ISSN 1070-4280, Russian Journal of Organic Chemistry, 2006, Vol. 42, No. 11, pp. 1741–1744. © Pleiades Publishing, Inc. 2006.
Original Russian Text © V.V. Shevchenko, A.A. Shakhmin, V.A. Nikolaev, 2006, published in Zhurnal Organicheskoi Khimii, 2006, Vol. 42, No. 11, pp. 1749–1752.

SHORT COMMUNICATIONS

Catalytic Decomposition of 5-Diazo-2,2-dimethyl-1,3-dioxane-4,6-dione and Its Analogs

V. V. Shevchenko, A. A. Shakhmin, and V. A. Nikolaev

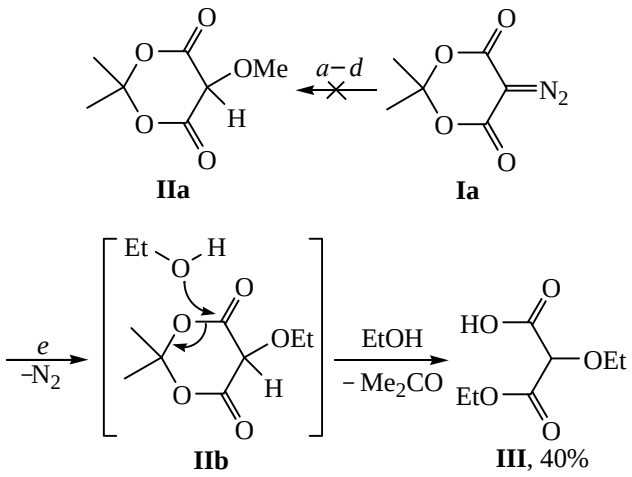
St. Petersburg State University, St. Petersburg, 198504 Russia
e-mail: vnikola@VN6646.spb.edu

Received July 12, 2006

DOI: 10.1134/S1070428006110273

Insertion of carbenoids into X–H bonds of various substrates (X = N, O, P, S etc.) becomes now a standard procedure of preparative organic synthesis [1]. The carbenoids generation in these reactions is performed as a rule by catalytic decomposition of diazo compounds with variable valence metals at room temperature; the reaction proceeds with high yields and a good chemoselectivity. Quite a number of examples of this reaction is known in the series of hydroxy group containing organic compounds (X = O) at the use of rhodium, copper catalysts, boron trifluoride etherate etc. [1].

In the study of photochemical transformations of 5-diazo-2,2-dimethyl-1,3-dioxane-4,6-dione (**Ia**) and its analogs it was necessary to synthesize 5-methoxydioxanedione (**IIa**) whose formation was presumed to occur at the photolysis of the diazo compound **Ia** [2]. We believed that one of the most efficient procedures for the synthesis of this methoxy ether was the catalytic decomposition of easily available diazo compound **Ia** with dirhodium tetraacetate in the presence of methanol. We report here on the results of investigation of catalytic reactions with diazodioxanedione **Ia** and also with its acyclic and carbocyclic analogs, dimethyl diazomalonate (**Ib**) and diazodimedone (**Ic**).



(*a*) $Rh_2(OAc)_4$–CH_2Cl_2 (20°C), (*b*) $Rh_2(OAc)_4$–benzene (20°C), (*c*) $Cu(CF_3SO_3)_2$–CH_2Cl_2 (20°C), (*d*) $BF_3 \cdot Et_2O$–CH_2Cl_2 (20°C), (*e*) $Rh_2(OAc)_4$–benzene (80°C).

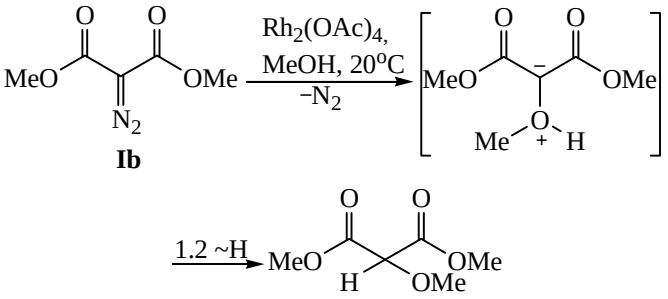
The initial attempt to carry out the catalytic decomposition of diazo compound **Ia** under standard conditions of insertion into X–H bond, namely, with the help of dirhodium tetraacetate $Rh_2(OAc)_4$ in a mixed CH_2Cl_2–MeOH at 20°C [1], were unsuccessful. Diazodioxanedione **Ia** proved to be quite stable under these conditions and did not suffer any notable decomposition even on adding into the reaction mixture of 3–5-fold excess of rhodium catalyst. Variation of different parameters of the process (catalyst, solvent) at 18–20°C did not visibly accelerate the catalytic reaction, and only at heating the reaction mixture to 80°C (in benzene–ethanol solution) the catalytic decomposition by dirhodium tetraacetate occurred with a considerable rate.

It however turned out that occurred not only elimination of the nitrogen of the initial diazo compound **Ia** but also the opening of the dioxane ring, and as a result we isolated in 40% yield only 2-ethoxymalonic acid monoethyl ester (**III**). Since the 1,3-dioxane derivatives relatively easily undergo the cleavage of the heterocyclic system in the presence of acidic catalysts or on silica gel [3], it is

presumable that initially at 80°C the catalytic decomposition occurs of diazo compound **Ia** yielding a product of insertion into O–H bond, ethoxyether **IIb**, which then under the reaction conditions is converted into 2-ethoxymalonate **III** along the above scheme.

Hence the catalytic decomposition of diazodioxanedione **Ia** in the presence of alcohols (MeOH, EtOH) failed to provide under standard conditions common products **II** of intermediate carbenoid insertion into the O–H bond of alcohols.

For the sake of comparison we also studied the catalytic reactions of acyclic and carbocylic analogs of diazodioxanedione **Ia**, dimethyl diazomalonate (**Ib**) and diazodimedone (**Ic**). It turned out that the reaction of dimethyl diazomalonate (**Ib**) took the usual route [1], and on its decomposition in the presence of CH_3OH was

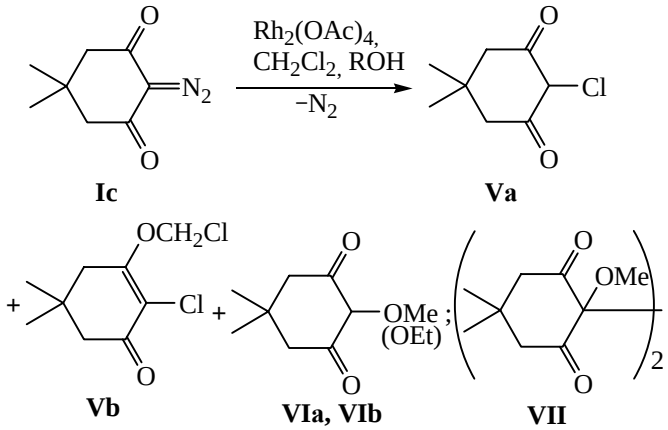


Ib

IV, 70%

obtained in good yield (70%) the expected product of insertion into O–H bond, dimethyl 2-methoxymalonate (**IV**).

The catalytic decomposition of diazodimedone (**Ic**) occurred in different ways and depended on the alcohol concentration in solution and on reaction temperature. In dilute methanol solution in CH_2Cl_2 (~1:20 by volume) at



Ic **Va**

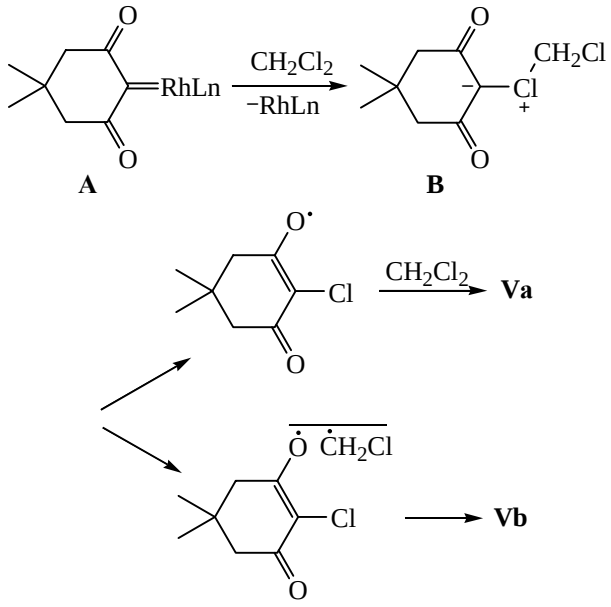
Vb **VIa, VIb** **VII**

18–20°C formed mainly products of reaction between the intermediate Rh(II)-carbenoid and dichloromethane (**Va**, 65%), (**Vb**, 6%), and the yield of the target product of insertion into O–H bond **VIa** was only 10%.

On decomposition of diazodimedone (**Ic**) in neat CH_3OH the reaction provided mainly dimeric adduct **VII** (82%) alongside a small amount of 2-methoxycyclohexanone (**VIa**) (9%). The catalytic decomposition of diazodimedone (**Ic**) in benzene at 80°C in the presence of ethanol gave rise to the expected product of insertion into O–H bond **VIb** but in a moderate preparative yield (40%).

Structure of compounds **III–VII** obtained was confirmed by spectral data reported in the experimental section.

The appearance in the reaction mixture of 2-chlorodimedone (**Va**) and 3-chloromethoxy derivative **Vb** is due



A **B**

apparently to the reaction of the intermediate dioxocarbenoid **A** with dichloromethane following, for example, the below scheme and proceeding through a chloronium ylide **B**, homolytic rupture of the C–Cl bond in this ylide and subsequent reactions of arising radicals.

The alternative route of transformation of halogenonium ylide **B** cannot be excluded: [1,4]-σ-shift of CH_2Cl group with formation of enol ether **Vb** and product of its further hydrolysis **Va**.

The formation of bisadduct **VII** obviously originated from the oxidative dimerization of the primary product of

insertion into O–H bond **VIa** under the conditions of the catalytic process. Analogous reaction was formerly observed with 2-ethoxydimedone (**VIb**) in the course of catalytic decomposition of diazodimedone (**Ic**) on a copper Cu(II)-catalyst in the presence of ethanol [4].

It may be stated in conclusion that unlike acyclic **Ib** and carbocyclic **Ic** analogs diazodioxane **Ia** in reaction of catalytic decomposition is relatively stable and at ambient temperature does not give products of insertion into O–H bond characteristic of other diazocarbonyl compounds. On raising the temperature of the catalytic process the 1,3-dioxane ring suffers opening, and the initially formed products of insertion into O–H bond undergo further transformations.

Catalytic decomposition of diazodioxanedione Ia by dirhodium tetraacetate in benzene at 80°C in the presence of EtOH. To a suspension of 17 mg (0.04 mmol) of $Rh_2(OAc)_4$ in 1.2 ml (20 mmol) of ethanol and 1 ml of benzene was added a solution of 0.340 g (2 mmol) of diazo compound **Ia** in 3 ml of benzene, and the mixture was boiled for 3 days. During chromatographic separation of the reaction mixture were isolated in the order of elution diazo compound **Ia**, yield 0.087 g (26%) and 2-ethoxy-malonic acid monoethyl ester (**III**)), yield 0.141 g (40%) (calculated on reacted diazodioxanedione).

2,3-Diethoxy-3-oxopropionic acid (**III**). ^{1}H NMR spectrum, δ, ppm: 1.30 t (3H, CH_3, *J* 6.5 Hz), 1.32 t (3H, CH_3, *J* 6.6 Hz), 3.70 q (2H, CH_2, J_1 6.6, J_2 1.4 Hz), 4.30 q (2H, CH_2, *J* 6.5 Hz), 4.55 s (1H, CH), 9.5 br.s (1H, OH) [5].

Catalytic decomposition of dimethyl diazomalonate (Ib). To a mixture of 0.16 ml (4 mmol) of CH_3OH, 1 ml of of dichloromethane, and 26 mg (0.09 mmol) of $Rh_2(OAc)_4$ was added dropwise a solution of 0.474 g (3 mmol) of diazoester **Ib** in 3 ml of dichloromethane, and the reaction mixture was stirred for 48 h at 18–20°C. After chromatographic separation followed by microdistillation of the main fraction we obtained 0.341 g (70%) of 2-methoxymalonate **IV**, bp 75–80°C (1–2 mm Hg) [6].

Catalytic decomposition of diazodimedone (Ic) by dirhodium tetraacetate in the presence of CH_3OH in CH_2Cl_2 solution. To a suspension of 17 mg (0.04 mmol) of $Rh_2(OAc)_4$ in 0.16 ml (4 mmol) of methanol and 1 ml of dichloromethane was added dropwise a solution of 0.332 g (2 mmol) of diazo compound **Ic**, and the mixture was stirred for 2 h at 18–20°C. After chromatographic separation of the mixture on silica gel we obtained in the order of elution the following substances: 0.034 g (10%) of 2-methoxy-3-hydroxy-5,5-dimethyl-2-cyclohexen-1-one (**VIa**), 0.027 g (6%) of 2-chloro-3-(chloromethoxy)-5,5-dimethyl-2-cyclohexen-1-one (**Vb**), 0.227 g (65%) of 2-chloro-5,5-dimethyl-1,3-cyclohexandione (**Va**).

3-Hydroxy-5,5-dimethyl-2-methoxy-2-cyclohexen-1-one (VIa). ^{1}H NMR spectrum, δ, ppm: 1.16 s (6H, $2CH_3$), 2.52 br.s (2H, CH_2), 3.02 br.s (2H, CH_2), 3.85 (3H, OCH_3), 5.92 br.s (1H, OH). ^{13}C NMR spectrum, δ, ppm: 27.9 (CH_3), 32.7 (C^5), 44.2 (C^4), 47.8 (C^6), 53.0 (OCH_3), 161.6 (C^2), 178.0 (C^3), 193.1 (C^1). Mass spectrum, *m/z* (I_{rel}, %): 170 (4) $[M]^+$, 143 (100), 115 (20), 108 (8), 101 (16), 97 (22), 83 (83). Found, %: C 63.45; H 8.18. $C_9H_{14}O_3$. Calculated, %: C 63.51; H 8.29.

5,5-Dimethyl-2-chloro-3-(chloromethoxy)-2-cyclohexen-1-one (Vb). ^{1}H NMR spectrum, δ, ppm: 1.16 s (6H, 2 CH_3), 2.44 s (2H, CH_2), 2.69 s (2H, CH_2), 5.83 s (2H, OCH_2Cl). ^{13}C NMR spectrum, δ, ppm: 28.6 (CH_3), 32.8 (C^5), 40.0 (C^4), 51.0 (C^6), 74.9 (OCH_2), 115.9 (C^2), 165.4 (C^3), 191.3 (C^1). Mass spectrum, *m/z* (I_{rel}, %): 226 (1) $[M + 4]^+$, 224 (20) $[M + 2]^+$, 222 (26) $[M]^+$, 194 (22), 174 (27), 166 (50), 136 (26), 118 (100). Found, %: C 48.33; H 5.51. $C_9H_{12}Cl_2O_2$. Calculated, %: C 48.45; H 5.42.

5,5-Dimethyl-2-chloro-1,3-cyclohexanedione (Va), mp 158–160°C [7]. ^{1}H NMR spectrum, δ, ppm: 1.11 s (6H, 2 CH_3), 2.47 s (4H, CH_2), 5.95 br.s (1H). Mass spectrum, *m/z* (I_{rel}, %): 176 (10) $[M + 2]^+$, 174 (30) $[M]^+$, 159 (12), 146 (11), 120 (32), 118 (100).

Catalytic decomposition of diazodimedone (Ic in methanol. To a suspension of 26 mg (0.06 mmol) of $Rh_2(OAc)_4$ in 2 ml (50 mmol) of methanol was added dropwise a solution of 0.332 g (2 mmol) of diazodiketone **Ic** in 2 ml of methanol, and the reaction mixture was stirred for 48 h at 18–20°C. After chromatographic separation of the mixture on silica gel we obtained in the order of elution the following substances: 0.031 g (9%) of 2-methoxy-3-hydroxy-5,5-dimethyl-2- cyclohexen-1-one (**VIa**) and 0.277 g (82%) of bis(1-methoxy-4,4-dimethyl-2,6-cyclohexanedione) (**VII**).

Bis(4,4-dimethyl-1-methoxy-2,6-cyclohexandione) (VII). ^{1}H NMR spectrum, δ, ppm: 1.10 s (12H, $4CH_3$), 2.35 s (8H, 4 CH_2), 3.74 (6H, $2OCH_3$). ^{13}C NMR spectrum, δ, ppm: 28.3 ($4CH_3$), 31.7 (C^5), 47.8 ($C^{4,6}$), 50.5 (OCH_3), 81.9 (C^2), 193.2 ($C^{1,3}$). Mass spectrum, *m/z* (I_{rel},%): 338 (20) $[M]^+$, 185 (27), 170 (100), 154 (27), 143 (40), 124 (30). Found, %: C 63.96; H 7.68. $C_{18}H_{26}O_6$. Calculated, %: C 63.89; H 7.74.

Catalytic decomposition of diazodimedone (Ic) in the presence of ethanol in benzene solution (80°C). To a mixture of 1.2 ml (20 mmol) of ethanol, 1 ml of benzene, 17 mg (0.04 mmol) of $Rh_2(OAc)_4$ was added dropwise a solution of 0.332 g (2 mmol) of diazodiketone **Ic** in 3 ml of benzene, and the mixture was boiled for 24 h. On separating the reaction mixture on silica gel we obtained 0.147 g (40%) of 2-ethoxydimedone (**VIb**).

3-Hydroxy-5,5-dimethyl-2-ethoxy-2-cyclohexen-1-one (VIb) [4]. ^{1}H NMR spectrum, δ, ppm: 1.17 s (6H, $2CH_3$), 1.36 t (3H, CH_3, *J* 6.9 Hz), 2.52 s (2H, CH_2), 3.01 s (2H, CH_2), 4.30 q (2H, CH_2, *J* 6.9 Hz), 5.84 s (1H, CH). ^{13}C NMR spectrum, δ, ppm: 14.0 (CH_3), 27.9 (CH_3), 32.7 (C^5), 44.2 (C^4), 47.7 (C^6), 62.5 (OCH_2), 161.3 (C^2), 177.6 (C^3), 193.6 (C^1). Mass spectrum, *m/z* (I_{rel}, %): 184 (3) $[M]^+$, 171(11), 143 (100), 127 (18), 115 (22), 101 (15), 97 (18), 83 (57).

^{1}H (300 MHz) and ^{13}C (75.5 MHz) NMR spectra were registered on a spectrometer Bruker AM-300 in $CDCl_3$ solution, internal reference $(CH_3)_4Si$. Mass spectra of electron impact were obtained at the direct admission of the sample into the ionization chamber, ionizing electrons energy 70 eV.

REFERENCES

1. Doyle, M.P., McKervey, M.A., Ye, T., *Modern Catalytic Methods for Organic Synthesis with Diazo Compounds: from Cyclopropanes to Ylides*, New York: J. Wiley & Sons, 1998, 655 p.; Maas, G., *Top. Curr. Chem*., 1987, vol. 137, p. 75; Shapiro, E.A., Djatkin, A.B., and Nefedov, O.M., *Diazoesters*, Moscow: Nauka, 1992, 148 p.; Davies, H.M.L. and Beckwith, R.E.J., *Chem. Rev.*, 2003, vol. 103, p. 2861.
2. Nikolaev, V.A., Shevchenko, V.V., Khimich, N.N., and Platz, M.S., *Zh. Org. Khim*., 2006, 42, p. 840; Bogdanova, A. and Popik, V.V., *J. Am. Chem. Soc.*, 2003, vol. 125, p. 14153.
3. Nikolaev, V.A., Khimich, N.N., and Korobitsina, I.K., *Khim. Geterotsikl. Soedin*., 1985, p. 321; Ap'ok, I., Bartok, M., Karakhanov, R.A., and Shuikin, N.I., *Usp. Khim.*, 1969, vol. 38, p. 72; Barnett, J.E.G. and Kent, P.W., *Nature*, 1961, vol. 192, p. 556.
4. Hayasi, Y., Okada, T., and Kawanisi, M., *Bull. Chem. Soc. Jpn.*, 1970, vol. 43, p. 2506.
5. Fiarweather, D.A., *Chem. Zentralbl*., 1925, vol. 96, no. II, p. 1595.
6. Ando, W., Hagiwara, T., and Migita, T., *Bull. Chem. Soc. Jpn.*, 1975, vol. 48, p. 1951.