

# REACTION OF TRANSITION METAL CARBONYLS WITH HETEROCYCLIC SYSTEMS—III

## S<sub>N</sub>2'-TYPE REACTION OF COMPLEXED $\pi$ -ALLYL SYSTEMS

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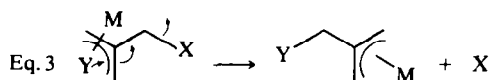
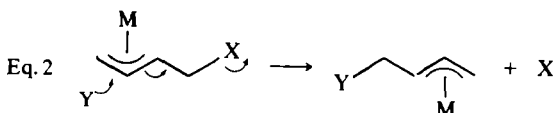
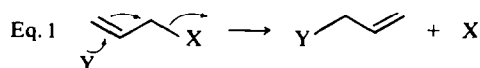
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**Abstract**—A proposition regarding the capability of a complexed  $\pi$ -allyl system to undergo a displacement reaction was advanced (eqn 2) and examined experimentally. A unique structural feature of this system is the four rather than three C atoms which intervene between the displaced and entering groups. The experiment was carried out using lactone 1c which is internally complexed and was properly labelled with deuterium. The product of its reaction with aniline has been found to be rearranged with respect to the D label, thus substantiating an S<sub>N</sub>2'-type mechanism in a complexed  $\pi$ -allyl system (eqn 2). From an intramolecular comparison study of the reactivity of an allyl and complexed  $\pi$ -allyl system in S<sub>N</sub>2'-type displacement reactions using compound 10, it was concluded that the latter is more reactive than the former. Furthermore, the  $\pi$ -allyl lactone 12, in which the displaced and entering groups are separated by three C atoms, was also found to undergo a displacement reaction.

### INTRODUCTION

Structurally, an S<sub>N</sub>2' reaction can be defined as a displacement reaction, the leaving and entering groups, which are separated by three C atoms, are at the two ends of an allyl system, and migration of the double bond occurs in the product, as formulated by eqn (1).<sup>†</sup> A  $\pi$ -allyl system is spread over three C atoms and must be stabilized by a metal atom. The disposition of a leaving group X with respect to the  $\pi$ -allyl system (eqn 2) is similar to that of an allyl system (eqn 1). However, unlike the common S<sub>N</sub>2' reactions (eqn 1), the entering nucleophile and the leaving groups in eqn (2) are separated by



four rather than three C atoms. The question which arises is whether such a system can also undergo an S<sub>N</sub>2'-type displacement with concomitant migration of the  $\pi$ -allyl bond as formulated by eqn (2).

Another interesting reaction system is represented by eqn (3) where the leaving group X is "cross conjugated" with respect to the  $\pi$ -allyl system. The entering nucleophile and the leaving group are now separated by three C atoms, and therefore this system (eqn 3) more closely resembles the structural situation represented by eqn (1).

In the present report we shall describe experiments which have bearing on the above and related problems.

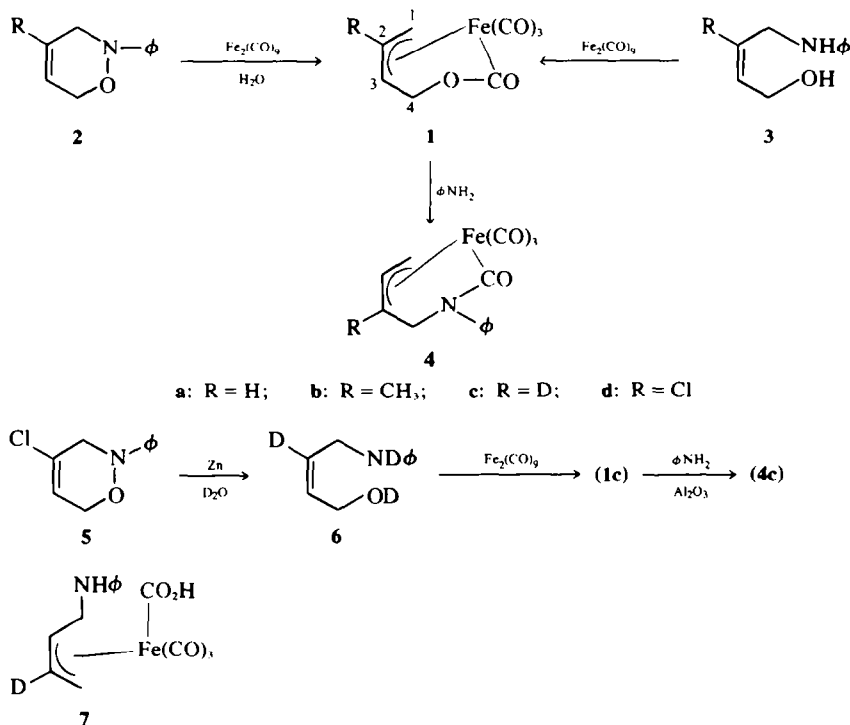
### RESULTS AND DISCUSSION

Recently we have demonstrated<sup>1</sup> that the  $\pi$ -allyl  $\sigma$ -lactone 1a is formed either by direct reaction of 2 and Fe<sub>2</sub>(CO)<sub>9</sub> in the presence of water or by the known reaction<sup>2</sup> of 3 and Fe<sub>2</sub>(CO)<sub>9</sub>. In fact it was found that 3 is an intermediate in the reaction 2  $\rightarrow$  1.<sup>1</sup> Treatment of 1a with aniline induced a very fast amidation reaction yielding 4a under very mild conditions. Closer investigation of this reaction<sup>1</sup> using 1b revealed that the product of amidation is the formally rearranged 4b. It was therefore concluded that this reaction is of the S<sub>N</sub>2'-type inasmuch as the amine attacks at C-1 rather than at the lactone carbonyl.<sup>1</sup> Although this result apparently confirms the hypothesis formulated by eqn (2), it was argued the Me substitution (1b) constitutes a significant modification of the molecular structure which could have perturbed the course of the amidation reaction under investigation. It was therefore desirable to study the amidation reaction using the deuterio derivative (1c). To this end we prepared 4-anilino-3-deuterio-2-buten-1-ol (6)<sup>‡</sup> by reduction of 4-chloro-N-phenyldihydrooxazine (5). The latter is obtained as the sole product of the cycloaddition of nitrosobenzene to chloroprene,<sup>3</sup> and its NMR spectrum exhibits a singlet which was assigned to the CH<sub>2</sub> group adjacent to the N atom. When 6 was treated with Fe<sub>2</sub>(CO)<sub>9</sub> under the usual reaction conditions, lactone 1c was isolated. Unequivocal evidence regarding the position of the D atom was adduced from the NMR spectrum of 1c (Fig. 1). The diastereotopic terminal protons of C-1 must resonate at highest field. These gave rise to two signals (H<sub>a</sub> and H<sub>b</sub>; Fig. 1), which unlike the spectrum of 1a<sup>1</sup> (which clearly displays the *cis* and *trans* couplings between the terminal CH<sub>2</sub> protons and the adjacent C-H) were uncoupled.

We are now in the position to perform the amidation experiment on the properly labelled (1c). Thus, when 1c was treated with aniline in the presence of Al<sub>2</sub>O<sub>3</sub> a lactam was obtained. It was necessary to determine the position of attachment of the D atom. Referring to the NMR spectrum of the lactam (Fig. 2) it is clearly evident that the

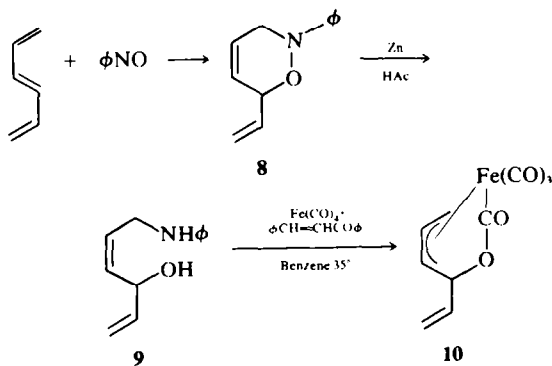
<sup>†</sup>This subject has been recently reviewed by F. G. Bordwell, *Accounts of Chem. Res.* 3, 281 (1970).

<sup>‡</sup>The acidic NH and OH protons were also exchanged with D in the reduction.



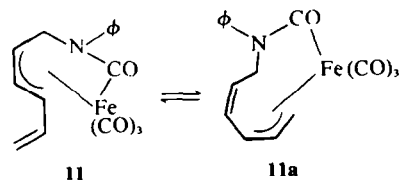
high field signals of the terminal protons regained a coupling pattern assignable to the spin-spin interaction of the above protons with the adjacent C-2 proton, much like as in the spectrum of **4a**.<sup>1</sup> Thus structure **4c** must be assigned to this lactam and the formal "migration" of the D atom must be the consequence of the reaction of aniline at C-1 of **1**, migration of the  $\pi$ -allyl system and displacement of the group attached to C-4. *These results conclusively support an S<sub>N</sub>2'-type mechanism in a  $\pi$ -allyl system as was outlined in eqn (2).* Although the subsequent mechanistic details have not been investigated, it is logical to invoke intermediate (**7**), the immediate product of the displacement, which then lactamizes in the presence of alumina.

In a further study of the above reaction and similar molecular systems we have prepared the  $\sigma$ - $\pi$ -allyl lactone complex (**10**). This system now possesses three potential reaction sites for aniline, namely, the lactone carbonyl, the allyl system of the exocyclic double bond and the complexed  $\pi$ -allyl system. The synthetic route which was employed in its preparation is described below:



The 2-phenyl-6-vinyl-3,6-dihydro oxazine (**8**) is the sole product in the reaction between 1,3,5-hexatriene and nitrosobenzene. Its structure was established by mass spectrum, NMR and IR spectra. A two protons-signal at  $\delta$  3.78 in the NMR spectra of **8** and also in that of the unsubstituted oxazine **2** was assigned to the CH<sub>2</sub>N protons. The vinyl group is therefore attached to C-6 of the oxazine system (**8**). Reduction of **8** resulted in the anilino alcohol (**9**). Both **8** and **9** were found to be too reactive to Fe<sub>2</sub>(CO)<sub>9</sub> inasmuch as only decomposition products were encountered. However, when **9** was reacted with benzalacetophenone-Fe(CO)<sub>5</sub> complex,<sup>4</sup> a lactone was isolated. Comparison of its NMR spectrum with that of the unsubstituted lactone (**1a**) leaves no doubt as to the proposed structure **10**. The signals of the protons of the  $\pi$ -allyl and the vinyl groups are chemically shifted and consequently allowed for the clear identification of these groups.

When **10** was reacted with aniline in the presence of Al<sub>2</sub>O<sub>3</sub>, a single lactam was isolated. Its mass spectrum, elemental analysis, IR and NMR spectra supported structure **11**. The most striking NMR spectral feature of **11** is the disappearance of the high field signals of the *terminal geminal* protons of the  $\pi$ -allyl system which are present in the spectrum of its precursor (**10**). Instead, a



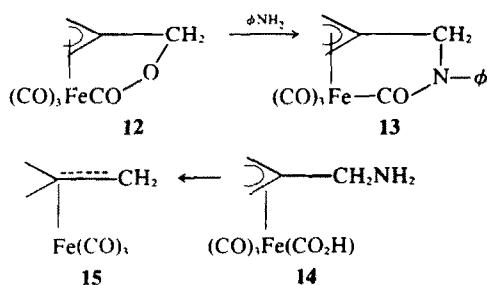
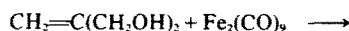
three proton-signal of an essentially ABX pattern was recorded in the region of  $\delta$  5.25–6.25, and was identified with the vinyl system of **11**. The rest of the spectrum was found to be in accord with the proposed structure **11**. It is therefore concluded that aniline attacks exclusively at the terminal C atom (C-1) of the  $\pi$ -allyl system of **10**.<sup>†</sup> We

<sup>†</sup>This statement is made subject to the condition that products which originate from attack either on the CO group or the un-coordinated vinyl group are stable enough to be isolated.

infer that the  $\pi$ -allyl system in lactone **10**, and most probably in other similar systems, is electron deficient with respect to a double bond. This is most probably due to the electron donation from the  $\pi$  orbital of the double bond to the empty d orbitals of the iron atom, which apparently outweighs the back-donation from iron to  $\pi^*$  of the double bond.

The  $\pi$ -allyl system of **11** is conjugated with the un-coordinated double bond. Conceivably, a thermal isomerization such as **11**  $\rightleftharpoons$  **11a** may take place. Heating a solution of **11** in  $C_6H_5CD_3$  in the NMR probe produced no changes indicative of such an isomerization process. Apparently either a large energy barrier or considerable difference in stability of the two isomers precludes such as isomerization.

Finally, we have examined the lactone **12** obtained by the reaction of 2-hydroxymethylene allyl alcohol with



$Fe_2(CO)_9$ , according to the procedure of Murdoch.<sup>2</sup> Treatment of **12** with aniline under the usual reaction conditions generated a lactam of structure **13**. Aside from the aromatic H signals, the NMR spectra of **12** and **13** are quite similar. Amidation has also taken place in this system, but the lactone **12** does not allow us to distinguish between an  $S_N2'$  and a direct displacement reaction. Thus, although the nucleophilic displacement of a "cross conjugated" leaving group does occur, a rigorous proof of the proposition outlined in eqn (3) is still lacking.

It is interesting to note that when the lactone **12** was treated with ammonia rather than aniline, trimethylene- $Fe(CO)_3$  complex (**15**) was isolated. This type of reaction has already been encountered; when **1a** was treated with ammonia, butadiene- $Fe(CO)_3$  complex was isolated.<sup>1</sup> Elimination of  $CO_2H$  and  $NH_3$  elements from an intermediate **14**, which is analogous with **7** may account for the formation of **15**. The difference in behavior of ammonia and aniline in these reactions is not clear.

#### EXPERIMENTAL

**cis-4-Anilino-3-d,2-buten-1-ol 3d.** Compound **3c**,<sup>3</sup> (1.5 g) was added dropwise to a boiling and stirred mixture of powdered Zn (5.28 g; tech grade), anhyd  $CuCl_2$  (260 mg) and NaI (44 mg) in 10 ml  $D_2O$  (99.75%). After 3 hr the mixture was cooled to room temp. and extracted with chloroform. Evaporation of the chloroform gave 1.1 g bright-oily residue which was chromatographed on basic alumina. Elution with methylene chloride gave 0.5 g of colorless oil, which was characterized as **3d**, NMR( $CDCl_3$ ,  $\delta$ ): 7.05(m, 5H), 6.53(m, 3H), 5.58(m, 1H), 4.1(d,  $J = 7.5$  Hz, 1H), 3.67(s, 2H), 2.9(s, 2H); IR(neat): 3540(free OH), 3350(bonded OH)  $cm^{-1}$ .

**2-d,1-Hydroxymethyl- $\pi$ -allylcarboxyirontricarboxyl lactone 1c.** This compound was prepared according to the previously described procedure for the non-deuterated lactone **1a**,<sup>1</sup> m.p. 112–114(dec).  $m/e$  239( $M^+C_6H_4FeO_3$ ). Its NMR spectrum is presented in Fig. 1.

**1-d,1-Anilinomethyl- $\pi$ -allylcarboxyirontricarboxyl lactam 4c.** This compound was prepared from **1c** according to the previously described procedure for the non-deuterated lactam **4a**,<sup>1</sup> m.p. 104–105° (dec);  $m/e$  314( $M^+$ ,  $C_{14}H_{10}DFeNO_4$ ). Its NMR spectrum is presented in Fig. 2.

**6-Vinyl-N-phenyl-3,6-dihydro-1,2-oxazine 8.** A mixture of hexatriene (4.8 g) and nitrosobenzene (6.5 g) in 50 ml chloroform was allowed to stand at 3° for 24 hr. A small amount of red crystals were removed by filtration, and evaporation of the filtrate left a semi-solid residue which was extracted with petrol-ether (60–80°) followed by evaporation. The dull red oil left was further purified on neutral alumina in 40% benzene-petrol ether, to give 6 g of dull orange oil; NMR( $CDCl_3$ ,  $\delta$ ): 7.10(m, 5H), 5.98(m, 3H), 5.30(d,  $J = 16$  Hz, 1H) 5.20(d,  $J = 10$  Hz, 1H), 4.96(m, 1H), 3.76(br, s, 2H),  $m/e$  187, ( $M^+$ ,  $C_{14}H_{11}NO$ ).

**cis-6-Anilino-1,4-hexadiene-3-ol 9.** The vinyl oxazine **8** (6 g) was reduced with powdered Zn (technical; 15 g) in 160 ml AcOH and 50 ml ether. The mixture was stirred for 6 hr, and then filtered to remove all solids. The filtrate was diluted with 150 ml ice-water and this was followed by neutralization with NaOH. The oily layer was extracted with  $CHCl_3$ , dried over  $K_2CO_3$  and evaporated to give 5.85 g of yellow-oil which was chromatographed on neutral

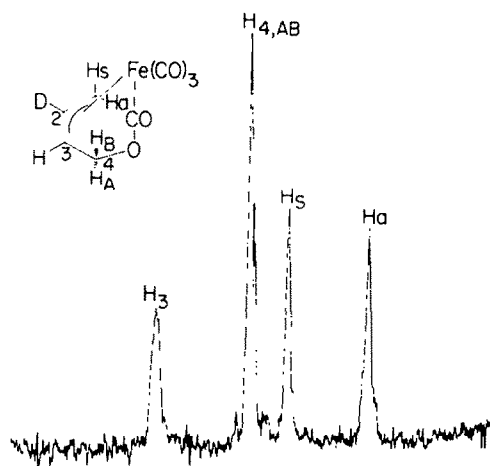


Fig. 1.

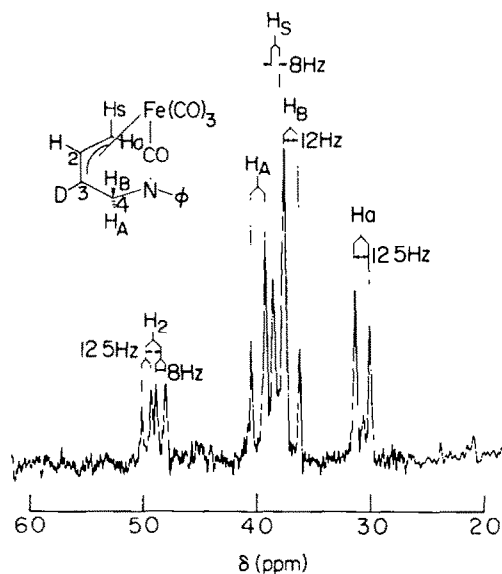


Fig. 2.

Fig. 1. NMR spectra of **1c** (Fig. 1) and **4c** (Fig. 2) in  $CDCl_3$  (100 MHz) relative to TMS (aromatic region was omitted).

alumina. Elution with  $\text{CH}_2\text{Cl}_2$ : pet. ether/1:1 afforded 5.6 g pure oily liquid; NMR ( $\text{CDCl}_3$ ,  $\delta$ ): 7.18(m, 2H), 6.65(m, 3H), 5.87(ddd,  $J = 17, 10$  and 6 Hz, 1H), 5.55(q, 2H), 5.22(dd,  $J = 17$  and 1.5 Hz, 1H), 5.08(dd, 10 and 1.5 Hz, 1H), 4.90(dd,  $J = 6$  Hz, 1H), 3.67(m, 2H), 3.20(s, 2H); IR ( $\text{CHCl}_3$ ): 3580(OH free) 3350(intramolecular OH bonded)  $1600, 1500(\text{Ph})\text{cm}^{-1}$ ;  $m/e$  189( $\text{M}^+$ ,  $\text{C}_{14}\text{H}_{13}\text{NO}$ ). The double adduct of **9** with  $\text{ONCO}$  was prepared, m.p. 120–120.5°, after crystallization from ether. (Found: C, 72.59; H, 6.02. Calc. for  $\text{C}_{17}\text{H}_{15}\text{NO}$ : C, 73.0; H, 5.86%).

**1-Hydroxy vinyl methyl- $\pi$ -allylcarboxyirontricarbonyl-lactone 10.** The anilino alcohol **9** (3.5 g, 18.6 mmol) and **4** (1.4 g, 37 mmol) were stirred at 34° under  $\text{N}_2$  in 60 ml benzene for 36 hr. The gray mixture was washed with dil. HCl, water and sat NaCl aq. Evaporation of the solvent left a dark residue which was chromatographed on basic alumina. Elution with 20%  $\text{CH}_2\text{Cl}_2$ -pet. ether afforded a mixture of benzalacetophenone and its irontricarbonyl complex. Subsequent elution with a mixture of 50%  $\text{CH}_2\text{Cl}_2$ -pet. ether gave 1.1 g of **10** which solidified on standing, m.p. 57–9° (yellow needles after crystallization from  $\text{CH}_2\text{Cl}_2$ -pet. ether; NMR ( $\text{CDCl}_3$ ,  $\delta$ ): 5.86(ddd  $J = 5.0$  Hz, 1H), 5.28(d  $J = 17.0$  Hz, 1H), 5.18(d  $J = 11.0$  Hz, 1H), 4.88(ddd  $J = 8.0$  Hz, 1H), 4.62(m, 2H), 3.68(dd  $J = 2.0, 8.0$  Hz, 1H), 3.04(dd  $J = 13.0$  Hz, 1H); IR ( $\text{CHCl}_3$ ): 1650( $\text{OCOFe}$ ); IR (Hexane): 2080, 2030, 2010 ( $\text{C}\equiv\text{O}$ ) $\text{cm}^{-1}$ ;  $m/e$  264( $\text{M}^+$ ,  $\text{C}_{10}\text{H}_8\text{O}_4\text{Fe}$ ), 220( $\text{M}^+ - \text{CO}_2$ ), 192(220-CO), 164(220-2CO), 136(220-3CO).

**3-Vinyl-1-anilino methyl- $\pi$ -allylcarboxyirontricarbonyl-lactam 11.** A mixture of **10** (1 g) and aniline (0.1 ml) in THF (15 ml) was stirred at room temp. for 36 hr. After filtration, the solvent was evaporated and the residue chromatographed on basic alumina. Elution with 60%  $\text{CH}_2\text{Cl}_2$ -pet. ether afforded 155 mg of **11**, m.p. 110°(dec) as yellow needles; NMR ( $\text{CDCl}_3$ ,  $\delta$ ): 5.98(ddd, 1H), 5.53

(dd  $J = 17.0$  Hz, 1H), 5.23(dd  $J = 9.0, 1.5$  Hz, 1H), 4.90(dd  $J = 12.5$  Hz, 1H), 4.58(dd  $J = 9.0$  Hz, 1H), 4.26(ddd  $J = 7.5$  Hz, 1H), 3.94(dd  $J = 6.0$  Hz, 1H), 3.68(dd  $J = 13.0, 1.5$  Hz, 1H); IR ( $\text{CHCl}_3$ ): 1575( $\text{NCOFe}$ ), 1600, 1500(Ph); IR (Hexane): 2062, 2010 and 1995( $\text{C}\equiv\text{O}$ )  $\text{cm}^{-1}$ ;  $m/e$  339( $\text{M}^+$ ), 311( $\text{M}^+ - \text{CO}$ ), 283( $\text{M}^+ - 2\text{CO}$ ), 255( $\text{M}^+ - 3\text{CO}$ ), 227( $\text{M}^+ - 4\text{CO}$ ). (Found: C, 56.60; H, 3.83; N, 4.14. Calc. for  $\text{C}_{16}\text{H}_{13}\text{FeNO}_4$ : C, 56.85; H, 3.85; N, 4.39%).

**2-Anilinomethyl- $\pi$ -allylcarboxyirontricarbonyl lactam 13.** This compound was obtained in 65% yield from lactone **12**<sup>2</sup> using the general procedure described for **1a**<sup>1</sup>; yellow needles; m.p. 111–112° (dec) after crystallization from hexane; NMR( $\text{CDCl}_3$ ,  $\delta$ ): 7.25(m, 5H); 4.00(s, 2H), 3.75(s, 2H), 2.48(s, 2H); IR ( $\text{CHCl}_3$ ): 1580 ( $\text{NCOFe}$ ), 1600, 1500 (Ph); IR (hexane): 2075, 2010 ( $\text{C}\equiv\text{O}$ )  $\text{cm}^{-1}$ ;  $m/e$  313( $\text{M}^+$ ,  $\text{C}_{14}\text{H}_{11}\text{FeNO}_4$ ), 285( $\text{M}^+ - \text{CO}$ ), 257( $\text{M}^+ - 2\text{CO}$ ), 229( $\text{M}^+ - 3\text{CO}$ ), 201( $\text{M}^+ - 4\text{CO}$ ).

**Trimethylene irontricarbonyl 15.** When the lactone **10** in ether and  $\text{Al}_2\text{O}_3$  was treated with ammonia at room temp. **15** was obtained (50%), m.p. 32–3°, lit.<sup>3</sup> 33°.

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