# Cycloadditions of Ketenes Generated in the Wolff Rearrangement. Stereoselective Synthesis of Aminoalkyl-Substituted β-Lactams from α-Amino Acids†

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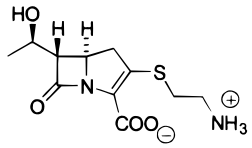
Diazo ketones **1**−**16**, derived from suitable protected amino acids (Ala, Leu, Val, Ile, Tle, Phe, Pro, Orn, Lys, Ser, and Thr), have been photochemically rearranged, leading to the corresponding ketene intermediates. They were trapped with *N*-benzylbenzaldimine **17** to give β-lactams **18**−**33** in up to 90% yield. In these cycloadditions, two of the four possible diastereoisomers were formed exclusively. The selectivity ranged from 60:40 to 93:7 and the bulkiness of the parent amino acid side chain is the governing factor. The relative configuration was proved by three X-ray crystal structures. The diastereoselectivity in these reactions is also influenced by the use of chiral *N*-phenethylbenzaldimines **34** and **35**. With regard to a projected deprotection of the lactam-nitrogen, *N*-allyl- (**49**) and *N*-(*p*-methoxybenzyl)benzaldimine (**44**) were used in this reaction. This led to the *N*-allyl β-lactams **50** and **51** in 62 and 56% yield, respectively, and to the *p*-methoxybenzyl-substituted β-lactams **45** and **46** (50 and 72% yield). The *p*-methoxybenzyl group on the valine-derived β-lactam **45a** can be cleaved with potassium peroxodisulfate in 63% yield.

## Introduction

β-Lactam antibiotics have been sucessfully used in the treatment of infectious diseases for many years.[1] Despite the plethora of compounds bearing a β-lactam moiety which have already been synthesized and tested, there is still a need for new compounds of this kind[2] due to the increasing restistance of bacterial strains to certain types of antibiotics.[3]

Thienamycin, a broad-spectrum antibiotic of the carbapenem series, is effective against almost all kinds of bacteria.[1] In addition, it is stable[1] with respect to the lactamase present in the bacteria which would lead to a ring-opening of the β-lactam moiety.[4] In thienamycin, a hydroxyalkyl group is attached to C-3 of the trans-substituted β-lactam ring. β-Lactams which bear an aminoalkyl instead of a hydroxyalkyl group in position C-3 are also of interest. Merck has patented some aminoethyl-substituted β-lactams,[5] and a method to prepare similar compounds *via* the cycloaddition of ester enolates has been published recently.[6] Although the reaction of ketenes (Staudinger reaction)[7] or ester enolates[8] (which are ketene equivalents) with an imine is one of the most straightforward reaction sequences for the preparation of β-lactams,[9] the trans-substitution is sometimes hard to achieve. The use of ketenes (mostly generated from acid chlorides) in the cycloaddition with imines usually gives rise to cis-substituted ring systems (*vide infra*), whereas employing ester enolates often leads to a mixture of cis- and trans-substituted products.




Thienamycin

The Arndt−Eistert reaction sequence is a well-established protocol for the homologation of carboxylic acids.[10] In the second step of this reaction, the Wolff rearrangement,[11] a ketene is formed as an intermediate which cannot usually be isolated. It reacts with a nucleophile present in the reaction mixture to form the corresponding carboxylic acid derivatives. This reaction sequence was used by Balenović *et al.* in the late 1950s for the preparation of enantiopure β-amino acids starting from appropriately protected α-amino acids.[12] They employed water, alcohols, and amines as nucleophiles and obtained β-amino acids, esters, and amides, respectively. Seebach and co-workers used amino acid,[13] peptide,[14] sugar,[13,15] and nucleoside derivatives[15] as nucleophiles to produce

† This paper is dedicated to Dieter Seebach on the occasion of his 60th birthday.

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‡ Part of the diploma thesis of M.R.L., Universität Stuttgart, 1997.

⊗ Abstract published in *Advance ACS Abstracts,* August 1, 1997.

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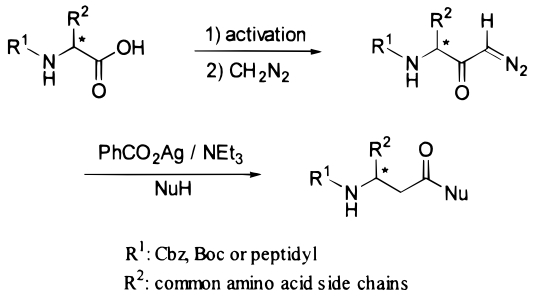
**Scheme 1**



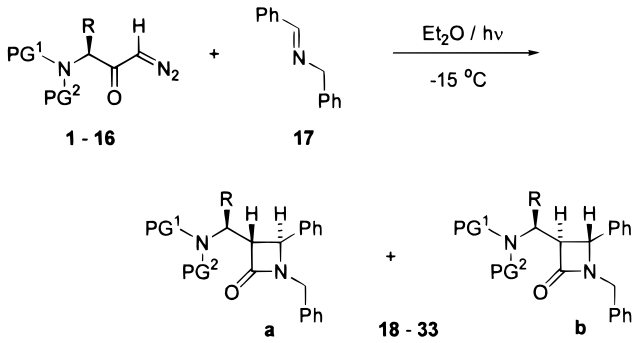

the corresponding biomolecules linked to a $\beta$-amino acid (Scheme 1).[16]

The reaction of aminoalkyl-substituted ketenes with nucleophiles has been described in several publications, including some reports on the synthesis of natural products.[17] Surprisingly, cycloadditions with ketenes generated in the Wolff rearrangement have hardly been investigated,[18] and chiral ketenes have been reported only once.[19] In this paper, we present a diastereoselective synthesis of trans-substituted $\beta$-lactams by the cycloaddition of ketenes derived from easily accessible α-amino acid derivatives. An aminoalkyl group at C-3 of the products was introduced by way of the amino acid derivatives employed.[20]

## Results and Discussion

The starting materials, the diazo ketones derived from Boc-, Cbz-, Fmoc- [[(9-fluorenylmethyl)oxy]carbonyl], and Pht- (phthaloyl) protected amino acids (Ala, Leu, Val, Ile, Tle (*tert*-leucin), Phe, Pro, Orn, Lys, Ser, and Thr, **1**−**16**), were prepared according to known procedures.[13] As a starting point, we used the simple imine *N*-benzylbenzaldimine (**17**), which is known to react well with ketenes to form the corresponding $\beta$-lactams (Scheme 2 and Table 1). Nevertheless, when we stirred the diazo ketones with catalytic silver benzoate in the presence of the imine, no reaction occurred and the diazo ketone was recovered quantitatively. Either the silver catalyst was complexed by the imine, a problem that is known for bis-imines,[21] or the imine is oxidized by the silver salt.[22] As an obvious alternative, the decomposition of the diazo ketones was achieved by irradiation through a quartz filter and monitoring by TLC. To enable a complete reaction with the imine, the reaction mixture was stirred for an additional 30 min. We tested several reaction conditions in the rearrangement of the Cbz-valine-derived diazo ketone **5**: We found that the degradation of the diazo

**Scheme 2**[a]




[a] For specification of the substituents, see Table 1.

compounds was complete after 90 min even at lower reaction temperatures. Nevertheless, it should be kept in mind that the reaction times might be longer when more concentrated solutions or weaker irradiation lamps are used. No changes in yields and selectivities were observed when the reaction was performed at 20, 2, and −24 °C, respectively. When 4, 2, and 1.1 equiv imine were used, again no significant difference in the yields was observed. Besides diethyl ether, we tested pentane as a solvent. This was unsuitable because the starting materials were insoluble and no reaction occurred. *tert*-Butyl methyl ether did not affect the selectivity, but the yield decreased slightly due to additional side products. Using a Durane filter instead of the quartz filter did not change the selectivity or yield of the $\beta$-lactam products. Therefore, all subsequent experiments were performed with 1.5 equiv of the imine in diethyl ether with a quartz filter at about −15 °C, except when otherwise noted.

Irradiation of the diazo ketones in the presence of the imine **17**[23] gave rise to two of the four possible diastereoisomeric $\beta$-lactams **18**−**33**. The ratios were determined by HPLC analysis of the crude reaction mixtures. The configuration of the products was established by $^1$H NMR analysis. The coupling constants between the protons at C-3 and C-4 is about 2 Hz, which gives strong evidence for a 3,4-trans-substitution of the $\beta$-lactams (*vide infra*). Assignment of the NMR spectra of the products and comparision with three X-ray crystal structures of **20b**, **21a**, and **48** (*vide infra*) allowed the determination of the relative configurations in all diastereoisomers. In the $^1$H NMR spectra the coupling constant between H-3 and H-1′ in the isomers **18**−**33a** is significantly smaller than in **18**−**33b**.

The diastereoselectivity seems to be predominantly influenced by the bulkiness of the parent amino acid side chain. While primary substituents as in alanine, leucine, phenylalanine, serine, ornithine, and lysine (entries 1, 2, 4, 9, and 11−14 in Table 1) gave poor selectivities of about 70:30, the ratios are improved to better than 80:20 with secondary side chains (valine, isoleucine, and threonine, entries 5−7, 15, and 16). The best results were obtained when a tertiary side chain as in *tert*-leucine is present (ratio 93:7, entry 8). The nature of the carbamate protection group at the nitrogen seems to have no significant influence (entries 1, 2 and 5, 6) on the diaseteroselectivity of the reaction. The TBDMS protecting group seems to be unsuitable (entries 15 and 16). Yields drop significantly with this protecting group,

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**Table 1. Decomposition of Amino Acid Derived Diazo Ketones in the Presence of Imine 17 Leading to β-Lactams (See Scheme 2)**

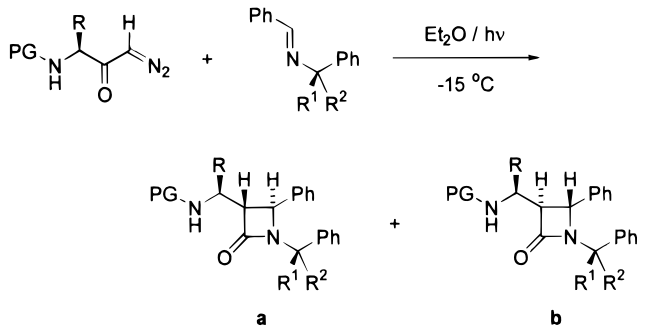
| entry | diazo ketone | PG[1] | PG[2] | R | amino acid | product | yield (%) | ratio[a] |
|---|---|---|---|---|---|---|---|---|
| 1 | **1** | Cbz | H | Me | Ala | **18** | 71 | 67:33 |
| 2 | **2** | Boc | H | Me | Ala | **19** | 70 | 71:29 |
| 3 | **3** | Pht | | Me | Ala | **20** | 54 | 17:83 |
| 4 | **4** | Cbz | H | $^{i}$Bu | Leu | **21** | 89 | 70:30 |
| 5 | **5** | Cbz | H | $^{i}$Pr | Val | **22** | 89 | 82:18 |
| 6 | **6** | Fmoc | H | $^{i}$Pr | Val | **23** | 79 | 77:23 |
| 7 | **7** | Cbz | H | $^{s}$Bu | Ile | **24** | 90 | 83:17 |
| 8 | **8** | Cbz | H | $^{t}$Bu | Tle | **25** | 88 | 93:7 |
| 9 | **9** | Cbz | H | Bn | Phe | **26** | 58 | 59:41 |
| 10 | **10** | Boc | | $-(CH_2)_3-$ | Pro | **27** | 63 | 63:37 |
| 11 | **11** | Boc | H | $CbzNH(CH_2)_3$ | Orn(Cbz) | **28** | 73 | 70:30 |
| 12 | **12** | Cbz | H | $BocNH(CH_2)_3$ | Orn(Boc) | **29** | 70 | 70:30 |
| 13 | **13** | Boc | H | $CbzNH(CH_2)_4$ | Lys(Cbz) | **30** | 71 | 65:35 |
| 14 | **14** | Boc | H | $BnOCH_2$ | Ser(Bn) | **31**[b] | 63 | 70:30 |
| 15 | **15** | Cbz | H | TBDMSOCH($CH_3$) | Thr(TBDMS) | **32** | 45 | 80:20 |
| 16 | **16** | Boc | H | TBDMSOCH($CH_3$) | Thr(TBDMS) | **33** | 37[c] | 80:20[d] |

[a] Ratio of diastereoisomers determined by HPLC. [b] Diastereoisomers could not be separated; the experiment is not included in the experimental section. [c] Isolated yield of **33a**. [d] Determined by $^1$H NMR spectroscopy.

seemingly due to a partial decomposition of these compounds on silica gel. This decomposition seems to be faster for isomer **33b**, since the ratio of **33a**/**b** changes from 80:20 before chromatography (determined by $^1$H NMR spectroscopy) to better than 95:5 (no second isomer detected) after filtrative chromatography. The diastereoisomeric ratio was inverted with the phthaloyl protecting group (entry 3, ratio of 17:83). Unfortunately it is not possible to prove the universal validity of this result, since it is known that phthaloyl-protected amino acid derivatives with a β-proton in the side chain rearrange when irradiated,[24] and therefore, no further examples with a phthaloyl protection were investigated. Even the diazo ketone derived from phthaloylphenylalanine (which bears no β-proton) decomposes to an undefinable mixture when irradiated in the presence of imine **17**. The yields in the cyclization reactions were better than 60%, except for the phthaloyl protection (**20**, entry 3) and for the threonine-derived diazo ketones **32** and **33** (entries 15 and 16). The good result for the Fmoc-protected diazo ketone (**6**, entry 6) was quite astonishing, since this protecting group might have been suspected to be sensitive against irradiation. This result should be advantageous for the possible use of these products in future solid phase synthesis, in which Fmoc protection is most commonly used.[25] All diastereoisomeric mixtures except for the serine-derived β-lactams **31a**,**b** (entry 14, experiment is not included in the Experimental Section) were separated by either flash column chromatography or by MPLC (medium pressure liquid chromatography). The best separation efficiency could be achieved with light petroleum/isopropyl alcohol solvent systems, but in most cases mixtures of light petroleum and ethyl acetate mixtures gave sufficient separations.

The stereoselectivity in these reactions may be additionally controlled by the use of a chiral imine (Scheme 3 and Table 2). When (*R*)- or (*S*)-*N*-phenethylbenzaldimine (**34**, **35**) were used, a match−mismatch interaction was observed.[26] The elaboration of the isoleucine-derived

**Scheme 3**[a]




[a] For specification of the substituents, see Table 2.

diazo ketone **7** led to an improvement to 86:14 (**39a**/**b**) with the (*S*)-imine **35** and to a decrease to 73:27 (**38a**/**b**) with (*R*)-imine **34** (*cf.* the result with the achiral imine **17** → **24a**/**b**, 83:17). When the alanine-derived diazo ketone **2** was used, the influence was much more significant: improvement from 71:29 (**19a**/**b**) to 88:12 (**37a**/**b**) with (*S*)-imine **35** and a decrease to 55:45 (**36a**/**b**) with (*R*)-imine **34** was observed.

Sometimes the *N*-benzyl protection, which was introduced to optimize the reaction conditions, is disadvantageous, since this protecting group is hard to remove.[27] Therefore, we tried cycloadditions with *N*-trimethylsilyl- (**40**),[28] *N*-sulfonyl- (**41**),[29] and *N*-bis(trimethylsilyl)methyl-substituted imines (**42**).[30] However, no β-lactams were isolated with these imines. When the oxidatively removable *p*-methoxyphenyl group (PMP)[31] was introduced with the corresponding imine **43**, a partial cleavage of the PMP group seemed to occur under our reaction conditions and this led to no isolable product. When we used the related *p*-methoxybenzyl (PMB) substituted imine **44**,[32] no cleavage was observed: starting with the

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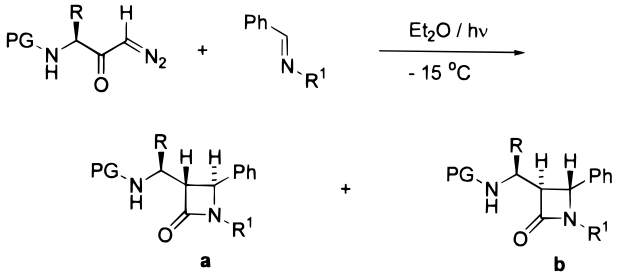
**Table 2. Decomposition of Diazoketones in the Presence of Chiral Imines (See Scheme 3)**

| entry | diazo ketone | PG | R | amino acid | $R^1$ | $R^2$ | imine | configuration of imine | product | yield (%) | ratio |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | **2** | Boc | Me | Ala | Me | H | **34** | (*R*) | **36** | 72 | 55:45 |
| 2 | **2** | Boc | Me | Ala | H | H | **17** | | **19** | 70 | 71:29 |
| 3 | **2** | Boc | Me | Ala | H | Me | **35** | (*S*) | **37** | 88 | 88:12 |
| 4 | **7** | Cbz | $^s$Bu | Ile | Me | H | **34** | (*R*) | **38** | 72 | 73:27 |
| 5 | **7** | Cbz | $^s$Bu | Ile | H | H | **17** | | **24** | 90 | 83:17 |
| 6 | **7** | Cbz | $^s$Bu | Ile | H | Me | **35** | (*S*) | **39** | 56 | 86:14 |

**Table 3. Decomposition of Diazoketones in the Presence of PMB- and *N*-Allyl-substituted Imines (See Scheme 4)**

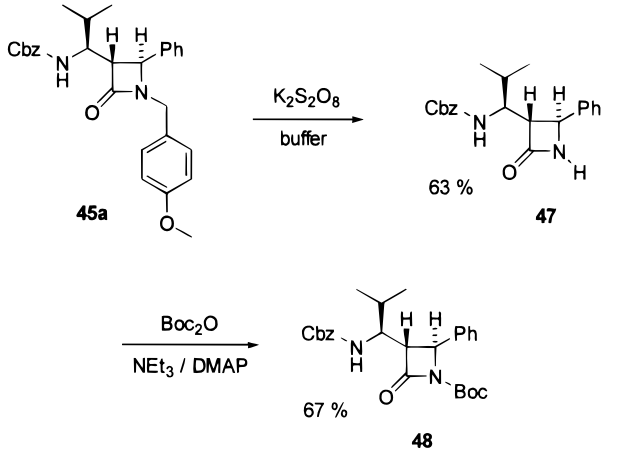
| entry | diazo ketone | PG | R | parent amino acid | $R^1$ | imine | product | yield (%) | ratio |
|---|---|---|---|---|---|---|---|---|---|
| 1 | **5** | Cbz | $^i$Pr | Val | PMB | **44** | **45** | 50 | 84:16 |
| 2 | **8** | Cbz | $^t$Bu | Tle | PMB | **44** | **46** | 72 | 92:8 |
| 3 | **2** | Boc | Me | Ala | Allyl | **49** | **50** | 62 | 68:32 |
| 4 | **7** | Cbz | $^s$Bu | Ile | Allyl | **49** | **51** | 56 | 85:15 |

**Scheme 4**[a]

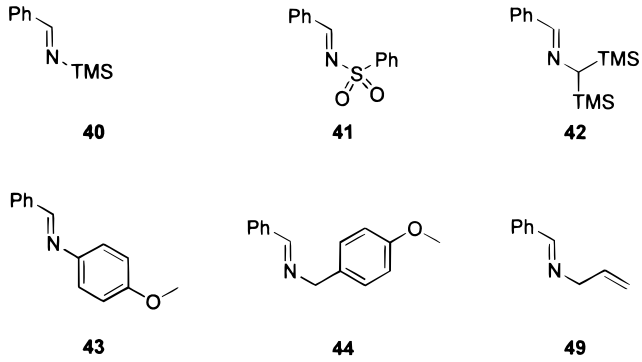



[a] For specification of the substituents, see Table 3.

**Scheme 5**




Cbz-valine-derived diazo ketone **5**, the corresponding $\beta$-lactams **45a**,**b** were isolated with a 84:16 ratio and 50% yield (Table 3 and Scheme 4). Reaction of the *tert*-leucine-derived diazo ketone **8** led to the $\beta$-lactams **46a**,**b** in 72% yield (92:8 ratio). Oxidative deprotection of the PMB group in **45a** with cerium ammonium nitrate (CAN) led predominantly (50%) to an overoxidation of the *p*-methoxybenzyl group to the corresponding *N*-substituted *p*-methoxybenzamide. The deprotected $\beta$-lactam **47** was formed in only 17% yield. Selective deprotection of **45a** could be successfully performed with potassium peroxodisulfate in 63% yield (Scheme 5).[33] The mild oxidant 2,3-dichloro-5,6-dicyano-1,4-quinone (DDQ) led to no cleavage of the PMB group.[34] Subsequent reprotection of $\beta$-lactam **47** with *tert*-butyl pyrocarbonate ($Boc_2O$)[35] gave rise to the Boc-protected $\beta$-lactam **48** (67% yield) whose structure could be unambiguously determined by X-ray crystal structure analysis.[36] *N*-Allyl-substituted $\beta$-lactams are easy to deprotect[37] and, additionally, are interesting precursors for subsequent transformations. Elaboration of the diazo ketones **2** and **7** derived from Boc-alanine and Cbz-isoleucine with *N*-allylbenzaldimine **49** led to the corresponding $\beta$-lactams **50a**,**b** (62%, 68:32) and **51a**,**b** (56%, 85:15, Scheme 4 and Table 3).




When we synthesized $\beta$-lactams in accordance with the above mentioned reaction protocol, we observed the exclusive formation of the two diastereoisomers in which the substituents in positions C-3 and C-4 were trans-oriented. This seemed surprising to us, since electronically similar ketenes (*i.e.* the ketene derived from $\beta$-silyloxybutyryl chloride)[38] are known to yield the corresponding cis-substituted ring systems. Georg *et al.* presented a useful classification of ketenes which enables the prediction of whether a cis- or trans-substitution should be expected. Nevertheless, this classification is based upon steric rules, which seem to be somewhat inconsistent, since, according to these rules, the methyl-substituent is categorized to belong to the bulky substituents, which lead to trans-substitution. Electronic properties of the ketenes can also be considered. We tested whether the special amino substitution is responsible for the observed selectivity in our case using a hydroxyalkyl ketene and an alkyl-substituted ketene in our reaction

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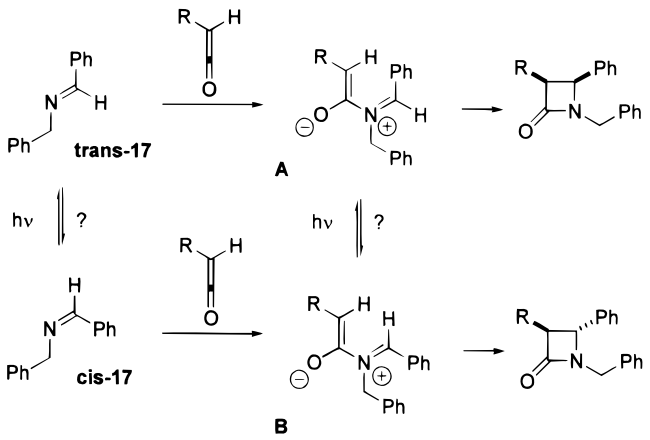
(36) The author has deposited atomic coordinates for this structure with the Cambridge Crystallographic Data Centre. The coordinates can be obtained, on request, from the Director, Cambridge Crystallographic Data Centre, 12 Union Road, Cambridge CB2 1EZ, UK.

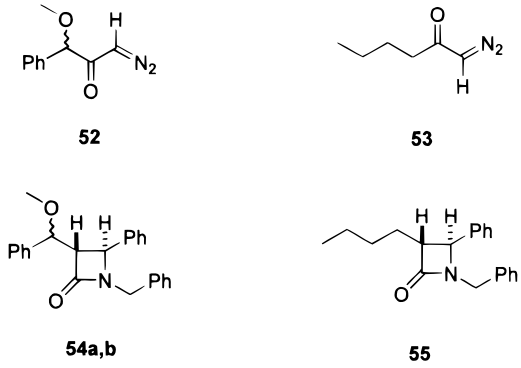
(37) (a) Rhodium-catalyzed deprotection: Laguzza, B. C.; Ganem, B. *Tetrahedron Lett.* **1981**, *22*, 1483−1486. (b) Multistep deprotection: Fukuyama, T.; Laird, A. A.; Schmidt, C. A. *Tetrahedron Lett.* **1984**, *25*, 4709−4712.

(38) (a) Lynch, J. E.; Riseman, S. M.; Laswell, W. L.; Tschaen, D. M.; Volante, R. P.; Smith, G. B.; Shinkai, I. *J. Org. Chem.* **1989**, *54*, 3792−3796. (b) Tschaen, D. M.; Fuentes, L. M.; Lynch, J. E.; Laswell, W. L.; Volante, R. P.; Shinkai, I. *Tetrahedron Lett.* **1988**, *29*, 2779−2782.

**Scheme 6**

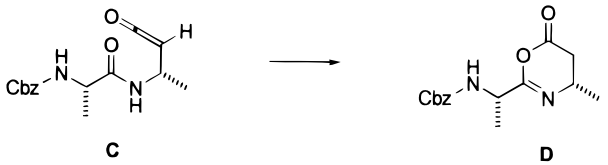



protocol. The diazo ketones derived from racemic *O*-methyl mandelic acid (**52**) and valeric acid (**53**) again led to the corresponding trans-substituted $\beta$-lactams (**54a**/**b**, ratio 1:1 and **55**, respectively). Obviously, the special aminoalkyl substitution is not responsible for the trans-selectivity.




This means that it is either the fact that our ketenes were prepared from diazo ketones or the reaction protocol that is responsible for the trans-substitution. To the best of our knowledge, the only preparation of $\beta$-lactams from diazo ketones resulted in the formation of derivatives bearing two phenyl substituents in the 3-position.[18] It is therefore impossible to determine whether a cis- or trans-substitution occurred in these cases. Hegedus *et al.* have performed photochemically induced Staudinger reactions starting with chromium carbene complexes.[39] In their opinion, the phenyl-substitution is responsible for the observed trans-substitution. The weakening of the double bond in the intermediate **A** should allow for a rotation to the less hindered intermediate **B**, which after ring closure should lead to the trans-substituted $\beta$-lactam (Scheme 6).[40] Other examples with the same imine **17**, however, gave rise to cis-substituted $\beta$-lactams—obviously no isomerization **A** → **B** occurred.[7,41] Possibly, the photochemical activation is responsible for the observed diastereoselectivity, either due to a photochemical excitation of the intermediate **A** and therefore a weakening of the double bond[42] or due to a photochemical-induced equilibration of the imine *trans*-**17** to the cis-substituted imine *cis*-**17** (Scheme 6). These cis-substituted imines, which are less hindered with respect to their nucleophilic attack to the ketene, are known to be persistent with a half time of 0.1−1 s.[42]

Fortunately, a previously observed intramolecular stabilization of peptide-derived ketene **C** seems to play no important role in our case.[14] Obviously, the dihydrooxazinone **D**, which is much more stable than the initial ketenes **C**, is not able to undergo a cycloaddition, since the double bond is lost. Either, this stabilization does not occur under our reaction conditions or, as is more likely, the ketene is trapped *in situ* by the imine present in the reaction mixture before the intramolecular attack.




The relative configuration of the $\beta$-lactams was determined by three X-ray crystal structures[36] and by comparision of the NMR spectroscopic data. The crystal structure of the phthaloyl-protected isomer **20b** indicates a (3*S*,4*R*,1′*S*)-configuration. On the other hand, the crystal structure of the Cbz-protected isomers **21a** and **48**, and therefore their derivatives **45a** and **47**, turned out to be of the (3*R*,4*S*,1′*S*)-configuration. (This is in contrast to a previously made assignment, in which the configuration of the isomers has erroneously been indicated to be (3*R*,4*R*) and (3*S*,4*S*), respectively.[20]) Obviously the product ratio seems to be determined by which of the two substituents (the protected amino function or the amino acid side chain) is sterically more demanding. Fortunately, the relative configuration seems to be related to the proton NMR coupling constant between the protons at C-3 and at C-1′ (former α-position of the amino acid). A larger coupling constant indicates a (3*S*,4*R*,1′*S*)-configuration, and a small coupling constant indicates a (3*R*,4*S*,1′*S*)-configuration (for details, see the Experimental Section).

In the present paper, we have demonstrated the versatility of amino acid derived ketenes for the preparation of aminoalkyl-substituted $\beta$-lactams. The reaction conditions used (*i.e.* photochemical-induced rearrangement of diazo ketones) lead exclusively to trans-substituted $\beta$-lactams, a substitution pattern that is otherwise difficult to obtain. Diazo ketones derived from other chiral starting materials (*e.g.* hydroxy acids) should give rise to similar compounds; work in this direction is already ongoing in our laboratories.

## Experimental Section

**General.** Solvents for chromatography and for workup, *e.g.* ethyl acetate (EA) and light petroleum (PE), were distilled prior to use, diethyl ether (ether) was distilled over KOH/$FeSO_4$. Ether and THF used for reactions were distilled over Na/benzophenone. $Et_3N$ was distilled over $CaH_2$, and $ClCO_2Et$

(39) (a) McGuire, M. A.; Hegedus, L. S. *J. Am. Chem. Soc.* **1982**, *104*, 5538−5540. (b) Hegedus, L. S.; McGuire, M. A.; Schultze, L. M.; Yijun, C.; Anderson, O. P. *J. Am. Chem. Soc.* **1984**, *106*, 2680−2687. (c) Borel, C.; Hegedus, L. S.; Krebs, J.; Satoh, Y. *J. Am. Chem. Soc.* **1987**, *109*, 1101−1105. (d) Hegedus, L. S.; de Weck, G.; D'Andrea, S. *J. Am. Chem. Soc.* **1988**, *110*, 2122−2126. (e) Hegedus, L. S.; Imwinkelried, R.; Alarid-Sargent, M.; Dvorak, D.; Satoh, Y. *J. Am. Chem. Soc.* **1990**, *112*, 1109−1117.

(40) Hegedus, L. S.; Montgomery, J.; Narukawa, Y.; Snustad, D. C. *J. Am. Chem. Soc.* **1991**, *113*, 5784−5791.

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(42) (a) Wettermark, G.; Wallstrom, E. *Acta. Chem. Scand.* **1968**, *22*, 675−680. (b) Wettermark, G. in *The Chemistry of the Carbon-Nitrogen Double Bond*; Patai, S.,Ed.; Interscience: London, 1970; pp 565−596.

and aldehydes were distilled and stored over molecular sieves (4 Å). The diazo ketones **1**−**16**,[13] **52**[43] and **53**[44] and the imines **40**,[28] **41**,[29] **42**,[30] and **17**[45] were prepared according to literature procedures; the other imines were used directly after preparation.[46] Amino acid derivatives were prepared by standard methods.[35,47] Common amino acid abbreviations are used.[48] Moisture-sensitive reactions were performed in dried vessels (150 °C, 24 h) under a nitrogen atmosphere using syringe techniques. Photochemically induced rearrangements were performed in a UV reactor system (Heraeus) with a quartz or durane filter. An immersion UV lamp (TQ 150, Philips) was used. **Caution:** The generation and the handling of diazomethane requires special precautions.[49] Merck silica gel 60 (230−400 mesh) was used for flash column chromatography. For TLC, Precoated sheets (Alugram SIL G/$UV_{254}$ Macherey-Nagel) with detection by UV extinction or by cerium molybdate solution [phosphomolybdic acid (25 g), $Ce(SO_4)_2 \cdot H_2O$ (10 g), concn $H_2SO_4$ (60 mL), $H_2O$ (940 mL)] was used. For MPLC, detection was done with a UV detector. HPLC analyses of diastereoisomer distribution were carried out with a Pharmacia RSD 2140 apparatus with a Pharmacia RSD 2249 mixer, and diode-array detection (Pharmacia RSD 2140) on a LiChrosorb Si 60 (Merck) (hexane/EA; flow, 2.0 mL/min) and a LiChrospher Si 60 (5 $\mu$m, Merck) (hexane/$^i$PrOH; flow, 1.5 mL/min) chromatographic column, respectively. $^1$H and $^{13}$C NMR spectra were recorded at rt in $CDCl_3$ unless otherwise indicated with $\delta$ in ppm relative to internal TMS (0 ppm) or to resonances of the solvent ($^1$H, $CHCl_3$, 7.24 ppm; $^{13}$C, $CDCl_3$, 77.0 ppm), and $J$ are recorded in Hz; in spectra of higher order, $\delta$s and $J$s are not corrected. Mass spectra were recorded using FAB or CI ($CH_4$ or $NH_3$) techniques. IR spectra were recorded with a FTIR instrument. Elemental analyses were performed by the service of the Institut für Organische Chemie, Stuttgart. Melting points are not corrected.

**General Procedure for the Preparation of Diazo Ketones.**[13] The amino acid derivative was dissolved in THF (0.2 M) under an atmosphere of nitrogen. At −15 °C $Et_3N$ (1 equiv) and $ClCO_2Et$ (1 equiv) were added to the solution. After 15 min the suspension was allowed to warm to 0 °C. A solution of $CH_2N_2$ in $Et_2O$ was added until the intense yellow color persisted over a longer period. The mixture was allowed to warm to rt and then stirred for 3 h. Excess $CH_2N_2$ was destroyed by addition of a small amount of 0.5 N HOAc. After aqueous workup by extraction with saturated $NaHCO_3$ and NaCl solutions, the organic layer was separated and dried ($MgSO_4$), and the solvents were evaporated. Chromatography of the residue on silica gel or recrystallization afforded the pure diazo ketone.

**General Procedure for the Preparation of $\beta$-Lactams.** In a quartz photo reactor the diazo ketone and the imine were dissolved in diethyl ether (300 mL), and the mixture was cooled to −15 °C and irradiated for 90 min. The mixture was stirred for another 30 min at that temperature and warmed to rt. The solution was concentrated and the imine, and other nonpolar compounds (polymerized ether) were removed by filtrative column chromatography (20 g $SiO_2$, PE/EA 7:1 → 1:1). After determination of the isomer ratio (HPLC and $^1$H NMR), the diastereoisomers were separated by chromatography.

**(3*R*,4*S*,1′*S*)- and (3*S*,4*R*,1′*S*)-1-Benzyl-3-[1-[(benzyloxycarbonyl)amino]ethyl]-4-phenylazetidin-2-one (18a,b).** Following the general procedure, diazo ketone **1** (247 mg, 1.00 mmol) and imine **17** (1.56 g, 8.00 mmol) were irradiated at −15 °C to yield a mixture of **18a** and **18b** (67:33, 294 mg, 71%). The pure isomers **18a** (187 mg, 45%) and **18b** (87 mg, 21%) were obtained by MPLC (PE/$^i$PrOH 98.5:1.5). **18a** (first eluted): colorless solid; mp 132−133 °C; $t_R$ (HPLC, hexane/$^i$PrOH 19:1) 4.23 min; $[\alpha]^{20}_D$ −0.2 (*c* 1.24, $CHCl_3$); IR (KBr) 3272, 3012, 1722, 1705 cm$^{-1}$; $^1$H NMR (250 MHz) $\delta$ 1.33 (d, $J$ = 6.9, 3 H), 3.13 (s, 1 H), 3.71 (d, $J$ = 15.0, 1 H), 4.20 ($m_c$, 1 H), 4.24 (s, 1 H), 4.85 (d, $J$ = 15, 1 H), *ca.* 4.83 (m, 1 H), 4.91, 5.12 (2 d, $J$ = 12.3, 12.3, 2 H), 7.09−7.35 (m, 15 H); $^{13}$C NMR (75 MHz) $\delta$ 15.0 (q), 44.1 (t), 44.9 (d), 56.5 (d), 65.0 (d), 66.4 (t), 126.3, 127.3, 127.7, 127.8, 128.0, 128.2, 128.2, 128.4, 128.7 (9d), 135.1, 136.2, 137.1 (3 s), 155.9 (s), 167.5 (s); MS (CI, $CH_4$) $m/z$ (%) 415 (68, $[M + 1]^+$), 238 (42, $[M - C_{10}H_{10}NO_2]^+$), 91 (85, $C_7H_7^+$), 75 (100). Anal. Calcd for $C_{26}H_{26}N_2O_3$ (414.5): C, 75.34; H, 6.32; N, 6.76. Found: C, 75.16; H, 6.41; N, 6.87. **18b** (second eluted): colorless solid; mp 118−119 °C; $t_R$ (HPLC, hexane/$^i$PrOH 19:1) 7.00 min; $[\alpha]^{20}_D$ −6.5 (*c* 1.1, $CHCl_3$); IR (KBr) 3340, 3012, 1750, 1705 cm$^{-1}$; $^1$H NMR (250 MHz) $\delta$ 1.28 (d, $J$ = 6.7, 3 H), 3.04 (dd, $J$ = 7.1, 1.6, 1 H), 3.76 (d, $J$ = 14.9, 1 H), 4.16 (sextet, $J$ = 7.7, 1 H), 4.32 (s, 1 H), 4.80 (d, $J$ = 14.9, 1 H), 4.85 (d, $J$ = 7.7, 1 H), 5.03, 5.11 (2 d, $J$ = 12.3, 12.2, 2 H), 7.10−7.32 (m, 15 H); $^{13}$C NMR (63 MHz) $\delta$ 18.6 (q), 44.5 (t), 46.4 (d), 58.2 (d), 65.6 (d), 66.7 (t), 126.4, 127.8, 128.2, 128.4, 128.5, 128.8, 129.0 (7 d), 135.4, 136.4, 137.3 (3 s), 155.5 (s), 167.4 (s); MS (CI/$CH_4$) $m/z$ (%) 415 (10, $[M + 1]^+$), 238 (10, $[M - C_{10}H_{10}NO_2]^+$), 91 (100, $C_7H_7^+$).

**(3*R*,4*S*,1′*S*)- and (3*S*,4*R*,1′*S*)-1-Benzyl-3-[1-[(*tert*-butoxycarbonyl)amino]ethyl]-4-phenylazetidin-2-one (19a,b).** Following the general procedure, diazo ketone **2** (213 mg, 1.00 mmol) and imine **17** (1.56 g, 8.00 mmol) were irradiated at −15 °C to yield a mixture of **19a** and **19b** (71:29, 266 mg, 70%). The pure isomers **19a** (179 mg, 47%) and **19b** (68 mg, 18%) were obtained by MPLC (PE/$^i$PrOH 99:1). **19a**: colorless oil; $t_R$ (HPLC, hexane/$^i$PrOH 49:1) 6.30 min; $[\alpha]^{20}_D$ +17.9 (*c* 1, $CHCl_3$); IR (film) 3328, 2977, 2932, 1751, 1707 cm$^{-1}$; $^1$H NMR (300 MHz) $\delta$ 1.30 (d, $J$ = 7.0, 1 H), 1.37 (s, 9 H), 3.13 (br s, 1 H), 3.73 (d, $J$ = 15.0, 1 H), 4.12 ($m_c$, 1 H), 4.24 (d, $J$ = 2.2, 1 H), 4.71 (br d, $J$ = 8.5, 1 H), 4.87 (d, $J$ = 15.0, 1 H), 7.25−7.39 (m, 10 H); $^{13}$C NMR (75 MHz) $\delta$ 19.7 (q), 28.3 (q) 44.3 (d) 44.3 (t), 56.9 (d), 65.4 (d), 79.4 (s), 126.5, 127.6, 128.3, 128.4, 128.8, 129.0 (6 d), 135.5, 137.3 (2 s), 155.5 (s), 167.9 (s); MS (CI, $CH_4$) $m/z$ (%) 381 (8, $[M + 1]^+$), 325 (100, $[M - C_4H_7]^+$), 281 (21, $[M - C_5H_7O_2]^+$), 238 (23, $[M - C_7H_{12}NO_2]^+$), 91 (3, $C_7H_7^+$), 57 (4, $C_4H_9^+$). Anal. Calcd for $C_{23}H_{28}N_2O_3$ (380.5): C, 72.60; H, 7.42; N, 7.36. Found: C, 72.20; H, 7.61; N, 7.30. **19b** (second eluted): colorless oil; $t_R$ (HPLC, hexane/$^i$PrOH 49:1) 10.8 min; $[\alpha]^{20}_D$ −3.4 (*c* 1.9, $CHCl_3$); IR (film) 3332, 2976, 2932, 1751, 1707 cm$^{-1}$; $^1$H NMR (300 MHz) $\delta$ 1.27 (d, $J$ = 6.7, 1 H), 1.41 (s, 9 H), 3.02 (br d, $J$ = 7.3, 1 H), 3.78 (d, $J$ = 14.8, 1 H), 4.09 ($m_c$, 1 H), 4.38 (br s, 1 H), 4.63 (br d, $J$ = 8.0, 1 H), 4.80 (d, $J$ = 14.9, 1 H), 7.11−7.37 (m, 10 H); $^{13}$C NMR (75 MHz) $\delta$ 18.6 (q), 28.4 (q), 44.5 (d), 45.8 (t), 58.5 (d), 66.0 (d), 79.4 (s), 126.5, 127.7, 128.4, 128.4, 128.8, 128.9 (6 d), 135.5, 137.5 (2 s), 154.9 (s), 167.6 (s); MS (CI, $CH_4$) $m/z$ (%) 381 (40, $[M + 1]^+$), 325 (100, $[M - C_4H_7]^+$), 281 (8, $[M - C_5H_7O_2]^+$), 238 (23, $[M - C_7H_{12}NO_2]^+$), 91 (3, $C_7H_7^+$), 57 (3, $C_4H_9^+$). Anal. Calcd for $C_{23}H_{28}N_2O_3$ (380.5): C, 72.60; H, 7.42; N, 7.36. Found: C, 72.44; H, 7.55; N, 7.18.

**(3*R*,4*S*,1′*S*)- and (3*S*,4*R*,1′*S*)-1-Benzyl-4-phenyl-3-(1-phthalimidoethyl)azetidin-2-one (20a,b).** Following the general procedure, diazo ketone **3** (486 mg, 2.00 mmol) and imine **17** (1.56 g, 8.00 mmol) were irradiated at −15 °C to yield a mixture of **20a** and **20b** (17:83, 443 mg, 54%). The pure isomers **20a** (58 mg, 7%) and **20b** (354 mg, 43%) were obtained by MPLC (PE/EA 7:3). **20b** (first eluted): colorless solid; mp 176−177 °C; $t_R$ (HPLC, hexane/EA 7:3) 3.9 min; $[\alpha]^{20}_D$ +19.7 (*c* 1.07, $CHCl_3$); IR (KBr) 1755, 1705 cm$^{-1}$; $^1$H NMR (300 MHz) $\delta$ 1.61 (d, $J$ = 7.0, 3 H), 3.72 (d, $J$ = 15.0, 1 H), 3.78 (dd, $J$ = 11.0, 2.0, 1 H), 4.14 (d, $J$ = 2.1, 1 H), 4.66 (dq, $J$ = 11.0, 7.0, 1 H), 4.72 (d, $J$ = 15.0, 1 H), 6.88−7.69 (m, 14 H); $^{13}$C NMR (75 MHz) $\delta$ 17.0 (q), 44.4 (t), 46.8 (d), 59.0 (d), 62.7 (d), 123.3, 126.0, 127.7, 128.3, 128.4, 128.7, 128.9, 134.1 (8 d), 131.4, 135.2, 136.8 (3 s), 167.2, 167.9 (2 s); MS (CI, $CH_4$) $m/z$ (%) 411 (100, $[M + 1]^+$), 238 (63, $[M - C_{10}H_6NO_2]^+$), 174 (45, $C_{10}H_8NO_2^+$), 91 (20, $C_7H_7^+$). Anal. Calcd for $C_{26}H_{22}N_2O_3$ (410.5): C, 76.08; H, 5.40; N, 6.82. Found: C, 76.15; H, 5.35;

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N, 6.76. **20a** (second eluted): colorless solid; mp 124−126 °C; $t_R$ (HPLC, hexane/EA 7:3) 4.9 min; $[\alpha]^{20}_D$ +15.5 (*c* 1.42, $CHCl_3$); IR (KBr) 1745, 1707 $cm^{-1}$; $^1H$ NMR (300 MHz) $\delta$ 1.42 (d, $J$ = 7.0, 3 H), 3.63 (dd, $J$ = 9.5, 1.9, 1 H), 3.64 (d, $J$ = 14.6, 1 H), 4.26 (d, $J$ = 2.0, 1 H), 4.66 (dq, $J$ = 9.5, 7.1, 1 H), 4.74 (d, $J$ = 15.0, 1 H), 7.05−7.76 (m, 14 H); $^{13}C$ NMR (75 MHz) $\delta$ 16.3 (q), 44.2 (t), 45.5 (d), 58.7 (d), 61.9 (d), 123.2, 126.6, 127.6, 128.3, 128.5, 128.7, 128.9, 133.8 (8 d), 131.8, 135.3, 136.8 (3 s), 166.9, 167.9 (2 s); MS (CI, $CH_4$) *m*/*z* (%) 821 (8, $[2M + 1]^+$), 411 (95, $[M + 1]^+$), 238 (100, $[M - C_{10}H_6NO_2]^+$), 174 (85, $C_{10}H_8NO_2^+$), 91 (70, $C_7H_7^+$). Anal. Calcd for $C_{26}H_{22}N_2O_3$ (410.5): C, 76.08; H, 5.40; N, 6.82. Found: C, 75.84; H, 5.55; N, 6.79.

**(3*R*,4*S*,1′*S*)- and (3*S*,4*R*,1′*S*)-1-Benzyl-3-[1-[(benzyloxycarbonyl)amino]-3-methylbutyl]-4-phenylazetidin-2-one (21a,b).** Following the general procedure, diazo ketone **4** (579 mg, 2.00 mmol) and imine **17** (1.56 g, 8.00 mmol) were irradiated at −15 °C to yield a mixture of **21a** and **21b** (70:30, 816 mg, 89%). The pure isomers **21a** (525 mg, 57%) and **21b** (215 mg, 24%) were obtained by column chromatography (PE/EA 5:1). **21a** (first eluted): colorless solid; mp 134.5−135.0 °C; $t_R$ (HPLC, hexane/EA 4:1) 5.47 min; $[\alpha]^{20}_D$ +3.99 (*c* 1, $CHCl_3$); IR (KBr) 3310, 1745, 1680 $cm^1$; $^1H$-NMR (300 MHz) $\delta$ 0.86, 0.88 (2 d, $J$ = 6.7, 6.6, 6 H), 1.28−1.37 (m, 1 H), 1.59−1.83 (2 m, 2 H), 3.12 (s, 1 H), 3.72 (d, $J$ = 15.0, 1 H), 4.16 ($m_c$, 1 H), 4.27 (s, 1 H), 4.75 (d, $J$ = 9.5, 1 H), 4.84 (d, $J$ = 15.0, 1 H), 4.90, 5.14 (2 d, $J$ = 12.4, 12.3, 2 H), 7.11−7.37 (m, 15 H); $^{13}C$ NMR (75 MHz) $\delta$ 21.4, 23.0 (2 q), 24.6 (d), 42.5, 44.3 (2 t), 47.3 (d), 56.6 (d), 64.9 (d), 66.6 (t), 126.5, 127.4, 127.6, 127.9, 128.1, 128.3, 128.4, 128.5, 128.8 (9 d), 135.3, 136.3, 137.2 (3 s), 156.4 (s), 167.7 (s); MS (CI, $CH_4$) *m*/*z* (%) 457 (100, $[M + 1]^+$), 91 (16, $C_7H_7^+$). Anal. Calcd for $C_{29}H_{32}N_2O_3$ (456.6): C, 76.29; H, 7.06; N, 6.14. Found: C, 76.41; H, 7.12; N, 6.09. **21b** (second eluted): colorless solid; mp 124.0−124.5 °C; $t_R$ (HPLC, hexane/EA 4:1) 7.00 min; $[\alpha]^{20}_D$ −33.2 (*c* 0.94, $CHCl_3$); IR (KBr) 3308, 1745 $cm^{-1}$; $^1H$ NMR (300 MHz) $\delta$ 0.89, 0.90 (2 d, $J$ = 6.2, 6.5, 6 H), 1.27−1.37, 1.49−1.75 (2 m, 3 H), 3.04 (dd, $J$ = 7.8, 1.1, 1 H), 3.78 (d, $J$ = 14.9, 1 H), 4.16 ($m_c$, 1 H), 4.31 (d, $J$ = 1.6, 1 H), 4.67 (d, $J$ = 9.5, 1 H), 4.78 (d, $J$ = 15.0, 1 H), 5.01, 5.16 (2 d, $J$ = 12.3, 12.3, 2 H), 7.09−7.37 (m, 15 H); $^{13}C$ NMR (75 MHz) $\delta$ 19.5, 21.5 (2 q), 22.6 (d), 39.7 (t), 42.6 (t), 46.8 (d), 56.1 (d), 63.6 (d), 64.7 (t), 124.9, 125.8, 126.2, 126.4, 126.5, 126.5, 126.8, 127.0 (8 d), 133.4, 134.5, 135.5 (3 s), 153.9 (s), 165.6 (s); MS (CI, $CH_4$) *m*/*z* (%) 457 (100, $[M + 1]^+$), 91 (16, $C_7H_7^+$). Anal. Calcd for $C_{29}H_{32}N_2O_3$ (456.6): C, 76.29; H, 7.06; N, 6.14. Found: C, 76.13; H, 7.15; N, 5.90.

**(3*R*,4*S*,1′*S*)- and (3*S*,4*R*,1′*S*)-1-Benzyl-3-[1-[(benzyloxycarbonyl)amino]-2-methylpropyl]-4-phenylazetidin-2-one (22a,b).** Following the general procedure, diazo ketone **5** (551 mg, 2.00 mmol) and imine **17** (429 mg, 2.20 mmol) were irradiated at −15 °C to yield a mixture of **22a** and **22b** (82:18, 786 mg, 89%). The pure isomers **22a** (543 mg, 61%) and **22b** (75 mg, 9%) were obtained by column chromatography (PE/EA 5:1). **22a** (first eluted): colorless solid; mp 75−76 °C; $t_R$ (HPLC, hexane/EA 4:1) 6.2 min; $[\alpha]^{20}_D$ +23.6 (*c* 1.33, $CHCl_3$); IR (film) 3300, 2940, 1720 $cm^{-1}$; $^1H$ NMR (300 MHz) $\delta$ 0.94, 0.94 (2 d, $J$ = 6.8, 6.7, 6 H), 1.94 (octet, $J$ = 6.9, 1 H), 3.28 (br s, 1 H), 3.72 (d, $J$ = 14.9, 1 H), 3.86 (ddd, $J$ = 10.3, 7.5, 3.0, 1 H), 4.20 (d, $J$ = 2.1, 1 H), 4.83 (d, $J$ = 14.9, 1 H), 4.87 (d, $J$ = 7.7, 1 H), 4.93, 5.16 (2 d, $J$ = 12.3, 12.3, 2 H), 7.08−7.42 (m, 15 H); $^{13}C$ NMR (75 MHz) $\delta$ 19.1, 19.9 (2 q), 31.8 (d), 44.4 (t), 55.1 (d), 57.5 (d), 62.7 (d), 66.8 (t), 126.7, 127.5, 127.8, 128.0, 128.3, 128.5, 128.51, 128.7, 129.0 (9 d), 135.4, 136.6, 137.3 (3 s), 156.9 (s), 167.5 (s); MS (CI, $NH_3$) *m*/*z* (%) 460 (62, $[M + NH_4]^+$), 443 (100, $[M + H]^+$), 309 (41, $[M - C_8H_5O_2]^+$). Anal. Calcd for $C_{28}H_{30}N_2O_3$ (442.6): C, 75.99; H, 6.83; N, 6.33. Found: C, 76.04; H, 6.83; N, 6.26. **22b** (second eluted): yellowish oil; $t_R$ (HPLC, hexane/EA 4:1) = 9.6 min; $[\alpha]^{20}_D$ −6.5 (*c* 0.95, $CHCl_3$); IR (film) 3310, 2945, 1740 $cm^{-1}$; $^1H$ NMR (300 MHz) $\delta$ 0.75, 0.83 (2 d, $J$ = 6.9, 6.8, 6 H), 2.13 ($m_c$, 1 H), 3.01 (dd, $J$ = 9.6, 1.8, 1 H), 3.71 (d, $J$ = 15.0, 1 H), 4.02 ($m_c$, 1 H), 4.27 (d, $J$ = 1.7, 1 H), 4.56 (d, $J$ = 10.1, 1 H), 4.67 (d, $J$ = 15.0, 1 H), 4.93, 5.13 (2 d, $J$ = 12.2, 12.2, 2 H), 6.97−7.25 (m, 15 H); $^{13}C$ NMR (75 MHz) $\delta$ 14.2, 17.9 (2 q), 28.1 (d), 42.5 (t), 53.7 (d), 56.7 (d), 61.6 (d), 64.9 (t), 124.4, 125.7, 126.3, 126.4, 126.6, 126.8, 127.0 (7 d), 133.4, 134.5, 135.5 (3 s), 154.3 (s), 165.3 (s); MS (CI, $NH_3$) *m*/*z* (%) 443 (100, $[M + 1]^+$), 309 (80, $[M - C_8H_5O_2]^+$). Anal. Calcd for $C_{28}H_{30}N_2O_3$ (442.6): C, 75.99; H, 6.83; N 6.33%. Found: C, 76.05; H, 6.87; N, 6.27.

**(3*R*,4*S*,1′*S*)- and (3*S*,4*R*,1′*S*)-1-Benzyl-3-[1-[[(fluoren-9-ylmethoxy)carbonyl]amino]-2-methylpropyl]-4-phenylazetidin-2-one (23a,b).** Following the general procedure, diazo ketone **6** (727 mg, 2.00 mmol) and imine **17** (781 mg, 4.00 mmol) were irradiated at −15 °C to yield a mixture of **23a** and **23b** (77:23, 838 mg, 79%). The pure isomers **23a** (615 mg, 58%) and **23b** (170 mg, 16%) were obtained by column chromatography (PE/EA 8:1 → 2:1). **23a** (first eluted): colorless foam, softening range 40−70 °C; $t_R$ (HPLC, hexane/EA 4:1) 6.61 min; $[\alpha]^{20}_D$ +12.2 (*c* 1.05, $CHCl_3$); IR (KBr) 3300, 2940, 1740, 1712 $cm^{-1}$; $^1H$ NMR (300 MHz) $\delta$ 0.93, 0.95 (2 d, $J$ = 6.4, 6.3, 6 H), 1.96 (octet, $J$ = 7.0, 1 H), 3.29 (t, $J$ = 2.7, 1 H), 3.74 (d, $J$ = 14.9, 1 H), 3.84 (ddd, $J$ = 10.2, 7.8, 2.9, 1 H), 4.10−4.23 (m, 3 H), 4.54 (dd, $J$ = 10.0, 6.5, 1 H), 4.81 (d, $J$ = 14.9, 1 H), 4.88 (d, 1 H), 7.07−7.80 (m, 18 H); $^{13}C$ NMR (63 MHz) $\delta$ 19.0, 19.9 (2 q), 31.6 (d), 44.6 (t), 47.3 (d), 55.1 (d), 57.5 (d), 62.6 (d), 66.9 (t), 120.0, 125.1, 126.7, 127.1, 127.6, 127.8, 128.4, 128.5, 128.7, 129.0 (10 d), 135.3, 137.2, 141.3, 143.9 (4 s), 156.7 (s), 167.5 (s); MS (CI, $CH_4$) *m*/*z* (%) 309 (100, $[M - C_{15}H_9O_2]^+$), 179 (95, $C_{14}H_{11}^+$), 132 (48, $C_8H_6NO^+$), 91 (16, $C_7H_7^+$). Anal. Calcd for $C_{35}H_{34}N_2O_3 \cdot {}^1/_2H_2O$ (539.7): C, 77.90; H, 6.54; N, 5.19. Found: C, 78.24; H, 6.57; N, 5.11. **23b** (second eluted): colorless foam, softening range 60−75 °C; $t_R$ (HPLC, hexane/EA 4:1) = 11.4 min; $[\alpha]^{20}_D$ +11.9 (*c* 1.07, $CHCl_3$); IR (KBr) 3310, 2940, 1745, 1717 $cm^{-1}$; $^1H$ NMR (300 MHz) $\delta$ 0.84, 0.90 (2 d, $J$ = 6.9, 6.8, 6 H), 2.21 ($m_c$, 1 H), 3.10 (dd, $J$ = 9.1, 1.7, 1 H), 3.81 (d, $J$ = 14.9, 1 H), 4.11 ($m_c$, 1 H), 4.20 (t, $J$ = 6.5, 1 H), 4.32 (d, $J$ = 1.8, 1 H), 4.42−4.50 (m, 2 H), 4.54 (d, $J$ = 10.4, 1 H), 4.77 (d, $J$ = 15.0, 1 H), 7.09−7.78 (m, 18 H); $^{13}C$ NMR (63 MHz) $\delta$ 16.1, 19.8 (2 q), 30.1 (d), 44.4 (t), 47.3 (d), 55.6 (d), 58.6 (d), 63.3 (d), 66.4 (t), 119.9, 124.8, 126.2, 127.0, 127.6, 128.3, 128.7, 129.0 (8 d), 135.2, 137.4, 141.2, 143.7 (4 s), 156.2 (s), 167.2 (s); MS (CI, $CH_4$) *m*/*z* (%) 309 (100, $[M - C_{15}H_9O_2]^+$), 178 (82, $C_{14}H_{10}^+$), 132 (80, $C_8H_6NO^+$), 91 (10, $C_7H_7^+$). Anal. Calcd for $C_{35}H_{34}N_2O_3 \cdot {}^1/_2H_2O$ (539.7): C, 77.90; H, 6.54; N, 5.19. Found: C, 77.81; H, 6.54; N, 5.13.

**(3*R*,4*S*,1′*S*,2′*S*)- and (3*S*,4*R*,1′*S*,2′*S*)-1-Benzyl-3-[1-[(benzyloxycarbonyl)amino]-2-methylbutyl]-4-phenylazetidin-2-one (24a,b).** Following the general procedure, diazo ketone **7** (579 mg, 2.00 mmol) and imine **17** (1.56 g, 8.00 mmol) were irradiated at −15 °C to yield a mixture of **24a** and **24b** (83:17, 820 mg, 90%). The pure isomers **24a** (507 mg, 56%) and **24b** (59 mg, 6%) were obtained by column chromatography (PE/EA 7:1). **24a** (first eluted): colorless oil; $t_R$ (HPLC, hexane/EA 4:1) 5.1 min; $[\alpha]^{20}_D$ +19.4 (*c* 1.75, $CHCl_3$); IR ($CDCl_3$) 1730 $cm^{-1}$; $^1H$ NMR (300 MHz) $\delta$ 0.84 (t, $J$ = 7.3, 3 H), 0.93 (d, $J$ = 6.7, 3 H), 1.08 ($m_c$, 1 H), 1.55 ($m_c$, 1 H), 1.71 ($m_c$, 1 H), 3.28 (br s, 1 H), 3.72 (d, $J$ = 15.0, 1 H), 3.93 (ddd, $J$ = 10.3, 7.7, 2.8, 1 H), 4.22 (d, $J$ = 2.1, 1 H), 4.83 (d, $J$ = 15.0, 1 H), 4.89 (d, $J$ = 7.9, 1 H), 4.93, 5.15 (2 d, $J$ = 12.3, 12.4, 2 H), 7.08−7.42 (m, 15 H); $^{13}C$ NMR (75 MHz) $\delta$ 11.0 (q), 15.8 (q), 25.4 (t), 38.1 (d), 44.4 (t), 53.7 (d), 57.3 (d), 62.3 (d), 66.8 (t), 126.5, 127.5, 127.7, 128.0, 128.2, 128.4, 128.4, 128.6, 128.9 (9 d), 135.3, 136.4, 137.2 (3 s), 156.6 (s), 167.4 (s); MS (CI, $NH_3$) *m*/*z* (%) 457 (100, $[M + 1]^+$), 323 (11, $[M - C_8H_5O_2]^+$), 91 (28, $C_7H_7^+$). Anal. Calcd for $C_{29}H_{32}N_2O_3$ (456.6): C, 76.29; H, 7.06; N, 6.14. Found: C, 76.19; H, 7.13; N, 6.17. **24b** (second eluted): colorless oil; $t_R$ (HPLC, hexane/EA 4:1) 9.2 min; $[\alpha]^{20}_D$ −18.2 (*c* 1.3, $CHCl_3$); IR ($CDCl_3$) 1740, 1715 $cm^{-1}$; $^1H$ NMR (300 MHz) $\delta$ 0.86−1.90 (m, 9 H), 3.17 (dd, $J$ = 9.0, 1.9, 1 H), 3.78 (d, $J$ = 15.0, 1 H), 4.10−4.17 (m, 1 H), 4.32 (d, $J$ = 1.8, 1 H), 4.57 (d, $J$ = 10.0, 1 H), 4.77 (d, $J$ = 15.0, 1 H), 5.02, 5.21 (2 d, $J$ = 12.2, 12.2, 2 H), 7.06−7.36 (m, 15 H); $^{13}C$ NMR (75 MHz) $\delta$ 11.6 (q), 16.1 (q), 23.6 (t), 37.1 (d), 44.5 (t), 55.4 (d), 58.3 (d), 63.3 (d), 66.8 (t), 126.4, 127.7, 128.3, 128.4, 128.6 128.8, 129.0 (7 d), 135.4, 136.4, 137.5 (3 s), 156.3 (s), 167.4 (s); MS (CI, $NH_3$) *m*/*z* (%) 457 (100, $[M + 1]^+$), 323 (24, $[M - C_8H_5O_2]^+$), 91 (10, $C_7H_7^+$).

**(3*R*,4*S*,1′*S*)-1-Benzyl-3-[1-[(benzyloxycarbonyl)amino]-2,2-dimethylpropyl]-4-phenylazetidin-2-one (25).** Following the general procedure, diazo ketone **8** (579 mg, 2.00 mmol) and imine **17** (586 mg, 3.00 mmol) were irradiated at −15 °C to yield a mixture of **25a** and **25b** (93:7, 804 mg, 88%). The major isomer **25a** (731 mg, 80%) could be isolated by column chromatography (PE/EA 7:1): colorless oil; $t_R$ (HPLC, hexane/

EA 4:1) 4.10 min; $[\alpha]^{20}_D$ +40.7 (*c* 1, $CHCl_3$); IR (film): 3319, 3031, 2962, 1756 $cm^{-1}$; $^1H$ NMR (300 MHz) $\delta$ 0.94 (s, 9 H), 3.34 (br s, 1 H), 3.70 (d, $J$ = 15.1, 1 H), 3.90 (dd, $J$ = 10.7, 2.1, 1 H), 4.18 (d, $J$ = 2.2, 1 H), 4.82 (d, $J$ = 15.0, 1 H), 4.93 (d, $J$ = 12.3, 1 H), 5.04 (d, $J$ = 10.7, 1 H), 5.19 (d, $J$ = 12.4, 1 H), 7.08−7.40 (m, 15 H); $^{13}C$ NMR (75 MHz): $\delta$ 26.5 (q), 34.3 (s), 44.1 (t), 57.8 (d), 57.9 (d), 61.2 (d), 66.5 (t), 126.4, 127.2, 127.5, 127.8, 127.9, 128.2, 128.3, 128.7 (8 d), 135.0, 136.2, 136.8 (3 s), 156.6 (s), 166.8 (s); MS (CI,$CH_4$) *m*/*z* (%) 457 (100, $[M + 1]^+$), 238 (43, $[M - C_{13}H_{16}NO_2]^+$), 196 (35, $PhCH_2NH{=}CHPh^+$), 91 (23, $C_7H_7^+$). Anal. Calcd for $C_{29}H_{32}N_2O_3$ (456.6): C, 76.29; H, 7.06; N, 6.14. Found: C, 75.98; H, 7.07; N, 5.91.

**(3*R*,4*S*,1′*S*)- and (3*S*,4*R*,1′*S*)-1-Benzyl-3-[1-[(benzyloxycarbonyl)amino]-2-phenylethyl]-4-phenylazetidin-2-one (26a,b).** Following the general procedure, diazo ketone **9** (582 mg, 1.80 mmol) and imine **17** (1.41 g, 7.22 mmol) were irradiated at −15 °C to yield a mixture of **26a** and **26b** (59:41, 512 mg, 58%). The pure isomers **26a** (265 mg, 32%) and **26b** (185 mg, 23%) were obtained by column chromatography (PE/EA 5:1). **26a** (first eluted): colorless solid; mp 147−148 °C; $t_R$ (HPLC, hexane/EA 4:1) 7.4 min; $[\alpha]^{20}_D$ +18.8 (*c* 1.07, $CHCl_3$); IR (KBr) 3260, 1720, 1708 $cm^{-1}$; $^1H$ NMR (300 MHz) $\delta$ 3.02 (d, $J$ = 7.7, 2 H), 3.18 (br s, 1 H), 3.72 (d, $J$ = 15.0, 1 H), 4.26 (d, $J$ = 1.7, 1 H), 4.35 ($m_c$, 1 H), 4.84 ($m_c$, 2 H), 4.92 (d, $J$ = 9.4, 1 H), 5.08 (d, $J$ = 12.5, 1 H), 7.06−7.35 (m, 20 H); $^{13}C$ NMR (75 MHz) $\delta$ 39.8 (t), 44.5 (t), 50.5 (d), 56.9 (d), 62.9 (d), 66.7 (t), 126.6, 127.6, 128.0, 128.3, 128.5, 128.5, 128.7, 128.9, 129.2 (9 d), 135.3, 136.3, 136.9, 137.1 (4 s), 156.3 (s), 167.7 (s); MS (CI, $NH_3$) *m*/*z* (%) 491 (100, $[M + 1]^+$), 357 (17, $[M - C_8H_5O_2]^+$), 266 (8, $[357 - C_7H_7]^+$), 91 (6, $C_7H_7^+$). Anal. Calcd for $C_{32}H_{30}N_2O_3 \cdot {}^1/_2H_2O$ (499.6): C, 76.93; H, 6.25; N, 5.61. Found: C, 76.94; H, 6.08; N, 5.54. **26b** (second eluted): mp 126−127 °C; $t_R$ (HPLC, hexane/EA 4:1) 8.9 min; $[\alpha]^{20}_D$ −9.93 (*c* 1.09, $CHCl_3$); IR (KBr) 3290, 1721, 1710 $cm^{-1}$; $^1H$ NMR (300 MHz) $\delta$ 2.99 (m, 3 H), 3.82 (d, $J$ = 14.9, 1 H), 4.35−4.45 (m, 2 H), 4.61 (d, $J$ = 9.3, 1 H), 4.80 (d, $J$ = 14.7, 1 H), 4.99, 5.10 (2 d, $J$ = 12.2, 12.0, 2 H), 7.05−7.32 (m, 20 H); $^{13}C$ NMR (75 MHz) $\delta$ 38.3 (t), 44.5 (t), 51.3 (d), 58.9 (d), 63.5 (d), 66.7 (t), 126.4, 126.7, 127.8, 128.1, 128.2, 128.4, 128.5, 128.8, 129.0, 129.9 (10 d), 135.3, 136.3, 137.2 (3 s), 155.6 (s), 167.3 (s); MS (CI, $NH_3$) *m*/*z* (%) 491 (100, $[M + 1]^+$), 357 (16, $[M - C_8H_5O_2]^+$), 266 (9, $[357 - C_7H_7]^+$), 91 (13, $C_7H_7^+$). Anal. Calcd for $C_{32}H_{30}N_2O_3$ (490.6): C, 78.34; H, 6.16; N, 5.71. Found: C, 78.31; H, 6.23; N 5.62.

**(2*S*,3′*R*,4′*S*)- and (2*S*,3′*S*,4′*R*)-*tert*-Butyl 2-(1-Benzyl-2-oxo-4-phenylazetidin-3-yl)pyrrolidine-1-carboxylate (27a,b).** Following the general procedure, diazo ketone **10** (480 mg, 2.01 mmol) and imine **17** (1.57 g, 8.04 mmol) were irradiated at −15 °C to yield a mixture of **27a** and **27b** (63:37, 515 mg, 63%). The pure isomers **27a** (275 mg, 34%) and **27b** (179 mg, 22%) were obtained by MPLC (PE/EA 3:1). **27a** (first eluted): colorless oil; $t_R$ (HPLC, hexane/EA 3:1) 5.17 min; $[\alpha]^{20}_D$ +131 (*c* 0.5, $CHCl_3$); IR (film) 2976, 2882, 1749, 1690 $cm^{-1}$; $^1H$ NMR (300 MHz) $\delta$ 1.24−1.47 (m, 9 H), 1.86−1.96 (m, 4 H), 3.00−3.12 (m, 1 H), 3.21−3.25 (m, 2 H), 3.71−3.84 (m, 1 H), 4.15−4.26 (m, 1 H), 4.84−4.79 (m, 1 H), 4.92 ($m_c$, 1 H), 7.13−7.29 (m, 10 H); $^{13}C$ NMR (250 MHz) $\delta$ 23.4, 29.1 (2 t), 28.3 (q), 44.2 (t), 46.4 (t), 56.4 (d), 59.7 (d), 64.5 (d), 79.1 (s), 126.6, 127.5, 128.0, 128.4, 128.6 (5 d), 135.6, 137.9 (2 s), 154.7 (s), 167.8 (s); MS (FAB) *m*/*z* (%) 836 (3, $[2 M + Na + 1]^+$), 429 (18, $[M + Na]^+$), 407 (62, $[M + 1]^+$), 351 (31, $[M - C_4H_7]^+$), 307 (100, $[M - C_5H_7O_2]^+$), 91 (35, $C_7H_7^+$). **27b** (second eluted): colorless solid; mp 123−124 °C; $t_R$ (HPLC, hexane/EA 3:1) 6.02 min; $[\alpha]^{20}_D$ −4.59 (*c* 0.5, $CHCl_3$); IR (film) 2976, 1748, 1694 $cm^{-1}$; $^1H$ NMR (250 MHz) $\delta$ 1.14−1.53 (m, 9 H), 1.52−.20 (m, 4 H), 3.28−3.76 (m, 4 H), 4.10−4.51 (m, 2 H), 4.87 (d, $J$ = 15.0, 1 H), 7.12−7.37 (m, 10 H); $^{13}C$ NMR (75 MHz, 325 K) $\delta$ 23.7, 28.8 (2 t), 28.2 (s), 44.5 (t), 47.2 (t), 54.8 (d), 56.6 (d), 64.2 (d), 79.5 (s), 126.4, 127.5, 128.1, 128.3, 128.6, 128.9 (6 d), 135.9, 138.0 (2 s), 156.0 (s), 168.2 (s); MS (FAB) *m*/*z* (%) 836 (3, $[2 M + Na + 1]^+$), 429 (23, $[M + Na]^+$), 407 (100, $[M + 1]^+$), 351 (41, $[M - C_4H_7]^+$), 307 (35, $[M - C_5H_7O_2]^+$), 91 (32, $C_7H_7^+$). Anal. Calcd for $C_{25}H_{30}N_2O_3$ (406.5): C, 73.86; H, 7.44; N, 6.89. Found: C, 73.66; H, 7.40; N, 6.85.

**(3*R*,4*S*,1′*S*)- and (3*S*,4*R*,1′*S*)-1-Benzyl-3-[4-[(benzyloxycarbonyl)amino]-1-[[(*tert*-butyloxy)carbonyl]amino]butyl]-4-phenyl-azetidin-2-one (28a,b).** Following the general procedure, diazo ketone **11** (195 mg, 499 $\mu$mol) and imine **17** (390 mg, 2.00 mmol) were irradiated at −15 °C to yield a mixture of **28a** and **28b** (70:30, 203 mg, 73%). MPLC (PE/$^i$PrOH 97:3) gave rise to the pure isomers **28a** (95 mg, 34%) and **28b** (39 mg, 14%). **28a** (first eluted): colorless oil; $t_R$ (HPLC, hexane/$^i$PrOH 19:1) 8.95 min; $[\alpha]^{20}_D$ +2 (*c* 1, $CHCl_3$); IR (film) 3329, 3032, 2975, 1706 $cm^{-1}$; $^1H$ NMR (250 MHz) $\delta$ 1.36 (s, 9 H), 1.45−1.74 (m, 4 H), 3.12 (s, 2 H), 3.18 (d, $J$ = 5.3, 1 H), 3.73 (d, $J$ = 15.0, 1 H), 4.00 (m, 1 H), 4.21 (s, 1 H), 4.64 (d, $J$ = 9.4, 1 H), 4.87 (m, 2 H), 5.07 (s, 2 H), 7.16−7.37 (m, 15 H); $^{13}C$ NMR (63 MHz) $\delta$ 26.6, 31.1, 40.6 (3 t), 28.2 (q), 44.4 (t), 48.3 (d), 56.9 (d), 64.5 (d), 66.6 (t), 79.6 (s), 126.6, 127.7, 128.1, 128.4, 128.5, 128.8, 129.0 (7 d), 135.5, 136.6, 137.2, (3 s), 156.0, 156.4 (2 s), 167.7 (s); MS (FAB) *m*/*z* (%) 558 (100, $[M + 1]^+$). Anal. Calcd for $C_{33}H_{39}N_3O_5 \cdot {}^1/_2H_2O$ (566.7): C, 69.94; H, 7.11; N, 7.41. Found: C, 70.02; H, 7.03; N, 7.35. **28b** (second eluted): colorless oil; $t_R$ (HPLC, hexane/$^i$PrOH 19:1) 11.0 min; $[\alpha]^{20}_D$ −2 (*c* 1, $CHCl_3$); IR (film) 3329, 3032, 2975, 1701 $cm^{-1}$; $^1H$ NMR (250 MHz) $\delta$ 1.41 (s, 9 H), 1.47−1.82 (m, 4 H), 3.02 (d, $J$ = 8.2, 1 H), 3.19 (q, $J$ = 6.3, 2 H), 3.79 (d, $J$ = 15.0, 1 H), 4.00 (d, $J$ = 7.1, 1 H), 4.38 (s, 1 H), 4.54 (d, $J$ = 9.3, 1 H), 4.77 (d, $J$ = 15.0, 1 H), 4.92 (br s, 1 H), 5.08 (s, 2 H), 7.11−7.36 (m, 15 H); $^{13}C$ NMR (63 MHz) $\delta$ 26.2, 30.0, 40.7 (3 t), 28.4 (q), 44.6 (t), 49.9 (d), 58.6 (d), 65.3 (d), 66.7 (t), 79.7 (s), 126.6, 127.0, 128.1, 128.6, 128.9, 129.0 (6 d), 135.4, 136.7, 137.5 (3 s), 155.4, 156.5 (2 s), 167.6 (s); MS (FAB) *m*/*z* (%) 558 (100, $[M + 1]^+$).

**(3*R*,4*S*,1′*S*)- and (3*S*,4*R*,1′*S*)-1-Benzyl-3-[1-[(benzyloxycarbonyl)amino]-4-[[(*tert*-butyloxy)carbonyl]amino]butyl]-4-phenylazetidin-2-one (29a,b).** Following the general procedure, diazo ketone **12** (780 mg, 2.00 mmol) and imine **17** (390 mg, 2.00 mmol) were irradiated at −15 °C to yield a mixture of **29a** and **29b** (70:30, 778 mg, 70%). The pure isomers **29a** (345 mg, 31%) and **29b** (148 mg, 13%) were obtained by MPLC (PE/$^i$PrOH 49:1). **29a** (first eluted): colorless oil; $t_R$ (HPLC, hexane/$^i$PrOH 19:1) 8.23 min; $[\alpha]^{20}_D$ +12 (*c* 1, $CHCl_3$); IR (film) 3318, 3032, 2931, 1714 $cm^{-1}$; $^1H$ NMR (250 MHz) $\delta$ 1.41 (s, 9 H), 1.47−1.77 (m, 4 H), 3.08 (d, $J$ = 5.9, 1 H), 3.15 (s, 2 H), 3.71 (d, $J$ = 14.9, 1 H), 4.07 (m, 1 H), 4.23 (d, $J$ = 1.8, 1 H), 4.52 (br s, 1 H), 4.84 (d, $J$ = 15.0, 1 H), 4.91 (s, 1 H), 4.94 (d, $J$ = 12.3, 1 H), 5.13 (d, $J$ = 12.3, 1 H), 7.08−7.36 (m, 15 H); $^{13}C$ NMR (75 MHz) $\delta$ 26.8, 31.1, 40.1 (3 t), 28.5 (q), 44.6 (t), 49.3 (d), 56.9 (d), 64.5 (d), 67.0 (t), 79.2 (s), 126.7, 127.7, 128.0, 128.2, 128.4, 128.6, 128.8, 129.1 (8 d), 135.4, 136.4, 137.2 (3 s), 156.0, 156.6 (2 s), 167.7 (s); MS (FAB) *m*/*z* (%) 558 (100, $[M + 1]^+$). Anal. Calcd for $C_{33}H_{39}N_3O_5$ (557.7): C, 71.07; H, 7.05; N, 7.53. Found: C, 71.04; H, 7.08; N, 7.44. **29b** (second eluted): colorless oil; $t_R$ (HPLC, hexane/$^i$PrOH 19:1) 9.68 min; $[\alpha]^{20}_D$ −27 (*c* 1, $CHCl_3$); IR (film) 3325, 3031, 2930, 1712 $cm^{-1}$; $^1H$ NMR (250 MHz) $\delta$ 1.43 (s, 9 H), 1.50−1.83 (m, 4 H), 3.02−3.11 (m, 3 H), 3.77 (d, $J$ = 14.9, 1 H), 4.02−4.10 (m, 1 H), 4.33 (d, $J$ = 1.6, 1 H), 4.57 (br s, 1 H), 4.78 (d, $J$ = 14.9, 1 H), 4.84 (s, 1 H), 5.00−5.17 (m, 2 H), 7.09−7.33 (m, 15 H); $^{13}C$ NMR (63 MHz) $\delta$ 26.4, 29.9, 40.1 (3 t), 28.4 (q), 44.6 (t), 50.6 (d), 58.2 (d), 65.0 (d), 66.8 (t), 79.2 (s), 126.4, 127.8, 128.2, 128.4, 128.5, 128.8, 129.0 (7 d), 135.3, 136.4, 137.3 (3 s), 156.0 (s), 167.3 (s); MS (FAB) *m*/*z* (%) 558 (100, $[M + 1]^+$). Anal. Calcd for $C_{33}H_{39}N_3O_5 \cdot {}^1/_2H_2O$ (566.7): C, 69.94; H, 7.11; N, 7.41. Found: C, 69.94; H, 6.97; N, 7.33.

**(3*R*,4*S*,1′*S*)- and (3*S*,4*R*,1′*S*)-1-Benzyl-3-[5-[(benzyloxycarbonyl)amino]-1-[[(*tert*-butyloxy)carbonyl]amino]pentyl]-4-phenylazetidin-2-one (30a,b).** Following the general procedure, diazo ketone **13** (1.21 g, 2.99 mmol) and imine **17** (1.17 g, 5.99 mmol) were irradiated at −15 °C to yield a mixture of **30a** and **30b** (65:35, 1.21 g, 71%). The pure isomers **30a** (440 mg, 26%) and **30b** (260 mg, 15%) were obtained by MPLC (PE/$^i$PrOH 9:1). **30a** (first eluted): colorless oil; $t_R$ (HPLC, hexane/$^i$PrOH 19:1) 8.68 min; $[\alpha]^{20}_D$ −1 (*c* 1, $CHCl_3$); IR (film) 3344, 3032, 2926, 1720, 1708 $cm^{-1}$; $^1H$ NMR (250 MHz) $\delta$ 1.36 (s, 9 H), 1.42−1.61, 1.70 (m, s, 6 H), 3.13−3.19 (m, 3 H), 3.73 (d, $J$ = 15.0 Hz, 1 H), 3.97 (m, 1 H), 4.21 (d, $J$ = 2.1, 1 H), 4.58 (d, $J$ = 9.5, 1 H), 4.81 (s, 1 H), 4.87 (d, $J$ = 15.1, 1 H), 5.07 (s, 2 H), 7.25−7.41 (m, 15 H); $^{13}C$ NMR (75 MHz) $\delta$ 23.1, 29.3, 33.3, 40.6 (4 t), 28.2 (q), 44.4 (t), 48.2 (d), 56.9 (d), 64.5 (d), 66.5 (t), 79.4 (s), 126.5, 127.6, 127.9, 128.0,

128.3, 128.4, 128.7, 128.9 (8 d), 135.5, 136.6, 137.2 (3 s), 156.0, 156.4 (2 s), 167.8 (s); MS (FAB) *m/z* (%) 572 (100, $[M + 1]^+$). Anal. Calcd for $C_{34}H_{41}N_3O_5$ (571.7): C, 71.43; H, 7.23; N, 7.35. Found: C, 71.27; H, 7.12; N, 7.33. **30b** (second eluted): colorless oil; $t_R$ (HPLC, hexane/$^i$PrOH 19:1) 12.2 min; $[\alpha]^{20}_D$ −23 (*c* 1, $CHCl_3$); IR (film) 3333, 3031, 2933, 1701 $cm^{-1}$; $^1H$ NMR (250 MHz) $\delta$ 1.40 (s, 9 H), 1.40−1.50, 1.68 (m, s, 6 H), 3.02 (d, *J* = 8.7, 1 H), 3.17 (s, 2 H), 3.80 (d, *J* = 15.0, 1 H), 3.98 (d, *J* = 8.6, 1 H), 4.41 (s, 1 H), 4.55 (d, *J* = 9.3, 1 H), 4.77 (d, *J* = 15.0, 1 H), 4.89 (s, 1 H), 5.09 (s, 2 H), 7.21−7.34 (m, 15 H); $^{13}C$ NMR (75 MHz) $\delta$ 22.3, 29.4, 32.1, 40.4 (4 t), 28.3 (q), 44.4 (t), 49.9 (d), 58.6 (d), 65.3 (d), 66.5 (t), 79.4 (s), 126.4, 127.7, 128.0, 128.4, 128.7, 128.9 (6 d), 135.3, 136.6, 137.4 (3 s), 155.4, 156.4 (2 s), 167.5 (s); MS (FAB) *m/z* (%) 572 (100, $[M + 1]^+$). Anal. Calcd for $C_{34}H_{41}N_3O_5 \cdot {}^1/_2H_2O$ (580.7): C, 70.32; H, 7.29; N, 7.24. Found: C, 70.24; H, 7.22; N, 7.11.

**(3*R*,4*S*,1′*R*,2′*R*)- and (3*S*,4*R*,1′*R*,2′*R*)-1-Benzyl-3-[1-[(benzyloxycarbonyl)amino]-2-[(*tert*-butyldimethylsilyl)oxy]propyl]-4-phenylazetidin-2-one (32a,b).** Following the general procedure, diazo ketone **15** (740 mg, 1.89 mmol) and imine **17** (780 mg, 3.99 mmol) were irradiated at −15 °C to yield a mixture of **32a** and **32b** (80:20, 480 mg, 45%). The pure isomers **32a** (380 mg, 36%) and **32b** (95 mg, 9%) were obtained by column chromatography (PE/EA 20:1 → 6:1). **32a** (first eluted): colorless oil; $t_R$ (HPLC, hexane/EA 4:1) 1.22 min; $[\alpha]^{20}_D$ +20 (*c* 1, $CHCl_3$); IR (film) 3303, 3032, 2928, 2955, 1756 $cm^{-1}$; $^1H$ NMR (250 MHz) $\delta$ −0.25, −0.05 (2 s, 6 H), 0.70 (s, 9 H), 1.14 (d, *J* = 6.2, 3 H), 3.32 (d, *J* = 5.9, 1 H), 3.74 (d, *J* = 15.0, 1 H), 3.85 (m, 1 H), 4.03 (m, 1 H), 4.20 (s, 1 H), 4.85 (d, *J* = 15.0, 1 H), 5.04−5.18 (m, 3 H), 7.12−7.40 (m, 15 H); $^{13}C$ NMR (75 MHz) $\delta$ −5.4, −4.4 (2 q), 17.7 (s), 20.2 (q), 25.6 (q), 44.3 (t), 55.8, 58.1, 60.7, 68.6 (4 d), 67.0 (t), 126.6, 127.6, 128.1, 128.3, 128.5, 128.7, 129.0 (7 d), 135.3, 136.4, 137.1 (3 s), 156.5 (s), 167.6 (s); MS (FAB) *m/z* (%) 559 (100, $[M + 1]^+$). Anal. Calcd for $C_{33}H_{42}N_2O_4Si$ (558.8): C, 70.93; H, 7.58; N, 5.01. Found: C, 70.58; H, 7.64; N, 5.00. **32b** (second eluted): colorless oil; $t_R$ (HPLC, hexane/EA 4:1) 1.36 min; $[\alpha]^{20}_D$ +4 (*c* 1, $CHCl_3$); IR (film) 3318, 3031, 2954, 2928, 1755 $cm^{-1}$; $^1H$ NMR (250 MHz) $\delta$ 0.11, 0.12 (2 s, 6 H), 0.82 (s, 9 H), 1.14 (d, *J* = 6.2, 3 H), 3.16 (dd, *J* = 11.4, 2.0, 1 H), 3.82 (d, *J* = 15.0, 1 H), 3.94 (m, 1 H), 4.47 (q, *J* = 6.1, 1 H), 4.56 (d, *J* = 2.0, 1 H), 4.71 (d, *J* = 15.0, 1 H), 5.01 (d, *J* = 12.1, 2 H), 5.21 (d, *J* = 12.2, 1 H), 7.03−7.37 (m, 15 H); $^{13}C$ NMR (75 MHz) $\delta$ −4.7, −4.5 (2 q), 18.0 (s), 20.8 (q), 25.9 (q), 44.5 (t), 56.6, 59.1, 62.9, 67.4 (4 d), 66.8 (t), 126.4, 127.7, 128.3, 128.4, 128.6, 128.8, 128.9 (7 d), 135.4, 136.5, 137.8, (3 s), 156.5 (s), 167.3 (s); MS (FAB) *m/z* (%) 559 (100, $[M + 1]^+$). Anal. Calcd for $C_{33}H_{42}N_2O_4Si$ (558.8): C, 70.93; H, 7.58; N, 5.01. Found: C, 70.66; H, 7.60; N, 4.92.

**(3*R*,4*S*,1′*R*,2′*R*)- and (3*S*,4*R*,1′*R*,2′*R*)-1-Benzyl-3-[2-[(*tert*-butyldimethylsilyl)oxy]-1-[[(*tert*-butyloxy)carbonyl]amino]propyl]-4-phenylazetidin-2-one (33a).** Diazo ketone **16** (360 mg, 1.01 mmol) and imine **17** (390 mg, 2.00 mmol) in $Et_2O$ (300 mL) were irradiated at −15 °C for 90 min. The volatile components were evaporated and the diastereoisomeric ratio was determined by $^1H$ NMR spectroscopy (**33a**/**b** 80:20). Purification by column chromatography (PE/EA 20:1) yielded pure **33a** (195 mg, 37%). **33a**: colorless oil; $t_R$ (HPLC, hexane/EA 17:3) 5.45 min; $[\alpha]^{20}_D$ +8 (*c* 1, $CHCl_3$); IR (film) 3320, 3031, 2928, 1760, 1715 $cm^{-1}$; $^1H$ NMR (250 MHz) $\delta$ −0.35, −0.17 (2 s, 6 H), 0.60 (s, 9 H), 1.02 (d, *J* = 6.2, 3 H), 1.32 (s, 9 H), 3.18 (dd, *J* = 5.8, 1.7, 1 H), 3.63 (d, *J* = 15.1, 1 H), 3.70 (m, 1 H), 3.83 (m, 1 H), 4.06 (s, 1 H), 4.64−4.74 (m, 2 H), 6.99−7.21 (m, 10 H); $^{13}C$ NMR (75 MHz) $\delta$ −4.9, −4.0 (2 q), 18.2 (s), 20.7 (q), 26.0 (q), 28.8 (q), 44.7 (t), 55.5, 58.6, 61.4, 69.1 (4 d), 79.8 (s), 127.0, 128.0, 128.7, 128.9, 129.1, 129.3 (6 d), 135.8, 137.7 (2 s), 156.3 (s), 168.1 (s); MS (FAB) *m/z* (%) 525 (100, $[M + 1]^+$). Anal. Calcd for $C_{30}H_{44}N_2O_4Si$ (524.8): C, 68.66; H, 8.45; N, 5.34. Found: C, 68.40; H, 8.67; N, 5.19.

**(3*R*,4*S*,1′*S*,1″*R*)-3-[1-[[(*tert*-Butyloxy)carbonyl]amino]ethyl]-4-phenyl-1-(1-phenylethyl)azetidin-2-one (36a).** Following the general procedure, diazo ketone **2** (430 mg, 2.02 mmol) and imine **34** (1.61 g, 7.69 mmol) were irradiated at −15 °C to yield a mixture of **36a** and **36b** (55:45, 576 mg, 72%). The pure isomer **36a** (292 mg, 37%) was obtained by column chromatography (PE/EA 20:1 → 6:1). **36a** (first eluted): colorless solid; mp 100−102 °C; $t_R$ (HPLC, hexane/$^i$PrOH 49:1) 5.24 min; $[\alpha]^{20}_D$ −29.1 (*c* 1, $CHCl_3$); IR (KBr) 2940, 1720, 1708 $cm^{-1}$; $^1H$ NMR (300 MHz) $\delta$ 1.31 (d, *J* = 7.0 Hz, 3 H), 1.39 (s, 9 H), 1.78 (d, *J* = 7.2, 3 H), 3.04 (t, *J* = 2.8, 1 H), 4.10 (m, 1 H), 4.21 (d, *J* = 2.3, 1 H), 4.30 (q, *J* = 7.2, 1 H), 4.63 (br d, *J* = 8.0 Hz, 1 H), 7.17−7.30 (m, 10 H); $^{13}C$ NMR (75 MHz) $\delta$ 19.7 (q), 20.1 (q), 28.2 (q), 44.3 (d), 54.4 (d), 56.8 (d), 64.5 (d), 79.4 (s), 126.6, 126.8, 127.4, 128.2, 128.6, 128.7 (6 d), 137.8, 141.3 (2 s), 155.5 (s), 168.1 (s); MS (FAB) *m/z* (%) 395 (100, $[M + 1]^+$), 339 (82, $[M - C_4H_7]^+$), 252 (35, $[M - C_7H_{12}NO_2]^+$), 105 (56, $C_8H_9^+$), 57 (27, $C_4H_9^+$). Anal. Calcd for $C_{24}H_{30}N_2O_3$ (394.5): C, 73.07; H, 7.66; N, 7.10. Found: C, 72.91; H, 7.64; N, 7.06.

**(3*R*,4*S*,1′*S*,1″*S*)- and (3*S*,4*R*,1′*S*,1″*S*)-3-[1-[[(*tert*-Butyloxy)carbonyl]amino]ethyl]-4-phenyl-1-(1-phenylethyl)azetidin-2-one (37a,b).** Following the general procedure, diazo ketone **2** (420 mg, 1.97 mmol) and imine **35** (1.62 g, 7.74 mmol) were irradiated at −15 °C to yield a mixture of **37a** and **37b** (88:12, 686 mg, 88%). The pure isomers **37a** (560 mg, 72%) and **37b** (58 mg, 7%) were obtained by MPLC (PE/$^i$PrOH 99:1). **37a** (first eluted): colorless solid: mp 102−104 °C; $t_R$ (HPLC, hexane/$^i$PrOH 49:1) 6.38 min; $[\alpha]^{20}_D$ −5.7 (*c* 1.07, $CHCl_3$); IR (KBr) 3260, 2963, 1720, 1693 $cm^{-1}$; $^1H$ NMR (250 MHz) $\delta$ 1.25 (d, *J* = 6.9, 3 H), 1.31 (d, *J* = 7.2, 3 H), 1.39 (s, 9 H), 3.07 (br s, 1 H), 4.04 (br s, 1 H), 4.15 (br s, 1 H), 4.49 (br d, 1 H), 4.99 (q, *J* = 7.1, 1 H), 7.21−7.35 (m, 10 H); $^{13}C$ NMR (75 MHz) $\delta$ 18.9, 19.7 (2 q), 28.3 (q), 44.3 (d), 52.2 (d), 57.2 (d), 64.3 (d), 79.3 (s), 126.8, 127.2, 127.7, 128.3, 128.6, 128.7 (6 d), 139.1, 140.0 (2 s), 155.5 (s), 168.2 (s); MS (CI, $CH_4$) *m/z* (%) 395 (100, $[M + 1]^+$), 339 (100, $[M - C_4H_7]^+$), 295 (15, $[M - C_5H_7O_2]^+$), 252 (9, $[M - C_7H_{12}NO_2]^+$). Anal. Calcd for $C_{24}H_{30}N_2O_3$ (394.5): C, 73.07; H, 7.66; N, 7.10. Found: C, 72.83; H, 7.61; N, 6.90. **37b** (second eluted): mp 94.5−95.0 °C; $t_R$ (HPLC hexane/$^i$PrOH 49:1) 9.32 min; $[\alpha]^{20}_D$ −10 (*c* 0.8, $CHCl_3$); IR (KBr) 3280, 2960, 1720, 1690 $cm^{-1}$; $^1H$ NMR (250 MHz) $\delta$ 1.28 (d, *J* = 6.7, 3 H), 1.41 (s, 9 H), 1.76 (d, *J* = 7.1, 3 H), 2.94 (dd, *J* = 8.4, 2.1, 1 H), 4.07 (sextet, *J* = 7.1, 1 H), 4.28−4.35 (m, 2 H), 4.61 (d, *J* = 8.6, 1 H), 7.12−7.29 (m, 10 H); $^{13}C$ NMR (63 MHz) $\delta$ 18.6 (q), 20.0 (q), 28.4 (q), 45.8 (d), 54.3 (d), 58.3 (d), 65.1 (d), 79.4 (s), 126.6, 126.9, 127.6, 128.3, 128.6, 128.8 (6 d), 139.0, 141.2 (2 s), 155.0 (s), 167.8 (s); MS (FAB) *m/z* (%) 395 (94, $[M + 1]^+$), 339 (100, $[M - C_4H_7]^+$), 252 (34, $[M - C_7H_{12}NO_2]^+$), 105 (53, $C_8H_9^+$), 57 (12, $C_4H_9^+$).

**(3*R*,4*S*,1′*S*,2′*S*,1″*R*)-3-[1-[(Benzyloxycarbonyl)amino]-2-methylbutyl]-4-phenyl-1-(1-phenylethyl)azetidin-2-one (38a).** Following the general procedure, diazo ketone **7** (579 mg, 2.00 mmol) and imine **34** (1.05 g, 5.02 mmol) were irradiated at −15 °C to yield a mixture of **38a** and **38b** (73:27, 678 mg, 72%). Isomer **38a** (424 mg, 45%) could be isolated by MPLC (PE/$^i$PrOH 99.5:0.5). **38a** (first eluted): colorless oil; $t_R$ (HPLC, hexane/$^i$PrOH 49:1) 3.94 min; $[\alpha]^{20}_D$ +32.7 (*c* 0.94, $CHCl_3$); IR (film) 3302, 2945, 2917, 1725 $cm^{-1}$; $^1H$ NMR (250 MHz) $\delta$ 0.81 (t, *J* = 7.3, 3 H), 0.90 (d, *J* = 6.7, 3 H), 0.94−1.68 (m, 3 H), 1.27 (d, 3 H), 3.22 (d, *J* = 2.5, 1 H), 3.85 (ddd, *J* = 10.2, 7.7, 2.6, 1 H), 4.12 (d, *J* = 2.3, 1 H), 4.78 (d, *J* = 10.1, 1 H), 4.90−4.98 (m, 2 H), 5.14 (d, *J* = 12.4, 1 H), 7.16−7.43 (m, 15 H); $^{13}C$ NMR (63 MHz) $\delta$ 11.0 (q), 15.8 (q), 18.7 (q), 25.4 (t), 38.1 (d), 52.3 (d), 53.7 (d), 57.6 (d), 61.4 (d), 66.8 (t), 126.9, 127.2, 127.6, 127.9, 128.1, 128.4, 128.5, 128.7 (8 d), 136.4, 139.1, 139.9 (3 s), 156.5 (s), 167.8 (s); MS (CI, $CH_4$) *m/z* (%) 471 (97, $[M + 1]^+$), 363 (100, $[M - C_8H_{11}]^+$), 91 (72, $C_7H_7^+$). Anal. Calcd for $C_{30}H_{34}N_2O_3 \cdot {}^1/_2H_2O$ (479.6): C, 75.13; H, 7.36; N, 5.84. Found: C, 75.39; H, 7.39; N, 5.79.

**(3*R*,4*S*,1′*S*,2′*S*,1″*S*)-3-[1-[(Benzyloxycarbonyl)amino]-2-methylbutyl]-4-phenyl-1-(1-phenylethyl)azetidin-2-one (39a).** Following the general procedure, diazo ketone **7** (579 mg, 2.00 mmol) and imine **35** (1.18 g, 5.64 mmol) were irradiated at −15 °C to yield a mixture of **39a** and **39b** (86:14, 527 mg, 56%). Isomer **39a** (404 mg, 43%) could be isolated by MPLC (PE/$^i$PrOH 99.5:0.5). **39a** (first eluted): colorless oil; $t_R$ (HPLC, hexane/EA 9:1) 12.1 min; $[\alpha]^{20}_D$ +24.8 (*c* 1, $CHCl_3$); IR (film) 3316, 2962, 2931, 1736 $cm^{-1}$; $^1H$ NMR (300 MHz) $\delta$ 0.83 (t, *J* = 7.3, 3 H), 0.92 (d, *J* = 6.7, 3 H), 0.99−1.21, 1.43−1.66 (2 m, 3 H), 1.71 (d, *J* = 7.2, 3 H), 3.20 (t, *J* = 2.4, 1 H), 3.92 (ddd, *J* = 10.1, 7.6, 2.6, 1 H), 4.16 (d, *J* = 2.2, 1 H), 4.26 (q, *J* = 7.2, 1 H), 4.95 (d, *J* = 10.1, 1 H), 5.00, 5.14 (2 d, *J* =

12.4, 12.3 , 2 H), 7.14−7.42 (m, 15 H); $^{13}$C NMR (63 MHz) $\delta$ 10.9 (q), 15.8 (q), 19.8 (q), 25.4 (t), 38.0 (d), 53.7, 54.4 (2 d), 57.3 (d), 61.4 (d), 66.7 (t), 126.6, 127.3, 127.8, 128.0, 128.2, 128.4, 128.7 (7 d), 136.4, 137.6, 141.0 (3 s), 156.6 (s), 167.7 (s); MS (CI, $CH_4$) *m*/*z* (%) 471 (100, $[M + 1]^+$). Anal. Calcd for $C_{30}H_{34}N_2O_3$ (470.6): C, 76.57; H, 7.28; N, 5.95. Found: C, 76.35; H, 7.34; N, 5.86.

**(3*R*,4*S*,1′*S*)- and (3*S*,4*R*,1′*S*)-3-[1-[(Benzyloxycarbonyl)amino]-2-methylpropyl]-1-[(4-methoxyphenyl)methyl]-4-phenylazetidin-2-one (45a).** Following the general procedure, diazo ketone **5** (551 mg, 2.00 mmol) and imine **44** (901 mg, 4.00 mmol) were irradiated at −15 °C to yield a mixture of **45a** and **45b** (84:16, 473 mg, 50%). The pure isomer **45a** (331 mg, 35%) was obtained by MPLC (PE/EA 4:1). **45a** (first eluted): yellowish oil; $t_R$ (HPLC, hexane/EA 4:1) 10.7 min; $[\alpha]^{20}_D$ +13.7 (*c* 0.9, $CHCl_3$); IR (film) 3315, 2961, 1739 cm$^{-1}$; $^1$H NMR (250 MHz) $\delta$ 0.93, 0.94 (2 d, *J* = 6.8, 6.7, 6 H), 1.93 ($m_c$, 1 H), 3.25 (t, *J* = 2.6, 1 H), 3.67 (d, *J* = 15.3, 1 H), 3.68 (s, 3 H), 3.85 (ddd, *J* = 10.5, 7.6, 3.0, 1 H), 4.19 (d, *J* = 2.2, 1 H), 4.77 (d, *J* = 14.8, 1 H), 4.88, (d, *J* = 10.3, 1 H), 4.93, 5.19 (2 d, *J* = 12.4, 12.5, 2 H), 6.72, 7.02 (2 d, *J* = 8.6, 8.6, 4 H), 7.24−7.37 (m, 10 H); $^{13}$C NMR (63 MHz) $\delta$ 18.8, 19.7 (2 q), 31.7 (d), 43.7 (t), 54.9, 57.1 (d, q), 62.3 (d), 66.6 (t), 113.9, 126.5, 127.5, 127.9, 128.3, 128.4, 128.8, 129.5 (8 d), 127.2, 136.4, 137.2, 158.9 (4 s), 156.6 (s), 167.3 (s); MS (FAB) *m*/*z* (%) 473 (85, $[M + 1]^+$), 121 (100, $C_8H_9O^+$), 91 (94, $C_7H_7^+$). Anal. Calcd for $C_{29}H_{32}N_2O_4 \cdot {}^1/_2H_2O$ (481.6): C, 72.33; H, 6.91; N, 5.82. Found: C, 72.63; H, 6.88; N, 5.80.

**(3*R*,4*S*,1′*S*)- and (3*S*,4*R*,1′*S*)-3-[1-[(Benzyloxycarbonyl)amino]-2,2-dimethylpropyl]-1-[(4-methoxyphenyl)-methyl]-4-phenylazetidin-2-one (46a).** Following the general procedure, diazo ketone **8** (868 mg, 3.00 mmol) and imine **44** (901 g, 4.00 mmol) were irradiated at −15 °C to yield a mixture of **46a** and **46b** (92:8, 1.05 g, 72%). Column chromatography (PE/EA 8:1 → 5:1) yielded the pure isomer **46a** (847 mg, 58%). **46a** (first eluted): yellowish oil; $t_R$ (HPLC, hexane/EA 4:1) 6.63 min; $[\alpha]^{20}_D$ +36.7 (*c* 1.1, $CHCl_3$); IR (film) 3317, 2960, 1746 cm$^{-1}$; $^1$H NMR (300 MHz) $\delta$ 0.93 (s, 9 H), 3.27 (t, *J* = 1.9, 1 H), 3.65 (d, *J* = 15.3, 1 H), 3.69 (s, 3 H), 3.90 (dd, *J* = 10.7, 2.3, 1 H), 4.17 (d, *J* = 2.3, 1 H), 4.75 (d, *J* = 14.9, 1 H), 4.93 (d, *J* = 12.5, 1 H), 5.07 (d, *J* = 10.7, 1 H), 5.21 (d, *J* = 12.5, 1 H), 6.72, 7.01 (2 d, *J* = 8.6, 8.7, 4 H), 7.24−7.39 (m, 10 H); $^{13}$C NMR (250 MHz) $\delta$ 26.7 (q), 34.6 (s), 43.8 (t), 55.1 (d), 58.0, 58.1 (q, d), 61.2 (d), 66.8 (t), 114.0, 126.6, 127.5, 128.0, 128.4, 128.5, 128.9, 129.5 (8 d), 127.3, 136.4, 137.1, 158.9 (4 s), 156.8 (s), 167.0 (s); MS (FAB) *m*/*z* (%) 487 (100, $[M + 1]^+$), 121 (43, $C_8H_9O^+$), 91 (49, $C_7H_7^+$). Anal. Calcd for $C_{30}H_{34}N_2O_4$ (486.6): C, 74.05; H, 7.04; N, 5.76. Found: C, 73.81; H, 7.19; N, 5.66.

**(3*R*,4*S*,1′*S*)-3-[1-[(Benzyloxycarbonyl)amino]-2-methylpropyl]-4-phenylazetidin-2-one (47).** A solution of $K_2HPO_4$ (279 mg, 1.60 mmol) and $K_2S_2O_8$ (838 mg, 3.10 mmol) in water (5 mL) was added in 4 portions to a solution of **45a** (220 mg, 466 $\mu$mol) in water/acetonitrile (15 mL, 1:2). The solution was kept at 75 °C for 70 min and subsequently concentrated at reduced pressure and extracted with EA (3 × 5 mL). The organic layers were extracted with saturated $NaHCO_3$ and NaCl solutions (20 mL each), and the new aqueous layers were reextracted with EA (5 mL). The combined organic layers were evaporated and the residue was purified by MPLC (PE/EA 4:1) to yield **47** (356 mg, 63%) as a colorless solid: mp 104−105 °C; $t_R$ (HPLC, hexane/EA 3:1) 15.7 min; $[\alpha]^{20}_D$ +47.4 (*c* 0.43, $CHCl_3$); IR (KBr) 3295, 2948, 2917, 1755, 1710 cm$^{-1}$; $^1$H NMR (250 MHz) $\delta$ 0.95 (d, *J* = 6.7, 6 H), 1.97 (octet, *J* = 6.9, 1 H), 3.26 (t, *J* = 2.9, 1 H), 3.92 (ddd, *J* = 10.6, 7.8, 3.5, 1 H), 4.46 (d, *J* = 2.3, 1 H), 5.15 (s, 2 H), 5.32 (d, *J* = 10.0, 1 H), 6.37 (s, 1 H), 7.25−7.35 (m, 10 H); $^{13}$C NMR (63 MHz) $\delta$ 19.0, 19.8 (2 q), 31.6 (d), 54.5 (d), 55.1 (d), 63.7 (d), 67.0 (t), 125.7, 128.0, 128.2, 128.6, 128.8 (5 d), 136.4, 139.5 (2 s), 157.0 (s), 168.5 (s); MS (CI, $NH_3$) *m*/*z* (%) 353 (100, $[M + 1]^+$), 106 (26, $C_7H_6O^+$), 91 (23, $C_7H_7^+$). Anal. Calcd for $C_{21}H_{24}N_2O_3$ (352.4): C, 71.57; H, 6.86; N, 7.95. Found: C, 71.20; H, 6.89; N, 7.80.

***tert*-Butyl (3*R*,4*S*,1′*S*)-3-[1-[(Benzyloxycarbonyl)amino]-2-methylpropyl]-2-oxo-4-phenylazetidine-1-carboxylate (48).** $Boc_2O$ (93 mg, 426 $\mu$mol), $Et_3N$ (21.6 mg, 213 $\mu$mol), and DMAP (one crystal) were added to a solution of **47** (75 mg, 213 $\mu$mol) in $CH_2Cl_2$ (4 mL), and the solution was stirred for 4 h at rt. Brine and $Et_2O$ were added, and the organic layer was subsequently extracted with saturated $NH_4Cl$ solution and brine, dried ($MgSO_4$), and evaporated at reduced pressure. Purification by column chromatography (PE/EA 9:1) yielded pure **48** (65 mg, 67%) as a colorless solid: mp 96−98 °C; $R_f$ (TLC, PE/EA 5:1) 0.38; $[\alpha]^{20}_D$ −8.6 (*c* 0.54, $CHCl_3$); IR (KBr) 3350, 2950, 2912, 1796, 1718, 1691 cm$^{-1}$; $^1$H NMR (500 MHz) $\delta$ 0.92, 0.95 (2 d, *J* = 6.7, 6 H), 1.35 (s, 9 H), 1.94 (octet, *J* = 6.8, 1 H), 3.28 (t, *J* = 3.5, 1 H), 3.93 ($m_c$, 1 H), 4.72 (d, *J* = 3.2, 1 H), 4.85 (d, *J* = 10.0, 1 H), 5.18 (s, 2 H), 7.26−7.41 (m, 10 H); $^{13}$C NMR (125 MHz) $\delta$ 18.8, 19.8 (2 q), 27.8 (q), 31.8 (d), 55.1, 57.9, 62.0 (3 d), 67.1 (s), 83.4 (t), 125.9, 127.9, 128.2, 128.5, 128.6, 128.9 (6 d), 136.3, 137.6 (2 s), 147.2, 156.8 (2 s), 165.6 (s); MS (FAB) *m*/*z* (%) 475 (14, $[M + Na]^+$), 397 (26, $[M - C_4H_7]^+$), 353 (14, $[M - C_5H_7O_2]^+$), 91 (100, $C_7H_7^+$), 57 (25, $C_4H_9^+$). Anal. Calcd for $C_{26}H_{32}N_2O_5$ (452.6): C, 69.01; H, 7.13; N, 6.19. Found: C, 69.58; H, 7.13; N, 6.19.

**(3R,4S,1′S)- and (3S,4R,1′S)-3-[1-[[(*tert*-Butyloxy)carbonyl]amino]ethyl]-4-phenyl-1-prop-2-enylazetidin-2-one (50a,b).** Following the general procedure, diazo ketone **2** (426 mg, 2.00 mmol) and imine **49** (1.16 g, 7.99 mmol) were irradiated at −15 °C to yield a mixture of **50a** and **50b** (68:32, 410 mg, 62%). The pure isomers **50a** (231 mg, 35%) and **50b** (119 mg, 18%) were obtained by MPLC (PE/EA 4:1). **50a** (first eluted): colorless oil; $t_R$ (HPLC, hexane/EA 3:1) 13.2 min; $[\alpha]^{20}_D$ +24.8 (*c* 1.02, $CHCl_3$); IR (film) 3320, 2977, 2933, 1746, 1704 cm$^{-1}$; $^1$H NMR (300 MHz) $\delta$ 1.33 (d, *J* = 7.0, 3 H), 1.47 (s, 9 H), 3.09 (br s, 1 H), 3.29 (ddd, *J* = 15.7, 7.1, 0.9, 1 H), 4.11−4.27 (m, 2 H), 4.44 (d, *J* = 2.2, 1 H), 4.70 (br d, *J* = 7.1, 1 H), 5.09−5.12 (m, 2 H), 5.70 ($m_c$, 1 H), 7.29−7.41 (m, 5 H); $^{13}$C NMR (63 MHz) $\delta$ 19.7 (q), 28.3 (q), 42.8 (t), 44.2 (d), 57.0 (d), 65.5 (d), 79.4 (s), 118.4 (t), 126.4, 128.3, 128.9, 137.6 (3 d, s), 131.5 (d), 155.6 (s), 167.9 (s); MS (FAB) *m*/*z* (%) 331 (100, $[M + 1]^+$), 275 (75, $[M - C_4H_7]^+$), 188 (38, $[M - C_7H_{12}NO_2]^+$). Anal. Calcd for $C_{19}H_{26}N_2O_3$ (330.4): C, 69.06; H, 7.93; N, 8.48. Found: C, 68.90; H, 7.99; N, 8.43. **50b** (second eluted): colorless solid; mp 108.0−108.5 °C; $t_R$ (HPLC, hexane/EA 3:1) 15.0 min; $[\alpha]^{20}_D$ −47.6 (*c* 1.09, $CHCl_3$); IR (KBr) 3291, 2960, 2910, 1727, 1690 cm$^{-1}$; $^1$H NMR (250 MHz) $\delta$ 1.33 (d, *J* = 6.7, 3 H), 1.45 (s, 9 H), 2.94 (dd, *J* = 9.1, 2.2, 1 H), 3.35 (dd, *J* = 15.5, 7.1, 1 H), 4.12−4.20 (m, 2 H), 4.57−4.62 (m, 2 H), 5.05−5.17 (m, 2 H), 5.72 ($m_c$, 1 H), 7.24−7.40 (m, 5 H); $^{13}$C NMR (75 MHz) $\delta$ 18.9 (q), 28.3 (q), 43.0 (t), 46.1 (d), 58.8 (d), 66.2 (d), 79.4 (s), 118.7 (t), 126.3, 128.3, 128.8 (3 d), 137.8 (s), 131.3 (d), 155.0 (s), 167.5 (s); MS (CI, $CH_4$) *m*/*z* (%) 331 (100, $[M + 1]^+$), 275 (63, $[M - C_4H_7]^+$), 188 (18, $[M - C_7H_{12}NO_2]^+$). Anal. Calcd for $C_{19}H_{26}N_2O_3$ (330.4): C, 69.06; H, 7.93; N, 8.48. Found: C, 69.11; H, 7.91; N, 8.56.

**(3R,4S,1′S,2′S)- and (3S,4R,1′S,2′S)-3-[1-[(Benzyloxycarbonyl)amino]-2-methylbutyl]-4-phenyl-1-prop-2-enylazetidin-2-one (51a,b).** Following the general procedure, diazo ketone **7** (579 mg, 2.00 mmol) and imine **49** (1.16 g, 7.99 mmol) were irradiated at −15 °C to yield a mixture of **51a** and **51b** (85:15, 455 mg, 56%). The pure isomers **51a** (317 mg, 39%) and **51b** (48 mg, 6%) were obtained by MPLC (PE/EA 4:1). **51a** (first eluted): colorless solid; mp 93.5−94.0 °C; $t_R$ (HPLC, hexane/EA 4:1) 6.00 min; $[\alpha]^{20}_D$ +77.8 (*c* 0.8, $CHCl_3$); IR (KBr) 3290, 2950, 2910, 1750, 1710, 1680 cm$^{-1}$; $^1$H NMR (300 MHz) $\delta$ 0.85 (t, *J* = 7.3, 3 H), 0.93 (d, *J* = 6.7, 3 H), 1.02−1.17, 1.50−1.63, 1.65−1.78 (3 m, 3 H), 3.22−3.30 (m, 2 H), 3.99 (ddd, *J* = 10.3, 7.7, 2.8, 1 H), 4.15 (ddt, *J* = 15.6, 4.9, 1.7, 1 H), 4.37 (d, *J* = 2.3, 1 H), 4.92 (br d, *J* = 10.2, 1 H), 4.98−5.07 (m, 2 H), 5.12, 5.21 (2 d, *J* = 12.3, 12.3, 2 H), 5.59 ($m_c$, 1 H), 7.25−7.41 (m, 10 H); $^{13}$C NMR (75 MHz) $\delta$ 11.4 (q), 14.6 (q), 25.9 (t), 38.5 (d), 43.3 (t), 54.1 (d), 58.1 (d), 62.9 (d), 67.3 (t), 118.9 (t), 126.9, 128.4, 128.6, 128.8, 128.9, 129.3 (6 d), 136.9, 137.9 (2 s), 131.7 (d), 157.2 (s), 167.9 (s); MS (CI,$CH_4$) *m*/*z* (%) 407 (100, $[M + 1]^+$), 91 (38, $C_7H_7^+$). Anal. Calcd for $C_{25}H_{30}N_2O_3$ (406.5): C, 73.86; H, 7.44; N, 6.89. Found: C, 73.84; H, 7.47; N, 6.89. **51b** (second eluted): colorless solid; mp 85−86 °C; $t_R$ (HPLC, hexane/EA 4:1) 7.73 min; $[\alpha]^{20}_D$ −39 (*c* 0.3, $CHCl_3$); IR (KBr) 3290, 2942, 1744, 1708, 1686 cm$^{-1}$; $^1$H NMR (300 MHz) $\delta$ 0.91−1.00, 1.43−1.52, 1.78−2.00 (3 m, 9 H), 3.08 (dd, *J* = 10.2, 2.0, 1 H), 3.34 (dd, 15.5, 7.1, 1 H), 4.09−4.20 (m, 2 H), 4.52 (d, *J* = 2.0, 1 H), 4.62 (br d, *J* = 10.3,

1 H), 5.04 − 5.13 (m, 2 H), 5.04, 5.26 (2 d, $J$ = 12.2, 12.2, 2 H), 5.70 ($m_c$, 1 H), 7.10−7.13, 7.26−7.38 (2 m, 10 H); $^{13}$C NMR (75 MHz) $\delta$ 11.7 (q), 16.1 (q), 23.1 (t), 36.7 (d), 43.1 (t), 55.9 (d), 58.9 (d), 63.3 (d), 66.8 (t), 118.7 (t), 125.8, 126.2, 127.9, 128.2, 128.5, 128.9 (6 d), 136.4, 137.8 (2 s), 131.3 (d), 156.3 (s), 167.2 (s); MS (FAB) $m/z$ (%) 836 (5, $[2\,M + Na + 1]^+$), 814 (4, $[2\,M + 2]^+$), 429 (33, $[M + Na]^+$), 407 (100, $[M + 1]^+$), 91 (78, $C_7H_7^+$).

**(*rac*)-(3,4-*trans*)-1-Benzyl-3-[(methoxyphenyl)methyl]-4-phenylazetidin-2-one (54a,b).** Following the general procedure, the racemic diazo ketone **52** (190 mg, 1.00 mmol) and imine **17** (390 mg, 2.00 mmol) were irradiated at −15 °C, to yield a mixture of **54a** and **54b** (50:50). The pure isomers **54a** (110 mg, 31%) and **54b** (100 mg, 28%) were obtained by column chromatography (PE/EA 9:1). **54a** (first eluted): colorless oil; $R_f$ (TLC, PE/EA 5:1) 0.21; IR (KBr) 3030, 2830, 1755 cm$^{-1}$; $^1$H NMR (300 MHz) $\delta$ 3.28 (s, 3 H), 3.52 (dd, $J$ = 4.7, 2.3, 1 H), 3.64 (d, $J$ = 15.4, 1 H), 4.24 (d, $J$ = 2.2, 1 H), 4.61 (d, $J$ = 4.7, 1 H), 4.81 (d, $J$ = 15.4, 1 H), 6.74−7.45 (m, 15 H); $^{13}$C NMR (75 MHz) $\delta$ 43.9 (t), 55.9, 56.9 (d, q), 65.4 (d), 80.5 (d), 126.3, 127.1, 127.5, 127.7, 128.0, 128.1, 128.4, 128.4, 128.7, 135.0, 137.4, 137.9 (9 d, 3 s), 167.2 (s); MS (FAB) $m/z$ (%) 358 (10, $[M + 1]^+$), 193 (100, $C_{14}H_{11}N^+$). **54b** (second eluted): mp 122.5−123.0 °C; $R_f$ (TLC, PE/EA 5:1) 0.15; IR (KBr) 2910, 2888, 2800, 1750 cm$^{-1}$; $^1$H NMR (300 MHz) $\delta$ 3.31 (t, $J$ = 2.6, 1 H), 3.36 (s, 3 H), 3.78 (d, $J$ = 15.3, 1 H), 4.64 (d, $J$ = 2.2, 1 H), 4.68 (d, $J$ = 3.7, 1 H), 4.92 (d, $J$ = 15.5, 1 H), 6.97−7.31 (m, 15 H); $^{13}$C NMR (75 MHz) $\delta$ 44.3 (t), 55.5, 57.2 (d, q), 66.4 (d), 79.5 (d), 126.3, 126.4, 127.3, 127.9, 127.9, 128.1, 128.5, 128.5, 128.7 (9 d), 135.4, 137.6, 138.9 (3 s), 168.1 (s); MS (EI) $m/z$ (%) 358 (100, $[M + 1]^+$), 224 (47, $[M - C_8H_7NO]^+$). Anal. Calcd for $C_{24}H_{23}NO_2$ (357.5): C, 80.64; H, 6.49; N; 3.92. Found: C, 80.56; H, 6.53; N, 3.95.

**(3,4-*trans*)-1-Benzyl-3-butyl-4-phenylazetidin-2-one (55).** Following the general procedure, diazo ketone **53** (505 mg, 4.00 mmol) and imine **17** (1.17 g, 5.99 mmol) were irradiated at −15 °C. The racemic $\beta$-lactam **55** (252 mg, 21%) was obtained by column chromatography (PE/EA 9:1): colorless oil; $R_f$ (TLC, PE/EA 5:1) 0.4; IR (film) 2956, 2929, 1751 cm$^{-1}$; $^1$H NMR (300 MHz) $\delta$ 0.85 (t, $J$ = 7.0, 3 H), 1.23−1.39, 1.60−1.70, 1.78−1.87 (3 m, 6 H), 3.01 (dd, $J$ = 8.4, 6.3, 1 H), 3.72 (d, $J$ = 14.9, 1 H), 4.03 (d, $J$ = 2.0, 1 H), 4.84 (d, $J$ = 14.9, 1 H), 7.12−7.40 (m, 10 H); $^{13}$C NMR (63 MHz) $\delta$ 13.8 (q), 22.6, 28.3, 29.3, 44.2 (4 t), 60.6, 60.8 (2 d), 126.5, 127.6, 128.3, 128.5, 128.7, 129.0 (6 d), 135.8, 138.0 (2 s), 170.5 (s); MS (EI) $m/z$ (%) 160 (100, $[M - C_8H_7NO]^+$), 91 (43, $C_7H_7^+$). Anal. Calcd for $C_{20}H_{23}NO$ (293.4): C, 81.87; H, 7.90; N; 4.77. Found: C, 81.32; H, 7.94; N, 4.73.

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**Supporting Information Available:** NMR data with peak assignments for all compounds, ORTEP drawings, and details of X-ray data aquisition for **48**, **20b**, and **21a** (15 pages). This material is contained in libraries on microfiche, immediately follows this article in the microfilm version of the journal, and can be ordered from the ACS; see any current masthead page for ordering information.

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