

## Manuscript Style Guide

### Synthesis of highly substituted allenylsilanes by alkylidenation of silylketenes 1

Sharon P. Marsden<sup>\*1</sup> and Pascal C. Ducept<sup>2</sup> 2

Address: <sup>1</sup>School of Chemistry, University of Leeds, Leeds LS2 9JT, United Kingdom and

<sup>2</sup>Department of Chemistry, Imperial College London, London SW7 2AY, United Kingdom

Email: Sharon P. Marsden - s.p.marsden@leeds.ac.uk

\* Corresponding author

- 
- 1 The title of an article should be clear, concise and comprehensible to all readers with the purpose of quickly identifying the focus of the reported work. It should be brief and contain the most important keywords for search engine optimization. The use of capitals should be restricted to the first word and proper nouns. As far as possible abbreviations should be avoided.
- 2 For all authors who have made substantial contributions to the work, first name, middle initial(s) and last (family) name must be provided. Below this information the institutional address should be written in a separate line in the following format: department, organization, street/P.O. box, city/town and zip code/postal code, country. If several affiliations need to be mentioned, consecutive Arabic numerals should precede the address and these numerals must also be placed as superscript after the respective author's name. At least one author must be designated with an asterisk as the person to whom correspondence should be addressed. The full name and the email address of the corresponding author(s) separated by a hyphen should be given in a new paragraph following the affiliation. Finally, the meaning of the asterisk must be explained.

## Abstract

3

Allenylsilanes are useful intermediates in organic synthesis. An attractive, convergent but little used approach for their synthesis is the alkylidenation of stable silylketenes. Reactions thus far have been limited to the use of unsubstituted silylketenes (or equivalents) with stabilised or semi-stabilised ylides only. The current study explores the reactions of substituted ketenes prepared through rhodium(II)-mediated rearrangement of silylated diazoketones. A range of novel 1,3-disubstituted and 1,3,3-trisubstituted allenylsilanes were prepared using stabilised and semi-stabilised ylides. Alkylidenation with non-stabilised phosphorus ylides was not viable, but the use of titanium-based methylenating reagents was successful, allowing access to 1-substituted allenylsilanes. Many novel allenylsilanes may be accessed by alkylidenation of substituted silylketenes. Importantly, for the first time, simple methylenation of silylketenes has been achieved using titanium carbenoid-based reagents.

4

## Keywords

5

allenylsilanes; rhodium(II) octanoate-mediated rearrangement; silylketenes; titanium carbenoids; ylide

3

The abstract should summarize the context and purpose of the study, the main findings and provide a brief summary and potential implications. Abbreviations should be used sparingly in the abstract. Citations and references should not be given in abstracts. Only standard characters and those that can be included using the font type "symbol" are allowed.

4

Common fonts (Arial, Times, Helvetica, Courier) should be used and words should not be hyphenated at line breaks. The entire manuscript should be formatted as single column text using double line spacing. Greek and other special characters should preferably be included using the font type "symbol".

5

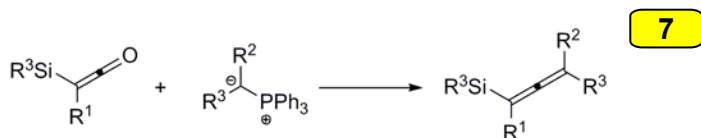
Five keywords in alphabetical order describing the main topics of the paper should appear below the abstract for indexing purpose. They should be separated by a semicolon.

## Introduction

6

Allenylsilanes are versatile intermediates for organic synthesis [1,2]. They have two main modes of reactivity: firstly, as propargyl anion equivalents in thermal [3,4] or Lewis acid-mediated [5,6] addition to carbonyls, acetals and imines, and secondly as three-carbon partners in [3+2] annulation reactions. Thus, reaction with aldehydes [7], imines/iminiums [7,8], enones [9-11] and nitrosyl cations [12] leads to dihydrofurans, dihydropyrroles, cyclopentenones and isoxazoles respectively [13]. In most cases the silicon is retained in the final product and can be used as a handle for further synthetic elaboration.

Amongst the myriad methods to prepare allenylsilanes [1,14], an attractive disconnection is to consider a Wittig-type alkylidenation of a silylketene (Figure 1).



**Figure 1:** Alkylidenation approach to the synthesis of allenylsilanes.

6

The introduction section should be written from the standpoint of researchers without specialist knowledge in that area. It should clearly state the background of the research, as well as its purposes and significance, and should include a brief statement of what is being reported in the article.

7

All figures and schemes must be embedded in the manuscript text after the paragraph where they are first mentioned. Diagrams, graphs, spectra, micrographs or other types of illustrations should be presented in the manuscript as a figure. The designation scheme should be used primarily for reaction schemes. The following guidelines must be considered when preparing figures and schemes:

- Figures and schemes are consecutively numbered with Arabic numerals in the order they are first cited in the manuscript text (i.e. Figure 1, Figure 2, etc.).
- The caption of figures and schemes should be positioned directly below the corresponding graphic. The caption should comprise the word **"Figure"** or **"Scheme"** followed by the corresponding figure or scheme number and a colon, all in boldface font, followed by a detailed description of the contents.
- Each figure or scheme should comprise only a single file. Multi-panel figures with individual parts, a, b, c, etc., should be included as a single composite file.
- Each figure or scheme must fit a width of 8.0 cm (single column) or 16.0 cm (double column) and should be prepared accordingly. The maximum height is 23.0 cm (including the legend).
- Figures and schemes should be cropped as closely as possible to minimize white space surrounding the graphic.
- Individual compounds must be numbered with boldface Arabic numerals in the order in which the compounds are first mentioned in the text. Boldface lower case letters may be added to distinguish compounds that differ only in the identity of substituents.

This convergent approach potentially allows for tremendous variation in substitution pattern at both termini of the allenylsilane, yet has been little exploited thus far. Ruden first demonstrated that the stabilised phosphorane carbethoxymethylenetriphenylphosphorane underwent Wittig condensation with trimethylsilylketene at sub-ambient temperature in high yield, but found that non-stabilised phosphoranes led to complex mixtures of products [15]. Other workers later extended this chemistry to include a wider range of stabilised phosphoranes, but attempts to promote the reaction with semi-stabilised ylides such as benzylidenetriphenylphosphorane were unsuccessful unless bis(trialkylsilyl)ketenes were used as substrates [16,17]. Thus, only 3-substituted and 3,3-disubstituted allenylsilanes have thus far been accessed by alkylidenation of silylketenes, whilst no reports of the successful introduction of non-stabilised ylide equivalents have been forthcoming.

A second impediment to the generalisation of the approach has been the paucity of methods for preparing substituted silylketenes [18,19]. Methods based upon the thermolysis of siloxyalkynes [20] and dehydrohalogenation of substituted  $\alpha$ -silyl acid halides [21,22] have not found general application. We recently reported a mild and functional group tolerant approach to substituted silylketenes based upon a rhodium-mediated formal Wolff rearrangement of silylated diazoketones [23]. Related photolytic approaches also hold some promise [24-27]. These methods allow access for the first time to a wide range of substituted silylketenes which will allow the chemistry of these fascinating persistent ketenes [18] to be better delineated.

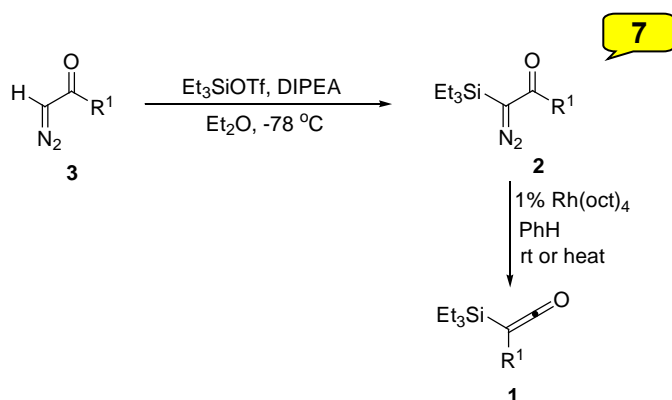
In this paper we outline the synthesis of 1,3-disubstituted and 1,3,3-trisubstituted allenylsilanes by the condensation of stabilised and semi-stabilised ylides with substituted silylketenes, and report for the first time the methylenation of silylketenes to give 1-substituted allenylsilanes using titanium-based methodology.

8

The references should be inserted at the appropriate location in the text by writing the reference number in square brackets. Multiple citations should be separated by commas within the square brackets. For sequential references, a range should be given. In general the reference should appear before the punctuation mark and not after.

## Results and Discussion

Our investigations began with the preparation of substituted silylketenes **1** as substrates for the alkylidenation chemistry. This was carried out under our previously reported conditions for rhodium(II) octanoate-mediated rearrangement of silyl diazoketones **2** [23], which in turn were prepared by C-silylation of the parent diazoketones **3** with triethylsilyl triflate [28] (Scheme 1, Table 1). It should be noted that while the alkyl-substituted silylketenes are relatively stable and show little decomposition at room temperature over several days, the (hetero)aromatic-substituted silylketenes are much less robust and should be used quickly or stored in a freezer.



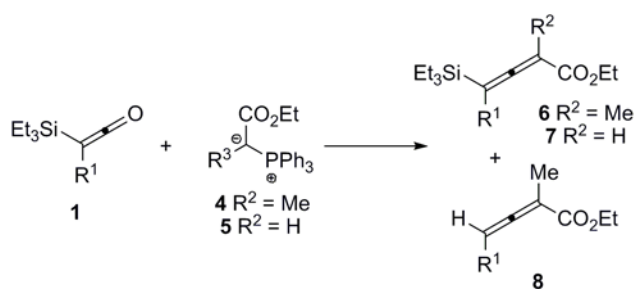
**Scheme 1:** Synthesis of substituted silylketenes **1**.

[...]

9

The results and discussion section should contain a description of the experimental results that substantiates the conclusions of the work. A comprehensible discussion which links the results to related investigations and to existing knowledge in the relevant field should follow. The sections may also be separated. The presentation of experimental details in this section should be kept to a minimum. Information already obvious in tables, figures or schemes should not be reiterated in the text if not necessary for any important discussion.

With the requisite silylketenes in hand, attention turned to their reaction with the carboethoxy-stabilised phosphoranes **4** and **5**. At the outset, it was by no means certain that these would react efficiently with substituted silylketenes **1** since it is well documented that nucleophiles attack silylketenes *anti* to the silicon [29], i.e. the phosphoranes would be approaching from the same side as the R<sup>1</sup>-substituent. Since in all previous examples this substituent has been a hydrogen atom, the extension to bulkier substituents could not be taken for granted. In the event, however, we were pleased to find that in nearly all cases the desired allenylsilanes were formed in moderate to excellent yield (Scheme 2, Table 2, see Supporting Information File 1 for full experimental data).



**Scheme 2:** Reaction of substituted silylketenes with ester-stabilised phosphoranes.

**10** Supporting information files may be referenced at an appropriate place in the section “Results and Discussion” or “Experimental” to allow the creation of a hyperlink in the full text version.

**Table 2:** Reaction of substituted silylketenes with ester-stabilised phosphoranes.

Entry	Ketene	Ylide	Temp (°C)	t (h)	Solvent	Yield 6/7 (8)
1	<b>1a</b>	<b>4</b>	80	24	PhH	54%
2	<b>1a</b>	<b>5</b>	rt	3	CH <sub>2</sub> Cl <sub>2</sub>	60%
3	<b>1b</b>	<b>4</b>	110	24	toluene	45%
4	<b>1b</b>	<b>5</b>	reflux	24	CH <sub>2</sub> Cl <sub>2</sub>	77%
5	<b>1c</b>	<b>4</b>	80	24	PhH	60%
6	<b>1c</b>	<b>5</b>	rt	6	CH <sub>2</sub> Cl <sub>2</sub>	81%
7	<b>1d</b>	<b>4</b>	110	48	toluene	22% <sup>a</sup>
8	<b>1d</b>	<b>5</b>	80	48	toluene	78%
9	<b>1e</b>	<b>4</b>	80	24	PhH	55% (7%)
10	<b>1f</b>	<b>4</b>	60	5	CH <sub>2</sub> Cl <sub>2</sub>	44% (3%)
11	<b>1h</b>	<b>4</b>	rt	6	CH <sub>2</sub> Cl <sub>2</sub>	0% (57%)
12	<b>1h</b>	<b>4</b>	50	1	CH <sub>2</sub> Cl <sub>2</sub>	7% (23%)
13	<b>1i</b>	<b>4</b>	rt	10	CH <sub>2</sub> Cl <sub>2</sub>	0% (67%)
14	<b>1i</b>	<b>5</b>	rt	2	CH <sub>2</sub> Cl <sub>2</sub>	98%
15	<b>1j</b>	<b>4</b>	80	12	PhH	74% (19%)

<sup>a</sup>60% of starting material recovered

11

All tables must be inserted in the manuscript text after the paragraph where they are first mentioned. Large datasets can be uploaded separately as supporting information files. The following guidelines must be considered when preparing tables:

- Tables are consecutively numbered with Arabic numerals in the order they are first cited in the manuscript text (i.e. Table 1, Table 2, etc.).
- Tables must be cell-based and thus should be created using the “Table object” in MS Word.
- Line returns and tabs should not be used within the cells.
- The caption should appear above the table with the word “**Table**” and corresponding Arabic table number and colon, all in bold font, followed by a short and concise description.
- All table columns must have a short and self-explanatory heading.
- Footnotes should be typed below the table using lower case letter designations. They should be referenced in the table with lower case superscript letters. The sequence of letters should proceed by row rather than by column.
- Each table must fit a width of 8 cm (single column) or 16 cm (double column) and should be prepared accordingly.
- Individual compounds must be numbered with boldface Arabic numerals in the order in which the compounds are first mentioned in the text. Boldface lower case letters may be added to distinguish compounds that differ only in the identity of substituents.
- Color and shading should not be used.

As expected, reactions with the more substituted ylide **4** were significantly slower than those with the parent ylide **5** (compare reaction temperatures and times, entries 1, 3 and 5 versus entries 2, 4 and 6). [...]

## Supporting Information 12

Supporting information features copies of  $^1\text{H}$  NMR spectra of silylated diazoketones **2** and silylketenes **1**, plus  $^1\text{H}$  and  $^{13}\text{C}$  NMR spectra of allenylsilanes **6**, **7**, and **14–19**.

Supporting Information File 1:

File Name: S1.pdf

File Format: PDF

Title: Experimental part

Supporting Information File 2:

File Name: S2.pdf

File Format: PDF

Title: NMR spectra of compounds **1,2,6** and **7**

Supporting Information File 3:

File Name: S3.pdf

File Format: PDF

Title: NMR spectra of compounds **14–19**

---

**12**

If supporting information files are provided, each should be described in this section of the manuscript, including the following information:

- a consecutive Arabic numeral in the order of the first mention in the manuscript text (e.g. Supporting Information File 1, Supporting Information File 2, etc.)
- the file name
- the file format (including the name and the URL link of an appropriate viewer if the format is unusual)
- a concise and descriptive title of 15 words maximum
- optional: a detailed description of the dataset.



## Acknowledgements

We acknowledge Prof. H. Vlassov for the helpful discussions of the results and J. Martin for assistance with the synthesis.

## Funding

The following sources of funding are acknowledged: National Natural Science Foundation of China (S.P.M.; Grant Nos. 51502240, 11674273, U1856203), Wellcome Trust (S.P.M., Award No. 094542/Z/12/Z, EPSRC (P.C.D.; Grant No. GR/L60135/01 (PCD)), and both authors thank the generous research funding from Pfizer for financial support.

## References

1. Porner, J. Product Subclass 32: Allenylsilanes. In *Science of Synthesis*; Fleming, I., Ed.; Georg Thieme Verlag: Stuttgart, 2002; Vol. 4, pp 669–683.
2. Masse, C. E.; Panek, J. S. *Chem. Rev.* **1995**, *95*, 1293–1316.
3. Jian, J.; Smith, D. T.; Weinreb, S. M. *J. Org. Chem.* **1995**, *60*, 5366–5367.
4. Weinreb, S. M.; Smith, D. T.; Jin, J. *Synthesis* **1998**, 509–521.
5. Danheiser, R. L.; Carini, D. J. *J. Org. Chem.* **1980**, *45*, 3925–3927.
6. Danheiser, R. L.; Carini, D. J.; Kwasigroch, C. A. *J. Org. Chem.* **1986**, *51*, 3870–3878.
7. [...]

13

In this section the authors can dedicate the article to a scientist of outstanding merit or acknowledge technical assistance and other contributions or advice from persons who are not coauthors.

14

In this section the authors can acknowledge the source(s) of financial support for the research reported in their article by naming the financially supporting body(s) followed by associated grant number(s) (if applicable). It is the responsibility of the corresponding author to provide the relevant funding information from all authors.

15

A complete list of all references should be provided at the end of the article with an individual reference number for each reference. All references must be numbered consecutively with Arabic numerals, in the order in which they are first cited in the text, followed by any references in tables or legends.

The references should be presented in a style consistent with the [ACS Style Guide](#) and should not contain any form of note or comment. If automatic numbering systems are used, the reference numbers must be finalized and the bibliography must be fully formatted before submission.