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SYNTHESIS OF NOVEL TETRA- AND PENTACYCLIC BENZIMIDAZOLE DERIVATIVES

Jae Sang Yi and Kyongtae Kim*

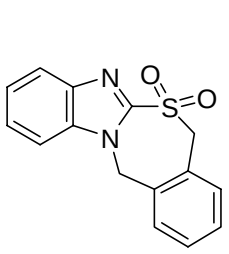
School of Chemistry and Molecular Engineering, Seoul National University, Seoul 151-742, Korea
kkim@plaza.snu.ac.kr

Abstract - Treatment of 7,12-dihydro[5,6][1,3]thiazepino[3,2-*a*]benzimidazole 6,6-dioxide **(1)** with NaH (1.2 equiv.) for 30 min in THF at room temperature under nitrogen atmosphere, followed by addition of alkyl propiolate (4 equiv.) gave tetracyclic benzimidazole derivatives **(7)**. Subsequent reactions of **7** with Na in *p*-xylene at reflux, followed by addition of HOAc at room temperature gave pentacyclic benzimidazole derivative **(8)** in good to excellent yields.

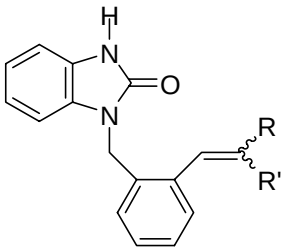
Benzimidazoles are one of the most extensively studied classes of heterocyclic compounds owing partly to their biological activities such as anticonvulsant,[1] sedative,[1] immunosuppresant,[1] antitumor,[1] antihistaminic,[1] and antifugal,[2] *etc*. There is considerable interest in exploring new stereoselective synthesis[3] and biological evaluation of new benzimidazole derivatives[4] despite the existence of numerous synthetic methods of benzimidazole derivatives.[5]

We have previously shown that 7,12-dihydro[5,6][1,3]thiazepino[3,2-*a*]benzimidazole 6,6-dioxide **(1)**[6] can be utilized for the synthesis of various benzimidazole derivatives such as 1-(2-vinylbenzyl)benzimidazolin-2-ones **(2),**[6] 2-alkoxy-1-(2-formylbenzyl)benzimidazoles **(3a),**[6] 2-alkylthio-1-(2-formylbenzyl)benzimidazoles **(3b)**,[6] 1-(2-formylbenzyl)benzimidazoles **(4)**,[6] 1-(2-formylbenzimidazolin-2-one **(5)**,[7] and *Se*-aryl 2-[(benzimidazol-1-yl)methyl]selenobenzoates **(6)**.[8]

In continuing to explore new functionalized benzimidazole derivatives, we were interested in the reactions of the carbanion generated from **1** with alkyl propiolates since it might give a Michael-type product **(7)** or tetracyclic benzimidazole derivatives **(8)**. The latter compounds are expected in view of the previous results, leading to benzimidazole derivatives **(2 - 6)**. Therefore, we investigate the reactions with alkyl propiolates. In addition, the results were compared with those obtained from the reactions with *N,N*-dialkylpropiolamides which are analogous to alkyl propiolates as far as the conjugate system is concerned. The results are described herein.



1



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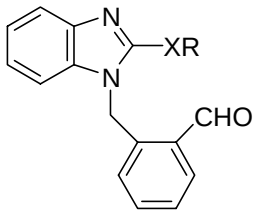
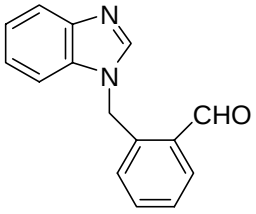


3a, X = O
3b, X = S



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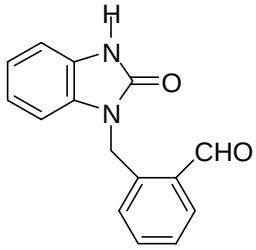

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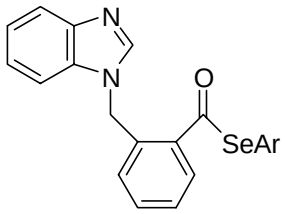

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Results and Discussion

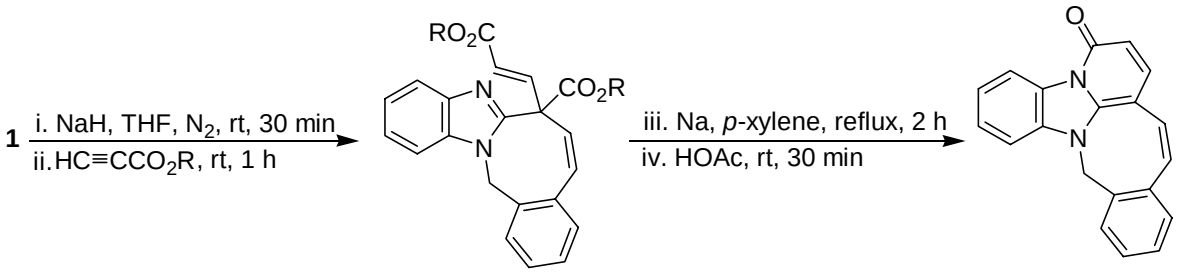
(A) Reactions with Alkyl Propiolates

Treatment of **1** with NaH (1.2 equiv.) for 30 min in THF at room temperature under nitrogen atmosphere, followed by addition of ethyl propiolate (4 equiv.) with stirring for 15 h at room temperature gave a tetracyclic compound **(7a)** in 35% yield with the recovery of unreacted **(1)**. The yield of **7a** increased to 57% by addition of **1** (0.12 equiv.) in one portion into a stirred mixture of ethyl propiolate (1 equiv.) and NaH (1 equiv.) for 30 min in THF under the same conditions.[9] The reaction did not complete but was a relatively clean reaction as evidenced by two spots corresponding to **7a** (R_f = 0.6) and **1** (R_f = 0.3) on TLC (*n*-hexane : EtOAc = 2 : 1). Consequently a considerable amount of unreacted **1** was always recovered. Similarly, analogous compounds **(7b - f)** were prepared by the latter procedure. Yields of **7a - f** are shown in Scheme 1. Other attempts [i. NaH (1.2 equiv.), DMSO, N_2, 15 min, room temperature; ii. HC≡CCO_2Et (2 equiv.), N_2,1 h, room temperature and i. *t*-BuOK (1.3 equiv.), DMSO, N_2, 30 min, room temperature ii. HC≡CCO_2Et (3 equiv.), N_2, 2 h, room temperature] for increasing the yield of **7a** were tried. In these cases, the reactions were quenched when no spot corresponding to **1** had been observed on TLC. Compound **(7a)** was obtained in 18 and 5% yields, respectively along with unknown mixtures, which were inseparable by chromatography.

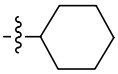
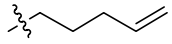
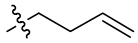
The structures of **7** were determined based on spectroscopic (^{1}H, and ^{13}C NMR, IR, MS) and analytical data. In particular, the ^{13}C NMR spectra together with the HMBC spectrum (Table 1) were informative of the structure of **7a**. The coupling constants, $J_{4.5}$ = 16 Hz, and $J_{14.15}$ = 12 Hz were indicative of *trans* and *cis* stereochemistry, respectively.[10] In addition, the IR (neat) absorptions at 1731 and 1712 cm^{-1} were indicative of the presence of two ester carbonyl groups and a mass number (*m/z*) of 416 (M^+, 25.6%) corresponded to

the molecular weight of **7a**.

Interestingly, treatment of **7a -f** with Na (4 equiv.) in *p*-xylene at reflux for 2 h under a nitrogen atmosphere, followed by addition of HOAc at room temperature gave the same pentacyclic compound **(8),**



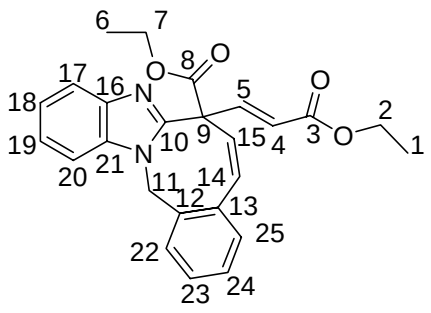
7 **8**

a, R = Et	57%	93%
b, R = Me	32%	89%
c, R = *n*-Bu	38%	75%
d, R = 	49%	73%
e, R = 	26%	94%
f, R = 	33%	89%

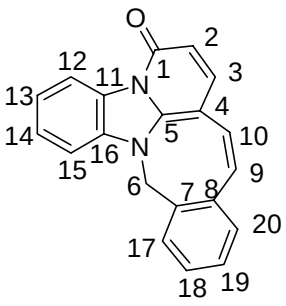
Scheme 1

regardless of the ester R groups, in good to excellent yields,[11] as is shown in Scheme 1. The ^{13}C NMR spectroscopic data of **8** and HMBC (Table 2) spectral data support the structure of **8**. In addition, IR (KBr) absorption at 1684 cm^{-1} was indicative of a characteristic lactam carbonyl group and a mass number (*m/z*) of 298 (M^+, 100%) corresponded to the molecular weight of **8**.

The mechanism for the formation of **7** may be explained by a Michael-type addition of a carbanion **(9)**, generated by deprotonation of **1** by a base, to alkyl propiolate to give a vinyl carbanion **(10)**, which undergoes an intramolecular nucleophilic attack to the imino carbon of the benzimidazole moiety, followed by extrusion of a stable sulfur dioxide molecule to generate a carbanion of azacyclooctene **(12)** (Scheme 2).



7a



8

The carbanion **(12)** may be stabilized by an alkoxycarbonyl and imino groups. Subsequent Michael-type addition of the carbanion **(12)** to the second molecule of alkyl propiolate, followed by protonation would

give **7**.

Table 1. NMR spectral data and HMBC correlations for **7a**

No	^{1}H ($CDCl_3$, 500 MHz)	^{13}C ($CDCl_3$, 125 MHz)	HMBC, H-C
1	1.19 - 1.35 (m, 3H)	14.1	C-2
2	4.07 (q, *J* = 7.2 Hz, 2H)	60.3	C-1, C-3
3		165.5	
4	5.13 (d, *J* = 16 Hz, 1H)	122.3	C-3, C-5, C-9
5	7.17 (d, *J* = 16 Hz, 1H)	146.4	C-3, C-8, C-9, C-10
6	1.19 - 1.35 (m, 3H)	13.9	C-7
7	4.20 (q, *J* = 7.2 Hz, 2H)	62.7	C-6, C-8
8		170.0	
9		57.8	
10		148.5	
11	5.22 (d, *J* = 6.3 Hz, 2H)	47.1	C-10, C12, C-13, C-21, C-22
12		137.1	
13		133.2	
14	7.11 (d, *J* = 12 Hz, 1H)	133.4	C-9, C-13, C-25
15	6.32 (d, *J* = 12 Hz, 1H)	130.1	C-8, C-9, C-10, C-13
16		142.4	
17	7.58 (d, *J* = 8.0 Hz, 1H)	109.3	C-16, C-18
18	7.20 - 7.28 (m, 1H)	122.3	C-16, C-17
19	7.35 - 7.37 (m, 1H)	122.9	C-20, C-21
20	7.76 (d, *J* = 8.0 Hz, 1H)	120.5	C-19, C-21
21		135.4	
22	7.35 - 7.37 (m, 1H)	129.7	C-12, C-23 (or C-24)
23	7.20 - 7.28 (m, 1H)	128.5 (or 128.7)	C-12, C-24 (or C-23)
24	7.18 - 7.19 (m, 1H)	128.7 (or 128.5)	C-25
25	7.20 - 7.28 (m, 1H)	129.1	C-13

An analogous type of extrusion of sulfur dioxide *via* a five-membered cyclic transition state such as **11**

was proposed when compounds **(2)** were formed from **1**.[6]

Table 2. NMR spectral data and HMBC correlations for **8**

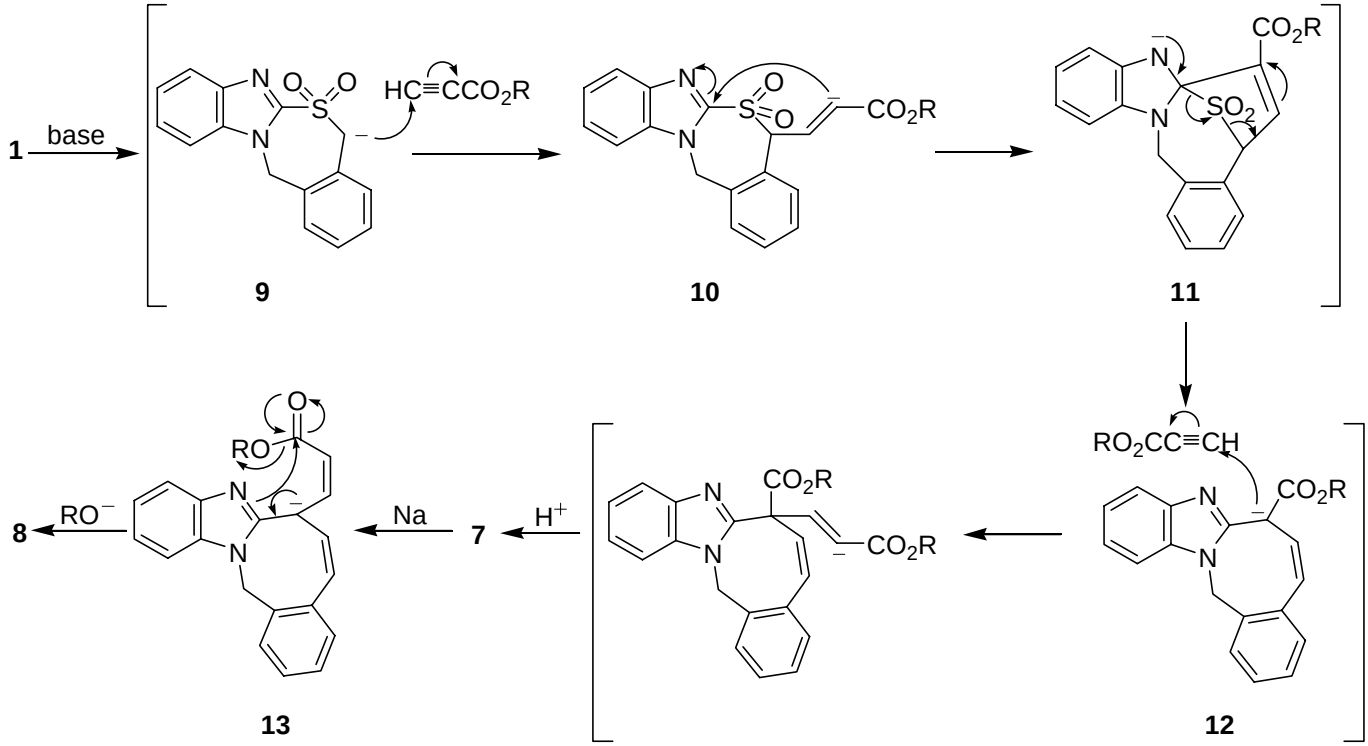
No	^{1}H ($CDCl_3$, 500 MHz)	^{13}C ($CDCl_3$, 125 MHz)	HMBC, H-C
1		159.3	
2	6.12 (d, *J* = 9.1 Hz, 1H)	104.5	C-1, C-4
3	7.27 (d, *J* = 9.1 Hz, 1H)	142.8	C-1, C-5, C-10
4		95.9	C-5, C-7, C-8
5		143.5	
6	5.11 (d, *J* = 15 Hz,1H) 6.16 (d, *J* = 15 Hz, 1H)	47.1	
7		139.8	
8		133.2	
9	6.28 (d, *J* = 13 Hz, 1H)	124.4	C-4, C-8, C-20
10	6.47 (d, *J* = 13 Hz, 1H)	129.3	C-5
11		131.6	
12	8.90 (d, *J* = 8.2 Hz, 1H)	118.2	C-11, C-13
13	7.50 (d, *J* = 4.2 Hz, 1H)	126.2	C-11, C-12
14	7.25 - 7.29 (m, 1H)	122.0	C-15
15	7.50 (d, *J* = 4.2 Hz, 1H)	106.7	
16		128.0	
17	7.45 (d, *J* = 7.6 Hz, 1H)	129.7	C-6, C-7, C-18
18	7.31 - 7.34 (m, 1H)	129.3	C-7, C-17
19	7.16 - 7.19 (m, 1H)	127.4	C-8
20	7.16 - 7.19 (m, 1H)	130.6	C-8, C-9, C-19

The formation of **8** may be rationalized by assuming the formation of carbanion **(13)** by a sequence of an electron transfer from Na to **7**, followed by cyclization. However, it is unusual[12] that decarboxylation of carboxylic esters in non-nucleophilic media by Na as electron source proceeds so efficiently and chemoselectively. To the best of our knowledge, tetra- and pentacyclic imidazole derivatives such as **7** and **8**, respectively have never been reported.

(B) Reaction with *N,N*-Dialkylpropiolamides

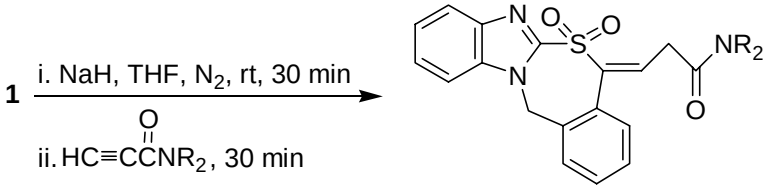
Treatment of **1** with NaH (1.2 equiv.) in THF for 30 min under the same conditions as described in (A),

followed by addition of *N,N*-dialkylpropiolamide (2 equiv.) with stirring for an additional 30 min gave an addition-proton migration product **(14a)** in 33% yield. Analogous compounds **(14b - e)** were obtained from the reactions with other *N,N*-dialkylpropiolamides although yields are not satisfactory. In the meantime, for a free carbanion, 15-crown-5 (1.4 equiv.) was added to the reaction mixture with stirring for 30 min prior to addition of *N,N*-dialkylpropiolamides, followed by stirring for an additional 1 to 24 h.



Scheme 2

However, yields of **14** decreased significantly and considerable amounts of unknown mixtures, which were unsuccessful to purify, were obtained. Yields of **14** in the presence and in the absence of 15-crown-5 are summarized in Table 3.



14a, R = Me

Scheme 3

In the hope of a nucleophilic attack to C-2 of benzimidazole moiety as shown in the formation of **7**, compound **(14c)** was treated with NaOEt [Na (2.9 equiv.) in EtOH (5 mL)] in THF for 1 h at room temperature under nitrogen atmosphere. However, **14c** was recovered in 91% yield. Similarly **14c** was treated with *n*-BuLi (3 equiv.) at room temperature for 1 h, followed by addition of benzaldehyde. However, no benzaldehyde derived product was detected. Compound **(14c)** and benzaldhyde were recovered in 84 and 86% yields, respectively. The results indicate that compounds **(14)** are quite stable under the strong basic

conditions.

Table 3. Reaction time and yields of **14** in the absence and in the presence of 15-crown-5

Compound	R	Time (h)	Yield[a] (%)
14a	Me	0.5	33
14b	Et	0.5	57 (21)
14c	*n*-Pr	1	49
14d	$CH_2(CH_2)_2CH_2$	0.5	50 (31)
14e	$CH_2(CH_2)_3CH_2$	1	52 (24)

[a]Isolated yields. Number in the parenthesis represents yield in the presence of 15-crown-5.

EXPERIMENTAL

The ^{1}H NMR spectra were recorded at 300 MHz or 500 MHz in $CDCl_3$ solution containing tetramethylsilane as an internal standard. The ^{13}C NMR spectra were recorded at 75 MHz or 125 MHz in $CDCl_3$, unless otherwise specified containing tetramethylsilane as an internal standard. IR spectra were recorded in KBr or as thin films on KBr plates. GC-MS spectra were obtained by electron impact at 70 eV. FAB MS spectra were recorded by the National Center for Inter-University Research Facilties, Seoul National University. Elemental analyses were determined by the same institute as above. Column chromatography was performed using silica gel (230 - 400 mesh ASTM, Merck). Melting points uncorrected. 7,12-Dihydro[5,6][1,3]thiazepino[3,2-*a*]benzimidazole 6,6-dioxide **(1)** was prepared by the previous reported method.[6]

General Procedure for the Synthesis of Tetracyclic Compounds (7)

To a solution of alkyl propiolate (0.48 - 1.40 mmol) in THF (50 - 80 mL) at rt under nitrogen atmosphere was added NaH (60% dispersion in mineral oil, 19 - 56 mg, 0.48 - 1.40 mmol), followed by addition of **1** (0.24 - 0.70 mmol). The mixture was stirred for 30 min. The reaction mixture was quenched with water (30 mL). After removal of the solvent *in vacuo*, the residue was extracted with CH_2Cl_2 (70 mL × 2). The combined extracts were dried over $MgSO_4$. Removal of the solvent gave residue, which was chromatographed on a silica gel (2 × 10 cm, EtOAc : *n*-hexane = 1 : 2) to give compounds **(7)** (26 - 57%) and unreacted **(1)** (19 - 43%).

Compound (7a): oil; IR (KBr) (cm^{-1}) 2928, 1731, 1712, 1446, 1216; MS (EI) *m*/*z* 416 (M^+, 21.8%), 343 (83.3), 269 (100). *Anal*. Calcd for $C_{25}H_{24}N_2O_4$: C, 72.10; H, 5.81; N, 6.73. Found: C, 72.23; H, 5.77; N, 6.82.

Compound (7b): oil; ^{1}H NMR (δ, ppm) 3.53 (3H, s, OCH_3), 3.62 (3H, s, OCH_3), 5.09 (1H, d, *J* = 16 Hz, CH), 5.12 (2H, s, NCH_2), 6.23 (1H, d, *J* = 12 Hz, CH), 7.03 (1H, d, *J* = 12 Hz, CH), 7.09 (1H, d, *J* = 16 Hz,

CH), 7.14 -7.29 (6H, m, ArH), 7.49 (1H, d, *J* = 8.1 Hz, ArH), 7.67 (1H, d, *J* = 7.9 Hz, ArH); ^{13}C NMR (δ, ppm) 46.7, 51.5, 52.3, 57.3, 109.6, 120.9, 122.1, 122.5, 122.9, 128.4, 128.9, 129.2, 129.9, 130.1, 133.2, 133.8, 135.8, 137.5, 142.7, 146.9, 149.1, 166.1, 170.8; IR (KBr) (cm^{-1}) 2928, 1728, 1715, 1644, 1446, 1241, 736; MS (FAB) *m*/*z* 388 (M^+, 15.0%), 329 (100), 269 (60). *Anal*. Calcd for $C_{23}H_{20}N_2O_4$: C, 72.10; H, 5.81; N, 6.73. Found: C, 72.23; H, 5.77; N, 6.82.

Compound (7c): oil; ^{1}H NMR (δ, ppm) 0.70 - 0.93 (6H, m, 2CH_3), 1.26 - 1.35 (4H, m, 2CH_2), 1.53 - 1.60 (4H, m, 2CH_2), 4.01 (2H, t, *J* = 6.7 Hz, OCH_2), 4.16 (2H, t, *J* = 8.5 Hz, OCH_2), 5.15 (1H, d, *J* = 16 Hz, CH), 5.22 (2H, d, *J* = 3.9 Hz, NCH_2), 6.32 (1H, d, *J* = 12 Hz, CH), 7.09 (1H, d, *J* = 12 Hz, CH), 7.16 (1H, d, *J* = 16 Hz, CH), 7.25 - 7.37 (6H, m, ArH), 7.58 (1H, d, *J* = 8.0 Hz, ArH), 7.72 (1H, d, *J* = 8.0 Hz, ArH); ^{13}C NMR (δ, ppm) 13.7, 14.1, 19.3, 19.4, 30.8, 31.4, 47.3, 57.6, 64.4, 66.1, 108.9, 120.6, 122.1, 122.7, 123.4, 128.4, 128.9, 129.2, 129.9, 130.9, 133.4, 133.5, 136.1, 137.3, 142.8, 146.9, 147.9, 166.0, 169.8; IR (KBr) (cm^{-1}) 2944, 1732, 1715, 1638, 1449, 1446, 1041, 736; MS (FAB) *m*/*z* 472 (M^+). *Anal*. Calcd for C, 72.10; H, 5.81; N, 6.73. Found: C, 72.23; H, 5.77; N, 6.82.

Compound (7d): oil; ^{1}H NMR (δ, ppm) 1.18 - 1.74 (20H, m), 4.60 - 4.62 (1H, m, OCH), 4.80 - 4.88 (1H, m, OCH), 4.99 (1H, d, *J* = 16 Hz, CH), 5.16 (2H, d, *J* = 6.8 Hz, NCH_2), 6.26 (1H, d, *J* = 12 Hz, CH), 7.00 (1H, d, *J* = 12 Hz, CH), 7.04 (1H, d, *J* = 16 Hz, CH), 7.08 - 7.31 (6H, m, ArH), 7.51 (1H, d, *J* = 8.2 Hz, ArH), 7.72 (1H, d, *J* = 7.8 Hz, ArH); ^{13}C NMR (δ, ppm) 20.8, 21.4, 23.4, 24.1, 25.4, 25.8, 31.2, 31.3, 31.9, 32.2, 47.6, 58.4, 72.4, 73.3, 110.2, 119.8, 121.2, 121.9, 122.3, 128.2, 129.0, 129.1, 130.0, 130.2, 133.3, 133.8, 135.9, 138.3, 143.3, 146.6, 148.7, 168.9, 173.2; IR (KBr) (cm^{-1}) 2928, 2848, 1729, 1712, 1638, 1443, 1011, 732; MS (FAB) *m*/*z* 524 (M^+, 12.1%), 398 (100), 269(29.5). *Anal*. Calcd for $C_{25}H_{24}N_2O_4$: C, 72.10; H, 5.81; N, 6.73. Found: C, 72.23; H, 5.77; N, 6.82.

Compound (7e): oil; ^{1}H NMR (δ, ppm) 1.57 - 1.62 (4H, m), 1.92 - 1.99 (4H, m), 3.95 (2H, t, *J* = 6.6 Hz, OCH_2), 4.09 (2H, t, *J* = 5.4 Hz, OCH_2), 4.84 (1H, q, *J* = 1.4 Hz, CH), 4.89 (1H, q, *J* = 1.1 Hz, CH), 4.93 (1H, q, *J* = 1.8 Hz, CH), 4.98 (1H, q, *J* = 1.8 Hz, CH), 5.06 (1H, d, *J* = 16 Hz, CH), 5.14 (2H, d, *J* = 5.8 Hz, NCH_2), 5.49 - 5.73 (2H, m, 2CH), 6.26 (1H, d, *J* = 12 Hz, CH), 7.03 (1H, d, *J* = 12 Hz, CH), 7.08 (1H, d, *J* = 16 Hz, CH), 7.13 - 7.30 (6H, m, ArH), 7.51 (1H, d, *J* = 8.0 Hz, ArH), 7.68 (1H, d, *J* = 8.0 Hz, ArH); ^{13}C NMR (δ, ppm) 27.6, 28.1, 29.5, 30.3, 46.9, 57.4, 61.4, 64.2, 109.1, 114.7, 115.3, 120.7, 122.0, 122.4, 123.5, 128.7, 128.8, 129.0, 130.1, 131.4, 132.7, 133.5, 134.9, 136.8, 137.1, 138.4, 142.9, 147.2, 149.1, 166.8, 169.3; IR (KBr) (cm^{-1}) 2928, 1728, 1712, 1638, 1446, 1244; MS (FAB) *m*/*z* 496 (M^+, 48.7%), 383 (100), 269 (27.6). *Anal*. Calcd for $C_{31}H_{32}N_2O_4$: C, 75.0; H, 6.5; N, 5.6. Found: C, 75.0; H, 6.45; N, 5.7.

Compound (7f): oil; ^{1}H NMR (δ, ppm) 2.22 - 2.29 (4H, m, 2CH_2), 3.98 (2H, t, *J* = 6.8 Hz, OCH_2), 4.11 (2H, t, *J* = 4.5 Hz, OCH_2), 4.88 - 5.06 (4H, m, 2CH_2), 5.09 (1H, d, *J* = 16 Hz, CH), 5.14 (2H, d, *J* = 1.6 Hz, NCH_2), 5.56 - 5.67 (2H, m, 2CH), 6.23 (1H, d, *J* = 12 Hz, CH), 7.01 (1H, d, *J* = 12 Hz, CH), 7.10 (1H, d, *J* = 16 Hz, CH), 7.18 - 7.30 (6H, m, ArH), 7.50 (1H, d, *J* = 7.9 Hz, ArH), 7.67 (1H, d, *J* = 7.9 Hz, ArH); ^{13}C

NMR (δ, ppm) 33.1, 33.3, 47.8, 58.1, 62.5, 64.3, 109.6, 113.5, 114.3, 121.3, 121.9, 122.0, 123.1, 128.1, 128.7, 129.1, 130.0, 131.9, 133.2, 133.5, 135.4, 136.6, 137.1, 138.1, 142.4, 146.6, 147.9, 166.2, 170.3; IR (KBr) (cm^{-1}) 3056, 2944, 1731, 1715, 1638, 1446, 1273, 739; MS (FAB) *m*/*z* 468 (M^+, 28.6%), 369 (100), 269 (33.2). *Anal*. Calcd for $C_{25}H_{24}N_2O_4$: C, 72.10; H, 5.81; N, 6.73. Found: C, 72.23; H, 5.77; N, 6.82.

General Procedure for the Synthesis of Pentacyclic Compound (8)

To a solution of **7a** (60 mg, 0.14 mmol) in *p*-xylene (20 mL) was added Na (13 mg, 0.57 mmol) under nitrogen atmpshpere. The mixture was stirred for 2 h at reflux, followed by addition of HOAc. The mixture was additionally stirred for 30 min at rt, which was extracted with EtOAc (50 mL × 2). The combined extracts were dried over $MgSO_4$. After removal of the solvent *in vacuo*, the residue was chromatographed on a silica gel (1 × 10 cm, EtOAc : *n*-hexane = 1: 1) to give compound **(8)** (39 mg, 93%).

Compound (8): mp 256 - 258 °C (CH_2Cl_2 -*n*-hexane); ^{1}H NMR (δ, ppm) 5.11 (1H, d, *J* = 15 Hz, NCH), 6.12 (1H, d, *J* = 9.1 Hz, CH), 6.16 (1H, d, *J* = 15 Hz, NCH), 6.28 (1H, d, *J* = 13 Hz, CH), 6.47 (1H, d, *J* = 13 Hz, CH), 7.16 - 7.19 (2H, m, ArH), 7.27 (1H, d, *J* = 9.1 Hz, CH), 7.25 - 7.29 (1H, m, ArH), 7.31 - 7.34 (1H, m, ArH), 7.45 (1H, d, *J* = 7.6 Hz, ArH), 7.50 (2H, d, *J* = 4.2 Hz, ArH), 8.90 (1H, d, *J* = 8.2 Hz, ArH); ^{13}C NMR (δ, ppm) 47.1, 95.9, 104.5, 106.7, 118.2, 122.0, 124.4, 126.2, 127.4, 128.0, 129.3, 129.7, 130.6, 131.6, 133.2, 139.8, 142.8, 143.5, 159.3; IR (KBr) (cm^{-1}) 1684, 1609, 1515, 1464, 1246, 737; MS (FAB) *m*/*z* 298 (M^+, 100%), 269 (73), 207 (15). *Anal*. Calcd for $C_{20}H_{14}N_2O$: C, 80.52; H, 4.73; N, 9.39. Found: C, 80.47; H, 4.71; N, 9.42.

General Procedure for the Synthesis of 5-[2-(*N*,*N*-Dialkylcarbonyl)ethylidene]-7,12-dihydro[5,6][1,3]thiazepino[3,2-*a*]benzimidazole 6,6-Dioxides (14)

To a solution of **1** (100 mg, 0.35 mmol) in THF (50 mL) at rt under nitrogen atmosphere was added NaH (60% dispersion in mineral oil, 17 mg, 0.42 mmol). The mixture was stirred for 30 min, followed by addition of *N*,*N*-dialkyl- propiolamides (0.42 - 0.70 mmol) with stirring for an additional 0.5 to 1 h. Removal of the solvent, *in vacuo* gave a residue, which was extracted with EtOAc (200 mL × 2) and dried ($MgSO_4$). After the solvent was removed *in vacuo*, the residue was chromatographed on a silica gel (70 – 230 mesh, 2 × 10 cm) using a mixture of EtOAc and *n*-hexane (2 : 1) to give **14**.

7,12-Dihydro-5-[2-(*N*,*N*-dimethylcarbonyl)]ethylidene[5,6][1,3]thiazepino[3,2-*a*]benzimidazole 6,6-dioxide (14a): mp 238 - 240 °C (decomp) (EtOAc - *n*-hexane); ^{1}H NMR (DMSO-d_6, δ, ppm) 2.80 (3H, s, Me), 2.86 (3H, s, Me), 3.40 (2H, d, *J* = 7.1 Hz, CH_2), 5.58 (2H, s, NCH_2), 7.40 (1H, t, *J* = 7.9 Hz, ArH), 7.49 - 7.58 (4H, m, ArH), 7.63 (1H, t, *J* = 7.0 Hz, CH), 7.79 (2H, t, *J* = 7.9 Hz, ArH), 8.12 (1H, d, *J* = 8.3 Hz, ArH); ^{13}C NMR (DMSO-d_6, δ, ppm) 33.9, 35.8, 37.6, 47.3, 112.8, 121.5, 124.8, 126.3, 130.6, 130.9, 131.2, 131.3, 132.3, 134.5, 136.5, 139.7, 140.8, 144.2, 151.4, 168.6; IR (KBr) (cm^{-1}) 3040, 2912, 1635, 1449, 1312, 1139, 720; *Anal*. Calcd for $C_{20}H_{19}N_3O_3S$: C, 62.97; H, 5.02; N, 11.02; S, 8.41. Found: C, 62.71; H, 4.92; N, 10.97; S, 8.55.

5-[2-(*N*,*N*-Diethylcarbonyl)]ethylidene-7,12-dihydro[5,6][1,3]thiazepino[3,2-*a*]benzimidazole 6,6-dioxide (14b): mp 240 - 241 °C (decomp) (EtOAc); ^{1}H NMR (DMSO-d_6, δ, ppm) 0.93 - 0.99 (6H, m, $2CH_3$), 3.13 - 3.26 (4H, m, $2CH_2$), 3.34 (2H, d, *J* = 7.0 Hz, CH_2), 5.59 (2H, s, NCH_2), 7.40 (1H, t, *J* = 7.4 Hz, ArH), 7.50 - 7.57 (4H, m, ArH), 7.63 (1H, t, *J* = 6.8 Hz, CH), 7.79 (2H, t, *J* = 7.9 Hz, ArH), 8.13 (1H, d, *J* = 8.2 Hz, ArH); ^{13}C NMR (DMSO-d_6, δ, ppm) 14.3, 15.9, 34.2, 38.5, 38.9, 47.7, 112.5, 120.8, 123.9, 127.4, 129.9, 130.6, 131.0, 131.2, 133.5, 134.9, 137.2, 138.9, 139.9, 143.8, 150.9, 168.9; IR (KBr) (cm^{-1}) 2960, 1622, 1440, 1308, 1136, 720; *Anal*. Calcd for $C_{22}H_{23}N_3O_3S$: C, 64.53; H, 5.66; N, 10.26; S, 7.83. Found: C, 64.31; H, 5.52; N, 10.42; S, 7.53.

7,12-Dihydro-5-[2-(*N*,*N*-dipropylcarbonyl)]ethylidene[5,6][1,3]thiazepino[3,2-*a*]benzimidazole 6,6-dioxide (14c): mp 222 - 223 °C (decomp) (EtOAc - *n*-hexane); ^{1}H NMR (DMSO-d_6, δ, ppm) 0.69 (3H, t, *J* = 7.4 Hz, CH_3), 0.78 (3H, t, *J* = 7.4 Hz, CH_3), 1.36 - 1.43 (4H, m, $2CH_2$), 3.05 (2H, t, *J* = 7.7 Hz, CH_2), 3.16 (2H, t, *J* = 7.6 Hz, CH_2), 3.34 (2H, d, *J* = 7.0 Hz, CH_2), 5.58 (2H, s, NCH_2), 7.40 (1H, t, *J* = 7.4 Hz, ArH), 7.49 - 7.57 (4H, m, ArH), 7.63 (1H, t, *J* = 7.0 Hz, CH), 7.79 (2H, t, *J* = 7.9 Hz, ArH), 8.12 (1H, d, *J* = 8.2 Hz, ArH); ^{13}C NMR (DMSO-d_6, δ, ppm); 11.9, 12.8, 24.6, 25.8, 34.5, 43.8, 44.7, 47.5, 112.7, 121.1, 122.2, 126.8, 128.8, 129.9, 130.8, 131.1, 132.8, 136.3, 138.2, 138.4, 140.6, 142.6, 149.7, 168.2; IR (KBr) (cm^{-1}) 2944, 1625, 1430, 1312, 1145, 726, 649; *Anal*. Calcd for $C_{24}H_{27}N_3O_3S$: C, 65.88; H, 6.22; N, 9.60; S, 7.33. Found: C, 66.04; H, 6.15; N, 9.47; S, 7.53.

7,12-Dihydro-5-[(2-pyrrolidinylcarbonyl)]ethylidene[5,6][1,3]thiazepino[3,2-*a*]benzimidazole 6,6-dioxide (14d): mp 222 - 223 °C (decomp) (EtOAc - *n*-hexane); ^{1}H NMR (DMSO-d_6, δ, ppm) 1.24 - 1.57 (4H, m, $2CH_2$), 3.21 - 3.34 (4H, m, $2NCH_2$), 3.27 (2H, d, *J* = 7.0 Hz, CH_2), 5.39 (2H, s, NCH_2), 7.21 - 7.49 (8H, m, CH and ArH), 7.93 (1H, d, *J* = 8.2 Hz, ArH); ^{13}C NMR (DMSO-d_6, δ, ppm) 25.8, 26.4, 33.2, 43.5, 44.1, 47.1, 111.2, 118.6, 121.4, 125.8, 128.6, 129.3, 130.4, 132.6, 134.2, 134.7, 135.9, 139.1, 140.6, 142.7, 151.1, 167.8; IR (KBr) (cm^{-1}) 3056, 2960, 1635, 1315, 1138, 828, 688; *Anal*. Calcd for $C_{22}H_{21}N_3O_3S$: C, 64.85; H, 5.19; N, 10.31; S, 7.87. Found: C, 64.99; H, 5.11; N, 10.22; S, 7.84.

7,12-Dihydro-5-[(2-piperidinylcarbonyl)]ethylidene[5,6][1,3]thiazepino[3,2-*a*]benzimidazole 6,6-dioxide (14e): mp 257 - 259 °C (decomp) (EtOAc); ^{1}H NMR (DMSO-d_6, δ, ppm) 0.92 - 1.26 (6H, m, $3CH_2$), 3.00 - 3.11 (4H, m, $2NCH_2$), 3.18 (2H, d, *J* = 7.0 Hz, CH_2), 5.34 (2H, s, NCH_2), 7.15 - 7.54 (8H, m, CH and ArH), 7.96 (1H, d, *J* = 8.2 Hz, ArH); ^{13}C NMR (DMSO-d_6, δ, ppm) 24.6, 25.7, 27.6, 34.5, 43.7, 46.4, 47.9, 113.1, 120.2, 123.9, 127.7, 129.2, 130.8, 131.0, 131.8, 132.9, 133.7, 135.1, 140.3, 141.0, 143.5, 150.8, 168.0; IR (KBr) (cm^{-1}) 2960, 1625, 1452, 1321, 1244, 1135, 1057, 862, 469; *Anal*. Calcd for $C_{23}H_{23}N_3O_3S$: C, 65.54; H, 5.50; N, 9.97; S, 7.61. Found: C, 65.47; H, 5.63; N, 10.07; S, 7.43.

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