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Formal dipolar cycloaddition of allylsilanes to *o*-quinonoid compounds: a convenient route to benzofused and spirofused heterocycles†

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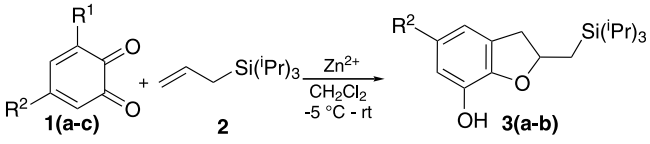
Abstract—Formal dipolar cycloaddition of allylsilanes to *o*-benzoquinones proceeds in a [2+3] manner affording dihydrobenzofurans. With isatins [3+2] annulation of the keto carbonyl occurs yielding spiro-oxindole derivatives.

Quinonoid compounds have assumed much importance since they have found application as pharmaceuticals, hormones, and pigments as well as playing very crucial roles in photosynthesis and electron transport chains. They are also versatile building blocks in organic synthesis by virtue of their multiple reactivity profiles.[1] Our studies have uncovered some novel reaction pathways of *o*-quinones, especially in the area of cycloaddition.[2] In this context it was of interest to probe the reactivity of allylsilanes, versatile silicon stabilized nucleophiles,[3] towards *o*-quinonoid compounds with their different electrophilic sites,[4] both from the synthetic and mechanistic standpoints. Herein we disclose our preliminary results on the Lewis acid-promoted addition of allyltriisopropylsilane to two classes of *o*-quinonoid compounds, viz., *o*-benzoquinones and isatins.[5] To the best of our knowledge, no reaction of allylsilanes with *o*-benzoquinones has been reported previously.

Addition of allyltriisopropylsilane to 4-*tert*-butyl-1,2-benzoquinone promoted by ZnI_2 constituted our initial experiment. In the event, a facile [2+3] annulation by the allylsilane occurred affording the dihydrobenzofuran derivative **3a**[6] in good yield (Scheme 1). 1,2-Benzoquinones **1(b–c)** behaved analogously giving the corresponding adducts (Table 1).

Mechanistically, the reaction may be viewed as a two-step process, an initial addition of the allylsilane to the Lewis acid complexed *o*-quinone moiety and the subsequent quenching of the β-silylcation. The initial addition occurs in a 1,6-fashion and the β-silylcation so formed is quenched by the quinone carbonyl to afford **3a**, as depicted in Scheme 2.[7]

Our studies on the reactivity of isatins started with addition of allyltriisopropylsilane to *N*-methylisatin leading to the interesting spiro-heterocyclic system **5a**. It is worth mentioning that isatins are useful precursors for spiro-oxindoles, which are found in a number of biologically interesting molecules.[8] Initial screening studies revealed that $SnCl_4$ is the Lewis acid of choice for this transformation. The reaction appears to be



Scheme 1.

Table 1.

Entry	Substrate	Time	Yields (%)
1a	$R^1=H$, $R^2={}^t$Bu	1.5	84
1b	$R^1=R^2={}^t$Bu	4.5	76
1c	$R^1=H$, $R^2=Tr$	2.0	56

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† This paper is dedicated with respect and affection to Professor Gilbert Stork on the occasion of his 80th birthday, whose original contributions have enriched organic chemistry forever.

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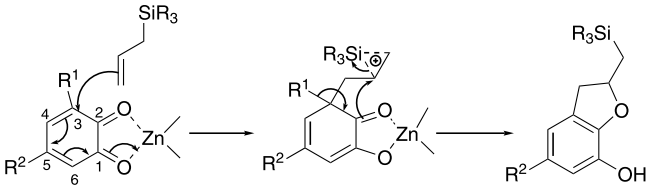
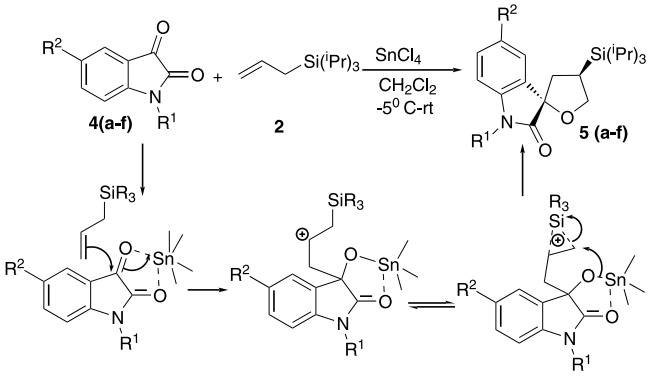


Scheme 2.

general and useful yields of the spiro-adducts were obtained with various isatin derivatives (Scheme 3, Table 2).[9] The relative stereochemistry of the silyl substituent with respect to the amide group was found to be *cis* by single crystal X-ray analysis (Fig. 1).

In summary, formal dipolar cycloaddition of allylsilanes with *o*-quinones occurs in a [2+3] fashion whereas with isatin derivatives, [3+2] annulation was observed. The products are dihydrobenzofuran and spirooxindole derivatives; such motifs are encountered in a number of naturally occurring molecules of interest. Further studies employing other allylsilanes, and to explore the chemistry of the adducts formed, are currently underway.



Scheme 3.

Table 2.

Entry	Substrate	Time (h)	Yield (%)
4a	R^1 = Me, R^2 = H	3	91
4b	R^1 = R^2 = H	3	74
4c	R^1 = CH_2Ph, R^2 = H	4	68
4d	R^1 = Ph, R^2 = H	4	70
4e	R^1 = Ts, R^2 = H	6	62
4f	R^1 = H, R^2 = Br	4	66

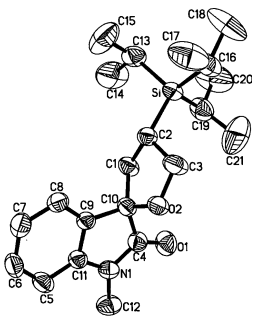


Figure 1. Single crystal X-ray structure of **5a**.

Acknowledgements

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References

1. *The Chemistry of Quinonoid Compounds*; Patai, S.; Rappoport, Z., Eds.; John Wiley and Sons: New York, 1988; Vol. 2, Parts I and II.
2. (a) Nair, V.; Kumar, S. *J. Chem. Soc., Chem. Commun.* **1994**, 1341; (b) Nair, V.; Kumar, S. *Synlett* **1996**, 1143; (c) Nair, V.; Radhakrishnan, K. V.; Nair, A. G.; Bhadbhade, M. M. *Tetrahedron Lett.* **1996**, *37*, 5623; (d) Nair, V.; Vinod, A. U.; Nair, J. S.; Sreekanth, A. R.; Rath, N. P. *Tetrahedron Lett.* **2000**, *41*, 6675; (e) Nair, V.; Mathew, B. *Tetrahedron Lett.* **2000**, *41*, 6919; (f) Nair, V.; Rajesh, C.; Dhanya, R.; Vinod, A. U. *Tetrahedron Lett.* **2001**, *42*, 2045.
3. (a) Hosomi, A.; Sakurai, H. *Tetrahedron Lett.* **1977**, *18*, 4041; (b) Hosomi, A. *Acc. Chem. Soc.* **1988**, *21*, 200; (c) Fleming, I. In *Comprehensive Organic Synthesis*; Trost, B. M.; Fleming, I.; Heathcock, C. H., Eds.; Pergamon: Oxford, 1991; Vol. 2, p. 563; (d) Fleming, I. *Org. React.* **1994**, *33*, 1; (e) Masse, C. E.; Panek, J. S. *Chem. Rev.* **1995**, *95*, 1293; (f) Knölker, H.-J.; Foitzik, N.; Goesmann, H.; Graf, R. *Angew. Chem., Int. Ed. Engl.* **1993**, *32*, 1081; (g) Akiyama, T.; Yamanaka, M. *Synlett* **1996**, 1095; (h) Ipaktschi, J.; Heydari, A. *Angew. Chem., Int. Ed. Engl.* **1992**, *31*, 313; (i) Murphy, W. S.; Neville, D. *Tetrahedron Lett.* **1997**, *38*, 7933; (j) Naruta, Y.; Uno, H.; Maruyama, K. *Tetrahedron Lett.* **1981**, *22*, 5221.
4. *p*-Quinonoid compounds have been studied extensively in this regard, however, *o*-quinonoid species, especially *o*-benzoquinones, have attracted only limited attention. The only notable exception being the Thiele–Winter acetoxylation, McOmie, J. F. W.; Blatchly, J. M. *Org. React.* Wiley: New York, 1972; Vol. 19, p. 199. For the addition of allyltin to *o*-benzoquinones, see, Maruyama, K.; Takuwa, A.; Naruta, Y.; Satao, K.; Soga, O. *Chem. Lett.* **1981**, 47.
5. Isatins can be considered as quinones according to Trost's definition of non-benzenoid quinones as any dicarbonyl species whose two electron reduction product would generate a non-benzenoid aromatic system, Turney, T. A. In *The Chemistry of Quinonoid Compounds*; Patai, S., Ed.; John Wiley and Sons: New York, 1974; Part 2, p. 857. However, the most important aspect taken into consideration here is the fact that isatins are very useful synthetic intermediates and find increasing application in organic synthesis.
6. Data for **3a**: IR (cm^{-1}): 3424, 2946, 2866, 1616, 1492, 1183, 1050, 882. ^1H NMR (δ): 6.74 (s, 1H), 6.71 (s, 1H), 5.07–4.99 (m, 1H), 4.89 (1H, *exchangeable with* D_2O), 3.32 (dd, 1H, J=14.9, 8.4 Hz), 2.87 (dd, 1H, J=14.9, 8.2 Hz)

1.44–1.31 (m, 2H), 1.26 (s, 9H), 1.09 (d, 18H, $J=4.5$ Hz), 0.87–0.83 (m, 3H). ^{13}C NMR: 144.62, 143.78, 139.26, 127.46, 113.36, 112.10, 83.42, 39.86, 34.37, 31.61, 18.87, 18.08, 11.40.

7. Regarding the site of attack by the nucleophile, no specific pattern emerges from the literature. All, 1,2-, 1,4- and 1,6-additions have precedence. In the present case with **1b**, it was surprising to note that 1,6-addition occurs at the more hindered of the two positions available. This may be due to the ability of C-3 to accommodate the incipient +ve charge better.
8. For a review on the chemistry of isatin, see, da Silva, J. F. M.; Garden S. J.; Pinto, A. C. *J. Braz. Chem. Soc.* **2001**, *12*, 273. For dipolar cycloaddition of isatins, see: Nair, V.; Sheela, K. C.; Sethumadhavan D.; Bindu S.; Rath N. P.; Eigendorf G. K. *Synlett* **2001**, 272.
9. Data for **5a**: IR (cm^{-1}): 2946, 2871, 1725, 1619, 1475, 1375, 1249, 1005, 773, 673. ^{1}H NMR: (δ) 7.27 (t, 2H, $J=7.2$ Hz), 7.03 (d, 1H, $J=7.2$ Hz), 6.78 (d, 1H, $J=7.2$ Hz), 4.42–4.36 (m, 1H), 4.29 (dd, 1H, $J=12.4$, 8.2 Hz), 3.17 (s, 3H), 2.55–2.46 (m, 1H), 2.24 (dd, 1H, $J=12.4$, 7.2 Hz), 2.05–1.91 (m, 1H), 1.13 (overlapping doublet and multiplet, 21H). ^{13}C NMR: 178.43, 143.28, 139.02, 129.17, 122.94, 122.89, 108.03, 81.76, 73.59, 40.21, 26.04, 25.89, 18.99, 11.34.