March 1995 Communications to the Editor *Chem. Pharm. Bull.* **43**(3) 523—525 (1995)

CATALYTIC ACTIVITIES OF DICYANOKETENE ACETALS IN ALCOHOLYSIS OF EPOXIDES

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The catalytic activity of various types of capto-dative ethylenes has been investigated on alcoholysis of epoxides, and dicyanoketene dimethyl acetal (DCKDMA) and dicyanoketene ethylene acetal (DCKEA) are found to be efficient and mild catalysts.

KEY WORDS dicyanoketene acetal; π-acid; epoxide; alcoholysis; catalyst

Reactions of epoxides offer useful synthetic methods in the aliphatic field due to high regio- and stereoselectivity and specificity.¹⁾ Among the reactions of epoxides, nucleophilic substitution with carbon- and heteroatomic nucleophiles is widely used in synthetic reactions, which generally proceed under basic or acidic conditions. Mild, neutral, and catalytic reaction conditions have been sought for the ring opening of epoxides, particularly with heteroatomic nucleophiles such as alcohols, thiols, and amines in view of highly selective organic synthesis.2)

Iranpoor and co-workers have disclosed that widely used neutral oxidants, 2,3-dichloro-5,6-dicyano-*p*-benzoquinone (DDQ) and ceric ammonium nitrate (CAN), catalyze ring-opening reaction of epoxides with alcohols, thiols, and acetic acid.3) DDQ was also reported to catalyze tetrahydropyranylation of alcohols,4) C-glycosidation of glycals,5) and deprotection of acetals6) and orthoesters.7) In this context, we have reported that a catalytic amount of tetracyanoethylene (TCNE), a representative π-acid and one-electron acceptor,8) accelerates substrate-specific rearrangement, acetonidation9) and alcoholysis of epoxides,10) and Mukaiyama Aldol reaction of acetals.11) In the course of the investigation on methanolysis of epoxides catalyzed by TCNE, we found that dicyanoketene dimethyl acetal (DCKDMA; **2a**) was formed in the reaction system and that DCKDMA (**2a**) is an active catalyst as well as TCNE. We disclose herein the examination of π-acid catalytic activity of various types of capto-dative ethylenes and the effectiveness of dicyanoketene acetals12) as catalysts for alcoholysis of epoxides under mild reaction conditions.

We examined the catalytic activity of various types of capto-dative ethylenes in alcoholysis of styrene oxide as a model reaction, and the results are summarized in TABLE I. The relative activity of dicyanoketene acetals as a π-acid catalyst was the following order: **2a** ≈ **2b** > **2c** > **2d**. **2e** is a poor catalyst for alcoholysis of epoxides, and no reaction proceeds at all. Although the activity of **2f** appeared nearly equal to that of DCKEA (**2c**), the net activity of **2f** is ambiguous because **2f** was found to be converted partially to reactive DCKDMA (**2a**) under the reaction conditions. Therefore, we selected DCKDMA (**2a**), which is the most reactive catalyst examined, and dicyanoketene ethylene acetal (DCKEA; **2c**),13) which is easily available and highly reactive, and have investigated their catalytic activity in the alcoholysis of epoxides.

Treatment of a cyclohexene oxide (**4**) in MeOH with catalytic amount (0.2 equiv.) of DCKDMA (**2a**) at room temperature for 0.5 hr gave a secondary alcohol (**5a**) in good yield (87%). In several alcohols including allyl alcohol and *i*-PrOH, ring-opening reaction of the cyclohexene oxide (**4**) proceeded smoothly at room temperature or 50 °C. Typical epoxides have been examined in view of regio- and chemoselectivity of the reaction, and the results are summarized in TABLE II.

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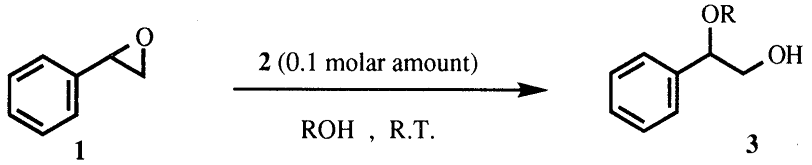
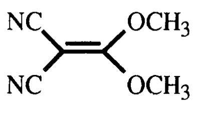
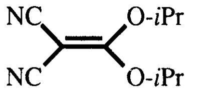
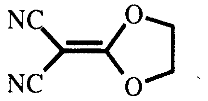
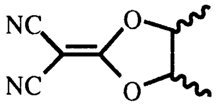
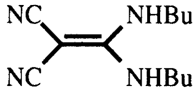
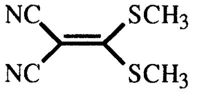
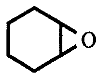
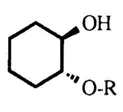
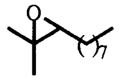
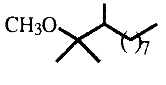
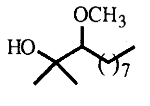
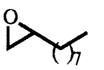
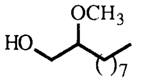
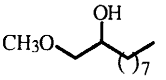
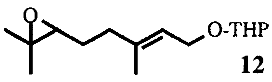
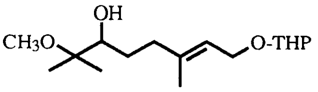
TABLE I. The Catalytic Activity of Capto-dative Ethylenes for Alkolysis of Styrene Oxide



Entry	Catalyst	ROH	Time	Yield
1	 **2a**	CH_3OH	1 h	94 %
2		*i*-PrOH	20 h	78 %[a,b]
3		*t*-BuOH	45 h	36 %[b,c]
4	 **2b**	CH_3OH	1 h	94 %
5	 **2c**	CH_3OH	1 h	trace
6		CH_3OH	18 h	91 %
7	 **2d**	CH_3OH	24 h	trace
8	 **2e**	CH_3OH	24 h	0 %
9	 **2f**	CH_3OH	1 h	trace
10		CH_3OH	18 h	97 %

a) Compound **14** was obtained as a by-product in 14% yield based on the catalyst (**2a**) used. b) 0.3 molar amount of catalyst (**2a**) was used. c) Compound **14** was obtained as a by-product in 50% yield based on the catalyst (**2a**) used.

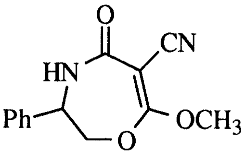
TABLE II. Alcoholysis of Epoxides Catalyzed by Dicyanoketene Acetals

Epoxide	Catalyst	Molar Amount	Alcohol (Solvent)	Temp.	Time	Product / Yield
 **4**	**2a**	0.2	CH_3OH	R.T.	0.5 h	 **5a** R = CH_3 87%
	2a	0.2	Allyl-OH	R.T.	21 h	**5b** R = $CH_2CH{=}CH_2$ 96%[a]
	2a	0.2	*i*-PrOH	50 °C	23 h	**5c** R = *i*-Pr 59%[b]
	2c	0.2	CH_3OH	R.T.	3 h	**5a** R = CH_3 92%
	2c	0.2	Allyl-OH	40 °C	24 h	**5b** R = $CH_2CH{=}CH_2$ 73%
 **6**	**2a**	0.2	CH_3OH	R.T.	1 h	 **7** 95%  **8** 3%
	2c	0.1	CH_3OH	R.T.	19 h	95% 3%
 **9**	**2c**	0.2	CH_3OH	R.T.	25 h	 **10** 39%  **11** 54%
 **12**	**2c**	0.1	CH_3OH	R.T.	4 h	 **13** 87%

a) Compound **15** was obtained as a by-product in 11% yield based on the catalyst (**2a**) used. b) Compound **15** was obtained as a by-product in 72% yield based on the catalyst (**2a**) used.

Reaction of trisubstituted epoxides involved highly regioselective introduction of alkoxy groups at the more substituted side providing secondary alcohols. Terminal epoxides underwent alcoholysis with low or without regioselectivity except for styrene oxide, which gave results analogous to those observed generally in acid-catalyzed epoxide opening reactions,1) and afforded exclusively primary alcohols. The conditions of DCKEA-catalyzed alcoholysis of epoxides left the acid-labile functions (tetrahydropyranyl ethers (**12**)) intact.

As described in the preceding communication,12) it is worth noting that the reduction-potential of DCKEA measured was very low (E_p^{red} <-2.0V vs. SCE in MeCN) compared with those of TCNE (E_p^{red} 0.15V vs. SCE in MeCN)6) and DDQ (E_p^{red} 0.59V vs. SCE in MeCN),6) and that no charge-transfer (CT) absorption band could be detected in the UV spectroscopic measurement of the mixture of DCKEA and cyclohexene oxide (**4**) in CH_3CN, although the same mixture of TCNE exhibited a CT absorption band. The adducts (**14, 15**) of DCKDMA and epoxides (**1, 4**) were detected as by-products in the reaction mixture. These adducts (**14, 15**) may be formed via nucleophilic attack of the oxygen of epoxides to the double bond of DCKDMA associated with epoxide ring fission accompanied by cyclization. Although mechanisms for the present reaction are still ambiguous on the basis of the above observations so far, coordination between the π-system of dicyanoketene acetals and the oxygen of epoxides is presumed to be one of the factors responsible for the activation of the C-O bond of epoxides.



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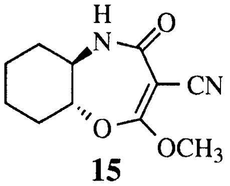

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(Received November 14, 1994; accepted January 24, 1995)