Highly Diasteroselective and Remarkably π-Facially Selective Lewis Acid-Catalysed Diels–Alder Cycloaddition Reactions: Access to Novel 1,3,4-Trisubstituted 2-Azetidinones

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Diastereoselective and π-facially selective Lewis acid-catalysed intermolecular Diels–Alder reactions of 3-butadienyl-azetidin-2-ones with a variety of symmetrical dienophiles (maleic anhydride, *N*-phenylmaleimide, *N*-*p*-tolylmaleimide, benzoquinone and naphthoquinone) resulting in the synthesis of diastereomerically pure 1,3,4-trisubstituted 2-azetidinones are reported. The effects of different Lewis acids on the yields of the selectively formed diastereoisomers under different reaction conditions are also examined. Preferential chelation between the Lewis acid complexes of the different dienophiles and the carbonyl oxygens in the dienylazetidin-2-ones has been invoked to explain the observed π-facial selectivity. The Lewis acid complexes of the dienophiles have been shown to approach preferentially from the *si*-faces of the dienes, resulting in the formation of π-facially selective "*endo*" adducts. The structures of these "*endo*" adducts have even been supported by X-ray diffraction studies.

Introduction

Diels–Alder cycloaddition reactions of appropriately functionalised 1,3-dienes continue to stimulate the imaginations of an increasing number of chemists for the selective construction of variously substituted six-membered rings in a wide variety of organic compounds including natural products.[1] There has been a recent upsurge in the development of simpler methods for the synthesis of such functionalised 1,3-dienes because of their pertinence as intermediates in the syntheses/structures of various natural products.[2a] However, most of the reported methods invariably suffer from various disadvantages, such as large numbers of steps involved, cumbersome experimental procedures and low isolated yields.[2b] It was felt that the dienyl-substituted carbocyclic/heterocyclic compounds might be easily obtainable through cycloaddition reactions between appropriately substituted substrates and butadienyl ketene. Accordingly, reports from our laboratory have described convenient routes for the synthesis of dienylazetidin-2-one and pyrimidinone derivatives through [2+2] and [4+2] cycloaddition reactions between butadienylketene and imines[3] and 1,3-diazabuta-1,3-dienes,[4] respectively. Numerous reports have shown the importance of 3,4-disubstituted and 1,3,4-trisubstituted monocyclic β-lactams as effectual antibacterial agents, antielastogenic agents, potent cholesterol absorption inhibitors, human cytomegalovirus protease inhibitors and thrombin inhibitors.[5,6,7,8,9] This prompted us to explore the syntheses of such substituted 2-azetidinones by means of Diels–Alder cycloaddition reactions of 3-dienylazetidin-2-ones. Previously attempted Diels–Alder cycloaddition reactions of 3- and 4-dienylazetidin-2-ones had employed heating of the reactants in toluene at reflux in the absence of any catalyst, and the lack of topographic discrimination under these conditions had resulted in mixtures of *endo* and *exo* adducts.[3,9] To date, reported π-facially selective cycloadditions involving dienes or dienophiles with stereogenic centres at their allylic positions[10,11] have resulted predominantly in unequal mixtures of "*endo*" adducts. The π-facial selectivities observed in such cases have been explained in terms of dominant steric and conformational factors, thus providing little insight into the contribution of electronic factors.[12] In addition, most of these reported π-facially selective Diels–Alder cycloaddition studies are restricted to dienes/dienophiles embedded in rigid cyclic frameworks.[10] In view of the importance of selectivity in organic synthesis, it was felt that the carbonyl groups in the dienylazetidin-2-ones **1a**–**1c** and **5a**–**5c** may play important roles for the desired topographic discrimination through chelation with

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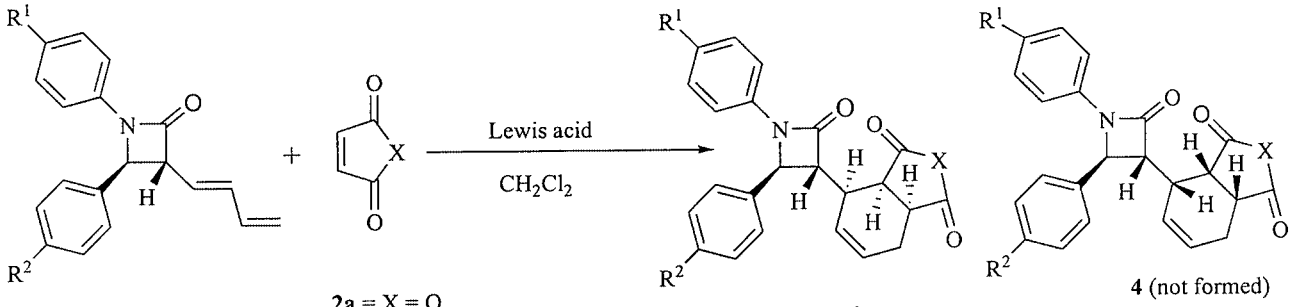
Lewis acid-associated symmetrical dienophiles. Here we report convenient and remarkably diastereoselective and π-facially selective Lewis acid-catalysed Diels–Alder cycloaddition reactions of unactivated dienyl components of 3-dienylazetidin-2-ones with α and β stereocentres.

Results and Discussion

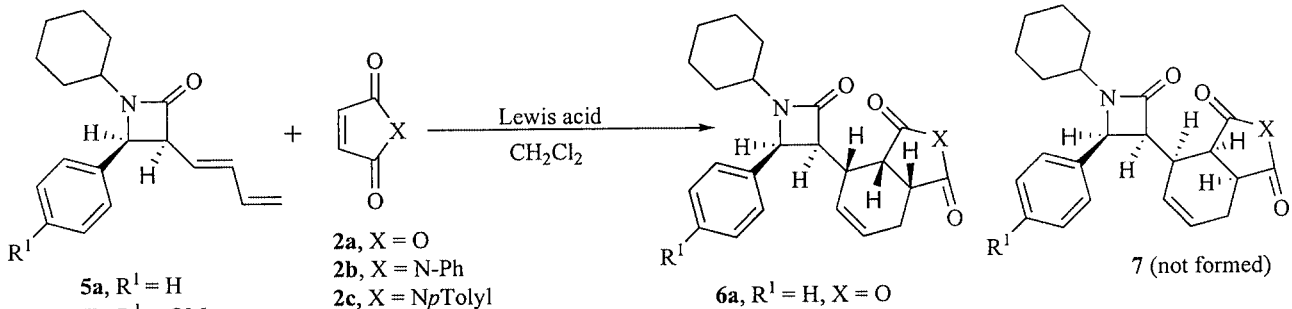
The 3-butadienylazetidin-2-ones **1a**–**c** and **5a**–**c** required for these studies were easily obtained by treatment of the butadienyl ketene, generated in situ from sorbyl chloride



1a, $R^1 = H$, $R^2 = H$
1b, $R^1 = H$, $R^2 = OMe$
1c, $R^1 = Me$, $R^2 = H$

2a = X = O
2b = N-Ph
2c = N-Ph-CH_3
2d = -CH=CH-
2e = -C_6H_4

3a, $R^1 = H$, $R^2 = H$, X = O
3b, $R^1 = H$, $R^2 = OCH_3$, X = O
3c, $R^1 = CH_3$, $R^2 = H$, X = O
3d, $R^1 = H$, $R^2 = H$, X = N-Ph
3e, $R^1 = H$, $R^2 = OCH_3$, X = N-Ph
3f, $R^1 = CH_3$, $R^2 = H$, X = N-Ph
3g, $R^1 = H$, $R^2 = H$, X = N-Ph-CH_3
3h, $R^1 = H$, $R^2 = OCH_3$, X = N-Ph-CH_3
3i, $R^1 = CH_3$, $R^2 = H$, X = N-Ph-CH_3
3j, $R^1 = H$, $R^2 = H$, X = -CH=CH-
3k, $R^1 = H$, R^2 =O CH_3, X = -CH=CH-
3l, $R^1 = CH_3$, $R^2 = H$, X = -CH=CH-
3m, $R^1 = H$, $R^2 = H$, X = C_6H_4
3n, $R^1 = H$, $R^2 = OCH_3$, X = C_6H_4
3o, $R^1 = CH_3$, $R^2 = H$, X = C_6H_4



5a, $R^1 = H$
5b, $R^1 = OMe$
5c, $R^1 = Cl$

2a, X = O
2b, X = N-Ph
2c, X = N*p*Tolyl
2d, X = -CH=CH-
2e, X = -C_6H_4

6a, $R^1 = H$, X = O
6b, $R^1 = OCH_3$, X = O
6c, $R^1 = Cl$, X = O
6d, $R^1 = H$, X = N-Ph
6e, $R^1 = OCH_3$, X = N-Ph
6f, $R^1 = Cl$, X = N-Ph
6g, $R^1 = H$, X = N-Ph-CH_3
6h, $R^1 = OCH_3$, X = N-Ph-CH_3
6i, $R^1 = Cl$, X = N-Ph-CH_3
6j, $R^1 = H$, X = -CH=CH-
6k, $R^1 = OCH_3$, X = -CH=CH-
6l, $R^1 = Cl$, X = -CH=CH-
6m, $R^1 = H$, X = C_6H_4
6n, $R^1 = OCH_3$, X = C_6H_4
6o, $R^1 = Cl$, X = C_6H_4

Scheme 1. Reactions of dienylazetidin-2-ones with symmetrical dienophiles.

and triethylamine in dry dichloromethane, with *N*-aryl[5] and *N*-aliphatic imines, respectively. Treatment of 3-butadienylazetidin-2-ones **1a**–**c** and **5a**–**c** with cyclic dienophiles **2a**–**2e** in the presence of the Lewis acids resulted in the diastereoselective and π-facially selective formation of highly "*endo*" adducts **3a**–**3o** and **6a**–**6o**, respectively, in 26–98% yields (Scheme 1, Table 1 and Table 2). The common Lewis acids aluminium(III) chloride, titanium(IV) chloride and tin(IV) chloride were examined for their comparative effects on the yields and desired diastereoselectivity in these Diels–Alder reactions (Table 1 and Table 2). Interestingly, the use of all these Lewis acids promoted remarkably high π-facial selectivity, and not even high-resolution ^{1}H NMR spectra (500 MHz) of the crude reaction mixtures of adducts were able to show the presence of traces of any other diastereoisomers. The best results in terms of yields and selectivity were obtained with the use of titanium(IV) chloride as catalyst. Thus, treatment of **1a**–**1c** and **5a**–**5c** with maleic anhydride (**2a**) in the presence of titanium(IV) chloride resulted in the exclusive formation of diastereomerically pure "*endo*" adducts **3a**–**3c** and **6a**–**6c** in good yields (69–72% and 54–59%, Entries 1–6 in Table 1 and Table 2). The yields were further improved by conducting the reactions at –78 °C (84–88% and 85–90%, Entry 4 in Tables 1 and 2). However, the reactions with maleic anhydride did not proceed in the presence of tin(IV) chloride (Entries 5 and 6 in Table 1 and Table 2) and showed deterioration of the adducts with the use of aluminium(III) chloride, possibly owing to its strong acidity (Entries 1 and 2 in Table 1 and Table 2).

Table 1. Lewis-acid-catalysed reactions of **1a**–**1c** with different dienophiles.

Entry	Lactam	Dienophile	LA	Temp. (°C)	Yield (%)
1	**1a/1b/1c**	**2a**	$AlCl_3$	room temp.	26/29/36
2	**1a/1b/1c**	**2a**	$AlCl_3$	–78	43/54/42
3	**1a/1b/1c**	**2a**	$TiCl_4$	room temp.	69/65/72
4	**1a/1b/1c**	**2a**	$TiCl_4$	–78	89/85/90
5	**1a/1b/1c**	**2a**	$SnCl_4$	room temp.	–/–
6	**1a/1b/1c**	**2a**	$SnCl_4$	–78	–/–
7	**1a/1b/1c**	**2b**	$AlCl_3$	room temp.	43/52/58
8	**1a/1b/1c**	**2b**	$AlCl_3$	–78	63/69/62
9	**1a/1b/1c**	**2b**	$TiCl_4$	room temp.	78/85/80
10	**1a/1b/1c**	**2b**	$TiCl_4$	–78	91/90/86
11	**1a/1b/1c**	**2b**	$SnCl_4$	room temp.	54/52/49
12	**1a/1b/1c**	**2b**	$SnCl_4$	–78	62/59/65
13	**1a/1b/1c**	**2c**	$AlCl_3$	room temp.	48/58/52
14	**1a/1b/1c**	**2c**	$AlCl_3$	–78	65/60/69
15	**1a/1b/1c**	**2c**	$TiCl_4$	room temp.	55/42/36
16	**1a/1b/1c**	**2c**	$TiCl_4$	–78	70/71/77
17	**1a/1b/1c**	**2c**	$SnCl_4$	room temp.	54/58/52
18	**1a/1b/1c**	**2c**	$SnCl_4$	–78	96/91/88
19	**1a/1b/1c**	**2d**	$AlCl_3$	room temp.	43/62/65
20	**1a/1b/1c**	**2d**	$AlCl_3$	–78	62/66/72
21	**1a/1b/1c**	**2d**	$TiCl_4$	room temp.	49/48/39
22	**1a/1b/1c**	**2d**	$TiCl_4$	–78	72/75/79
23	**1a/1b/1c**	**2d**	$SnCl_4$	room temp.	57/59/46
24	**1a/1b/1c**	**2d**	$SnCl_4$	–78	94/96/82
25	**1a/1b/1c**	**2e**	$AlCl_3$	room temp.	47/49/46
26	**1a/1b/1c**	**2e**	$AlCl_3$	–78	69/68/59
27	**1a/1b/1c**	**2e**	$TiCl_4$	room temp.	54/52/48
28	**1a/1b/1c**	**2e**	$TiCl_4$	–78	78/75/68
29	**1a/1b/1c**	**2e**	$SnCl_4$	room temp.	54/58/52
30	**1a/1b/1c**	**2e**	$SnCl_4$	–78	92/95/90

Table 2. Lewis-acid-catalysed reactions of **5a**–**5c** with different dienophiles.

Entry	Lactam	Dienophile	LA	Temp. (°C)	Yield (%)
1	**5a/5b/5c**	**2a**	$AlCl_3$	room temp.	27/31/35
2	**5a/5b/5c**	**2a**	$AlCl_3$	–78	38/32/39
3	**5a/5b/5c**	**2a**	$TiCl_4$	room temp.	54/59/58
4	**5a/5b/5c**	**2a**	$TiCl_4$	–78	84/88/85
5	**5a/5b/5c**	**2a**	$SnCl_4$	room temp.	–/–
6	**5a/5b/5c**	**2a**	$SnCl_4$	–78	–/–
7	**5a/5b/5c**	**2b**	$AlCl_3$	room temp.	64/60/69
8	**5a/5b/5c**	**2b**	$AlCl_3$	–78	93/95/92
9	**5a/5b/5c**	**2b**	$TiCl_4$	room temp.	75/72/87
10	**5a/5b/5c**	**2b**	$TiCl_4$	–78	87/87/82
11	**5a/5b/5c**	**2b**	$SnCl_4$	room temp.	53/55/52
12	**5a/5b/5c**	**2b**	$SnCl_4$	–78	67/65/69
13	**5a/5b/5c**	**2c**	$AlCl_3$	room temp.	68/69/75
14	**5a/5b/5c**	**2c**	$AlCl_3$	–78	75/77/78
15	**5a/5b/5c**	**2c**	$TiCl_4$	room temp.	64/69/75
16	**5a/5b/5c**	**2c**	$TiCl_4$	–78	72/79/86
17	**5a/5b/5c**	**2c**	$SnCl_4$	room temp.	51/58/49
18	**5a/5b/5c**	**2c**	$SnCl_4$	–78	92/90/96
19	**5a/5b/5c**	**2d**	$AlCl_3$	room temp.	67/48/58
20	**5a/5b/5c**	**2d**	$AlCl_3$	–78	70/65/59
21	**5a/5b/5c**	**2d**	$TiCl_4$	room temp.	65/68/52
22	**5a/5b/5c**	**2d**	$TiCl_4$	–78	74/65/75
23	**5a/5b/5c**	**2d**	$SnCl_4$	room temp.	54/58/54
24	**5a/5b/5c**	**2d**	$SnCl_4$	–78	95/98/91
25	**5a/5b/5c**	**2e**	$AlCl_3$	room temp.	42/39/36
26	**5a/5b/5c**	**2e**	$AlCl_3$	–78	65/72/71
27	**5a/5b/5c**	**2e**	$TiCl_4$	room temp.	54/51/55
28	**5a/5b/5c**	**2e**	$TiCl_4$	–78	77/74/75
29	**5a/5b/5c**	**2e**	$SnCl_4$	room temp.	55/51/52
30	**5a/5b/5c**	**2e**	$SnCl_4$	–78	95/88/89

In continuation of these studies and in an attempt to generalise the observed diastereoselectivity, the reactions of **1a**–**1c** and **5a**–**5c** with *N*-phenylmaleimide (**2b**) and *N*-*p*-tolylmaleimide (**2c**) as dienophiles were then examined. Treatment of **1a**–**1c** and **5a**–**5c** with **2b** and **2c** (Entries 7–18 in Table 1 and Table 2) with titanium(IV) chloride as catalyst resulted in good yields (43–96%) of the corresponding "*endo*" adducts even at room temperature (Entries 9, 10, 15 and 16 in Table 1 and Table 2). With the use of aluminium(III) chloride as catalyst, however, these reactions also resulted in deterioration of the adducts, with natural decreases in the yields (Entries 7, 8, 13 and 14 in Table 1 and Table 2). The methodology was extended further to the Diels–Alder cycloaddition reactions of **1a**–**1c** and **5a**–**5c** with benzoquinone (**2d**) and naphthoquinone (**2e**). The use of the above Lewis acids also resulted in the exclusive formation of the "*endo*" adducts in good yields in these reactions (46–96%) (Entries 19–30 in Table 1 and Table 2). However, with the use of titanium(IV) chloride and tin(IV) chloride, the yields of the adducts were significantly increased, especially when the reactions were conducted at –78 °C (Entries 9, 10, 15, 16, 18 and 30 in Table 1 and Table 2).

The obtained diastereomerically pure adducts were characterised with the help of analytical data and spectral evidence, details of which are described in the Experimental

Section, while the salient features are discussed here. Compound **3a,** for example, analysed for $C_{23}H_{19}NO_4$ and showed a molecular ion peak at *m/z* 373 in its mass spectrum. Its IR spectrum showed a strong absorption peak at 1727 cm^{-1}, due to the β-lactam ring carbonyl group. Its high-resolution ^1H NMR (500 MHz) spectrum showed a characteristic doublet at δ = 4.75 (J = 2.2 Hz) corresponding to H_4 of the β-lactam ring, a multiplet (ddddd, J = 15.8, 8.2, 3.0, 3.0, 3.0 Hz) at δ = 2.28, due to H_{8b}, a doublet of a doublet of a doublet at δ = 2.81 (J = 15.8, 7.0, 1.2 Hz) assigned to H_{8a} and another multiplet (ddddd, J = 11.0, 5.8, 3.0, 3.0, 3.0, Hz), due to H_5, at δ = 2.86 ppm. The coupling constant of J = 5.8 Hz between H_5 and H_{12} established the *cis* stereochemistry between these protons, while the coupling constant of J = 11.0 Hz confirmed the *trans* stereochemical assignment between protons H_5 and H_3. Its ^{13}C NMR spectrum showed the presence of three carbonyls at δ = 165.8, δ = 171.5 and δ = 173.8 (C-10 and C-11). (Figure 1).

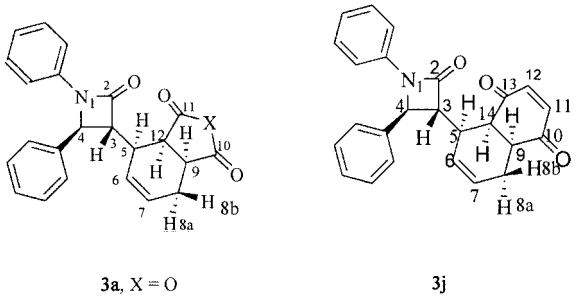


Figure 1. Stereochemistry of the "*endo*" adducts.

Similarly, a coupling constant value of J = 10.5 Hz between protons H_3 and H_5 in the ^1H NMR spectrum of **3j** established a *trans* relationship between them. Additionally, the presence of two doublets at δ = 6.52 and δ = 6.65 with a coupling constant of J = 10.5 Hz between protons H_{11} and H_{12} confirmed the single addition of the dienyl component of dienylazetidin-2-one to the benzoquinone. This observation is further supported by the presence of two characteristic α,β-unsaturated carbonyls at δ = 198.3 and δ = 200.1 in its ^{13}C NMR spectrum.

Configurational Assignment of Diels–Alder Adducts

In agreement with expectations, the Diels–Alder cycloaddition reactions of 3-dienylazetidin-2-ones **1a**–**1c** and **5a**–**5c** with symmetrical dienophiles **2a**–**2e** in the presence of Lewis acids have evidently resulted in topographic discrimination to afford the "*endo*" adducts exclusively. However, the presence of stereocentres in the α-positions of the α-dienyl-β-lactams makes the two faces of the dienyl component distinguishable (Figure 2).

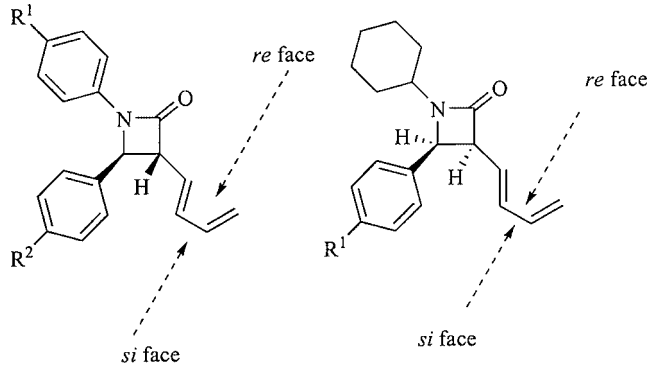


Figure 2. Facial discrimination in the dienylazetidin-2-ones.

Accordingly, one may expect two possible "*endo*" adducts, differing in the stereochemical relationship between the stereocentres on the lactam and on the cyclohexene moieties (Scheme 1 and Figure 3).

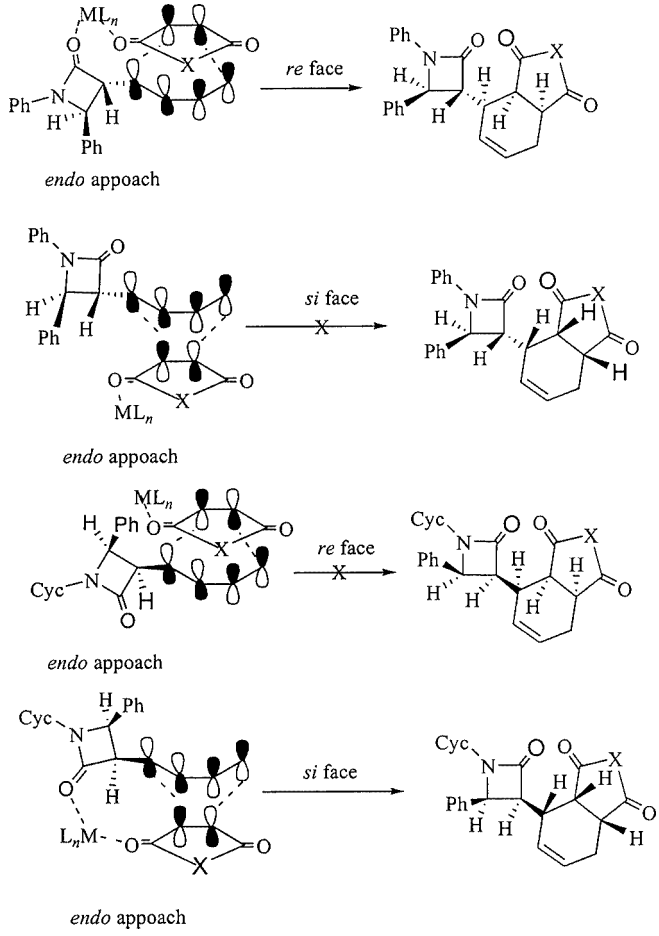


Figure 3. Various possible approaches of LA–dienophile complexes towards dienylazetidin-2-ones.

Attempts to distinguish such "*endo*" adducts on the basis of available high-resolution ^1H NMR and NOE spectroscopic data have so far been unsuccessful, due largely to the complexity of their ^1H NMR spectra.

However, X-ray crystallographic studies of the DA adducts obtained on treatment of **1a** and **5a** with maleic anhy-

dride **2a** and *N*-phenylmaleimide **2b**, respectively, unequivocally established the "*endo*" structures **3a** and **6d** for these adducts (Figure 4 and Figure 5).[13,14]

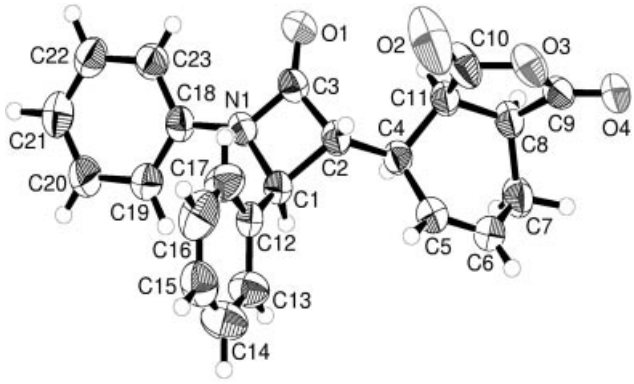


Figure 4. Projection of molecules of compound **3a** as determined by X-ray crystallography.

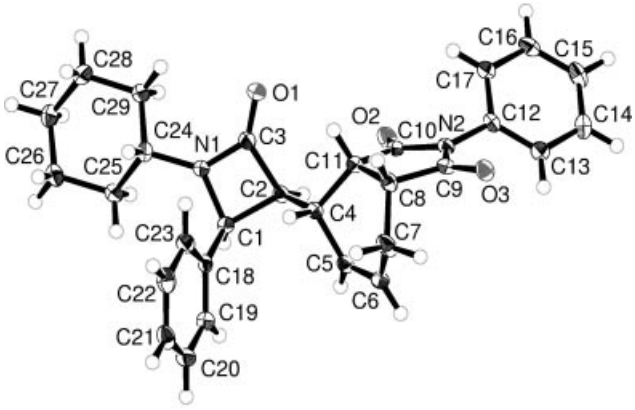


Figure 5. Projection of molecules of compound **6d** as determined by X-ray crystallography.

The observed π-facial selectivity is probably due to the more favourable chelation of the remote carbonyl oxygen with the dienophile-associated Lewis acid in the *re*-face approach resulting in the exclusive formation of "*endo*" adducts **3a**–**3o** and **6a**–**6o** (Figure 3). The observed dihedral angle of 179.6° for ^{3}H-^{3}C-$^{1'}$C-$^{1'}$H in the crystal lattice of adduct **3a** and the 179.9° calculated by AM1 calculations is also supported by the observed coupling constant of 11 Hz between H_3 and H_5 in its 500-MHz ^{1}H NMR spectrum. The approach of the complex to the *si*-face of the diene is energetically disfavoured as viewed with the help of molecular models. However, in a DA cycloaddition reaction of *N*-cyclohexyl-2-azetidinones the *si*-face approach appears to be energetically more favourable.

Conclusions

A convenient and unprecedented Lewis acid catalysis-based methodology for the Diels–Alder reactions of unusual dienes possessing α- and β-stereocentres has been developed, providing "*endo*" adducts in exclusive, diastereoselective and π-facially selective manner, and not mixtures of "*endo*" and "*endo*/*exo*" adducts as reported earlier. The obtained selectivity could presumably be due to the preferential chelation of Lewis-acid-associated dienophile with the β-lactam carbonyl oxygen. Further work on the synthesis and Diels–Alder cycloadditions of such unusual dienes possessing α,β-stereocentres is in progress.

Experimental Section

General Remarks: Melting points were determined by open capillary with a Veego Precision Digital Melting Point apparatus (MP-D) and are uncorrected. IR spectra were recorded on a Shimadzu D-8001 spectrophotometer. ^{1}H NMR spectra were recorded in deuterochloroform with Bruker AC-E 200 (200 MHz and 500 MHz) spectrometers with TMS as internal standard. Chemical shift values are expressed as ppm downfield from TMS and *J* values are in Hz. Splitting patterns are indicated as s: singlet, d: doublet, t: triplet, m: multiplet, q: quartet and br: broad peak. ^{13}C NMR spectra were also recorded on a Bruker AC 200E (60 MHz) spectrometer in deuterochloroform with TMS as internal standard. Mass spectra were recorded on a Shimadzu GCMS-QP-2000 mass spectrometer. Elemental analyses were performed on a Heraus CHN-O-Rapid Elemental Analyzer. Column chromatography was performed on silica gel (60–120) or a Harrison Research Chromatotron with 2 mm plates (silica gel 60 PF254). *trans*-Dienylazetidin-2-ones were prepared by the reported methods[3] and the same procedure was employed for the synthesis of *cis*-dienylazetidin-2-ones by use of *N*-alkylimines.

General Procedure: The typical procedure for the Diels–Alder reactions involved the addition of the Lewis acid (1.5 mmol) to a well stirred solution of dienophile (1 mmol) in dry dichloromethane (10 mL) at the reaction temperature. The solution was allowed to stir for 5 min, followed by the addition of the dienylazetidin-2-one (1 mmol). The progress of the reaction was monitored by tlc with diene taken as the limiting reactant.

4-(2-Oxo-1,4-diphenylazetidin-3-yl)-3a,4,7,7a-tetrahydroisobenzofuran-1,3-dione (3a): m.p. 195–196 °C. ^{1}H NMR ($CDCl_3$, 500 MHz): δ_H = 2.28 (ddddd, *J* = 3.0, 3.0, 3.0, 8.2, 15.8 Hz, 1 H, H^{8b}), 2.81 (ddd, *J* = 1.2, 7.0, 15.8 Hz, 1 H, H^{8a}), 2.86 (ddddd, *J* = 3.0, 3.0, 3.0, 5.8, 11.0 Hz, 1 H, H^{5}), 3.49 (ddd, *J* = 1.2, 8.2, 9.8 Hz, 1 H, H^{9}), 3.97 (dd, *J* = 2.2, 11.0 Hz, 1 H, H^{3}), 4.05 (dd, *J* = 5.8, 9.8 Hz, 1 H, H^{12}), 4.75 (d, *J* = 2.2 Hz, 1 H, H^{4}) 5.89 (dd, *J* = 3.0, 9.2 Hz, 1 H, H^{6}), 6.10 (dddd, *J* = 3.0, 3.0, 7.0, 9.2 Hz, 1 H, H^{7}), 7.24 (m, 10 H, H, aromatic) ppm. ^{13}C NMR ($CDCl_3$, 75 MHz): δ_C = 24.7, 36.5, 40.4, 42.9, 59.1, 61.2, 117.0, 124.2, 126.0, 128.9, 129.1, 129.4, 129.8, 130.7, 137.0, 137.3, 165.8, 171.5, 173.8 ppm. IR (KBr): $\tilde{\nu}$ = 1727, 1702, 1492, 1385 cm^{-1}. *m*/*z* 373 $[M]^+$. Elemental analysis calcd. for $C_{23}H_{19}NO_4$ (373.13): C 73.98, H 5.13, N 3.75; found C 74.15, H 5.33, N 3.36.

4-[2-(4-Methoxyphenyl)-4-oxo-1-phenylazetidin-3-yl]-3a,4,7,7a-tetrahydroisobenzofuran-1,3-dione (3b): M.p. 179–180 °C. ^{1}H NMR ($CDCl_3$, 200 MHz): δ_H = 2.37 (unresolved dddd, *J* = 3.2, 8.7, 13.0 Hz, 1 H, H^{8b}), 2.89 (unresolved ddd, *J* = 7.2 13.0 Hz, 1 H, H^{8a}), 2.97 (unresolved dddd, *J* = 3.2, 5.8, 11.5 Hz, 1 H, H^{5}), 3.53 (ddd, *J* = 3.1, 8.7, 9.9 Hz, 1 H, H^{9}), 3.80 (s, 3 H, –OCH_3), 4.15 (dd, *J* = 2.3, 11.7 Hz, 1 H, H^{3}), 4.20 (dd, *J* = 5.3, 9.9 Hz, 1 H, H^{12}), 4.80 (d, *J* = 2.3 Hz, 1 H, H^{4}), 5.98 (dd, *J* = 3.2, 9.7 Hz, 1 H, H^{6}), 6.15 (unresolved ddd, *J* = 7.2, 9.7 Hz, 1 H, H^{7}), 7.37 (m, 9 H, arom.) ppm. ^{13}C NMR ($CDCl_3$, 60 MHz): δ_C = 25.3, 37.3, 41.4, 43.3, 55.2, 60.1, 62.3, 118.0, 125.2, 127.0, 129.0, 129.3, 129.8, 129.9, 131.7, 138.0, 138.2, 166.8, 172.5, 174.8 ppm. IR (KBr): $\tilde{\nu}$ = 1727,

1708, 1482, 1381 cm^{-1}. *m*/*z* 403 [*M*]$^+$. Elemental analysis calcd. for $C_{24}H_{21}NO_5$ (403.14): C 71.45, H 5.25, N 3.47; found C 71.58, H 5.13, N 3.36.

4-(2-Oxo-4-phenyl-1-*p*-tolylazetidin-3-yl)-3a,4,7,7a-tetrahydroisobenzofuran-1,3-dione (3c): M.p. 177–178 °C. ^{1}H NMR ($CDCl_3$, 200 MHz): δ_H = 2.23 (unresolved dddd, *J* = 3.0, 8.0, 13.2 Hz, 1 H, H^{8b}), 2.31 (s, 3 H, –CH_3), 2.74 (unresolved ddd, *J* = 6.8, 13.2 Hz, 1 H, H^{8a}), 2.92 (unresolved ddd, *J* = 3.0, 5.6, 11.9 Hz, 1 H, H^5), 3.45 (ddd, *J* = 1.6, 8.0, 9.7 Hz, 1 H, H^9), 4.02 (dd, *J* = 2.3, 11.9 Hz, 1 H, H^3), 4.07 (dd, *J* = 5.6, 9.7 Hz, 1 H, H^{12}), 4.70 (d, *J* = 2.3 Hz, 1 H, H^4), 5.84 (dd, *J* = 3.0, 9.3 Hz, 1 H, H^6), 6.07 (unresolved ddd, *J* = 6.7, 9.3 Hz, 1 H, H^7), 7.35 (m, 9 H, arom.) ppm. ^{13}C NMR ($CDCl_3$, 60 MHz): δ_C = 20.2, 25.7, 37.3, 40.5, 42.8, 60.2, 61.5, 118.0, 124.3, 127.0, 128.5, 128.9, 131.0, 131.5, 132.4, 137.0, 137.3, 165.8, 171.6, 173.9 ppm. IR (KBr): $\tilde{\nu}$ = 1732, 1709, 1435, 1373 cm^{-1}. *m*/*z* 387 [*M*]$^+$. Elemental analysis calcd. for $C_{24}H_{21}NO_4$ (387.15): C 74.40, H 5.46, N 3.62; found C 74.52, H 5.30, N 3.35.

4-(2-Oxo-1,4-diphenylazetidin-3-yl)-2-phenyl-3a,4,7,7a-tetrahydroisoindole-1,3-dione (3d): M.p. 250–251 °C. ^{1}H NMR ($CDCl_3$, 500 MHz): δ_H = 2.29 (unresolved ddddd, *J* = 3.0, 3.0, 8.2, 15.3 Hz, 1 H, H^{8b}), 2.80 (unresolved ddd, *J* = 7.2, 15.3 Hz, 1 H, H^{8a}) 2.93 (unresolved ddddd, *J* = 3.0, 3.0, 7.2, 11.4 Hz, 1 H, H^5), 3.34 (ddd, *J* = 1.5, 8.2, 10.5 Hz, 1 H, H^9), 3.93 (dd, *J* = 2.2, 11.4 Hz, 1 H, H^3) 4.18 (dd, 3.0, 10.5 Hz, 1 H, H^{12}) 4.77 (d, *J* = 2.2 Hz, 1 H, H^4), 5.85 (dd, *J* = 3.0, 9.1 Hz, 1 H, H^6), 6.12 (ddd, *J* = 3.0, 7.2, 9.1 Hz, 1 H, H^7) 7.21 (m, 15 H, arom. H) ppm. ^{13}C NMR ($CDCl_3$, 75 MHz): δ_C = 25.0, 37.3, 39.9, 41.9, 59.6, 61.3, 116.9, 123.9, 126.0, 126.4, 128.5, 128.6, 128.9, 129.0, 129.2, 129.4, 130.4, 131.6, 137.3, 137.4, 166.5, 176.6, 178.5 ppm. IR (KBr): $\tilde{\nu}$ = 1765, 1754, 1685, 1625, 1378, 1356 1291, 1184 cm^{-1}. *m*/*z* 448 [*M*]$^+$. Elemental analysis calcd. for $C_{29}H_{24}N_2O_3$ (448.18): C 77.67, H 5.35, N 6.25; found C 77.81, H 5.54, N 5.94.

4-[2-(4-Methoxyphenyl)-4-oxo-1-phenylazetidin-3-yl]-2-phenyl-3a,4,7,7a-tetrahydroisoindole-1,3-dione (3e): M.p. 215–216 °C. ^{1}H NMR ($CDCl_3$, 200 MHz): δ_H = 2.29 (unresolved dddd, *J* = 3.0, 9.2, 13.7 Hz, 1 H, H^{8b}), 2.87 (unresolved ddd, *J* = 6.5, 13.7 Hz, 1 H, H^{8a}), 2.98 (unresolved dddd, *J* = 3.0, 5.5, 11.7 Hz, 1 H, H^5), 3.52 (ddd, *J* = 3.1, 9.2, 9.9 Hz, 1 H, H^9), 3.79 (s, 3 H, –OCH_3), 3.99 (dd, *J* = 2.3, 11.7 Hz, 1 H, H^3), 4.09 (dd, *J* = 5.9, 9.9 Hz, 1 H, H^{12}), 4.81 (d, *J* = 2.3 Hz, 1 H, H^4), 5.85 (dd, *J* = 3.0, 9.8 Hz, 1 H, H^6), 6.07 (unresolved ddd, *J* = 6.7, 9.8 Hz, 1 H, H^7), 7.23 (m, 14 H, arom.) ppm. ^{13}C NMR ($CDCl_3$, 60 MHz): δ_C = 26.0, 38.3, 39.7, 41.3, 55.0, 60.2, 62.3, 116.2, 123.9, 126.7, 127.0, 128.3, 128.7, 128.9, 129.0, 129.3, 129.4, 129.5, 130.5, 137.8, 137.9, 166.9, 177.0, 178.6 ppm. IR (KBr): $\tilde{\nu}$ = 1770, 1760, 1672, 1623, 1371, 1340, 1176 cm^{-1}. *m*/*z* 478 [*M*]$^+$. Elemental analysis calcd. for $C_{30}H_{26}N_2O_4$ (478.19): C 75.30, H 5.48, N 5.85; found C 75.44, H 5.40, N 5.79.

4-(2-Oxo-4-phenyl-1-*p*-tolylazetidin-3-yl)-2-phenyl-3a,4,7,7a-tetrahydroisoindole-1,3-dione (3f): M.p. 205–206 °C. ^{1}H NMR ($CDCl_3$, 200 MHz): δ_H = 2.28 (s, 3 H, –CH_3), 2.34 (unresolved dddd, *J* = 3.0, 8.9, 13.5 Hz, 1 H, H^{8b}), 2.89 (unresolved ddd, *J* = 6.6, 13.5 Hz, 1 H, H^{8a}), 2.99 (ddd, *J* = 3.5, 5.6, 11.2 Hz, 1 H, H^5), 3.58 (ddd, *J* = 1.8, 8.8, 9.9 Hz, 1 H, H^9), 4.05 (dd, *J* = 2.3, 11.2 Hz, 1 H, H^3), 4.20 (dd, *J* = 5.6, 9.9 Hz, 1 H, H^{12}), 4.77 (d, *J* = 2.30 Hz, 1 H, H^4), 5.95 (dd, *J* = 3.5, 9.9 Hz, 1 H, H^6), 6.25 (unresolved ddd, *J* = 6.9, 9.9 Hz, 1 H, H^7), 7.38 (m, 14 H, arom.) ppm. ^{13}C NMR ($CDCl_3$, 60 MHz): δ_C = 21.2, 23.8, 37.2, 41.8, 43.9, 60.1, 62.0, 118.0, 125.5, 126.0, 127.5, 128.7, 128.9, 129.5, 129.9, 130.0, 130.8, 131.1, 132.5, 137.0, 137.5, 166.8, 178.6, 180.5 ppm. IR (KBr): $\tilde{\nu}$ = 1727, 1765, 1379, 1355, 1292, 1184 cm^{-1}. *m*/*z* 462 [*M*]$^+$. Elemental analysis calcd. for $C_{30}H_{26}N_2O_3$ (462.19): C 77.90, H 5.67, N 6.06; found C 78.17, H 5.72, N 5.81.

4-(2-Oxo-1,4-diphenylazetidin-3-yl)-2-*p*-tolyl-3a,4,7,7a-tetrahydroisoindole-1,3-dione (3g): m.p. 225–226 °C. ^{1}H NMR ($CDCl_3$, 200 MHz): δ_H = 2.27 (unresolved dddd, *J* = 3.3, 8.7, 14.1 Hz, 1 H, H^{8b}), 2.33 (s, 3 H, –CH_3), 2.82 (unresolved ddd, *J* = 7.2, 14.1 Hz, 1 H, H^{8a}), 2.93 (unresolved ddd, *J* = 5.9, 11.3 Hz, 1 H, H^5), 3.53 (ddd, *J* = 1.5, 8.7, 9.9 Hz, 1 H, H^9), 3.97 (dd, *J* = 2.1, 11.3 Hz, 1 H, H^3), 4.10 (dd, *J* = 5.9, 9.9 Hz, 1 H, H^{12}), 4.78 (d, *J* = 2.2, 1 H, H^4), 5.92 (dd, *J* = 3.3, 9.7, 1 H, H^6), 6.18 (unresolved ddd, *J* = 7.2, 9.7 Hz, 1 H, H^7), 7.28 (m, 14 H, arom.) ppm. ^{13}C NMR ($CDCl_3$, 60 MHz): δ_C = 21.2, 25.7, 38.3, 39.9, 41.9, 60.0, 61.4, 117.9, 122.9, 125.0, 125.8, 126.9, 128.3, 128.7, 129.2, 129.3, 129.5, 130.5,131.7, 137.5, 138.2, 167.0, 177.3, 178.2 ppm. IR (KBr): $\tilde{\nu}$ = 1730, 1704, 1442, 1370 cm^{-1}. *m*/*z* 462 [*M*]$^+$. Elemental analysis calcd. for $C_{30}H_{26}N_2O_3$ (462.19): C 77.99, H 5.67, N 6.06; found C 78.10, H 5.58, N 6.03.

4-[2-(4-Methoxyphenyl)-4-oxo-1-phenylazetidin-3-yl]-2-*p*-tolyl-3a,4,7,7a-tetrahydroisoindole-1,3-dione (3h): m.p. 211–212 °C. ^{1}H NMR ($CDCl_3$, 200 MHz): δ_H = 2.31 (unresolved dddd, *J* = 3.0, 9.5, 13.5 Hz, 1 H, H^{8b}), 2.36 (s, 3 H, –CH_3), 2.89 (unresolved ddd, *J* = 6.6, 13.5 Hz, 1 H, H^{8a}), 2.92 (unresolved ddd, *J* = 5.5, 11.5 Hz, 1 H, H^5), 3.55 (ddd, *J* = 2.5, 9.2, 9.5 Hz, 1 H, H^9), 3.79 (s, 3 H, –OCH_3), 4.01 (dd, *J* = 2.3, 11.5 Hz, 1 H, H^3), 4.10 (dd, *J* = 5.5, 9.2 Hz, 1 H, H^{12}), 4.80 (d, *J* = 2.3 Hz, 1 H, H^4), 5.95 (dd, *J* = 3.5, 9.3 Hz, 1 H, H^6), 6.21 (unresolved ddd, *J* = 7.0, 9.3 Hz, 1 H, H^7), 7.28 (m, 13 H, arom.) ppm. ^{13}C NMR ($CDCl_3$, 60 MHz): δ_C = 20.5, 25.6, 36.8, 37.9, 42.1, 55.8, 60.6, 62.3, 118.0, 124.9, 126.4, 127.0, 128.1, 128.4, 128.6, 128.7, 129.0, 129.5, 130.1, 131.6, 137.4, 137.5,167.5,177.2,178.5 ppm. IR (KBr): $\tilde{\nu}$ = 1730, 1705, 1456, 1372, 1356, 1290, 1178 cm^{-1}. *m*/*z* 492 [*M*]$^+$. Elemental analysis calcd. for $C_{31}H_{28}N_2O_4$ (492.20): C 75.59, H 5.73, N 3.69; found C 74.52, H 5.30, N 3.66.

4-(2-Oxo-4-phenyl-1-*p*-tolylazetidin-3-yl)-2-*p*-tolyl-3a,4,7,7a-tetrahydroisoindole-1,3-dione (3i): M.p. 212–213 °C. ^{1}H NMR ($CDCl_3$, 200 MHz): δ_H = 2.25 (unresolved dddd, *J* = 3.0, 9.2, 13.0 Hz, 1 H, H^{8b}), 2.36 (s, 3 H, –CH_3), 2.40 (s, 3 H, –CH_3), 2.80 (unresolved ddd, *J* = 7.1, 13.0 Hz, 1 H, H^{8a}), 2.95 (unresolved ddd, *J* = 5.2, 11.1 Hz, 1 H, H^5), 3.48 (ddd, *J* = 2.2, 9.2, 9.8 Hz, 1 H, H^9), 3.92 (dd, *J* = 2.2, 11.1 Hz, 1 H, H^3), 4.02 (dd, *J* = 5.2, 9.8 Hz, 1 H, H^{12}), 4.75 (d, *J* = 2.2 Hz, 1 H, H^4), 5.88 (dd, *J* = 3.0, 9.8 Hz, 1 H, H^6), 6.12 (unresolved ddd, *J* = 6.8, 9.8 Hz, 1 H, H^7), 7.21(m, 13 H, arom.) ppm. ^{13}C NMR ($CDCl_3$, 60 MHz): δ_C = 20.1, 21.2, 25.7, 37.8, 38.8, 41.9, 58.6, 63.0, 117.9, 123.3, 126.4, 127.5, 128.2, 128.6, 128.7,128.9, 129.2, 129.5, 130.4, 131.6, 137.3, 137.4, 167.0, 175.6, 179.0 ppm. IR (KBr): $\tilde{\nu}$ = 1766, 1622, 1375, 1352, 1181, 1152 cm^{-1}. *m*/*z* 476 [*M*]$^+$. Elemental analysis calcd. for $C_{31}H_{28}N_2O_3$ (476.21): C 78.13, H 5.92, N 5.88; found C 78.32, H 5.89, N 5.72.

5-(2-Oxo-1,4-diphenylazetidin-3-yl)-4a,5,8,8a-tetrahydro-1,4-naphthoquinone (3j): M.p. 204–205 °C. ^{1}H NMR ($CDCl_3$, 500 MHz): δ_H = 2.17 (m, 1 H, H^{8b}), 2.37 (m, 1 H,H^{8a}), 2.95 (unresolved ddd, *J* = 5.5, 10.5 Hz, 1 H, H^5), 3.20 (m, 1 H, H^9), 3.91 (dd, 2.3, 10.5 Hz, 1 H, H^3), 4.00 (dd, *J* = 5.5, 11.0 Hz, 1 H, H^{14}), 4.78 (d, *J* = 2.3 Hz, 1 H, H^4), 5.70 (m, 2 H, $H^{6,7}$), 6.52 (d, 10.5 Hz, 1 H, H^{11}), 6.65 (d, *J* = 10.5 Hz, 1 H, H^{12}), 7.23 (m, 10 H, arom. H) ppm. ^{13}C NMR ($CDCl_3$, 75 MHz): δ_C = 26.37, 37.98, 48.41, 48.53, 60.47, 61.61, 116.96, 123.91, 125.50, 126.04, 126.36, 128.59, 129.02, 129.18, 137.08, 137.40, 137.55, 141.08, 166.54, 198.32, 200.18 ppm. IR (KBr): $\tilde{\nu}$ = 1765, 1754, 1685, 1625, 1378, 1356, 1291, 1184 cm^{-1}. *m*/*z* 383 [*M*]$^+$. Elemental analysis calcd. for $C_{25}H_{21}NO_3$ (383.15): C 78.32, H 5.48, N 3.65; found C 78.47, H 5.62, N 3.39.

5-[2-(4-Methoxyphenyl)-4-oxo-1-phenylazetidin-3-yl]-4a,5,8,8a-tetrahydro-1,4-naphthoquinone (3k): M.p. 171–172 °C. ^{1}H NMR ($CDCl_3$, 200 MHz): δ_H = 2.32 (m, 1 H, H^{8b}), 2.43 (m, 1 H, H^{8a}),

3.02 (unresolved ddd, J = 5.3, 1.8 Hz, 1 H, H^5), 3.28 (unresolved ddd, J = 8.2, 9.6 Hz, 1 H, H^9), 3.83 (s, 3 H, –OCH_3), 4.05 (dd, J = 2.5, 11.2 Hz, 1 H, H^3), 4.15 (dd, J = 5.3, 9.6 Hz, 1 H, H^{14}), 4.83 (d, J = 2.3 Hz, 1 H, H^4), 5.83 (m, 2 H, H^6, H^7), 6.63 (d, J = 10.5 Hz, 1 H, H^{11}), 6.73 (d, J = 10.4 Hz, 1 H, H^{12}), 7.34 (m, 9 H, arom.) ppm. ^{13}C NMR ($CDCl_3$, 60 MHz): δ_C = 27.5, 38.9, 49.4, 49.9, 55.2, 61.2, 61.9, 117.2, 123.4, 125.6, 126.2, 126.3, 128.6, 129.5, 129.7, 137.3, 137.7, 137.9, 141.3, 166.5, 198.4, 201.3 ppm. IR (KBr): $\tilde{\nu}$ = 1748, 1718, 1672, 1357 cm^{-1}. m/z 413 $[M]^+$. Elemental analysis calcd. for $C_{26}H_{23}NO_4$ (413.16): C 75.53, H 5.61, N 3.39; found C 75.66, H 5.52, N 3.34.

5-(2-Oxo-4-phenyl-1-*p*-tolylazetidin-3-yl)-4a,5,8,8a-tetrahydro-1,4-naphthoquinone (3l): M.p. 185–186 °C. ^{1}H NMR ($CDCl_3$, 200 MHz): δ_H = 2.27 (m, 1 H, H^{8b}), 2.28 (s, 3 H, –CH_3), 2.43 (m, 1 H, H^{8a}), 2.98 (unresolved ddd, J = 5.8, 11.3 Hz, 1 H, H^5), 3.28 (unresolved ddd, J = 7.9, 9.0 Hz, 1 H, H^9), 3.92 (dd, J = 2.5, 11.8 Hz, 1 H, H^3), 4.09 (dd, J = 5.3, 9.6 Hz, 1 H, H^{14}), 4.56 (d, J = 2.5 Hz, 1 H, H^4), 6.01 (m, 1 H, H^6), 6.15 (m, 1 H, H^7), 6.63 (d, J = 10.5 Hz, 1 H, H^{11}), 6.73 (d, 10.5 Hz, 1 H, H^{12}), 7.23 (m, 9 H, arom.) ppm. ^{13}C NMR ($CDCl_3$, 60 MHz): δ_C = 20.2, 26.5, 38.2, 48.4, 48.9, 60.5, 61.6, 117.2, 124.4, 125.6, 126.0, 126.3, 127.8, 128.5, 129.2, 137.2, 137.5, 137.6, 141.8, 166.7, 198.7, 200.3 ppm. IR (KBr): $\tilde{\nu}$ = 1740, 1728, 1682, 1350 cm^{-1}. m/z 397 $[M]^+$. Elemental analysis calcd. for $C_{26}H_{23}NO_3$ (397.17): C 78.57, H 5.83, N 3.52; found C 78.67, H 5.71, N 3.33.

1-(2-Oxo-1,4-diphenylazetidin-3-yl)-1,4,4a,9a-tetrahydroanthraquinone (3m): M.p. 208–209 °C. ^{1}H NMR ($CDCl_3$, 200 MHz): δ_H = 2.15 (m, 1 H, H^{8b}), 2.23 (m, 1 H, H^{8a}), 2.93 (unresolved ddd, J = 5.6, 11.8 Hz, 1 H, H^5), 3.37 (m, 1 H, H^9), 4.2 (dd, J = 2.10, 11.8 Hz, 1 H, H^3), 4.25 (dd, J = 5.8, 9.0 Hz, 1 H, H^{18}), 4.85 (d, J = 2.1 Hz, H^4), 5.7 (m, 1 H, H^6) 5.8 (m, 1 H, H^7), 7.44 (m, 14 H, arom.) ppm. ^{13}C NMR ($CDCl_3$, 60 MHz): δ_C = 26.3, 37.3, 49.1, 50.2, 60.2, 62.9, 117.4, 123.9, 125.3, 126.9, 127.8, 128.2, 129.5, 129.6, 130.6, 130.7, 131.2, 137.5, 137.6, 142.0, 166.3, 199.3, 201.3 ppm. IR (KBr): $\tilde{\nu}$ = 1747, 1636, 1614, 1608, 1536, 1504, 1372, 1232, 1176, 1132 cm^{-1}. m/z 433 $[M]^+$. Elemental analysis calcd. for $C_{29}H_{23}NO_3$ (433.17): C 80.35, H 5.35, N 3.23; found C 80.48, H 5.23, N 3.19.

1-[2-(4-Methoxyphenyl)-4-oxo-1-phenylazetidin-3-yl]-1,4,4a,9a-tetrahydroanthraquinone (3n): M.p. 230–231 °C. ^{1}H NMR ($CDCl_3$, 200 MHz): δ_H = 2.18 (m, 1 H, H^{8b}), 2.39 (m, 1 H, H^{8a}), 3.03 (unresolved ddd, J = 5.6, 11.8 Hz, 1 H, H^5), 3.37 (m, 1 H, H^9), 3.82 (s, 3 H, –OCH_3), 4.08 (dd, J = 2.10, 11.8 Hz, 1 H, H^3), 4.16 (dd, J = 5.6, 9.2 Hz, 1 H, H^{18}), 4.85 (d, J = 2.1 Hz, H^4), 5.7 (m, 2 H, H^6 and H^7), 7.36 (m, 13 H, arom.) ppm. ^{13}C NMR ($CDCl_3$, 60 MHz): δ_C = 25.3, 38.7, 49.1, 50.2, 55.3, 60.9, 62.0, 117.2, 123.9, 125.5, 126.8, 127.8, 128.1, 129.1, 129.2, 130.1, 131.4, 136.2, 137.4, 137.8, 142.0, 166.5, 198.3, 202.3 ppm. IR (KBr): $\tilde{\nu}$ = 1737, 1655, 1612, 1597, 1514, 1500, 1318, 1249, 1176, 1145, 1083, 1031 cm^{-1}. m/z 463 $[M]^+$. Elemental analysis calcd. for $C_{30}H_{25}NO_4$ (463.18): C 77.74, H 5.44, N 3.02; found C 77.86, H 5.32, N 2.89.

1-(2-Oxo-4-phenyl-1-*p*-tolylazetidin-3-yl)-1,4,4a,9a-tetrahydroanthraquinone (3o): M.p. 230–231 °C. ^{1}H NMR ($CDCl_3$, 200 MHz): δ_H = 2.08 (m, 1 H, H^{8b}), 2.23 (m, 1 H, H^{8a}), 2.35 (s, 3H –CH_3), 2.98 (unresolved ddd, J = 5.6, 11.8 Hz, 1 H, H^5), 3.48 (m, 1 H, H^9), 4.3 (dd, J = 2.3, 11.8 Hz, 1 H, H^3), 4.37 (dd, J = 5.4, 9.2 Hz, 1 H, H^{18}), 4.89 (d, J = 2.1 Hz, H^4), 5.73 (m, 1 H, H^6), 5.92 (m, 1 H, H^7), 7.32 (m, 13 H, arom.) ppm. ^{13}C NMR ($CDCl_3$, 60 MHz): δ_C = 21.2, 26.1, 38.3, 48.2, 50.1, 60.8, 62.1, 117.4, 123.8, 125.6, 127.2, 127.3, 128.3, 129.2, 129.6, 130.7, 130.9, 132.3, 136.5, 137.5, 142.0, 166.3, 198.3, 200.3 ppm. IR (KBr): $\tilde{\nu}$ = 1735, 1658, 1614, 1596, 1536, 1370, 1232, 1176, 1130 cm^{-1}. m/z 447 $[M]^+$. Elemental analysis calcd. for $C_{30}H_{25}NO_3$ (447.18): C 80.51, H 5.63, N 3.13; found C 80.63, H 5.47, N 3.02.

4-(1-Cyclohexyl-2-oxo-4-phenylazetidin-3-yl)-3a,4,7,7a-tetrahydroisobenzofuran-1,3-dione (6a): M.p. 183–184 °C. ^{1}H NMR ($CDCl_3$, 200 MHz): δ_H = 1.49 (m, 10 H, H cyclohexyl), 1.98 (m, 1 H, H^{8b}), 2.6 (m, 1 H, H^{8a}), 2.87 (unresolved ddd, J = 5.8, 11.3 Hz, 1 H, H^5), 3.38 (m, 1 H, H^9), 3.65 (m, 1 H, H cyclohexyl), 3.95 (dd, J = 5.5, 11.3 Hz, 1 H, H^3), 4.65 (dd, J = 5.8, 9.6 Hz, 1 H, H^{12}), 4.86 (d, J = 5.5 Hz, 1 H, H^4), 5.30 (unresolved dd, J = 9.0 Hz,1 H, H^6), 5.50 (unresolved ddd, J = 6.6, 9.0 Hz, 1 H, H^7), 7.48 (m, 5 H, arom. H) ppm. ^{13}C NMR ($CDCl_3$, 75 MHz): δ_C = 22.46, 24.10, 30.47, 32.53, 36.42, 40.71, 42.85, 52.13, 59.07, 61.23, 123.92, 125.85, 126.98, 128.03, 129.42, 136.82, 164.84, 169.89, 173.42 ppm. IR (KBr): $\tilde{\nu}$ = 1709, 1688, 1452, 1385, 1322, 1278, 1124 cm^{-1}. m/z 379 $[M]^+$. Elemental analysis calcd. for $C_{23}H_{25}NO_4$ (379.18): C 72.82, H 6.59, N 3.69; found C 72.94, H 6.74, N 3.44.

4-[1-Cyclohexyl-2-(4-methoxyphenyl)-4-oxoazetidin-3-yl]-3a,4,7,7a-tetrahydroisobenzofuran-1,3-dione (6b): M.p. 188–189 °C. ^{1}H NMR ($CDCl_3$, 200 MHz): δ_H = 1.34 (m, 10 H, cyclohexyl), 1.49 (m, 1 H, H^{8b}), 2.39 (m, 1 H, H^{8a}), 2.62 (unresolved ddd, J = 3.0, 5.3, 11.7 Hz, 1 H, H^5), 3.24 (m, 1 H, H^9), 3.44 (m, 1 H, cyclohexyl), 3.80 (s, 3 H, –OCH_3), 3.90 (dd, J = 5.5, 11.7 Hz, 1 H, H^3), 4.32 (dd, J = 5.3, 9.3 Hz, 1 H, H^{12}), 4.91 (d, J = 5.5 Hz, 1 H, H^4), 5.25 (m, 1 H, H^6), 6.02 (m, 1 H, H^7), 7.32 (m, 4 H, arom.) ppm. ^{13}C NMR ($CDCl_3$, 60 MHz): δ_C = 22.1, 24.3, 30.4, 32.5, 36.3, 40.7, 42.8, 52.1, 55.2, 59.2, 61.3, 123.9, 126.8, 127.9, 128.4, 129.5, 137.0, 165.2, 170.1, 174.3 ppm. IR (KBr): $\tilde{\nu}$ = 1709, 1693, 1438, 1375, 1312, 1259, 1121 cm^{-1}. m/z 409 $[M]^+$. Elemental analysis calcd. for $C_{24}H_{27}NO_5$ (409.19): C 70.40, H 6.65, N 3.42; found C 70.61, H 6.78, N 3.09.

4-[2-(4-Chlorophenyl)-1-cyclohexyl-4-oxoazetidin-3-yl]-3a,4,7,7a-tetrahydroisobenzofuran-1,3-dione (6c): M.p. 205–206 °C. ^{1}H NMR ($CDCl_3$, 200 MHz): δ_H = 1.42 (m, 10 H, cyclohexyl), 1.97 (m, 1 H, H^{8b}), 2.53 (m, 1 H, H^{8a}), 2.89 (unresolved ddd, J = 5.6, 12.0 Hz, 1 H, H^5), 3.38 (m, 1 H, H^9), 3.65 (m, 1 H, cyclohexyl), 4.01 (dd, J = 5.5, 12.0 Hz, 1 H, H^3), 4.69 (dd, J = 5.6, 9.6 Hz, 1 H, H^{12}), 4.91 (d, J = 5.5 Hz, 1 H, H^4), 5.35 (m, 1 H, H^6), 5.80 (m, 1 H, H^7), 7.49 (m, 4 H, arom.) ppm. ^{13}C NMR ($CDCl_3$, 60 MHz): δ^C = 22.5, 24.8, 26.1, 30.2, 32.1, 36.4, 40.0, 42.8, 59.0, 61.3, 124.7, 125.9, 127.0, 128.1, 129.4, 136.9, 164.6, 174.8, 178.7 ppm. IR (KBr): $\tilde{\nu}$ = 1738, 1718, 1648, 1345 cm^{-1}. m/z 413 $[M]^+$. Elemental analysis calcd. for $C_{23}H_{24}NO_4Cl$ (413.14): C 66.74, H 5.84, N 3.38; found C 66.87, H 5.97, N 3.14.

4-(1-Cyclohexyl-2-oxo-4-phenylazetidin-3-yl)-2-phenyl-3a,4,7,7a-tetrahydroisoindole-1,3-dione (6d): M.p. 190–191 °C. ^{1}H NMR ($CDCl_3$, 500 MHz): δ_H = 1.48 (m, 10 H, H cyclohexyl), 2.06 (unresolved, dddd, J = 3.5, 8.0, 12.8 Hz, 1 H, H^{8b}), 2.40 (unresolved ddd, J = 6.9, 12.8 Hz, 1 H, H^{8a}), 2.57 (unresolved, ddd, J = 5.5, 9.0 Hz, 1 H, H^5), 3.20 (ddd, J = 1.5, 8.0, 9.6 Hz, 1 H, H^9), 3.43 (m, 1 H, cyclohexyl), 3.89 (dd, J = 5.5, 9.0 Hz, 1 H, H^3) 4.5 (dd, J = 5.5, 9.6 Hz, 1 H, H^{12}), 4.92 (d, J = 5.5 Hz, 1 H, H^4) 5.21 (dd, J = 3.5, 10.8 Hz, 1 H, H^6), 5.55 (unresolved ddd, J = 6.9, 10.8 Hz, 1 H, H^7), 7.28 (m, 10 H, arom. H) ppm. ^{13}C NMR ($CDCl_3$, 75 MHz): δ_C = 22.6, 25.1, 30.3, 32.8, 36.2, 40.5, 42.4,52.1, 59.7, 61.5, 126.5, 126.8, 12.4, 128.2, 128.9, 129.2, 129.4, 129.9, 132.1, 136.5, 166.5, 176.7, 178.8 ppm. IR (KBr): $\tilde{\nu}$ = 1745, 1724, 1655, 1621, 1325, 1254, 1121 cm^{-1}. m/z 454 $[M]^+$. Elemental analysis calcd. for $C_{29}H_{30}N_2O_3$ (454.23): C 76.65, H 6.60, N 6.16; found C 76.88, H 6.79, N 5.56.

4-[1-Cyclohexyl-2-(4-methoxyphenyl)-4-oxoazetidin-3-yl]-2-phenyl-3a,4,7,7a-tetrahydroisoindole-1,3-dione (6e): M.p. 195–196 °C. ^{1}H NMR ($CDCl_3$, 200 MHz): δ_H = 1.38 (m, 10 H, cyclohexyl), 1.52

(m, 1 H, H^{8b}), 2.42 (m, 1 H, H^{8a}), 2.62 (unresolved dd, J = 12.4 Hz, 1 H, H^5), 3.29 (unresolved ddd, J = 8.5, 9.6 Hz, 1 H, H^9), 3.44 (m, 1 H, cyclohexyl), 3.80 (s, 3 H, $-OCH_3$), 3.97 (dd, J = 5.5, 12.2 Hz, 1 H, H^3), 4.59 (dd, J = 5.9, 9.7 Hz, 1 H, H^{12}), 4.92 (d, J = 5.5 Hz, 1 H, H^4), 5.28 (m, 1 H, H^6), 5.73 (m, 1 H, H^7), 7.38 (m, 8 H, arom.) ppm. ^{13}C NMR ($CDCl_3$, 60 MHz): δ_C = 22.8, 24.6, 30.1, 36.1, 32.6, 40.6, 42.5, 51.1, 55.3, 59.3, 61.6, 126.5, 126.9, 127.4, 128.4, 128.9, 129.4, 129.7, 130.0, 132.2, 137.0, 166.6, 176.8, 178.4 ppm. IR (KBr): $\tilde{\nu}$ = 1752, 1726, 1649, 1334 cm^{-1}. m/z 484 $[M]^+$. Elemental analysis calcd. for $C_{30}H_{32}N_2O_4$ (484.24): C 74.36, H 6.66, N 5.78; found C 74.51, H 6.73, N 5.54.

4-[2-(4-Chlorophenyl)-1-cyclohexyl-4-oxoazetidin-3-yl]-2-phenyl-3a,4,7,7a-tetrahydroisoindole-1,3-dione (6f): M.p. 217–218 °C. ^{1}H NMR ($CDCl_3$, 200 MHz): δ_H = 1.48 (m, 10 H, cyclohexyl), 1.52 (m, 1 H, H^{8b}), 2.41 (m, 1 H, H^{8a}), 2.64 (unresolved ddd, J = 5.8, 11.9 Hz, 1 H, H^5), 3.24 (unresolved ddd, J = 8.3, 9.3 Hz, 1 H, H^9), 3.45 (m, 1 H, cyclohexyl), 3.90 (dd, J = 5.5, 11.9 Hz, 1 H, H^3), 4.42 (dd, J = 5.8, 9.0 Hz, 1 H, H^{12}), 4.91 (d, J = 5.5 Hz, 1 H, H^4), 5.29 (m, 1 H, H^6), 5.98 (m, 1 H, H^7), 7.34 (m, 9 H, arom.) ppm. ^{13}C NMR ($CDCl_3$, 60 MHz): δ_C = 22.9, 25.4, 30.5, 33.0, 36.3, 40.6, 42.5, 52.6, 59.7, 62.1, 127.3, 127.4, 127.6, 128.4, 128.9, 129.6, 129.8, 130.1, 132.1, 137.2, 166.5, 176.8, 178.8 ppm. IR (KBr): $\tilde{\nu}$ = 1752, 1721, 1651, 1678, 1319, 1232, 1113 cm^{-1}. m/z 489 $[M]^+$. Elemental analysis calcd. for $C_{29}H_{29}N_2O_3$ (488.19): C 71.23, H 5.98, N 5.73; found C 71.48, H 6.21, N 5.45.

4-(1-Cyclohexyl-2-oxo-4-phenylazetidin-3-yl)-2-*p*-tolyl-3a,4,7,7a-tetrahydroisoindole-1,3-dione (6g): M.p. 174–175 °C. ^{1}H NMR ($CDCl_3$, 200 MHz): δ_H = 1.30 (m, 10 H, cyclohexyl), 1.57 (m, 1 H, H^{8b}), 2.28 (s, 3 H, $-CH_3$), 2.43 (m, 1 H, H^{8a}), 2.70 (unresolved ddd, J = 5.3,11.2 Hz, 1 H, H^5), 3.37 (ddd, J = 3.2, 8.4, 9.6 Hz, 1 H, H^9), 3.47 (m, 1 H, cyclohexyl), 3.93 (dd, J = 5.5, 11.2 Hz, 1 H, H^3), 4.57 (dd, J = 5.6, 9.8 Hz, 1 H, H^{12}), 4.93 (d, J = 5.5 Hz, 1 H, H^4), 5.29 (m, 1 H, H^6), 5.66 (m, 1 H, H^7), 7.41 (m, 9 H, arom.) ppm. ^{13}C NMR ($CDCl_3$, 60 MHz): δ_C = 19.3, 22.1, 25.3, 30.4, 32.8, 36.4, 39.2, 42.8, 52.5, 59.2, 61.2, 125.0, 125.5, 126.7, 127.8, 127.9, 128.4, 129.3, 130.9, 132.5, 137.0, 165.6, 176.2, 178.1 ppm. IR (KBr): $\tilde{\nu}$ = 1758, 1730, 1640, 1338 cm^{-1}. m/z 468 $[M]^+$. Elemental analysis calcd. for $C_{30}H_{32}N_2O_3$ (468.24): C 76.90, H 6.88, N 5.98; found C 76.98, H 6.97, N 5.81.

4-[1-Cyclohexyl-2-(4-methoxyphenyl)-4-oxoazetidin-3-yl]-2-*p*-tolyl-3a,4,7,7a-tetrahydroisoindole-1,3-dione (6h): M.p. 185–186 °C. ^{1}H NMR ($CDCl_3$, 200 MHz): δ_H = 1.45 (m, 10 H, cyclohexyl), 1.62 (m, 1 H, H^{8b}), 2.28 (s, 3 H, $-CH_3$), 2.43 (m, 1 H, H^{8a}), 2.62 (unresolved ddd, J = 5.5, 11.60 Hz, 1 H, H^5), 3.35 (unresolved ddd, J = 8.4, 9.8 Hz, 1 H, H^9), 3.47 (m, 1 H, cyclohexyl), 3.83 (s, 3 H, $-OCH_3$), 4.01 (dd, J = 5.5, 11.6 Hz, 1 H, H^3), 4.67 (dd, J = 5.6, 9.8 Hz, 1 H, H^{12}), 4.97 (d, J = 5.5 Hz, 1 H, H^4), 5.35 (m, 1 H, H^6), 5.82 (m, 1 H, H^7), 7.41 (m, 8 H, arom.) ppm. ^{13}C NMR ($CDCl_3$, 60 MHz): δ_C = 20.23, 22.3, 25.1, 30.2, 32.6, 36.4, 40.6, 42.8, 52.3, 55.2, 59.2, 61.5, 126.7, 126.9, 127.4, 128.5, 128.9, 129.4, 129.7, 129.9, 132.2, 136.7, 166.6, 176.8, 178.7 ppm. IR (KBr): $\tilde{\nu}$ = 1740, 1711, 1638, 1338 cm^{-1}. m/z 498 $[M]^+$. Elemental analysis calcd. for $C_{31}H_{34}N_2O_4$ (498.25): C 74.67, H 6.87, N 5.62; found C 74.89, H 6.92, N 5.33.

4-[2-(4-Chlorophenyl)-1-cyclohexyl-4-oxoazetidin-3-yl]-2-*p*-tolyl-3a,4,7,7a-tetrahydroisoindole-1,3-dione (6i): M.p. 241–242 °C. ^{1}H NMR ($CDCl_3$, 200 MHz): δ_H = 1.40 (m, 10 H, cyclohexyl), 1.52 (m, 1 H, H^{8b}), 2.31 (s, 3 H, $-CH_3$), 2.39 (m, 1 H, H^{8a}), 2.57 (unresolved dd, J = 11.8 Hz, 1 H, H^5), 3.18 (unresolved ddd, J = 8.5, 9.4 Hz, 1 H, H^9), 3.37 (m, 1 H, cyclohexyl), 3.84 (dd, J = 5.5, 11.8 Hz, 1 H, H^3), 4.48 (dd, J = 5.8, 9.3 Hz, 1 H, H^{12}), 4.87 (d, J = 5.5 Hz, 1 H, H^4), 5.28 (m, 1 H, H^6), 5.67 (m, 1 H, H^7), 7.25 (m, 8 H, arom.) ppm. ^{13}C NMR ($CDCl_3$, 60 MHz): δ_C = 19.8, 22.9, 25.0, 30.2, 32.56, 36.3, 40.6, 42.1, 52.2, 59.3, 62.3, 127.3, 127.4, 127.5, 128.5, 128.9, 129.7, 129.5, 130.2, 132.2, 137.3, 166.6, 176.8, 178.7 ppm. IR (KBr): $\tilde{\nu}$ = 1750, 1720, 1648, 1320 cm^{-1}. m/z 502 $[M]^+$. Elemental analysis calcd. for $C_{30}H_{31}N_2O_3$ (502.20): C 71.63, H 6.21, N 5.57; found C 71.78, H 6.36, N 5.23.

5-(1-Cyclohexyl-2-oxo-4-phenylazetidin-3-yl)-4a,5,8,8a-tetrahydro-1,4-naphthoquinone (6j): M.p. 221–222 °C. ^{1}H NMR ($CDCl_3$, 200 MHz): δ_H = 1.45 (m, 10 H, H cyclohexyl), 2.09 (m, 1 H, H^{8b}), 2.57 (m, 1 H, H^{8a}), 2.78 (unresolved ddd, J = 6.2, 10.4 Hz, 1 H, H^5), 3.23 (m, 1 H, H^9), 3.31 (m, 1 H, cyclohexyl), 3.87 (dd, J = 5.5, 10.4 Hz, 1 H, H^3), 4.43 (dd, J = 6.2, 9.6 Hz, 1 H, H^{14}), 4.84 (d, J = 5.5 Hz, 1 H, H^4), 5.32 (unresolved dd, J = 10.1 Hz, 1 H, H^6), 5.41 (dd, J = 9.9 Hz, 1 H, H^7) 6.50 (d, J = 10.5 Hz, 1 H, H^{11}), 6.61 (d, J = 10.5 Hz, 1 H, H^{12}), 7.23 (m, 5 H, arom. H) ppm. ^{13}C NMR ($CDCl_3$, 60 MHz): δ_C = 22.5, 25.1, 30.3, 32.1, 36.1, 40.5, 42.9, 52.1, 59.1, 61.2, 126.2, 126.9, 127.7, 128.2, 128.8, 137.0, 137.5, 141.0, 166.2, 199.4, 200.1 ppm. IR (KBr): $\tilde{\nu}$ = 1756, 1723, 1634, 1625, 1378, 1356, 1291, 1184 cm^{-1}. m/z 389 $[M]^+$. Elemental analysis calcd. for $C_{25}H_{27}NO_3$ (389.20): C 77.12, H 6.94, N 3.59; found C 77.25, H 7.07, N 3.30.

5-[1-Cyclohexyl-2-(4-methoxyphenyl)-4-oxoazetidin-3-yl]-4a,5,8,8a-tetrahydro-1,4-naphthoquinone (6k): M.p. 225–226 °C. ^{1}H NMR ($CDCl_3$, 200 MHz): δ_H = 1.48 (m, 10 H, cyclohexyl), 2.04 (m, 1 H, H^{8b}), 2.62 (m, 1 H, H^{8a}), 2.78 (m, 1 H, H^5), 3.01 (unresolved ddd, J = 8.2, 9.2 Hz, 1 H, H^9), 3.32 (m, 1 H, cyclohexyl), 3.83 (s, 3 H, $-OCH_3$), 3.93 (dd, J = 5.5, 11.7 Hz, 1 H, H^3), 4.45 (dd, J = 5.8, 9.6 Hz, 1 H, H^{14}), 4.94 (d, J = 5.5 Hz, 1 H, H^4), 5.32 (m, 1 H, H^6), 5.48 (m, 1 H, H^7), 6.50 (d, J = 10.5 Hz, 1 H, H^{11}), 6.69 (d, J = 10.5 Hz, 1 H, H^{12}), 7.32 (m, 4 H, arom.) ppm. ^{13}C NMR ($CDCl_3$, 60 MHz): δ_C = 22.3, 25.5, 30.1, 32.2, 36.2, 40.6, 42.8, 52.1, 55.2, 59.2, 61.3, 127.2, 127.4, 127.8, 128.3, 128.9, 137.2, 137.6, 142.0, 166.6, 199.5, 201.9 ppm. IR (KBr): $\tilde{\nu}$ = 1738, 1720, 1680, 1345 cm^{-1}. m/z 419 $[M]^+$. Elemental analysis calcd. for $C_{26}H_{29}NO_4$ (419.21): C 74.44, H 6.97, N 3.34; found C 74.56, H 7.11, N 3.07.

5-[2-(4-Chlorophenyl)-1-cyclohexyl-4-oxoazetidin-3-yl]-4a,5,8,8a-tetrahydro-1,4-naphthoquinone (6l): M.p. 201–202 °C. ^{1}H NMR ($CDCl_3$, 200 MHz): δ_H = 1.49 (m, 10 H, cyclohexyl), 2.00 (m, 1 H, H^{8b}), 2.43 (m, 1 H, H^{8a}), 2.85 (unresolved ddd, J = 6.2, 11.4 Hz, 1 H, H^5), 3.31 (unresolved ddd, J = 8.8, 9.5 Hz, 1 H, H^9), 3.35 (m, 1 H, cyclohexyl), 3.92 (dd, J = 5.5, 11.6 Hz, 1 H, H^3), 4.57 (dd, J = 5.8, 9.6 Hz, 1 H, H^{14}), 4.88 (d, J = 5.5 Hz, 1 H, H^4), 5.43 (m, 1 H, H^6), 5.53 (m, 1 H, H^7), 6.51 (d, J = 10.3 Hz, 1 H, H^{11}), 6.63 (d, J = 10.3 Hz, 1 H, H^{12}), 7.32 (m, 4 H, arom.) ppm. ^{13}C NMR: δ_C = ($CDCl_3$, 60 MHz): 22.5, 25.6, 30.3, 32.2, 36.2, 40.7, 42.9, 52.2, 59.2, 61.2, 126.2, 126.4, 127.8, 128.3, 128.9, 137.2, 137.6, 141.5, 166.6, 199.7, 200.9 ppm. IR (KBr): $\tilde{\nu}$ = 1740, 1728, 1680, 1345 cm^{-1}. m/z 423 $[M]^+$. Elemental analysis calcd. for $C_{25}H_{26}ClNO_3$ (423.16): C 70.83, H 6.18, N 3.30; found C 70.94, H 6.29, N 3.07.

1-(1-Cyclohexyl-2-oxo-4-phenylazetidin-3-yl)-1,4,4a,9a-tetrahydroanthraquinone (6m): M.p. 207–208 °C. ^{1}H NMR ($CDCl_3$, 200 MHz): δ_H = 1.51 (m, 10 H, cyclohexyl), 1.92 (m, 1 H, H^{8b}), 2.02 (m, 1 H, H^{8a}), 2.69 (unresolved ddd, J = 6.5, 11.4 Hz, 1 H, H^5), 3.30 (m, 1 H, cyclohexyl), 3.32 (m, 1 H, H^9), 4.27 (dd, J = 5.5, 11.6 Hz, 1 H, H^3), 4.37 (dd, J = 5.4, 9.0 Hz, 1 H, H^{18}), 4.92 (d, J = 5.5 Hz, H^4), 5.82 (m, 1 H, H^6) 5.99 (m, 1 H, H^7), 7.41 (m, 8 H, arom.) ppm. ^{13}C NMR: δ_C = ($CDCl_3$, 60 MHz): 21.2, 25.6, 30.6, 32.2, 36.4, 40.4, 42.9, 52.8, 58.9, 61.2, 127.2, 127.3, 127.4, 127.9, 128.0, 128.5, 128.9, 137.2, 137.5, 143.8, 168.2, 199.2, 201.0 ppm. IR (KBr): $\tilde{\nu}$ = 1760, 1635, 1620, 1520, 1378, 1176, 1141 cm^{-1}. m/z 439 $[M]^+$. Elemental

analysis calcd. for $C_{29}H_{29}NO_3$ (439.21): C 79.24, H 6.65, N 3.19; found C 79.38, H 6.79, N 3.05.

1-[1-Cyclohexyl-2-(4-methoxyphenyl)-4-oxoazetidin-3-yl]-1,4,4a,9a-tetrahydroanthraquinone (6n): M.p. 235–236 °C. ^{1}H NMR ($CDCl_3$, 200 MHz): δ_H = 1.42 (m, 10 H, cyclohexyl), 2.02 (m, 1 H, H^{8b}), 2.17 (m, 1 H, H^{8a}), 2.89 (unresolved ddd, J = 5.6, 11.4 Hz, 1 H, H^5), 3.32 (m, 1 H, cyclohexyl), 3.41 (m, 1 H, H^9), 3.75 (s, 3 H, –OCH_3), 4.12 (dd, J = 5.5, 11.8 Hz, 1 H, H^3), 4.23 (dd, J = 5.4, 9.0 Hz, 1 H, H^{18}), 4.89 (d, J = 5.5 Hz, H^4), 5.63 (m, 1 H, H^6) 5.92 (m, 1 H, H^7), 7.54 (m, 8 H, arom.) ppm. ^{13}C NMR: δ_C = ($CDCl_3$, 60 MHz): 22.8, 25.2, 30.3, 32.5, 36.4, 40.6, 42.9, 52.4, 55.2, 59.3, 62.2, 127.2, 127.3, 127.9, 128.3, 128.4, 128.9, 130.1, 137.5, 137.8, 142.0, 167.3, 198.2, 201.3 ppm. IR (KBr): $\tilde{\nu}$ = 1754, 1638, 1612, 1503, 1370, 1232, 1176, 1130 cm^{-1}. *m/z* 469 $[M]^+$. Elemental analysis calcd. for $C_{30}H_{31}NO_4$ (469.23): C 76.73, H 6.65, N 2.98; found C 76.84, H 6.73, N 2.81.

1-[2-(4-Chlorophenyl)-1-cyclohexyl-4-oxoazetidin-3-yl]-1,4,4a,9a-tetrahydroanthraquinone (6o): M.p. 240–242 °C. ^{1}H NMR ($CDCl_3$, 200 MHz): δ_H = 1.32 (m, 10 H, cyclohexyl), 1.89 (m, 1 H, H^{8b}), 2.10 (m, 1 H, H^{8a}), 2.74 (m, 1 H, H^5), 3.30 (m, 1 H, cyclohexyl), 3.42 (m, 1 H, H^9), 4.02 (dd, J = 5.5, 11.8 Hz, 1 H, H^3), 4.43 (unresolved dd, J = 9.0 Hz, 1 H, H^{18}), 4.81 (d, J = 5.5 Hz, H^4), 5.65 (m, 1 H, H^6) 5.62 (m, 1 H, H^7), 7.23 (m, 8 H, arom.) ppm. ^{13}C NMR ($CDCl_3$, 60 MHz): δ_C = 22.2, 25.3, 30.6, 32.4, 36.4, 40.6, 42.9, 52.9, 59.3, 62.2, 127.2, 127.7, 128.3, 128.7, 129.2,129.4, 130.5, 132.1, 137.4, 142.8, 167.2, 198.2, 201.3 ppm. IR (KBr): $\tilde{\nu}$ = 1750, 1640, 1615, 1500, 137.8, 1176, 1130 cm^{-1}. *m/z* 473 $[M]^+$. Elemental analysis calcd. for $C_{29}H_{28}NO_3Cl$ (473.18): C 73.48, H 5.95, N 2.96; found C 73.71, H 6.08, N 2.73.

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[13] CCDC-235761 (for **3a)** contains the supplementary crystallographic data for this paper. These data can be obtained free of charge from The Cambridge Crystallographic Data Centre via www.ccdc.cam.ac.uk/data_request/cif.Crystal data for **3a**: $C_{23}H_{19}NO_4$, M = 373.39, triclinic, space group $P\bar{1}$ (#2), a = 6.4785(6), b = 12.5578(12), c = 13.2151(12) Å, α = 106.327(2)°, β = 99.958(2)°, γ = 98.036(2)°, V = 995.83(16) Å^3, Z = 2, $D_{calcd.}$ = 1.245 g cm^{-3}, μ(Mo-$K\alpha$) = 0.86 cm^{-1}, T = 296(2) K, λ= 0.71073 Å, $R1$ = 0.0538 for $I > 2.0\sigma(I)$, $wR2$ = 0.1704 for all data (2859 reflections), GOF = 1.148 (311 parameters). Diffraction data were measured on a Bruker APEX CCD-Detector X-ray diffractometer. Structure solution, refinement were carried out with Shelx-97.

[14] CCDC-235760 (for **6d)** contains the supplementary crystallographic data for this paper. These data can be obtained free of charge from The Cambridge Crystallographic Data Centre via www.ccdc.cam.ac.uk/data_request/cif.Crystal data for **6d**: $C_{29}H_{30}N_2O_3$, M = 454.55, triclinic, space group $P\bar{1}$ (#2), a = 9.8358(8), b = 10.7661(9), c = 11.9804(10) Å, α = 85.591(2)°, β = 73.050(2)°, γ = 75.242(2)°, V = 1173.49(17) Å^3, Z = 2, $D_{calcd.}$ = 1.286 g cm^{-3}, μ(Mo-$K\alpha$) = 0.83 cm^{-1}, T = 100(2) K, λ= 0.71073 Å, $R1$ = 0.0403 for $I > 2.0\sigma(I)$, $wR2$ = 0.1011 for all data (4397 reflections), GOF = 1.027 (307 parameters).

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