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ORIGINAL PAPER

Facile radical mediated synthesis of azetidin-2,3-diones: potential synthons for biologically active compounds

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Abstract An operationally simple and efficient approach for the synthesis of azetidin-2,3-diones is described. The starting substrate 2-(2-bromobenzyloxy)ethanoyl chloride was treated with appropriate Schiff's bases in triethylamine and dichloromethane to afford 3-(2-bromobenzyloxy)azetidin-2-ones. The synthesis of azetidin-2,3-diones was successfully achieved via radical mediated rearrangement of appropriately substituted 3-(2-bromobenzyloxy)azetidin-2-ones using *n*-tributyltin hydride and AIBN in refluxing dry benzene.

Keywords Azetidin-2,3-diones · 3-(2-Bromobenzyloxy)azetidin-2-ones · β-Lactams · Radical mediated rearrangement

Introduction

Since the discovery of new β-lactam antibiotics such as monobactams and nocardicins, a lot of interest has been aroused in the study of monocyclic β-lactams [1, 2]. The synthesis of functionalized monocyclic β-lactams is an important area of research. Recently, monocyclic β-lactams have been shown to be biologically active as cholesterol acyl transferase inhibitors [2–4], thrombin inhibitors [5], and apoptosis inductors [6, 7].

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Several research groups have shown that azetidin-2,3-diones are useful synthetic targets for the construction of β-lactams with the cephamycin, asparenomycin, and noncardican type side chains [8]. In addition, azetidin-2,3-diones are important synthons for 3-alkyl/aryl/allyl-β-lactams, 3-alkylidene-β-lactams, and bicyclic β-lactams [9]. Moreover, azetidin-2,3-diones with known configuration serve as the precursors to α-hydroxy-β-amino acids [10], peptides [11, 12], taxol, taxotere (highly promising anticancer drugs) [13–15], and bestatin, a peptide enzyme inhibitor with antimicrobial, anticancer, and immunomodifier properties [16].

Over the past few decades, many synthetic methods, such as oxidation of 3-hydroxyazetidin-2-ones [8], reaction of 3-hydroxy-β-lactam with diisopropyl carbodiimide and methyl sulfoxide [17, 18], treatment of 3-amino-β-lactam with mercuric chloride [19], reactions of bis(3-ethylthio)azetidin-2-ones with excess of *N*-bromosuccinimide in acetonitrile/water [20], ozonolysis of α-ethylidene-β-lactams [21], and hydrolysis of 3-chloro-3-mercaptoazetidin-2-ones with moist silica gel and catalytic amount of zinc chloride [22], have been developed for the synthesis of azetidin-2,3-diones. Recently, a convenient access to enantiopure azetidin-2,3-diones using L-(+)-diethyl tartrate derived ketenes and imines in a Staudinger cycloaddition has been listed [9].

The application of free-radical reactions in organic synthesis has grown enormously during the past decade providing a wealth of useful new chemistry [23, 24]. Very recently, the stereoselective synthesis of bi- and tricyclic β-lactams by radical cyclization has been established as an efficient methodology in organic chemistry [25, 26]. In connection with our earlier studies aimed towards the synthesis of novel β-lactams and their functionalization [27–31], we report herein full details of a facile synthetic

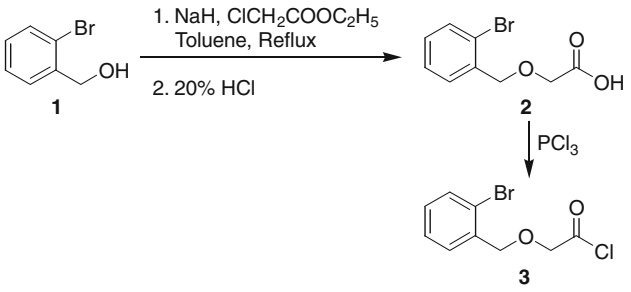
route to azetidin-2,3-diones through radical mediated rearrangement of appropriately substituted 3-(2-bromobenzyloxy)azetidin-2-ones.

Results and discussion

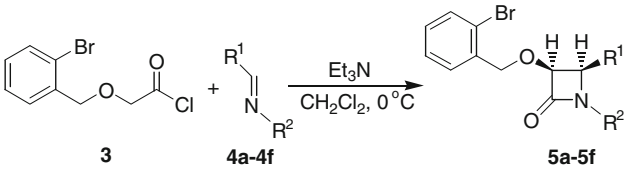
2-(2-Bromobenzyloxy)ethanoic acid (**2**) required for these studies was prepared by treating 2-bromobenzyl alcohol (**1**) with ethyl 2-chloroethanoate using sodium hydride in refluxing dry toluene, followed by subsequent acidification with 20% hydrochloride (Scheme 1) according to the reported procedure [32–35]. The starting substrate, 2-(2-bromobenzyloxy)ethanoyl chloride (**3**), was conveniently prepared by reaction of acid **2** and phosphorus trichloride (Scheme 1) using a literature method [36].

2-(2-Bromobenzyloxy)ethanoyl chloride (**3**) was further used as a ketene precursor in a Staudinger cycloaddition reaction. Initially, reaction of **3** with Schiff base **4a** in the presence of triethylamine and dichloromethane exclusively afforded *cis*-3-(2-bromobenzyloxy)-*β*-lactam **5a** in good yield according to the procedure reported for synthesis of 3-phenylthio/benzylthio-*β*-lactams [27, 28]. This reaction was performed with different Schiff's bases **4b–4f** under similar conditions and furnished *cis*-3-(2-bromobenzyloxy)-*β*-lactams **5b–5f** in good yields (Scheme 2; Table 1).

β-lactams **5a–5f** were characterized by FT-IR, ^{1}H NMR, ^{13}C NMR, ^{13}C DEPT-135 NMR spectroscopic studies, and CHN analysis. The stereochemistry at C3-H and C4-H of *β*-lactams **5a–5f** was assigned *cis* on the basis of coupling constants (J = 4.8–5.1 Hz, C3-H and C4-H) in ^{1}H NMR spectra [28].



Scheme 1



Scheme 2

Table 1 Synthesis of *cis*-3-(2-bromobenzyloxy)-*β*-lactams **5a–5f** from substrates **3** and **4a–4f**

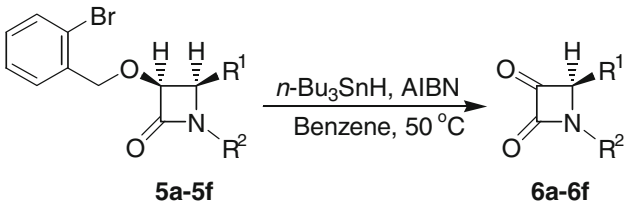
Entry	Product	R^1	R^2	Yield[a] (%)
1	**5a**	C_6H_5	4-MeO-C_6H_4	79
2	**5b**	4-Br-C_6H_4	4-MeO-C_6H_4	72
3	**5c**	4-MeO-C_6H_4	4-MeO-C_6H_4	76
4	**5d**	4-MeO-C_6H_4	4-Me-C_6H_4	69
5	**5e**	4-Cl-C_6H_4	4-Me-C_6H_4	65
6	**5f**	C_6H_5	C_6H_5	70

[a] Isolated yield

The exclusive formation of *cis*-3-(2-bromobenzyloxy)-*β*-lactams **5** in this case can be rationalized on the basis of the similar mechanism as discussed in our recent publication [28] and through the previous experimental classification as proposed by George and Ravikumar [37].

The synthesis of azetidin-2,3-diones **6a–6f**, serving as potential synthons for biologically active compounds, was successfully achieved through radical mediated rearrangement of appropriately substituted 3-(2-bromobenzyloxy) azetidin-2-ones **5a–5f**. Initially, the reaction of **5a** with 1.1 equiv of *n*-tributyltin hydride and a catalytic amount of AIBN in refluxing dry benzene afforded azetidin-2,3-dione **6a** in good yield. Similar results were obtained for free radical intramolecular rearrangements of *β*-lactams **5b–5f** (Scheme 3; Table 2).

The structures of azetidin-2,3-diones **6a–6f** were established on the basis of their spectral data such as UV-vis, FT-IR, ^{1}H NMR, ^{13}C NMR, ^{13}C DEPT-135 NMR, and CHN analysis. The azetidin-2,3-diones **6a**, **6d**, **6f** are

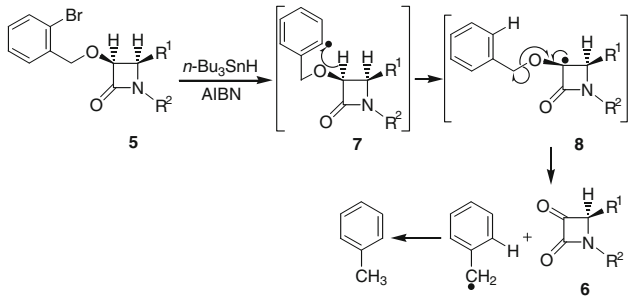


Scheme 3

Table 2 Synthesis of azetidin-2,3-diones **6** through radical mediated rearrangement of **5** using *n*-Bu_3SnH and AIBN

Entry	Substrate	R^1	R^2	Product	Yield[a] (%)
1	**5a**	C_6H_5	4-MeO-C_6H_4	**6a**	76
2	**5b**	4-Br-C_6H_4	4-MeO-C_6H_4	**6b**	73
3	**5c**	4-MeO-C_6H_4	4-MeO-C_6H_4	**6c**	69
4	**5d**	4-MeO-C_6H_4	4-Me-C_6H_4	**6d**	71
5	**5e**	4-Cl-C_6H_4	4-Me-C_6H_4	**6e**	64
6	**5f**	C_6H_5	C_6H_5	**6f**	68

[a] Isolated yield



Scheme 4

known, and they were identified by comparison of their data with those in [22]. However, the unreported data of **6a**, **6d**, **6f** have been given in the "Experimental".

A plausible mechanism for radical mediated rearrangement of *cis*-3-(2-bromobenzyloxy)azetidin-2-ones **5** has been depicted in Scheme 4. Homolytic cleavage of the C–Br bond of *β*-lactam **5** by *n*-tributyltin hydride and the radical initiator AIBN afforded phenyl radical **7**, which further on C3-H abstraction generated C-3 radical *β*-lactam **8**. The radical intermediates **8** undergo rearrangement involving benzylic carbon–oxygen (C–O) bond cleavage to furnish azetidin-2,3-dione **6** in good yields.

In conclusion, we described a convenient route to azetidin-2,3-diones **6a**–**6f**, employing radical mediated rearrangements of *cis*-3-(2-bromobenzyloxy)azetidin-2-ones **5a**–**5f** using *n*-tributyltin hydride and AIBN in refluxing dry benzene. Due to the operational simplicity and efficiency, this synthetic procedure represents an interesting alternative to existing methodologies.

Experimental

Melting points were determined in open glass capillaries on a melting point apparatus and are corrected. FT-IR spectra were recorded on a Perkin-Elmer 1430 FT-IR spectrophotometer ($\bar{\nu}$ in cm^{-1}). ^1H NMR (300 MHz) and ^{13}C NMR (75 MHz) spectra were recorded on a JEOL AL 300 (300 MHz) spectrometer. The chemical shifts are given in δ (ppm) relative to tetramethylsilane as an internal standard ($\delta = 0$ ppm) for ^1H NMR and $CDCl_3$ ($\delta = 77.0$ ppm) for ^{13}C NMR spectra. Ultraviolet spectra were recorded on a JASCO V-530 UV-vis spectrophotometer. Elemental analysis data were performed with a Perkin-Elmer 2400 elemental analyzer. Their results agreed favorably with the calculated values. For purification, column chromatography was carried out using silica gel (60–120 mesh, Merck) with *n*-hexane:EtOAc (9:1) as an eluent system. Analytical thin layer chromatography (TLC) was performed using silica gel G (Merck) with *n*-hexane:EtOAc (8:2) as an eluent system. For visualization, TLC plates were stained with iodine vapors. The reactions for the synthesis of *cis*-3-(2-bromobenzyloxy)-*β*-lactams **5a**–**5f** and azetidin-2,3-diones **6a**–**6f** were carried out under dry and deoxygenated nitrogen atmosphere. Sodium hydride (Qualigen), ethyl 2-chloroethanoate (Alfa Aesar), *n*-tributyltin hydride (Fluka), AIBN (Himedia), and all other commercially available compounds/reagents were of analytical grade and used without further purification. Dichloromethane distilled over P_2O_5 was redistilled over CaH_2 before use. Benzene and toluene were distilled from sodium-benzophenone immediately before use.

2-(2-Bromobenzyloxy)ethanoic acid (**2**, $C_9H_9BrO_3$)
The starting acid **2** was prepared from 1.87 g **1** (10.0 mmol), 0.50 g sodium hydride (20.8 mmol), and 1.22 g ethyl 2-chloroethanoate (10.0 mmol) in 55 cm^3 toluene according to [32–35]. Colorless crystalline solid (1.81 g, 74%); m.p.: 67–68 °C (Ref. [32] 70 °C); FT-IR ($CHCl_3$): $\bar{\nu} = 1{,}757$ (C=O) cm^{-1}; ^1H NMR (300 MHz, $CDCl_3$): $\delta = 3.90$ (s, 2H, $PhCH_2O$), 4.40 (s, 2H, CH_2CO), 7.00–7.90 (m, 4H Ar–H), 8.89 (s, 1H, COOH) ppm; ^{13}C NMR (75 MHz, $CDCl_3$): $\delta = 174.7$ (C=O), 136.6, 130.0, 128.2, 127.7 (*Ar*–C), 72.9 (*Ph*CH_2O), 66.2 (*C*H_2CO) ppm.

2-(2-Bromobenzyloxy)ethanoyl chloride
(**3**, $C_9H_8BrClO_2$)
Compound **3** was prepared from 2.00 g **2** (8.16 mmol) and 1.12 g PCl_3 (8.16 mmol, 0.71 cm^3) according to [36]. Yellow oil (1.80 g, 83%); FT-IR ($CHCl_3$): $\bar{\nu} = 1{,}753$ (C=O) cm^{-1}; ^1H NMR (300 MHz, $CDCl_3$): $\delta = 3.60$–3.65 (m, 4H, $2CH_2$), 7.05–7.80 (m, 4H, Ar–H) ppm; ^{13}C NMR (75 MHz, $CDCl_3$): $\delta = 171.4$ (C=O), 139.3, 132.7, 128.5, 126.1, 120.3 (*Ar*–C), 79.3 (*Ph*CH_2O), 65.7 (CH_2CO) ppm.

General procedure for the preparation of compounds ***5a–5f***

Compounds **5a**–**5f** were prepared from 1.1 mmol **3**, 1.0 mmol **4a**–**4f**, and 3.0 mmol Et_3N in 50 cm^3 CH_2Cl_2 by the procedure reported earlier for the synthesis of 3-phenyl/benzylthio-*β*-lactams [27, 28].

cis-3-(2-Bromobenzyloxy)-1-(4-methoxyphenyl)-4-phenylazetidin-2-one (**5a**, $C_{23}H_{20}BrNO_3$)
Starting from 1.37 g **3** (5.19 mmol), 1.0 g **4a** (4.73 mmol) and 1.43 g Et_3N (1.97 cm^3, 14.15 mmol). Colorless crystalline solid (1.72 g, 79%); m.p.: 142–144 °C; FT-IR (KBr): $\bar{\nu} = 1{,}748$ (C=O) cm^{-1}; ^1H NMR (300 MHz, $CDCl_3$): $\delta = 3.70$ (s, 3H, OMe), 4.31 (d, 1H, $J = 13.2$ Hz, $PhCH_2O$), 4.58 (d, 1H, $J = 13.2$ Hz, $PhCH_2O$), 4.90 (d, 1H, $J = 4.8$ Hz, C4-H), 5.10 (d, 1H, $J = 4.8$ Hz, C3-H), 6.70–7.40 (m, 13H, Ar–H) ppm; ^{13}C NMR (75 MHz, $CDCl_3$): $\delta = 163.4$ (C=O), 129.3, 129.1, 128.0, 127.8, 127.6, 117.2, 113.8 (*Ar*–C), 82.1 (C–3), 72.0 (*Ph*CH_2O), 61.2 (C–4), 54.8 (OCH_3) ppm.

cis-3-(2-Bromobenzyloxy)-4-(4-bromophenyl)-1-(4-methoxyphenyl)azetidin-2-one (**5b**, $C_{23}H_{19}Br_2NO_3$)
Starting from 0.99 g **3** (3.75 mmol), 1.0 g **4b** (3.44 mmol) and 1.04 g Et_3N (1.44 cm^3, 10.29 mmol). Colorless crystalline solid (1.33 g, 72%); m.p.: 139–141 °C; FT-IR (KBr): $\bar{\nu} = 1{,}753$ (C=O) cm^{-1}; ^1H NMR (300 MHz, $CDCl_3$): $\delta = 3.69$ (s, 3H, OMe), 4.40 (d, 1H, $J = 12.9$ Hz, $PhCH_2O$), 4.60 (d, 1H, $J = 13.2$ Hz, $PhCH_2O$), 4.96 (d, 1H, $J = 4.8$ Hz, C4-H), 5.00 (d, 1H, $J = 5.1$ Hz, C3-H), 6.67–7.38 (m, 12H, Ar–H) ppm; ^{13}C NMR (75 MHz, $CDCl_3$): $\delta = 156.5$ (C=O), 132.6, 132.3, 131.7, 129.6, 129.3, 127.7, 127.4, 122.7, 118.7, 114.5 (*Ar*–C), 83.3 (C–3), 71.9 (*Ph*CH_2O), 61.5 (C–4), 55.4 (OCH_3) ppm.

cis-3-(2-Bromobenzyloxy)-1,4-bis(4-methoxyphenyl)-azetidin-2-one (**5c**, $C_{24}H_{22}BrNO_4$)
Starting from 1.19 g **3** (4.51 mmol), 1.0 g **4c** (4.14 mmol) and 1.25 g Et_3N (1.72 cm^3, 12.37 mmol). Colorless crystalline solid (1.54 g, 76%); m.p.: 138–140 °C; FT-IR (KBr): $\bar{\nu} = 1{,}749$ (C=O) cm^{-1}; ^1H NMR (300 MHz, $CDCl_3$): $\delta = 3.73$ (s, 3H, OMe), 3.79 (s, 3H, OMe), 4.50 (d, 1H, $J = 4.8$ Hz, C4-H), 4.62 (d, 1H, $J = 13.1$ Hz, $PhCH_2O$), 4.70 (d, 1H, $J = 4.8$ Hz, C3-H), 4.81 (d, 1H, $J = 13.1$ Hz, $PhCH_2O$), 6.71–7.33 (m, 12H, Ar–H) ppm; ^{13}C NMR (75 MHz, $CDCl_3$): $\delta = 163.1$ (C=O), 159.8, 156.2, 137.2, 130.9, 129.2, 128.5, 128.2, 128.0, 127.4, 127.3, 118.7, 114.5, 114.3 (*Ar*–C), 89.8 (C–3), 73.0 (*Ph*CH_2O), 63.3 (C–4), 55.3 (OCH_3), 55.0 (OCH_3).

cis-3-(2-Bromobenzyloxy)-4-(4-methoxyphenyl)-1-(4-methylphenyl)azetidin-2-one (**5d**, $C_{24}H_{22}BrNO_3$)
Starting from 1.28 g **3** (4.85 mmol), 1.0 g **4d** (4.43 mmol) and 1.34 g Et_3N (1.85 cm^3, 13.26 mmol). Colorless crystalline solid (1.51 g, 69%); m.p.: 145–146 °C; FT-IR (KBr): $\bar{\nu} = 1{,}752$ (C=O) cm^{-1}; ^1H NMR (300 MHz, $CDCl_3$): $\delta = 2.26$ (s, 3H, Me), 3.72 (s, 3H, OMe), 4.34 (d, 1H, $J = 13.2$ Hz, $PhCH_2O$), 4.90 (d, 1H, $J = 12.9$ Hz, $PhCH_2O$), 4.96 (d, 1H, $J = 4.8$ Hz, C4-H), 5.11 (d, 1H, $J = 4.8$ Hz, C3-H), 6.81–7.42 (m, 12H, Ar–H) ppm; ^{13}C NMR (75 MHz, $CDCl_3$): $\delta = 163.7$ (C=O), 132.5, 130.0, 129.8, 129.6, 129.3, 129.1, 128.9, 127.5, 127.4, 126.3, 121.9, 117.5, 115.2, 114.1 (*Ar*–C), 83.3 (C–3), 71.5 (*Ph*CH_2O, 64.8 (C–4), 55.0 (OCH_3), 21.1 (CH_3) ppm.

cis-3-(2-Bromobenzyloxy)-4-(4-chlorophenyl)-1-(4-methylphenyl)azetidin-2-one (**5e**, $C_{23}H_{19}BrClNO_2$)
Starting from 1.26 g **3** (4.78 mmol), 1.0 g **4e** (4.35 mmol) and 1.31 g Et_3N (1.81 cm^3, 12.97 mmol). Colorless crystalline solid (1.35 g, 65%); m.p.: 144–145 °C; FT-IR (KBr): $\bar{\nu} = 1{,}754$ (C=O) cm^{-1}; ^1H NMR (300 MHz, $CDCl_3$): $\delta = 2.21$ (s, 3H, Me), 4.43 (d, 1H, $J = 11.7$ Hz, $PhCH_2O$), 4.54 (d, 1H, $J = 11.7$ Hz, $PhCH_2O$), 4.82 (d, 1H, $J = 4.8$ Hz, C4-H), 5.01 (d, 1H, $J = 5.1$ Hz, C3-H), 6.92–7.34 (m, 12H, Ar–H) ppm; ^{13}C NMR (75 MHz, $CDCl_3$): $\delta = 163.0$ (C=O), 136.2, 134.6, 133.3, 132.3, 129.4, 129.2, 128.6, 128.1, 127.8, 117.0 (*Ar*–C), 82.1, 72.2 (*Ph*CH_2O), 60.8 (C–4), 20.9 (CH_3) ppm.

cis-3-(2-Bromobenzyloxy)-1,4-diphenylazetidin-2-one (**5f**, $C_{22}H_{18}BrNO_2$)
Starting from 1.59 g **3** (6.03 mmol), 1.0 g **4f** (5.51 mmol) and 1.67 g Et_3N (2.31 cm^3, 16.53 mmol). Colorless crystalline solid (1.65 g, 70%); m.p.: 139–140 °C; FT-IR (KBr): $\bar{\nu} = 1{,}750$ (C=O) cm^{-1}; ^1H NMR (300 MHz, $CDCl_3$): $\delta = 4.30$ (d, 1H, $J = 12.9$ Hz, $PhCH_2O$), 4.52 (d, 1H, $J = 11.7$ Hz, $PhCH_2O$), 4.90 (d, 1H, $J = 5.1$ Hz, C4-H), 5.14 (d, 1H, $J = 4.8$ Hz, C3-H), 6.95–7.48 (m, 14H, Ar–H) ppm; ^{13}C NMR (75 MHz, $CDCl_3$): $\delta = 163.6$ (C=O), 137.5, 137.1, 136.7, 132.7, 132.2, 129.2, 129.0, 128.9, 128.7, 128.6, 128.5, 128.2, 128.1, 128.0, 126.0, 124.1, 117.4 (*Ar*–C), 89.8 (C–3), 72.8 (*Ph*CH_2O), 63.6 (C–4) ppm.

General procedure for the preparation of compounds ***6a–6f***

Compounds **6a–6f** were prepared from 1.0 mmol **5a–5f**, 1.1 mmol *n*-Bu_3SnH, and a catalytic amount of AIBN in 10 cm^3 C_6H_6 using the protocol previously described for the *n*-Bu_3SnH reduction of 3-alkoxy-3-phenyl/benzylthio-β-lactams [28].

1-(4-Methoxyphenyl)-4-phenylazetidin-2,3-dione (**6a**, $C_{16}H_{13}NO_3$)
Starting from 0.10 g **5a** (0.22 mmol) and 0.073 g *n*-Bu_3SnH (0.067 cm^3, 0.25 mmol). Yellowish-white crystalline solid (0.034 g, 56%); FT-IR, ^1H NMR, m.p., and CHN analysis of compound **6a** were found to be identical with the one described in Ref. [22]; UV-vis: λ_{max} (ε) = 350 (9,000) nm; ^{13}C NMR (75 MHz): $\delta = 189.8$ (C=O), 154.4 (C=O), 131.8, 130.3, 129.5, 129.3, 126.3, 119.7, 114.8 (*Ar*–C), 74.6 (C–4), 55.2 (OCH_3) ppm.

4-(4-Bromophenyl)-1-(4-methoxyphenyl)azetidin-2,3-dione (**6b**, $C_{16}H_{12}BrNO_3$)
Starting from 0.10 g **5b** (0.19 mmol) and 0.061 g *n*-Bu_3SnH (0.056 cm^3, 0.20 mmol). White solid (0.044 g, 66%); m.p.: 187–188 °C; FT-IR (KBr): $\bar{\nu} = 1{,}769$ (ketone C=O), 1,830 (amide C=O) cm^{-1}; ^1H NMR (300 MHz, $CDCl_3$): $\delta = 3.72$ (s, 3H, OMe), 5.55 (s, 1H, C4-H), 6.74–7.39 (m, 8H, Ar–H) ppm; ^{13}C NMR (75 MHz, $CDCl_3$): $\delta = 189.0$ (C=O), 150.6 (C=O), 143.9, 143.4, 129.6, 129.4, 126.3, 119.5, 114.6 (*Ar*–C), 74.5 (C–4), 55.1 (OCH_3) ppm.

1,4-Bis(4-methoxyphenyl)azetidin-2,3-dione (**6c**, $C_{17}H_{15}NO_4$)
Starting from 0.10 g **5c** (0.21 mmol) and 0.068 g *n*-Bu_3SnH (0.062 cm^3, 0.23 mmol). White solid (0.032 g,

50%); m.p.: 179–180 °C; FT-IR (KBr): $\bar{\nu}$ = 1,750 (ketone C=O), 1,800 (amide C=O) cm^{-1}; ^1H NMR (300 MHz, $CDCl_3$): δ = 3.75 (s, 3H, OMe), 3.81 (s, 3H, OMe), 5.26 (s, 1H, C4-H), 6.81–7.37 (m, 8H, Ar–H) ppm; ^{13}C NMR (75 MHz, $CDCl_3$): δ = 188.7 (C=O), 152.1 (C=O), 143.1, 142.8, 129.3, 129.0, 126.1, 118.9, 114.1 (*Ar*–C), 74.2 (C–4), 55.4 (OCH_3), 55.1 (OCH_3) ppm.

4-(4-Methoxyphenyl)-1-(4-methylphenyl)azetidin-2,3-dione (**6d**)

Starting from 0.10 g **5d** (0.22 mmol) and 0.070 g *n*-Bu_3SnH (0.064 cm^3, 0.24 mmol). White crystalline solid (0.029 g, 47%); FT-IR, ^1H NMR, m.p., and CHN analysis of compound **6d** were found to be identical with the one described in Ref. [22]; ^{13}C NMR (75 MHz, $CDCl_3$): δ = 191.0 (C=O), 153.7 (C=O), 143.3, 142.9, 129.5, 129.1, 126.3, 118.5, 113.8 (*Ar*–C), 73.9 (C–4), 55.0 (OCH_3), 21.4 (CH_3) ppm.

4-(4-Chlorophenyl)-1-(4-methylphenyl)azetidin-2,3-dione (**6e**, $C_{16}H_{12}ClNO_2$)

Starting from 0.10 g **5e** (0.21 mmol) and 0.070 g *n*-Bu_3SnH (0.064 cm^3, 0.24 mmol). White solid (0.040 g, 64%); m.p.: 186–188 °C; FT-IR (KBr): $\bar{\nu}$ = 1,770 (ketone C=O), 1,820 (amide C=O) cm^{-1}; ^1H NMR (300 MHz, $CDCl_3$): δ = 2.24 (s, 3H, Me), 5.23 (s, 1H, C4-H), 6.92–7.44 (m, 8H, Ar–H) ppm; ^{13}C NMR (75 MHz, $CDCl_3$): δ = 190.6 (C=O), 151.8 (C=O), 143.9, 143.8, 130.2, 129.4, 126.5, 119.7, 114.8 (*Ar*–C), 74.7 (C–4), 21.6 (CH_3) ppm.

1,4-Diphenylazetidin-2,3-dione (**6f**)

Starting from 0.10 g **5f** (0.24 mmol) and 0.078 g *n*-Bu_3SnH (0.072 cm^3, 0.26 mmol). White solid (0.030 g, 52%); FT-IR, ^1H NMR, m.p., and CHN analysis of compound **6f** were found to be identical with the one described in Ref. [22]; UV-vis: λ_{max} (ε) = 352 (9,100) nm.

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