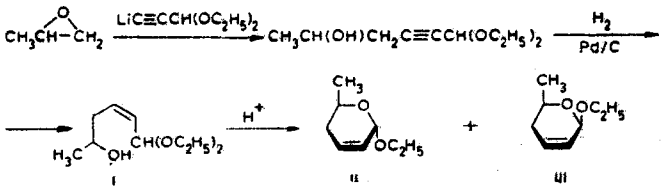
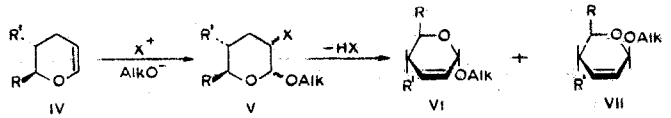
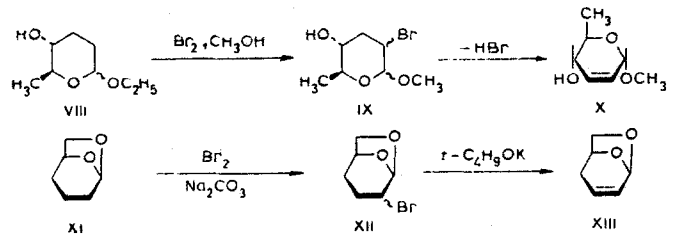


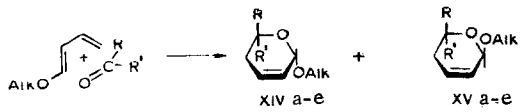
Another method for the preparation of alkoxydihydropyrans VI is conversion of 3,4-dihydropyrans IV to the corresponding 2-alkoxy-3-halotetrahydropyrans V and their subsequent dehydrohalogenation [2-13].



It should be emphasized that the conversion of dihydropyrans IV to haloalkoxy derivatives V has been accomplished by different methods: either the dihydropyrans were initially converted to the corresponding dibromides by bromination and subsequent replacement of the bromine atom in the 2 position by an alkoxy group by the action of an alcohol solution of ammonia [9, 10], or alkoxy bromides V were obtained by treatment of dihydropyrans IV with an alcohol solution of N-bromosuccinimide (NBS) [2, 5-7], N-bromophthalimide [14, 15], 1,3-dibromo-5,5-dimethylhydantoin [8], or electrolytic bromoalkoxylation [15]. Cahu and Descotes [12] have obtained alkoxychloride V (X = Cl) by hypochlorination of dihydropyran IV and subsequent acetalization of the resulting chlorohydrin by means of alcohol. Dehydrohalogenation to give alkoxydihydropyrans VI has usually been accomplished by heating tetrahydro derivatives V with alcohol solutions of potassium hydroxide or sodium ethoxide. It must be noted that high stereoselectivity is observed in the preparation of 6-substituted 2-alkoxy-5,6-dihydro-2H-pyrans (VI); this leads to the predominant formation of isomer VI containing a small amount of isomer VII. This fact, which was first noted in 1969 [2], was subsequently studied in detail in [6, 7]. Alkoxybromides IX and XII were obtained by bromination of tetrahydropyrans VIII and XI. Dehydrobromination of IX and XII leads to the corresponding alkoxydihydropyrans X and XIII [13, 16, 17]:



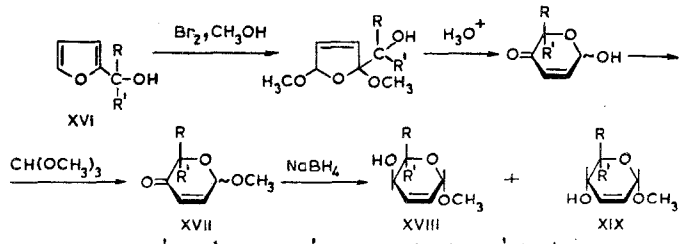
One of the simplest and most effective methods for the preparation of 2-alkoxy-5,6-dihydro-2H-pyrans and their 6-substituted derivatives (XIV and XV) is the retrograde diene condensation of 1-alkoxy-1,3-butadienes with carbonyl compounds, which was first described in 1962 by Kubler [18] in the case of the reaction of formaldehyde with 1-methoxy-1,3-butadiene:



XIV, XV a R=R'=H; b R=CCl_3, R'=H; c R=CO_2Alk, R'=H; d R=R'=CO_2Alk; e R=CH_3, R'=H

Chloral [19] and glyoxylic [19-21] and mesoxalic [20, 22] acid esters were later used as the carbonyl-containing component. It has been recently shown [23] that aldehydes with electron-donor groups also undergo a similar reaction at high pressures. Diene condensation with dialkoxybutadienes has also been described [24]. A study of the stereospecificity of the diene condensation of 1-alkoxy-1,3-butadiene with chloral showed the high stereoselectivity of this reaction [25, 26], which leads to individual trans isomer XIVb, whereas condensation with glyoxylic acid esters leads to mixture of cis and trans isomers XIVc and XVc. Although the relative percentages of the isomers depend to a great degree on the synthetic conditions [21, 26, 27], individual isomers could not be obtained by this method. Jurczak and Zamojski [28] and Achmatowicz and Szechner [29] subsequently studied this reaction with optically active glyoxylic acid esters; this reaction also leads to the corresponding mixtures of cis and trans isomers in low optical yields.

A method for the preparation of 5-hydroxy-2-methoxy-5,6-dihydro-2H-pyrans XVIII and XIX from furfuryl alcohols XVI was recently developed [30-34]:

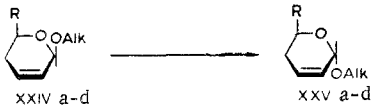


XVI–XIX a R=R'=H ; b R=CH$_3$, R'=H ; c R=CH$_2$OAc ; R'=H etc.

It should be noted that in most cases the reduction of ketone XVII to the corresponding alcohols XVIII and XIX is not stereoselective.

The isomerization of epoxides XX and XXII under the influence of butyllithium is a stereospecific method for the preparation of the corresponding bicyclic dihydropyranols XXI and XXIII [35]:

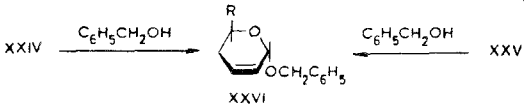
A large number of studies have been devoted to the modification of synthesized 2-alkoxy-5,6-dihydro-2H-pyrans to some other compounds that are substrates in the total synthesis of racemic sugars. Of these methods, one should primarily note the isomerization of the cis isomers of 6-substituted 2-alkoxy-5,6-dihydro-2H-pyrans (XXIV) to trans isomers of the corresponding mixtures of cis and trans isomers to the practically individual trans isomer XXV [2, 6, 21, 26, 36-38]:



XXIV, XXV a R=CH$_3$; b R=CH$_2$OAc ; c R=CONH$_2$; d R=CO$_2$Alk

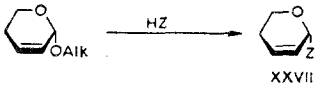
The isomerization is realized by treatment of dihydropyrans XXIV with boron trifluoride etherate [26, 36, 37] or a methanol solution of hydrogen chloride [21] or by heating in a high-boiling solvent [38]. The isomerization leads to the thermodynamically more stable isomer with an equatorial orientation of the substituent in the 6 position and, because of the anomeric effect [39-42], a pseudoaxial orientation of the alkoxy group.

Since 2-alkoxy-5,6-dihydro-2H-pyrans are α,β-unsaturated acetals, they are capable of undergoing facile transacetalization with benzyl alcohol [43, 44]. It is interesting to note that this reaction with 6-substituted dihydropyrans always leads to the production of trans isomer XXVI regardless of the isomer (XXIV or XXV) used as the starting compound:



XXIV–XXVI R=CH$_3$, CONH$_2$

The high alkylating ability of 2-alkoxy-5,6-dihydro-2H-pyrans has been used for the preparation of some N-substituted dihydropyrans (XXVII), which are substrates for the synthesis of nucleosidelike compounds [44]:

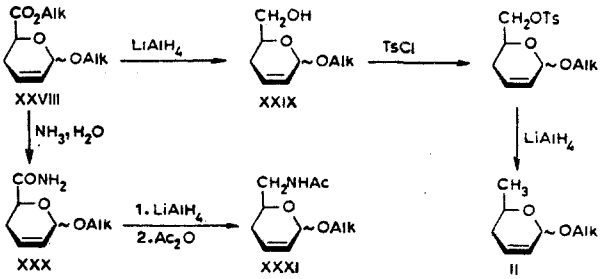


XXVII a Z=NHCO$_2$Alk
b Z=1-imidazolyl
c Z=1-benzimidazolyl
d Z=1,3-dimethyl-7-xanthyl

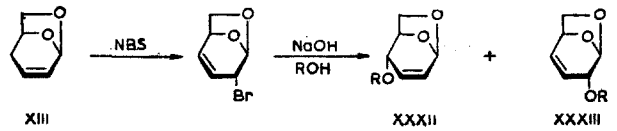
The modification of the alkoxycarbonyl group of dihydropyrans XXVIII to hydroxymethyl (XXIX) [2, 19-22, 27, 45], amido (XXX) [37], acetamidomethyl (XXXI) [36], and methyl (II) [2, 46] groups has been described (see Scheme A at top of next page).

Allylic bromination of bicyclic dihydropyran XIII has been studied as a method for the incorporation of a hydroxyl group in compounds of the alkoxydihydropyran series. Hydrolysis or alcoholysis of the bromination product leads to a mixture of isomeric XXXII and XXXIII [47] (see Scheme B at top of next page).

Scheme A

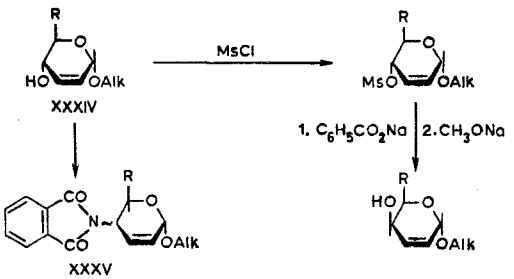


Scheme B



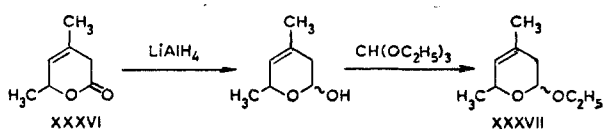
XXXII, XXXIII a R=H ; b R=CH_3

Polish chemists have studied the possibility of isomerization of alkoxydihydropyrans XXXIV [32] and exchange of the hydroxyl group in them by a phthalimido group (XXXV) [48]:

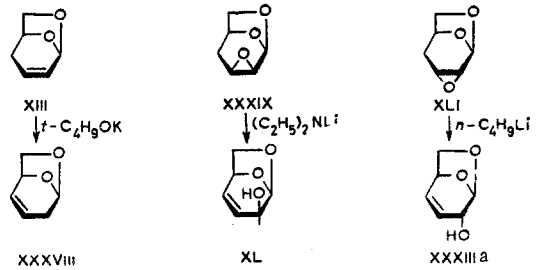


Dialkoxydihydropyrans have also been used for the preparation of aliphatic substrates in the synthesis of racemic sugars [49].

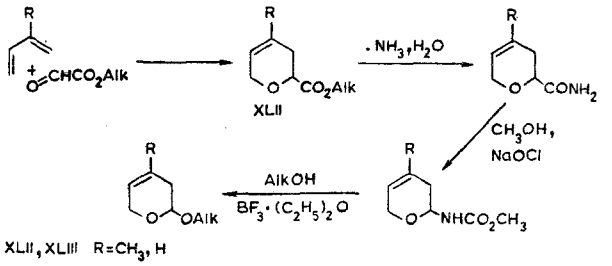
6-Alkoxy-5,6-dihydro-2H-pyrans. Dihydropyrans of this type are substrates in the synthesis of 2-deoxy sugars. One of the first research efforts in this area was the synthesis of dihydropyran XXXVII from lactone XXXVI [50]:



The low degree of accessibility of the starting lactones and the possibility of migration of the multiple bond during the synthesis make this a method of little promise. Of interest is a method for the formation of bicyclic alkoxydihydropyrans XXXVIII, XL, and XXXIIIa, which were obtained either by migration of the multiple bond [17] or by isomerization of the corresponding epoxides (XXXIX and XLI) under the influence of alkaline agents [35, 51-53]. However, it should be noted that analogous reactions with monocyclic derivatives could not be accomplished.

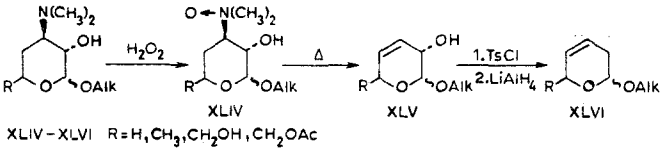


Soviet chemists have developed two methods for the preparation of monocyclic alkoxydihydropyrans of this sort. The synthesis of dihydropyrans XLIII, which do not contain a hydroxyl group, is based on the use of the readily accessible [54] adducts of heterodiene condensation (XLII) [55-57]:



XLII, XLIII R=CH_3, H

The second method [58] makes it possible to obtain the corresponding dihydropyrans XLV, which contain a hydroxyl group. The key step in this method is cleavage of N-oxides XLIV by the Cope reaction. This method was subsequently used by Polish chemists for the preparation of diverse substituted dihydropyrans [59-61]:



XLIV-XLVI R=H, CH_3, CH_2OH, CH_2OAc

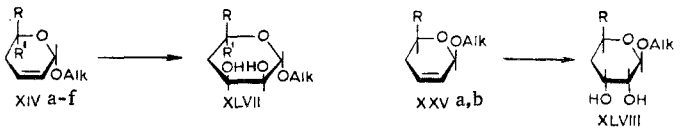
Replacement of the hydroxyl group of dihydropyran XLV by a hydrogen atom (XLVI) has been described [60].

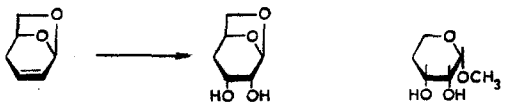
The structures of alkoxydihydropyran compounds have been studied intensively by PMR spectroscopy [62-65]. A number of studies [66-71] have been devoted to the mass spectrometry of this class of compounds.

Stereochemical Specificity of cis-Hydroxylation and Epoxidation of Alkoxydihydropyrans

cis-Hydroxylation. The oxidation of the multiple bond of alkoxydihydropyrans to give a cis-glycol grouping is one of the principal steps in the total synthesis of racemic sugars and deoxy sugars. Aqueous potassium permanganate solution (Wagner's reagent), a solution of hydrogen peroxide in tert-butyl alcohol in the presence of osmium tetroxide (the Milas reagent), osmic acid in pyridine, and iodine in the presence of silver acetate or benzoate (Woodward's reagent) are usually employed as hydroxylating agents.

cis-Hydroxylation of alkoxydihydropyran compounds makes it possible to accomplish the one-step construction of two chiral centers with a fully known spatial orientation of the two hydroxyl groups. Although up until now there have been no correlating data on the effect of the structure of the substrate undergoing oxidation on the rate [72] and stereospecificity of cis-hydroxylation, some aspects of this reaction have been investigated in the case of hydroxylation of alkoxydihydropyrans. High sensitivity of this reaction to the steric hindrance created by substituents, particularly those adjacent to the multiple bond, has been observed during a study of the stereospecificity of cis-hydroxylation. This fact makes it possible in a number of cases to realize stereospecific synthesis of racemic sugars and deoxy sugars. Thepseudoaxialalkoxy group displays a high orienting effect. Thus it has been shown that the hydroxylation of 6-substituted 2-alkoxy-5,6-dihydro-2H-pyrans XIV, XXV, and XIII both with a potassium permanganate solution [14, 37, 73] and with the Milas reagent [46, 74] or osmium tetroxide in pyridine [17, 52, 75, 76] leads to the production of individual glycols XLVII-XLIX, in which the glycol grouping is trans-oriented with respect to the orienting alkoxy group. In addition to hydroxylation product XLVIIa, isomer L with a cisoid orientation of the substituents was obtained only in the case of hydroxylation of 2-methoxy-5,6-dihydro-2H-pyran (XIVa, Alk = CH_3) with potassium permanganate; this can probably be explained by the small effective volume of the orienting methoxy group [73]. The hydroxylation of dihydropyran XIVa (Alk = CH_3) with osmium tetroxide in pyridine [76] takes place exclusively in the trans position relative to the methoxy group:

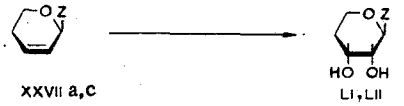




XIII XLIX L

XIV a R=R'=H; b R=CH$_3$, R'=H; c R=CH$_2$OH, R'=H; d R=CO$_2$CH$_3$, R'=H; e R=CONH$_2$, R'=H; f R=R'=CO$_2$CH$_3$;
XXV a R=CO$_2$CH$_3$; b R=CONH$_2$

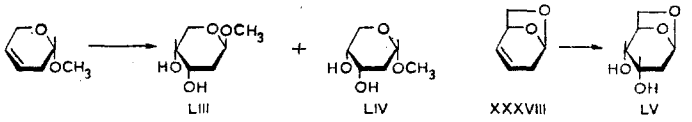
Dihydropyrans XXVIIa and XXVIIc, which contain nitrogen-containing substituents instead of an alkoxy group, are also hydroxylated stereoselectively to give glycols LI and LII [73] with a transoid orientation of the glycol grouping and the nitrogen-containing substituent:



XXVII a,c LI, LII

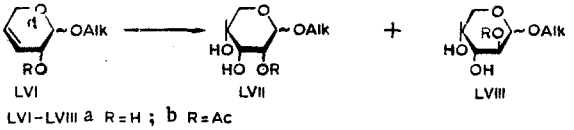
XXVII a, LI Z = NHCO$_2$CH$_3$; XXVII c, LII Z = 1-benzimidazolyl

Removal of the alkoxy group from the multiple bond undergoing hydroxylation leads to weakening of the orienting effect of the substituent, as a result of which a mixture of hydroxylation products LIII and LIV is obtained in the case of hydroxylation with both potassium permanganate [56] and the Milas reagent [62]. Bicyclic dihydropyran XXXVIII is hydroxylated stereoselectively by osmium tetroxide to give glycol LV [75]:



LIII LIV XXXVIII LV

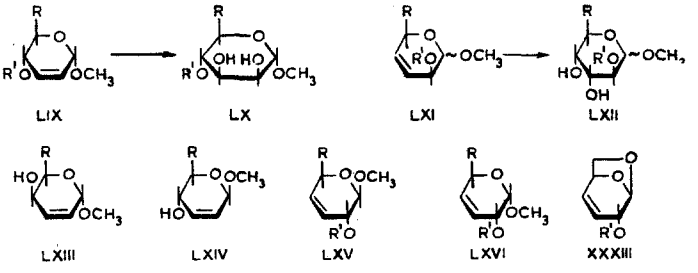
The orienting effect of a substituent depends on its effective volume, which is quite apparent from a comparison of data on the hydroxylation of dihydropyrans with a hydroxyl group in the α position relative to the multiple bond (LVIa); hydroxylation proceeds nonstereoselectively in this case to give a mixture of LVIIa and LVIIIa. Hydroxylation of dihydropyrans LVIb, which contain an acetoxy group, gives only isomer LVIIIb [76].



LVI LVII LVIII

LVI–LVIII a R=H; b R=Ac

High stereospecificity of cis-hydroxylation is observed for LIX and LXI with a cisoid orientation of the two orienting substituents in the vicinal positions relative to the multiple bond. The only products in these cases are LX and LXII, in which the glycol grouping formed in the reaction is trans-oriented with respect to the orienting substituent [77–81]:



LIX LX LXI LXII

LXIII LXIV LXV LXVI XXXIII

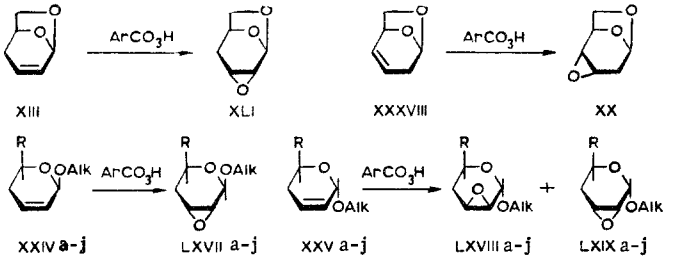
R=H, CH$_3$, CH$_2$OH, CH$_2$OAc; R=H, CH$_3$, Ac

Alkoxydihydropyrans LXIII–LXVI and XXXIII, in which the vicinal (relative to the multiple bond) orienting substituents have a transoid orientation, are hydroxylated nonstereospecifically to give a mixture of isomers [52, 79–81]. Most of the data on the effect of vicinal substituents on the stereospecificity of cis-hydroxylation have been obtained by utilization of the Milas reagent as the hydroxylating agent, although a similar tendency has been noted in the case of osmium tetroxide in pyridine, potassium permanganate solution, and, in individual cases, Woodward's reagent [80]. The hydroxylation of alkoxydihydrofurans [82] and alkylthiodihydrothiapyrans [83] has also been studied.

Epoxidation Reactions. The most effective and stereoselective method for the creation of a trans-glycol grouping of racemic sugars is hydrolysis of the oxirane ring of epoxytetrahydropyrans. Epoxides of the pyran series are therefore some of the key products in the synthesis of racemic sugars and deoxy sugars.

Various methods for the preparation of epoxytetrahydropyrans have been studied in detail in recent years: epoxidation of dihydropyrans with peracids (the Prilezhaev reaction) [2, 4, 8-10, 16, 22, 25, 27, 36, 37, 43, 46, 51, 53, 55, 58, 74, 78, 84-93] or with hydrogen peroxide in the presence of nitriles (the Pine reaction) [59, 86, 89] and their hypochlorination and subsequent dehydrochlorination of the resulting chlorohydrins [1, 84-86]. The first method has become the most widely used procedure because of the exceptionally high sensitivity of the Prilezhaev reaction to steric factors; in a number of cases this makes it possible to carry out the epoxidation stereoselectively. The other two methods are also finding application in the synthesis of epoxytetrahydropyrans, since, because of their low stereospecificity, one can obtain mixtures of epoxides that cannot be obtained via the Prilezhaev reaction. Although there have been no special studies involving a comparison of the effect of epoxidizing agents on dihydropyran compounds, one may note the somewhat higher stereoselectivity of epoxidation with perbenzoic acid as compared with substituted aromatic peracids, but this difference is extremely small.

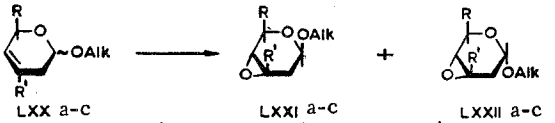
The epoxidation of alkoxydihydropyrans with aromatic peracids is extremely sensitive to substituents in the α position relative to the multiple bond, and this makes it possible to use this reaction for the stereospecific preparation of a number of epoxides. Thus bicyclic dihydropyrans XIII and XXXVIII are epoxidized stereoselectively by m-chloroperbenzoic acid to give individual epoxides XLI and XX, in which the epoxide ring has a transoid orientation with respect to the 1,6-anhydro ring [75]:



XXIV, XXV, LXVII–LXIX a: R=H; b R=CH_3; c R=CH_2OH; d R=CH_2OAc; e R=CO_2Alk; f R=CCl_3; g R=$CONH_2$; h R=CH_2NHAc; i R=CH_2OCH_3; j R=CH_2OTr

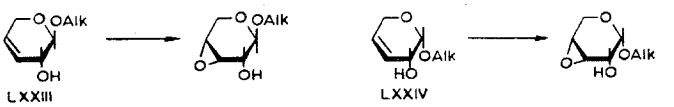
A large number of papers [2, 4, 8-10, 16, 22, 25, 27, 36, 37, 43, 46, 74, 75, 84-86, 88, 89] have been devoted to the study of the stereospecificity of the epoxidation of dihydropyrans XXIV and XXV. In all cases epoxidation of alkoxydihydropyrans XXIV with a cisoid orientation of the substituents attached to 2-C and 6-C proceeds stereoselectively to give only one reaction product (LXVII) [10, 16, 86, 89]. Alkoxydihydropyrans XXV with a transoid orientation of such substituents, as well as 6-unsubstituted alkoxydihydropyran XXVa, are epoxidized mainly in the trans position relative to the anomeric alkoxy group (LXVIII); however, the percentage of a second isomer (LXIX), which usually does not exceed several percent, may increase in the case of XXVb,d,e.

In a number of cases [50,55] even an alkoxy group that is far away from the multiple bond displays a high orienting effect, leading to the formation of individual epoxides (LXXIb,c), although 6-methoxy-5,6-dihydro-2H-pyran (LXXa) [87] is epoxidized to give a mixture of epoxides LXXIa and LXXIIa in a ratio of 3:1.



LXX–LXXII a R=R'=H; b R=H R'=CH_3; c R=R'=CH_3

It must be noted that, in contrast to the trans-orienting effect on cis-hydroxylation, in the case of epoxidation with peracids the hydroxyl group in the α position relative to the multiple bond has a cis-orienting effect. Because of this effect, alkoxydihydropyrans XVIIIa, XIXa, XXXIIIa, LXXIII, and LXXIV are epoxidized highly stereospecificically to give practically individual epoxides with a cisoid orientation of the epoxide ring with respect to the hydroxyl group [51, 53, 58, 78, 87, 92, 93]:



The inconsistent orienting effect of the substituents in the α positions relative to the multiple bond leads, in the case of epoxidation, to the formation of mixtures of isomeric epoxides [78, 87, 90, 91].

The stereoselectivity of the epoxidation of dihydropyrans with peracids and the high yields in conjunction with the possibility of efficient preparative separation of the isomeric epoxides by chromatography on silica gel make epoxytetrahydropyrans important intermediates in the total synthesis of sugars, deoxy sugars, and their derivatives.

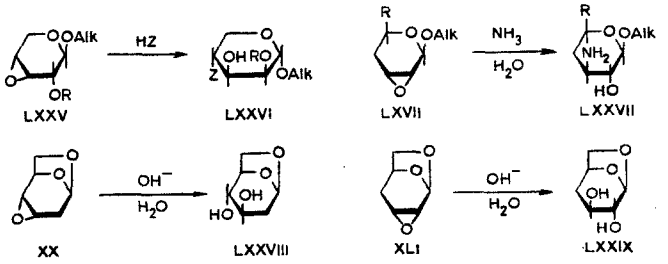
Structural Specificity and Stereospecificity of Opening of the Epoxide Ring of Epoxytetrahydropyrans

The principles of the effect of structural and electronic factors on the direction and stereochemistry of opening of the epoxide ring have been studied extensively in recent years [94]. Some of the aspects of this problem are currently under investigation in the case of epoxytetrahydropyran compounds [95, 96]. In connection with the ease of conversion from alkoxyepoxytetrahydropyrans to derivatives of racemic sugars, deoxy sugars, and amino deoxy sugars, extensive study has been devoted to the reactivities and regiospecificity and stereospecificity of the reactions of these compounds with water, ammonia, amines, alcohols, and some other nucleophilic agents.

Transoid opening of the epoxide ring of epoxytetrahydropyrans by nucleophilic agents has been noted in all cases. The carbon atom of the epoxide ring (at which attack of a nucelophilic agent is directed) is determined, on the one hand, by the polarization of the epoxide ring and the steric accessibility of axial attack by the nucleophilic particle on one of these atoms and, on the other, by the character of the attacking agent, since the transition states differ in the case of opening of the epoxide ring under conditions of acid or alkaline catalysis. Higher regioselectivity of opening of the ring epoxytetrahydropyrans under acidic conditions is noted in some studies. However, the chief factor that determines the direction of opening of the epoxide ring is the structure of the starting alkoxyepoxytetrahydropyran. Thus the acid hydrolysis and aminolysis of epoxytetrahydropyrans LXXI and LXXII always proceed stereoselectively and regioselectively with attack of the nucleophilic agent on the least substituted carbon atom of the epoxide ring [50, 55]:

LXXI-LXXII R = H, CH_3; Z = OH, $N(CH_3)_2$; LXVIII R = H, CH_3, CH_2OAc, $CONH_2$, CH_2NHAc, CCl_3, CO_2Alk ; Z = OH, NH_2, NHAlk, $N(Alk)_2$, OAlk, SH, CN, 1-benzimidazolyl

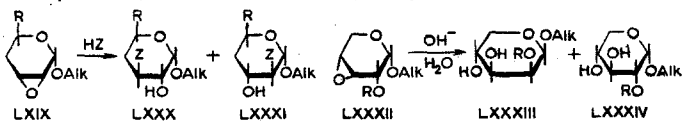
High regiospecificity of observed in the case of hydrolysis [12, 74] and alcoholysis [46, 88] under alkaline and acidic conditions, in the case of aminolysis [1, 2, 4, 12, 27, 36, 37, 43, 46, 59, 84, 85, 97, 98], and in the reaction with some other nucleophilic agents [12, 86, 98] of epoxides LXVIII. In all cases the epoxide ring carbon atom that is farthest away from the alkoxy group undergoes nucleophilic attack. The aminolysis and acid hydrolysis of epoxides LXXV to give glycosides with an α-lyso configuration (LXXVI) proceed regiospecifically and stereospecifically [58, 76, 93]:



LXXV, LXXVI R = H, Ac ; LXVII, LXXVII R = H, CH_3, CH_2OAc

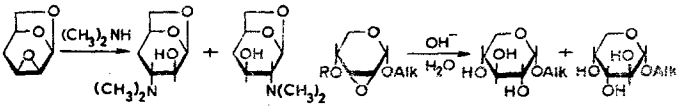
Epoxides LXVII, XX, and XLI regiospecifically and stereospecifically undergo aminolysis [97] to give amino derivatives LXXVII and hydrolysis to give deoxy sugars LXXVIII and LXXIX [16, 35, 75].

When the alkoxy group is cis-oriented relative to the epoxide ring (LXIX), regioselectivity of opening of the epoxide ring is observed when hydrolysis and alcoholysis are carried out only under acidic conditions [46, 74, 88] and, in individual cases (R = H), in the case of aminolysis reactions [14, 59, 85, 97]:



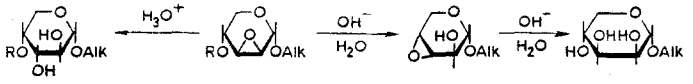
LXIX LXXX LXXXI LXXXII LXXXIII LXXXIV

Hydrolysis and alcoholysis [9, 46, 74, 76] under alkaline conditions and aminolysis [46] of epoxides LXIX and LXXXII lead to the formation of mixtures of isomeric LXXX and LXXXI, as well as LXXXIII and LXXXIV, in which 5-30% of isomers LXXXI and LXXXIV are present. The aminolysis of epoxide XXXIX [35] and alkaline hydrolysis of epoxide LXXXV [78] also proceed ambiguously.



XXXIX LXXXV

It must be noted that isomerization of the epoxide ring, which leads to anomalous hydrolysis products (LX), may occur under alkaline conditions of ring opening of epoxides when there is a transoid-oriented hydroxyl or acyloxy group in the vicinal position relative to the epoxide ring [78, 91]. Glycosides with an α-arabino configuration (LXXXVI) have been obtained under acidic conditions:

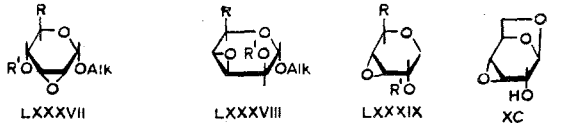


LXXXVI LX

LXXXVI R = H, CH_3, Ac

Hydrolysis or alcoholysis of epoxides in acidic media may also be accompanied by side processes involving destruction of the glycoside bond or its anomerization [99].

The structural specificity of opening of the epoxide ring in epoxides LXXXVII [78, 92], LXXXVIII, LXXXIX [100, 101], and XC [53] with amines, water, and alcohols has been studied.



LXXXVII LXXXVIII LXXXIX XC

LXXXVII-LXXXIX R = H, CH_3, CH_2OAc; R = H, Ac

The structure and composition of glycosides of amino deoxy sugars and some of their derivatives have been studied by various physicochemical methods [102-104].

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