CHEMICAL PROPERTIES OF 3,6- AND 5,6-DIHYDRO-2H-PYRANS (REVIEW)

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The reactions of 3,6- and 5,6-dihydro-2H-pyrans that are due to the presence of double and ether bonds are correlated.

Owing to the advances in organic and petrochemical synthesis in the last 10 years, cyclic ethers such as 3,6- and 5,6-dihydro-2H-pyrans (DHP) have also become accessible [1-5]. This has stimulated intensive research on the chemistry of di- and tetrahydropyrans and has led to the development of new syntheses of natural compounds (citric acid, cis-3-hexen-1-ol, rose-oxide, etc.) and their analogs, which have valuable properties. Dihydropyrans can serve as convenient intermediates for organic synthesis. However, with the exception of a previous review [6], there have been no publications that correlate the properties of these compounds.

The present review encompasses virtually all of the known reactions of DHP (data on 2-alkoxy, hydroxy, and carboxy derivatives and pyrones are not included), which can be conveniently classified in the following way: addition to the double bond and isomerization, oxidative transformations, and reactions that are accompanied by ring opening.

ADDITION AND ISOMERIZATION REACTIONS

The hydrogenation of DHP is accomplished in both the liquid and gas phase with the use of ordinary (Pt, Pd, Ni) catalysts.

Alkyl-substituted DHP I are hydrogenated quite smoothly to II (76-95%) on Raney nickel in ether [7, 8], in ethanol [9, 10], or without a solvent [1].

Polyunsaturated diether III is hydrogenated virtually completely (95%) when Ni modified with 5% Mo is used [11].

Similar results were obtained in the hydrogenation of 2,2-dimethyl-4-vinylethynyl-3,6-dihydropyran on Pt30 [12]. 4-Methyltetrahydropyran (IV) is formed in quantitative yield from an industrial pyran fraction at 120-180°C and atmospheric pressure on Ni/Cr2O3 [13] and on Pd/C (0.5% Pd) at 150-250°C [14]. An increase in the Pd content to 5% and an increase in pressure make it possible to carry out the reaction at room temperature (86Z yield) [15].

Steric factors have an appreciable effect in the hydrogenation of spiro derivatives V on the same catalyst — the yield of products VI decreases substantially if R H or R Me [16].
Functional derivatives of DHP behave like other substituted olefins under hydrogenation conditions. A number of examples illustrate the possibility of the selective addition of H₂ to the double bond of DHP. Palladium on carbon (Pd/C) was used in the synthesis of 2-acetonyl-4-methyltetrahydropyran [17, 18], while Pd/CaCO₃ was used in the synthesis of 2-trifluoromethyl-4-methyltetrahydropyran (98%) [19] and a number of hydroxytetrahydropyrans VIII [20] from the corresponding DHP VII.

\[
\begin{align*}
\text{VII} & \quad \text{VIII} \\
\end{align*}
\]

Similar results were also obtained in the hydrogenation of Pt₂O of 4,5-dimethyl-2-trichloromethyl-3,6-dihydropyran (96%) [21] and butanedione IX (75%) [22].

\[
\begin{align*}
\text{IX} & \quad \text{X} \\
\end{align*}
\]

The DHP ring can be cleaved at the C–O bond when Pt metal is used. For example, amyl alcohol (38%) is formed along with tetrahydropyran (34%) from 5,6-dihydropyran (X) [23], while a mixture of hydrocarbons is formed from 4-methyl-5,6-dihydropyran (XI) [13].

Ionic hydrogenation is an alternative catalytic reaction of olefins with H₂. However, in the case of ether XI the yield of IV did not exceed 30-40%; this is due to a decrease in the relative reactivity of the double bond due to complexing of AlCl₃ with the heteroatom [24].

\[
\begin{align*}
\text{XI} & \quad \text{IV} \\
\end{align*}
\]

The halogenation, particularly the bromination, of DHP has been described [21, 25-27]. Substituted olefins XII react smoothly with Br₂ (90-97%) at 0 to -70°C in ordinary halogen-containing solvents.

\[
\begin{align*}
\text{XII} & \quad \text{XIII} \\
\end{align*}
\]

R¹, R², R³, R⁴=H, Alk, di- and trihaloalkyl, alkenyl

Such conditions are favorable for the formation of trans-dibromides, which should exist in the form of spatial isomers. However, the stereochemical aspects of the reaction are not discussed in the indicated studies.

Chlorine is more active in reactions with DHP; it is therefore not surprising that the trichloride is obtained along with the dichloride from XIV [28].

\[
\begin{align*}
\text{XIV} & \quad \text{XV} \quad \text{XVI} \\
\end{align*}
\]

Examples of the reaction of DHP also with other halogen-containing reagents have been described in the literature. Thus the hydrochlorination of 4-methyl-2-isopropyl- and 4-methyl-2-isobutyl-dihydropyran (XV and XVI) [2, 29] proceeds in accordance with the Markownikoff rule and leads to a mixture (80%) of spatial isomers A and B with preponderance of the former.