

A Novel Preparative Method for γ -Butyrolactams *via* Carbon–Carbon Bond Formation: Copper or Ruthenium-catalysed Cyclization of *N*-Allyl Trichloroacetamides

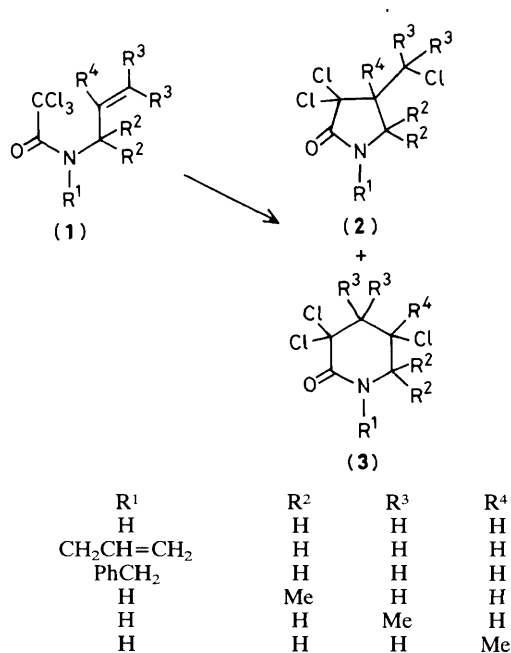
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Trichlorinated γ -butyrolactams are formed by copper or ruthenium-catalysed cyclization of *N*-allyl trichloroacetamides.

γ -Lactams are important intermediates in routes to five-membered heterocyclic compounds. Most approaches to γ -lactams have been dependent on cyclization *via* acyl–nitrogen bond formation.¹ Cyclization involving carbon–carbon bond formation is an alternative route; however, this potential methodology has received little attention. Recently, Mori and co-workers reported a palladium-catalysed cyclization of *N*-allyl iodoacetamides, in which the intramolecular addition reaction of the carbon–iodine bond to an olefinic linkage is a key step.² Although this approach is very attractive as a new pattern of γ -lactam synthesis, its utility seems to be rather limited because of the low yield of the products. In this paper we describe the efficient cyclization of *N*-allyl trichloroacetamides (**1**) using CuCl or RuCl₂(PPh₃)₃³ as a catalyst (Scheme 1). Using this procedure, α,α,γ -trichloro- γ -butyrolactams (**2**) have been obtained in high yields.

Compounds (**1**) were prepared with ease by trichloroacetylation of allylic amines or by [3.3]-sigmatropic rearrangement of allyl trichloroacetoimidates.⁴ Compounds (**1a**), (**1d**), and (**1e**), in which R¹ = H, gave (**2a**), (**2d**), and (**2e**), respectively, (>66% yields) when benzene solutions of (**1**) were heated in sealed tubes at 140°C in the presence of RuCl₂(PPh₃)₃ (5 mol%) (Table 1, method A, entries 1, 12, 13). When an acetonitrile solution of (**1a**) containing CuCl (30 mol%) was heated at 140°C (method B) (**2a**) was obtained again, but in lower yield (entry 3). In contrast, tertiary amides, (**1b**) and (**1c**), underwent the cyclization with either method, and excellent yields were attained even at temperatures below 140°C.



Scheme 1

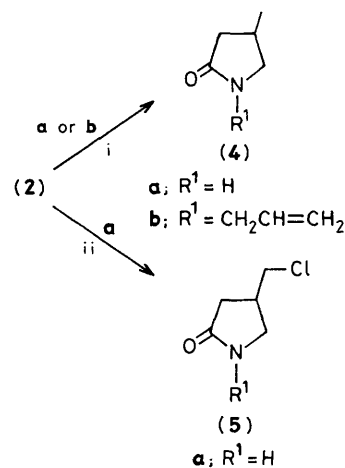
A potential problem in this cyclization procedure is that δ -lactams may be formed as by-products. However, in the cases described above, no δ -lactams were detected. As an exception, the ruthenium-catalysed cyclization of (**1f**) yielded a mixture of (**2f**) (23%) and (**3f**) (17%), because of the steric hindrance of the methyl group in (**1f**).

Treatment of (**2**) with Bu₃SnH affords reductively dechlorinated lactams (**4**) and (**5**).⁵ As typical examples, (**2a**) and (**2b**) reacted with Bu₃SnH (3.3 equiv.) (neat) and a small amount of azoisobutyronitrile (AIBN) at 140°C for 3 h to give (**4a**) and

Table 1. Cyclization of *N*-allyl trichloroacetamides (**1**) to α,α,γ -trichloro- γ -butyrolactams (**2**), and α,α,γ -trichloro- δ -lactams (**3**).

Entry	(1)	Procedure ^a	Temp. (°C)	Time (h)	Products (% yield)
1	a	A	140	2	(2a) 68
2	a	A	110	24	(2a) 52
3	a	B	140	20	(2a) 57
4	b	A	140	1	(2b) 84
5	b	A	110	1	(2b) 88
6	b	A	80	20	(2b) 58
7	b	B	140	1	(2b) 87
8	b	B	140	3	(2b) 90
9	b	B	110	3	(2b) 90
10	b	B	80	20	(2b) 81
11	c	A	140	3	(2c) 68
12	d	A	140	3	(2d) 66
13	e	A	140	3	(2e) 82
14	f	A	140	3	(2f) 23; (3f) 17

^a Method A: heating in benzene in the presence of RuCl₂(PPh₃)₃ (5 mol%). Method B: heating in acetonitrile in the presence of CuCl (30 mol%). After the reaction was complete, the mixture was concentrated, and the residue was purified by column chromatography (silica-gel; hexane–diethyl ether). In cases where the yields are lower than 80%, a considerable amount of (**1**) is recovered.



Scheme 2. Reagents and conditions: i, Bu₃SnH (3.3 equiv.) (neat), AIBN, 140°C, 3 h; ii, Bu₃SnH (2.2 equiv.), AIBN, benzene, 80°C, 0.5 h.

(4b), respectively. In contrast, selective dechlorination of (2a) to (5a) was accomplished by refluxing its benzene solution containing Bu_3SnH (2.2 equiv.) and AIBN for 0.5 h.

The described formation and selective dechlorination of compounds (2) should be applicable to the syntheses of various nitrogen-heterocycles.

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