BULLETIN OF THE CHEMICAL SOCIETY OF JAPAN, VOL. 51 (11), 3391—3392 (1978)

The Chemistry of Isocyanic Acid and Its Derivatives. Part V.[1] The Oxidative Coupling of Ethyl Carbamate and Urea with Cyclohexene, Tetrahydrofuran, and Cyclooctadiene Effected by Palladium(II) Chloride[2]

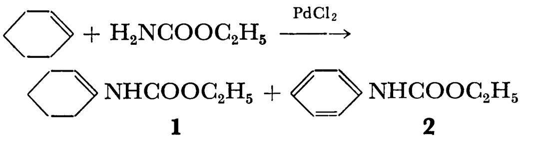
Shoichiro Ozaki* and Akihiro Tamaki
Research Center, Mitsui Toatsu Chemicals, Inc., Kasama-cho, Totsuka-ku, Yokohama 247

(Received December 16, 1977)

Synopsis. The reaction of ethyl carbamate with cyclohexene promoted by $PdCl_2$ gave ethyl 1-cyclohexenylcarbamate. The reaction of ethyl carbamate and tetrahydrofuran gave ethyl 2-tetrahydrofurylcarbamate. Ethyl carbamate and 1,5-cyclooctadiene–$PdCl_2$ complex (**4**) reacted to give ethyl 4-cyclooctenylcarbamate. The reaction of urea and **4** afforded cyclooctylurea and 4-cyclooctenylurea.

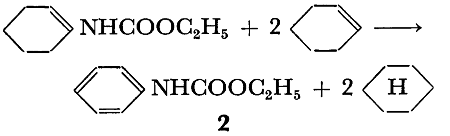
Although various compounds bearing active hydrogens are known to undergo oxidative coupling reactions by the aid of palladous chloride,[3] the reactions of carbamates and ureas have been little studied. The communications by Kasahara *et al.* on the *intra*molecular cyclization reactions of unsaturated amides[4] and ureas[5] prompted the present authors to publish the results of their studies[2] of the *inter*molecular oxidative coupling reactions of ethyl carbamate and urea with cyclic olefins.

Ethyl 1-cyclohexenylcarbamate (**1**) and ethyl phenylcarbamate (**2**) were obtained by heating a mixture of cyclohexene, ethyl carbamate, and palladium(II) chloride.[2a]



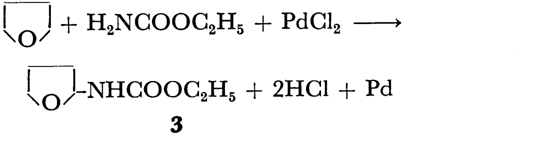
(1)

It is of interest that ethyl carbamate did not attack the allylic position of cyclohexene, while CN^-[6] and AcO^-[7] did. The hydrogen-transfer reaction, *e.g.*, Eq. 2, might be responsible for the formation of **2**:



(2)

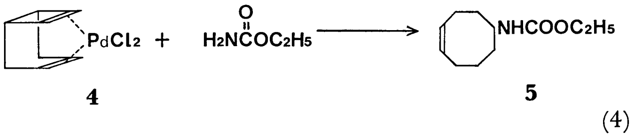
An attempted reaction of the same mixture in tetrahydrofuran did not give the expected products, but instead gave ethyl 2-tetrahydrofurylcarbamate (**3**) in a 30% yield.[2b]



(3)

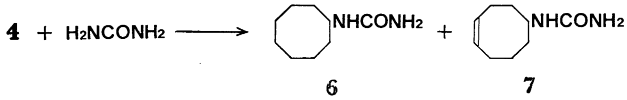
This reaction is a new type of oxidative coupling, in which tetrahydrofuran, instead of olefin, is activated by palladium(II) chloride. Attempted reactions in benzene, diethyl ether, anisole, ethanol, or *N,N*-dimethylformamide, did not give any oxidative coupling products.

Ethyl carbamate also reacted with the 1.5-cyclooctadiene palladous chloride complex (**4**) to afford ethyl 4-cyclooctenylcarbamate (**5**).[2c]



(4)

Urea did not give any coupling product with cyclohexene, in either the presence or absence of a solvent. Urea-olefin coupling products, cyclooctylurea (**6**) and 4-cyclooctenylurea (**7**), however, were obtained when **4** was made to react with urea in *N,N*-dimethylacetamide.



(5)

Experimental

Reaction of Cyclohexene with Ethyl Carbamate. Cyclohexene (15 g, 0.183 mol), ethyl carbamate (30 g, 0.337 mol), and palladium(II) chloride (1 g, 0.00562 mol) were mixed and stirred at 60 °C for 23 h. After agitation under an hydrogen atmosphere for 3 h, the reaction mixture was extracted with petroleum benzine, the solvent was removed by evaporation, and the residue was distilled under reduced pressure to give two fractions. The first fraction (0.39 g; 38.1%, based on palladium(II) chloride; bp 64 °C/0.18 mmHg) was found to be **1** by means of an NMR measurement [(neat) δ 1.22 (3H, triplet, CH_3), 1.17 (8H, multiplet, CH_2-ring) 4.02 (2H, quartet, OCH_2-C), 5.12 (1H, singlet, NH), 5.54 (1H, multiplet, -CH=)], and elemental analysis. Found: C, 64.13; H, 9.01; N, 7.97%. Calcd for $C_9H_{15}NO_2$: C, 63.88; H, 8.94; N, 8.28%. The second fraction (0.53 g; 53.0%; bp 78—82 °C/0.14 mmHg) was found to be **2** by means of an NMR measurement [(neat) δ 1.25 (3H, triplet, CH_3), 4.15 (2H, quartet, O-CH_2-C), 7.25 (5H, multiplet, C_6H_5+NH)], and elemental analysis. Found: C, 65.22; H, 7.00; N, 8.19%. Calcd for $C_9H_{11}NO_2$: C, 65.44; H, 6.71; N, 8.48%.

Ethyl 2-Tetrahydrofurylcarbamete (3). A mixture of tetrahydrofuran (41 g, 0.5 mol), palladium(II) chloride (1.0 g, 0.0056 mol), ethyl carbamate (0.89 g, 0.01 mol), and disodium hydrogenphosphate (1.6 g, 0.0112 mol) was stirred for 1 h at room temperature, and then cyclohexene (5.0 ml, 0.049 mol) was added; there after the mixture was stirred for additional 17 h at room temperature and subsequently exposed to a hydrogen atmosphere for 4 h. The mixture was then filtered, and the filtrate was concentrated and, after the addition of a small amount of water, extracted with benzene and ether. The extract was dried with anhydrous sodium sulfate and distilled under reduced pressure. The product (0.267 g, 30%) (bp 71—5 °C/0.08 mmHg), which slowly solidified at room temperature and which melted at 44—46 °C, was found to be **3** by means of an NMR measurement [(in $CDCl_3$) δ 1.24 (3H, triplet, CH_3), 1.92 (4H, multiplet, CH_2-ring), 3.87 (2H, quartet, OCH_2-ethyl), 4.14 (2H, triplet, OCH_2-ring) 5.53 (2H, multiplet, CH=NH)] and elemental analysis. Found: C, 53.01; H, 8.26; N, 8.68%. Calcd for $C_7H_{13}NO_3$: C, 52.81; H, 8.23; N, 8.80%.

Ethyl 4-Cyclooctenylcarbamate (5). A mixture of **4** (2.0 g, 7 mmol), ethyl carbamate (1.50 g, 16.9 mmol), sodium carbonate (0.787 g, 7.3 mmol), and *N,N*-dimethylacetamide (40 ml) was stirred for 5 h at room temperature. Calcium hydride (3 g) was then added, and the mixture was agitated for an additional 10 h. The precipitated palladium black was filtered off, and the filtrate was concentrated and distilled under reduced pressure. Ethyl 4-cyclooctenylcarbamate (**5**) (0.811 g, 58.7% based on **4**) was thus obtained as a viscous oil; bp 110 °C/0.2 mmHg; NMR ($CDCl_3$) δ 1.23 (3H, t, CH_3), 1.58 (6H, m, CH_2), 2.25 (4H, m, =CH-$\underline{CH_2}$), 3.75 (1H, m, CH), 4.02 (2H, m, O-CH_2), 5.68 (3H, m, CH=CH+NH); IR (KBr), 3360, 2925., 1964, 1528, 1468, 1245, 1100, 1050, 780 cm^{-1}. Found: C, 67.16; H, 10.07; N, 7.35%. Calcd for $C_{11}H_{19}NO_2$: C, 66.97; H, 9.71; N, 7.10%.

Reaction of **4** *with Urea.* Urea (7.5 g, 0.125 mol), **4** (15 g, 0.052 mol), and anhydrous sodium carbonate (5.6 g, 0.052 mol) were added to *N,N*-dimethylacetamide (150 ml), and the mixture was stirred for 6.5 h at room temperature; palladium black separated in the meantime. Agitation was continued for an additional 41 h while calcium hydride (18 g) was added in small portions. The mixture was then filtered, and the filtrate was concentrated and extracted with chloroform at 50 °C. The subsequent evaporation of the solvent left 5.48 g of a white, crystalline solid (mp 144—155 °C), which was a mixture of cyclooctylurea (**6**) and cyclooctenylurea (**7**); on hydrogenation over the Pd-C catalyst, it gave **6** (5.21 g, 58.3% based on **4**); mp 175.5—176 °C; NMR (DMSO-d_6) δ 1.51 (14H, multiplet, CH_2), 3.53 (1H, multiplet, CH), 5.20 (3H, multiplet, NH+NH_2); molecular weight by vapor-pressure osmometry, 171 (Calcd, 170.23). Found: C, 63.43; H, 10.85; N, 16.39%. Calcd for $C_9H_{18}N_2O$: C, 63.49; H, 10.66; N, 16.45%.

References

1) For Paper IV in this series, see Y. Miyake, S. Ozaki, and Y. Hirata, *J. Polym. Sci., Part A1*, 899 (1969).

2) The authors have applied for Japanese Patents on their results. (a) Jpn. Patent 44-4541 (1969); *Chem. Abstr.* **71**, 60852c (1969); (b) Jpn. Patent 44-28900 (1969); *Chem. Abstr.* **72**, 43412q (1970); (c) Jpn. Patent 46-29844 (1971), *Chem. Abstr.* **76**, 140059v (1972).

3) P. M. Maitlis, "The Organic Chemistry of Palladium", New York, Academic Press, (1971), and the references therein.

4) A. Kasahara and T. Saito, *Chem. Ind.*, **1975**, 745.

5) A. Kasahara and N. Fukuda, *Chem. Ind.*, **1976**, 485.

6) J. Odaira, T. Oishi, T. Yukawa, and S. Tsutsumi, *J. Am. Chem. Soc.*, **88**, 4105 (1966).

7) W. Kitching, Z. Rappoport, S. Winstein, and W. G. Young, *J. Am. Chem. Soc.*, **88**, 2054 (1966).