Stereoselective Preparation of 4,5-Dihydroxy-5,6-dihydro-4*H*-1,2-oxazines and Their Derivatives

Reinhold Zimmer, Kai Homann,[1] Jörg Angermann,[2] Hans-Ulrich Reissig*

Institut für Organische Chemie der Technischen Universität Dresden, D-01062 Dresden, Germany
Fax +49(351)4637030; E-mail: hans.reissig@chemie.tu-dresden.de

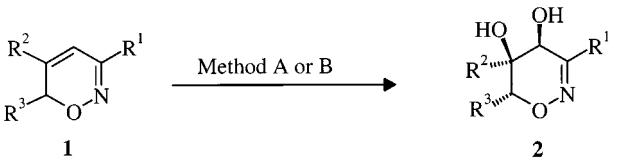
Received 22 December 1998; revised 18 February 1999

Abstract: *cis*-Dihydroxylation of 6*H*-1,2-oxazines **1** proceeds efficiently either by potassium permanganate at low temperature (Method A) or by ruthenium trichloride/sodium periodate at 0-5°C (Method B). The resulting 4,5-dihydroxylated 1,2-oxazines **2** were usually obtained as diastereomerically pure compounds with the two newly introduced hydroxy groups positioned *trans* to the 6-alkoxy group. These products can be protected by standard methods either as acetals **4** or as diacetoxy compounds **5**. In addition, the bicyclic orthoesters **7** and **8**, dimesylates **15**, and cyclic sulfates **19** have been prepared. First experiments dealing with transformations of the oxygen functionalities are described.

Key words: 1,2-oxazine, *cis*-dihydroxylation, acetylation, mesylation, cyclic sulfate, elimination, 1,3,5-trioxa-6-azaindene

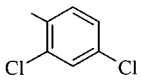
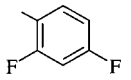
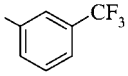
Polyhydroxylated heterocycles have been the subject of intensive studies during the last decade mainly due to their potential as biologically active compounds. Of particular interest are polyhydroxylated pyrrolidine or piperidine derivatives which may specifically inhibit glycosidases, and therefore provide novel pharmaceutical lead compounds for new drugs.[3] In this report we describe syntheses of a variety of 4,5-dihydroxylated 1,2-oxazines which may function by themselves as biologically active compounds but in addition they may be converted by several methods either into other functionalized 1,2-oxazines or by ring contraction into *cis*-dihydroxylated pyrrolidine derivatives or by ring cleavage into acyclic amino alcohols.

Our approach to 4,5-dihydroxylated 1,2-oxazines **2** is based on the good availability of 6*H*-1,2-oxazines **1** by hetero Diels–Alder reactions of α-nitroso alkenes with suitable electron-rich olefins.[4,5] Initial *cis*-dihydroxylation experiments were performed with osmium tetroxide and different reoxidizing components. Heterocycle **1a** was treated according to standard protocols but led only to rather low conversions into **2a** even after very long reaction times. Dihydroxylated 1,2-oxazine **2a** could be isolated in roughly 25% yield together with unconsumed starting material **1a**. Thus, we were very pleased that the use of potassium permanganate in the presence of magnesium sulfate produced 4,5-dihydroxylated 1,2-oxazines **2a–h** in good yields and high purities (Method A, Scheme 1).[6] However, strict control of temperature and reaction time is crucial for the successful performance of the reaction. In all cases performed with Method A only one diastereomer was isolated. It is very likely for mechanistic reasons that the two new *cis*-positioned hydroxy groups are introduced *trans* with respect to the 6-ethoxy substituent. All NMR data are in accordance with this assignment.

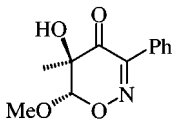


1 **2**

Method A: $KMnO_4$, $MgSO_4$, EtOH/H_2O; –45 °C, 50 min
Method B: $RuCl_3$•3 H_2O, $NaIO_4$, EtOAc/MeCN; 0–5 °C, 5–6 min

Compound	R^1	R^2	R^3	Method	Product	Yield[a]
1a	Ph	H	OEt	A	**2a**	78%
1a	Ph	H	OEt	B	**2a**	93%
1b		H	OEt	A	**2b**	73%
1b		H	OEt	B	**2b**	95%
1c		H	OEt	B	**2c**	89%[b]
1d		H	OEt	B	**2d**	99%
1e	CO_2Et	H	OEt	A	**2e**	88%
1e	CO_2Et	H	OEt	B	**2e**	99%
1f	CF_3	H	OEt	A	**2f**	70%
1f	CF_3	H	OEt	B	**2f**	79%
1g	Ph	Me	OMe	B	**2g**	98%[c]
1h	CO_2Et	H	H	A	**2h**	quant.[d]

[a] Crude product.
[b] Two diastereomers (93:7).
[c] Product contains 22% of compound **3**.
[d] Product contains impurities.

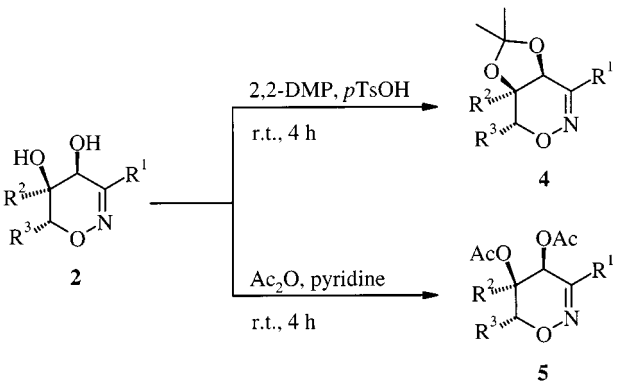


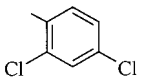
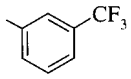
3

Scheme 1

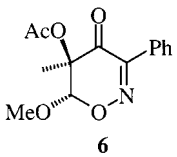
Although Method A allowed the preparation of **2** in good yields the experimental handling was relatively circumstantial. Shing's method[7] offered an extremely useful alternative using catalytical amounts of ruthenium trichloride and sodium periodate which perfectly worked for our purpose (Method B). As depicted in Scheme 1 this procedure involving ruthenium tetroxide as dihydroxylating agent requires 0–5°C and it is complete after a few minutes ("minute dihydroxylation") affording the desired products **2** in excellent yields. When Methods A and B have been performed the latter generally provided considerably higher yields and it is experimentally more easier to execute. In the case of 1,2-oxazine **2c** we obtained a 93:7 mixture of two diastereomers. We assume that the minor compound has all-*cis*-configuration; however, no plausible explanation can be offered for the lower stereoselectivity of this singular reaction. Dihydroxylation of 5-methyl substituted 6*H*-1,2-oxazine **1g** with Method B furnished the expected diol **2g** together with its oxidation product **3**[8] as minor component. This was the only case where subsequent oxidation to a defined compound was observed. Compounds **2a**, **2b** and **2d–h** were routinely protected at the hydroxy groups (Scheme 2), either as acetals **4** with 2,2-dimethoxypropane (2,2-DMP), or by acylation with acetic anhydride to give diacetoxy compounds **5** (and the monoacetoxy product **6**).

In addition, singular 1,2-oxazines **2** were converted into bicyclic orthoesters by acid catalyzed treatment with trimethyl orthoformiate or with trimethyl orthoacetate (Scheme 3).[9] As expected, compounds **7** and **8** were obtained as a mixture of isomers with respect to substituent R^2. For orthoester **7a** higher reaction temperature leads to a shift of the ratio of isomers. We assume thermodynamic control under these conditions.



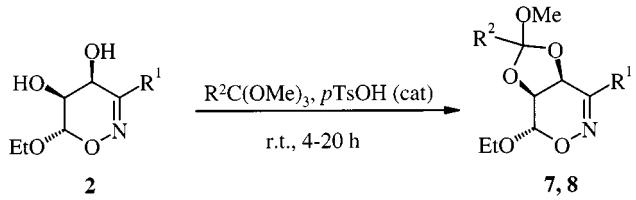
Compound	R^1	R^2	R^3	Product	Yield
2a	Ph	H	OEt	**4a**	88%
2b		H	OEt	**4b**	66%
2d		H	OEt	**4d**	70%
2e	CO_2Et	H	OEt	**4e**	84%
2f	CF_3	H	OEt	**4f**	95%
2g	Ph	Me	OMe	**4g**	41%
2h	CO_2Et	H	H	**4h**	28%
2a	Ph	H	OEt	**5a**	77%
2e	CO_2Et	H	OEt	**5e**	79%
2g	Ph	Me	OMe	**5g**	53%[a]

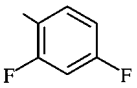
[a] Additional 11% of compound **6**.



6

Scheme 2

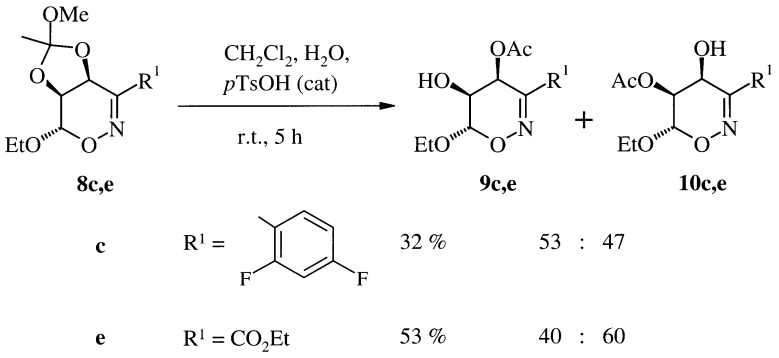


R^1	R^2	Product	Yield	Ratio of isomers
Ph	H	**7a**	56%	92:8[a]
Ph	H	**7a**	82%	34:66
Ph	Me	**8a**	92%	57:43
	Me	**8c**	85%	50:50[b]
CO_2Et	Me	**8e**	78%	50:50

[a] Reaction at 102°C.
[b] Product **8c** contains 10% of the all-*cis*-isomer (50:50).

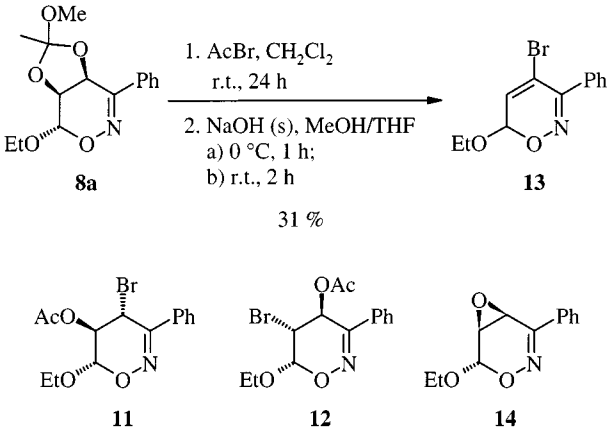
Scheme 3

With compounds **8c** and **8e** we examined whether a regioselective dioxolane ring cleavage[9] is feasible. However, these orthoesters afforded both possible monoacetoxy products **9** and **10** in ratios close to 1:1 (Scheme 4); during purification of **9c**/**10c** the minor components arising from the all-*cis*-substituted starting material **8c** disappeared.



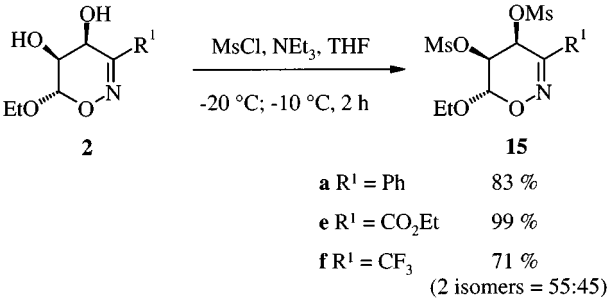
Scheme 4

An alternative way to regioselective orthoester cleavage was tested on 1,2-oxazine **8a** (Scheme 5).[9] Unfortunately, by treatment with acetyl bromide a mixture of **11**, **12**, **13**, and **14** (≈ 40:25:25:10) was obtained. It was hoped that both bromo acetoxy compounds **11** and **12** could be transformed into the epoxide **14** by base, however, stirring with sodium hydroxide promoted further elimination to eventually produce the known 4-bromo-6*H*-1,2-oxazine **13**[10] as the only isolable product in low overall yield. Alternative routes to epoxide **14** have to be developed.[11]



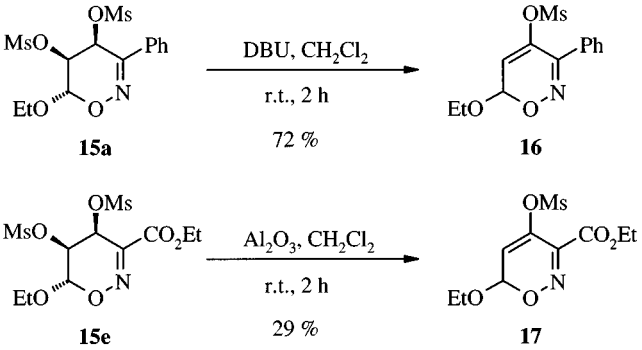
Scheme 5

Further experiments were carried out to transform the two hydroxy substituents of **2** into better leaving groups which would allow nucleophilic substitutions at C-4 and C-5 of the 1,2-oxazine system. Thus, **2a**, **2e** and **2f** were converted into the corresponding dimesylates **15a**, **15e** and **15f** in good yields by a standard protocol (Scheme 6). Surprisingly, compound **15f** was obtained as a 55:45 mixture of two diastereomers. A mechanism involving base induced elimination and readdition of methane sulfonic acid may account for this fact,[12] possibly, these steps are accelerated by the strongly electron-withdrawing 3-CF_3 group.[13]



Scheme 6

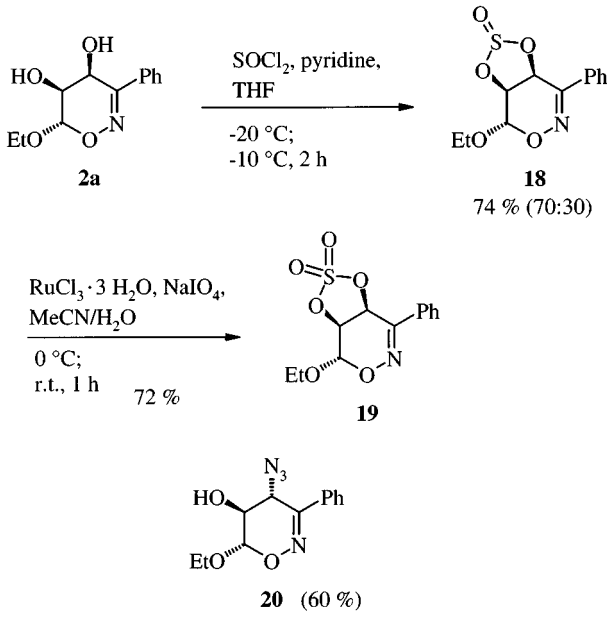
It turned out that dimesylates **15** are rather prone to elimination already during purification attempts (Scheme 7). Deliberate conversion of **15a** into monomesylate **16** succeeded by treatment with 1,8-diazabicyclo[5.4.0]undec-7-ene (DBU) at room temperature. As alternative may be used neutral aluminium oxide since during an attempt to purify dimesylate **15e** we obtained a 1:1 mixture of monomesylate **17** (29% yield) and starting material **15e**. Further experiments aiming at the substitution of one or two mesyl groups by other functional groups were frustated by the dominating elimination process.[2]



Scheme 7

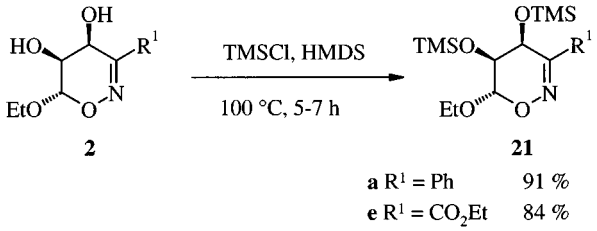
An additional possibility to activate vicinally located hydroxy groups employs reaction with thionyl chloride, followed by subsequent oxidation of the resulting cyclic sulfites.[14] Following these lines we could prepare sulfate

19 by ruthenium tetroxide promoted oxidation of intermediate **18** (Scheme 8). Treatment of **19** with sodium azide in DMF at 70°C furnished a 60:40 mixture of azide **20** and starting material **19**. The regiochemistry of the ring opening of **19** to **20** is as tentative as the suggested *trans,trans*-configuration of the azide. More experiments are required to substantiate the feasibility of this reaction which may finally lead to 4-amino-5-hydroxy substituted 1,2-oxazines and derived products.



Scheme 8

The protection of two 1,2-oxazines **2** into trimethylsiloxy compounds **21** proceeded as expected without problems (Scheme 9). Consecutive reactions of **21**, e.g. fluoride induced conversion into nonafluorobutanesulfonates,[15] have been so far unsuccessful.[2]



Scheme 9

In this paper we have demonstrated that 4,5-dihydroxy substituted 1,2-oxazines **2** are easily available by *cis*-dihydroxylation of 6*H*-1,2-oxazines **1** either with potassium permanganate or with (catalytic amounts of) ruthenium tetroxide. Both methods proceed with high efficiency and excellent diastereoselectivity. Further reactions were performed to protect and to activate the resulting 1,2-oxazines **2**. Orientating experiments show that regioselective substitution of the 4/5-hydroxy functions is difficult to achieve. However, reductive transformations of protected 4,5-dihydroxy-5,6-dihydro-4*H*-1,2-oxazines are possible in several varations[1] and will be reported in due course.[16]

All reactions were performed under argon atmosphere in flame-dried flasks, and the components were added by means of syringes. All solvents were dried by standard methods. IR spectra were measured with a Perkin Elmer spectrometer IR-325 or Nicolet 205. ^{1}H and ^{13}C NMR spectra were recorded on Bruker instruments (AC 200 or AC 300) in $CDCl_3$ solution. The chemical shifts are given in relative to the TMS or to the $CDCl_3$ signal (δ_H = 7.27, δ_C = 77.0). Missing signals of the minor isomer are hidden by signals of the major isomer, or they could not be unambiguously identified due to low intensity. Neutral alumina (activity III, Fa. Merck) was used for column chromatography. Boiling points of compounds obtained in small-scale experiments refer to the temperature in a Büchi Kugelrohroven. Melting points (uncorrected) were measured with an apparatus from Büchi (SMP-20) and Gallenkamp (MPD 350). 2,2-DMP, $RuCl_3$ and DBU were commercially available and were used as received.

Starting materials 6*H*-1,2-oxazines **1a–1f**,[4] **1g**,[5] and **1h**[1] were prepared by literature procedures.

cis-Dihydroxylation of 6*H*-1,2-Oxazines by $KMnO_4$; General Procedure 1

Method A: To a vigorously stirred solution of **1** (1 equiv) in EtOH (10 mL/mmol of 1,2-oxazine) was added over a period of 20 min at –45°C a solution of $KMnO_4$ (0.975 equiv) and $MgSO_4$ (0.875 equiv) dissolved in H_2O (6 mL/mmol of 1,2-oxazine). The resulting mixture was stirred for further 30 min at this temperature. Then 40% aq $NaHSO_3$ solution (2 mL/mmol of 1,2-oxazine) was added, and the mixture was allowed to warm up to r.t. After filtration of the suspension and evaporation of EtOH, the residue was saturated with NaCl. The resulting mixture was extracted with EtOAc (3 × 10 mL/mmol of 1,2-oxazine) and the combined organic phases were dried ($MgSO_4$). Evaporation of the solvent under reduced pressure gave the corresponding 4,5-dihydroxylated compound **2** which was generally NMR spectroscopically pure (Tables 1, 3, 4).

cis-Dihydroxylation of 6*H*-1,2-Oxazines by $RuCl_3/NaIO_4$; General Procedure 2

Method B: To a vigorously stirred solution of **1** (1 equivalent) in a mixture of EtOAc/MeCN (18 mL each/mmol of 1,2-oxazine) was added at 0–5°C a solution of $RuCl_3.3H_2O$ (0.07 equiv) and $NaIO_4$ (1.5 equiv) in H_2O (5 mL/mmol of 1,2-oxazine). The mixture was stirred vigorously for 5–6 min and then quenched with satd. aq $Na_2S_2O_3$ solution (10 mL/mmol of 1,2-oxazine). The aqueous phase was separated, extracted with EtOAc (3 × 20 mL/mmol of 1,2-oxazine) and the combined organic extracts were dried ($MgSO_4$). Evaporation of the solvent under reduced pressure gave the corresponding 4,5-dihydroxylated compound **2** which was generally NMR spectroscopically pure (Tables 1, 3, 4).

r-4,*c*-5-Dihydroxy-*t*-6-methoxy-*t*-5-methyl-3-phenyl-5,6-dihydro-4*H*-1,2-oxazine (2g) and 5-Hydroxy-6-methoxy-5-methyl-3-phenyl-5,6-dihydro-4*H*-1,2-oxazin-4-one (3)

According to the alternative dihydroxylation protocol as described in Ref.[7] (Method B) the reaction of 1,2-oxazine **1g** (1.02 g, 5.00 mmol), $RuCl_3$•$3H_2O$ (0.092 g, 0.352 mmol), $NaIO_4$ (1.60 g, 7.52 mmol) in MeCN/H_2O (60 mL/10 mL) (reaction time: 3 min at 0–3°C) provided after purification by chromatography (EtOAc/hex-

Table 1 Synthesis of 4,5-Dihydroxy-4*H*-1,2-oxazines by Oxidation with $KMnO_4/MgSO_4$ (Method A) or $RuCl_3/NaIO_4$ (Method B)

1,2-Oxazine **1** g (mmol)	Reaction Conditions g (mmol)	Product[a]	Yield g (%)	mp (°C)	IR[b] ν [cm^{-1}]
1a 3.25 (16.0)	2.47 (15.6) $KMnO_4$ / 1.69 (14.0) $MgSO_4$	**2a**	2.95 (78)	150–151	3490 (O–H), 3075–2760 (=CH, C–H),
1a 2.03 (10.0)	0.183 (0.70) $RuCl_3$ / 3.21 (15.0) $NaIO_4$	**2a**	2.20 (93)	(dec)	1575 (C=N)
1b 0.350 (1.29)	0.199 (1.26) $KMnO_4$ / 0.136 (1.13) $MgSO_4$	**2b**	0.287 (73)	oil	3440 (O–H), 3050–2920 (=CH, C–H),
1b 0.272 (1.00)	0.018 (0.07) $RuCl_3$ / 0.321 (1.50) $NaIO_4$	**2b**	0.291 (95)		1590 (C=N)
1c 0.440 (1.84)	0.034 (0.129) $RuCl_3$ / 0.591 (2.76) $NaIO_4$	**2c**	0.445 (89)[c]	126–129	3480 (O–H), 3080–2800 (=CH, C–H), 1580 (C=N), 1140, 1110 (C–F)
1d 0.15 (0.553)	0.010 (0.039) $RuCl_3$ / 0.178 (0.83) $NaIO_4$	**2d**	0.168 (99)	oil	3460 (O–H), 3120–2860 (=CH, C–H), 1575 (C=N), 1145, 1120 (C–F)
1e 5.31 (26.7)	4.11 (26.0) $KMnO_4$ / 2.81 (23.4) $MgSO_4$	**2e**	5.48 (88)	91–92	3480 (O–H), 3100–2760 (=CH, C–H),
1e 0.996 (5.00)	0.092 (0.35) $RuCl_3$ / 1.61 (7.50) $NaIO_4$	**2e**	1.16 (99)		1715 (C=O), 1590 (C=N)
1f 0.390 (2.00)	0.308 (1.95) $KMnO_4$ / 0.211 (1.75) $MgSO_4$	**2f**	0.321 (70)	oil	3370 (O–H), 2980–2900 (=CH, C–H),
1f 0.565 (2.90)	0.053 (0.203) $RuCl_3$ / 0.931 (4.35) $NaIO_4$	**2f**	0.525 (79)		1620 (C=N), 1150, 1130 (C–F)
1g 1.02 (5.00)	0.092 (0.352) $RuCl_3$ / 1.60 (7.52) $NaIO_4$	**2g**	1.17 (98)[d]	oil	3470 (O–H), 3080–2780 (=CH, C–H), 1570 (C=N)
1h 0.310 (2.00)	0.308 (1.95) $KMnO_4$ / 0.211 (1.75) $MgSO_4$	**2h**	0.459[e]	oil	–

[a] Satisfactory microanalysis obtained: C ± 0.43, H ± 0.18, N ± 0.33; exceptions: **2f** (N – 0.51); for **2d**, **2g**, **2h** the elemental analyses were carried out after the next reaction step.
[b] Oils as film or in CCl_4, solids as KBr pellets.
[c] Mixture of diastereomers: 5,6-*trans* : 5,6-*cis* isomer = 93 : 7.
[d] Mixture of products: **2g** and **3** = 78 : 22.
[e] Crude product with impurities.

ane, 3:1 → 1:0) 1.17 g (98%) of a mixture of **2g/3** (78:22). ^1H and ^{13}C NMR data are identical with those reported earlier.[8]

Acetalization of 4,5-Dihydroxy-4*H*-1,2-oxazines 2 with 2,2-DMP; General Procedure 3

To a solution of the well dried 1,2-oxazine **2** in acetone (4–20 mL/mmol of 1,2-oxazine) were added 2,2-DMP (1–10 mL/mmol of 1,2-oxazine) and *p*TsOH (20 mg/mmol of 1,2-oxazine). The mixture was stirred for 4 h at r.t., then an excess of solid $NaHCO_3$ was added. The mixture was filtered, the solvent removed in vacuo, and the resulting crude product **4** was purified by column chromatography (hexane/EtOAc, 4:1 or 8:1). The IR and NMR data of **4** are given in Tables 2–4.

Acetylation of 4,5-Dihydroxy-4*H*-1,2-oxazines 2 with Ac_2O; General Procedure 4

To a solution of 1,2-oxazine **2** (1 equiv) in anhyd. pyridine (20 mL/mmol of 1,2-oxazine) was added Ac_2O (50 equiv), and the solution was stirred at r.t. After 4 h MeOH (5 mL/mmol of 1,2-oxazine), and after further 2 h H_2O (15 mL/mmol of 1,2-oxazine) were added and the mixture was stirred for additional 17 h at r.t. The solution was concentrated in vacuo, and the residue was dissolved in Et_2O (50 mL/mmol of 1,2-oxazine). The solution was washed successively with 2 N HCl solution (2 × 45 mL/mmol of 1,2-oxazine), aq satd. $NaHCO_3$ solution (2 × 45 mL/mmol of 1,2-oxazine), and H_2O (2 × 45 mL/mmol of 1,2-oxazine), and dried ($MgSO_4$). The evaporation of the solvent gave the crude product **5** which was purified by Kugelrohr distillation (105°C/0.02 mbar) or by column chromatography (hexane/EtOAc, 6:1 → 1:1). The NMR data are given in Tables 3 and 4.

Reaction of 4,5-Dihydroxy-4*H*-1,2-oxazines 2 with Orthoesters; General Procedure 5

To a solution of 1,2-oxazine **2** in the corresponding orthoester (5 mL/mmol of 1,2-oxazine) was added *p*TsOH (20 mg/mmol of 1,2-oxazine). The mixture was stirred for 18–20 h at r.t., then solid K_2CO_3 (100 mg/mmol of 1,2-oxazine) was added. After additional 2 h at r.t. the suspension was filtered and the solvent was removed by distillation in vacuo. The residue was purified as indicated in the individual experiments. The NMR data of **7** and **8** are given in Tables 3 and 4.

r-4-Acetoxy-3-(2',4'-difluorophenyl)-*t*-6-ethoxy-*c*-5-hydroxy-5,6-dihydro-4*H*-1,2-oxazine (9c) and *c*-5-Acetoxy-3-(2',4'-difluorophenyl)-*t*-6-ethoxy-*r*-4-hydroxy-5,6-dihydro-4*H*-1,2-oxazine (10c)

A solution of 1,2-oxazine **8c** (0.100 g, 0.304 mmol) in CH_2Cl_2 (3 mL) was treated with *p*TsOH (1.5 mg) and H_2O (10 μL). After 5 h at r.t. the volatile components were removed in vacuo and the residue was purified by chromatography (silica gel, hexane/EtOAc, 2:1). Yield: 0.031 g (32%) of a mixture of **9c**/**10c** (53:47). The NMR data are given in Tables 3 and 4.

IR (neat): ν = 3450 (O–H), 3080–2870 (=C–H, C–H), 1750 (C=O), 1610 (C=N), 1140, 1120 cm^{-1} (C–F).

Anal. calcd. for $C_{14}H_{15}F_2NO_5$ (315.3): C, 53.33; H, 4.81; N, 4.44. Found: C, 53.10; H, 5.27; N, 4.14.

Ethyl *r*-4-Acetoxy-*t*-6-ethoxy-*c*-5-hydroxy-5,6-dihydro-4*H*-1,2-oxazine-3-carboxylate (9e) and Ethyl *c*-5-Acetoxy-*t*-6-ethoxy-*r*-4-hydroxy-5,6-dihydro-4*H*-1,2-oxazine-3-carboxylate (10e)

A solution of 1,2-oxazine **8e** (0.356 g, 1.23 mmol) in CH_2Cl_2 (12.5 mL) was treated with *p*TsOH (6 mg) and H_2O (30 μL). After 5 h at r.t. the volatile components were removed in vacuo and the residue was purified by chromatography (hexane/EtOAc, 2:1). Yield: 0.180

Table 2 Preparation of Derivatives **4, 5, 7, 8, 15** and **21** According to General Procedures 3–7

1,2-Oxazine	g (mmol)	Product[a]	Yield g (%)	mp (°C)	General Proced.	IR[b] ν (cm^{-1})
2a	1.86 (7.76)	**4a**	1.90 (88)	98–103.5	3	3100–2700 (=C–H, C–H), 1575 (C=N)
2b	0.29 (0.945)	**4b**	0.216 (66)	oil	3	3070–2880 (=C–H, C–H), 1570 (C=N)
2d	0.168 (0.55)	**4d**	0.133 (70)	oil	3	3070–2930 (=C–H, C–H), 1630 (C=N), 1170, 1130 (C–F)
2e	5.48 (23.5)	**4e**	5.38 (84)	81.5–83	3	3100–2640 (=C–H, C–H), 1725 (C=O), 1590 (C=N)
2f	0.321 (1.4)	**4f**	0.359 (95)	38–41	3	3050–2930 (=C–H, C–H), 1625 (C=N), 1170, 1135 (C–F)
2g	0.455 (2.0)	**4g**	0.214 (41)	oil	3	3170–2780 (=C–H, C–H), 1757 (C=N)
2h	0.459 (2.0)	**4h**	0.129 (28)	oil	3	3120–2700 (=C–H, C–H), 1725 (C=O), 1580 (C=N)
2a	0.42 (1.77)	**5a**	0.496 (77)	95–96.5	4	3100–2740 (=C–H, C–H), 1740 (C=O), 1570 (C=N)
2e	1.12 (4.8)	**5e**	1.52 (79)	69.5–73.5	4	2990, 2950, 2890 (=C–H, C–H), 1760, 1730 (C=O), 1605 (C=N)
2g	1.17[c]	**5g**	0.829 (53)[d]	oil	4	3040–2880 (=C–H, C–H), 1745 (C=O), 1590 (C=N)
2a	0.238 (1.0)	**7a**	0.228 (82)[e]	75–76	5	3070–2940 (=C–H, C–H), 1500 (C=N)
2a	0.105 (0.44)	**7a**	0.069 (56)[f]		5[g]	
2a	0.238 (1.0)	**8a**	0.271 (92)[h]	79–81	5	3100–2640 (=C–H, C–H), 1725 (C=O), 1590 (C=N)
2c	0.413 (1.5)	**8c**	0.421 (85)[i]	resin	5	–[j]
2e	2.0 (8,5)	**8e**	1.92 (78)[k]	oil	5	2980–2940 (C–H), 1730 (C=O), 1610 (C=N)
2a	0.10 (0.421)	**15a**	0.138 (83)	oil	6	3070–2950 (=C–H, C–H, 1630 (C=N), 1370, 1180 (SO_2)
2e	0.226 (0.97)	**15e**	0.375 (99)	oil	6	2990–2940 (C–H), 1730 (C=O), 1620 (C=N), 1370, 1180 (SO_2)
2f	0.458 (2.0)	**15f**	0.547 (71)[l]	oil	6	2970–2950 (C–H), 1625 (C=N), 1370, 1180 (SO_2), 1150 (C–F)
2a	0.237 (1.0)	**21a**	0.347 (91)	oil[m]	7	3080–2900 (=C–H, C–H), 1600 (C=N)
2e	0.933 (4.0)	**21e**	1.23 (84)	oil	7	2980–2900 (C–H), 1720 (C=O), 1600 (C=N)

[a] Satisfactory microanalyses obtained: C ± 0.46, H ± 0.27, N ± 0.18; exceptions: **4b** (C + 0.67) **4d** (H + 0.60), **4f** (C – 0.88), **5g** (H–0.57).
[b] Oils as film or in CCl_4, solids as KBr pellets.
[c] Mixture of **2g**/**3** (79:22).
[d] Additional 0.224 g (11 %) of compound **6**.
[e] Mixture of two diastereomers (**a**:**b** = 66:34).
[f] Mixture of two diastereomers (**a**:**b** = 8:92).
[g] Reaction was performed at 102°C.
[h] Mixture of two diastereomers (57:43).
[i] Mixture of four diastereomers (45:45:5:5).
[j] Compound **8c** was not sufficiently stable for full characterization, which was carried out on the next step (see **9c**/**10c**).
[k] Mixture of two diastereomers (50:50).
[l] Mixture of two diastereomers (55:45).
[m] Compound **21a** contains ca. 4 % of hexamethyldisilazane.

Table 3 ^{1}H NMR Data of Compounds **2, 4 – 12** and **14 – 21**

Compound	^{1}H NMR (300 MHz, $CDCl_3$ / TMS); δ, *J* (Hz)
2a[a]	7.76–7.70, 7.39–7.35 (2 m, 2 H, 3 H, C_6H_5), 5.10 (d, *J* = 4, 1 H, 6-H), 4.74 (d, *J* = 5, 1 H, 4-H), 4.63, 4.26 (2 br s, 1 H each, 2 OH), 3.98 (m_c, 1 H, 5-H), AB part of ABX_3 system (δ_A = 3.87, δ_B = 3.67, $J_{AX} = J_{BX}$ = 7, J_{AB} = 10, 2 H, OCH_2), 1.18 (t, *J* = 7, 3 H, CH_3)
2b	7.45–7.44, 7.35–7.28 (2 m, 1 H, 2 H, $C_6H_3Cl_2$), 5.18 (d, *J* = 3.2, 1 H, 6-H), 4.80 (d, *J* = 4.7, 1 H, 4-H), 4.09 (dd, *J* = 3.2, 4.7, 1 H, 5-H), 4.02–3.92, 3.76–3.63 (2 m, 2 H, OCH_2), 2.52, 1.67 (2 br s, 1 H each, 2 OH) 1.26 (t, *J* = 7, 3 H, CH_3)
2c (*trans*) [a,b]	7.48–7.34, 7.10–6.85 (2 m, 1 H, 2 H, $C_6H_3F_2$), 5.01 (d, *J* = 3, 1 H, 6-H), 4.61–3.83 (m, 4 H, 4-H, 5-H, 2 OH), 3.79–3.67, 3.65–3.47 (2 m, 1 H each, OCH_2), 1.06 (t, *J* = 7, 3 H, CH_3)
2c (*cis*) [a,b,e]	5.42 (d, *J* = 6, 1 H, 6-H)
2d[a,b]	8.03 (s, 1 H, 2'-H), 7.92, 7.66 (2 d, *J* = 7.7 each, 2 H, 4'-H, 6'-H), 7.52 (t, *J* = 7.7, 1 H, 5'-H), 5.16 (d, *J* = 3.8, 1 H, 6-H), 4.75 (d, *J* = 4.9, 1 H, 4-H), 4.13–4.01 (m, 2 H, 5-H, OH), 3.98–3.86, 3.76–3.61 (2 m, 1 H each, OCH_2), 2.80 (br s, 1 H, OH), 1.23 (t, *J* = 7, 3 H, CH_3)
2e[b]	5.11 (d, *J* = 3.5, 1 H, 6-H), 4.64, 4.52 (2 m_c, 1 H each, 4-H, 5-H), 4.27 (q, *J* = 7, 2 H, OCH_2 [ester]), AB part of ABX_3 system (δ_A = 3.86, δ_B = 3.69, $J_{AX} = J_{BX}$ = 7, J_{AB} = 9.5, 2 H, OCH_2), 3.94, 3.09 (2 m_c, 1 H each, 2 OH), 1.30, 1.18 (2 t, *J* = 7 each, 3 H each, CH_3)
2f[a,b]	5.06 (d, *J* = 3.3, 1 H, 6-H), 4.54 (br s, 1 H, OH), 4.33 (d, *J* = 4.6, 1 H, 4-H), 3.90–3.86 (m, 1 H, 5-H), 3.81–3.39 (m, 3 H, OCH_2, OH), 1.05 (t, *J* = 7, 3 H, CH_3)
2h[b]	4.53 (m_c, 1 H, 4-H), 4.37 (q, *J* = 7, 2 H, OCH_2 [ester]), 4.32–3.93 (m, 5 H, 5-H, 6-H, 2 OH), 1.38 (t, *J* = 7, 3 H, CH_3)
4a	7.88–7.81, 7.44–7.36 (2 m, 2 H, 3 H, C_6H_5), 4.97 (d, *J* = 3.5, 1 H, 6-H), 4.96 (d, *J* = 7, 1 H, 4-H), 4.39 (dd, *J* = 3.5, 7, 1 H, 5-H), AB part of ABX_3 system (δ_A = 3.95, δ_B = 3.68, $J_{AX} = J_{BX}$ = 7, J_{AB} = 10, 2 H, OCH_2), 1.44, 1.41 (2 s, 3 H each, 2 CH_3), 1.18 (t, *J* = 7, 3 H, CH_3)
4b[a]	7.46–7.45, 7.32–7.31 (2 m, 1 H, 2 H, $C_6H_3Cl_2$), 5.11 (d, *J* = 2.9, 1 H, 6-H), 4.95 (d, *J* = 6.9, 1 H, 4-H), 4.44 (dd, *J* = 2.9, 6.9, 1 H, 5-H), 3.99–3.87, 3.76–3.64 (2 m, 2 H, OCH_2), 1.49, 1.37 (2 s, 3 H each, 2 CH_3), 1.24 (t, *J* = 7, 3 H, CH_3)
4d[a]	8.14 (s, 1 H, 2'-H), 8.03, 7.68 (2 d, *J* = 7.8 each, 1 H each, 4'-H, 6'-H), 7.54 (t, *J* = 7.8, 1 H, 5'-H), 5.04 (d, *J* = 3.4, 1 H, 6-H), 4.94 (d, *J* = 6.7, 1 H, 4-H), 4.42 (dd, *J* = 3.4, 6.7, 1 H, 5-H), 4.03–3.88, 3.78–3.62 (2 m, 1 H each, OCH_2), 1.46, 1.41 (2 s, 3 H each, 2 CH_3), 1.23 (t, *J* = 7, 3 H, CH_3)
4e	5.12 (d, *J* = 3, 1 H, 6-H), 4.88 (d, *J* = 6.5, 1 H, 4-H), 4.38 (q, *J* = 7, 2 H, OCH_2 [ester]), 4.36 (dd, *J* = 3, 6.5, 1 H, 5-H), AB part of ABX_3 system (δ_A = 3.89, δ_B = 3.66, $J_{AX} = J_{BX}$ = 7, J_{AB} = 10, 2 H, OCH_2), 1.41 (s, 6 H, 2 CH_3), 1.39, 1.21 (2 t, *J* = 7 each, 3 H each, CH_3)
4f	5.18 (d, *J* = 2.5, 1 H, 6-H), 4.65 (d, *J* = 6.5, 1 H, 4-H), 4.38 (dd, *J* = 2.5, 6.5, 1 H, 5-H), AB part of ABX_3 system (δ_A = 3.89, δ_B = 3.68, $J_{AX} = J_{BX}$ = 7, J_{AB} = 10, 2 H, OCH_2), 1.44, 1.42 (2 s, 3 H each, 2 CH_3), 1.21 (t, *J* = 7, 3 H, CH_3)
4g	7.87–7.84, 7.44–7.39 (2 m, 2 H, 3 H, C_6H_5), 4.64, 4.62 (2 s, 1 H each, 4-H, 6-H), 3.61 (s, 3 H, OCH_3), 1.51 (s, 3 H, CH_3), 1.42 (s, 6 H, 2 CH_3)
4h	4.82 (d, *J* = 6.5, 1 H, 4-H), 4.49–4.34 (m, 3 H, 5-H, OCH_2 [ester]), AB part of ABX system (δ_A = 4.13, δ_B = 3.92, $J_{AX} = J_{BX}$ = 6, J_{AB} = 12, 2 H, 6-H), 1.44 (s, 6 H, 2 CH_3), 1.38 (t, *J* = 7, 3 H, CH_3)
5a	7.51–7.46, 7.42–7.29 (2 m, 2 H, 3 H, C_6H_5), 6.19 (d, *J* = 5, 1 H, 6-H), 5.39 (dd, *J* = 3.5, 5, 1 H, 5-H), 5.17 (d, *J* = 3.5, 1 H, 4-H), AB part of ABX_3 system (δ_A = 3.95, δ_B = 3.70, $J_{AX} = J_{BX}$ = 7, J_{AB} = 9.5, 2 H, OCH_2), 2.12, 1.93 (2 s, 3 H each, 2 $COCH_3$), 1.24 (t, *J* = 7, 3 H, CH_3)
5e	5.96 (d, *J* = 5, 1 H, 6-H), 5.29 (dd, *J* = 3.5, 5, 1 H, 5-H), 5.18 (d, *J* = 3.5, 1 H, 4-H), 4.34 (m_c, 2 H, OCH_2 [ester]), AB part of ABX_3 system (δ_A = 3.92, δ_B = 3.69, $J_{AX} = J_{BX}$ = 7, J_{AB} = 9.5, 2 H, OCH_2), 2.12, 2.07 (2 s, 3 H each, 2 $COCH_3$), 1.36, 1.23 (2 t, *J* = 7 each, 3 H each, CH_3)
5g	7.44–7.34 (m, 5 H, C_6H_5), 6.16 (s, 1 H, 6-H), 5.73 (s, 1 H, 4-H), 3.55 (s, 3 H, OCH_3), 2.07, 1.95 (2 s, 3 H each, 2 $COCH_3$), 1.61 (s, 3 H, 5-CH_3)
6	7.45–7.36 (m, 5 H, C_6H_5), 5.55 (s, 1 H, 6-H), 3.64 (s, 3 H, OCH_3), 2.14 (s, 3 H, $COCH_3$), 1.56 (s, 3 H, 5-CH_3)
7a[a] (isomer a)	7.87–7.83, 7.45–7.37 (2 m, 2 H, 3 H, C_6H_5), 5.84 (s, 1 H, CH), 5.13 (d, *J* = 7, 1 H, 4-H), 4.96 (d, *J* = 4, 1 H, 6-H), 4.55 (dd, *J* = 4, 7, 1 H, 5-H), 4.03–3.88, 3.77–3.16 (2 m, 1 H each, OCH_2), 3.40 (s, 3 H, OCH_3), 1.24 (t, *J* = 8, 3 H, CH_3)
7a[a] (isomer b)	7.86–7.82, 7.45–7.41 (2 m, 2 H, 3 H, C_6H_5), 5.93 (s, 1 H, CH), 5.13 (d, *J* = 3.5, 1 H, 6-H), 5.01 (d, *J* = 7.5, 1 H, 4-H), 4.46 (dd, *J* = 3.5, 7.5, 1 H, 5-H), 4.04–3.92, 3.78–3.66 (2 m, 1 H each, OCH_2), 3.17 (s, 3 H, OCH_3), 1.23 (t, *J* = 7, 3 H, CH_3)

Table 3 (continued)

Compound	^{1}H NMR (300 MHz, $CDCl_3$ / TMS); δ, *J* (Hz)
8a[a] (major)	7.86–7.77, 7.45–7.32 (2 m, 2 H, 3 H, C_6H_5), 5.14 (d, *J* = 2.9, 1 H, 6-H), 4.98 (d, *J* = 7.5, 1 H, 4-H), 4.46 (dd, *J* = 2.9, 7.5, 1 H, 5-H), 4.00–3.84, 3.75–3.59 (2 m, 1 H each, OCH_2), 3.12 (s, 3 H, OCH_3), 1.60 (s, 3 H, CH_3), 1.20 (t, *J* = 7, 3 H, CH_3)
8a[a,e] (minor)	5.11 (d, *J* = 7.3, 1 H, 4-H), 4.96 (d, *J* = 3.5, 1 H, 6-H), 4.54 (dd, *J* = 3.5, 7.3, 1 H, 5-H), 3.36 (s, 3 H, OCH_3), 1.55 (s, 3 H, CH_3), 1.22 (t, *J* = 7, 3 H, CH_3)
8c[a,c] (major)	7.70–7.56, 6.99–6.83 (2 m, 1 H, 2 H, $C_6H_3F_2$), 5.16 (dd, J_{HF} = 1, J_{HH} = 7, 0.5 H, 4-H), 5.09 (d, *J* = 3.5, 0.5 H, 6-H), 5.07 (dd, J_{HF} = 1.5, J_{HH} = 7.5, 0.5 H, 4-H), 4.99 (d, *J* = 3.5, 0.5 H, 6-H), 4.55 (dd, *J* = 3.5, 7, 0.5 H, 5-H), 4.47 (dd, *J* = 3.5, 7.5, 0.5 H, 5-H), 4.05–3.88, 3.78–3.62 (2 m, 1 H each, OCH_2), 3.31, 3.13 (2 s, 1.5 H each, OCH_3), 1.56, 1.53 (2 s, 1.5 H each, CH_3), 1.25 (t, *J* = 7, 3 H, CH_3)
8c[a,c,d,e] (minor)	4.96–4.93 (m, 1 H, 4-H), 4.83, 4.79 (2 d, *J* = 5 each, 0.5 H each, 6-H), 4.41–4.36 (m, 1 H, 5-H), 3.40, 3.29 (2 s, 1.5 H each, OCH_3), 1.68, 1.59 (2 s, 1.5 H, CH_3)
8e[a,d]	5.15 (d, *J* = 2.2, 0.5 H, 6-H), 5.04 (d, *J* = 2.6, 0.5 H, 6-H), 4.98 (d, *J* = 7.2, 0.5 H, 4-H), 4.84 (d, *J* = 7.4, 0.5 H, 4-H), 4.46 (dd, *J* = 2.6, 7.2, 0.5 H, 5-H), 4.39–4.24 [m, 2.5 H, OCH_2 (ester), 5-H], 3.87–3.72, 3.67–3.49 (2 m, 1 H each, OCH_2), 3.25, 3.11 (2 s, 1.5 H each, OCH_3), 1.50, 1.46 (2 s, 3 H each, 2 CH_3), 1.31 (t, *J* = 7, 1.5 H, CH_3), 1.28 (t, *J* = 7, 1.5 H, CH_3), 1.13 (t, *J* = 7, 3 H, CH_3)
9c	7.65–7.56, 6.97–6.83 (2 m, 1 H, 2 H, $C_6H_3F_2$), 5.24 (d, *J* = 2.8, 1 H, 6-H), 5.19 (dd, *J* = 2.8, 5, 1 H, 5-H), 4.94 (br d, *J* ≈ 5, 1 H, 4-H), 4.02–3.89, 3.77–3.63 (2 m, 1 H each, OCH_2), 2.24 (br s, 1 H, OH), 2.15 (s, 3 H, $COCH_3$), 1.26 (t, *J* = 7, 3 H, CH_3)
9e	5.86 (d, *J* = 4.8, 1 H, 6-H), 5.12 (d, *J* = 4.1, 1 H, 4-H), 4.37 (q, *J* = 7, 2 H, OCH_2 [ester]), 4.11 (br t, *J* ≈ 4.5, 1 H, 5-H), 4.00–3.84, 3.73–3.62 (2 m, 1 H each, OCH_2), 3.76 (br s, 1 H, OH), 2.15 (s, 3 H, $COCH_3$), 1.35 (t, *J* = 7, 3 H, CH_3), 1.24 (t, *J* = 7, 3 H, CH_3)
10c	7.65–7.56, 6.97–6.83 (2 m, 1 H, 2 H, $C_6H_3F_2$), 5.89 (dd, *J* = 2, 4.6, 1 H, 5-H), 5.16 (d, *J* = 2, 1 H, 6 H), 4.27 (br d, *J* ≈ 5, 1 H, 4-H), 4.02–3.89, 3.77–3.63 (2 m, 1 H each, OCH_2), 2.27 (br s, 1 H, OH), 2.00 (s, 3 H, $COCH_3$), 1.24 (t, *J* = 7, 3 H, CH_3)
10e	5.25 (dd, *J* = 3, 4.9, 1 H, 5-H), 5.21 (d, *J* = 3, 1 H, 6-H), 4.77 (d, *J* = 4.9, 1 H, 4-H), 4.38 (q, *J* = 7, 2 H, OCH_2 [ester]), 4.00–3.84, 3.73–3.62 (2 m, 1 H each, OCH_2), 2.76 (br s, 1 H, OH), 2.14 (s, 3 H, $COCH_3$), 1.41 (t, *J* = 7, 3 H, CH_3), 1.21 (t, *J* = 7, 3 H, CH_3)
11[a]	7.77–7.54, 7.44–7.39 (2 m, 2 H, 3 H, C_6H_5), 5.31, 5.26 (2 d, *J* = 5 each, 1 H each, 4-H, 6-H), 5.12 (t, *J* = 5, 1 H, 5-H), 4.08–3.90, 3.80–3.59 (2 m, 1 H each, OCH_2), 2.20 (s, 3 H, $COCH_3$), 1.26 (t, *J* = 7, 3 H, CH_3)
12[a,e]	5.51 (dd, *J* = 1.5, 2.5, 1 H, 5-H), 5.17 (dd, *J* = 0.5, 2.5, 1 H, 6-H), 4.62 (dd, *J* = 0.5, 1.5, 1 H, 4-H), 2.12 (s, 3 H, $COCH_3$), 1.26 (t, *J* = 7, 3 H, CH_3)
14	7.83–7.73, 7.49–7.38 (2 m, 2 H, 3 H, C_6H_5), 5.42 (s, 1 H, 6-H), 3.83 (s, 2 H, 4-H, 5-H), AB part of ABX_3 system (δ_A = 3.96, δ_B = 3.69, J_{AX} = J_{BX} = 7, J_{AB} = 9.5, 2 H, OCH_2), 1.24 (t, *J* = 7, 3 H, CH_3)
15a[a]	7.67–7.62, 7.49–7.46 (2 m, 2 H, 3 H, C_6H_5), 6.03 (d, *J* = 4.5, 1 H, 6-H), 5.46 (d, *J* = 4.1, 1 H, 4-H), 5.24 (dd, *J* = 4.1, 4.5, 1 H, 5-H), 4.04–3.78 (m, 2 H, OCH_2), 3.31, 3.14 (2 s, 3 H each, 2 SO_2CH_3), 1.24 (t, *J* = 7, 3 H, CH_3)
15e[a,b]	5.71 (d, *J* = 4.5, 1 H, 6-H), 5.48 (d, *J* = 4.5, 1 H, 4-H), 5.16 (t, *J* = 4.5, 1 H, 5-H), 4.44–4.23, 3.98–3.83 (2 m, 2 H each, 2 OCH_2), 3.35, 3.30 (2 s, 3 H each, 2 SO_2CH_3), 1.35, 1.25 (2 t, *J* = 7 each, 3 H each, 2 CH_3)
15f[a,b] (major)	5.79 (d, *J* = 4.4, 1 H, 6-H), 5.31 (t, *J* ≈ 4.3, 1 H, 5-H), 4.90–4.80 (m, 1 H, 4-H), 3.98–3.72 (m, 2 H, OCH_2), 3.31, 3.27 (2 s, 3 H each, 2 SO_2CH_3), 1.24 (t, *J* = 7, 3 H, CH_3)
15f[a,b,e] (minor)	5.63 (d, *J* = 3.6, 1 H, 6-H), 5.45 (t, *J* ≈ 3.4, 1 H, 5-H), 4.42–4.38 (m, 1 H, 4-H), 3.41, 3.35 (2 s, 3 H each, 2 SO_2CH_3), 1.22 (t, *J* = 7, 3 H, CH_3)
16[a]	7.63–7.57, 7.47–7.40 (2 m, 2 H, 3 H, C_6H_5), 6.31, 5.85 (2 d, *J* = 5 each, 1 H each, 5-H, 6-H), 4.13–3.94, 3.90–3.63 (2 m, 1 H each, OCH_2), 2.71 (s, 3 H, SO_2CH_3), 1.22 (t, *J* = 7, 3 H, CH_3)
17[a]	6.22, 5.86 (2 d, *J* = 5 each, 1 H each, 5-H, 6-H), 4.42–4.28, 4.00–3.88, 3.85–3.62 (3 m, 1 H, 2 H, 1 H, 2 OCH_2), 3.25 (s, 3 H, SO_2CH_3), 1.42, 1.21 (2 t, *J* = 7 each, 3 H each, 2 CH_3)
18[a] (major)	7.84–7.76, 7.50–7.39 (2 m, 2 H, 3 H, C_6H_5), 5.74 (d, *J* = 7, 1 H, 4-H), 5.18 (dd, *J* = 4, 7, 1 H, 5-H), 5.08 (d, *J* = 4, 1 H, 6-H), 4.10–3.95, 3.90–3.71 (2 m, 1 H each, OCH_2), 1.26 (t, *J* = 7, 3 H, CH_3)
18[a,e] (minor)	5.52 (d, *J* = 7.5, 1 H, 4-H), 5.29 (d, *J* = 4.5, 1 H, 6-H), 4.83 (dd, *J* = 4.5, 7.5, 1 H, 5-H), 1.27 (t, *J* = 7, 3 H, CH_3)
19[a]	7.77–7.72, 7.51–7.42 (2 m, 2 H, 3 H, C_6H_5), 5.70 (d, *J* = 7, 1 H, 4-H), 5.29 (d, *J* = 3.5, 1 H, 6-H), 5.17 (dd, *J* = 3.5, 7, 1 H, 5-H), 3.97–3.75 (m, 2 H, OCH_2), 1.25 (t, *J* = 7, 3 H, CH_3)

Table 3 (continued)

Compound	^{1}H NMR (300 MHz, $CDCl_3$ / TMS); δ, *J* (Hz)
20[a]	7.72–7.65, 7.43–7.34 (2 m, 2 H, 3 H, C_6H_5), 5.04 (d, *J* = 3, 1 H, 6-H), 4.13 (dd, *J* = 2.5, 3, 1 H, 5-H), 3.96–3.81, 3.74–3.55 (2 m, 2 H, 1 H, 4-H, OCH_2), 2.55 (br s, 1 H, OH), 1.19 (t, *J* = 7, 3 H, CH_3)
21a	7.58–7.49, 7.38–7.34 (2 m, 2 H, 3 H, C_6H_5), 5.02 (d, *J* = 6.3, 1 H, 4-H), 4.62 (d, *J* = 3.8, 1 H, 6-H), 4.09–3.99, 3.75–3.64 (2 m, 1 H each, OCH_2), 3.85 (dd, *J* = 3.8, 6.3, 1 H, 5-H), 1.28 (t, *J* = 7, 3 H, CH_3), 0.19, 0.03 [2 s, 9 H each, 2 $Si(CH_3)_3$]
21e	4.82 (d, *J* = 7.4, 1 H, 4-H), 4.42 (d, *J* = 3.9, 1 H, 6-H), 4.24–4.07 (m, 2 H, OCH_2 [ester]), 3.90–3.79, 3.59–3.45 (2 m, 1 H each, OCH_2), 3.53 (dd, *J* = 3.9, 7.4, 1 H, 5-H), 1.19, 1.11 (2 t, *J* = 7 each, 3 H each, 2 CH_3), 0.00, –0.04 [2 s, 9 H each, 2 $Si(CH_3)_3$]

[a] Recorded on a 200 MHz spectrometer.
[b] In acetone-d_6.
[c] Two isomers (50:50).
[d] Minor compounds refer to the all-*cis*-isomer of **7c**.
[e] Missing signals are hidden by the signals of the major isomer.

g (53%) of a mixture of **9e**/**10e** (40:60). The NMR data are given in Tables 3 and 4.

IR (neat): ν = 3470 (O–H), 2980–2910 (C–H), 1730 (C=O), 1600 cm^{-1} (C=N).

Anal. calcd. for $C_{11}H_{17}NO_7$ (275.3): C, 47.99; H, 6.24; N, 5.08. Found: C, 47.54; H, 6.30; N, 5.12.

4-Bromo-6-ethoxy-3-phenyl-6*H*-1,2-oxazine (13)
1,2-Oxazine **8a** (0.440 g, 1.50 mmol) was dissolved in CH_2Cl_2 (8 mL) and the solution was treated with freshly distilled acetyl bromide (135 µL, 1.80 mmol). After 24 h the volatile components were removed in vacuo to yield 0.497 g of a mixture of **11**, **12**, **13**, and **14** (40:25:25:10). The resulting crude product mixture was used for the subsequent step without further purification. The NMR data are given in Tables 3 and 4.

A solution of the mixture of **11**, **12**, **13**, and **14** (0.171 g), as isolated above, in MeOH/THF (3 mL/1 mL) was treated with finely divided NaOH (0.040 g, 1.00 mmol) and the resulting mixture was stirred for 1 h at 0°C. The solution was allowed to warm up to r.t., and was left at r.t. for further 2 h. The mixture was then diluted with Et_2O (15 mL), washed successively with H_2O and brine (15 mL each), dried (Na_2SO_4) and the solvent was concentrated in vacuo. The purification by kugelrohr distillation (bp 120°C/0.01 mbar) gave 0.046 g (31%) of **13** as a yellow oil. ^{1}H and ^{13}C NMR data are identical with those reported earlier.[10]

Mesylation of 4,5-Dihydroxy-4*H*-1,2-oxazines 2 with Methanesulfonyl Chloride; General Procedure 6
The solution of 4*H*-1,2-oxazines **2** (1 equiv) in anhyd. THF (10 mL/mmol of 1,2-oxazine) was cooled to –20°C. Then freshly distilled NEt_3 (3.5 equiv) and $MeSO_2Cl$ (3 equiv) were added slowly. The mixture was allowed to warm up successively to –10°C (2 h) and then to r.t. After 1 h at r.t. the mixture was quenched with H_2O (10 mL/mmol of 1,2-oxazine), the aqueous layer was extracted with Et_2O (5 × 10 mL/mmol of 1,2-oxazine) and the combined organic extracts were dried (Na_2SO_4). Evaporation of the solvent furnished the dimesylate **15** which was used without further purification in the subsequent step. The NMR data of **15** are given in Tables 3 and 4.

6-Ethoxy-4-(methylsulfonyloxy)-3-phenyl-6*H*-1,2-oxazine (16)
A solution of dimesylate **15a** (0.072 g, 0.183 mmol) and DBU (0.042 g, 0.275 mmol) in CH_2Cl_2 (1 mL) was stirred for 2 h at r.t. Then the solvent was removed and the residue was filtered through a pad of Al_2O_3 (hexane/EtOAc, 3:1). Yield: 0.039 g (72%) of **16** as a yellow oil. The NMR data are given in Tables 3 and 4.

IR (neat): ν = 2980–2750 (C–H), 1655 (C=C), 1625 (C=N), 1375, 1180 cm^{-1} (SO_2).

Anal. calcd. for $C_{13}H_{15}NO_5S$ (297.3): C, 52.52; H, 5.09; N, 4.71; S, 10.76. Found: C, 52.00; H, 5.13; N, 4.66; S, 10.69.

Ethyl 6-Ethoxy-4-(methylsulfonyloxy)-6*H*-1,2-oxazine-3-carboxylate (17)
Dimesylate **15e** (0.190 g, 0.488 mmol) was dissolved in EtOAc (5 mL). The solution was filtered through an Al_2O_3 column (neutral, activity III; elution with hexane/EtOAc, 1:1). The filtrate was concentrated, and the residue was dried in vacuo (30°C/2 mbar). Yield: 0.095 g of a 1:1 mixture of **17** and **15e** (calcd. yield for **17**: 29%). The NMR data are given in Tables 3 and 4.

7-Ethoxy-3a,5,6a,7-tetrahydro-5-oxo-3-phenyl-dioxathiolan[4,5-d]-1,2-oxazine (18)
Diol **2a** (0.356 g, 1.50 mmol) and pyridine (0.356 g, 4.50 mmol) were dissolved in anhyd. THF (5 mL) and the solution was cooled to –20°C. To the stirred solution $SOCl_2$ (0.286 g, 2.25 mmol) was slowly added. Stirring was continued for 2 h at –10°C. Then the mixture was quenched with H_2O (5 mL) and the aqueous layer was extracted with Et_2O (5 × 10 mL). The combined organic extracts were dried (Na_2SO_4), and the solvent was removed under reduced pressure. Yield: 0.314 g (74%) of **18** (2 diastereomers = 70:30) as a yellow solid (mp 179–183°C). The NMR data are given in Tables 3 and 4.

MS (EI, 70 eV): *m*/*z* (%) = 283 (M^+, 12), 181 (14), 180 (69), 159 (16), 158 (100), 152 (12), 151 (25), 146 (17), 145 (74), 144 (84), 135 (15), 132 (17), 130 (38), 117 (22), 116 (12), 115 (20), 107 (25), 106 (27), 105 (14), 104 (55), 103 (Ph – C≡N^+, 68), 102 (16), 91 (14), 90 (18), 89 (19), 87 (30), 79 (16), 77 ($C_6H_5^+$, 83), 76 (23), 71 (12), 64 (SO_2^+, 10), 63 (14), 61 (14), 59 (32), 51 (27), 50 (19), 43 (16).

No correct elemental analysis could be obtained for the crude product.

7-Ethoxy-3a,5,6a,7-tetrahydro-5,5-dioxo-3-phenyl-dioxathiolan[4,5-d]-1,2-oxazine (19)
To a vigorously stirred solution of 1,2-oxazine **18** (0.295 g, 1.04 mmol) in MeCN (5 mL) was added at 0 °C a solution of $RuCl_3$ trihydrate (5 mg) and $NaIO_4$ (0.334 g, 1.56 mmol) in H_2O (2 mL). The reaction mixture was stirred for 1 h at r.t. and then diluted with Et_2O (10 mL). The organic phase was separated and washed successively with H_2O, aq satd $NaHCO_3$ solution, and brine (10 mL each), and dried (Na_2SO_4). Evaporation of the solvent under reduced pressure led to **19** (0.224 g, 72%) as a pale yellow solid (mp 112–114°C). The NMR data are given in Tables 3 and 4.

Table 4 ^{13}C NMR Data[a] of 1,2-Oxazines **2**, **4 – 12** and **14 – 21**; δ, *J* (Hz)

Compound	C-3 (s)	C-4 (d)	C-5 (d)	C-6 (d)	Other Signals
2a	158.6	61.0	65.6	101.1	135.6, 129.8, 128.8, 128.2 (s, 3 d, C_6H_5), 65.0 (t, OCH_2), 15.4 (q, CH_3)
2b	159.3	61.5	64.0	99.7	136.0, 133.7, 131.5, 131.9, 129.6, 127.3 (3 s, 3 d, $C_6H_3Cl_2$), 64.8 (t, OCH_2), 15.0 (q, CH_3)
2c[b,c] (*trans*)	157.0 (d $^3J_{CF}$ = 2)	61.7 (dd $^4J_{CF}$ = 4)	64.5	101.2	164.2 (dd, $^{1,3}J_{CF}$ = 253, 12, =CF), 161.9 (dd, $^{1,3}J_{CF}$ = 253, 12, =CF), 132.6 (ddd, $^{3,3}J_{CF}$ = 6, 10, =CH), 120.4 (dd, $^{2,4}J_{CF}$ = 12, 4, *i*-C), 111.9 (ddd, $^{2,4}J_{CF}$ = 4, 22, =CH), 104.4 (td, $^{2,2}J_{CF}$ = 27, =CH), 64.8 (t, OCH_2), 15.3 (q, CH_3)
2c[b,c] (*cis*)	–	63.3 (dd $^4J_{CF}$ = 4)	–	106.5	64.7 (t, OCH_2), 14.6 (q, CH_3)
2d[b]	157.6	60.2	64.8	99.8	134.1 (s, C-1'), 130.9 (q, $^2J_{CF}$ = 26, C-3'), 130.7 (dq, $^4J_{CF}$ = 1, C-5'), 128.8 (d, C-6'), 126.4, 124.3 (2 dq, $^3J_{CF}$ = 4 each, C-2', C-4'), 123.9 (q, $^1J_{CF}$ = 275, CF_3), 65.2 (t, OCH_2), 15.0 (q, CH_3)
2e[b,c]	153.8	60.1	64.6	101.5	163.6 (s, *C*O_2Et), 65.5, 62.1 (2 t, OCH_2), 15.3, 14.4 (2 q, $2CH_3$)
2f[b,c]	149.5 (q $^2J_{CF}$ = 32)	58.8	63.0	100.5	120.0 (q, $^1J_{CF}$ = 277, CF_3), 65.4 (t, OCH_2), 14.6 (q, CH_3)
2h[c]	149.6	58.9	62.3	67.9 (t)	163.2 (s, *C*O_2Et), 62.1 (t, OCH_2), 14.0 (q, CH_3)
4a	157.4	72.3	65.5	97.8	133.5, 130.2, 128.6, 126.8 (s, 3 d, C_6H_5), 111.1 (s, *C*Me_2), 65.0 (t, OCH_2), 27.1, 26.0 [2 q, C(*C*H_3)$_2$], 15.0 (q, CH_3)
4b[b]	158.6	71.9	65.8	96.2	136.0, 133.6, 131.6, 132.1, 129.8, 127.3 (3 s, 3 d, $C_6H_3Cl_2$), 111.5 (s, *C*Me_2), 64.5 (t, OCH_2), 27.0, 25.7 [2 q, C(*C*H_3)$_2$], 14.8 (q, CH_3)
4d[b]	156.3	72.1	64.0	97.5	134.4 (s, C-1'), 131.5 (q, $^2J_{CF}$ = 30, C-3'), 130.0 (dq, $^4J_{CF}$ = 1, C-5'), 129.0 (d, C-6'), 126.5, 123.5 (2 dq, $^3J_{CF}$ = 4 each, C-2', C-4'), 124.2 (q, $^1J_{CF}$ = 268, CF_3), 111.2 (s, *C*Me_2), 65.0 (t, OCH_2), 27.0, 25.9 [2 q, C(*C*H_3)$_2$], 14.8 (q, CH_3)
4e	151.4	70.7	62.9	97.6	161.8 (s, *C*O_2Et), 111.1 (s, *C*Me_2), 64.9, 61.9 (2 t, OCH_2), 26.7, 25.6 [2 q, C(*C*H_3)$_2$], 14.4, 13.8 (2 q, $2CH_3$)
4f	149.6 (q $^2J_{CF}$ = 33)	70.4	62.1	97.2	120.1 (q, $^1J_{CF}$ = 277, CF_3), 112.2 (s, C*C*Me_2), 65.2 (t, OCH_2), 26.7, 25.8 [2 q, C(*C*H_3)$_2$], 14.5 (q, CH_3)
4g	156.5	72.7	77.4 (s)	102.6	133.1, 129.9, 128.3, 126.3 (s, 3 d, C_6H_5), 110.6 (s, *C*Me_2), 57.3 (q, OCH_3), 27.4[d] [q, C(*C*H_3)$_2$], 19.1 (q, CH_3)
4h	150.4	68.7	62.7	67.2(t)	162.2 (s, *C*O_2Et), 111.0 (s, *C*Me_2), 62.1 (t, OCH_2), 27.2, 25.7 [2 q, C(*C*H_3)$_2$], 13.9 (q, CH_3)
5a	154.9	59.3	62.9	97.2	169.9, 169.5 (2 s, *C*OMe), 132.5, 129.6, 128.9, 126.5 (s, 3 d, C_6H_5), 64.7 (t, OCH_2), 20.5, 20.2 (2 q, CO*C*H_3), 14.7 (q, CH_3)
5e	148.8	58.6	62.5	98.1	169.9, 169.0 (2 s, *C*OMe), 160.8 (s, *C*O_2Et), 65.6, 62.3 (2 t, OCH_2), 20.7, 20.4 (2 q, CO*C*H_3), 14.8, 14.0 (2 q, CH_3)
5g	154.6	65.6	77.2 (s)	99.8	169.9, 169.4 (2 s, *C*OMe), 132.3, 129.6, 128.4, 126.8 (s, 3 d, C_6H_5), 56.8 (q, O*C*H_3), 21.8, 20.6 (2 q, CO*C*H_3), 17.6 (q, CH_3)
6	154.2	188.0 (s)	73.5 (s)	106.8	169.5 (s, *C*OMe), 133.0, 129.8, 128.4, 128.0 (s, 3 d, C_6H_5), 57.8 (q, O*C*H_3), 21.5 (q, O*C*H_3), 16.9 (q, CH_3)
7a[b] (isomer a)	156.7	71.7	64.7	67.2(t)	132.9, 130.4, 128.6, 126.6 (s, 3 d, C_6H_5), 115.9 (d, C-2), 65.0 (t, OCH_2), 52.2 (q, OCH_3), 14.8 (q, CH_3)
7a[b] (isomer b)	157.4	72.9	64.5	97.13	133.2, 130.2, 128.5, 126.7 (s, 3 d, C_6H_5), 116.6 (d, C-2), 64.9 (t, OCH_2), 51.0 (q, OCH_3), 14.9 (q, CH_3)

Table 4 (continued)

Compound	C-3 (s)	C-4 (d)	C-5 (d)	C-6 (d)	Other Signals
8a[b] (major)	157.2	72.3	64.0	96.5	133.3, 130.2, 128.5, 126.6 (s, 3 d, C_6H_5), 123.5 (s, *C*OMe), 64.6 (t, OCH_2), 49.3 (q, OCH_3), 23.0 (q, CH_3), 14.8 (q, CH_3)
8a[b] (minor)	157.2	73.1	65.3	97.0	133.1, 130.3, 128.5, 126.6 (s, 3 d, C_6H_5), 122.9 (s, *C*OMe), 64.8 (t, OCH_2), 50.1 (q, OCH_3), 21.9 (q, CH_3), 14.8 (q, CH_3)
8c[b,e] (major)	157.2 (d $^3J_{CF}$ = 2)	66.6, 66.0 (2 dd $^4J_{CF}$ = 6)	72.6, 74.5	97.5, 97.2	164.2 (dd, $^{1,3}J_{CF}$ = 253, 12, =CF), 161.0 (dd, $^{1,3}J_{CF}$ = 254, 12, =CF), 131.4 (ddd, $^{3,3}J_{CF}$ = 4, 10, =CH), 126.6, 122.9 (2 s, 2 *C*OMe), 120.0 (dd, $^{2,4}J_{CF}$ = 11, 3, *i*-C), 111.9 (ddd, $^{2,4}J_{CF}$ = 3, 21, =CH), 104.7 (td, $^2J_{CF}$ = 26, =CH), 65.0 (t, OCH_2), 49.9, 49.8 (2 q, 2 OCH_3), 22.3, 22.1 (2 q, 2 CH_3), 14.9, 14.8 (2 q, 2CH_3)
8e[b,e]	151.5, 151.4	71.7, 70.9	61.8, 63.1	96.6, 96.5	161.8, 161.6 (2 s, 2 CO_2Et), 123.5, 123.1 (2 s, 2 *C*OMe), 65.1, 64.9, 62.3, 62.2 (4 t, 4 OCH_2), 49.8, 49.2 (2 q, 2 OCH_3), 22.7, 22.3 (2 q, 2 CH_3), 14.6, 14.5, 14.0, 13.9 (4 q, 4 CH_3)
9c	155.7	59.7 (dd $^4J_{CF}$ = 5)	65.2	100.0	169.5 (s, *C*OMe), 163.9 (dd, $^{1,3}J_{CF}$ = 251, 12, =CF), 159.3 (dd, $^{1,3}J_{CF}$ = 251, 12, =CF), 131.3 (ddd, $^{3,3}J_{CF}$ = 6.5, 10, =CH), 117.6 (dd, $^{2,4}J_{CF}$ = 17, 4, *i*-C), 111.8 (ddd, $^{2,4}J_{CF}$ = 3, 22, =CH), 104.2 (td, $^2J_{CF}$ = 26, =CH), 64.9 (t, OCH_2), 20.9 (q, CO*C*H_3), 14.9 (q, CH_3)
9e	148.9	61.2[f]	62.7[f]	100.4	169.4 (s, *C*OMe), 161.1 (s, *C*O_2Et), 65.6, 62.1 (2 t, 2 OCH_2), 20.6 (q, CO*C*H_3), 14.8, 13.9 (2 q, 2 CH_3)
10c	152.8	64.3 (dd $^4J_{CF}$ = 4)	62.0	97.4	170.6 (s, *C*OMe), 111.9 (ddd, $^{2,4}J_{CF}$ = 3, 21, =CH), 104.0 (td, $^2J_{CF}$ = 26, =CH), 65.0 (t, OCH_2), 20.5 (q, CO*C*H_3), 14.9 (q, CH_3)
10e	150.6	64.1	58.2	98.2	170.3 (s, *C*OMe), 163.1 (s, *C*O_2Et), 65.4, 62.5 (2 t, 2 OCH_2), 20.7 (q, CO*C*H_3), 14.7, 13.9 (2 q, 2 CH_3)
11[b]	155.2	66.5	36.7	94.7	169.9 (s, *C*OMe), 133.1, 129.7, 128.8, 128.0 (s, 3 d, C_6H_5), 64.3 (t, OCH_2), 20.7 (q, CO*C*H_3), 14.8 (q, CH_3)
12	153.7	28.3	69.1	97.2	169.4 (s, *C*OMe), 133.0, 130.1, 128.4, 126.6 (s, 3 d, C_6H_5), 65.3 (t, OCH_2), 20.6 (q, CO*C*H_3), 14.9 (q, CH_3)
14	158.3	41.3	55.6	93.8	133.7, 130.4, 128.8, 126.3 (s, 3 d, C_6H_5), 64.9 (t, OCH_2), 14.9 (q, CH_3)
15a[b]	154.0	66.7	71.1	98.4	133.3, 130.8, 129.3, 128.4 (s, 3 d, C_6H_5), 39.1, 38.8 (2 q, SO_2CH_3), 15.2 (q, CH_3)
15e[b,c]	147.4	66.0	70.5	99.2	161.5 (s, *C*O_2Et), 66.9, 63.2 (2 t, 2 OCH_2), 39.0, 38.8 (2 q, 2 SO_2CH_3), 15.1, 14.1 (2 q, 2 CH_3)
15f[b,c] (major)	144.3(q) $^2J_{CF}$ = 34)	67.9	71.8	100.0	121.1 (q, $^1J_{CF}$ = 275, CF_3), 66.4 (t, OCH_2), 39.1, 39.0 (2 q, 2 SO_2CH_3), 15.1 (q, CH_3)
15f[b,c] (minor)	–	64.6	69.3	99.9	120.5 (q, $^1J_{CF}$ = 275, CF_3), 67.0 (t, OCH_2), 38.8, 38.4 (2 q, 2 SO_2CH_3), 15.0 (q, CH_3)
16[b]	152.9	137.2 (s)	114.5	95.7	131.7, 130.2, 128.6, 127.4 (s, 3 d, C_6H_5), 64.6 (t, OCH_2), 38.3 (q, SO_2CH_3), 14.9 (q, CH_3)
17[b]	145.9	135.7 (s)	113.2	96.4	159.9 (s, *C*O_2Et), 66.3, 62.6 (2 t, 2 OCH_2), 38.2 (q, SO_2CH_3), 14.8, 14.0 (2 q, 2 CH_3)
18[b] (major)	154.3	74.3	68.3	95.9	130.9, 131.8, 128.8, 126.5 (s, 3 d, C_6H_5), 65.6 (t, OCH_2), 14.7 (q, CH_3)
18[b] (minor)	156.1	78.0	70.2	97.4	130.7, 132.1, 128.7, 126.8 (s, 3 d, C_6H_5), 65.8 (t, OCH_2), 14.8 (q, CH_3)
19[b]	153.0	74.7	67.7	94.4	131.0, 131.2, 129.0, 126.5 (s, 3 d, C_6H_5), 65.7 (t, OCH_2), 14.7 (q, CH_3)

Table 4 (continued)

Compound	C-3 (s)	C-4 (d)	C-5 (d)	C-6 (d)	Other Signals
20[b]	154.1	53.1	67.7	97.0	132.8, 130.6, 128.6, 126.4 (s, 3 d, C_6H_5), 65.5 (t, OCH_2), 14.5 (q, CH_3)
21a	157.9	65.5	69.0	100.7	134.1, 129.2, 128.1, 127.4 (s, 3 d, C_6H_5), 65.5 (t, OCH_2), 15.2 (q, CH_3), 0.6, 0.3 [2 q, 2 $Si(CH_3)_3$]
21e	150.8	63.4	67.8	101.4	162.5 (s, CO_2Et), 66.2, 61.9 (2 t, 2 OCH_2), 15.1, 14.1 (2 q, 2 CH_3), 0.43, 0.22 [2 q, 2 $Si(CH_3)_3$]

[a] 75.5 MHz, $CDCl_3$.
[b] Recorded on 50.3 MHz spectrometer.
[c] In acetone-d_6.
[d] Signal has double intensity.
[e] Two diastereomers (50:50).
[f] Assignment ambiguous; signals are exchangeable within the line.

MS (EI, 70 eV): m/z (%) = 299 (M^+, 11), 253 (23), 237 (27), 203 (10), 202 (74), 174 (23), 173 (50), 159 (11), 158 (57), 146 (36), 145 (91), 144 (57), 133 (14), 131 (11), 130 (23), 122 (33), 117 (24), 116 (13), 115 (44), 105 (23), 104 (69), 103 (Ph – C≡N^+, 100), 102 (18), 91 (17), 90 (10), 89 (18), 78 (10), 77 ($C_6H_5^+$, 94), 76 (25), 65 (19), 64 (SO_2^+, 9), 63 (14), 59 (24), 58 (17), 55 (14), 51 (33), 50 (13).

IR (neat): ν = 2990–2790 (C–H), 1650 (C=C), 1620 (C=N), 1080 cm^{-1} (SO_2).

Anal. calcd. for $C_{12}H_{13}NO_6S$ (299.3): C, 48.16; H, 4.37; N, 4.68; S, 10.71. Found: C, 48.37; H, 4.50; N, 4.73; S, 9.73.

r-4-Azido-*c*-6-ethoxy-*t*-5-hydroxy-3-phenyl-5,6-dihydro-4*H*-1,2-oxazine (20)

1,2-Oxazine **19** (0.024 g, 0.085 mmol) and NaN_3 (0.011 g, 0.169 mmol) were dissolved in anhyd. DMF (3 mL) and the solution was heated at 70°C for 23 h. After cooling to r.t. 25% aq H_2SO_4 solution (2.5 mL) was added and the mixture was extracted with EtOAc (2 × 10 mL). The combined organic phases was washed successively with 2N H_2SO_4 solution, H_2O, satd $NaHCO_3$ solution and brine (5 mL each), and dried (Na_2SO_4). After removal of the solvent under reduced pressure 0.017 g of a mixture of **20**/**19** (60:40) was isolated. The NMR data of **20** are given in Tables 3 and 4.

IR (KBr): ν = 3440 (br, O–H), 3000–2840 (=C–H, C–H), 2110 (N_3), 1610 cm^{-1} (C=N).

Silylation of 4,5-Dihydroxy-4*H*-1,2-oxazines; General Procedure 7

To a mixture of 1,2-oxazine **2** and hexamethyldisilazane (2.5–5 mL/mmol of 1,2-oxazine) was added TMSCl (0.25–0.5 mL/mmol of 1,2-oxazine). After heating at 100°C for 5–7 h the suspension was cooled to r.t., the volatile components were removed in vacuo (40°C/50–0.01 mbar) and the residue was purified by filtration (neutral alumina, activity III; *t*BuOMe) to give the silylated product **21**. The NMR data of **21** are given in Tables 3 and 4.

Acknowledgement

We are most grateful for generous support of this work by the Deutsche Forschungsgemeinschaft (Graduiertenkolleg: "Struktur-Eigenschafts-Beziehungen bei Heterocyclen") and the Fonds der Chemischen Industrie. We thank Robert Pulz, Ute Hain, and the late Elke Marks for experimental help.

References

(1) Homann, K. *Dissertation*, Technische Hochschule Darmstadt, 1994.
(2) Angermann, J. *Dissertation*, Technische Universität Dresden,1997.
(3) For excellent up-to-date reviews, see: Iminosugars as Glycosidase Inhibitors – Nojirimycin and Beyond; Stütz, A. E.; Ed., Wiley-VCH: Weinheim, 1999.
Bols, M. *Acc. Chem. Res.* **1998**, *31*, 1.
For recent synthetic work, see: Defoin, A.; Sarazin, H.; Sifferlen, T.; Strehler, C.; Streith, J. *Helv. Chim. Acta* **1998**, *81*, 1417.
Kieß, F.-M.; Poggendorf, P.; Picasso, S.; Jäger, V. *Chem. Commun.* **1998**, 19.
Hümmer, W.; Dubois, E.; Gracza, T.; Jäger, V. *Synthesis* **1997**, 634.
Defoin, A.; Sarazin, H.; Streith, J. *Tetrahedron* **1997**, *53*, 13769.
Defoin, A.; Sifferlen, T.; Streith, J.; Dosbaâ, I.; Foglietti, M.-J. *Tetrahedron: Asymmetry* **1997**, *8*, 363.
Streith, J.; Defoin, A. *Synlett* **1996**, 189.
(4) Homann, K.; Angermann, J.; Collas, M.; Zimmer, R.; Reissig, H.-U. *J. Prakt. Chem.* **1998**, *340*, 649.
(5) Zimmer, R.; Reissig, H.-U. *Angew. Chem.* **1988**, *100*, 1576; *Angew. Chem. Int. Ed. Engl.* **1988**, *27*, 1518.
Zimmer, R.; Reissig, H.-U. *Liebigs Ann. Chem.* **1991**, 553.
(6) Preliminary communication: Angermann, J.; Homann, K.; Reissig, H.-U.; Zimmer, R. *Synlett* **1995**, 1014.
(7) Shing, T. K. M.; Tai, V. W.-F.; Tam, E. K. W. *Angew. Chem.* **1994**, *106*, 2408; *Angew. Chem. Int. Ed. Engl.* **1994**, *33*, 2312.
Shing, T. K. M.; Tam, E. K. W.; Tai, V. W.-F.; Chung, I. H. F.; Jiang, Q. *Chem. Eur. J.* **1996**, *2*, 50.
(8) Zimmer, R.; Angermann, J.; Hain, U.; Hiller, F.; Reissig, H.-U. *Synthesis* **1997**, 1467.
(9) Kolb, H. C.; Sharpless, K. B. *Tetrahedron* **1992**, *48*, 10515.
Wang, Z.-M.; Kolb, H. C.; Sharpless, K. B. *J. Org. Chem.* **1994**, *59*, 5104.
Oikawa, M.; Wada, A.; Okazaki, F.; Kusumoto, S. *J. Org. Chem.* **1996**, *61*, 4469.
(10) Paulini, K.; Gerold, A.; Reissig, H.-U. *Liebigs Ann.* **1995**, 667.
(11) Angermann, J.; Collas, M.; Homann, K.; Reissig, H.-U. unpublished results.
(12) The NMR data do not exclude the possibility of anomerization at C-6, however, we can not see a reason why this should occur with **15f** and not with the related compounds **15a** and **15e**.
(13) Zimmer, R.; Reissig, H.-U. *J. Org. Chem.* **1992**, *57*, 339.

(14) Review: Lohray, B. B. *Synthesis* **1992**, 1035.
(15) Short reviews: Zimmer, R.; Webel, M.; Reissig, H.-U. *J. Prakt. Chem.* **1998**, *340*, 274.
Subramanian, L. R.; Garcia Martinez, A.; Hanack, M. In *Encyclopedia of Reagents for Organic Synthesis;* Paquette, L. A.; Ed., Wiley: Chichester, 1995, Vol. 6, p 3780.
(16) Homann, K.; Zimmer, R.; Reissig, H.-U., manuscript in preparation.

Article Identifier:
1437-210X,E;1999,0,07,1223,1235,ftx,en;H11298SS.pdf