Decomposition of tosylhydrazones of benzoin, benzoin acetate, and benzoin benzoate with alkali and metal complex hydrides

Tsukasa Iwadare, Yoshiyuki Ichinohe, and Kazuhiko Orito

Abstract: Treatment of tosylhydrazones of benzoin, benzoin acetate, and benzoin benzoate with alkali under protic and aprotic conditions yielded diphenyl acetylene together with desoxybenzoin. An increase in leaving aptitude of the adjacent group enhanced the formation of diphenyl acetylene. By treatment with $LiAlH_4$ and with $NaBH_4$, the tosylhydrazones gave stilbenes in good yields. Selective formation of *cis*- or *trans*-stilbene was observed in some cases.

Key words: tosylhydrazone, benzoin derivatives, decomposition, metal complex hydrides.

Résumé: Le traitement des tosylhydrazones de la benzoïne, de l'acétate de benzoïne et du benzoate de benzoïne par des alcalis dans des conditions tant protiques qu'aprotiques fournit du diphénylacétylène et de la désoxybenzoïne. Une augmentation du pouvoir migratoire du groupe adjacent tend à provoquer une formation accrue de diphénylacétylène. Par traitement avec du LiAlH₄ et du NaBH₄, les tosylhydrazones conduisent aux stilbènes avec de bons rendements. Dans certains cas, des formation sélectives de *cis*- ou *trans*- stilbène ont été observées.

Scheme 1.

Mots clés : tosylhydrazone, dérivés de la benzoïne, décomposition, hydrures métalliques complexes.

[Traduit par la rédaction]

Introduction

Since the report of Bamford and Stevens (1), a number of papers have been published (2, 3) on the decomposition of tosylhydrazones. The reaction developed by Shapiro and Heath (4) was particularly significant for progress in the synthesis of substituted alkenes. In recent years, there have been many studies on photolysis (5–7) and pyrolysis (8–13) of metal salts of tosylhydrazones via a carbene intermediate. Reductive decomposition of tosylhydrazones with LiAlH₄ and with NaBH₄ to alkane or alkene was reported by Caglioti and Magi (14–16). The reaction has been modified by using NaBH₃CN (17) to give reduction products in excellent yields. However, there have been only a few reports (18–20) on the reaction of tosylhydrazones containing a leaving group on the adjacent carbon. In this paper, we report the reactions of such a tosylhydrazone.

Bamford and Stevens (1) reported that the tosylhydrazone (1) of benzoin gave desoxybenzoin (2) in 65% yield by decom-

Received March 15, 1995.¹

T. Iwadare.^{1,2,3} Department of Chemistry, Yokohama City University, Kanazawaku, Yokohama 236, Japan.

Y. Ichinohe. Department of Chemistry, Faculty of Science and Engineering, Nihon University, Narashinodai, Funabashi, Chiba 274, Japan.

K. Orito. Laboratory of Organic Synthesis, Division of Molecular Chemistry, Graduate School of Engineering, Hokkaido University, Sapporo 060, Japan.

- ¹ Revision received November 20, 1995.
- 2 Author to whom correspondence may be addressed.
- ³ Present address: Software Research Laboratory, Nishinopporo 45, Ebetsu, Hokkaido 069, Japan. Telephone: 011-382-1155. Fax: 011-382-7788. E-mail: aizu@em.srl.co.jp





position in a protic solvent (Na, $HOCH_2CH_2OH$). Although they did not refer to the formation of diphenylacetylene (3), the reaction is expected to give 3 according to the reaction sequence shown (Scheme 1). The study by Hassner and Reuss (21) on the reaction of nitrooxazolidines with NaOMe, providing 3 through the same intermediate, gives supportive evidence for the reaction pathway to 3 assumed in Scheme 1.

Results and discussion

Benzoin, benzoin acetate, and benzoin benzoate were con-

Table 1. Decomposition of tosylhydrazones (1a,b,c) with alkali.



a: R = H, b: R = COMe, c: R = COPh

Entry	Tosylhydrazone	Reaction conditions	Yield $(\%)^a$	
			2	3
1	1 <i>a</i>	NaOCH ₂ CH ₂ OH in (CH ₂ OH) ₂ reflux, 40 min	55.9	10.1
2	1 <i>b</i>	NaOCH ₂ CH ₂ OH in (CH ₂ OH) ₂ reflux, 40 min	42.7	52.6
3	1 <i>c</i>	NaOCH ₂ CH ₂ OH in (CH ₂ OH) ₂ reflux, 40 min	41.5	42.2
4	1 <i>a</i>	CH ₃ ONa in (EtOCH ₂ CH ₂) ₂ O reflux, 40 min	71.8	13.3
5	1 b	CH ₃ ONa in (EtOCH ₂ CH ₂) ₂ O reflux, 40 min	3.3	94.4
6	1c	CH_3ON a in $(EtOCH_2CH_2)_2O$ reflux, 40 min	0	98.4

^aGLC yields.

verted into the respective tosylhydrazones (1a,b,c) by the usual method, and treated with alkali under protic and aprotic conditions. The product mixtures were separated by preparative TLC and analyzed by GLC. As shown in Table 1, the anticipated triple bond formation took place under both protic and aprotic conditions. Also, it was revealed that an increase in the leaving aptitude of the OR group (R = H, COMe, COPh) results in facile formation of 3. Freedman and Schechter (22) have proven that decomposition of tosylhydrazones proceeds via a carbene intermediate under aprotic conditions. If elimination of the adjacent group does not take place a carbene intermediate (route a) is formed, and gives 2 via the enolate. However, an alternative pathway via protonation (route b) must also be considered for entries 1, 2, 3, and 4. The results revealed that the elimination (route c) of the acetoxyl and benzoyloxyl groups of 1b and 1c under aprotic conditions strongly predominates over the formation of **2**.

Djerassi and co-workers (23) showed that the reductive decomposition of tosylhydrazones with LiAlH₄ proceeds via a carbanion intermediate, which incorporates proton in the course of work-up leading to products. However, it seems reasonable to assume that alkene formation would be strongly favored in the presence of a suitable leaving group on the carbon adjacent to the incipient carbanion. Thus 1*a*, 1*b*, and 1*c* would be expected to give stilbenes (*cis*: 4, *trans*: 5) by decomposition with LiAlH₄ via the sequence shown in Scheme 2. Accordingly, 1*a*, 1*b*, and 1*c* were treated with LiAlH₄ in ethyl ether, THF, and dioxane, and the products were analyzed by GLC. While 4 and 5 were obtained in good yields in each case, stereoselectivity in the formation of stilbene isomers was observed only when ethyl ether was employed as a solvent



(entries 1, 2, 3), as shown in Table 2. Desoxybenzoin (2) and 1,2-diphenylethanol, which may form through protonation of the carbanion intermediate, were not detected at all.

Djerassi and co-workers demonstrated (23) that tosylhydrazones are decomposed to alkane or alkene by treatment with NaBH₄ through an alkyl diimide intermediate. In our experiments, if a similar carbanion intermediate is formed via the diimide by treatment of tosylhydrazones (1a,b,c) with NaBH₄, stilbene must be produced. Thus 1a, 1b, and 1c were treated with NaBH₄ in dioxane, and the products were analyzed by GLC. As shown in Table 3, stilbenes (4, 5) were formed in good yields. The results support the above assumption. Formation of 5 was selective only when 1b was the substrate (entry 2), and 1c afforded predominantly 4 (entry 3). However, a reasonable explanation of these differences in stereoselectivity cannot be given at the present point.

On the basis of the results, we conclude that (i) decomposition with alkali of tosylhydrazones containing a leaving group on the adjacent carbon gives rise to triple bond formation

Table 2. Decomposition of tosylhydrazones (1a,b,c) with LiAlH₄.



a: R = H, b: R = COMe, c: R = COPh

Entry	Tosylhydrazone	Solvent and reaction conditions	Yield (%) ^a	
			4	5
1	1 <i>a</i>	Et ₂ O r.t. 1 h, reflux 1h	0	99.9
2	1 <i>b</i>	Et ₂ O r.t. 1 h, reflux 1h	5.7	82.9
3	1 <i>c</i>	Et ₂ O r.t. 1 h, reflux 1h	11.6	88.4
4	1 <i>a</i>	THF r.t. 1 h, reflux 1h	41.6	53.9
5	1 <i>b</i>	THF r.t. 1 h, reflux 1h	67.5	32.5
6	1 <i>c</i>	THF r.t. 1 h, reflux 1h	57.8	42.2
7	1a	Dioxane r.t. 1 h, reflux 1h	42.6	57.1
8	1 <i>b</i>	Dioxane r.t. 1 h, reflux 1h	55.6	32.8
9	1c	Dioxane r.t. 1 h, reflux 1h	32.6	61.6

^aGLC yields.

Can. J. Chem. Downloaded from www.nrcresearchpress.com by UNIVERSITAT DE GIRONA on 11/14/14 For personal use only.

Table 3. Decomposition of tosylhydrazones (1a,b,c) with NaBH₄.



a: R = H, *b*: R = COMe, *c*: R = COPh

Entry	Tosylhydrazone	Solvent and reaction conditions	Yield $(\%)^a$	
			4	5
1	1a	Dioxane r.t. 1 h, reflux 1h	49.5	38.8
2	1 b	Dioxane r.t. 1 h, reflux 1h	3.6	96.4
3	1 <i>c</i>	Dioxane r.t. 1 h, reflux 1h	72.4	20.0



through the sequential pathway, as shown in Scheme 1 (route c), and (ii) treatment with metal complex hydrides yields alkenes resulting form 1,2-elimination between the incipient carbanion and the leaving group (Schemes and 2 and 3).

Experimental

Melting points were uncorrected. GLC analysis was carried out using a Hitachi 263-50 gas chromatograph and D-7500 integrator (Quadrex bonded fused silica capillary column methyl silicone (0.53 mm i.d. \times 10 m \times 3.0 mm) at 205°C; injector temperature, 180°C; detector temperature, 220°C; carrier gas, N₂; flow rate, 13.0 mL/min) for *cis*-stilbene (4) (retention time, 2.54 min), diphenylacetylene (3) (retention time, 3.78 min), *trans*-stilbene (5) (retention time, 4.34 min), desoxybenzoin (2) (retention time 4.51 min), and benzoin (retention time 5.63 min). Preparative TLC was performed on Merck silica gel 60 PF₂₅₄, being developed with a 1:1 mixture of benzene and hexane for 2 (R_f 0.33) and 3 (R_f 0.92), and also with hexane for 4 (R_f 0.53) and 5 (R_f 0.42). The products were identified by direct comparison with authentic samples prepared by the usual methods.

Preparation of tosylhydrazones (1a,b,c)

A solution of benzoin (2.5 g, 11.80 mmol) and tosylhydrazine (2.2 g, 11.81 mmol) in EtOH (30 mL) was refluxed for 4 h. EtOH was evaporated under reduced pressure, and the residue crystallized after standing overnight. Recrystallization from MeOH gave colorless needles of 1*a*, mp 145–145.5°C. Tosylhydrazones of benzoin acetate (1*b*, mp 127–129°C) and benzoin benzoate (1*c*, mp 153–154.5°C) were prepared in the same manner.

Decomposition of tosylhydrazones (1a,b,c) with sodium ethylene glycolate in ethylene glycol

Tosylhydrazone (1*a*, 1*b*, or 1*c*, 2.6 mmol) was added to a solution of Na metal (60 mg, 2.61 mmol) in ethylene glycol (10 mL), and the solution was refluxed for 40 min. The cooled reaction mixture was diluted with water (50 mL), extracted with ether (50 mL), and the ethereal layer was washed successively with saturated brine (10 mL), water (10 mL), and then dried over anhydrous Na₂SO₄. After evaporation of the solvent, the residue was subjected to GLC analysis and to preparative TLC for isolation and identification of the products.

Decomposition of tosylhydrazones with NaOMe in diethyleneglycol diethyl ether

A solution of NaOMe (141 mg, 2.51 mmol) and tosylhydrazone (1*a*, 1*b*, or 1*c*, 2.61 mmol) in diethyleneglycol diethyl ether (10 mL) was refluxed for 40 min. The reaction mixture was cooled, diluted with water (50 mL), and extracted with ether (50 mL). The extract was washed with water (5 \times 10 mL), dried over anhydrous Na_2SO_4 , and the solvent was evaporated. The residue was subjected to GLC analysis and to preparative TLC for isolation and identification of the products.

Decomposition of tosylhydrazones with LiAlH₄

A suspension of tosylhydrazone (1*a*, 1*b*, or 1*c*, 2.61 mmol) and LiAlH₄ (100 mg, 2.64 mmol) in an appropriate solvent (30 mL) was stirred at room temperature for 1 h and then refluxed for 1 h. The excess LiAlH₄ was decomposed (24) by the successive addition of water (1 mL), 15% NaOH solution (1 mL), and water (3 mL). The precipitate that formed was filtered off, and the filtrate was extracted with ether (50 mL). The ethereal extract was washed with water (10 mL), dried over anhydrous Na₂SO₄, and the ether was evaporated. The residue was subjected to GLC analysis and to preparative TLC for isolation and identification of the products.

Samples of 4 and 5 were recovered unchanged after being subjected to the above reaction conditions.

Decomposition of tosylhydrazones with NaBH₄

A solution of tosylhydrazone (1*a*, 1*b*, or 1*c*, 2.61 mmol) and NaBH₄ (100 mg, 2.65 mmol) in dioxane (30 mL) was stirred at room temperature for 1 h and then refluxed for an additional 2 h. The excess reagent was decomposed with acetic acid. The reaction mixture was made alkaline with 5% Na₂CO₃ solution, and then extracted with ether (50 mL). The ethereal layer was washed with water (10 mL), and then dried over anhydrous Na₂SO₄. The solvent was evaporated and the residue was subjected to GLC analysis and to preparative TLC.

Samples of **4** and **5** were recovered unchanged after being subjected to the above experimental conditions.

Acknowledgement

We thank Professor Shoji Eguchi of Nagoya University for helpful discussion.

References

- 1. W.R. Bamford and T.R. Stevens. J. Chem. Soc. 4735 (1952).
- 2. R.H. Shapiro. Org. React. (NY), 23, 405 (1975), and literature cited therein.
- 3. R.M. Adlington and G.M. Barrett. Acc. Chem. Res. 16, 55 (1983), and literature cited therein.
- 4. R.H. Shapiro and M.H. Heath. J. Am. Chem. Soc. 89, 5734 (1967).
- 5. T. Ogata, K. Kawata, T. Oshikawa, H. Yoshida, and S. Inokawa. Nippon Kagaku Kaishi, 1370 (1988).
- 6. W. Kirmse and U. Mrotzeck. Chem. Ber. 121, 485 (1988).
- 7. A.A. Frimer, J. Weiss, and Z. Rosental. J. Org. Chem. **59**, 2518 (1994).
- P.K. Freeman, A.M. Tafesh, and B.E. Clapp. J. Org. Chem. 54, 782 (1989).
- 9. H. Tomioka, Y. Ohtawa, and S. Murata. J. Chem. Soc. Perkin Trans. 1, 1864 (1989).
- P.K. Freeman, J.C. Danino, B.K. Stevenson, K. Brian, and G.E. Clapp. J. Org. Chem. 55, 3887 (1990).
- 11. M.E. Jung and A. Hagiwara. Tetrahedron Lett. 32, 3025 (1991).
- B. Miller, X. Shi, G. Grosu, and R. Zhou. J. Org. Chem. 58, 2320 (1993).
- 13. C.O. Kappe, C.T. Pedersen, J. Catel, and Y. Mollior. J. Chem. Soc. Perkin Trans. 2, 351 (1994).
- 14. L. Caglioti and M. Magi. Tetrahedron Lett. 1261 (1982).
- 15. L. Caglioti and M. Magi. Tetrahedron, 19, 1127 (1963).

Iwadare et al.

- 16. L. Caglioti. Tetrahedron, 22, 487 (1966).
- 17. R.O. Hutchins. C.A. Milewski, and B.E. Marynoff. J. Am. Chem. Soc. 95, 3662 (1973).
- 18. S.J. Cristol and J.K. Harrington. J. Org. Chem. 28, 1413 (1983).
- 19. T. Iwadare, I. Adachi, M. Hayashi, A. Matsunaga, and T. Kitai. Tetrahedron Lett. 4447 (1969).
- 20. P. Wieland. Helv. Chim. Acta, 53, 171 (1970).

- 21. A. Hassner and R.H. Reuss. J. Org. Chem. 39, 171 (1959).
- 22. L. Freedman and H. Schechter, J. Am. Chem. Soc. 81, 5512 (1959).
- 23. M. Fischer, Z. Pelah, D.H. Williams, and C. Djerassi. Chem. Ber. 98, 3236 (1985).
- 24. V.M. Micozic and M.L. Mihailovic. J. Org. Chem. 18, 1190 (1953).