Samarium triiodide catalyzed cycloaddition of epoxides with isocyanates: a facile synthesis of oxazolidinones

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Oxazolidinones were synthesized in high yields via cycloaddition of epoxides with isocyanates catalyzed by samarium triiodide.

Organolanthanide chemistry is of great interest now and the reports on using samarium(III) in organic chemistry have rapidly increased. For example, α-haloketones could react with aldehydes to give α,β-unsaturated ketones promoted by SmI3. Also mediated by SmI3, β-diketones or β-ketoesters could condense with aldehydes to form benzylidene-substituted β-diketones or β-ketoesters. Besides, catalyzed by SmI3, tetrahydrofuran ring could be opened with acyl chlorides or acid anhydrides to yield 4-iodobutyl esters.

Oxazolidinones are widely used in drug and polymeric materials. Among reported methods, the cycloaddition of epoxides with isocyanates seems to be a simple and convenient one for synthesis of oxazolidinones. As a result, a number of catalysts have been developed for this reaction with varying degree of success. However, in the reaction using these catalysts, vigorous reaction temperature and/or reactive polar solvents are required and thus they are often accompanied by undesirable reactions, such as the trimerization of isocyanates and addition to solvents. Therefore, in some cases dropwise addition is necessary to suppress the undesirable reactions. Recently n-Bu3SnI-Ph3PO and n-Bu3SnI-Ph3Sb have been reported to be relatively effective catalysts for this reaction. However, till date, only one document concerning the addition reaction of epoxides with heterocumulenes catalyzed by rare earth compounds has been reported. Herein we wish to report SmI3 catalyzed cycloaddition of epoxides with isocyanates to give oxazolidinones in high yields under very mild conditions (Scheme 1).

Results and discussion

On treating epoxides 1 and isocyanates 2 with 10 mol% SmI3 for about 3 h at room temperature, oxazolidinones were obtained in high yields. The results are summarized in Table 1.

| Compd. | R¹ | R² | Time | Yield | M.p. °C |
|--------|-----|-----|------|-------|-------|
| 3a     | CH3Cl | Ph | 3    | 98    | 99-101 (98-100) |
| 3b     | CH3Cl | 4-CIC6H4 | 3 | 95 | 127-128 |
| 3c     | CH3Cl | 1-Naphthyl | 3.5 | 92 | 120-121 |
| 3d     | CH3Br | Ph | 3    | 96    | 77-79 |
| 3e     | CH3   | Ph | 3    | 96    | 78-80 |
| 3f     | CH3   | 4-CIC6H4 | 3.5 | 93 | 109-110 |
| 3g     | CH3   | 1-Naphthyl | 3 | 90 | Oil |
| 3h     | PhOCH2 | Ph | 3.5 | 89 | 136-138 (139) |
| 3i     | PhOCH2 | 1-Naphthyl | 3.5 | 87 | 132-134 |

*Reported m.p. in parenthesis (Ref. 8).
In our experiment, the reaction conditions were well studied. We found that only catalytic amount of SmI₃ (10 mol% based on isocyanates) was needed in the reaction to give satisfactory yields of the products. On using higher amounts of SmI₃ (20, 50, 80%) or even stoichiometric amount of SmI₃, the yields were not increased much.

According to reported work, a possible mechanism of SmI₃ catalyzed cycloaddition of epoxides with isocyanates is presented in Scheme 2.

As shown in Scheme 2, initially an intermediate 4 is produced in situ via ring-opening of epoxide by SmI₃. Then further addition of 4 to isocyanate 2 generates intermediate 5. Finally, substitution of iodo group by nitrogen anion leads to the cycloaddition product 3. It can be concluded that only catalytic amounts of SmI₃ is needed for the reaction. Besides, since intermediate 5 having iodo group is more easily substituted by nitrogen anion that an intermediate with a chloro group, it seems reasonable that the reaction can proceed at lower temperature than that reported earlier.

In conclusion, it has been found that cycloaddition of epoxides with isocyanates could be efficiently by SmI₃ to give oxazolidinones in high yields. The notable advantages of the present procedure are its mild conditions, simple operation, short reaction time, high regioselectivity and good to excellent yields.

Experimental

Tetrahydrofuran was distilled from sodium-benzenophene prior to use. All reactions were conducted under a nitrogen atmosphere. M.ps. were obtained on an electrothermal apparatus and are uncorrected. Infrared spectra (KBr) were recorded on a Shimadzu IR-408 spectrophotometer and ¹H NMR spectra (CDCl₃) on a Bruker AC-300 (300 MHz) spectrometer, chemical shifts being expressed in δ ppm downfield from internal tetramethylsilane.

General procedure for synthesis of oxazolidinones: To a pale yellow suspension of SmI₃ (0.1 mmol) in THF under nitrogen atmosphere, were added epoxide 1 (1 mmol) and isocyanate 2 (1 mmol) and stirred for time given in Table 1 (monitored by TLC, about 3 h) at room temperature. Then water was added to the mixture and the product was extracted with diethyl ether. The organic phase was collected, dried over Na₂SO₄ and evaporated to afford the crude product. It was further purified by preparative TLC on silica gel using cyclohexane and ethyl acetate (5:1) as eluent. All the products were identified: 3a, νmax 1737 (C=O) cm⁻¹; δ 3.84 (1H, dd, J₁ 5.8, J₂ 9.2 Hz, 4-H₃), 3.92–4.03 (2H, m, ClCH₂), 4.19 (1H, t, J 9.20 Hz, 4-H₈), 4.96–5.01 (1H, m, 5-H), 7.09–7.56 (5H, m, ArH); 3b (Found: C, 48.68, H, 3.61, N, 5.74, C₁₀H₈ClNO₂ calculated for: C, 48.81, H, 3.69, N, 5.69%); νmax 1742 cm⁻¹ (C=O); δ 3.83 (1H, dd, J₁ 5.8, J₂ 9.2 Hz, 4-H₃), 3.92–4.04 (2H, m, ClCH₂), 4.20 (1H, t, J 9.2 Hz, 4-H₈), 4.98–5.03 (1H, m, 5-H), 7.46 (2H, d, J 9.0 Hz, ArH), 7.58 (2H, d, J 9.0 Hz, ArH); m/z 249 (M⁺+4), 247 (M⁺+2), 245 (M⁺); 3c, νmax 1735 cm⁻¹ (C=O); δ 3.82 (1H, dd, J₁ 5.8, J₂ 9.2 Hz, 4-H₈), 4.05–4.09 (2H, m, ClCH₂), 4.22 (1H, t, J 9.20 Hz, 4-H₈), 5.15–5.17 (1H, m, 5-H), 7.56–7.59 (4H, m, ArH), 7.93–8.01 (3H, m, ArH); m/z 263 (M⁺+2), 261 (M⁺); 3d, νmax 1738 cm⁻¹ (C=O); δ 3.56 (1H, dd, J₁ 5.8, J₂ 9.2 Hz, 4-H₈), 3.76–3.88 (2H, m, ClCH₂), 4.18 (1H, t, J 9.20 Hz, 4-H₈), 4.93–4.98 (1H, m, 5-H), 7.09–7.56 (5H, m, ArH); m/z 255 (M⁺+2), 253 (M⁺); 3e, νmax 1753 cm⁻¹ (C=O); δ 1.39 (3H, s, CH₃), 1.63 (1H, dd, J₁ 6.5, J₂ 8.70 Hz, 4-H₈), 1.12 (1H, t, J 8.7 Hz, 4-H₈), 4.71–4.82 (1H, m, 5-H), 7.07–7.54 (5H, m, ArH); 3f, νmax 1742 cm⁻¹ (C=O); δ 1.40 (3H, s, CH₃), 1.65 (1H, dd, J₁ 6.8, J₂ 8.6 Hz, 4-H₈), 4.14 (1H, t, J 8.6 Hz, 4-H₈), 4.76–4.83 (1H, m, 5-H), 7.46 (2H, d, J 9.0 Hz, ArH), 7.58 (2H, d, J 9.0 Hz, ArH); m/z 213 (M⁺+2), 211 (M⁺); 3g, νmax 1748 cm⁻¹ (C=O); δ 1.49 (3H, s, CH₃), 1.63 (1H, dd, J₁ 6.5, J₂ 8.5 Hz, 4-H₈), 4.13 (1H, t, J 8.5 Hz, 4-H₈), 4.88–5.00 (1H, m, 5-H), 7.54–7.60 (4H, m, ArH), 7.91–8.00 (3H, m, ArH); m/z 227 (M⁺); 3h, νmax 1739 cm⁻¹ (C=O); δ 3.93 (1H, dd, J₁ 5.8, J₂ 8.6 Hz, 4-H₈), 4.20–4.30 (3H, m, 4-H₈, PhOCH₃), 5.05–5.07 (1H, m, 5-H), 6.97–7.60 (10H, m, ArH); 3i, νmax 1733 cm⁻¹ (C=O); δ 3.95 (1H, dd, J₁ 5.8, J₂ 8.6 Hz, 4-H₈), 4.28–4.40 (3H, m, 4-H₈, PhOCH₃), 5.18–5.21 (1H, m, 5-H), 6.99–8.07 (12H, m, ArH); m/z 319 (M⁺). All compounds gave satisfactory C, H and N analyses.

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