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Reactions of azepine and diazepine derivatives with palladium acetate in benzene: a novel skeletal rearrangement of azepine derivatives

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Abstract

Reactions of azepine derivatives with palladium acetate in benzene give the bicyclo[4.1.0]-3-azahepta-4-ene derivatives, although one diazepine derivative underwent ring-opening. A cycloheptatriene derivative yielded a phenylated product.

Introduction

Much attention has been paid to the reactions of olefins with transition metal complexes from the viewpoint of synthetic utility and reaction mechanism [1]. Recently, reactions of heterocyclic compounds with palladium complexes were actively investigated. Furans and pyrroles have been reported to undergo arylation and alkenylation in the presence of palladium salts [2]. However, reactions of seven-membered heterocyclic compounds such as azepines and diazepines with transition metal complexes have scarcely been reported [3]. Here, we report the results of reactions of azepines and diazepines with palladium acetate.

Results and discussion

When 1-ethoxycarbonyl-1*H*-azepine (**1a**) was allowed to react with palladium acetate in the presence of sodium acetate in benzene, a bicyclic product **2a** was obtained in 20.2% yield *. Under the same reaction conditions but using 1-methoxycarbonyl-1*H*-azepine (**1b**) the analogous bicyclic material **2b** was obtained in 10.5% yield. However, similar treatment of 1-ethoxycarbonyl-1*H*-1,2-diazepine

* All the yields are based on the starting olefins consumed.

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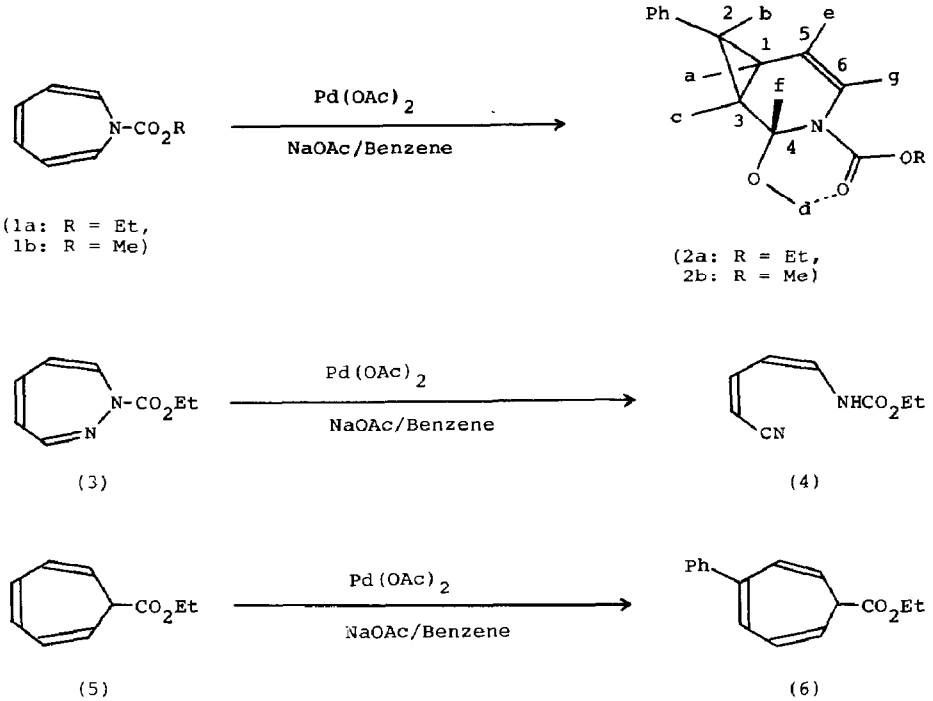

Fig. 1. Products of the reactions of azepine, diazepine, and cycloheptatriene derivatives with palladium acetate in the presence of benzene.

(3) gave no bicyclic product but produced a ring-opened product, 4, in 19.0% yield *.

The structure of 2 was deduced on the basis of the spectral, especially NMR spectral, data. The molecular ion peak in mass spectra shows that 2 is an adduct of the azepine derivative with phenyl and hydroxy groups. The fact that the H^d signal disappears in the ^1H NMR spectra measured in the presence of deuterium oxide shows that the proton H^d is associated with a hydroxy group. The coupling constant between H^d and H^f, which is observed in the ^1H NMR spectra measured in acetone-d_6, indicates that H^f and the hydroxy group are attached to the same carbon atom. ^1H and ^{13}C NMR spectra indicate that 2 contains only one olefinic bond. The chemical shifts and the coupling patterns of H^a, H^b, H^c, H^e, and H^g suggest the existence of a vinylcyclopropane moiety. The chemical shifts of C^1, C^2, and C^3 in the ^{13}C NMR spectrum also support the existence of the cyclopropane moiety. The value of J_{ac} is reasonable for a coupling constant between *cis*-protons of three-membered rings. J_{ab} and J_{bc}, which are larger than J_{ac}, suggest that H^b is *trans* to H^a and H^c. The small value of J_{cf} shows that the diheadral angle between C^3–H^c and C^4–H^f is close to 90° [5]. The flapping by the six-membered ring moiety is hindered by the hydrogen bond between the hydroxy group and the carbamate group forming a pseudo six-membered ring.

The reaction to form the bicyclic product 2 seems to proceed only with azepine derivatives. The diazepine derivative (3), a seven-membered heterocyclic compound,

* The structure of 4 was confirmed on the basis of coincidence of the spectral properties with those of the authentic samples [4].

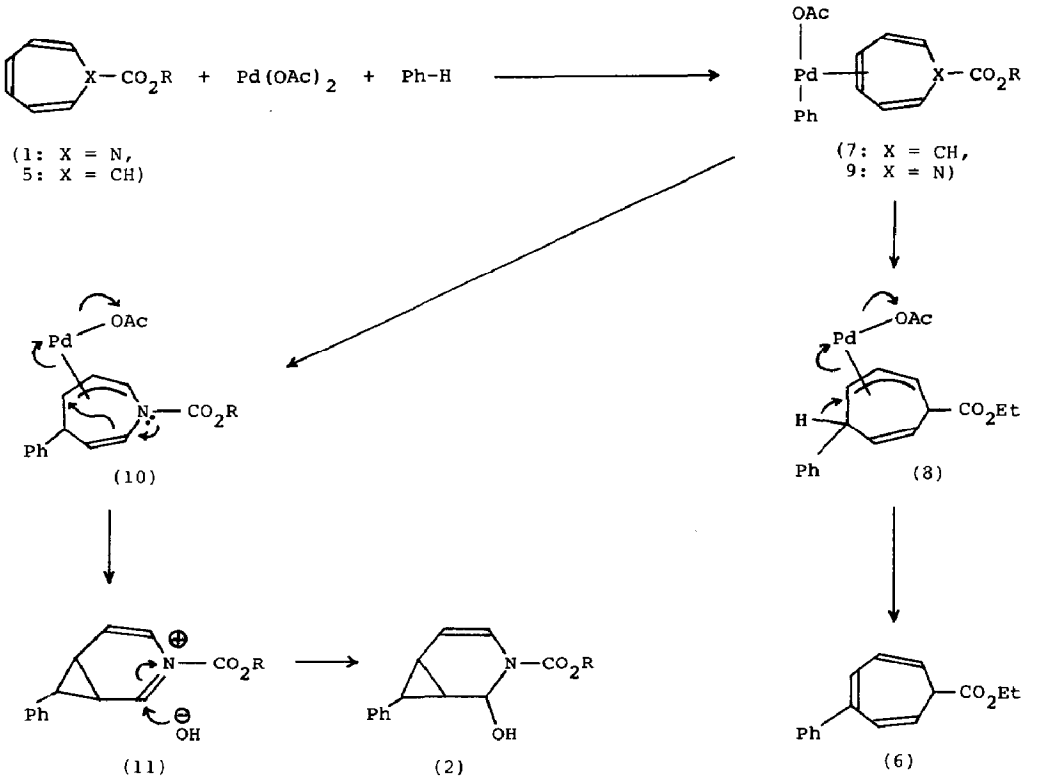

Fig. 2. Reaction mechanism of 7-ethoxycarbonylcycloheptatriene and azepine derivatives with palladium acetate in the presence of benzene.

does not give the bicyclic product. Seven-membered ring analogues such as troponoid compounds and cycloheptatriene derivatives have been reported to give only phenylated products under similar reaction conditions [6]. In order to investigate the influence of the ester group of the azepines, 7-ethoxycarbonylcycloheptatriene (**5**) was treated under the same reaction conditions. The reaction product was the phenylated compound **6** * and the bicyclic product was not detected at all.

The phenylation of **5** probably proceeds as follows. Reaction of **5** with palladium acetate in the benzene gives complex **7**. The subsequent insertion of the cycloheptatriene moiety into the palladium–phenyl bond gives the phenylated π-allyl complex **8**, which then forms **6** liberating palladium metal and acetic acid.

The reaction of **1** with palladium acetate is also considered to proceed by coordination of the palladium salt to azepines to form complex **9**. The insertion of the azepine moiety in the palladium–phenyl bond gives the phenylated π-allyl complex **10**. The delocalization of the lone-pair electrons on the nitrogen atom affords the cationic intermediate **11**. The difference in the reactivity of azepines compared with cycloheptatrienes can be attributed to this enamine-type behaviour in azepines [8]. Addition of hydroxy anion to **11** gives the bicyclic product **2**.

* The structure of **6** was established from the resemblance of its spectral data to those of analogous compounds [7].

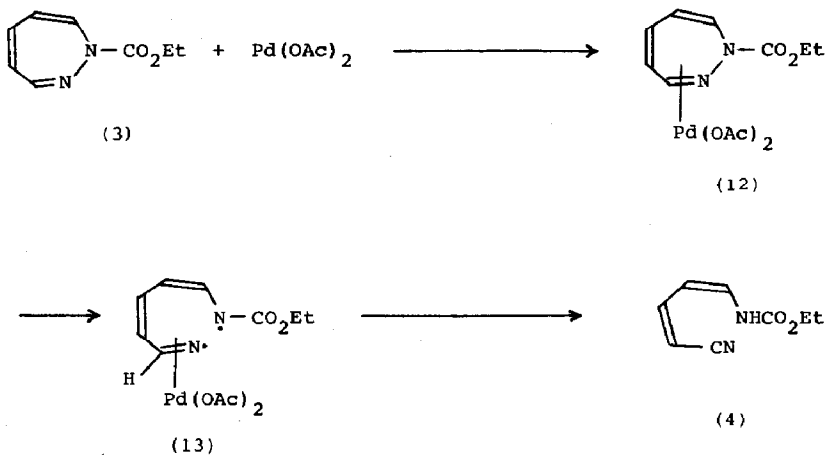

Fig. 3. Reaction mechanism of 1-ethoxycarbonyl-1*H*-1,2-diazepine with palladium acetate in the presence of benzene.

In the reaction of **3** with palladium acetate, the palladium salt probably coordinates to the carbon–nitrogen double bond to form **12**. The palladium is thought either to weaken the nitrogen-nitrogen bond in **12** or to stabilize the diradical intermediate that forms the complex **13**: Unfortunately a detailed mechanism of this reaction is not clear yet.

Experimental

*Reaction of 1-ethoxycarbonyl-1H-azepine (**1a**) with palladium acetate*

A mixture of **1a** (330 mg, 2 mmol), palladium acetate (448 mg, 2 mmol), and sodium acetate (1640 mg, 10 mmol) in anhydrous benzene (30 ml) was heated to reflux for 10 h. After addition of water, the mixture was extracted with ether. Drying of the extract over anhydrous sodium sulfate followed by evaporation of the solvent on a rotary evaporator resulted in an oily residue. This was thin-layer chromatographed on silica gel using benzene-ether 1/1 as a developing solvent to give the recovered **1a** (180 mg, $R_f = 0.85$) and an oil **2a** (50 mg, 20.2%, $R_f = 0.50$).

2a: Found: *m/z* 259.1226. $C_{15}H_{17}NO_3$ calcd.: *m/z* 259.1204. Mass *m/z* (rel intensity): 259 (m^+, 31), 242 (100), 230 (16), 198 (15). IR (oil): 3410, 3030, 2980, 1715, 1410, 1320 cm^{-1}. UV (EtOH): 240 nm (log, 3.60). ^1H NMR ($CDCl_3$): 1.28 (t, 3H, *J* 7.0 Hz), 1.70 (m, 1H, H^a), 2.10 (m, 1H, H^b), 2.28 (m, 1H, H^c), 4.21 (q, 2H, *J* 7.0 Hz), 4.98 (s, 1H, H^d), 5.50 (m, 1H, H^e), 6.11 (s, 1H, H^f), 6.40 (m, 1H, H^g), 6.9–7.4 (m, 5H, Ph). Coupling constants in Hz: J_{ab} 8.0, J_{ac} 2.0, J_{ae} 5.0, J_{bc} 4.0, J_{cf} 1.0, J_{eg} 8.0, (J_{df} 6.0, measured in acetone-d_6). ^{13}C NMR ($CDCl_3$): 20.067 (C^1), 29.692 (C^2), 22.651 (C^3), 71.866 (C^4), 110.246 (C^5), 119.511 (C^6).

*Reaction of 1-methoxycarbonyl-1H-azepine (**1b**) with palladium acetate*

A mixture of **1b** (3020 mg, 20 mmol), palladium acetate (2280 mg, 10 mmol), and sodium acetate (4100 mg, 50 mmol) in anhydrous benzene (100 ml) was heated to reflux for 5 h. The same procedure as above gave some unchanged **1b** (1790 mg) and **2b** (210 mg, 10.5%).

2b: Found: m/z 245.1064. $C_{14}H_{15}NO_3$ calcd.: m/z 245.1051. ^1H NMR ($CDCl_3$): 1.68 (m, 1H, H^a), 2.12 (m, 1H, H^b), 2.28 (m, 1H, H^c), 3.75 (s, 3H), 4.90 (s, 1H, H^d), 5.50 (m, 1H, H^e), 6.10 (s, 1H, H^f), 6.35 (m, 1H, H^g), 6.9–7.4 (m, 5H, Ph). Coupling constants in Hz: J_{ab} 8.0, J_{ac} 2.0, J_{ae} 5.0, J_{bc} 4.0, J_{cf} 1.0, J_{eg} 8.0, (J_{df} 6.0, measured in acetone-d_6).

Reaction of 1-ethoxycarbonyl-1H-1,2-diazepine (3) with palladium acetate

A mixture of **3** (660 mg, 4 mmol), palladium acetate (896 mg, 4 mmol), and sodium acetate (1640 mg, 20 mmol) in anhydrous benzene (60 ml) was heated to reflux for 15 h. The same procedure as above gave **4** (65 mg, 16.7%, benzene/ether 1/1, $R_f = 0.60$) and some unchanged **3** (270 mg, $R_f = 0.40$).

Reaction of 7-ethoxycarbonylcycloheptatriene (5) with palladium acetate

A mixture of **5** (820 mg, 5 mmol), palladium acetate (1140 mg, 5 mmol), and sodium acetate (2050 mg, 25 mmol) in anhydrous benzene (50 ml) was heated to reflux for 8 h. The same treatment as above gave **6** (280 mg, 23.3%, benzene, $R_f = 0.75$).

6: Found: m/z 240.1147. $C_{16}H_{16}O_2$ calcd.: m/z 240.1151. Mass m/z (rel intensity): 240 (M^+, 14), 211 (20), 193 (35), 167 (100). ^1H NMR ($CDCl_3$): 1.29 (t, 3H), 2.72 (t, 1H), 4.23 (q, 2H), 5.44 (m, 2H), 6.30 (m, 1H), 6.46 (m, 1H), 6.86 (m, 1H), 7.2 (m, 5H).

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References

1 R.F. Heck, J. Am. Chem. Soc., 90 (1968) 5542; Y. Fujiwara, I. Moritani, S. Danno, R. Asano, and S. Teranishi, ibids., 91 (1969) 7166; R. Asano, I. Moritani, A. Sonoda, Y. Fujiwara, and S. Teranishi, J. Chem. Soc. C, (1971) 3691; R.F. Heck and J.P. Jolly, J. Org. Chem., 37 (1972) 2320; H.A. Deck and R.F. Heck, J. Am. Chem. Soc., 96 (1974) 1133; H. Tanaka, Y. Fujiwara, I. Moritani, and S. Teranishi, Bull. Chem. Soc. Jpn., 48 (1975) 3372; H. Horino, N. Inoue, and T. Asao, Tetrahedron Lett., 22 (1981) 741.

2 R. Asano, I. Moritani, Y. Fujiwara, S. Teranishi, Bull. Chem. Soc. Jpn., 46 (1973) 663; O. Maruyama, M. Yoshidomi, Y. Fujiwara, and H. Taniguchi, Chem. Lett., (1979) 1229; T. Itahara, J. Chem. Soc. Chem. Commun., (1981) 254; Y. Fujiwara, O. Maruyama, M. Yoshidomi, and H. Taniguchi, J. Org. Chem., 46 (1981) 851; O. Maruyama, Y. Fujiwara, and H. Taniguchi, Bull. Chem. Soc. Jpn., 54 (1981) 2851.

3 K. Saito, Heterocycles, 24 (1986) 1831.

4 J. Streith, J.P. Luttringer, and M. Nastasi, J. Org. Chem., 36 (1971) 2962; K. Saito, H. Kojima, T. Okudaira, and K. Takahashi, Bull. Chem. Soc. Jpn., 56 (1983) 175.

5 M. Karplus, J. Am. Chem. Soc., 85 (1963) 2870.

6 K. Saito, J. Organometal. Chem., 338 (1988) 265.

7 E. Ciganek, J. Am. Chem. Soc., 89 (1967) 1458.

8 L.A. Paquette and D.E. Kuhla, J. Org. Chem., 34 (1969) 2885; L.A. Paquette, D.E. Kuhla, J.H. Barrett, and L.M. Leichter, ibid., 34 (1969) 2888; M. Yasuda, K. Harano, and K. Kanematsu, ibid., 45 (1980) 2368; K. Saito, H. Kojima, T. Okudaira, and K. Takahashi, Bull. Chem. Soc. Jpn., 56 (1983) 175; K. Saito, T. Mukai, and S. Iida, ibid., 59 (1986) 2485.