



## Trapping of Payne rearrangement intermediates with arylselenide anions



Michael E. Jung\*, Daniel L. Sun

Department of Chemistry and Biochemistry, University of California, Los Angeles, CA 90095-1569, United States

### ARTICLE INFO

#### Article history:

Received 26 October 2014

Revised 18 November 2014

Accepted 22 November 2014

Available online 27 November 2014

#### Keywords:

Epoxy alcohol opening

Aryl selenide anions

Payne rearrangement

Arylseleno diols

### ABSTRACT

The intermediate epoxy alcohols prepared via a Payne rearrangement can be trapped with arylselenide anions, giving mixtures of ring-opened products. The 1-arylseleno-2,3-diols are generally favored over the 3-arylseleno-1,2-diols in this process although the reaction of trisubstituted epoxyalcohols, for example, **17**, differs from those of disubstituted epoxyalcohols, for example, **21**.

© 2014 Elsevier Ltd. All rights reserved.

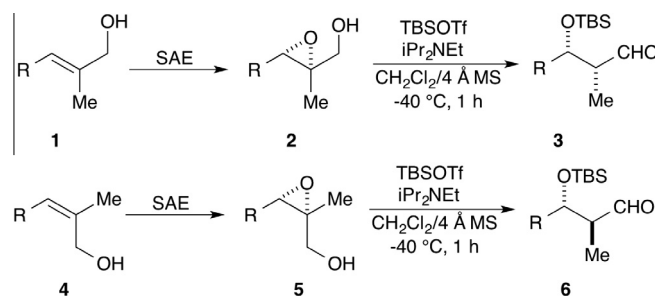
Several years ago we reported the rearrangement of epoxy alcohols and their silyl ethers using silyl triflates to produce silyl-protected aldol products in a process we termed the ‘non-aldol aldol’.<sup>1</sup> Although the epoxy alcohols **2** prepared using a Sharpless asymmetric epoxidation of the *E* 2-methyl allylic alcohols **1** gave very good yields of the aldol products **3**, the reaction of the epoxides **5** derived from the corresponding *Z* allylic alcohols **4** could be problematic due presumably to steric hindrance to the desired rearrangement, although conditions were found to produce the anti aldol products **6** (Scheme 1).<sup>2</sup> We wondered whether a longer sequence involving a double inversion process might allow us to obtain the anti aldol products **10** from the *E* epoxy alcohols **2** (Scheme 2). This would involve the trapping of the Payne rearrangement<sup>3</sup> equilibrium of **2** and **7** with a strong nucleophile to give **8**, followed by selective protection of the secondary alcohol and cyclization to the terminal epoxide **9** and then final Yamamoto rearrangement<sup>4</sup> to give the anti aldol product **10**. We report here our results of the trapping of the Payne rearrangement intermediates using aryl selenide anions.

In a beautiful approach to the synthesis of the alditols,<sup>5</sup> Sharpless and Masamune reported the interception of one of the intermediates of the Payne rearrangement with thiolates to give selectively the 1-thiophenyl-2,3-diols (Scheme 3). Thus treatment of the epoxy alcohol **11** with thiophenol and aq sodium hydroxide in dioxane afforded the product of selective opening of the intermediate rearranged epoxy alcohol **12** at the primary center to give

predominately the product **13**. Later Boeckman showed that this same process occurred with the methyl substituted epoxy alcohol **15** to give the diol **16** in an elegant synthesis of (–)-kromycin.<sup>6</sup> We decided to study the analogous rearrangement using arylselenide anions instead of the phenylthiolates. Herein we report the results of that investigation.

The epoxy alcohols were all prepared by an application of Sharpless asymmetric epoxidation<sup>7</sup> of the readily available *E*- and *Z*-allylic alcohols. We decided to test one substrate in order to find the best conditions for the rearrangement-trapping process (Scheme 4) and therefore prepared the known epoxy alcohol **17**.<sup>1a</sup>

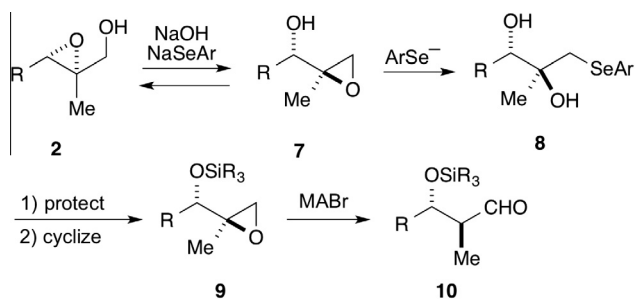
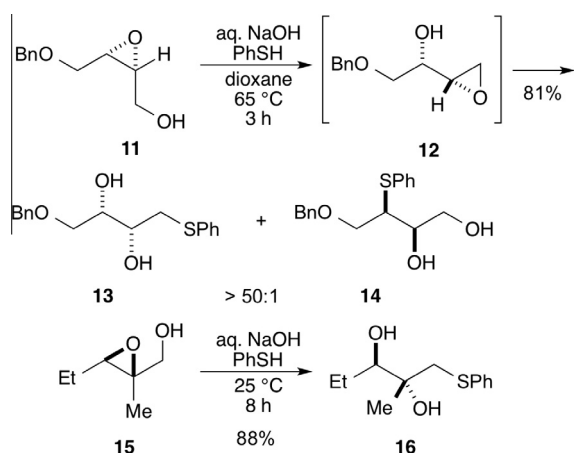
Since the preference for opening the terminal epoxide **18** over the internal epoxide **17** is due to steric hindrance, we decided to use a very sterically hindered arylselenide. Thus the known



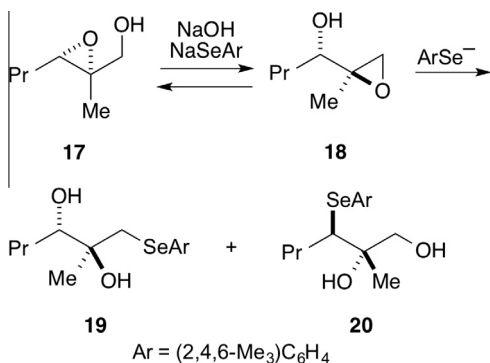
Scheme 1. Non-aldol aldol reaction to give **3** and **6**.

\* Corresponding author.

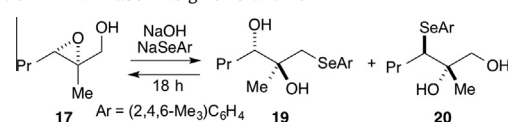
E-mail address: [jung@chem.ucla.edu](mailto:jung@chem.ucla.edu) (M.E. Jung).

Scheme 2. Alternative route for anti aldol products **10**.Scheme 3. Selective trapping of the Payne intermediate **12**.

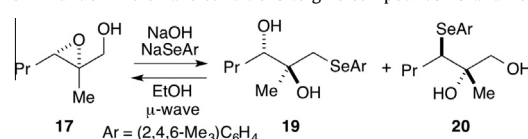
bis(2,4,6-trimethylphenyl)diselenide (dimesityl diselenide)<sup>8</sup> was reduced with sodium borohydride to give the mesitylselenide anion. To a solution of the epoxy alcohol **17** in ethanol was added over 2 h a solution of the sodium mesitylselenide and 1 M (or 0.5 M) NaOH. All of the reactions were stirred for 18 h. The results (Table 1) showed that the temperature had a significant effect, namely higher temperatures generally gave more of the desired 1-seleno-2,3-diol **19** than the product of direct opening, the 3-seleno-1,2-diol **20** (entries a–d).<sup>9</sup> Heating **17** with the selenide in ethanol at 85 °C (reflux) afforded the desired product in 48% yield along with 34% yield of the undesired product (entry d). Interestingly, adding all of the selenide and base at once seemed to improve the yield of the desired product (entry e vs entry b). However, higher temperatures in other solvents, for example, 100 °C in isopropanol or aq *tert*-butanol, gave much poorer results (entries f and g). The ratio of the desired to undesired product was



Scheme 4. Formation of the arylseleno diols.

Table 1  
Treatment of **17** with NaSeAr to give **19** and **20**

Entry	Solvent	Temp (°C)	<b>19</b> (%)	<b>20</b> (%)	Overall yield (%)
a	EtOH	0	13	45	58
b	EtOH	22	31	53	84
c	EtOH	45	40	23	63
d	EtOH	85	48	34	82
e <sup>a</sup>	EtOH	22	44	35	79
f <sup>b</sup>	<i>i</i> PrOH	100	30	13	43
g <sup>b</sup>	aq <i>t</i> BuOH	100	10	10	20

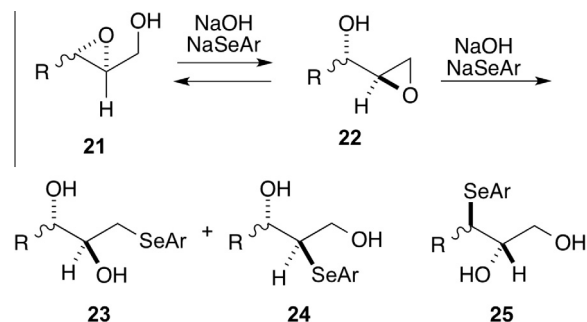
<sup>a</sup> Added all at once.<sup>b</sup> 0.5 M NaOH was used.Table 2  
Reaction of **17** under microwave conditions to give compounds **19** and **20**

Entry	Time (h)	Temp (°C)	<b>19</b> (%)	<b>20</b> (%)	Overall yield (%)
a	48	100	51	10	61
b	12	100	46	23	69
c	48	85	41	0	41
d	12	85	60	17	77
e <sup>a</sup>	60	80	56	0	56

<sup>a</sup> Not microwave; sealed tube.

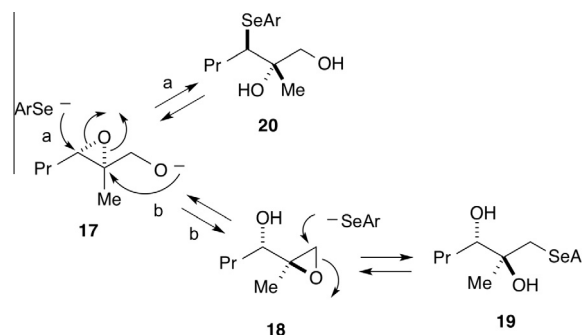
best at 45 °C (1.7:1) but the overall yield was lower than that at 85 °C where the ratio was 1.4:1 (entries c and d).

We next investigated the use of microwave heating for this process since some non-thermal effects have been observed especially in reactions of polar substrates.<sup>10</sup> Thus the epoxy alcohol **17** was treated with the sodium mesitylselenide and 1 M NaOH in ethanol at 22 °C. The mixture was then placed in an industrial microwave oven and heated to the indicated temperatures for the time shown. The results (Table 2) indicated that these microwave conditions were favorable for the formation of the desired product **19** in preference to the undesired product **20**. At all temperatures, shorter reaction times were better, presumably due to decomposition of the products on prolonged heating with base. Thus at 100 °C, the shorter time of 12 h was somewhat better than 48 h, although the ratio was better at longer times (entries a and b). And at 85 °C, heating for 12 h afforded 60% of the desired product **19** along

Scheme 5. Rearrangement-trapping of the disubstituted epoxy alcohols **21** to give the three products **23–25**.

with 17% of the undesired **20**, while heating for 48 h gave only the desired product but in the lower yield of 41% (entries c and d). Finally we also investigated the use of heating in a sealed tube for an extended period. Thus heating an ethanolic solution of **17** at 80 °C in a sealed tube for 60 h gave only the desired product **19** in an isolated yield of 56%. The undesired product **20** seems to be selectively destroyed on prolonged heating. Therefore the best method for preparing the desired products was heating at 80–85 °C in ethanol, either via microwave or thermal heating.

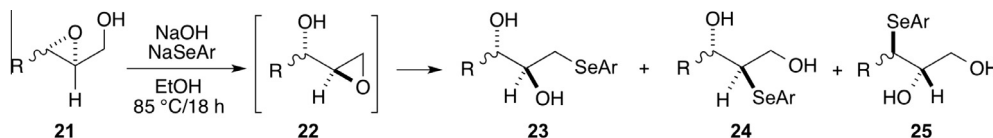
Using a series of disubstituted epoxides, we then looked at the substrate scope of the rearrangement-trapping process. In these substrates, three different products can be obtained, from opening at either end of the original epoxide **21**, giving **24** and **25**, or the terminal epoxide **22** giving **23** (Scheme 5). All of the epoxy alcohol substrates, **21a–g**, were prepared by known routes<sup>5</sup> using the Sharpless asymmetric epoxidation. Each was mixed with the sodium mesitylselenide and 1 M NaOH in ethanol and heated at 85 °C for 18 h. The results (Table 3) indicate firstly that the overall yields for these substrates were excellent, generally greater than 90%. Secondly, for these substrates not having the 2-methyl substituent, significant opening at C2 occurred to generate the 2-seleno-1,3-diol **24**.<sup>11</sup> Thus the relatively unhindered substrates gave significant amounts of the 2-seleno products (entries a–d) with relatively similar amounts of the 1-seleno and 3-seleno products, **23** and **25**, respectively. When the attack of the hindered arylselenide anion at C-3 is made more difficult, due to the steric interaction of the acetonides, then no opening at C-3 is observed but only a mixture of the C-1 and C-2 products, **23** and **24**. In these latter three cases (entries e–g), reasonable yields of the 1-seleno product **23** could be isolated.



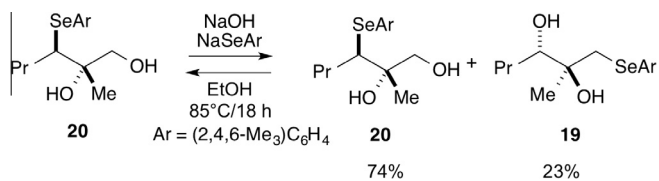
Scheme 6. Reversible formation of the selenodiol **19** and **20**.

Since heating the mixture of the epoxy alcohols and the arylselenide anion in ethanol for longer periods of time seemed to give more of the desired 1-seleno product with respect to the 3-seleno product (Table 2), we wondered if the formation of the selenodiol might well be reversible under these conditions. The product **20** formed by opening the starting epoxyalcohol **17** at C-3 might well be revert back to **17** via loss of the mesitylselenide anion before being converted via **18** into the desired product **19** (Scheme 6). Therefore we treated the isolated, pure 3-seleno-1,2-diol **20** with sodium mesitylselenide and 1 M sodium hydroxide in ethanol at 85 °C for 18 h and isolated a mixture of the two products, the starting material in 74% yield and the rearranged product **19** in 23% isolated yield (Scheme 7). Thus the seleno diol **20** must lose the mesitylselenide anion and revert back to the epoxide **17**, rearrange via Payne rearrangement to the isomeric epoxide **18**, and

Table 3  
Reactions of disubstituted epoxy alcohols



Entry	Substrate	Yield of 1-seleno-2,3-diol <b>23</b> (%)	Yield of 2-seleno-1,3-diol <b>24</b> (%)	Yield of 3-seleno-1,2-diol <b>25</b> (%)	Overall yield (%)
a		39	0	46	85
b		24	51	24	99
c		42	27	30	99
d		28	29	36	93
e		65	29	0	94
f		53	40	0	93
g		52	24	0	76



**Scheme 7.** Rearrangement-trapping of the disubstituted epoxy alcohols **21** to give the three products **23–25**.

then be opened at the terminal end of the epoxide **18** with the arylselenide anion to give **19**. This implies that the formation of the products may be partially controlled by thermodynamic effects and not merely kinetic effects.

In conclusion, we have developed a useful method for the conversion of 1,2-epoxy alcohols to the corresponding 1-seleno-2,3-diols using the hindered mesitylselenide anion under basic conditions in refluxing ethanol. The use of these compounds is under investigation and will be reported in due course.

### Acknowledgments

This material is based upon work supported by the United States National Science Foundation under equipment Grant no. CHE-1048804. We dedicate this publication to Harry Wasserman, a man of rare talent and grace.

### Supplementary data

Supplementary data associated with this article can be found, in the online version, at <http://dx.doi.org/10.1016/j.tetlet.2014.11.103>.

### References and notes

- (a) Jung, M. E.; D'Amico, D. C. *J. Am. Chem. Soc.* **1993**, *115*, 12208–12209; (b) Jung, M. E.; D'Amico, D. C. *J. Am. Chem. Soc.* **1997**, *119*, 12150–12158; (c) Jung, M. E.; Marquez, R. *Tetrahedron Lett.* **1999**, *40*, 3129–3132; (d) Jung, M. E.; Hoffmann, B.; Rausch, B.; Contreras, J.-M. *Org. Lett.* **2003**, *5*, 3159–3161.
- Jung, M. E.; Lee, W. S.; Sun, D. *Org. Lett.* **1999**, *1*, 307–309. The yields of the anti aldol products in these hindered cases were lower due to competing elimination to give the allylic bis(silyl ethers).
- (a) Payne, G. B. *J. Org. Chem.* **1962**, *27*, 3819–3822; (b) Hanson, R. M. In *Organic Reactions*; Overman, L. E. et al., Eds.; Wiley, 2002; Vol. 60, pp 1–156; (c) Wrobel, J. E.; Ganem, B. *J. Org. Chem.* **1983**, *48*, 3761–3769; (d) Jung, M. E.; van den Heuvel, A. *Tetrahedron Lett.* **2002**, *43*, 8169–8172.
- (a) Maruoka, K.; Sato, J.; Yamamoto, H. *J. Am. Chem. Soc.* **1991**, *113*, 5449–5450; (b) Maruoka, K.; Sato, J.; Yamamoto, H. *Tetrahedron* **1992**, *48*, 3749–3762.
- (a) Katsuki, T.; Lee, A. W. M.; Ma, P.; Martin, S. V.; Masamune, S.; Sharpless, K. B.; Tuddenham, D.; Walker, F. J. *J. Org. Chem.* **1982**, *47*, 1373–1378; (b) Behrens, C. H.; Ko, S. Y.; Sharpless, K. B.; Walker, F. J. *J. Org. Chem.* **1985**, *50*, 5687–5696.
- Boeckman, R. K., Jr.; Pruitt, J. R. *J. Am. Chem. Soc.* **1989**, *111*, 8286–8288.
- (a) Katsuki, T.; Sharpless, K. B. *J. Am. Chem. Soc.* **1980**, *102*, 5974–5976; (b) Johnson, R. A.; Sharpless, K. B. *Comp. Org. Synth.* **1991**, *7*, 389–436; (c) Katsuki, T.; Martin, V. S. *Org. React.* **1996**, *48*, 1–300.
- Hiroi, K.; Sato, S. *Synthesis* **1985**, 635–638.
- The structures of the 1-seleno-2,3-diol **19** and the 3-seleno-1,2-diol **20** were determined by high field proton NMR experiments, in which the chemical shift of the easily identifiable methylene group was at either lower field ( $\alpha$  to oxygen) or at higher field ( $\alpha$  to selenium).
- (a) de la Hoz, A.; Diaz-Ortiz, A.; Moreno, A. *Chem. Soc. Rev.* **2005**, *34*, 164–178; (b) Galema, S. A. *Chem. Soc. Rev.* **1997**, *26*, 233–238; (c) Mingos, M. P.; Baghurst, D. R. *Chem. Soc. Rev.* **1991**, *20*, 1–47; (d) Rosana, M. R.; Tao, Y.; Stiegman, A. E.; Dudley, G. B. *Chem. Sci.* **2012**, *3*, 1240–1244; (e) Kappe, C. O.; Pieber, B.; Dallinger, D. *Angew. Chem., Int. Ed.* **2013**, *52*, 1088–1094.
- The structures of the 2-seleno-1,3-diols **24** and the 3-seleno-1,2-diols, **25** were determined by high field proton NMR experiments, especially of the acetylated products, by careful matching of coupling constants and chemical shifts of the lower field protons, along with NOESY and COSY spectra.