93. Stereospecific Synthesis of 2-Oxazinyl-4-oxoazetidinecarbamates Starting from a 1,2-Diazepine. A New Type of Intramolecular Transbenzoylation

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Dedicated to Professor *Edward C. Taylor* at the occasion of his 65th anniversary

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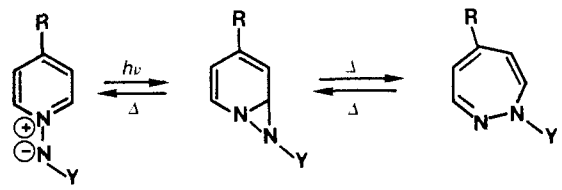
Azetidinodiazepines **4b** and **4c** react with acylnitroso dienophiles **5a–c**, specifically from their convexe α-side, but in a non-regiospecific way, leading thereby stereospecifically to the expected adducts **6a–d** and **7a–d**. The three-dimensional structures of **6a** and **7a** were determined by X-ray analyses which corroborated their NMR data. OsO_4 *cis*-glycolization occurred in good yield with the inverse adducts **7a** and **7e** and led to the rearranged products **10**. These latter ones result from an intramolecular N- to O-transbenzoylation of the short-lived intermediates **9** followed by fragmentation of the aminal function. X-Ray analysis of **7a** showed the N(10) atom to be pyramidal, a result which demonstrates that it does not have any pronounced benzamide character; otherwise no such N- to O-transbenzoylation would have taken place. Structure and relative configuration of **10a** were ascertained by X-ray analysis which confirmed its NMR data as well as the stereochemical outcome of its formation.

The Photoinduced Isomerization of 1-Iminopyridinium Ylides 1 to 1*H*-1,2-Diazepines and Some Applications Thereof. – The UV-induced ring enlargement of 1-iminopyridinium ylides **1** to the corresponding isomeric 1,2-diazepines **3**, the first examples of which had been described twenty years ago [1], is by now a well documented reaction [2] [3].

The *hydrophilic* zwitterionic educts **1** show a strong negative solvatochromism; their UV spectra have been measured using the stretched-film technique [4], and a *Pariser-Parr-Pople* model has been applied to their two first absorption bands. These physical and theoretical treatments permitted to assign to the photoactive band, which happens to be the lowest-energy one, a $\pi^* \leftarrow \pi$ transition with an intramolecular CT character [5]. Nevertheless, the diazanorcaradienes **2**, which were postulated as intermediates on the reaction pathway leading from the photoexcited **1** to **3**, could not be detected, not even by nanosecond flash photolysis.

Diazepines **3** are *hydrophobic* compounds. Some of them, when heated, revert back in quantitative yield to the corresponding ylides **1**. Thermochemical and kinetic measurements of these ring-contraction processes permitted to determine the overall reaction enthalpy and the activation parameters of the rate-determining step, respectively, norcaradienes **2** being the obvious reaction intermediates [6] *(Scheme)*.

Scheme



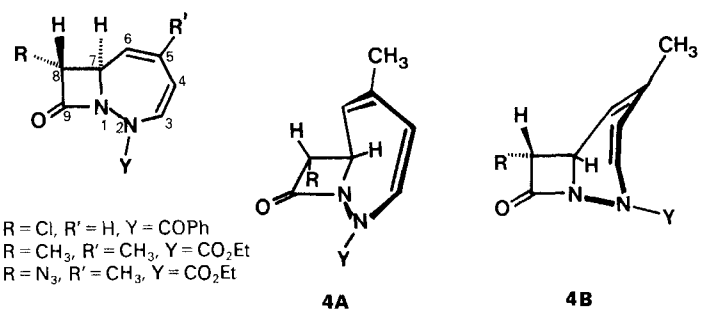
1 **2** **3**

a R = CH_3, Y = CO_2Et **b** R = H, Y = Ts

The pronounced hydrophilic character of the educts **1**, as compared to the strongly lipophilic one of the photoproducts **3**, led to some applications in the field of synthetic monolayers and of liposome bilayers. For example the self-assembling of amphiphilic molecules, which bear type **1** pyridinium-ylide head groups, lead to stable liposomes [7]. After photoisomerization of these zwitterionic head groups into the corresponding diazepines, the resulting liposomes proved to be metastable entities which collapse irreversibly after treatment with ultrasound [7] [8]. It was found, furthermore, that H_2O-soluble polymers containing type **1** pyridinium-ylide moieties, when subjected to UV irradiation, were converted into H_2O-insoluble and even H_2O-repellent diazepine polymers. These latter ones can be used for the waterproofing or hydrophobization of surfaces, and for the production of printing plates, negative photoresists, and printed circuit boards [9] [10].

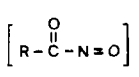
On the other hand, 1,2-diazepines proved to be versatile synthons for the construction of novel polyheterocyclic systems [3]. For example, diazoalcanes gave 1,3-dipolar cycloadditions, site-specifically with the 4-double bond of **3**, leading thereby to pyrazolinodiazepines [11]. These latter adducts could be pyrolyzed, either to homodiazepines [12] from which tricyclic systems were obtained by means of a torquospecific disrotation [13], or to pyrazolopyridines [12] which proved to be excellent precursors for the synthesis of cyclopropapyridines [14].

By means of X-ray diffractometry of **3b**, it was shown that 1,2-diazepines occur in a pronounced boat-shaped conformation. The internuclear distance of the 2-double bond is unexpectedly short (1.26 Å) and is likely to have the character of an imine double bond [15]. This proved to be true since monosubstituted ketene precursors (acyl chlorides) and methyl ketene reacted smoothly with these 2-double bonds, leading *stereospecifically* to the corresponding *trans*-substituted azetidinodiazepines **4** [16] [17].



4')**a** R = Cl, R' = H, Y = COPh
b R = CH_3, R' = CH_3, Y = CO_2Et
c R = N_3, R' = CH_3, Y = CO_2Et

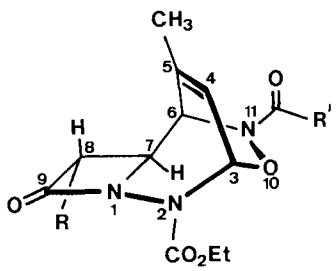
4A **4B**



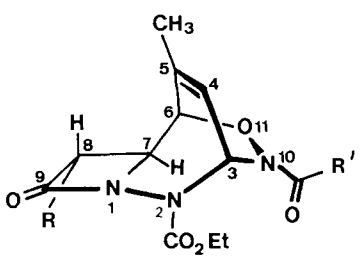
5a R = Ph
b R = CH_2Ph
c R = OCH_2Ph

In this paper, we shall describe some stereospecific syntheses with educts **4**, the target molecules being the novel β-lactam derivatives **10** which can be considered as model precursors for potential β-lactam antibiotics [19].

[4 + 2] Cycloadditions of Azetidinodiazepines 4 with Acylnitroso Dienophiles and with Singlet Oxygen. – The 8-chloroazetidinodiazepine[1]) **4a**, which had been synthesized previously from the corresponding diazepine [16], showed a coupling constant, $J(7,8) = 1.5$ Hz, whose magnitude is typical for *trans* β-lactams[1]). This relative configuration was corroborated by an X-ray analysis which showed furthermore that the molecules of **4a** were stacked in the crystal lattice in boat conformations as represented by **4A** [18]. Compounds **4** appear also in conformation **4A** in solution as shown by ^{1}H-NMR: the magnitude of the coupling constant $J(6,7) = 2$ Hz clearly indicates a dihedral angle of *ca.* 90–100° (according to a *Dreiding* model, this dihedral angle should have a value of *ca.* 100°), which agrees well with some published data of similar allylic products [20]. In conformation **4A**, the Y group is almost coplanar with respect to the β-lactam moiety, so that the α-side[2]) is less sterically crowded than the front side. In the other boat-shaped conformation **4B**, the $J(6,7)$ coupling constant would appear with a far greater magnitude (*ca.* 7 Hz) since the corresponding dihedral angle has a value of 20° according to a *Dreiding* model [20]. Furthermore, the Y group is almost orthogonal with respect to the β-lactam ring and is pointing towards the α-side. As a consequence, both sides of the

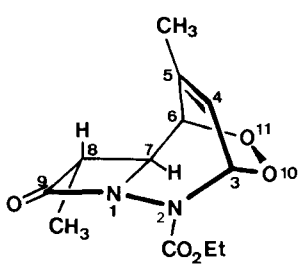


6[1])



7[1])

a R = CH_3, R' = Ph
b R = CH_3, R' = CH_2Ph
c R = CH_3, R' = OCH_2Ph
d R = N_3, R' = Ph
e R = $NHCOCH_2$Ph, R' = Ph



8

[1]) All azetidinodiazepines are numbered according to [16], *i.e.* as heterocyclic bridged systems (*von Baeyer* systems); systematic names in the *Exper. Part.*

[2]) α- and β-notations have the same significance as in the steroïd and triterpene field: the azetidinodiazepine being oriented and projected on the plane as represented in **4**, substituents pointing towards the reader are β-oriented; those pointing to the rearside are α-oriented [21] [22].

seven-membered ring are sterically congested: the β-side[1]) because of the β-lactam ring, the α-side[1]) because of the Y group. It appears clearly that **4A** is the favoured conformation in solution. Therefore, *Diels-Alder* reactions between the butadiene portion of educts **4** and the highly reactive *N*-acylnitroso dienophiles were expected to occur preferentially or exclusively from the α-side. These predictions were borne out by the following experiments.

Cooled solutions of azetidinodiazepines **4b** or **4c** reacted with anyone of the *in situ* formed acylnitroso dienophiles **5**, leading thereby in good overall yields, in all cases *to one pair only* of regioisomeric *Diels-Alder* adducts (see *Exper. Part*). The structure of these adducts, as determined by NMR analysis for all adducts and by X-ray diffractometry for **6a** and **7a**, was unambiguous and permitted to demonstrate that the dienophile approach occurred from the α-side *only*.

Chemical shifts *(Table 1)* and coupling constants of H–C(3), H–C(4), and H–C(6) led to the differentiation between the direct[3]) **6** and the inverse adducts[3]) **7**. The differentiation is even more pronounced when considering the chemical shifts of the corresponding C-atoms, *i.e.* C(3), C(4), and C(6) *(Table 2)*. Furthermore, we notice that the magnitude of ^1J(C(3), H) is greater by *ca.* 10 Hz for the direct adducts **6** as compared to the inverse adducts **7** *(Table 2)*, whereas the magnitude of ^1J(C(6), H) is greater by *ca.* 5 Hz for **7** as compared to **6** [26]. NOE measurements which were performed at high-field NMR conditions permitted to demonstrate the stereospecificity of the dienophile α-side approach as follows: irradiation of Me–C(5) led to NOE of H–C(4), H–C(6), and H–C(8) *(Table 3)*. Had we obtained the opposite stereoisomers, no NOE would have been observed for H–C(8), this latter H-atom being then located too far away from Me–C(5).

Table 1. *^{1}H-NMR Data* (80 MHz, $CDCl_3$) *of Adducts* **6a–c** *and* **7a–c**[1]). Temp. 298 K, δ in ppm, internal standard TMS (coupling constants omitted).

	H–C(3)	H–C(4)	H–C(6)		H–C(3)	H–C(4)	H–C(6)
6a	6.31	6.10	5.53	**7a**	7.00	6.28	4.83
6b	6.26	5.93	5.39	**7b**	7.00	6.18	4.59
6c	6.39	5.94	4.93	**7c**	6.73	6.22	4.80

Table 2. *^{13}C-NMR Data* (20.1 MHz, $CDCl_3$) *of Adducts* **6a–c** *and* **7a–c**[1]). Temp. 298 K, δ in ppm, internal standard TMS

	C(3)	C(4)	C(6)		C(3)	C(4)	C(6)
6a	83.3	121.1	57.8	**7a**	65.5	122.0	79.9
6b	82.9	121.0	56.8	**7b**	64.7	122.4	80.0
6c	82.4	119.3	61.4	**7c**	67.4	121.6	79.2
	^1J(C(3),H)	^1J(C(4),H)	^1J(C(6),H)		^1J(C(3),H)	^1J(C(4),H)	^1J(C(6), H)
6a	171	173	148	**7a**	162	173	153
6b	171	172	148	**7b**	164	175	153
6c	171	172	147	**7c**	162	173	152

Table 3. *Nuclear* Overhauser *Enhancements* (in %) *as Determined at 298 K for Adducts* **6a**/**7a** *and* **6c**/**7c** *during Irradiation of CH_3–C(5)*[1]). 400 MHz, $CDCl_3$.

	H–C(4)	H–C(6)	H–C(8)		H–C(4)	H–C(6)	H–C(8)
6a	9	9	10	**6c**	12	9	11
7a	7	7	8	**7c**	10	8	8

[3]) For the definition of 'direct' and 'inverse' adducts, see [23].

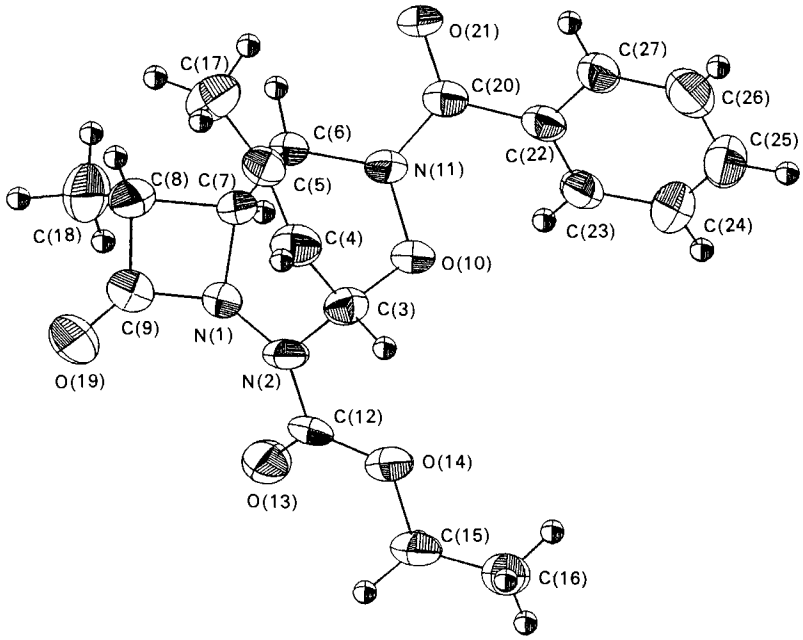


Fig. 1. *ORTEP view of* **6a**. Arbitrary numbering.

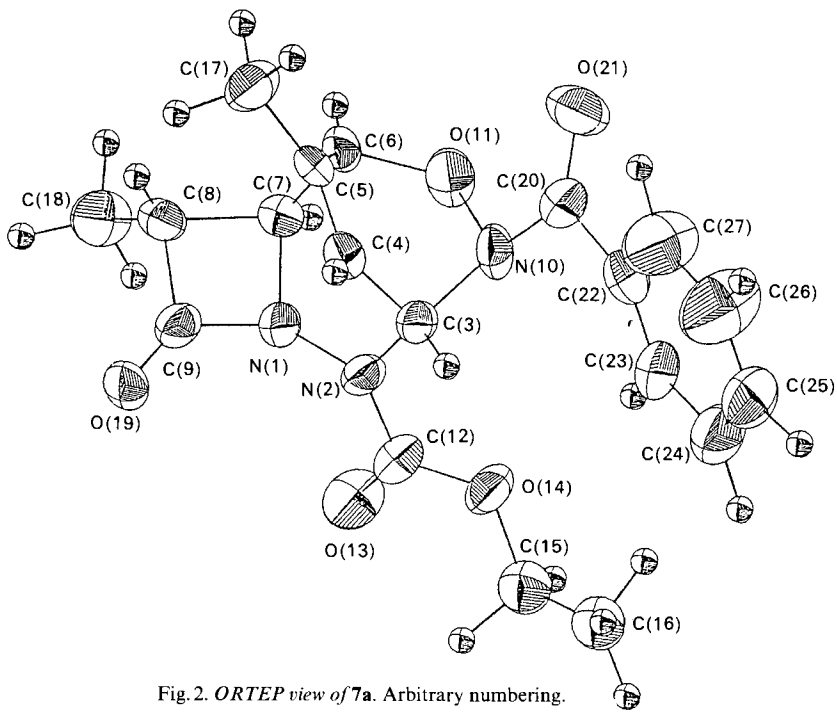


Fig. 2. *ORTEP view of* **7a**. Arbitrary numbering.

X-Ray diffraction analyses of the pair of regioisomers **6a** and **7a** nicely corroborated the conclusions which were drawn from NMR (see *Figs. 1* and *2*).

Cycloaddition reactions of acylnitroso dienophiles **5a** and **5b** with methyl 1,2-dihydropyridine-1-carboxylate led in high yield and in a regiospecific manner to the corresponding inverse adducts[3]) only, whereas **5c** gave a mixture of both regioisomers [23]. These results could best be accounted for by considering the interaction between the AO coefficients of the HOMO (of the planar dihydropyridine diene) and of the LUMO (of the acylnitroso dienophiles) [23]. The fact that the acylnitroso dienophiles **5a** and **5b** lead to cycloaddition reactions with dienes **4** in a non-regiospecific manner is undoubtedly due to the fact that these educts are *non-planar* species (see boat conformation **4A**), the magnitude of their AO coefficients becoming, therefore, difficult to evaluate. In our opinion, the loss of conjugation does affect the AO coefficients of these dienes **4**, leading thereby to the concomitant loss of regiospecificity, as compared to the results observed with the dihydropyridine derivative mentioned above.

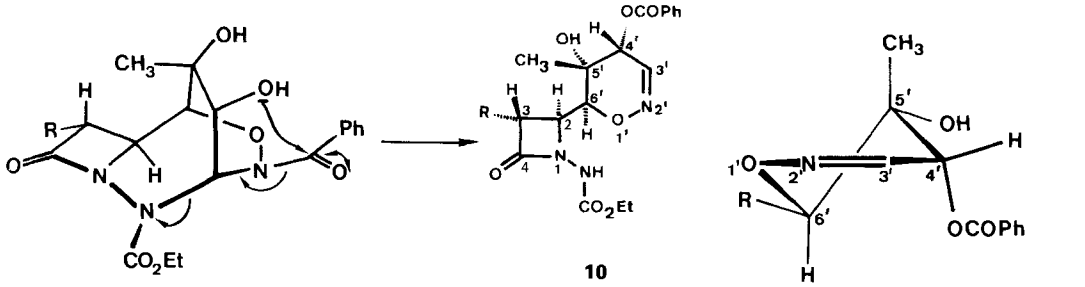
The phenylacetamido derivative **7d** was expected to be of some use for our ultimate goal, *i.e.* the synthesis of novel potential β-lactam antibiotics. For that purpose, the inverse[3]) azido adduct **7d** was treated sequentially with PPh_3 and H_2O according to [24] [25], and thence with phenylacetic acid in the presence of DCC, whereby **7e** was obtained in excellent overall yield.

Singlet molecular oxygen is also a good dienophile with educts **4** and led to the expected endoperoxides. Unfortunately, these latter ones proved to be rather unstable species. In a typical experiment, UV irradiation of a solution of educt **4b** and of a photosensitizer (*meso*-tetraphenylporphyrine) in toluene, through which O_2 was bubbled, led quickly and in good yield to an adduct whose spectral data agree well with the expected configuration (see *Exper. Part*) as depicted in *Formula* **8**. Due to its poor stability, this adduct was not used any further.

Synthesis of 2-Oxazinyl-4-oxoazetidinecarbamates 10a and 10b. – The tricyclic products **6** and **7** were formed by means of two stereospecific cycloadditions. Therefore, they were obtained with the relative configurations shown in their *Formulae* (4 asymmetric centers). Consideration of the *Dreiding* models led us to predict that *cis*-glycolization of the 4-double bond of **6** and **7**, if at all, should proceed in a stereospecific manner, *i.e. anti* with respect to the azetidinone ring.

This assumption proved to be correct with some inverse adducts[3]) **7** when reacted with OsO_4, whereas the direct adducts[3]) **6** were inert under the conditions chosen (see below and *Exper. Part*). Thus, adduct **7a** underwent glycolization with catalytic amounts of OsO_4, in the presence of a small excess of *N*-methylmorpholine oxide (NMO) at room temperature in an acetone/H_2O solution. The reaction rate proved to be very small, but the product **10a** was obtained in high yield (90%). Under the same conditions, **7e** led in good yield (69%) to **10b**. The structure analyses of **10a,b** *(vide infra)* revealed that the *cis*-glycols **9** were formed as short-lived intermediates in a stereospecific manner, followed by an intramolecular transbenzoylation to **10**. This was not entirely unexpected: the *N*-benzoyl moiety of **9** *is not an amide function* (otherwise the transbenzoylation would not occur), but rather an *N*-benzoylhydroxylamine derivative in which the *N–O bond is polarized* towards the O-atom. This is also corroborated by the pyramidal geometry of N(10) as demonstrated by the X-ray analysis of **7a** (see below). Thus, the

N–COPh bond is weaker than in a classical amide group. Furthermore, the secondary alcohol at C(4) reacts more easily by virtue of its close vicinity (proximity effect) to the N–COPh carbonyl function. After the transfer of the COPh group, the C(3)-centered aminal functionality collapses irreversibly to give product **10**. The whole intramolecular rearrangement occurs with conservation of all chiral centers but one (C(3)), so that **10** shows a linear sequence of five consecutive asymmetric C-atoms whose relative configuration unequivocally results from the two consecutive stereospecific cycloadditions, and from the *anti-cis*-glycolization.



9a R = CH_3
b R = $NHCOCH_2Ph$

10

10A R = β-lactam moiety

Table 4. *^{1}H-NMR Data* (400 MHz, $CDCl_3$) *of Oxazinyl-oxo-azetidinecarbamates* **10a** *and* **10b**. Temp. 298 K, δ in ppm and *J* in Hz, internal standard TMS.

	H–C(3)	H–C(2)	H–C(6′)	H–C(4′)	H–C(3′)	H_o	H_m	H_p
10a	3.20 (*qm*, *J*(2,3) = 2.3[a]))	3.89 (*dd*, *J*(2,6′) = 6.8)	3.98 (*d*)	5.01 (*d*, *J*(3′,4′) = 4.0)	7.49 (*d*)	8.07 (*dd*, *J*(*o*,*m*) = 8.0)	7.49 (*dd*, *J*(*m*,*p*) = 7.5)	7.63 (*dt*)
10b	4.89 (*dd*, *J*(2,3) = 2.5)	4.40 (*dd*, *J*(2,6′) = 5.5)	4.19 (*d*)	4.97 (*d*, *J*(3′,4′) = 4.0)	7.51 (*d*)	8.12 (*dl*, *J*(*o*,*m*) = 7.5)	7.48 (*t*, *J*(*m*,*p*) = 7.7)	7.63 (*t*)

	NH	OCH_2CH_3	OCH_2CH_3	CH_3–C(5′)	OH	Others
10a	6.93 (br. *s*)	4.17 (*q*, *J* = 7.2)	1.24 (*t*)	1.27 (*s*)	2.93 (br. *s*)	1.46 (*d*, *J* = 7.2, CH_3–C(3))
10b	7.05 (br. *s*)	4.13 (*m*[b])	1.20 (*t*)	1.21 (*s*)	2.91 (*s*)	7.36–7.25 (*m*, $CH_2C_6H_5$); 6.2 (*s*, NH); 3.64 (*s*, $CH_2C_6H_5$)

[a]) As determined at 323 K.
[b]) *AB* part of an *ABX*$_3$ spectrum; *J* = 7.0 and 14.0 Hz.

Table 5. *NOE Experiments with* **10a** *at 298 K*. 400 MHz, $CDCl_3$.

Irradiation at δ [ppm]	$H_{irrad.}$	NOE observed
1.27	CH_3–C(5′)	2.93 (OH); 3.20 (H–C(3)); 3.89 (H–C(2)); 3.98 (H–C(6′), weak); *5.01*[a]) (H–C(4′))
2.93	OH	3.98 (H–C(6′)); 5.01 (H–C(4′))
3.98	H–C(6′)	3.20 (H–C(3)); 2.93 (OH)
5.01	H–C(4′)	2.93 (OH); *7.49*[a]) (H–C(3′))

[a]) Pronounced enhancement.

High-field ^{1}H- and ^{13}C-NMR analyses permitted to determine the structure and the relative configuration of **10**, with a good degree of certainty (*Tables 4* and *5* and *Exper. Part*). The ^{1}H-NMR spectrum of **10a** is temperature-dependent: at 323 K, all absorption bands appear as sharp peaks, whereas at 298 K, broadening is observed with some peaks; at 253 K, most absorption bands appear as pairs of peaks. This phenomenon is obviously due to hindered rotation around the N–CO_2Et bond of the N(1) substituent, the ratio of the two rotamers being 4:1. The relative configuration of the dihydrooxazine can be deduced with a high degree of certainty from NOE experiments, the six-membered ring of **10a** being assumed to be in a half-chair conformation **10A.** Irradiation of Me–C(5′) demonstrates by the strong NOE on H–C(4′) that Me–C(5′) must be axially oriented, otherwise *both* H–C(4′) and H–C(6′) would show NOE's (see *Table 5*). Furthermore, the rather large value of J(3′,4′) agrees also with the pseudoequatorial orientation of H–C(4′). Irradiation of the tertiary OH leads to NOE with H–C(4′) *and* with H–C(6′), indicating thereby that this OH group is equatorial. No NOE is observed with H–C(6′) when H–C(4′) is irradiated, and none with H–C(4′) when H–C(6′) is irradiated. These latter two experiments demonstrate that H–C(4′) and H–C(6′) cannot be oriented both in an axial manner. Therefore, H–C(6′) has an axial orientation and a *trans* relationship to H–C(4′). Had it been *cis*, both substituents would have equatorial/pseudoequatorial orientation.

NMR-techniques did not permit to ascertain the relative configuration at C(6′) with respect to C(2), albeit chemical arguments (see above) seemed to be compelling in favour of a configuration as shown in **10a.** An X-ray analysis led unequivocally to the elucidation of the structure and to the determination of the relative configuration of **10a** as shown in *Fig. 3*, which corroborated the NMR analysis.

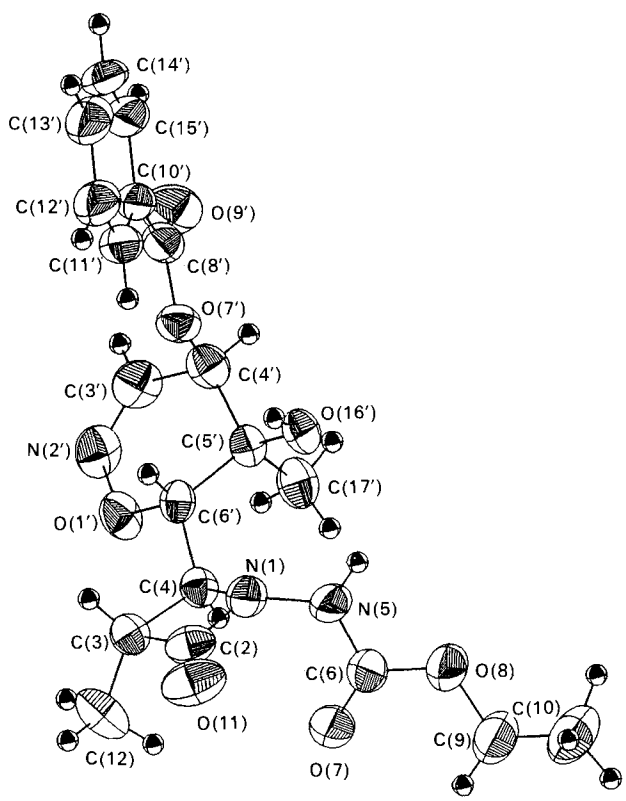


Fig. 3. *ORTEP view of* **10a**. Arbitrary numbering.

X-Ray Diffraction Analyses. – *Table 6* summarizes the crystal data, details of data collections, and structure determination parameters for **6a**, **7a**, and **10a**. Of particular interest is the geometry of the N(10) atom of **7a** which proved to be pyramidal[4]), the sum of the three angles C(3)–N(10)–O(11), C(3)–N(10)–CO, and O(11)–N(10)–CO being 339°, instead of *ca.* 360° had it been a typical planar benzamide N-atom.

Table 6. *Crystal Data and Parameters of Data Collections of* **6a**, **7a**, *and* **10a**

	6a	**7a**	**10a**
Formula	$C_{19}H_{21}N_3O_5$	$C_{19}H_{21}N_3O_5$	$C_{19}H_{23}N_3O_7$
Space group	monoclinic, $P2_1/n$	monoclinic, $P2_1/n$	triclinic, $P\bar{1}$
a [Å]	8.170(3)	7.729(2)	7.737(4)
b [Å]	23.568(4)	5.818(5)	11.292(3)
c [Å]	9.964(3)	40.879(12)	12.388(3)
α [deg]	90.0	90.0	112.24(2)
β [deg]	107.06(3)	91.26(2)	92.75(2)
γ [deg]	90.0	90.0	95.47(2)
V [Å^3]	1834.2	1837.8	993.1
Z	4	4	2
Crystal size [mm]	0.1 × 0.2 × 0.2	0.1 × 0.2 × 0.2	0.2 × 0.2 × 0.2
Temperature [K]	293	293	293
θ_{max} [deg]	25	26	25
Radiation	MoK_α (λ = 0.71069 Å)	MoK_α (λ = 0.71069 Å)	MoK_α (λ = 0.71069 Å)
μ [cm^{-1}]	0.60	0.60	0.65
F(000)	784	784	428
Scan type	$\omega/2\theta$	$\omega/2\theta$	$\omega/2\theta$
Collected intensities	$\pm h, +k, +l$	$\pm h, +k, +l$	$\pm h, +k, +l$
No. of independent reflections	2099	2161	2577
No. of reflections in refinements	1298 ($F_0 > 2\sigma(F_0)$)	1403 ($F_0 > 3\sigma(F_0)$)	1879 ($F_0 > 2\sigma(F_0)$)
No. of variables	325	279	351
Observations/parameter	3.99	5.03	5.35
Largest shift/esd	0.02	0.10	0.05
Largest peak on a final ΔF	0.46 e/Å^3	0.86 e/Å^3	0.51 e/Å^3
Final R_w	0.049	0.087	0.052
Weighting system	$1.41/(\sigma^2(F) + 5.3 \cdot 10^{-4}F^2)$	$2.87/(\sigma^2(F) + 3.1 \cdot 10^{-4}F^2)$	$1.53/(\sigma^2(F) + 5.2 \cdot 10^{-4}F^2)$

Unit cell parameters were determined from accurate centering of 25 independent strong reflections by the least-squares method. Four standard reflections monitored every 3600 s during data collections showed no significant intensity loss. The raw data sets were corrected for polarization effects. No corrections for absorbance were applied. The structures were solved by the SHELXS 86 program [27] using direct-methods strategies. All non-H-atoms were refined anisotropically; the H-atom positions were partly localized from final difference-*Fourier* maps and partly calculated and refined with thermal parameters. Scattering factors are taken from *Cromer et al.* [28]. Fractional coordinates, structure factors, individual bond lengths, and bond angles are deposited in the *Cambridge Crystallographic Data Base* or are available from *M. Z.*

The support of the *Centre National de la Recherche Scientifique* (URA-135) is gratefully acknowledged. We wish to thank Dr. *F. Gobert* and the *Rhone-Poulenc Company* for some NOE measurements *(Table 3)* and a research grant to *J. M. H.*, and the *Pharma-Forschung* department of *Ciba-Geigy Ltd.*, Basle for having synthetized 1 kg of educt **1a**.

[4]) A plane drawn through C(3), O(11), and C(20) *(Fig. 2)* is located 0.39 Å below the N(10) nucleus, the summit of the pyramidal N(10) pointing, in the crystal lattice, towards a direction which is opposite to C(4).

Experimental Part

General. Flash chromatography (FC) [29]: silica gel (*Merck 60*, 230–400 mesh). TLC: Alumina roll (*Merck 60 F_{254}*). M.p.: *Büchi SMP 20* and *Mettler FP 5* apparatus; not corrected. IR spectra (cm^{-1}): *Perkin-Elmer 157-G*. ^1H- and ^{13}C-NMR spectra: *Bruker WP-80-DS, WM-400* apparatus using double-irradiation techniques; TMS (^1H-NMR) and $CDCl_3$ ($\delta(CDCl_3) = 77.00$ ppm with respect to TMS; ^{13}C-NMR) as internal references; δ in ppm and J in Hz. Microanalyses were carried out by the *Service Central de Microanalyses* of the *C.N.R.S.*

N-*(4-Methylpyridinio)-(ethyl carbamate)*-N-*ate* (**1a**). Prepared on a 1-kg scale according to [30].

*Ethyl 5-Methyl-1*H-*1,2-diazepine-1-carboxylate* (**3a**). Prepared as yellow crystals on a 25-g scale by UV irradiation of **1a** in toluene, using a *Ciba-Geigy* falling-film photoreactor[5]), according to [32].

*6-Chloro-1*H-*azetidino[1,2-*b*][1,2]diazepin-1-yl Phenyl Ketone*[1]) (**4b**). Prepared as a colourless oil according to [17].

*Ethyl 6-Azido-1*H-*azetidino[1,2-*b*][1,2]diazepine-1-carboxylate*[1]) (**4c**). Prepared as a colourless oil according to [16].

Ethyl 4-Benzoyl-1,2α,5α,5aα,6β,7-hexahydro-6α,9-dimethyl-7-oxo-4 H-*2β,5β-ethenoazetidino[2,1-*d*][1,2,5,6]-oxatriazepine-1-carboxylate* (**6a**) *and Ethyl 3-Benzoyl-2α,3,5α,5aα,6β,7-hexahydro-6α,9-dimethyl-7-oxo-1* H-*2β,5β-ethenoazetidino[1,2-*e*][1,2,4,5]oxatriazepine-1-carboxylate* (**7a**)[1]). To a stirred and chilled soln. of **4b** (694 mg, 2.94 mmol) and Pr_4NIO_4 (370 mg, 0.98 mmol) in $CHCl_3$ (4 ml) was added benzohydroxamic acid (403 mg, 2.94 mmol) within 15 min. The mixture was left to stand at r.t. for 30 h, then treated with aq. Na_2SO_3 soln., and dried ($MgSO_4$). The resulting soln. was evaporated and the crude mixture separated by FC (AcOEt/cyclohexane 7:3) leading first to **6a** (322 mg, 30%) and then to **7a** (547 mg, 50%).

Data of **6a**: Colourless crystals (CH_2Cl_2/Et_2O). M.p. 149°. UV (MeOH): 205 (10100), 229 (7000), 242 (6600). IR (KBr): 1785, 1775, 1733, 1645. ^1H-NMR ($CDCl_3$, 80 MHz): 7.70 (*m*, 2 arom. H); 7.45 (*m*, 3 arom. H); 6.31 (*d*, $J = 6.3$, H–C(3)); 6.10 (*dquint.*, $J = 6.3, 1.5$, H–C(4)); 5.53 (*t*, $J = 1.5$, H–C(6)); 4.23 (*q*, $J = 7.2$, CH_2CH_3); 4.18 (br. *s*, H–C(5)); 2.81 (*qd*, $J = 7.2, 1.5$, H–C(8)); 2.11 (*d*, $J = 1.5$, CH_3–C(5)); 1.48 (*d*, $J = 7.2$, CH_3–C(8)); 1.26 (*t*, $J = 7.2$, CH_2CH_3). ^{13}C-NMR ($CDCl_3$, 20.1 MHz): 170.97 (*q*, $^3J = 6$, C(9)); 168.92 (*t*, $^3J = 3.5$, *C*OPh); 154.02 (*t*, $^3J = 3$, CO_2Et); 140.68 (*s*, C(5)); 132.66 (*s*, subst. arom. C); 131.02 (*dt*, $^1J = 162$, arom. C_p); 128.70 (*dt*, $^1J = 163$, arom. C_o); 127.51 (*dd*, $^1J = 162$, arom. C_m); 121.09 (*dsext.*, $^1J = 173$, C(4)); 83.29 (*dd*, $^1J = 171$, C(3)); 66.66 (*d*, $^1J = 160$, C(7)); 63.06 (*tq*, $^1J = 149$, CH_2CH_3); 57.78 (*d*, $^1J = 148$, C(6)); 44.48 (*d*, $^1J = 139$, C(8)); 22.16 (*qdd*, $^1J = 129$, CH_3–C(5)); 13.73 (*qt*, $^1J = 127$, CH_2CH_3); 12.96 (*qt*, $^1J = 129$, CH_3–C(8)). Anal. calc. for $C_{19}H_{21}N_3O_5$ (371.38): C 61.44, H 5.70, N 11.32; found. C 61.4, H 5.8, N 11.4.

Data of **7a**: Colourless crystals (CH_2Cl_2/Et_2O). M.p. 184°. UV (MeOH): 205 (10700), 226 (6300), 253 (sh, 4300). IR (KBr): 1775, 1735, 1685. ^1H-NMR ($CDCl_3$, 80 MHz): 7.73 (*m*, 2 arom. H); 7.45 (*m*, 3 arom. H); 7.00 (*d*, $J = 7.2$, H–C(3)); 6.28 (*dquint.*, $J = 7.2, 1.5$, H–C(4)); 4.83 (*t*, $J = 1.5$, H–C(6)); 4.26 (*q*, $J = 7.2$, CH_2CH_3); 4.15 (*t*, $J = 1.5$, H–C(7)); 2.67 (*qd*, $J = 7.2, 1.5$, H–C(8)); 1.98 (*d*, $J = 1.5$, CH_3–C(5)); 1.44 (*d*, $J = 7.2$, CH_3–C(8)); 1.29 (*t*, $J = 7.2$, CH_2CH_3). ^{13}C-NMR ($CDCl_3$, 20.1 MHz): 171.01 (*q*, $^3J = 5.5$, C(9)); 169.19 (*t*, $^3J = 4$, *C*OPh); 153.70 (*t*, $^3J = 3$, CO_2Et); 138.54 (*s*, C(5)); 132.61 (*s*, subst. arom. C); 131.25 (*dt*, $^1J = 162$, arom. C_p); 128.61 (*dt*, $^1J = 162$, arom. C_o); 127.65 (*dd*, $^1J = 162$, arom. C_m); 121.96 (*dd*, $^1J = 173$, C(4)); 79.91 (*dm*, $^1J = 153$, C(6)); 67.80 (*d*, $^1J = 160$, C(7)); 65.48 (*dd*, $^1J = 162$, C(3)); 62.93 (*tq*, $^1J = 149$, CH_2CH_3); 43.70 (*d*, $^1J = 139$, C(8)); 21.02 (*qdd*, $^1J = 129$, CH_3–C(5)); 13.78 (*qt*, $^1J = 127$, CH_2CH_3); 12.96 (*qt*, $^1J = 129$, CH_3–C(8)). Anal. calc. for $C_{19}H_{21}N_3O_5$ (371.38): C 61.44, H 5.70, N 11.32; found. C 61.6, H 5.7, N 11.4.

Ethyl 1,2α,5α,5aα,6β,7-Hexahydro-6α,9-dimethyl-7-oxo-4-(phenylacetyl)-4 H-*2β,5β-ethenoazetidino[2,1-*d*][1,2,5,6]oxatriazepine-1-carboxylate* (**6b**) *and Ethyl 2α,3,5α,5aα,6β,7-Hexahydro-6α,9-dimethyl-7-oxo-3-(phenylacetyl)-1*H-*2β,5β-ethenoazetidino[1,2-*e*][1,2,4,5]oxatriazepine-1-carboxylate* (**7b**)[1]). Similar procedure as above, starting from **4b** (623 mg, 2.64 mmol), Pr_4NIO_4 (395 mg, 1.05 mmol) and benzylhydroxamic acid (659 mg, 4.36 mmol) in $CHCl_3$ (6 ml). FC (AcOEt/cyclohexane 5:5) gave first **6b** (640 mg, 64%) and then **7b** (162 mg, 16%).

Data of **6b**: Colourless crystals (CH_2Cl_2/Et_2O). M.p. 127–128°. IR (KBr): 1780, 1725, 1635. ^1H-NMR ($CDCl_3$, 80 MHz): 7.24 (*s*, arom. H); 6.26 (*d*, $J = 6.3$, H–C(3)); 5.93 (*dquint*, $J = 6.3, 1.7$, H–C(4)); 5.39 (*t*, $J = 1.5$, H–C(6)); 4.22 (*q*, $J = 7.1$, CH_2CH_3); 3.91 (*t*, $J = 1.7$, H–C(7)); 3.71 (*s*, CH_2Ph); 2.71 (*qd*, $J = 7.3, 1.7$, H–C(8)); 1.97 (*d*, $J = 1.7$, CH_3–C(5)); 1.37 (*d*, $J = 7.3$, CH_3–C(8)); 1.28 (*t*, $J = 7.1$, CH_2CH_3). ^{13}C-NMR ($CDCl_3$, 20.1 MHz): 170.92 (*q*, C(9)); 170.01 (*t*, $COCH_2$Ph); 153.79 (*t*, $CO_2CH_2CH_3$); 139.81 (*s*, C(5)); 133.57 (*s*, subst. arom. C); 128.93 (*dm*, $^1J = 1.60$, arom. C_o); 127.97 (*dd*, $^1J = 161$, arom. C_m); 126.37 (*dt*, $^1J = 162$, arom. C_p); 120.95 (*dsext.*, $^1J = 172$, C(4)); 82.92 (*dd*, $^1J = 171$, C(3)); 66.61 (*d*, $^1J = 160$, C(7)); 62.97 (*tq*, $^1J = 150$, CH_2CH_3); 56.78 (*d*, $^1J = 148$, C(6)); 44.16 (*d*, $^1J = 140$, C(8)); 39.47 (*t*, $^1J = 132$, CH_2Ph); 21.89 (*qt*, $^1J = 130$, CH_3–C(5));

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[5]) For the description of the *Ciba-Geigy* falling-film photoreactor, see [31].

13.73 (*qt*, ^1J = 128, CH_2CH_3); 12.78 (*qt*, ^1J = 130, CH_3–C(8)). Anal. calc. for $C_{20}H_{23}N_3O_5$ (385.41): C 62.32, H 6.02, N 10.90; found. C 62.6, H 5.9, N 11.1.

Data of **7b**: Colourless crystals (CH_2Cl_2/Et_2O). Double m.p. 165–166°, 178–180°. IR (KBr): 1780, 1735, 1680. ^{1}H-NMR ($CDCl_3$, 80 MHz): 7.29 (*s*, arom. H); 7.00 (*d*, *J* = 7.3, H–C(3)); 6.18 (*dm*, *J* = 7.3, H–C(4)); 4.59 (*t*, *J* = 1.6, H–C(6)); 4.26 (*q*, *J* = 7.1, CH_2CH_3); 3.94 (*dd*, *J* = 1.8, 1.6, H–C(7)); 3.76 (*s*, CH_2Ph); 2.58 (*qd*, *J* = 7.2, 1.8, H–C(8)); 1.72 (*d*, *J* = 1.8, CH_3–C(5)); 1.41 (*d*, *J* = 7.2, CH_3–C(8)); 1.29 (*t*, *J* = 7.1, CH_2CH_3). ^{13}C-NMR ($CDCl_3$, 20.1 MHz): 171.19 (*s*, C(9)); 170.32 (*s*, $COCH_2$Ph); 154.02 (*t*, $CO_2CH_2CH_3$); 138.22 (*s*, C(5)); 133.53 (*s*, subst. arom. C); 129.15 (*dm*, ^1J = 161, arom. C_o); 128.47 (*dd*, ^1J = 162, arom. C_m); 126.78 (*d*, ^1J = 163, arom. C_p); 122.41 (*d*, ^1J = 175, C(4)); 80.05 (*d*, *J* = 153, C(6)); 67.94 (*d*, ^1J = 162, C(7)); 64.70 (*dd*, ^1J = 164, C(3)); 63.34 (*tq*, ^1J = 150, $CO_2CH_2CH_3$); 43.89 (*d*, ^1J = 134, C(8)); 40.47 (*t*, ^1J = 132, CH_2Ph); 21.16 (*qt*, ^1J = 130, CH_3–C(5)); 14.05 (*qt*, ^1J = 129, $CO_2CH_2CH_3$); 13.19 (*qt*, ^1J = 130, CH_3–C(8)). Anal. calc. for $C_{20}H_{23}N_3O_5$ (385.41): C 62.32, H 6.02, N 10.90; found: C 62.4, H 5.8, N 11.1.

Ethyl 4-(Benzyloxycarbonyl)-1,2α,5α,5aα,6β,7-hexahydro-6α,9-dimethyl-7-oxo-4 H*-2β,5β-ethenoazetidino[2,1-*d*][1,2,5,6]oxatriazepine-1-carboxylate* (**6c**) *and Ethyl 3-(Benzyloxycarbonyl)-2α,3,5α,5aα,6β,7-hexahydro-6α,9-dimethyl-7-oxo-1* H*-2β,5β-ethenoazetidino[1,2-*e*][1,2,4,5]oxatriazepine-1-carboxylate* (**7c**)[1]. Similar procedure as above starting from **4b** (751 mg, 3.18 mmol), Pr_4NIO_4 (400 mg, 1.06 mmol), and benzyloxycarbohydroxamic acid (531 mg, 3.18 mmol) in $CHCl_3$ (4 ml). FC (AcOEt/cyclohexane 4:6) gave first **6c** (612 mg, 49%) and then **7c** (228 mg, 18%).

Data of **6c**: Colourless crystals (CH_2Cl_2/Et_2O). M.p. 117°. UV (MeOH): 209 (13500). IR (KBr): 1780, 1770, 1745, 1710, 1660. ^{1}H-NMR ($CDCl_3$, 80 MHz): 7.33 (*s*, 5 arom. H); 6.39 (*d*, *J* = 6.4, H–C(3)); 5.94 (*dqd*, *J* = 6.4, 1.6, 1.3, H–C(4)); 5.25 (*d*, *J* = 12.5, 1 H, CH_2Ph); 5.08 (*d*, *J* = 12.5, 1 H, CH_2Ph); 4.93 (*t*, *J* = 1.3, H–C(6)); 4.23 (*q*, *J* = 7.2, CH_2CH_3); 4.04 (*t*, *J* = 1.3, H–C(7)); 2.73 (*qd*, *J* = 7.2, 1.3, H–C(8)); 1.94 (*d*, *J* = 1.6, CH_3–C(5)); 1.41 (*d*, *J* = 7.2, CH_3–C(8)); 1.28 (*t*, *J* = 7.2, CH_2CH_3). ^{13}C-NMR ($CDCl_3$, 20.1 MHz): 170.19 (*q*, ^3J = 5.5, C(9)); 156.62 (*t*, ^3J = 3.5, CO_2CH_2Ph); 154.34 (*t*, ^3J = 3, $CO_2CH_2CH_3$); 141.91 (*s*, C(5)); 135.03 (*m*, subst. arom. C); 128.15 (*d*, ^1J = 161, arom. C_p and C_m); 127.79 (*d*, ^1J = 161, arom. C_o); 119.27 (*dsext.*, ^1J = 172, C(4)); 82.37 (*dd*, ^1J = 171, C(3)); 67.98 (*tdm*, ^1J = 149, CO_2CH_2Ph); 66.07 (*d*, ^1J = 160, C(7)); 63.02 (tq, ^1J = 149, CH_2CH_3); 61.42 (*dm*, ^1J = 147, C(6)); 44.89 (*dm*, ^1J = 140, C(8)); 22.07 (*qdd*, ^1J = 129, CH_3–C(5)); 13.69 (*qt*, ^1J = 127, CH_2CH_3); 12.87 (*qt*, ^1J = 129, CH_3–C(8)). Anal. calc. for $C_{20}H_{23}N_3O_6$ (401.41): C 59.84, H 5.78, N 10.47, found. C 59.9, H 6.0, N 10.6.

Data of **7c**: Colourless crystals (CH_2Cl_2/Et_2O). M.p. 146°. UV (MeOH): 208 (10300), 233 (sh, 1700). IR (KBr): 1780, 1730, 1700, 1660. ^{1}H-NMR ($CDCl_3$, 80 MHz): 7.35 (*s*, 5 arom. H); 6.73 (*d*, *J* = 7.3, H–C(3)); 6.22 (*dquint.*, *J* = 7.3, 1.7, H–C(4)); 5.19 (*s*, CH_2Ph); 4.80 (*t*, *J* = 1.7, H–C(6)); 4.20 (*q*, *J* = 7.2, CH_2CH_3); 4.07 (*t*, *J* = 1.7, H–C(7)); 2.62 (*qd*, *J* = 7.3, 1.7, H–C(8)); 1.96 (*d*, *J* = 1.7, CH_3–C(5)); 1.41 (*d*, *J* = 7.3, CH_3–C(8)); 1.23 (*t*, *J* = 7.2, CH_2CH_3). ^{13}C-NMR ($CDCl_3$, 20.1 MHz): 171.01 (*q*, ^3J = 5.5, C(9)); 154.66 (*t*, ^3J = 3.5, CO_2CH_2Ph); 153.75 (*t*, ^3J = 3, $CO_2CH_2CH_3$); 138.67 (*s*, C(5)); 135.12 (*s*, subst. arom. C); 128.15 (*d*, ^1J = 161, arom. C_m); 128.01 (*d*, ^1J = 161, arom. C_p); 127.74 (*d*, ^1J = 161, arom. C_o); 121.59 (*dsext.*, ^1J = 173, C(4)); 79.19 (*dm*, ^1J = 152, C(6)); 67.89 (*t*, ^1J = 149, OCH_2Ph); 67.89 (*d*, ^1J = 160, C(7)); 67.43 (*dd*, ^1J = 162, C(3)); 62.83 (*tq*, ^1J = 149, CH_2CH_3); 43.70 (*d*, ^1J = 139, C(8)); 21.07 (*qdd*, ^1J = 128, CH_3–C(5)); 13.69 (*qt*, ^1J = 127, CH_2CH_3); 12.91 (*qt*, ^1J = 129, CH_3–C(8)). Anal. calc. for $C_{20}H_{23}N_3O_6$ (401.41): C 59.84, H 5.78, N 10.47; found. C 59.8, H 5.9, N 10.6.

Ethyl 6α-Azido-4-benzoyl-1,2α,5α,5aα,6β,7-hexahydro-9-methyl-7-oxo-1 H*-2β,5β-ethenoazetidino[2,1-*d*][1,2,5,6]oxatriazepine-1-carboxylate* (**6d**) *and Ethyl 6α-Azido-3-benzoyl-2α,3,5α,5aα,6β,7-hexahydro-9-methyl-7-oxo-1* H*-2β,5β-ethenoazetidino[1,2-*e*][1,2,4,5]oxatriazepine-1-carboxylate* (**7d**)[1]. Similar procedure as above, starting from **4c** (956 mg, 3.87 mmol), Pr_4NIO_4 (481 mg, 1.28 mmol), and benzohydroxamic acid (689 mg, 5.03 mmol) in $CHCl_3$ (5 ml). FC (AcOEt/cyclohexane 3:7) gave first **6d** (363 mg, 24%) and then **7d** (1.028 g, 67%).

Data of **6d**: Colourless crystals (CH_2Cl_2/Et_2O). M.p. 140°. IR (KBr): 2110, 1800, 1748, 1620. ^{1}H-NMR ($CDCl_3$, 80 MHz): 7.75 (*m*, 2 arom. H); 7.45 (*m*, 3 arom. H); 6.29 (*d*, *J* = 6.5, H–C(3)); 6.09 (*dquint.*, *J* = 6.3, 1.7, H–C(4)); 5.56 (*dd*, *J* = 1.7, 1.5, H–C(6)); 4.41 (*t*, *J* = 1.5, H–C(7)); 4.24 (*q*, *J* = 7.1, CH_2CH_3); 4.17 (*d*, *J* = 1.5, H–C(8)); 2.12 (*d*, *J* = 1.7, CH_3–C(5)); 1.27 (*t*, *J* = 7.1, CH_2CH_3). Anal. calc. for $C_{18}H_{18}N_6O_5$ (398.37): C 54.27, H 4.55, N 21.10; found: C 54.5, H 4.6, N 21.2.

Data of **7d**: Colourless crystals (CH_2Cl_2/Et_2O). M.p. 168–170°. IR (KBr): 2105, 1785, 1735, 1645. ^{1}H-NMR ($CDCl_3$, 80 MHz): 7.72 (*m*, 2 arom. H); 7.45 (*m*, 3 arom. H); 6.96 (*d*, *J* = 7.3, H–C(3)); 6.33 (*dquint.*, *J* = 7.3, 1.7, H–C(4)); 4.91 (*t*, *J* = 1.7, H–C(6)); 4.41 (*t*, *J* = 1.7, H–C(7)); 4.31 (*q*, *J* = 7.1, CH_2CH_3); 4.05 (*d*, *J* = 1.7, H–C(8)); 2.03 (*d*, *J* = 1.7, CH_3–C(5)); 1.33 (*t*, *J* = 7.1, CH_2CH_3). Anal. calc. for $C_{18}H_{18}N_6O_5$ (398.37): C 54.27, H 4.55, N 21.10; found. C 54.4, H 4.6, N 21.1

Ethyl 3-Benzoyl-2α,3,5α,5aα,6β,7-hexahydro-9-methyl-7-oxo-6α-(phenylacetamido)-1 H*-2β,5β-ethenoazetidino[1,2-*e*][1,2,4,5]oxatriazepine-1-carboxylate* (**7e**)[1]. A stirred soln. of **7d** (1.01 g, 2.54 mmol) and PPh_3 (881 mg,

3.31 mmol) was kept at r.t. for 24 h. After addition of H_2O (1 ml), the mixture was stirred at r.t. for another 24 h and CH_2Cl_2 added (10 ml). To this stirred soln. were successively added phenylacetic acid (437 mg, 3.05 mmol) and DCC (633 mg, 3.05 mmol) and the mixture kept for 15 h at r.t. After evaporation, the residue was purified by FC (AcOEt/cyclohexane 1:1): 1.16 g (93%) of **7e** as colourless crystals. M.p. 148–150°. IR (KBr): 1792, 1765, 1725, 1655. ^{1}H-NMR ($CDCl_3$, 80 MHz): 7.70 (*m*, 2 arom. H); 7.40 (*m*, 3 arom. H); 7.30 (*s*, 5 arom. H); 7.05 (*d*, J = 7.3, H–C(3)); 6.51 (br. *d*, J = 6.5, NH); 6.29 (*dquint.*, J = 7.3, 1.7, H–C(4)); 4.94 (*t*, J = 7, H–C(6)); 4.57 (*dd*, J = 6.5, 1.7, H–C(8)); 4.26 (*q*, J = 7.1, CH_2CH_3); 4.25 (*t*, J = 1.7, H–C(7)); 3.61 (*s*, CH_2Ph); 2.06 (*d*, J = 1.7, CH_3–C(5)); 1.29 (*t*, J = 7.1, CH_2CH_3). Anal. calc. for $C_{26}H_{26}N_4O_6$ (486.52): C 63.66, H 5.34, N 11.42; found: C 63.4, H 5.3, N 11.4.

Ethyl 2α,3,5α,5aα,6β,7-Hexahydro-6α,9-dimethyl-7-oxo-1 H*-2β,5β-ethenoazetidino[1,2-*e*][1,2,4,5]dioxadiazepine-1-carboxylate* (**8**)[1]. A soln. of **4b** (336 mg, 1.42 mmol) and *meso*-tetraphenylporphyrine (1 mg) in toluene (10 ml), through which O_2 was bubbled, was irradiated with a *Philips-SP-500* high-pressure Hg-vapour lamp *via* a cut-off filter soln. of K_2CrO_4 in H_2O. After 15 min, the reaction was completed (TLC), the resulting soln. evaporated, and the solid residue washed with Et_2O and recrystallized (CH_2Cl_2/Et_2O): colourless **8**. M.p. 168–170°. IR (KBr): 1772, 1735, 1668. ^{1}H-NMR ($CDCl_3$, 80 MHz): 6.44 (*dd*, J = 7.2, 1.7, H–C(3)); 6.20 (*dquint.*, J = 7.2, 1.7, H–C(4)); 4.75 (*q*, J = 1.7, H–C(6)); 4.27 (*q*, J = 7.2, CH_2CH_3); 4.18 (*t*, J = 1.7, H–C(7)); 2.67 (*qd*, J = 7.2, 1.7, H–C(8)); 2.06 (*d*, J = 1.7, CH_3–C(5)); 1.45 (*d*, J = 7.2, CH_3–C(8)); 1.31 (*t*, J = 7.2, CH_2CH_3). ^{13}C-NMR ($CDCl_3$, 20.1 MHz): 170.92 (*q*, ^3J = 5.5, C(9)); 154.66 (*t*, ^3J = 3, CO); 139.40 (*m*, C(5)); 119.86 (*dtq*, ^1J = 174, C(4)); 85.15 (*dd*, ^1J = 169, C(3)); 82.83 (*dm*, ^1J = 150, C(6)); 68.66 (*dm*, ^1J = 162, C(7)); 63.20 (*tq*, ^1J = 150, CH_2CH_3); 44.02 (*dm*, ^1J = 139, C(8)); 21.29 (*qt*, ^1J = 130, CH_3–C(5)); 13.87 (*qt*, J = 129, CH_2CH_3); 13.10 (*qt*, J = 131, CH_3–C(8)). Anal. calc. for $C_{12}H_{16}N_2O_5$ (268.26): C 53.72, H 6.01, N 10.44; found: C 53.5, H 6.2, N 10.3.

Ethyl 2β-[4′α-(Benzoyloxy)-5′,6′-dihydro-5′α-hydroxy-5′β-methyl-4′ H*-1′,2′-oxazin-6′-yl]-3α-methyl-4-oxoazetidine-1-carbamate* (**10a**). To a chilled (0°) and stirred soln. of **7a** (419 mg, 1.12 mmol) in acetone (15 ml) and NMO (173 mg, 1.28 mmol) in H_2O/acetone 2:3 (15 ml) was added the OsO_4 catalyst mixture[6]) (1.10 ml, 0.023 mmol) and the resulting mixture kept for 7 d at r.t. The soln. was evaporated and the crude residue separated by FC (AcOEt/cyclohexane 4:6): **10a** (410 mg, 90%) as colourless crystals (AcOEt/hexane). M.p. 173–174°. UV (MeOH): 281 (740), 274 (900), 230 (14000). IR (KBr): 1788, 1728, 1720, 1248. ^{1}H-NMR: *Table 4*. ^{13}C-NMR ((D$_6$)DMSO, 20.1 MHz): 171.00 (*dt*, C(4)); 164.94 (*q*, *C*OPh); 155.47 (*dt*, *C*O$_2$Et); 145.54 (*dd*, ^1J = 188, C(3′)); 133.83 (*dt*, ^1J = 163, arom. C$_p$); 129.73 (*dt*, ^1J = 165, arom. C$_o$); 129.23 (*t*, subst. arom. C); 128.82 (*dd*, ^1J = 164, arom. H$_m$); 74.84 (*d*, ^1J = 146, C(6′)); 66.10 (*ddt*, ^1J = 156, C(4′)); 65.64 (*s*, C(5′)); 61.32 (*tq*, ^1J = 148, CH_2CH_3); 61.10 (*d*, ^1J = 153, C(2)); 42.32 (*dm*, ^1J = 145, C(3)); 19.41 (*q*, ^1J = 130, CH_3–C(5′)); 14.31 (*qt*, ^1J = 127, CH_2CH_3); 12.95 (*qt*, ^1J = 129, CH_3–C(3)). Anal. calc. for $C_{19}H_{23}N_3O_7$ (405.40): C 56.29, H 5.72, N 10.37; found: C 56.6, H 5.8, N 10.4.

Ethyl 2β-[4′α-(Benzoyloxy)-5′,6′-dihydro-5′α-hydroxy-5′β-methyl-4′ H*-1′,2′-oxazin-6′-yl]-3α-(phenylacetamido)-4-oxoazetidine-1-carbamate* (**10b**). Similar procedure as above starting from **7e** (414 mg, 0.85 mmol) in acetone (6 ml) and NMO (137 mg, 1.01 mmol) in H_2O/acctone 1:2 (6 ml). To this stirred soln. was added the OsO_4 catalyst mixture[6]) (0.7 ml) and the resulting soln. left for 7 d at r.t. Then, the mixture was filtered over *Celite*, evaporated, and separated by FC (AcOEt/cyclohexane 1:1): **10b** (307 mg, 69%) as colourless crystals (AcOEt/hexane). M.p. 175°. IR (KBr): 1800, 1720–1700, 1665. ^{1}H-NMR: *Table 4*. ^{13}C-NMR ($CDCl_3$/(D$_6$)DMSO 4:1, 100.6 MHz): 170.44 (*m*, *C*OCH$_2$Ph); 167.0 (*s*, C(4)); 164.78 (*m*, O*C*OPh); 155.03 (*m*, N*C*O$_2$Et); 144.14 (*dd*, ^1J = 187, C(3′)); 134.59 (*m*, subst. C of CH_2Ph); 132.86 (*dt*, ^1J = 161, C$_p$ of CO*Ph*); 129.34, 128.47 (2 *dm*, ^1J = 160, C$_o$ of CO*Ph* and CH_2Ph); 128.39 (*m*, subst. C of CO*Ph*); 127.73, 127.72 (2 *dm*, ^1J = 160, C$_m$ of CO*Ph* and CH_2Ph); 126.00 (*dm*, ^1J = 160, C$_p$ of CH_2Ph); 73.84 (*d*, ^1J = 146, C(6′)); 65.66 (*dm*, ^1J = 155, C(4′)); 65.36 (*m*, C(5′)); 61.15 (*tq*, ^1J = 148, CH_2CH_3); 60.19 (*dm*, ^1J = 156, C(2)); 54.13 (*dm*, ^1J = 152, C(3)); 42.01 (*tm*, ^1J = 129, CH_2Ph); 18.84 (*qdd*, ^1J = 128, CH_3–C(5′)); 13.74 (*qt*, ^1J = 127, CH_2CH_3). Anal. calc. for $C_{26}H_{28}N_4O_8$ (524.52): C 59.53, H 5.38, N 10.68; found: C 59.3, H 5.4, N 10.7.

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[6]) The composition of the catalyst mixture was as follows: OsO_4 (1 g), *t*-BuOOH (1 ml), *t*-BuOH (200 ml).

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