ISOLATION OF $\Delta^3$-1,2,3-THIADIAZOLIN-1-ONES, A KEY INTERMEDIATE OF THE HURD-MORI REACTION

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Abstract - The Hurd-Mori reaction of N-ethoxycarbonyl- or p-toluenesulfonylhydrazones of 1,2-alkanediones (1) gave $\Delta^3$-1,2,3-thiadiazolin-1-ones (2) as each sole isolable product. Upon HCl treatment 2b was converted into 1,2,3-thiadiazole, an expected product of the Hurd-Mori reaction.

The Hurd-Mori reaction\(^1\) is the one which converts hydrazones into 1,2,3-thiadiazoles using thionyl chloride and has attracted synthetic\(^2,3\) and mechanistic interest. It is assumed that the reaction proceeds via $\Delta^2$- or $\Delta^3$-1,2,3-thiadiazolin-1-one (I), which then aromatizes to 1,2,3-thiadiazole (II).\(^1,4,5\) However, no evidence has been available that supports the formation of I or the conversion of I into II.\(^6,7\) Herein we report that the Hurd-Mori reaction of an appropriate hydrazone allows us to isolate 1,2,3-thiadiazolin-1-one which can be converted successfully into 1,2,3-thiadiazole.

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\begin{align*}
\text{R} & \quad \text{NH-Y} \\
\text{R'} & \quad \text{SOCl}_2 \quad \text{SOCl}_2 \\
\text{R} & \quad \text{-2HCl} \\
\text{R'} & \quad \text{R'} \\
\text{I} & \quad \text{N} \quad \text{N} \\
\text{R} & \quad \text{S} \\
\text{O} & \quad \text{Y} \\
\text{R} & \quad \text{III} \\
\end{align*}
\]

Whereas bis(N-ethoxycarbonylhydrazone) of propane-1,2-dione (1a) afforded a normal Hurd-Mori product as a sole product,\(^2\) the reaction of bis(N-ethoxycarbonylhydrazone) of butane-1,2-dione (1b) with 3 mol eq. of thionyl chloride under reflux in CH\(_2\)Cl\(_2\) gave 1,2,3-thiadiazolin-1-one (2b) as a major product in 44% yield along with 1,2,3-thiadiazole 3b (6%). The structure of 2b was assigned as $\Delta^3$-isomer based
on its $^1$H and $^{13}$C nmr spectra. The compound (2b) was converted into 3b in 63% yield by treatment with dry HCl in CH$_2$Cl$_2$.

Similar reaction of methoxyiminohydrazones (1c; $R^1$ = Me, $R^2$ = Me, $Y$ = CO$_2$Et, $Z$ = OMe) afforded $\Delta^3$-1,2,3-thiadiazolin-1-one (2c) in 38% yield with no trace of formation of 1,2,3-thiadiazole (3), but 1d ($R^1$ = Me, $R^2$ = Ph, $Y$ = CO$_2$Et, $Z$ = Me) gave normal product (3d) in 26% yield, hereby 1,2,3-thiadiazolin-1-one being not detected.

Hydrazones having various alkyl groups for $R^1$ and $R^2$ gave the corresponding $\Delta^3$-1,2,3-thiadiazolin-1-ones (2): $R^1$ = $R^2$ = Me, $Y$ = Tos, $Z$ = OMe (2e): 69% yield; $R^1$ = $R^2$ = Et, $Y$ = CO$_2$Et, $Z$ = OMe (2f): 48% yield; $R^1$ = $R^2$ = Et, $Y$ = Tos, $Z$ = OMe (2g): 57% yield; $R^1$ = i-Pr, $R^2$ = Me, $Y$ = CO$_2$Et, $Z$ = OMe (2h): 60% yield; $R^1$ = i-Pr, $R^2$ = Me, $Y$ = Tos, $Z$ = OMe (2i): 38% yield. In all cases, 2 was not accompanied by 3. Thus, $\Delta^3$-1,2,3-thiadiazolin-1-one (2) was a single isolable product particularly when $Y$ was CO$_2$Et or Tos. The structure of 2h was confirmed by X-ray crystallographic analysis as shown in Figure 1.
The most plausible mechanism of the Hurd-Mori reaction is as follows: The reaction of hydrazone (1) with thionyl chloride gives 4 which undergoes cyclization to afford 1,2,3-thiadiazolin-1-one (2). Protonation of 2 gives rise to sulfonium salt (5) that converts into 6 by intramolecular addition. Final compound 1,2,3-thiadiazole (3) may be produced from 6 by the elimination of EtOH, CO₂, and HCl.

The reaction of 1a and 1b suggests that an alkyl group at 5-position (R¹), in contrast to the case in which R¹ is hydrogen, stabilizes the sulfonium cation (5) or (6) which could revert to 2 after work-up, and makes it difficult to convert 5 or 6 into 3. However, in cases of R¹ = alkyl, 3d was not accompanied by 2, showing that a phenyl group for R² facilitates the production of aromatic compound (3). Substituents R¹ and R² play an important role in the isolation of 1,2,3-thiadiazolin-1-one (2).
The study reported herein clearly demonstrates that an intermediate of the Hurd-Mori reaction is 1,2,3-thiadiazolin-1-one. These findings should be useful for the synthesis of a variety of Δ3-1,2,3-thiadiazolin-1-one.  

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REFERENCES AND NOTES

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6. Ref. 1 reported that intermediates isolated in the Hurd-Mori reaction were $\Delta^2$-1,2,3-thiadiazolin-1-ones on the basis of elemental analysis. Ref. 7 also reported the isolation of a $\Delta^2$-1,2,3-thiadiazolin-1-one derivative whose structure was determined by elemental analysis and $^1$H nmr only, but one product in ref. 1 was later corrected to be a TosOH salt of 1,2,3-thiadiazole in ref. 5.


8. $^1$H Nmr (CDCl$_3$) $\delta$ 1.33 (t, $J = 7.1$ Hz, 3H), 1.43 (t, $J = 7.1$ Hz, 3H), 1.47 (d, $J = 7.8$ Hz, 3H), 4.29 (q, $J = 7.1$ Hz, 2H), 4.47 (q, $J = 7.1$ Hz, 2H), 4.58 (q, $J = 7.8$ Hz, 1H), 8.04 (s, 1H), 8.80 (br s, 1H); $^{13}$C nmr (DMSO d$_6$) $\delta$ 11.0 (q), 14.3 (q), 14.5 (q), 61.2 (t), 63.9 (t), 69.3 (d), 135.6 (d), 151.5 (s), 152.9 (s), 155.8 (s); ms m/z 304 (M$^+$); ir(KBr) 1040 cm$^{-1}$ (S=O); Anal. Calcd for C$_{10}$H$_{16}$N$_4$O$_5$S: C, 39.47; H, 5.30; N, 18.41; S, 10.54. Found: C, 39.80; H, 5.33; N, 18.24; S, 10.44.

9. Ethoxycarbonylhydrazones and tosylhydrazones have been used as the starting material of the Hurd-Mori reaction.


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