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First Synthesis of Bi- and Tricyclic α,β-Unsaturated δ-Oxacaprolactams from Cyclic Imines via Ring-Closing Metathesis

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A new class of α,β-unsaturated δ-oxacaprolactams was synthesized from imines as starting material. The synthetic procedure is based on an acyl chloride addition in the first step, followed by a ring-closing metathesis using a ruthenium catalyst.

α,β-Unsaturated lactams are a very interesting class of organic molecules. A plenty of these lactams show a high bioactivity because of their characteristics as a lactam as well as a Michael acceptor. A couple of these lactams can be isolated from natural products and are known and examined for a long time.[1]

Yet unknown were the α,β-unsaturated δ-oxacaprolactams, so our aim was to design this new substance class. We chose to start with some heterocyclic imines and wanted to add unsaturated carbonic acyl chlorides followed by treatment with allyl alcohol to prepare the acrylamides.[2] Doing a ring-closing metathesis (RCM) with these acrylamides the synthetic protocol products should straightly lead to the bi- or tricyclic lactams shown in Figure 1.

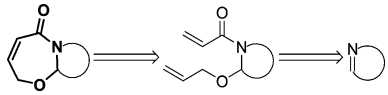

Figure 1. Retrosynthetical consideration of the target structure.

Some derivatives of α,β-unsaturated caprolactams show central nervous system activity and causes the loss of muscle control of mice.[3] Also activity against leucemia, melanoma and sarcoma cancer cells was reported.[4] Some saturated caprolactam derivatives are for example known for their cytotoxicity and the inhibition of proliferation of keratinocytes and fibroblasts[5] or antibacterial and antifungal effects.[6] Building blocks of the resulting caprolactams possess a double bond representing a useful handle for further functionalisation.

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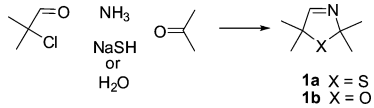
The cyclic amine parts of our lactams resulting from the imine precursors were selected because of being interesting building blocks in different applications. 3-Thiazolidine derivatives for example can be found in penicillins[7] and *Diabetes mellitus* drugs.[8] Clavulanic acid which is a strong β-lactamase inhibitor contains an 3-oxazolidine structure[7d,9] and the 1,4-benzothiazine respectively the 1,4-benzoxazine substructures are potent potassium and calcium channel openers,[10] inflammatory inhibitors[11] or antibiotica.[12]

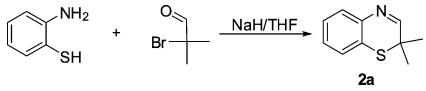
Synthesis of the Heterocyclic Imine Precursors

The used heterocyclic imines were on the one hand the monocyclic five-membered 2,5-dihydro-thiazole **1a**[13] and 2,5-dihydrooxazole **1b**,[14] which were synthesised by a modified protocol of the Asinger reaction[15] (Scheme 1) and on the other hand the bicyclic 2*H*-1,4-benzothiazine **2a** and 2*H*-1,4-benzoxazine **2b**.



Scheme 1. Synthesis of the 2,5-dihydro-thiazole **1a** and 2,5-dihydrooxazole **1b**.

The known 1,4-benzothiazine **2a** was synthesized by a modified protocol.[16] In a one-pot procedure the 2-aminothiophenol reacted with sodium hydride in THF. The resulting phenolate reacted with 2-bromo-2-methylpropanal whereupon the resulting amino aldehyde condensed in situ to give the cyclic imine (Scheme 2). The use of NaH/THF increased the yield by more than 20% compared to the described old protocol, in which the base sodium ethanolate was used.



Scheme 2. Synthesis of the 1,4-benzothiazine **2a**.

Attempts to synthesize 2,2-dimethyl-2*H*-1,4-benzoxazine (**2b**) by an analogous procedure using 2-aminophenol instead of 2-aminothiophenol failed. Instead of the benzoxazine compound **2b** we could isolate the 3,3-dimethyl-3,4-dihydro-2*H*-1,4-benzoxazine-2-ol (**3**), a stable hemiacetal (Figure 2).

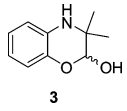
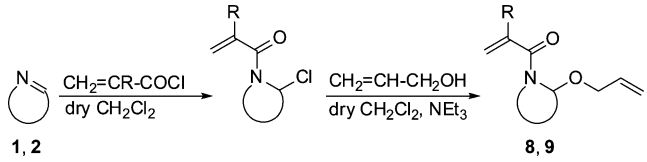


Figure 2. Hemiacetal **3**.

The preparation of compound **2b** was realized with a multistage synthetic route, based on 2-aminophenol (Scheme 3). In the first step the amino group was protected as a phthalic imide **4**. In the next step the phenolic ether **5** was synthesized by deprotonation with *t*BuOK/18-crown-6 in acetonitrile and treatment with 2-bromo-2-methylpropanal. After protecting the aldehyde with ethylene glycol as dioxolan **6** the phthalic imide was deprotected with hydrazine to get the free aniline derivative **7**. The formation of the **2b** was realised by deprotecting the aldehyde followed by the ring-closing reaction in concentrated hydrochloric acid and basifying with aqueous ammonia.

Addition of Acyl Chlorides to the Imines

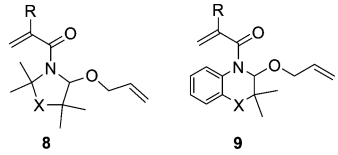
The addition of acyl chlorides to an imine was described first by Böhme and Hartke.[2a] They used some linear imines and added acyl chlorides. The resulting chlorides are not very stable so the chloride was substituted with a hydroxy or alkoxy group. This type of reaction was extended to cyclic imines by Schwarze et al.[2b] Thus, acryloyl chloride and 2-methylarcryloyl chloride, respectively, was added to the imines **1**, **2**. Without isolation of the addition product upon treatment with allyl alcohol the acrylamides **8**, **9** were obtained (Scheme 4).



Scheme 4. Formation of the acrylamides **8** and **9**.

After workup by crystallisation or column chromatography the unsaturated compounds **8a**–**d** and **9a**–**d** can be used as reaction partners for ring-closing metathesis (Table 1).

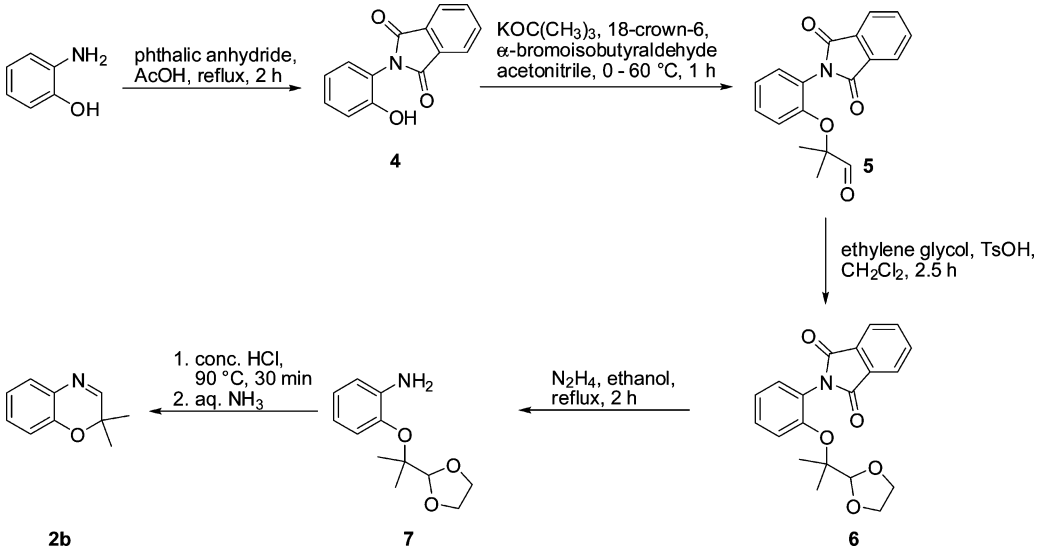
Table 1. Acrylamide precursor **8** and **9** for the RCM.



Imine	Amide	X	R	Yield [%]	Imine	Amide	X	R	Yield [%]
1a	**8a**	S	H	69	**2a**	**9a**	S	H	21
1a	**8b**	S	CH_3	83	**2a**	**9b**	S	CH_3	29
1b	**8c**	O	H	52	**2b**	**9c**	O	H	16
1b	**8d**	O	CH_3	48	**2b**	**9d**	O	CH_3	81

Ring-Closing Metathesis

The synthesis of the novel α,β-unsaturated ε-lactams **10**, **11** was finalised by ring-closing metathesis (RCM). A few



Scheme 3. New multistep synthesis of the 1,4-benzoxazine **2b**.

examples of ring-closing metathesis reactions, using acrylamides as precursors can be found in the literature.[17] The catalysts usually used were the commercially available first or second-generation Grubbs' ruthenium complexes (Figure 3).

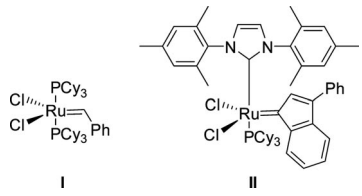


Figure 3. Used ruthenium catalysts **I** and **II**.

Inspired by a work of D'Annibale and Bassetti[18] we decided to use the inexpensive complex **I** in dichloromethane for our first attempt. Under the chosen conditions the ε-lactam **10a** was obtained with a moderate yield of 37%. Even after several modifications, for example the addition of Ti(O*i*Pr)$_4$[19] we were not able to obtain the ε-lactam **11b** based on the benzothiazine precursor **9b**. Only a mixture of isomers of the cross metathesis product **12** was received (Figure 4).

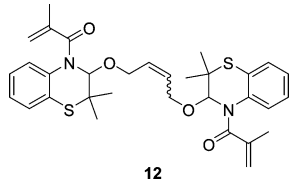
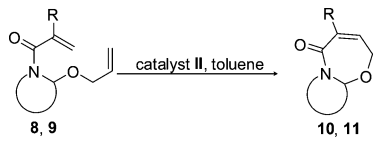


Figure 4. Cross metathesis product **12**.

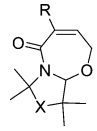
After this result we decided to change the used ruthenium complex and chose a catalyst of the second generation **II**. With this catalyst we optimised the reaction conditions for the already obtained lactam **10a** (Scheme 5). Interesting was the influence of the reaction temperature as well as the solvent. We were able to get the desired lactam **10a** (catalyst **II**: 5 mol-%, acrylamide: 0.03 M solution in CH_2Cl_2, reflux conditions) with a yield of 62%. The reaction was monitored by TLC and aborted when no more starting material **8a** was detected. Using toluene instead of dichloromethane at approximately 70 °C increased the yield to 87%.



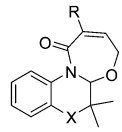
Scheme 5. Ring-closing metathesis to form lactams **10** and **11**.

With this improved reaction conditions we were able to obtain the remaining lactams **10**, **11** with good yields up to 87% (Table 2).

Table 2. α,β-Unsaturated δ-oxacaprolactams **10** and **11**.



10



11

Amide	Lactam	X	R	Yield [%]	Amide	Lactam	X	R	Yield [%]
8a	**10a**	S	H	87	**9a**	**11a**	S	H	82
8b	**10b**	S	CH_3	84	**9b**	**11b**	S	CH_3	31
8c	**10c**	O	H	64	**9c**	**11c**	O	H	82
8d	**10d**	O	CH_3	84	**9d**	**11d**	O	CH_3	77

We were able to obtain single crystals of compound **11d** and determined the proposed structure by X-ray analysis (Figure 5).[20]

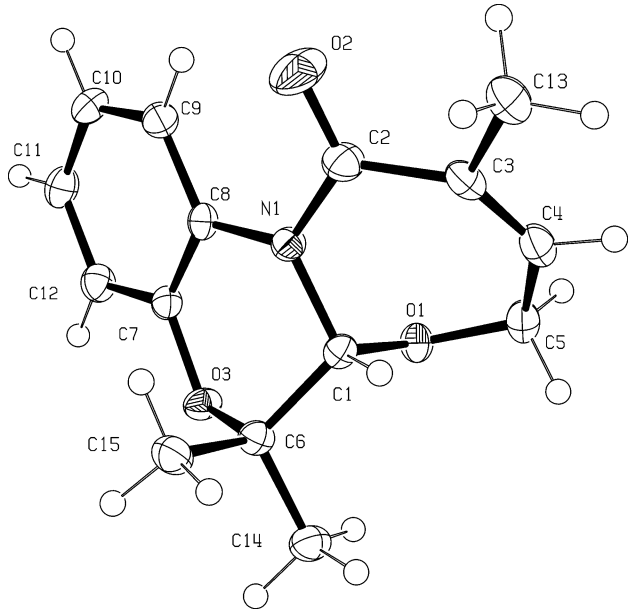


Figure 5. ORTEP representation of caprolactam **11d** in the solid state.[20]

Conclusions

Starting from imines **1**, the new class of α,β-unsaturated δ-oxacaprolactams **10**, **11** **2** can be obtained by an acyl chloride addition reaction and subsequent ring-closing metathesis. These new lactams are potentially bioactive because of their similarity to known and examined lactams (cyclic amine structures). By using ruthenium catalyst **II** in hot toluene overall yields of up to 70% referring to the starting imine could be reached. Due to the great number of known aldimines this reaction allows access to a large number of differently substituted lactams. Furthermore, the double bond in these lactams offers opportunity for further functionalisations.

Experimental Section

General Methods: Synthetic procedures, performed under argon atmosphere were performed on a vacuum line using standard Schlenk techniques. All reagents and solvents were commercial grade and were purified prior to use when necessary. Preparative column chromatography was carried out using Grace SiO_2 (0.035–0.070 mm, type KG 60). TLC was performed on Merck SiO_2 F254 plates on aluminium sheets. ^1H and ^{13}C NMR spectra were recorded with Bruker Avance DRX 500 and Avance DPX 300 spectrometers. Assignments of the signals in the ^{13}C NMR spectrum were supported by measurements applying DEPT and COSY techniques. EI-MS, CI-MS, and HRMS spectra were obtained with a Finnigan MAT 95 spectrometer. IR spectra were recorded with a Bruker Tensor 27 spectrometer equipped with a "Golden Gate" diamond-ATR unit.

2,2,5,5-Tetramethyl-2,5-dihydrothiazole (1a):[13] To a suspension of sodium hydrogen sulfide hydrate (11.58 g, 0.21 mol) in dry dichloromethane a solution of acetone (32.71 g, 0.56 mol) and 2-chloro-2-methylpropanal (20.00 g, 0.19 mol) was added under argon atmosphere. The suspension was cooled to –15 °C and gaseous ammonia was lead in for 15 min. The suspension was warmed up to room temperature and stirred for 12 h. Water (100 mL) was added and the aqueous layer was extracted with three portions of dichloromethane. The combined organic layers were dried with magnesium sulfate and the solvent was removed at the rotary evaporator. The residue was recrystallized from petroleum ether ether 40/60 and gave a colourless solid (24.74 g, 0.17 mol, 92%), m.p. 53 °C (50–52 °C).[13]

2,2,5,5-Tetramethyl-2,5-dihydrooxazole (1b):[14] To a solution of water (21.6 mL, 1.2 mol), 25% aqueous ammonia solution (90.8 mL, 1.2 mol) and acetone (88.1 mL, 1.2 mol) at 0 °C 2-chloro-2-methylpropanal (31.97 g, 0.3 mol) dissolved in dichloromethane (20 mL) was added dropwise while the temperature was not allowed to increase about 5 °C. After finished addition the solution was stirred one hour at 5 °C and overnight at room temperature.

The phases were separated and the aqueous phase was extracted with dichloromethane (3 × 30 mL). The recombined organic phases were dried with magnesium sulfate. After removal the solvent under reduced pressure, the crude product was purified by fractioning distillation (46–52 °C, 110 mbar) (117 °C, 760 Torr)[14] and obtained as colourless oil (17.17 g, 0.14 mol, 45%).

2,2-Dimethyl-2*H*-1,4-benzothiazine (2a):[16] Under argon atmosphere, to a suspension of sodium hydride (2.00 g, 50.00 mmol, 60% in oil) in anhydrous THF (70 mL) a solution of 2-aminothiophenol (6.00 g, 48.00 mmol) in anhydrous THF (20 mL) was added via a syringe at 0 °C. The resulted foamy white/violet coloured reaction mixture (a very effective stirrer bar was needed!) was stirred for 2 h at room temperature. The 2-bromo-2-methylpropanal (7.62 g, 50.50 mmol), solved in anhydrous THF (15 mL) was added dropwise. After the addition has been finished, molecular sieves was added and the reaction mixture was stirred overnight.

The mixture was filtered through celite and the solvent was removed on a rotary evaporator. The crude product was distilled with a kugelrohr distillation apparatus. The product was obtained at 140 °C (0.14 mbar) (63–65 °C, 0.01 mbar).[16] For further cleaning the benzothiazine **2a** was crystallized from petroleum ether/diethyl ether 40/60 (5.69 g, 32.10 mmol, 67%), m.p. 57–59 °C.

2,2-Dimethyl-2*H*-1,4-benzoxazine (2b): To phenylamine **7** (5.22 g, 23.40 mmol) was added concentrated HCl (30 mL) and heated to 90 °C and stirred for 30 min. The solution was poured in aqueous ammonia (100 mL, 25%). The reaction mixture was extracted with dichloromethane, the organic phase was washed with water and dried with magnesium sulfate. The solvent was removed and the residue was distilled in a kugelrohr apparatus (60 °C, 0.13 mbar). The product was obtained as a colourless solid (1.95 g, 12.10 mmol, 52%), m.p. 35–36 °C. ^1H NMR (500 MHz, $CDCl_3$): δ = 1.44 (s, 6 H, 2 × CH_3), 6.81 (dd, ^3J = 7.9, ^4J = 1.0 Hz, 1 H, *o*-$CH_{Ar}O$), 6.94 (ddd, ^3J = 7.6, ^3J = 7.4, ^4J = 1.0 Hz, 1 H, *p*-$CH_{Ar}O$), 7.13 (ddd, ^3J = 7.9, ^3J = 7.8, ^4J = 1.5 Hz, 1 H, *p*-$CH_{Ar}N$), 7.31 (dd, ^3J = 7.7, ^4J = 1.4 Hz, 1 H, *o*-$CH_{Ar}N$), 7.43 (s, 1 H, NCH) ppm. ^{13}C NMR (126 MHz, $CDCl_3$): δ = 24.37 (2 × CH_3), 72.55 [$C(CH_3)_2$], 116.49 (*o*-$CH_{Ar}O$), 121.60 (*p*-$CH_{Ar}O$), 127.34 (*o*-$CH_{Ar}N$), 129.26 (*p*-$CH_{Ar}N$), 131.54 (C_{Ar}-N), 146.04 ($C_{Ar}O$), 161.28 (CN) ppm. IR: $\tilde{\nu}$ = 2977, 2929, 756 cm^{-1}. MS (CI, isobutane): *m*/*z* (%) = 162.1 (100) $[MH]^+$. HRMS (CI, isobutane): calcd. for $[C_{10}H_{12}NO]^+$: 162.0932, found 162.0919.

3,3-Dimethyl-3,4-dihydro-2*H*-1,4-benzoxazine-2-ol (3): Under argon atmosphere, to a suspension of sodium hydride (2.00 g, 50.00 mmol, 60% in oil) in anhydrous THF (70 mL) a solution of 2-aminophenol (5.24 g, 48.00 mmol) in anhydrous THF (20 mL) was added via a syringe at 0 °C. The resulted violet coloured reaction mixture was stirred for 18 h at room temperature. The 2-bromo-2-methylpropanal (7.62 g, 50.50 mmol), solved in anhydrous THF (15 mL) was added dropwise. After the addition has been finished, molecular sieves was added and the reaction mixture was stirred overnight. The mixture was filtered through celite and the solvent was removed on a rotary evaporator. The crude product was purified by column chromatography on silica gel (solvent: *n*-hexane/ethyl acetate, 3:1, R_f = 0.23). The product was obtained as a colourless solid (1.79 g, 10.0 mmol, 21%), m.p. 82–83 °C. ^1H NMR (500 MHz, $CDCl_3$): δ = 1.18 (s, 3 H, CH_3), 1.26 (s, 3 H, CH_3), 3.38 (br. s, 2 H, NH, OH), 5.05 (s, 1 H, CH), 6.63 (dd, ^3J = 7.5, ^4J = 1.7 Hz, 1 H, *o*-$CH_{Ar}O$), 6.75 (ddd, ^3J = 7.5, ^3J = 7.5, ^4J = 1.8 Hz, 1 H, *p*-$CH_{Ar}N$), 6.81 (dd, ^3J = 7.5, ^4J = 1.8 Hz, 1 H, *o*-$CH_{Ar}N$), 6.85 (ddd, ^3J = 7.5, ^3J = 7.5, ^4J = 1.8 Hz, 1 H, *p*-$CH_{Ar}O$) ppm. ^{13}C NMR (126 MHz, $CDCl_3$): δ = 24.04 (CH_3), 24.53 (CH_3), 51.20 [$C(CH_3)_2$], 95.11 (COH), 115.81, 117.37, 120.09, 121.81, 131.05, 140.29 (C_{Ar}) ppm. IR: $\tilde{\nu}$ = 3415, 3325, 3273, 2983, 1254, 741 cm^{-1}. MS (CI, isobutane): *m*/*z* (%) = 180.0 (100) $[MH]^+$. HRMS (EI): calcd. for $C_{10}H_{13}NO_2$: 179.0946, found 179.0945.

2-(2-Hydroxyphenyl)isoindole-1,3-dione (4):[21] A mixture of 2-aminophenol (4.80 g, 44.00 mmol) and phthalic anhydride (6.52 g, 44.00 mmol) in acetic acid (100 mL) was refluxed for two hours and put in cooled water. The suspension was filtered and the aqueous filtrate was extracted with chloroform. The organic phase was dried with magnesium sulfate and the solvent was removed. The residue and the solid, achieved by filtration, was used in further steps without further purification (7.80 g, 33.00 mmol, 74%), m.p. 187–230 °C (238–240 °C).[21]

2-[2-(1,3-Dioxo-1,3-dihydroisoindole-2-yl)phenoxy]-2-methylpropionaldehyde (5): A solution of dione **4** (1.19 g, 5.00 mmol) in anhydrous acetonitrile (50 mL) was cooled to 0 °C. *t*BuOK (0.62 g, 5.55 mmol) was added in small amounts and stirred, while the reaction mixture was warmed up to room temperature. 18-crown-6 (1.32 g, 5.00 mmol) was added. The reaction mixture was allowed to stir for 15 min at room temperature and was then promptly taken to 0 °C. Freshly prepared solution of 2-bromo-2-methylpropanal (1.15 g, 7.60 mmol) in acetonitrile (20 mL) was added dropwise. The reaction was then brought to room temperature and subsequently heated to 60 °C for 1 h. The reaction mixture was cooled down to room temperature and then diluted in 300 mL diethyl

ether. The organic phase was washed with water and brine. The ether layer was dried with magnesium sulfate, filtered, and concentrated in vacuo. The crude product was purified by column chromatography on silica gel (solvent: *n*-hexane/ethyl acetate, 1:1, R_f = 0.60) and obtained as colourless crystals (0.30 g, 1.00 mmol, 19%). ^{1}H NMR (500 MHz, $CDCl_3$): δ = 1.33 (s, 6 H, 2×CH_3), 6.82 (dd, ^3J = 8.2, ^4J = 0.8 Hz, 1 H, H_{Ar}), 7.10 (ddd, ^3J = 8.0, ^3J = 7.8, ^4J = 1.2 Hz, 1 H, H_{Ar}), 7.21–7.34 (m, 2 H, H_{Ar}), 7.72–7.78 (m, 2 H, H_{Phth}), 7.88–7.94 (m, 2 H, H_{Phth}), 9.71 (s, 1 H, COH) ppm. ^{13}C NMR (126 MHz, $CDCl_3$): δ = 21.69 (2×CH_3), 84.06 [$C(CH_3)_2$], 117.57, 122.58, 123.15, 123.65, 130.08, 130.47, 132.09, 134.26, 151.50 (C_{Ar}), 167.16 (CO), 202.79 (COH) ppm. IR: $\tilde{\nu}$ = 2926, 2834, 1737, 1734, 1714, 1497 cm^{-1}. MS (CI, isobutane): *m*/*z* (%) = 310.1 (100) $[MH]^+$. HRMS (CI, isobutane): calcd. for $[C_{18}H_{16}NO_4]^+$: 310.1074, found 310.1081.

2-[2-(1-(1,3-Dioxolan-2-yl)-1-methylethoxy)phenyl]isoindole-1,3-dione (6): A solution of aldehyde **5** (260 mg, 0.840 mmol), ethylene glycol (57 mg, 0.930 mmol) and a catalytic amount of *p*-toluenesulfonic acid in dichloromethane was refluxed for 2.5 h in a Dean trap. The reaction mixture was cooled down to room temperature and washed with a saturated solution of sodium hydrogen carbonate, saturated sodium hydrogen sulfite and water. The organic layer was dried with magnesium sulfate and the solvent was removed. The obtained product was obtained as colourless crystals without further purification (280 mg, 0.790 mmol, 94%), m.p. 133–151 °C. ^{1}H NMR (500 MHz, $CDCl_3$): δ = 1.17 (s, 6 H, 2×CH_3), 3.48–3.64 (m, 4 H, O-CH_2-CH_2-O), 4.66 (s, 1 H, CH), 7.15–7.42 (m, 4 H, H_{Ar}), 7.72–7.79 (m, 2 H, H_{Phth}), 7.90–7.97 (m, 2 H, $_{Phth}$) ppm. ^{13}C NMR (126 MHz, $CDCl_3$): δ = 21.56 (2×CH_3), 65.17 (2×CH_2), 82.66 [$C(CH_3)_2$], 106.60 (CH), 123.30, 123.82, 124.24, 126.26, 129.70, 129.81, 132.65, 133.75, 151.80 (C_{Ar}), 167.29 (CO) ppm. IR: $\tilde{\nu}$ = 1734, 1713, 1500, 1463, 764, 749 cm^{-1}. MS (CI, isobutane): *m*/*z* (%) = 354.2 (100) $[MH]^+$. HRMS (EI): calcd. for $C_{20}H_{19}NO_5$: 353.1263, found 353.1263.

2-[1-(1,3-Dioxolan-2-yl)-1-methylethoxy]phenylamine (7): A solution of dioxolan **6** (110 mg, 0.310 mmol) and hydrazine hydrate (20 mg, 0.310 mmol, 80%) in ethanol (20 mL) was refluxed for 2 h. The reaction mixture was cooled down to room temperature and the mixture was filtered through celite. The solvent was removed and the crude product was purified by column chromatography on silica gel (solvent: *n*-hexane/ethyl acetate, 7:3, R_f = 0.27) and obtained as a red oil (62 mg, 0.280 mmol, 91%).^{1}H NMR (500 MHz, $CDCl_3$): δ = 1.30 (s, 6 H, 2×CH_3), 3.95–4.09 (m, 6 H, 2×CH_2, NH_2), 4.95 (s, 1 H, CHO_2), 6.62 (ddd, ^3J = 7.6, ^3J = 7.6, ^4J = 1.3 Hz, 1 H, *p*-$CH_{Ar}O$), 6.71 (dd, ^3J = 7.9, ^4J = 1.3 Hz, 1 H, *o*-$CH_{Ar}O$), 6.89 (ddd, ^3J = 7.7, ^3J = 7.5, ^4J = 1.3 Hz, 1 H, *p*-$CH_{Ar}NH_2$), 6.96 (dd, ^3J = 7.9, ^4J = 1.0 Hz, 1 H, *o*-$CH_{Ar}NH_2$) ppm. ^{13}C NMR (126 MHz, $CDCl_3$): δ = 21.36 (2×CH_3), 65.65 (2×CH_2), 81.92 [$C(CH_3)_2$], 107.35 (CH), 115.76 (*o*-$CH_{Ar}O$), 117.74 (*p*-$CH_{Ar}O$), 123.75 (*o*-$CH_{Ar}NH_2$), 124.39 (*p*-$CH_{Ar}NH_2$), 141.75 ($C_{Ar}O$) ppm. IR: $\tilde{\nu}$ = 3466, 3367, 2981, 2884, 1113, 733 cm^{-1}. MS (CI, isobutane): *m*/*z* (%) = 224.2 (100) $[MH]^+$. HRMS (CI, isobutane): calcd. for $[C_{12}H_{18}NO_3]^+$: 224.1281, found 224.1285.

General Procedure (GP A): Under argon atmosphere one equivalent of the respective imine dissolved in anhydrous dichloromethane was cooled down to 0–5 °C before 1.1 equiv. of the acyl chloride was added dropwise. After stirring for three hours at room temperature 3.7 equiv. of the respective alcohol and 1.75 equiv. anhydrous triethylamine in anhydrous dichloromethane were added dropwise at 0–5 °C. After stirring one hour at room temperature, the solution was poured in ice-water. The phases were separated and the aqueous phase was extracted with dichloromethane three times. The recombined organic phases were washed with saturated sodium hydrogen carbonate solution once, with water twice and dried with magnesium sulfate. The solvent was removed under reduced pressure. The purification of the crude product is described in the experiments.

1-(4-Allyloxy-2,2,5,5-tetramethylthiazolidin-3-yl)propenone (8a): Following **GP A**, dihydro-thiazole **1a** (3.50 g, 24.40 mmol), acryloyl chloride (2.21 g, 24.40 mmol), allyl alcohol (5.31 g, 91.50 mmol) and triethylamine (4.32 g, 42.70 mmol) were used. The crude product was dissolved in a small portion of dichloromethane and *n*-hexane was added dropwise until a stable clouding remained. At –30 °C the product was received as a colourless solid (4.30 g, 16.80 mmol, 69%), m.p. 185–210 °C. ^{1}H NMR (500 MHz, $CDCl_3$): δ = 1.39 [s, 3 H, SC(CH_3)$_2$CH], 1.47 [s, 3 H, SC(CH_3)$_2$CH], 1.82 [s, 3 H, SC(CH_3)$_2$N], 1.93 [s, 3 H, SC(CH_3)$_2$N], 3.90 (dd, ^2J = 12.5, ^3J = 3.7 Hz, 1 H, OCH_2CH=CH_2), 4.07 (dd, ^2J = 12.5, ^3J = 3.3 Hz, 1 H, OCH_2CH=CH_2), 5.11 (br. s, 1 H, NCH), 5.15 (dd, ^2J = n.a., ^3J = 10.5 Hz, 1 H, OCH_2CH=CH_2), 5.26 (dd, ^2J = n.a., ^3J = 17.2 Hz, 1 H, OCH_2CH=CH_2), 5.69 (dd, ^2J = n.a., ^3J = 10.4 Hz, 1 H, COCH=CH_2), 5.78–5.87 (m, 1 H, OCH_2CH=CH_2), 6.32 (dd, ^2J = n.a., ^3J = 16.6 Hz, 1 H, COCH=CH_2), 6.52 (dd, ^3J = 10.4, ^3J = 16.6 Hz, 1 H, COCH=CH_2) ppm. ^{13}C NMR (126 MHz, $CDCl_3$): δ = 23.22 [SC(CH_3)$_2$CH], 30.97 [SC(CH_3)$_2$N], 52.52 [SC(CH_3)$_2$CH], 67.61 (OCH_2CH=CH_2), 72.35 [SC(CH_3)$_2$N], 96.68 (NCH), 117.04 (OCH_2CH=CH_2), 128.37 (COCH=CH_2), 130.24 (COCH=CH_2), 133.66 (OCH_2CH=CH_2), 165.46 (CO) ppm. IR: $\tilde{\nu}$ = 2961, 2923, 2854, 1651, 1447, 1377, 1061 cm^{-1}. MS (CI, isobutane): *m*/*z* (%) = 256.0 (100) $[MH]^+$. HRMS (CI, isobutane): *m*/*z* calcd. for $[C_{13}H_{22}NO_2S]^+$: 256.1371, found 256.1372.

1-(4-Allyloxy-2,2,5,5-tetramethylthiazolidin-3-yl)-2-methylpropenone (8b): Following **GP A**, dihydro-thiazole **1a** (1.00 g, 7.00 mmol), 2-methylacryloyl chloride (0.73 g, 7.00 mmol), allyl alcohol (1.52 g, 26.20 mmol) and triethylamine (1.24 g, 12.20 mmol) were used. The crude product was crystallized from methanol at –30 °C and gave a light yellow solid (1.57 g, 5.80 mmol, 83%) which melted during warming up to room temperature. ^{1}H NMR (500 MHz, $CDCl_3$): δ = 1.35 [s, 3 H, SC(CH_3)$_2$CH], 1.50 [s, 3 H, SC(CH_3)$_2$CH], 1.80 [s, 3 H, SC(CH_3)$_2$N], 1.87 [s, 3 H, SC(CH_3)$_2$N], 1.95 [s, 3 H, COC(CH_3)=CH_2], 3.80 (dd, ^2J = 12.5, ^3J = 4.9 Hz, 1 H, OCH_2CH=CH_2), 3.99 (dd, ^2J = 12.5, ^3J = 4.1 Hz, 1 H, OCH_2CH=CH_2), 5.10–5.13 [m, 2 H, OCH_2CH=CH_2, COC(CH_3)=CH_2], 5.22–5.26 [m, 3 H, NCH, OCH_2CH=CH_2, COC(CH_3)=CH_2], 5.77–5.85 (m, 1 H, OCH_2CH=CH_2) ppm. ^{13}C NMR (126 MHz, $CDCl_3$): δ = 20.45 [COC(CH_3)=CH_2], 23.19 [SC(CH_3)$_2$CH], 30.86 [SC(CH_3)$_2$CH], 31.32 [SC(CH_3)$_2$N], 31.45 [SC(CH_3)$_2$N], 52.71 [SC(CH_3)$_2$CH], 68.13 (OCH_2CH=CH_2), 71.75 [SC(CH_3)$_2$N], 98.56 (NCH), 116.69, 117.74 [OCH_2CH=CH_2, COC(CH_3)=CH_2], 133.39 (OCH_2CH=CH_2), 141.85 [COC(CH_3)=CH_2], 171.16 (CO) ppm. IR: $\tilde{\nu}$ = 3085, 2978, 2930, 2964, 1650, 1628, 1385, 1375, 1356, 1062 cm^{-1}. MS (CI, isobutane): *m*/*z* (%) = 269.9 (100) $[MH]^+$. HRMS (CI, isobutane): *m*/*z* calcd. for $[C_{14}H_{24}NO_2S]^+$: 270.1528, found 270.1530.

1-(4-Allyloxy-2,2,5,5-tetramethyloxazolidin-3-yl)propenone (8c): Following **GP A**, dihydrooxazole **1b** (636 mg, 5.000 mmol), acryloyl chloride (498 mg, 5.500 mmol), allyl alcohol (1.074 mg, 18.500 mmol) und triethylamine (885 mg, 8.750 mmol) were used. The crude product was purified by column chromatography on silica gel (solvent: *n*-hexane/ethyl acetate, 7:3, R_f = 0.56) and obtained as colourless oil (620 mg, 2.591 mmol, 52%). ^{1}H NMR (500 MHz, $CDCl_3$): δ = 1.29 [s, 3 H, OC(CH_3)$_2$CH], 1.36 [s, 3 H, OC(CH_3)$_2$-CH], 1.61 [s, 3 H, OC(CH_3)$_2$N], 1.67 [s, 3 H, OC(CH_3)$_2$N], 4.01 (br.

s, 2 H, $OCH_2CH=CH_2$), 4.92 (s, 1 H, NCH), 5.16 (d, ^3J = 10.3 Hz, 1 H, $OCH_2CH=CH_2$), 5.27 (dd, ^2J = 1.6, ^3J = 17.1 Hz, 1 H, $OCH_2CH=CH_2$), 5.72 (dd, ^2J = 2.0, ^3J = 10.0 Hz, 1 H, $COCH=CH_2$), 5.81–5.90 (m, 1 H, $OCH_2CH=CH_2$), 6.41 (dd, ^2J = 2.0, ^3J = 16.8 Hz, 1 H, $COCH=CH_2$), 6.48 (dd, ^3J = 10.0, ^3J = 16.8 Hz, 1 H, $COCH=CH_2$) ppm. ^{13}C NMR (126 MHz, $CDCl_3$): δ = 22.94 (CH_3) 27.48 (CH_3), 27.62 (CH_3), 27.83 (CH_3), 68.88 ($OCH_2CH=CH_2$), 81.74 [$OC(CH_3)_2CH$], 91.43 (NCH), 95.48 [$OC(CH_3)_2N$], 116.86 ($OCH_2CH=CH_2$), 128.53 ($COCH=CH_2$), 129.12 ($COCH=CH_2$), 133.56 ($OCH_2CH=CH_2$), 164.02 (CO) ppm. IR: $\tilde{\nu}$ = 2983, 2937, 1659, 1416, 1068 cm^{-1}. MS (CI, isobutane): *m*/*z* (%) = 240.1 (79) $[MH]^+$, 182.1 (100) $[M - OCH_2CHCH_2]^+$. HRMS (CI, isobutane): *m*/*z* calcd. for $[C_{13}H_{22}NO_3]^+$: 240.1600, found 240.1601.

1-(4-Allyloxy-2,2,5,5-tetramethyloxazolidin-3-yl)-2-methylpropenone (8d): Following **GP A**, dihydrooxazole **1b** (636 mg, 5.000 mmol), 2-methylacryloyl chloride (575 mg, 5.500 mmol), allyl alcohol (1.074 mg, 18.500 mmol) und triethylamine (885 mg, 8.750 mmol) were used. The crude product was purified by column chromatography on silica gel (solvent: *n*-hexane/ethyl acetate, 7:3, R_f = 0.67) and obtained as colourless solid (610 mg, 2.408 mmol, 48%), m.p. 45–47 °C. ^{1}H NMR (500 MHz, $CDCl_3$): δ = 1.31 [s, 3 H, $OC(CH_3)_2CH$], 1.33 [s, 3 H, $OC(CH_3)_2CH$], 1.61 [s, 3 H, $OC(CH_3)_2N$], 1.64 [s, 3 H, $OC(CH_3)_2N$], 1.98 [s, 3 H, $C(CH_3)=CH_2$], 3.89 (dd, ^2J = 12.2, ^3J = 5.0 Hz, 1 H, $OCH_2CH=CH_2$), 3.95 (dd, ^2J = 12.2, ^3J = 4.2 Hz, 1 H, $OCH_2CH=CH_2$), 5.05 (br. s, 1 H, NCH), 5.13–5.14 [m, 2 H, $OCH_2CH=CH_2$, $COC(CH_3)=CH_2$], 5.24–5.27 [m, 2 H, $OCH_2CH=CH_2$, $COC(CH_3)=CH_2$], 5.80–5.88 (m, 1 H, $OCH_2CH=CH_2$) ppm. ^{13}C NMR (126 MHz, $CDCl_3$): δ = 20.29 [$C(CH_3)CH_2$], 22.80 (CH_3), 27.48 (CH_3), 69.38 ($OCH_2CH=CH_2$), 81.39 [$OC(CH_3)_2CH$], 93.17 (NCH), 95.01 [$OC(CH_3)_2N$], 116.55 [$OCH_2CH=CH_2$, $COC(CH_3)=CH_2$], 133.63 ($OCH_2CH=CH_2$), 141.76 [$COC(CH_3)=CH_2$], 170.61 (CO) ppm. IR: $\tilde{\nu}$ = 2989, 2941, 1646, 1619, 1367, 1063 cm^{-1}. MS (CI, isobutane): *m*/*z* (%) = 254.1 (100) $[MH]^+$, 196.1 (59) $[M - OCH_2CHCH_2]^+$. HRMS (CI, isobutane): *m*/*z* calcd. for $[C_{14}H_{24}NO_3]^+$: 254.1756, found 254.1757.

1-(3-Allyloxy-2,2-dimethyl-2,3-dihydro-1,4-benzothiazine-4-yl)propenone (9a): Following **GP A**, benzothiazine **2a** (500 mg, 2.820 mmol), acryloyl chloride (280 mg, 3.100 mmol), allyl alcohol (610 mg, 10.440 mmol) and triethylamine (500 mg, 4.900 mmol) were used. The crude product was purified by column chromatography on silica gel (solvent: dichloromethane, R_f = 0.58) and obtained as a colourless solid (170 mg, 0.590 mmol, 21%), m.p. 56 °C. ^{1}H NMR (500 MHz, $CDCl_3$): δ = 1.37 (s, 3 H, CH_3), 1.47 (s, 3 H, CH_3), 3.95–4.01 (m, 2 H, $OCH_2CH=CH_2$), 5.12 (dd, ^2J = 10.4, ^3J = 1.1 Hz, 1 H, $OCH_2CH=CH_2$), 5.22–5.28 (m, 1 H, $OCH_2CH=CH_2$), 5.72–5.80 (m, 2 H, $COCH=CH_2$, $OCH_2CH=CH_2$), 5.73 (s, 1 H, NCH), 6.41–6.53 (m, 2 H, $COCH=CH_2$), 6.94–6.97 (m, 1 H, *o*-$CH_{Ar}N$), 6.99 (ddd, ^3J = 7.5, ^3J = 7.1, ^4J = 1.4 Hz, 1 H, *p*-$CH_{Ar}S$), 7.00 (ddd, ^3J = 7.6, ^3J = 7.9, ^4J = 1.5 Hz, 1 H, *p*-$CH_{Ar}N$), 7.07 (dd, ^3J = 7.9, ^4J = 1.1 Hz, 1 H, *o*-$CH_{Ar}S$) ppm. ^{13}C NMR (126 MHz, $CDCl_3$): δ = 25.94 (CH_3), 30.41 (CH_3), 47.71 [$C(CH_3)_2$], 68.72 ($OCH_2CH=CH_2$), 82.35 (NCH), 117.98 ($OCH_2CH=CH_2$), 123.59 (*p*-$C_{Ar}N$), 125.66 (*p*-$C_{Ar}S$), 126.13 (*o*-$C_{Ar}S$), 126.65 (*o*-$C_{Ar}N$), 128.80 ($C_{Ar}S$), 129.27 ($COCH=CH_2$), 129.54 ($COCH=CH_2$), 130.82 ($C_{Ar}N$), 133.42 ($OCH_2CH=CH_2$), 166.17 (CO) ppm. IR: $\tilde{\nu}$ = 3071, 2967, 2932, 2867, 1651, 1475, 1233, 731 cm^{-1}. MS (CI, isobutane): *m*/*z* (%) = 290.1 (10) $[MH]^+$, 232.0 (100) $[M - OCH_3]^+$. HRMS (EI): calcd. for $C_{16}H_{19}NO_2S$: 289.1136, found 289.1137.

1-(3-Allyloxy-2,2-dimethyl-2,3-dihydro-1,4-benzothiazine-4-yl)-2-methylpropenone (9b): Following **GP A**, benzothiazine **2a** (500 mg, 2.820 mmol), 2-methylacryloyl chloride (320 mg, 3.100 mmol), allyl alcohol (610 mg, 10.440 mmol) and triethylamine (500 mg, 4.900 mmol) were used. The crude product was purified by column chromatography on silica gel (solvent: *n*-hexane/ethyl acetate, 7:3, R_f = 0.57) and obtained as a colourless solid (250 mg, 0.820 mmol, 29%), m.p. 98 °C. ^{1}H NMR (500 MHz, $CDCl_3$): δ = 1.47 (s, 3 H, CH_3), 1.49 (s, 3 H, CH_3), 1.86–1.87 [m, 3 H, $COC(CH_3)=CH_2$], 3.88–3.89 (m, 2 H, $OCH_2CH=CH_2$), 5.09–5.13 (m, 1 H, $OCH_2CH=CH_2$), 5.18–5.23 (m, 1 H, $OCH_2CH=CH_2$), 5.25–5.27 [m, 1 H, $COC(CH_3)=CH_2$], 5.28–5.29 [m, 1 H, $COC(CH_3)=CH_2$], 5.71–5.80 (m, 1 H, $OCH_2CH=CH_2$), 5.87 (s, 1 H, NCH), 6.91 (m, 2 H, CH_{Ar}), 6.99–7.04 (m, 1 H, CH_{Ar}), 7.08–7.11 (m, 1 H, CH_{Ar}) ppm. ^{13}C NMR (126 MHz, $CDCl_3$): δ = 19.53 [$COC(CH_3)=CH_2$], 26.42 (CH_3), 30.98 (CH_3), 48.75 [$C(CH_3)_2$], 68.70 ($OCH_2CH=CH_2$), 82.52 (NCH), 117.79 ($OCH_2CH=CH_2$), 121.80 [$COC(CH_3)=CH_2$], 123.53, 125.31, 125.82, 125.83 (CH_{Ar}), 128.26 ($C_{Ar}S$), 132.40 ($C_{Ar}N$), 133.44 ($OCH_2CH=CH_2$), 140.33 [$COC(CH_3)=CH_2$], 171.39 (CO) ppm. IR: $\tilde{\nu}$ = 3072, 2964, 2920, 1649, 1477, 1260, 756 cm^{-1}. MS (CI, isobutane): *m*/*z* (%) = 303.1 (10) $[MH]^+$, 246.0 (100) $[M - OCH_3]^+$. HRMS (EI): calcd. for $C_{17}H_{21}NO_2S$: 303.1293, found 303.1294.

1-(3-Allyloxy-2,2-dimethyl-2,3-dihydro-1,4-benzoxazine-4-yl)propenone (9c): Following **GP A**, benzoxazine **2b** (117 mg, 0.727 mmol), acryloyl chloride (72 mg, 0.799 mmol), allyl alcohol (156 mg, 2.690 mmol) and triethylamine (129 mg, 1.270 mmol) were used. The crude product was purified by column chromatography on silica gel (solvent: dichloromethane, R_f = 0.52) and obtained as a colourless oil (31 mg, 0.114 mmol, 16%). ^{1}H NMR (500 MHz, $CDCl_3$): δ = 1.18 (s, 3 H, CH_3), 1.52 (s, 3 H, CH_3), 4.03–4.12 (m, 2 H, $OCH_2CH=CH_2$), 5.11–5.14 (m, 1 H, $OCH_2CH=CH_2$), 5.21–5.26 (m, 1 H, $OCH_2CH=CH_2$), 5.67 (br. s, 1 H, NCH), 5.76–5.84 (m, 1 H, $OCH_2CH=CH_2$), 5.83 (dd, ^2J = 1.8, ^3J = 10.3 Hz, 1 H, $COCH=CH_2$), 6.54 (dd, ^2J = 1.8, ^3J = 16.8 Hz, 1 H, $COCH=CH_2$), 6.69 (dd, ^3J = 10.3, ^3J = 16.8 Hz, 1 H, $COCH=CH_2$), 6.85–6.89 (m, 1 H, *p*-$CH_{Ar}O$), 6.91 (dd, ^3J = 8.2, ^4J = 1.2 Hz, 1 H, *o*-$CH_{Ar}O$), 6.99–7.06 (m, 1 H, *p*-$CH_{Ar}N$), 7.07–7.11 (m, 1 H, *o*-$CH_{Ar}N$) ppm. ^{13}C NMR (126 MHz, $CDCl_3$): δ = 24.17 (CH_3), 24.43 (CH_3), 68.23 ($OCH_2CH=CH_2$), 77.17 [$C(CH_3)_2$], 80.56 (NCH), 117.44 (*o*-$CH_{Ar}O$), 117.59 ($OCH_2CH=CH_2$), 119.77 (*p*-$CH_{Ar}O$), 121.24 ($C_{Ar}N$), 124.46 (*o*-$CH_{Ar}N$), 126.32 (*p*-$CH_{Ar}N$), 128.99 ($COCH=CH_2$), 129.88 ($COCH=CH_2$), 133.77 ($OCH_2CH=CH_2$), 146.04 ($C_{Ar}O$), 165.32 (CO) ppm. IR: $\tilde{\nu}$ = 3063, 2979, 2935, 1658, 1493, 1261, 749 cm^{-1}. MS (CI, isobutane): *m*/*z* (%) = 274.1 (100) $[MH]^+$. HRMS (EI): calcd. for $[C_{16}H_{19}NO_3]$: 273.1365, found 273.1366.

1-(3-Allyloxy-2,2-dimethyl-2,3-dihydro-1,4-benzoxazine-4-yl)-2-methylpropenone (9d): Following **GP A**, benzoxazine **2b** (94 mg, 0.584 mmol), 2-methylacryloyl chloride (67 mg, 0.642 mmol), allyl alcohol (126 mg, 2.160 mmol) and triethylamine (103 mg, 1.020 mmol) were used. The crude product was purified by column chromatography on silica gel (solvent: *n*-hexane/ethyl acetate, 7:3, R_f = 0.55) and obtained as a colourless oil (135 mg, 0.470 mmol, 81%). ^{1}H NMR (500 MHz, $CDCl_3$): δ = 1.27 (s, 3 H, CH_3), 1.52 (s, 3 H, CH_3), 1.96 [s, 3 H, $COC(CH_3)=CH_2$], 4.04–4.14 (m, 2 H, $OCH_2CH=CH_2$), 5.09–5.13 (m, 1 H, $OCH_2CH=CH_2$), 5.20–5.25 (m, 1 H, $OCH_2CH=CH_2$), 5.32–5.34 [m, 1 H, $COC(CH_3)=CH_2$], 5.37–5.38 [m, 1 H, $COC(CH_3)=CH_2$], 5.62 (s, 1 H, NCH), 5.75–5.84 (m, 1 H, $OCH_2CH=CH_2$), 6.79 (ddd, ^3J = 7.8, ^3J = 7.4, ^4J = 1.3 Hz, 1 H, *p*-$CH_{Ar}O$), 6.88 (dd, ^3J = 8.2, ^4J = 1.3 Hz, 1 H, *o*-$CH_{Ar}O$), 7.04 (ddd, ^3J = 7.1, ^3J = 8.1, ^4J = 1.6 Hz, 1 H, *p*-$CH_{Ar}N$), 7.12 (d, ^3J = 7.9 Hz, 1 H, *o*-$CH_{Ar}N$) ppm. ^{13}C NMR (126 MHz, $CDCl_3$): δ = 19.82 [$COC(CH_3)=CH_2$], 24.53 (CH_3), 24.92 (CH_3), 68.80 ($OCH_2CH=CH_2$), 77.41 [$C(CH_3)_2$], 80.37 (NCH), 117.29 (*o*-

$CH_{Ar}O$), 117.31 ($OCH_2CH=CH_2$), 119.61 (*p*-$CH_{Ar}O$), 120.91 [$COC(CH_3)=CH_2$], 121.95 ($C_{Ar}N$), 123.50 (*o*-$CH_{Ar}N$), 125.86 (*p*-$CH_{Ar}N$), 133.92 ($OCH_2CH=CH_2$), 140.51 [$COC(CH_3)=CH_2$], 145.34 ($C_{Ar}O$), 170.21 (CO) ppm. IR: ṽ = 3065, 2981, 1651, 1494, 1259, 738 cm^{-1}. MS (CI, isobutane): *m*/*z* (%) = 288.1 (100) $[MH]^+$. HRMS (CI, isobutane): calcd. for $[C_{17}H_{21}NO_3]^+$: 287.1521, found 287.1520.

General Procedure (GP B): One equivalent of the acrylamides synthesized according to **GP A** and 0.05 equiv. of the ruthenium catalyst **II** in toluene (10 mL) were slowly heated to 70 °C until the reaction is finished controlled by thin layer chromatography. The solvent was removed under reduced pressure. The purification of the crude product is described in the experiments.

7,7,9,9-Tetramethyl-9,9a-dihydro[1,3]thiazolo[4,3-*b*][1,3]oxazepin-5(2*H*)-one (10a): (a) Under argon atmosphere acrylamide **8a** (200 mg, 0.783 mmol) was dissolved in dry dichloromethane (30 mL) and 5 mol-% of the ruthenium catalyst **I** (32 mg, 0.039 mol) were added. After stirring 15 h at room temperature DMSO (0.1 mL, 1.57 mmol) was added and the solution was stirred for another 24 h at room temperature. The solution was washed three times with water. The organic layer was dried with magnesium sulfate and the solvent removed on a rotary evaporator. The crude product was purified by column chromatography on silica gel (solvent: *n*-hexane/ethyl acetate, 7:4, R_f = 0.27). The product was received as colourless oil (66 mg, 0.290 mmol, 37%). **(b)** Acrylamide **8a** (54 mg, 0.212 mmol) was dissolved in dry dichloromethane (10 mL) and 5 mol-% of the ruthenium catalyst **II** (10 mg, 10.6 μmol) were added. The solution was refluxed for 35 d. The solvent was removed at the rotary evaporator and the crude product was purified as described above (30 mg, 0.132 mmol, 62%). **(c)** Following **GP B**, acrylamide **8a** (54 mg, 0.212 mmol) and ruthenium catalyst **II** (10.0 mg, 10.6 μmol) were used. The crude product was purified as described above (42 mg, 0.185 mmol, 87%). ^{1}H NMR (500 MHz, $CDCl_3$): δ = 1.36 [s, 3 H, $SC(CH_3)_2CH$], 1.50 [s, 3 H, $SC(CH_3)_2CH$], 1.83 [s, 3 H, $SC(CH_3)_2N$], 1.86 [s, 3 H, $SC(CH_3)_2N$], 4.38 (dd, ^2J = 18.9, ^3J = 2.4 Hz, 1 H, CH_2), 4.53 (dd, ^2J = 18.9, ^3J = 2.4 Hz, 1 H, CH_2), 4.98 (s, 1 H, NCH), 5.97 (d, ^3J = 12.5 Hz, 1 H, COC*H*=CH), 6.12 (ddd, ^3J = 12.5, ^3J = 2.4, ^3J = 2.4 Hz, 1 H, COCH=C*H*) ppm. ^{13}C NMR (126 MHz, $CDCl_3$): δ = 24.16 [$SC(CH_3)_2CH$], 30.22 [$SC(CH_3)_2CH$], 31.28 [$SC(CH_3)_2N$], 31.72 [$SC(CH_3)_2N$], 50.37 [$SC(CH_3)_2CH$], 70.03 (CH_2), 72.15 [$SC(CH_3)_2N$], 97.74 (NCH), 128.06 ($COCH=CH$), 138.86 ($COCH=CH$), 166.13 (CO) ppm. IR: ṽ = 2984, 2964, 2926, 1651, 1621, 1397, 1373, 1347, 1167, 1149 cm^{-1}. MS (CI, isobutane): *m*/*z* (%) = 228.1 (100) $[MH]^+$. HRMS (CI, isobutane): *m*/*z* calcd. for $[C_{12}H_{20}NO_2S]^+$: 228.1058, found 228.1058.

4,7,7,9,9-Pentamethyl-9,9a-dihydro[1,3]thiazolo[4,3-*b*][1,3]oxazepin-5(2*H*)-one (10b): Following **GP B**, acrylamide **8b** (57 mg, 0.213 mmol) and ruthenium catalyst **II** (10.0 mg, 10.6 μmol) were used. The crude product was purified by column chromatography on silica gel (solvent: *n*-hexane/ethyl acetate, 7:3, R_f = 0.75). The product was received as a clear oil (43.0 mg, 178.2 μmol, 84%). ^{1}H NMR (500 MHz, $CDCl_3$): δ = 1.36 [s, 3 H, $SC(CH_3)_2CH$], 1.54 [s, 3 H, $SC(CH_3)_2CH$], 1.85 [s, 3 H, $SC(CH_3)_2N$], 1.99 [s, 3 H, $SC(CH_3)_2N$], 1.99 [s, 3 H, $COC(CH_3)=CH$], 4.28–4.31 (m, 2 H, CH_2), 4.99 (s, 1 H, NCH), 5.94–5.98 [m, 1 H, $COC(CH_3)=CH$] ppm. ^{13}C NMR (126 MHz, $CDCl_3$): δ = 19.55 [$COC(CH_3)=CH$], 23.71 [$SC(CH_3)_2CH$], 30.17 [$SC(CH_3)_2CH$], 31.67 [$SC(CH_3)_2N$], 32.11 [$SC(CH_3)_2N$], 51.05 [$SC(CH_3)_2CH$], 64.42 (CH_2), 72.85 [$SC(CH_3)_2N$], 95.77 (NCH), 128.83 [$COC(CH_3)=CH$], 138.92 [$COC(CH_3)=CH$], 168.67 (CO) ppm. IR: ṽ = 3046, 2981, 2928, 2865, 1657, 1632, 1657, 1632, 1391, 1373, 1168, 1139 cm^{-1}. MS (CI, isobutane): *m*/*z* (%) = 483.1 (55) $[M_2H]^+$, 242.0 (100) $[MH]^+$. HRMS (CI, isobutane): *m*/*z* calcd. for $[C_{12}H_{20}NO_2S]^+$: 242.1215, found 242.1215.

7,7,9,9-Tetramethyl-9,9a-dihydro[1,3]oxazolo[4,3-*b*][1,3]oxazepin-5(2*H*)-one (10c): Following **GP B**, acrylamide **8c** (32 mg, 0.134 mmol) and ruthenium catalyst **II** (6.3 mg, 6.7 μmol) were used. The crude product was purified by column chromatography on silica gel (solvent: *n*-hexane/ethyl acetate, 1:1, R_f = 0.36) and obtained as colourless solid (18 mg, 0.085 mmol, 64%), m.p. 65–66 °C. ^{1}H NMR (500 MHz, $CDCl_3$): δ = 1.31 [s, 3 H, $OC(CH_3)_2CH$], 1.35 [s, 3 H, $OC(CH_3)_2CH$], 1.61 [s, 3 H, $OC(CH_3)_2N$], 1.64 [s, 3 H, $OC(CH_3)_2N$], 4.39 (ddd, ^2J = 19.3, ^3J = 2.5, ^4J = 2.5 Hz, 1 H, CH_2), 4.53 (ddd, ^2J = 19.3, ^3J = 2.5, ^4J = 2.5 Hz, 1 H, CH_2), 4.84 (s, 1 H, NCH), 5.97 (ddd, ^3J = 12.7, ^4J = 2.5, ^4J = 2.5 Hz, 1 H, COC*H*=CH), 6.15 (ddd, ^3J = 12.7, ^3J = 2.5, ^3J = 2.5 Hz, 1 H, COCH=C*H*) ppm. ^{13}C NMR (126 MHz, $CDCl_3$): δ = 23.79 (CH_3), 27.39 (CH_3), 27.96 (CH_3), 28.86 (CH_3), 70.28 (CH_2), 80.73 [$OC(CH_3)_2CH$], 92.13 (NCH), 95.47 [$OC(CH_3)_2N$], 126.91 ($COCH=CH$), 139.74 ($COCH=CH$), 164.62 (CO) ppm. IR: ṽ = 2984, 2937, 1658, 1614, 1420, 1102 cm^{-1}. MS (CI, isobutane): *m*/*z* (%) = 212.1 (100) $[MH]^+$. HRMS (CI, isobutane): *m*/*z* calcd. for $[C_{11}H_{18}NO_3]^+$: 212.1287, found 212.1290.

4,7,7,9,9-Pentamethyl-9,9a-dihydro[1,3]oxazolo[4,3-*b*][1,3]oxazepin-5(2*H*)-one (10d): Following **GP B**, acrylamide **8d** (32 mg, 0.126 mmol) and ruthenium catalyst **II** (6.0 mg, 6.3 μmol) were used. The crude product was purified by column chromatography on silica gel (solvent: *n*-hexane/ethyl acetate, 7:3, R_f = 0.43) and obtained as colourless solid (24 mg, 0.107 mmol, 84%), m.p. 53–54 °C. ^{1}H NMR (500 MHz, $CDCl_3$): δ = 1.31 [s, 3 H, $OC(CH_3)_2CH$], 1.33 [s, 3 H, $OC(CH_3)_2CH$], 1.63 [s, 3 H, $OC(CH_3)_2N$], 1.66 [s, 3 H, $OC(CH_3)_2N$], 1.98–1.99 [m, 3 H, $COC(CH_3)=CH$], 4.27–4.32 (m, 1 H, CH_2), 4.36–4.41 (m, 1 H, CH_2), 4.82 (s, 1 H, NCH), 5.99–6.01 [m, 1 H, $COC(CH_3)=CH$] ppm. ^{13}C NMR (126 MHz, $CDCl_3$): δ = 20.82 [$COC(CH_3)=CH$], 23.65 [$OC(CH_3)_2CH$], 27.63 [$OC(CH_3)_2N$], 28.06 [$OC(CH_3)_2N$], 28.70 [$OC(CH_3)_2CH$], 67.31 (CH_2), 80.92 [$OC(CH_3)_2CH$], 90.56 (NCH), 95.80 [$OC(CH_3)_2N$], 132.42 [$COC(CH_3)=CH$], 134.95 [$COC(CH_3)=CH$], 166.62 (CO) ppm. IR: ṽ = 2979, 2934, 1661, 1625, 1421, 1146 cm^{-1}. MS (CI, isobutane): *m*/*z* (%) = 226.0 (100) $[MH]^+$. HRMS (CI, isobutane): *m*/*z* calcd. for $[C_{12}H_{20}NO_3]^+$: 226.1443, found 226.1444.

6,6-Dimethyl-5a,6-dihydro[1,3]oxazepino[2,3-*c*][1,4]benzothiazin-1(4*H*)-one (11a): Following **GP B**, acrylamide **9a** (30 mg, 0.104 mmol) and ruthenium catalyst **II** (5.0 mg, 5.2 μmol) were used. The crude product was purified by column chromatography on silica gel (solvent: *n*-hexane/ethyl acetate, 7:3, R_f = 0.43) and obtained as a colourless oil (22 mg, 0.084 mmol, 82%). ^{1}H NMR (500 MHz, $CDCl_3$): δ = 1.09 (s, 3 H, CH_3), 1.44 (s, 3 H, CH_3), 4.48 (ddd, ^2J = 19.1, ^3J = 2.4, ^4J = 2.4 Hz, 1 H, CH_2), 4.65 (ddd, ^2J = 19.1, ^3J = 2.4, ^4J = 2.4 Hz, 1 H, CH_2), 5.35 (s, 1 H, NCH), 6.18 (ddd, ^3J = 12.7, ^3J = 2.4, ^3J = 2.4 Hz, 1 H, COCH=C*H*), 6.30 (ddd, ^3J = 12.7, ^4J = 2.4, ^4J = 2.4 Hz, 1 H, COC*H*=CH), 7.07 (ddd, ^3J = 7.4, ^3J = 7.4, ^4J = 1.0 Hz, 1 H, *p*-$CH_{Ar}N$), 7.23 (ddd, ^3J = 7.8, ^3J = 7.8,^{4}, J = 1.4 Hz, 1 H, *p*-$CH_{Ar}S$), 7.30 (dd, ^3J = 7.7, ^4J = 1.4 Hz, 1 H, *o*-$CH_{Ar}S$), 7.76 (dd, ^3J = 8.2, ^4J = 1.0 Hz, 1 H, *o*-$CH_{Ar}N$) ppm. ^{13}C NMR (126 MHz, $CDCl_3$): δ = 21.05 (CH_3), 26.37 (CH_3), 46.12 [$C(CH_3)_2$], 71.13 (CH_2), 92.53 (NCH), 125.11 (*p*-$CH_{Ar}N$), 126.39 (*p*-$CH_{Ar}S$), 126.66 ($COCH=CH$), 126.71 ($C_{Ar}S$), 126.85 (*o*-$CH_{Ar}N$), 130.04 (*o*-$CH_{Ar}S$), 136.39 ($C_{Ar}N$), 139.73 ($COCH=CH$), 166.92 (CO) ppm. IR: ṽ = 3062, 2978, 2929, 2836, 1662, 1474, 1322, 750 cm^{-1}. MS (CI, isobutane): *m*/*z* (%) = 262.1 (100) $[MH]^+$. HRMS (CI, isobutane): calcd. for $[C_{14}H_{16}NO_2S]^+$: 262.0896, found 262.0901.

2,6,6-Trimethyl-5a,6-dihydro[1,3]oxazepino[2,3-*c*][1,4]benzothiazin-1(4*H*)-one (11b): Following **GP B**, acrylamide **9b** (18 mg, 0.059 mmol) and ruthenium catalyst **II** (3.0 mg, 3.2 μmol) were used. The crude product was purified by column chromatography on silica gel (solvent: *n*-hexane/ethyl acetate, 8:2, R_f = 0.31) and obtained as a colourless oil (5 mg, 0.018 mmol, 31%). ^{1}H NMR (500 MHz, $CDCl_3$): δ = 1.11 (s, 3 H, CH_3), 1.45 (s, 3 H, CH_3), 2.09 [s, 3 H, COC(CH_3)=CH], 4.32–4.37 (m, 1 H, CH_2), 4.47–4.53 (m, 1 H, CH_2), 5.28 (s, 1 H, NCH), 6.17–6.21 [m, 1 H, COC(CH_3)=C*H*], 7.10 (ddd, ^3J = 7.4, ^3J = 7.4, ^4J = 1.1 Hz, 1 H, *p*-CH_{Ar}N), 7.23 (ddd, ^3J = 7.8, ^3J = 7.8, ^4J = 1.5 Hz, 1 H, *p*-CH_{Ar}S), 7.33 (dd, ^3J = 7.7, ^4J = 1.5 Hz, 1 H, *o*-CH_{Ar}S), 7.71 (dd, ^3J = 8.2, ^4J = 0.9 Hz, 1 H, *o*-CH_{Ar}N) ppm. ^{13}C NMR (126 MHz, $CDCl_3$): δ = 20.73 [COC(*C*H_3)=CH], 22.31 (CH_3), 27.05 (CH_3), 46.59 [*C*(CH_3)$_2$], 65.86 (CH_2), 90.36 (NCH), 125.44 (*p*-CH_{Ar}N), 126.36 (*p*-CH_{Ar}S), 126.92 (*o*-CH_{Ar}N), 127.64 (C_{Ar}S), 130.09 (*o*-CH_{Ar}S), 130.88 [COC(CH_3)=*C*H], 136.20 [CO*C*(CH_3)=CH], 136.27 (C_{Ar}N), 169.65 (CO) ppm. IR: $\tilde{\nu}$ = 3099, 2978, 2927, 2869, 1662, 1474, 1290, 748 cm^{-1}. MS (CI, isobutane): *m*/*z* (%) = 276.1 (100) [MH]$^+$. HRMS (CI, isobutane): calcd. for [$C_{15}H_{18}NO_2S$]$^+$: 276.1053, found 276.1057.

6,6-Dimethyl-6,6a-dihydro[1,3]oxazepino[2,3-*c*][1,4]benzoxazin-11(8*H*)-one (11c): Following **GP B**, acrylamide **9c** (30 mg, 0.109 mmol) and ruthenium catalyst **II** (5.2 mg, 5.4 μmol) were used. The crude product was purified by column chromatography on silica gel (solvent: *n*-hexane/ethyl acetate, 7:3, R_f = 0.21) and obtained as a colourless solid (22 mg, 0.089 mmol, 82%), m.p. 112–116 °C. ^{1}H NMR (500 MHz, $CDCl_3$): δ = 1.32 (s, 3 H, CH_3), 1.41 (s, 3 H, CH_3), 4.46 (ddd, ^2J = 18.1, ^3J = 3.3, ^4J = 1.6 Hz, 1 H, CH_2), 4.57 (ddd, ^2J = 18.1, ^3J = 2.8, ^4J = 1.9 Hz, 1 H, CH_2), 5.09 (s, 1 H, NCH), 6.19–6.22 (m, 1 H, COCH=C*H*), 6.25–6.29 (m, 1 H, COC*H*=CH), 6.91 (dd, ^3J = 7.9, ^4J = 1.7 Hz, 1 H, *o*-CH_{Ar}O), 6.96 (ddd, ^3J = 7.7, ^3J = 7.7, ^4J = 1.7 Hz, 1 H, *p*-CH_{Ar}O), 7.01 (ddd, ^3J = 7.6, ^3J = 7.5, ^4J = 1.5 Hz, 1 H, *p*-CH_{Ar}N), 8.56 (dd, ^3J = 8.3, ^4J = 1.6 Hz, 1 H, *o*-CH_{Ar}N) ppm. ^{13}C NMR (126 MHz, $CDCl_3$): δ = 22.52 (CH_3), 24.01 (CH_3), 69.22 (CH_2), 74.67 [*C*(CH_3)$_2$], 86.09 (NCH), 117.93 (*o*-CH_{Ar}O), 120.57 (*o*-CH_{Ar}N), 121.76 (*p*-CH_{Ar}O), 124.70 (*p*-CH_{Ar}N), 125.88 (C_{Ar}N), 127.75 (CO*C*H=CH), 137.87 (COCH=*C*H), 143.88 (C_{Ar}O), 167.30 (CO) ppm. IR: $\tilde{\nu}$ = 3137, 2989, 2924, 1659, 1489, 1263, 757 cm^{-1}. MS (CI, isobutane): *m*/*z* (%) = 246.1 (100) [MH]$^+$. HRMS (CI, isobutane): calcd. for [$C_{14}H_{16}NO_3$]$^+$: 246.1125, found 246.1130.

6,6,10-Trimethyl-6,6a-dihydro[1,3]oxazepino[2,3-*c*][1,4]benzoxazin-11(8*H*)-one (11d): Following **GP B**, acrylamide **9d** (52 mg, 0.181 mmol) and ruthenium catalyst **II** (8.6 mg, 9.1 μmol) were used. The crude product was purified by column chromatography on silica gel (solvent: *n*-hexane/ethyl acetate, 8:2, R_f = 0.32) and obtained as a colourless solid (36 mg, 0.139 mmol, 77%), m.p. 118–120 °C. ^{1}H NMR (500 MHz, $CDCl_3$): δ = 1.25 (s, 3 H, CH_3), 1.48 (s, 3 H, CH_3), 2.12 [s, 3 H, COC(CH_3)=CH], 4.14–4.19 (m, 1 H, CH_2), 4.24 (dd, ^2J = 13.4, ^3J = 7.0 Hz, 1 H, CH_2), 4.92 (s, 1 H, NCH), 6.09–6.13 [m, 1 H, COC(CH_3)=C*H*], 6.91–6.95 (m, 2 H, *o*-CH_{Ar}O, *p*-CH_{Ar}O), 7.01 (ddd, ^3J = 7.7, ^3J = 7.7, ^4J = 1.6 Hz), 1 H, *p*-CH_{Ar}N, 8.57–8.60 (m, 1 H, *o*-CH_{Ar}N) ppm. ^{13}C NMR (126 MHz, $CDCl_3$): δ = 18.76 [COC(*C*H_3)=CH], 23.26 (CH_3), 24.19 (CH_3), 62.23 (CH_2), 73.54 [*C*(CH_3)$_2$], 83.03 (NCH), 118.00 (*o*-CH_{Ar}O), 119.23 (*o*-CH_{Ar}N), 121.45 (*p*-CH_{Ar}O), 123.59 (C_{Ar}N), 124.78 (*p*-CH_{Ar}N), 127.81 [COC(CH_3)=*C*H], 139.71 [CO*C*(CH_3)=CH], 143.16 (C_{Ar}O), 170.06 (CO) ppm. IR: $\tilde{\nu}$ = 3163, 2990, 2910, 1655, 1492, 1255, 765 cm^{-1}. MS (CI, isobutane): *m*/*z* (%) = 246.1 (100) [MH]$^+$. HRMS (CI, isobutane): calcd. for [$C_{14}H_{16}NO_3$]$^+$: 246.1125, found 246.1130.

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