

## An Interpretation of the Diastereofacial Reactivity of (*E*)-3-Trimethylsilyloxybuta-1,3-dien-1-yl 2,3,4,6-Tetra-*O*-acetyl- $\beta$ -D-glucopyranoside based upon the *exo*-Anomeric Effect

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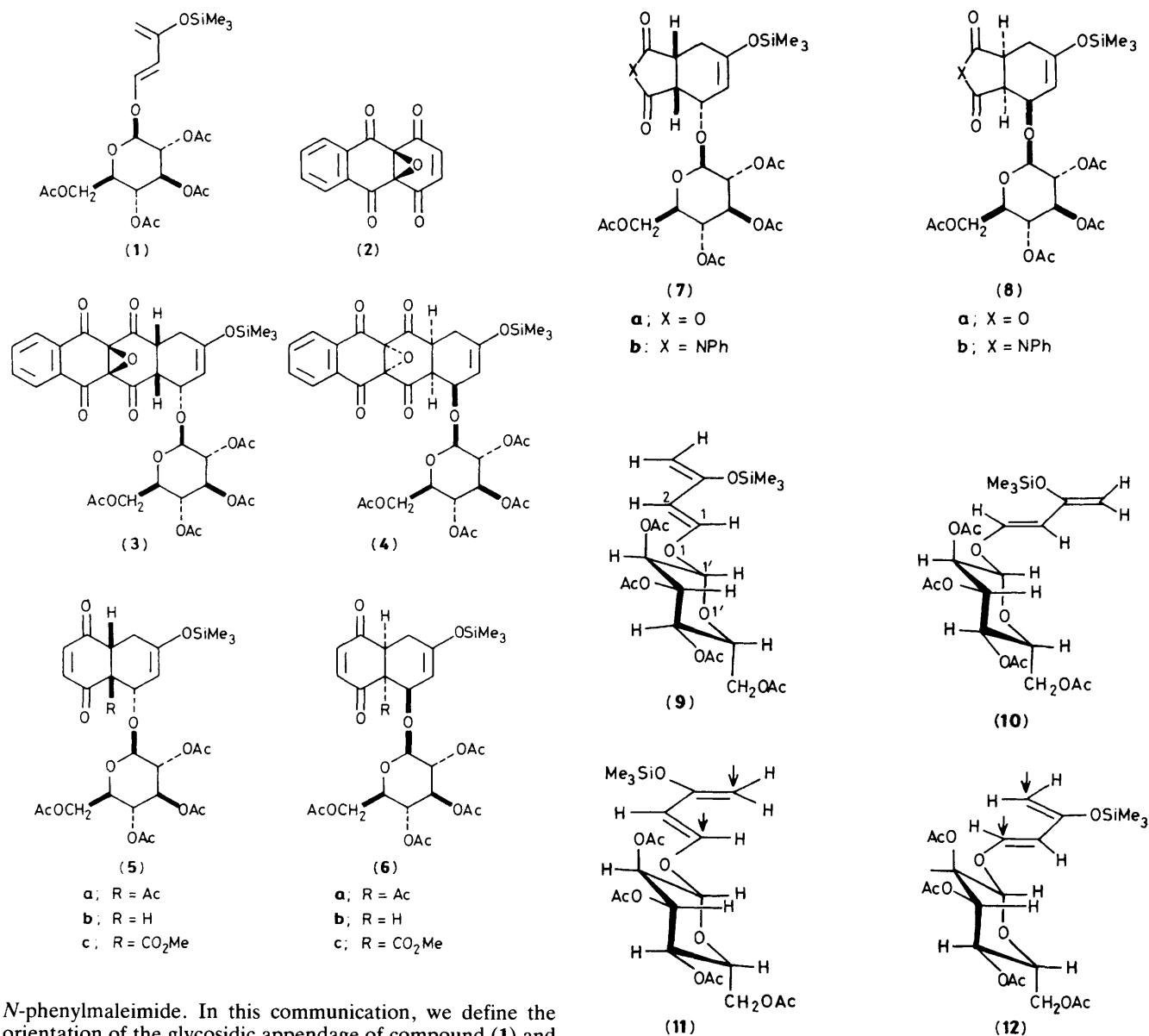
The geometry of the title diene has been probed by X-ray crystallography and by nuclear Overhauser effect difference spectroscopy; its diastereofacial discrimination in cycloadditions is ascribed to a reacting conformation determined by the *exo*-anomeric effect.

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Recently, we reported that the diene (**1**)<sup>1</sup> displayed a notable diastereofacial discrimination in cycloadditions with cyclic dienophiles.<sup>2</sup> Thus, in benzene at ambient temperature, it

afforded a 2.5 : 1 mixture of the cycloadducts (**3**) and (**4**) with the epoxy-tetraone (**2**), a 3 : 1 mixture of the cycloadducts (**5a**) and (**6a**) with 2-acetyl-*p*-benzoquinone, 8 : 1 mixtures of the cycloadducts (**5b,c**) and (**6b,c**) with *p*-benzoquinone and 2-methoxycarbonyl-*p*-benzoquinone, and 6 : 1 mixtures of the cycloadducts (**7a,b**) and (**8a,b**) with maleic anhydride and

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*N*-phenylmaleimide. In this communication, we define the orientation of the glycosidic appendage of compound (1) and propose an explanation for the diastereoselective Diels–Alder reactions.

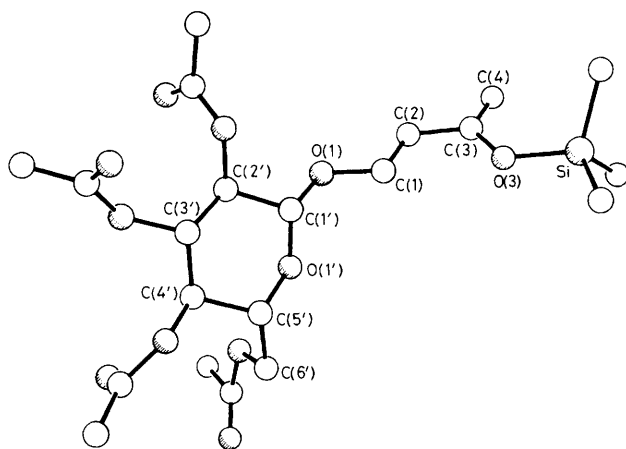
The *X*-ray structure of compound (1),<sup>‡</sup> which is shown in Figure 1, reveals that the diene moiety is planar and adopts the *s-trans* geometry. Of special interest is the disposition of the butadienyl moiety with respect to the sugar. Thus the C(1)–O(1)–C(1') bond angle of  $117.2(6)^\circ$  together with the C(1)–O(1)–C(1')–O(1') torsion angle of  $-87.0(7)^\circ$  suggest that O(1) is  $\text{sp}^2$  hybridised and that its *p*-orbital non-bonded electron pair is available for overlap with both a  $\pi^*$  orbital of the diene function and the  $\sigma^*$  orbital of the C(1')–O(1') bond.

<sup>‡</sup> Crystal data:  $\text{C}_{21}\text{H}_{32}\text{O}_{11}\text{Si}$ ,  $M = 488.6$ , orthorhombic,  $a = 7.883(2)$ ,  $b = 10.988(2)$ ,  $c = 30.055(7)$  Å,  $U = 2603$  Å<sup>3</sup>, space group  $P2_12_12_1$ ,  $Z = 4$ ,  $D_c = 1.25$  g cm<sup>-3</sup>,  $\mu(\text{Cu-K}\alpha) = 12$  cm<sup>-1</sup>. Data were measured on a Nicolet R3m diffractometer with  $\text{Cu-K}\alpha$  radiation (graphite monochromator) using  $\omega$ -scans. The structure was solved by direct methods and refined anisotropically to give  $R = 0.065$ ,  $R_w = 0.069$  for 1458 independent observed reflections [ $|F_o| > 3\sigma(|F_o|)$ ,  $\theta < 58^\circ$ ]. Atomic co-ordinates, bond lengths and angles, and thermal parameters have been deposited at the Cambridge Crystallographic Data Centre. See Notice to Authors, Issue No. 1, 1986.

This conformational arrangement is in accord with expectations<sup>§</sup> based upon the *exo*-anomeric effect.<sup>3</sup>

The geometry of compound (1) in deuteriochloroform solution was probed by nuclear Overhauser effect difference (n.O.e.d.) spectroscopy. Thus irradiation of C(1')H [a doublet ( $J$  8 Hz) at  $\delta$  4.77] caused a 13% enhancement of C(1)H [a doublet ( $J$  12 Hz) at  $\delta$  6.66] and a 4% enhancement of C(2)H [a doublet ( $J$  12 Hz) at  $\delta$  5.63]. When C(1)H and C(2)H were irradiated, C(1')H showed respective enhancements of 6% and 3%. On the basis of these results, it is inferred that compound (1) is present in deuteriochloroform as a mixture of conformers. The major conformer, *i.e.* (9), is believed to be

<sup>§</sup> In glycopyranosides in which the aglycone is linked by an  $\text{sp}^3$ -hybridised C, the aglycone O–C bond prefers to be *syn*-clinal to the ring O and the anomeric H (*i.e.* the torsion angle is *ca.*  $-60^\circ$ ); nevertheless, the glycosidic O still displays a significant amount of trigonal character (see ref. 3). As the  $\text{sp}^2$  character of the glycosidic O increases, the torsion angle is expected to approach  $-90^\circ$ .



**Figure 1.** The molecular structure of compound (1). The C(1)–O(1)–C(1') bond angle is 117.2(6)° and the C(1)–O(1)–C(1')–O(1') torsion angle is –87.0(7)°; selected bond lengths C(1')–O(1') 1.419(8), C(1')–O(1) 1.380(8), O(1)–C(1) 1.371(9), C(1)–C(2) 1.291(10), C(2)–C(3) 1.429(13), C(3)–C(4) 1.339(13) Å (e.s.d.s in parentheses).

comparable to that present in the crystal state; the minor conformer is considered to possess the structure (10).¶

To participate in a Diels–Alder reaction, a diene must adopt an *s-cis* geometry. In principle therefore, compound (1) may react by way of the conformers (11) and/or (12). To avoid *syn* 1,3-interactions with the C(1')–O(1') bonds, a dienophile is

¶ This conformer is also expected to be stabilised by the *exo*-anomeric effect.

expected to favour addition to the 'top faces' of conformers (11) and (12) (from the direction indicated by the arrows). The former event would lead to the cycloadducts (3), (5a–c), and (7a,b) whereas the latter pathway would give rise to the cycloadducts (4), (6a–c), and (8a,b). We therefore infer that the major cycloaddition pathway of the diene (1) involves attack of the dienophile to the least-hindered 'top face' of the conformer (11).||

Although the *exo*-anomeric effect is a well-documented phenomenon, hitherto it has only been used to explain the conformational properties of glycosides. To our knowledge, the present work represents the first demonstration that the effect can be associated with important chemical consequences.

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|| Ground-state geometries need not, of course, be relevant to transition-state geometries. However, the *exo*-anomeric effect is expected to operate (and may well be augmented) in the transition states of the cycloaddition reactions.