Reactions of Keto–Enol Tautomers of 2-Thiazolyl-, 2-Oxazolyl-, 2-Benzoxazolyl-, or 2-Benzothiazolyl-1-phenylethenols with α,β-Alkynyl Esters:

Syntheses of Highly Functionalized Fused-Ring Heterocycles:


Department of Chemistry, Mississippi State University, Mississippi State, MS 39762, USA

Supporting Information

Chemicals and solvents were purchased from commercial suppliers and used as received, except that acetonitrile and triethylamine were distilled from calcium hydride under nitrogen. All reactions were carried out under nitrogen. Silica gel (230-400 mesh and a pore size 60 Å) purchased from Sorbent Technologies, was used as the stationary phase for flash chromatography analyses. $^1$H NMR and $^{13}$C NMR spectra were recorded on a Bruker AVANCE III -300 or -600 spectrometers operating at 300 MHz and 600 MHz for proton, and 75 MHz and 150 MHz for carbon. Chemical shifts were reported in parts per million (ppm) on the delta (δ) scale relative to the internal standard, tetramethylsilylane for $^1$H (δ = 0 ppm) and the center line of the deuterated solvent for $^{13}$C (CDCl$_3$: δ = 77.0 ppm and DMSO-d$_6$: δ = 39.43 ppm). Splitting patterns are designed as “s, d, t, q, and m”, and these symbols indicate “singlet, doublet, triplet, quartet, and multiplet,” respectively. Coupling constants, $J$, were reported in Hertz (Hz). High-resolution mass spectra were recorded on a Bruker UHPLC-micro-Q/T MS/MS spectrometer in the ESI mode. Melting points were recorded with a Mel-Temp apparatus and were uncorrected. IR spectra were recorded on a Nicolet 6700 FT-IR spectrometer. A Bruker AXS Smart 1000 diffractometer, upgraded with an APEX II detector and software which incorporates
SHELX components, was employed for crystal structure determinations at -173 °C. All reactions were carried out under nitrogen.

**Preparation of enol-esters of thiazoles, oxazoles, benzoxazoles and benzothiazoles**

**(Z)-1-Phenyl-2-(thiazol-2-yl)vinyl benzoate (4)**

Triethylamine (1.83 g, 18.1 mmol, 3.6 eq.) was added to a stirred solution of 2-methylthiazole 1 (0.496 g, 5 mmol, 1 eq.) in CH₃CN (25 mL) at room temperature under nitrogen. Benzoyl chloride (2.13 g, 15 mmol, 3 eq.) in acetonitrile (20 mL) was added dropwise into this solution at room temperature under nitrogen. This solution was refluxed for 7 h. After cooling to room temperature, acetonitrile was removed by rotary evaporation. The residue was dissolved in dichloromethane (30 mL), washed with saturated aqueous NaHCO₃ (2 × 30 mL) and dried over anhydrous sodium sulfate and filtered. After removal of dichloromethane by rotary evaporation, the crude product was purified by column chromatography (silica gel, ethyl acetate/hexane = 1:3) to give the title compound 4 (1.364 g, 88.8%). This general procedure was also used for the syntheses of compounds 5, 6, 15-17 discussed in this section.

Rᵣ = 0.39 (ethyl acetate/hexane = 1:3); yellow solid; mp = 105-106 °C.

IR (neat): 3116, 3069, 3032, 2981, 1732, 1642, 1599, 1448, 1235, 1175, 1076, 1058, 1023, 762, 707, 692 cm⁻¹.

¹H NMR (300 MHz, CDCl₃): δ 8.33 (d, J = 7.48 Hz, –OCOC₆H₅ ortho, 2H), 7.82 (d, J = 3.0 Hz, –NCH=CHS, ortho, 1H), 7.71 (t, J = 7.40 Hz, –OCOC₆H₅ para, 1H), 7.63-7.55 and 7.37-7.40 (m, –OCOC₆H₅ meta, –CH= C(C₆H₅)O– ortho, meta and para, and N=S=CCH=, 8H), 7.25 (d, J = 3.0 Hz, –NCH=CHS, ortho, 1H).
$^{13}$C NMR (150 MHz, CDCl₃): δ 163.68 (–OCOC₆H₅), 161.42 (N,S≥C–), 150.18 (–CH=Ĉ(C₆H₅)O–), 142.77 (=NCH=CHS–), 134.13 (–OCOC₆H₅ para), 133.85 (–OCOC₆H₅ ipso), 130.57 (–OCOC₆H₅ ortho), 129.63 (–CH=Ĉ(C₆H₅)O– para), 128.89 (–OCOC₆H₅ meta), 128.85 (–CH=C(C₆H₅)O– meta), 128.82 (–CH=C(C₆H₅)O– ipso), 124.96 (–CH=C(C₆H₅)O– ortho), 119.66 (=NCH=CHS–), 112.08 (N,S≥CCH=).

DEPT 135 NMR (150 MHz, CDCl₃): δ 142.86, 134.23, 130.62, 129.73, 128.99, 128.92, 125.06, 119.76, 112.18.

(Z)-2-(4,5-dimethylthiazol-2-yl)-1-phenylvinyl benzoate (5)²

The title compound 5 (1.11 g, 66.1%) was obtained using 2,4,5-trimethylthiazole 2 (0.636 g, 5 mmol, 1 eq.), triethylamine (1.84 g, 18 mmol, 3.6 eq.) and benzoyl chloride (2.13 g, 15 mmol, 3 eq.) by the general procedure used for the synthesis and purification of 4. Ethyl acetate/hexane = 1:3 was used as the eluent for column chromatography.

Rf = 0.50 (ethyl acetate/hexane = 1:3); yellow solid; mp = 156-158 °C.

IR (neat): 3066, 3045, 2951, 2915, 1741, 1655, 1537, 1450, 1432, 1227, 1076, 1050, 1023, 885, 767, 694 cm⁻¹.

$^1$H NMR (300 MHz, CDCl₃): δ 8.33 (d, J = 7.55 Hz, –OCOC₆H₅ ortho, 2H), 7.72 (t, J = 7.40 Hz, –OCOC₆H₅ para, 1H), 7.62-7.56 and 7.38-7.35 (m, –OCOC₆H₅ meta, and –CH=C(C₆H₅)O– ortho, meta and para, 7H), 7.23 (s, N,S≥CCH=, 1H), 2.31 (s, =NC(CH₃)=C(CH₃)S or =NC(CH₃)=C(CH₃)S, 3H), 2.28 (s, =NC(CH₃)=C(CH₃)S or =NC(CH₃)=C(CH₃)S, 3H).

$^{13}$C NMR (150 MHz, CDCl₃): δ 163.84 (–OCOC₆H₅ or N,S≥C–), 156.69 (–OCOC₆H₅ or N,S≥C–), 148.75 (–CH=C(C₆H₅)O– or =NC(CH₃)=C(CH₃)S–), 148.38 (–CH=C(C₆H₅)O– or =NC(CH₃)=C(CH₃)S–), 134.03 (–OCOC₆H₅ ipso), 134.01
(–OCOC₆H₅ortho), 129.29 (–CH=C(C₆H₅)O– para), 129.00
(–OCOC₆H₅ipso), 128.85 (–OCOC₆H₅meta or –CH=C(C₆H₅)O– meta), 128.79
(–OCOC₆H₅meta or –CH=C(C₆H₅)O– meta), 127.80 (=NC(CH₃)=C(CH₃)S–), 124.73
(–CH=C(C₆H₅)O– ortho), 112.24 (N,S≥CCH=), 14.54 (=NC(CH₃)=C(CH₃)S– or
=NC(CH₃)=C(CH₃)S–), 11.35 (=NC(CH₃)=C(CH₃)S– or =NC(CH₃)=C(CH₃)S–).

DEPT 135 NMR (150 MHz, CDCl₃): δ 134.09, 130.81, 129.37, 128.93, 128.87,
124.81, 112.32, 14.62, 11.43.

(Z)-2-(4,5-dimethyloxazol-2-yl)-1-phenylvinyl benzoate (6)

The title compound 6 (1.26 g, 78.9%) was obtained using 2,4,5-trimethyloxazole
3 (0.585 g, 5 mmol, 1 eq.), triethylamine (1.87 g, 18.5 mmol, 3.7 eq.) and benzoyl
chloride (2.15 g, 15.1 mmol, 3 eq.). The general procedure used for both the synthesis
and purification of 4 was followed. The crude product was purified by column
chromatography using ethyl acetate/hexane = 1:4 over silica gel.

Rf = 0.54 (ethyl acetate/hexane =1:3); sticky oil.

IR (neat): 3062, 2978, 2953, 2923, 2858, 1738, 1633, 1449, 1236, 1175, 1082,
1064, 1024, 1000, 760, 705, 689 cm⁻¹.

¹H NMR (300 MHz, CDCl₃): δ 8.27 (d, J = 7.47 Hz, −OCOC₆H₅ortho, 2H),
7.69–7.37 (m, −OCOC₆H₅meta and para, and −CH=C(C₆H₅)O– ortho, meta and para,
8H), 6.83 (s, N,S≥CCH=, 1H), 2.01 (s, =NC(CH₃)=C(CH₃)O– or =NC(CH₃)=C(CH₃)O–,
3H), 1.92 (s, =NC(CH₃)=C(CH₃)O– or =NC(CH₃)=C(CH₃)O–, 3H).

¹³C NMR (150 MHz, CDCl₃): δ 164.62 (−OCOC₆H₅ or N,O≥C–), 155.83
(−OCOC₆H₅ or N,O≥C–), 149.71 (−CH=C(C₆H₅)O– or =NC(CH₃)=C(CH₃)O–), 143.42
(−CH=C(C₆H₅)O– or =NC(CH₃)=C(CH₃)O–), 133.82 (−OCOC₆H₅ipso), 133.42
para), 132.00 (−CH=C(C₆H₅)O− ipso), 130.16 (−OCOC₆H₅ ortho), 129.54
(−CH=C(C₆H₅)O− para), 129.73 (−NC(CH₃)=C(CH₃)O−), 128.69 (−OCOC₆H₅ meta or
−CH=C(C₆H₅)O− meta), 128.37 (−OCOC₆H₅ meta or −CH=C(C₆H₅)O− meta), 124.86
(−CH=C(C₆H₅)O− ortho), 103.10 (N,O≥CCH=), 10.92 (−NC(CH₃)=C(CH₃)O− or
(=NC(CH₃)=C(CH₃)O−), 9.59 (−NC(CH₃)=C(CH₃)O− or (−NC(CH₃)=C(CH₃)O−).

DEPT 135 NMR (150 MHz, CDCl₃): δ 133.62, 130.35, 129.73, 128.88, 128.56,
125.05, 103.29, 11.11, 9.78.

(Z)-2-(4-methylthiazol-2-yl)-1-phenylvinyl benzoate (15)

The title compound 15 (3.95 g, 61.5%) was obtained by reacting 2,4-
dimethylthiazole 14 (2.29 g, 20 mmol, 1 eq.), triethylamine (7.29 g, 72 mmol, 3.6 eq.)
and benzoyl chloride (8.54 g, 61 mmol, 3 eq.) using the general procedure for the
synthesis and purification of 4. The eluent used for column chromatography over silica
gel was ethyl acetate/hexane = 1:4.

Rᵣ = 0.40 (ethyl acetate/hexane = 1:4); yellow solid; mp = 125-126 °C.

IR (neat): 3107, 3073, 2971, 2929, 1731, 1635, 1599, 1510, 1448, 1421, 1232,
1079, 1059, 1025, 1000, 968, 871, 765, 750, 692 cm⁻¹.

¹H NMR (300 MHz, CDCl₃): δ 8.33 (d, J = 7.19 Hz, −OCOC₆H₅ ortho, 2H), 7.71
(t, J = 7.42 Hz, −OCOC₆H₅ para, 1H), 7.62-7.57 and 7.42-7.36 (m, −OCOC₆H₅ meta, and
−CH=C(C₆H₅)O− ortho, meta and para, 7H), 7.30 (s, =NC(CH₃)=CHS=, 1H), 6.80 (s,
N,S≥CCH=, 1H), 2.43 (s, −NC(CH₃)=CHS=, 3H).

¹³C NMR (75 MHz, CDCl₃): δ 163.73 (−OCOC₆H₅ or N,S≥C−), 160.64
(−OCOC₆H₅ or N,S≥C−), 152.69 (−CH=C(C₆H₅)O− or =NC(CH₃)=CHS=), 149.87
(−CH=C(C₆H₅)O− or =NC(CH₃)=CHS=), 134.06 (−OCOC₆H₅ para), 133.88 (−
OCOC₆H₅ ipso), 130.50 (−OCOC₆H₅ ortho), 129.52 (−CH=C(C₆H₅)O− para), 128.88 (−
OCOC₆H₅ meta, 128.78 (−CH=C(C₆H₅)O− meta, 3C), 124.84 (−CH=C(C₆H₅)O− ortho), 114.63 (−NC(CH₃)=CHS−), 111.95 (N,S=CH−), 16.90 (−NC(CH₃)=CHS−). The ipso carbon is overlapping with other peaks.

DEPT 135 NMR (150 MHz, CDCl₃): δ 134.15, 130.61, 129.62, 128.98, 128.87, 124.94, 114.71, 112.05, 17.00.

HRMS (ESI, M+H): calcd for C₁₉H₁₅NO₂S: 322.0900; found: 322.0880.

(Z)-2-(benzo[d]oxazol-2-yl)-1-phenylvinyl benzoate (16)

The title compound 16 (2.94 g, 43%) was obtained by the reaction of 2-methylbenzoxazole 7 (2.69 g, 20 mmol, 1 eq.), triethylamine (7.48 g, 74 mmol, 3.7 eq.) and benzoyl chloride (8.51 g, 60.5 mmol, 3 eq.). The general procedure used for the synthesis and purification of 4 was employed. The eluent used for column chromatography over silica gel was ethyl acetate/hexane = 1:5.

Rf = 0.58 (ethyl acetate/hexane = 1:4); white crystalline solid; mp = 97-98 °C.

IR (neat): 3078, 1731, 1644, 1605, 1540, 1451, 1234, 1181, 1152, 1084, 1067, 1027, 946, 848, 790, 746, 701, 687 cm⁻¹.

¹H NMR (300 MHz, CDCl₃): δ 8.32 (d, J = 7.68 Hz, −OCOC₆H₅ ortho, 2H), 7.71-7.67, 7.60-7.54, 7.41-7.40 and 7.24-7.18 (m, −OCOC₆H₅ meta and para, −CH=C(C₆H₅)O− ortho, meta and the four aromatic CHs on the benzoxazole ring, 11H), 7.11 (d, J = 8.04 Hz, −CH=C(C₆H₅)O− para, 1H) 7.04 (s, −CH=C(C₆H₅)O−, 1H).

¹³C NMR (150 MHz, CDCl₃): δ 164.47 (−OCOC₆H₅ or N,O≥C−), 159.75 (−OCOC₆H₅ or N,O≥C−), 154.09 (−CH=C(C₆H₅)O− or C next to O in the benzoxazole ring), 150.06 (−CH=C(C₆H₅)O− or C next to O on the benzoxazole ring), 141.57 (C next to N on the benzoxazole ring), 133.67 (−OCOC₆H₅ para), 133.58 (−OCOC₆H₅ ipso), 130.45 (−CH=C(C₆H₅)O− para), 130.41 (−OCOC₆H₅ ortho), 129.37 (−CH=C(C₆H₅)O−
128.87 (–OCOC₆H₅meta or –CH=C(C₆H₅)O– meta), 128.56 (–OCOC₆H₅meta or
(–CH=C(C₆H₅)O– meta), 125.48 (–CH=C(C₆H₅)O– ortho), 125.19, 124.39, 119.95 and
110.12 (aromatic CHs on the benzoxazole ring), 103.22 (N,O>C=CH=).

DEPT 135 NMR (150 MHz, CDCl₃): δ 133.84, 130.61, 130.58, 129.04, 128.72,
125.64, 125.36, 124.56, 120.11, 110.29. 103.38.

(Z)-2-(benzo[d]thiazol-2-yl)-1-phenylvinyl benzoate (17)

The title compound 17 (1.89 g, 53%) was prepared from 2-methylbenzothiazole 8
(1.51 g, 10 mmol, 1 eq.), triethylamine (3.71 g, 36.7 mmol, 3.7 eq.) and benzoyl chloride
(4.26 g, 30 mmol, 3 eq.) by the general procedure used for the synthesis and purification
of 4. Ethyl acetate/hexane = 1:6 was used as the eluent for column chromatography over
silica gel.

R₉ = 0.54 (ethyl acetate/hexane = 1:4); yellow solid; mp = 146-148 °C.

IR (neat): 3061, 2981, 1739, 1641, 1596, 1452, 1445, 1432, 1227, 1209, 1175,
1080, 1055, 1023, 1000, 850, 754, 656 cm⁻¹.

¹H NMR (600 MHz, CDCl₃): δ 8.36 (d, J = 7.80 Hz, –OCOC₆H₅ortho, 2H), 7.97
(d, J = 8.19 Hz, aromatic H in benzothiazole ring, 1H), 7.73 (dd, J = 7.80 and 7.61 Hz,
–OCOC₆H₅meta, 2H) 7.65 (d, J = 7.65 Hz, –CH=C(C₆H₅)O– ortho, 2H), 7.60 (dd, J =
7.65 and 7.56 Hz, –CH=C(C₆H₅)O– meta, 2H), 7.45-7.39 (m, –OCOC₆H₅para, three
aromatic CHs on the benzothiazole ring and –CH=C(C₆H₅)O–, 5H), 7.31 (t, J = 7.56 Hz,
–CH=C(C₆H₅)O– para, 1H).

¹³C NMR (150 MHz, CDCl₃): δ 163.71 (–OCOC₆H₅ or N,S≥C–), 161.38
(–OCOC₆H₅ or N,S≥C–), 152.57 (–CH=C(C₆H₅)O– or C next to S in the benzothiazole
ring), 152.48 (–CH=C(C₆H₅)O– or C next to S in the benzothiazole ring), 135.05 (C next
to N in the benzothiazole ring), 134.20 (–OCOC₆H₅para), 133.73 (–OCOC₆H₅ipso),
130.63 (–OCOC₆H₅ ortho), 130.05 (–CH=C(C₆H₅)O – para), 128.95 (–OCOC₆H₅ meta or
(–CH=C(C₆H₅)O – meta), 128.88 (–OCOC₆H₅ meta or (–CH=C(C₆H₅)O – meta), 128.80
(–CH=C(C₆H₅)O – ipso), 126.25 and 125.32 (aromatic CHs on the benzothiazole ring),
125.21 (–CH=C(C₆H₅)O – ortho), 123.00 and 121.29 (aromatic CHs on the benzothiazole
ring), 112.44 (N,S=C=CH=).

DEPT 135 NMR (150 MHz, CDCl₃): δ 134.32, 130.74, 130.17, 129.07, 129.00,
126.37, 125.44, 124.33, 123.12, 121.41, 112.56.

**Synthesis of the equilibrating tautomers of 2-(thiazole, oxazole, benoxazole and
benzothiazole)-1-phenylethenols**

(Z)-1-phenyl-2-(thiazol-2-yl)ethenol (18a) and 1-phenyl-2-(thiazol-2-yl)ethanone
(18b)

(Z)-1-Phenyl-2-(thiazol-2-yl)vinybenzoate 4 (2.144 g, 6.98 mmol, 1 eq.) was
dissolved in anhydrous MeOH (15 mL). KOH (0.788 g, 14.04 mmol, 2 eq.), dissolved in
MeOH (10 mL), was added dropwise into this solution and stirred for 24 h at room
temperature. Then MeOH was removed by rotary evaporation. The residue was dissolved
in water (30 mL), neutralized with 1M H₂SO₄ and extracted with dichloromethane (25
mL × 2). The organic layer was further washed with water (30 mL), dried over anhydrous
sodium sulfate and filtered. After removal of dichloromethane by rotary evaporation, the
crude product was purified by column chromatography (silica gel, ethyl acetate/hexane =
1:4) to isolate the titled compounds (1.273 g, 89.8%). ¹H and ¹³C NMR in CDCl₃
confirmed that the isolated product consists of the equilibrating tautomers (Z)-1-phenyl-
2-(thiazol-2-yl)ethenol 18a and 1-phenyl-2-(thiazol-2-yl)ethanone 18b in a 1:2:0 ratio.

Tautomers 18a and 18b (0.971 g, 97%) were isolated in another batch by reacting
(Z)-1-phenyl-2-(thiazol-2-yl)vinybenzoate 4 (1.509 g, 4.9 mmol) and KOH (0.554 g,
9.87 mmol, 2 eq.) in 30 mL of anhydrous MeOH. This general procedure was used for the hydrolysis of enol-esters 15, 5, 6, 16 and 17 to isolate corresponding equilibrating tautomers of 19-23, respectively.

R_f = 0.48 (ethyl acetate/hexane = 1:3); dark green oil.

IR (neat): 3117, 3084, 3060, 1687, 1622, 1598, 1576, 1494, 1483, 1449, 1263, 1210, 1100, 1070, 752, 686, 632 cm⁻¹.

¹H NMR (600 MHz, CDCl₃): δ 13.18 (broad OH, 1H), 7.99 (d, J = 7.56 Hz, C₆H₅ ortho in 18b, 2H), 7.74 (d, J = 7.95 Hz, ortho in 18a, 2H), 7.70 (d, J = 3.25, =NCH=CHS in 18b, 1H), 7.61 (d, J = 3.32 Hz, =NCH=CHS in 18a, 1H), 7.53 (t, J = 7.37 Hz, C₆H₅ meta in 18a, 2H), 7.42 (t, J = 7.70 Hz, C₆H₅ meta in 18b, 2H), 7.35-7.31 (m, para in both 18a and 18b, 2H), 7.26 (d, J = 3.25 Hz, =NCH=CHS in 18b, 1H), 7.00 (d, J = 3.32 Hz, =NCH=CHS in 18a, 1H), 6.28 (s, =CH⁻ in 18a, 1H), 4.69 (s, –CH₃ in 18b, 2H).

The areas of the peaks for 18a and 18b were considered separately since their mole ratio in the solution was not 1:1. All peaks were first integrated by setting the area of the vinyl proton (=CH) peak of the enol tautomer 18a at 6.28 ppm at one versus the rest of the resonances for 18a. The area of the methylene protons (=CH₂) of the keto tautomer 18b at 4.69 ppm was set at two versus the rest of the resonances for 18b. The integration values of each peak and coupling patterns were used when assigning proton signals for the each tautomer. To obtain the mole ratio between 18a and 18b in CDCl₃, the integrated area of the –CH₂ at 4.69 ppm was set at two and then the =CH peak at 6.28 ppm was integrated and found to have an area of 0.5 versus the integrated area of the methylene proton peak of the keto form. The enol =CH peak corresponds to one proton per molecule and the keto CH₂ peak corresponds to two protons per molecule. Therefore,
to calculate the mole ratio between 18a and 18b, half of the keto CH2 integrated area (1.0) of 18b was divided by the enol =CH integrated area (0.5). This gave 1:2.0 ratio for 18a:18b.

$^{13}$C NMR (150 MHz, CDCl3): δ 194.46 (–CH$_2$CO– in 18b), 168.35 (=C(OH)– in 18a), 162.15 and 160.64 (N,S$\geq$C– in 18a and 18b), 142.10 and 140.11 (>NCH=CHS– in 18a and 18b), 135.71 and 134.60 (–CO$_2$H$_5$, ipso in 18a and 18b), 133.71 and 129.63 (–CO$_2$H$_5$, para in 18a and 18b), 128.74 (–CO$_2$H$_5$, ortho in 18b), 128.52 (–CO$_2$H$_5$, meta in 18b), 128.34 (–CO$_2$H$_5$, ortho in 18a), 125.42 (–CO$_2$H$_5$, meta in 18a), 120.04 and 114.39 (=NCH=CHS– in 18a and 18b), 90.99 (N,S$\geq$CCH= in 18a), 42.65 (N,S$\geq$CCH$_2$– in 18b).

DEPT 135 NMR (150 MHz, CDCl3): δ 142.24, 140.25, 133.85, 129.77, 128.88, 128.66, 128.52, 125.56, 120.18, 114.53, 91.13, 42.78.

(Z)-2-(4-methylthiazol-2-yl)-1-phenylethenol (19a) and 2-(4-methylthiazol-2-yl)-1-phenylethanone (19b)

Tautomers (Z)-2-(4-methylthiazol-2-yl)-1-phenylethenol 19a and 2-(4-methylthiazol-2-yl)-1-phenylethanone 19b were synthesized by reacting (Z)-2-(4-methylthiazol-2-yl)-1-phenylvinyl benzoate 15 (1.045 g, 3.25 mmol, 1 eq.) in 15 mL of anhydrous MeOH and KOH (0.365 g, 6.51 mmol) in 10 mL MeOH by the general procedure used for the synthesis and purification of hydrolyzed product 18. The eluent used for column chromatography over silica gel was ethyl acetate/hexane = 1:7. Tautomers 19a and 19b (0.473 g, 66.9%) were isolated. $^1$H and $^{13}$C NMR in CDCl$_3$ confirmed that the isolated product consists of equilibrating tautomers (Z)-2-(4-methylthiazol-2-yl)-1-phenylethenol 19a and 2-(4-methylthiazol-2-yl)-1-phenylethanone 19b in a 1:1.32 ratio.
R_f = 0.42 (ethyl acetate/hexane = 1:7); yellow solid; mp = 96-97 °C.

IR (neat): 3106, 3053, 2956, 2918, 1608, 1574, 1519, 1492, 1454, 1259, 1035, 836, 758 cm⁻¹.

¹H NMR (300 MHz, CDCl₃): δ 13.44 (broad, OH, 1H), 7.98 (d, J = 7.23 Hz, C₆H₅ ortho in 19b, 2H), 7.74-7.72 (d, J = 7.73 Hz, C₆H₅ ortho in 19a, 2H), 7.52 (t, J = 6.90 Hz, C₆H₅ para in 19b, 1H), 7.42 (t, J = 7.79 Hz, C₆H₅ meta in 19b, 2H), 7.37-7.42 (m, C₆H₅ meta and para in 19a, 3H), 6.79 (d, J = 0.71 Hz, =NC(CH₃)=CHS in 19b, 1H), 6.53 (d, J = 0.74 Hz, =NC(CH₃)=CHS in 19a, 1H), 6.21 (s, =CH= in 19a, 1H), 4.63 (s, =CH= in 19b, 2H), 2.37 (s, J = 0.75 Hz, =NC(CH₃)=CHS= in 19b, 3H), 2.35 (d, J = 0.78 Hz, =NC(CH₃)=CHS= in 19a, 3H).

The areas of the peaks for 19a and 19b were considered separately since their mole ratio in the solution was not 1:1. All peaks were first integrated by setting the area of the vinyl proton (=CH) peak of the enol tautomer 19a at 6.21 ppm at one versus the rest of the resonances for 19a. The area of the methylene protons (–CH₂) of the keto tautomer 19b at 4.63 ppm was set at two versus the rest of the resonances for 19b. The integration values of each peak and coupling patterns were used when assigning proton signals for each tautomer. To obtain the mole ratio between 19a and 19b in CDCl₃, the integrated area of the –CH₂ at 4.63 ppm was set at two and then the =CH peak at 6.21 ppm was integrated and found to have an area of 0.76 versus the integrated area of the methylene proton peak of the keto form. The enol =CH peak corresponds to one proton per molecule and the keto CH₂ peak corresponds to two protons per molecule. Therefore, to calculate the mole ratio between 19a and 19b, half of the keto CH₂ integrated area (1.0) of 19b was divided by the enol =CH integrated area (0.76). This gave 1:1.32 ratio for 19a:19b.
$^{13}$C NMR (75 MHz, CDCl$_3$): $\delta$ 194.58 (–CH$_2$CO– in 19b), 167.58 (=C(OH)– in 19a), 161.37 and 160.52 (N,S≥C– in 19a and 19b), 152.02 and 150.11 (=NC(CH$_3$)=CHS– in 19a and 19b), 135.61 and 134.67 (–CO$_2$H$_5$, ipso in 19a and 19b), 133.70 and 129.53 (–CO$_2$H$_5$, para in 19a and 19b), 128.27 (–CO$_2$H$_5$, ortho in 19a), 128.44 and 128.37 (–CO$_2$H$_5$, meta in 19a and 19b), 125.30 (–CO$_2$H$_5$, ortho in 19a), 114.56 (=NC(CH$_3$)=CHS– in 19b), 108.92 (=NC(CH$_3$)=CHS– in 19a), 91.06 (N,S≥CCH= in 19a), 42.68 (N,S≥CCH$_2$– in 19b), 16.95 (=NC(CH$_3$)=CHS– in 19b), 16.68 (=NC(CH$_3$)=CHS– in 19b).

DEPT 135 NMR (150 MHz, CDCl$_3$): $\delta$ 133.74, 129.64, 128.83, 128.61, 128.48, 125.49, 114.6, 108.98, 91.19, 42.86, 17.01, 16.75.

(Z)-2-(4,5-dimethylthiazol-2-yl)-1-phenylethenol (20a) and 2-(4,5-dimethyl-thiazol-2-yl)-1-phenylethanone (20b)

Tautomers (Z)-2-(4,5-dimethylthiazol-2-yl)-1-phenylethenol 20a and 2-(4,5-dimethylthiazol-2-yl)-1-phenylethanone 20b were synthesized by reacting (Z)-2-(4,5-dimethylthiazol-2-yl)-1-phenylvinyl benzoate 5 (0.502 g, 1.50 mmol, 1 eq.) in 10 mL of anhydrous MeOH and KOH (0.168 g, 2.99 mmol, 2 eq.) in 10 mL MeOH by the general procedure used for the synthesis and purification of equilibrating tautomers of 18. The eluent used for column chromatography over silica gel was ethyl acetate/hexane = 1:7. Tautomers 20a and 20b (0.308 g, 84.8%) were isolated. $^1$H and $^{13}$C NMR in CDCl$_3$ confirmed that the isolated product consists of equilibrating tautomers (Z)-2-(4-methylthiazol-2-yl)-1-phenylethenol 20a and 2-(4-methylthiazol-2-yl)-1-phenylethanone 20b in a 1:1.41 ratio.

$R_f$ = 0.44 (ethyl acetate/hexane = 1:6); yellow solid; mp = 80-81 °C.
IR (neat): 3089, 3055, 3038, 2980, 2918, 1630, 1573, 1555, 1492, 1454, 1268, 1146, 1060, 817, 770, 747, 687, 648 cm\(^{-1}\).

\(^1\)H NMR (300 MHz, CDCl\(_3\)): \(\delta\) 13.52 (broad OH, 1H), 8.04 (d, \(J = 7.66\) Hz, C\(_6\)H\(_5\) ortho in 20b, 2H), 7.79 (d, \(J = 7.41\) Hz, C\(_6\)H\(_5\) ortho in 20a, 2H), 7.58 (t, \(J = 7.38\) Hz, C\(_6\)H\(_5\) para in 20b, 1H), 7.48 (t, \(J = 7.57\) Hz, C\(_6\)H\(_5\) meta in 20b, 2H), 7.41-7.35 (m, C\(_6\)H\(_5\) meta and para in 20a, 3H), 6.19 (s, =CH– in 20a, 1H), 4.61 (s, –CH\(_2\)– in 20b, 2H), 2.32, 2.31 and 2.30 (s, =NC(CH\(_3\))=C(CH\(_3\))S– and =NC(CH\(_3\))=C(CH\(_3\))S– in both 20a and 20b, 12H).

The areas of the peaks for 20a and 20b were considered separately since their mole ratio in the solution was not 1:1. All peaks were first integrated by setting the area of the vinyl proton (=CH) peak of the enol tautomer 20a at 6.19 ppm at one versus the rest of the resonances for 20a. The area of the methylene protons (–CH\(_2\)) of the keto tautomer 20b at 4.61 ppm was set at two versus the rest of the resonances for 20b. The integration values of each peak and coupling patterns were used when assigning proton signals for the each tautomer. To obtain the mole ratio between 20a and 20b in CDCl\(_3\), the integrated area of the –CH\(_2\) at 4.61 ppm was set at two and then the =CH peak at 6.19 ppm was integrated and found to have an area of 0.71 versus the integrated area of the methylene proton peak of the keto form. The enol =CH peak corresponds to one proton per molecule and the keto CH\(_2\) peak corresponds to two protons per molecule. Therefore, to calculate the mole ratio between 20a and 20b, half of the keto CH\(_2\) integrated area (1.0) of 20b was divided by the enol =CH integrated area (0.71). This gave 1:1.41 ratio for 20a:20b.

\(^{13}\)C NMR (75 MHz, CDCl\(_3\)): \(\delta\) 194.79 (–CH\(_2\)CO– in 20b), 164.01 (=C(OH)– in 20a), 160.45 and 157.33 (N,S=S=C– in both 20a and 20b), 147.50 and 145.00
(=NC(CH₃)=C(CH₃)S− in both 20a and 20b), 135.86 and 135.10 (−COC₆H₅, ipso in both 20a and 20b), 133.57 and 129.32 (−COC₆H₅, para in both 20a and 20b), 128.69 and 128.52 (−COC₆H₅, ortho in both 20a and 20b), 128.33 (−COC₆H₅, meta in 20a or 20b), 127.27 (=NC(CH₃)=C(CH₃)S− in 20a or 20b), 125.25 (−COC₆H₅, meta in 20a or 20b), 121.56 (=NC(CH₃)=C(CH₃)S− in 20a or 20b), 90.64 (N,S=C=CH− in 20a), 42.92 (N,S=C=CH− in 20b), 14.52 (=NC(CH₃)=C(CH₃)S− in 20b), 11.23 (=NC(CH₃)=C(CH₃)S− in 20b), 11.14 (=NC(CH₃)=C(CH₃)S− in 20a).

DEPT 135 NMR (150 MHz, CDCl₃): δ 133.68, 129.42, 128.80, 128.44, 125.35, 90.75, 43.02, 14.63, 14.34, 11.34, 11.25.

(Z)-2-(4,5-dimethyloxazol-2-yl)-1-phenylethenol (21a) and 2-(4,5-dimethyl-oxazol-2-yl)-1-phenylethanone (21b)

Tautomers (Z)-2-(4,5-dimethyloxazol-2-yl)-1-phenylethenol 21a and 2-(4,5-dimethyloxazol-2-yl)-1-phenylethanone 21b were synthesized by reacting (Z)-2-(4,5-dimethyloxazol-2-yl)-1-phenylvinyl benzoate 6 (1.6 g, 5.1 mmol, 1 eq.) in 15 mL of anhydrous MeOH and KOH (0.578 g, 10.3 mmol, 2 eq.) in 10 mL MeOH by the general procedure used for the synthesis and purification of equilibrating tautomers of 18. The eluent used for column chromatography over silica gel was ethyl acetate/hexane = 1:7. Tautomers 21a and 21b (0.811 g, 73.8%) were isolated. ¹H and ¹³C NMR in CDCl₃ confirmed that the isolated product consists of equilibrating tautomers (Z)-2-(4,5-dimethyloxazol-2-yl)-1-phenylethenol 21a and 2-(4,5-dimethyloxazol-2-yl)-1-phenylethanone 21b in 1:3.57 ratio.

Rₓ = 0.57 (ethyl acetate/hexane = 1:6); dark green oil.
IR (neat): 3059, 2980, 2953, 2924, 2882, 1693, 1633, 1598, 1578, 1532, 1496, 1449, 1293, 1201, 1066, 1012, 756, 713, 688, 639, 618 cm\(^{-1}\).

\(^1\)H NMR (600 MHz, CDCl\(_3\)): \(\delta\) –OH peak was not seen, 7.94 (d, \(J = 7.66\) Hz, \(C_6H_5\) \textit{ortho} in \(21b\), 2H), 7.71 (d, \(J = 7.72\), \(C_6H_5\) \textit{ortho} in \(21a\) 2H), 7.51 (m, \(C_6H_5\) \textit{meta} and \textit{para} in \(21a\), and \(C_6H_5\) \textit{meta} in \(21b\), 5H), 7.32 (t, \(J = 7.56\), \textit{para} in \(21b\), 1H), 5.91 (s, =CH– in \(21a\), 0.40H), 4.37 (s, –CH\(_2\)– in \(21b\), 2H), 2.17 (s, =NC(CH\(_3\))=C(CH\(_3\))S– or =NC(CH\(_3\))=C(CH\(_3\))O– in \(21a\), 3H), 2.14 (s, =NC(CH\(_3\))=C(CH\(_3\))O– or =NC(CH\(_3\))=C(CH\(_3\))O– in \(21b\), 3H), 2.03 (s, =NC(CH\(_3\))=C(CH\(_3\))O– or =NC(CH\(_3\))=C(CH\(_3\))O– in \(21a\), 3H), 2.02 (s, =NC(CH\(_3\))=C(CH\(_3\))O– or =NC(CH\(_3\))=C(CH\(_3\))O– in \(21b\), 3H).

The areas of the peaks for \(21a\) and \(21b\) were considered separately since their mole ratio in the solution was not 1:1. All peaks were first integrated by setting the area of the vinyl proton (=CH) peak of the enol tautomer \(21a\) at 5.91 ppm at one versus the rest of the resonances for \(21a\). The area of the methylene protons (–CH\(_2\)) of the keto tautomer \(21b\) at 4.37 ppm was set at two versus the rest of the resonances for \(21b\). The integration values of each peak and coupling patterns were used when assigning proton signals for each tautomer. To obtain the mole ratio between \(21a\) and \(21b\) in CDCl\(_3\), the integrated area of the –CH\(_2\) at 4.37 ppm was set at two and then the =CH peak at 5.91 ppm was integrated and found to have an area of 0.28 versus the integrated area of the methylene proton peak of the keto form. The enol =CH peak corresponds to one proton per molecule and the keto CH\(_2\) peak corresponds to two protons per molecule. Therefore, to calculate the mole ratio between \(21a\) and \(21b\), half of the keto CH\(_2\) integrated area (1.0) of \(21b\) was divided by the enol =CH integrated area (0.28). This gave 1:3.57 ratio for \(21a\):\(21b\).
$^{13}$C NMR (75 MHz, CDCl$_3$): $\delta$ 193.28 (–CH$_2$CO– in 21b), 161.23 (–C(OH)– in 21a), 160.92 (N,S=N in 21a), 155.28 (N,S=N in 21b), 143.98 (–NC(CH$_3$)=C(CH$_3$)O– in 21b), 140.21 (–NC(CH$_3$)=C(CH$_3$)O– in 21a), 135.63 (–COC$_6$H$_5$, ipso in 21b), 134.42 (–COC$_6$H$_5$, ipso in 21a), 133.49 (–COC$_6$H$_5$, para in 21b), 130.61 (–COC$_6$H$_5$, para in 21a), 129.41 (–NC(CH$_3$)=C(CH$_3$)O– in 21b), 128.88 (–NC(CH$_3$)=C(CH$_3$)O– in 21a), 128.57 (–COC$_6$H$_5$, ortho in 21b), 128.36 (–COC$_6$H$_5$, meta in 21b), 128.22 (–COC$_6$H$_5$, ortho in 21a), 125.08 (–COC$_6$H$_5$, meta in 21a), 84.01 (N,O=N=C=H in 21a), 38.81 (N,O=N=C=H in 21b), 10.88 (–NC(CH$_3$)=C(CH$_3$)O– in 21b), 10.73 (–NC(CH$_3$)=C(CH$_3$)O– in 21a), 9.75 (–NC(CH$_3$)=C(CH$_3$)O– in 21b), 9.63 (–NC(CH$_3$)=C(CH$_3$)O– in 21a).

DEPT 135 NMR (150 MHz, CDCl$_3$): $\delta$ 133.71, 129.62, 128.78, 128.58, 128.42, 125.30, 84.23, 39.04, 11.05, 10.95, 9.97, 9.86.

(Z)-2-(benzo[d]oxazol-2-yl)-1-phenylethenol (22a) and 2-(benzo[d]oxazol-2-yl)-1-phenylethanone (22b)

Tautomers (Z)-2-(benzo[d]oxazol-2-yl)-1-phenylethenol 22a and 2-(benzo[d]oxazol-2-yl)-1-phenylethanone 22b were synthesized by reacting (Z)-2-(benzo[d]oxazol-2-yl)-1-phenylvinyl benzoate 16 (0.844 g, 2.47 mmol, 1 eq.) in 15 mL of anhydrous MeOH and KOH (0.28 g, 5.2 mmol, 2.1 eq.) in 10 mL MeOH by the general procedure used for the synthesis and purification of equilibrating tautomers of 18. The eluent used for column chromatography over silica gel was ethyl acetate/hexane = 1:5. Tautomers 22a and 22b (0.541 g, 92.2%) were isolated. $^1$H and $^{13}$C NMR in CDCl$_3$ confirmed that the isolated product consists of equilibrating tautomers (Z)-2-(benzo[d]oxazol-2-yl)-1-phenylethenol 22a and 2-(benzo[d]oxazol-2-yl)-1-phenylethanone 22b in a 1.06:1 ratio.
Rf = 0.64 (ethyl acetate/hexane = 1:5); greenish white solid; mp = 87-89 °C.

IR (neat): 3065, 3032, 3044, 2979, 1625, 1576, 1530, 1453, 1277, 1250, 1164, 1064, 850, 792, 743, 762, 702, 685 cm⁻¹.

¹H NMR (600 MHz, CDCl₃): δ 12.62 (broad OH, 1H), 8.05 (d, J = 7.74 Hz, –C₆H₅ ortho, 2H), 7.88 (m, aromatic CH, 2H), 7.72 (m, aromatic CH, 1H), 7.61 (m, aromatic CH, 2H), 7.52-7.45 (m, aromatic CH, 7H), 7.34-7.31 (m, aromatic CH, 3H), 7.28 (t, J = 7.66 Hz, aromatic CH, 1H), 6.21 (s, =CH in 22a, 1H), 4.64 (s, –CH₂ in 22b, 2H).

The areas of the peaks for 22a and 22b were considered separately since their mole ratio in the solution was not 1:1. All peaks were first integrated by setting the area of the vinyl proton (–CH) peak of the enol tautomer 22a at 6.21 ppm at one versus the rest of the resonances for 22a. The area of the methylene protons (–CH₂) of the keto tautomer 22b at 4.64 ppm was set at two versus the rest of the resonances for 22b. The integration values of each peak and coupling patterns were used when assigning proton signals for the each tautomer. To obtain the mole ratio between 22a and 22b in CDCl₃, the integrated area of the –CH₂ at 4.64 ppm was set at two and then the =CH peak at 6.21 ppm was integrated and found to have an area of 1.06 versus the integrated area of the methylene proton peak of the keto form. The enol –CH peak corresponds to one proton per molecule and the keto CH₂ peak corresponds to two protons per molecule. Therefore, to calculate the mole ratio between 22a and 22b, half of the keto CH₂ integrated area (1.0) of 22b was used respect to the enol –CH integrated area (1.06). This gave 1.06:1 ratio for 22a:22b.

¹³C NMR (150 MHz, CDCl₃): δ 192.38 (–CH₂CO– in 22b), 166.19 (=C(OH)– in 22a), 165.68 (N,O=C– in 22b), 160.41 (N,O=C– in 22a), 151.24 (C next to O in
benzoxazole rings of 22b), 148.69 (C next to O in benzoxazole rings of 22a), 141.26 (C next to N in benzoxazole rings of 22b), 139.85 (C next to N in benzoxazole rings of 22a), 135.66 (−COC₆H₅, ipso in 22b), 134.03 (−COC₆H₅, ipso in 22a), 133.71 (−COC₆H₅, ipso in 22b, 128.59 (−COC₆H₅, meta in 22b, 128.53 (−COC₆H₅, meta in 22a), 125.82 (−COC₆H₅, ortho in 22b), 124.98 (aromatic CH on the benzoxazole ring in 22b), 124.16, 124.08 (aromatic CH on the benzoxazole ring in 22a), 119.95 (aromatic CH on the benzoxazole ring in 22b), 117.85 (aromatic CH on the benzoxazole ring in 22a), 110.19 (aromatic CH on the benzoxazole ring in 22a), 83.66 (N,O=CC= in 22a), 39.56 (N,O=CC=C in 22b).

DEPT 135 NMR (150 MHz, CDCl₃): δ 133.99, 130.64, 128.93, 128.67, 128.61, 125.90, 125.07, 124.69, 124.16, 120.03, 117.93, 110.69, 110.27, 83.74, 39.64.

(Z)-2-(benzo[d]thiazol-2-yl)-1-phenylethenol (23a) and 2-(benzo[d]thiazol-2-yl)-1-phenylethanone (23b)

Tautomers (Z)-2-(benzo[d]thiazol-2-yl)-1-phenylethenol 23a and 2-(benzo[d]thiazol-2-yl)-1-phenylethanone 23b were synthesized by reacting (Z)-2-(benzo[d]thiazol-2-yl)-1-phenylvinyl benzoate 17 (1.008 g, 2.82 mmol, 1 eq.) in 15 mL of anhydrous MeOH and KOH (0.316 g, 5.63 mmol, 2 eq.) in 10 mL MeOH by the general procedure used for the synthesis and purification of equilibrating tautomers of 18b. The eluent used for column chromatography over silica gel was ethyl acetate/hexane = 1:5. Tautomers 23a and 23b (0.516 g, 72.8%) were isolated. ¹H and ¹³C NMR in CDCl₃ confirmed that the isolated product consists of equilibrating tautomers 23a and 23b in a 1.63:1 ratio.
Rf = 0.64 (ethyl acetate/hexane = 1:5); yellowish green solid; mp = 111-112 °C.

IR (neat): 3057, 2922, 1610, 1596, 1573, 1494, 1473, 1436, 1378, 1264, 1249, 1136, 1057, 751, 729, 687, 668 cm⁻¹.

¹H NMR (600 MHz, CDCl₃): δ 13.91 (broad OH, 1H), 8.07 (d, J = 7.68 Hz, –C₆H₅ ortho in 23b, 2H), 7.99 (d, J = 8.13 Hz, aromatic CH in the benzothiazole ring of 23b, 1H), 7.85-7.87 (m, –C₆H₅ ortho in 23a and aromatic CH in the benzothiazole ring of 23b, 3H), 7.80 (d, J = 8.10 Hz, aromatic CH in the benzothiazole ring of 23a, 1H), 7.76 (d, J = 7.93 Hz, aromatic CH in the benzothiazole ring of 23a, 1H), 7.58 (dd, J = 8.13 and 7.91 Hz, aromatic CH in benzothiazole ring in 23b, 1H), 7.48 (dd, J = 7.68 and 7.53 Hz –C₆H₅ meta in 23b, 2H), 7.41-7.46 (m, –C₆H₅ meta in 23a and CH in the benzothiazole ring of 23a and 23b, 5H), 7.36 (t, J = 7.53 Hz, –C₆H₅ para in 23b, 1H), 7.27 (t, J = 7.53 Hz, –C₆H₅ para in 23a, 1H), 6.35 (s, =CH– in 23a, 1H), 4.81 (s, –CH₂– in 23b, 2H).

The areas of the peaks for 23a and 23b were considered separately since their mole ratio in the solution was not 1:1. All peaks were first integrated by setting the area of the vinyl proton (=CH) peak of the enol tautomer 23a at 6.35 ppm at one versus the rest of the resonances for 23a. The area of the methylene protons (–CH₂) of the keto tautomer 23b at 4.81 ppm was set at two versus the rest of the resonances for 23b. The integration values of each peak and coupling patterns were used when assigning proton signals for the each tautomer. To obtain the mole ratio between 23a and 23b in CDCl₃, the integrated area of the –CH₂ at 4.81 ppm was set at two and then the =CH peak at 6.35 pm was integrated and found to have an area of 1.63 versus the integrated area of the methylene proton peak of the keto form. The enol =CH peak corresponds to one proton per molecule and the keto CH₂ peak corresponds to two protons per molecule. Therefore, to calculate the mole ratio between 23a and 23b, half of the keto CH₂ integrated area
(1.0) of 23b was used with respect to the enol =CH integrated area (1.63). This gave 1:1.63 ratio for 23a:23b.

$^{13}$C NMR (150 MHz, CDCl$_3$): δ 194.05 (–CH$_2$C=O– in 23b), 168.07 (N,S–C– in 23b), 165.46 (N,S–C– in 23a), 163.44 (=C(OH)= in 23a), 152.68 (C next to N in the benzothiazole rings in 23b), 150.38 (C next to N in the benzothiazole rings in 23a), 135.88 and 135.78 (C next to S in the benzothiazole rings and –COC$_6$H$_5$, ipso in 23b), 134.74 (–COC$_6$H$_5$, ipso in 23a), 133.82 (–COC$_6$H$_5$, para 23b), 131.37 (C next to S in the benzothiazole rings of 23a), 130.28 (–COC$_6$H$_5$, para 23a), 128.81 and 128.64 (–COC$_6$H$_5$, meta and ortho in 23b, 4C), 128.48 (–COC$_6$H$_5$, meta in 23a, 2C), 126.46 and 125.96 (aromatic CH in the benzothiazole ring of 23a and 23b, 2C), 125.89 (–COC$_6$H$_5$, ortho in 23a, 2C), 125.05, 124.11, 122.85, 121.51, 121.37 and 119.95 (aromatic CH in the benzothiazole ring of 23a and 23b, 6C), 90.83 (N,S–C=CH= in 23a), 43.81 (N,S–CCH$_2$– in 23b).

DEPT 135 NMR (150 MHz, CDCl$_3$): δ 133.91, 130.38, 128.90, 128.73, 128.58, 126.56, 126.06, 125.98, 125.15, 124.20, 122.95, 121.60, 121.46, 120.04, 90.92, 43.91.

**Reaction of Tautomers 18a,b with Dimethyl Acetylenedicarboxylate**

MADC (0.63 g, 4.4 mmol, 2.5 eq.) in 5 mL of anhydrous MeOH was added dropwise to a stirred solution of the tautomers, (Z)-1-phenyl-2-(thiazol-2-yl)ethanol 18a and 1-phenyl-2-(thiazol-2-yl)ethanone 18b, (0.357 g, 1.76 mmol, 1 eq.) in 5 mL of anhydrous MeOH at room temperature under nitrogen. The molarities of DMAD and the tautomers are 0.44 M and 0.18 M, respectively. This solution was refluxed for 24 h under nitrogen and then MeOH was removed by rotary evaporation. The residue was dissolved in dichloromethane (40 mL), washed with water (2 × 40 mL) and dried over anhydrous sodium sulfate. After removal of dichloromethane by rotary evaporation, the crude
product was purified by column chromatography (silica gel, ethyl acetate/hexane = 1:3 → 3:1) and isolated. The open chain intermediate product 24 (0.079 g, 13%) eluted first followed by the 5,6-ring-fused product 25 (0.278 g, 50.5%). 0.135 g of orange color solid was isolated which is not identified. This general procedure was also used for the syntheses of compounds 24–40.

**Synthesis of compounds 24 and 25 under other reaction conditions**

Compounds 24 (0.054 g, 8.8%) and 25 (0.584 g, 69.8%) were prepared by combining solutions of DAMDC (0.378 g, 2.63 mmol, 1.49 eq.) in anhydrous MeOH (5 mL), and the tautomers 18a and 18b (0.357 g, 1.76 mmol, 1 eq.) in anhydrous MeOH (5 mL) and then following the general procedure mentioned above. The molarities of DMAD and the tautomers are 0.26 M and 0.18 M, respectively.

DAMDC (0.77 g, 5.36 mmol, 1.1 eq.) in anhydrous MeOH (10 mL) was added dropwise to a solution of the tautomers 18a and 18b (0.99 g, 4.87 mmol, 1 eq.) in anhydrous MeOH (20 mL) at room temperature under nitrogen. The molarities of DMAD and the tautomers are 0.18 M and 0.16 M, respectively. After stirring for 24 h at room temperature, 24 (0.426 g, 25.8%) and 25 (0.639 g, 41.9%) were isolated along with 10% of the starting tautomers at a 18a:18b ratio of 1:1.89. The products were worked up by the general procedure.

**Dimethyl (2E)-2-[2-Oxo-2-phenyl-1-(1,3-thiazol-2-yl)ethylidene]succinate (24)**

R<sub>f</sub> = 0.42 (ethyl acetate/hexane = 1:2); yellow solid; mp = 130-131 °C.

<sup>1</sup>H NMR (600 MHz, CDCl<sub>3</sub>): δ 8.08 (d, J = 7.73 Hz, C₆H₅ ortho, 2H), 7.96 (d, J = 2.64 Hz, =NCH=CHS=, 1H), 7.55 (t, J = 7.26 Hz, C₆H₅ para, 1H), 7.45 (m, C₆H₅ meta
and $\text{NCH=CHS}$, 3H), 4.12 (s, $-\text{CH}_2\text{CO}_2\text{CH}_3$, 2H), 3.79 (s, $=\text{C(}\text{CO}_2\text{CH}_3)$, 3H), 3.57 (s, $-\text{CH}_2\text{CO}_2\text{CH}_3$, 3H).

IR (neat): 3134, 3112, 3096, 3040, 3001, 2843, 1733, 1712, 1679, 1663, 1612, 1448, 1256, 1198, 1176, 1113, 1102 cm$^{-1}$.

$^{13}$C NMR (150 MHz, CDCl$_3$): $\delta$ 194.59 ($-\text{COC}_6\text{H}_5$), 171.01 ($-\text{CH}_2\text{CO}_2\text{CH}_3$), 166.17 ($=\text{C(}\text{CO}_2\text{CH}_3)$), 160.50 (N,S$\equiv$C$-$), 144.62 ($=\text{NCH=CHS}$), 143.84 ($-\text{CH}_2\text{C(}\text{CO}_2\text{CH}_3)$), 135.55 ($-\text{COC}_6\text{H}_5$, ipso), 133.55 ($-\text{COC}_6\text{H}_5$, para), 128.97 ($-\text{COC}_6\text{H}_5$, ortho), 128.80 ($-\text{COC}_6\text{H}_5$, meta), 127.17 ($-\text{C(}\text{COC}_6\text{H}_5$), 122.73 ($=\text{NCH=CHS}$), 52.54 ($-\text{CH}_2\text{CO}_2\text{CH}_3$), 52.54 ($=\text{C(}\text{CO}_2\text{CH}_3$), 35.11 ($=\text{CH}_2\text{CO}_2\text{CH}_3$).

DEPT 135 NMR (150 MHz, CDCl$_3$): $\delta$ 144.72, 133.65, 129.06, 128.90, 122.83, 2.63, 52.31, 35.20.

HRMS (ESI, [M+H]$^+$): calcd for C$_{17}$H$_{16}$NO$_5$S: 346.0749; found: 346.0740.

**Methyl 8-Benzoyl-5-oxo-5$H$-[1,3]thiazolo[3,2-a]pyridine-7-carboxylate (25)**

$R_f$ = 0.42 (ethyl acetate/hexane = 1:1); yellow solid; mp = 145-146 °C.

$^1$H NMR (600 MHz, CDCl$_3$): $\delta$ 8.36 (d, $J = 4.27$ Hz, $>\text{NCH=CHS}^-$, 1H), 7.59 (d, $J = 7.95$ Hz, C$_6$H$_5$ ortho, 2H), 7.53 (t, $J = 7.28$ Hz, C$_6$H$_5$ para, 1H), 7.46 (m, C$_6$H$_5$ meta, 2H), 7.31 (d, $J = 4.27$ Hz, $>\text{NCH=CHS}^-$, 1H), 6.67 (s, $-\text{CH}=-\text{C(}\text{CO}_2\text{CH}_3$), 1H), 3.18 (s, $-\text{CO}_2\text{CH}_3$, 3H).

IR (neat): 3158, 3125, 3091, 3062, 3030, 3008, 2953, 1725, 1681, 1663, 1619, 1595, 1472, 1439, 1409, 1331, 1252, 1159, 1096, 1077 cm$^{-1}$.

$^{13}$C NMR (150 MHz, CDCl$_3$): $\delta$ 191.20 ($-\text{COC}_6\text{H}_5$), 166.43 ($-\text{CO}_2\text{CH}_3$), 15 8.12 ($>\text{NCOCH}= \text{or} \ N,S\equiv\text{C}^-$), 154.89 ($>\text{NCOCH}= \text{or} \ N,S\equiv\text{C}^-$), 142.89 ($=\text{C(}\text{CO}_2\text{CH}_3$), 139.37 ($-\text{COC}_6\text{H}_5$, ipso), 131.86 ($-\text{COC}_6\text{H}_5$, para), 128.54 ($-\text{COC}_6\text{H}_5$, ortho), 127.85 ($-\text{COC}_6\text{H}_5$, meta), 124.14 ($>\text{NCH=CHS}^-$.
DEPT 135 NMR (150 MHz, CDCl₃): δ 131.95, 128.62, 127.93, 124.22, 117.85, 109.90, 52.48.


Single crystals were grown for X-ray crystallography by the vapor diffusion method. Hexane was diffused into a solution of compound 25 dissolved in chloroform.

**Reaction of Tautomers 19a,b with Dimethyl Acetylenedicarboxylate**

The open chain intermediate product 26 and the 5,6-ring-fused product 27 were synthesized by reacting DMAD (0.638 g, 4.44 mmol, 2.49 eq.) in anhydrous MeOH (5 mL) with the tautomers, (Z)-2-(4-methylthiazol-2-yl)-1-phenylethenol 19a and 2-(4-methylthiazol-2-yl)-1-phenylethanone 19b, (0.386 g, 1.78 mmol) in MeOH (5 mL) by the general procedure used for the synthesis and purification of 24 and 25. The molarities of DMAD and tautomers are 0.44 M and 0.18 M, respectively. The eluent used for column chromatography over silica gel was ethyl acetate/hexane = 1:1. The compound 26 (0.073 g, 11.5%), eluted first followed by the compound 27 (0.379 g, 65.2%). Trace amounts of (E) and (Z)-dimethyl 2-methoxymaleate 28 and 29 were also isolated as byproducts.

**Syntheses of compounds 26 and 27 under other reaction conditions**

DAMD (0.233 g, 1.62 mmol, 1 eq.) in anhydrous MeOH (10 mL) was added dropwise to a solution of the tautomers 19a and 19b (0.352 g, 1.62 mmol, 1 eq.) in anhydrous MeOH (10 mL) at room temperature under nitrogen. The molarities of DMAD and tautomers are 0.08 M and 0.08 M, respectively. After stirring for 24 h at room
temperature, 26 (0.147 g, 25.2%) and 27 (0.169 g, 31.9%) were isolated along with 15% of the starting tautomers at a 19a:19b ratio of 1:1.25. The products were worked up by the general procedure.

**Dimethyl (2E)-2-[1-(4-Methyl-1,3-thiazol-2-yl)-2-oxo-2-phenylethylidene]succinate (26)**

\[ R_f = 0.47 \text{ (ethyl acetate/hexane = 1:2)}; \text{ yellow solid; } mp = 114-115 \degree C. \]

IR (neat): 3100, 2997, 2949, 2933, 1733, 1711, 1679, 1604, 1505, 1446, 1257, 1231, 1198, 1172 cm\(^{-1}\).

\(^1\)H NMR (600 MHz, CDCl\(_3\)): \( \delta \) 8.07 (d, \( J = 6.74 \) Hz, \( \text{C}_6\text{H}_5 \text{ ortho} \), 2H), 7.54 (t, \( J = 6.39 \)Hz, \( \text{C}_6\text{H}_5 \text{ para} \), 1H), 7.45 (dd, \( J = 6.74 \) and 6.39 Hz, \( \text{C}_6\text{H}_5 \text{ meta} \), 2H), 7.26 (s, =NC(CH\(_3\))=CHS\( \cdots \), 1H), 4.12 (s, =CH\(_2\text{CO}_2\text{CH}_3\), 2H), 3.80 (s, =C(CO\(_2\text{CH}_3\)=, 3H), 3.57 (s, =CH\(_2\text{CO}_2\text{CH}_3\), 3H), 2.47 (s, =NC(CH\(_3\))=CHS\( \cdots \), 3H).

\(^{13}\)C NMR (150 MHz, CDCl\(_3\)): \( \delta \) 194.52 (=C(COC\(_6\text{H}_5\)), 171.19 (=CH\(_2\text{CO}_2\text{CH}_3\)), 166.23 (=C(CO\(_2\text{CH}_3\)=), 159.22 (N,S\( \equiv \)C or =C(COC\(_6\text{H}_5\)=)), 155.04 (N,S\( \equiv \)C or =C(COC\(_6\text{H}_5\)=)), 143.81 (=C(CO\(_2\text{CH}_3\)=)), 135.54 (=COC\(_6\text{H}_5\), ipso), 133.42 (=COC\(_6\text{H}_5\), \text{ para} \)), 128.86 (=CO\(_\text{C}_6\text{H}_5\), \text{ ortho} \), 128.69 (=CO\(_\text{C}_6\text{H}_5\), \text{ meta} \), 126.30 (=NC(CH\(_3\))=CHS\( \cdots \), 117.87 (=NC(CH\(_3\))=CHS\( \cdots \), 52.42 (=C(CO\(_2\text{CH}_3\)=), 51.98 (=CH\(_2\text{CO}_2\text{CH}_3\), 35.15 (=CH\(_2\text{CO}_2\text{CH}_3\), 17.02 (=N(CH\(_3\))C=CHS\( \cdots \)).

DEPT 135 NMR (150 MHz, CDCl\(_3\)): \( \delta \) 133.57, 129.06, 128.86, 117.95, 52.60, 52.16, 35.34.

IHRMS (ESI, [M+H]+): calcd for C\(_{18}\)H\(_{18}\)NO\(_5\)S: 360.0906; found: 360.0908.

**Methyl 8-Benzoyl-3-methyl-5-oxo-5H-[1,3]thiazolo[3,2-a]pyridine-7-carboxylate (27)**

\[ R_f = 0.53 \text{ (ethyl acetate/hexane = 1:1)}; \text{ yellow solid; } mp = 203-204 \degree C. \]
IR (neat): 3128, 3066, 2981, 2951, 1723, 1667, 1625, 1594, 1475, 1435, 1406, 1304, 1255, 1144, 1126 cm$^{-1}$.

$^1$H NMR (600 MHz, CDCl$_3$): $\delta$ 7.57 (d, $J = 7.14$ Hz, C$_6$H$_5$ ortho, 2H), 7.51 (t, $J = 7.38$ Hz, C$_6$H$_5$ para, 1H), 7.44 (dd, $J = 7.14$ and 7.38 Hz, C$_6$H$_5$ meta, 2H), 6.74 (s, >NC(CH$_3$)=CHS=, 1H), 6.53 (s, –CH=CCO$_2$CH$_3$, 1H), 3.16 (s, –CO$_2$CH$_3$, 3H), 2.92 (s, >NC(CH$_3$)=CHS=, 3H).

$^{13}$C NMR (150 MHz, CDCl$_3$): $\delta$ 190.97 (–COC$_6$H$_5$), 166.35 (–CO$_2$CH$_3$), 161.18 (>NCOCH= or N,S=C=), 157.55 (>NCOCH= or N,S=), 142.18 (–CCO$_2$CH$_3$), 139.56 (>NC(CH$_3$)=CHS= or –CO$_2$CH$_3$  ipso), 138.93 (>NC(CH$_3$)=CHS= or –CO$_2$CH$_3$ ipso), 131.64 (–CO$_2$H$_5$, para), 128.42 (–CO$_2$H$_5$, ortho), 127.78 (–CO$_2$H$_5$, meta), 112.36 (>NCOOH=), 111.34 (>NC(CH$_3$)=CHS=), 107.46 (=C(CO$_2$CH$_3$)=), 52.26 (–CO$_2$CH$_3$), 18.25 (>NC(CH$_3$)=CHS=).

DEPT 135 NMR (150 MHz, CDCl$_3$): $\delta$ 131.77, 128.55, 127.91, 112.50, 111.48, 52.40, 18.40.

HRMS (ESI, [M+H]$^+$): calcd for C$_{17}$H$_{13}$NO$_4$S: 328.0663; found: 328.0644.

(E)-Dimethyl 2-methoxymaleate (28)$^2$

Brown oil

$^1$H NMR (600 MHz, CDCl$_3$): $\delta$ 5.21 (s, =CH(CO$_2$CH$_3$), 1H), 3.89, 3.75 (s, two –CO$_2$CH$_3$, 6H), 3.71 (s, –OCH$_3$, 3H).

$^{13}$C NMR (600 MHz, CDCl$_3$): $\delta$ 166.38, 164.08 (two –CO$_2$CH$_3$), 162.59 (=C(CO$_2$CH$_3$)OCH$_3$), 93.26 (=CH(CO$_2$CH$_3$), 57.08, 53.04 (two –CO$_2$CH$_3$), 51.78 (–OCH$_3$).

(Z)-Dimethyl 2-methoxymaleate (29)$^2$

Brown oil
$^1$H NMR (600 MHz, CDCl$_3$): $\delta$ 6.19 (s, $\text{=CH(CO}_2\text{CH}_3$), 1H), 3.95, 3.85 (s, two $\text{–CO}_2\text{CH}_3$, 6H), 3.76 (s, $\text{–OCH}_3$, 3H).

$^{13}$C NMR (600 MHz, CDCl$_3$): $\delta$ 164.70, 163.21 (two $\text{–CO}_2\text{CH}_3$), 154.74 ($\text{=C(CO}_2\text{CH}_3\text{)OCH}_3$), 107.69 ($\text{=CH(CO}_2\text{CH}_3$)), 61.05, 52.85 (two $\text{–CO}_2\text{CH}_3$), 51.70 ($\text{–OCH}_3$).

Reaction of Tautomeric Pair 21a,b with Dimethyl Acetylenedicarboxylate

The open chain intermediate product 30, the 5,6-ring-fused product 31 and the 5,7-ring-fused product 32 were synthesized by reacting DMAD (0.638 g, 4.44 mmol, 2.49 eq.) in 5 mL of anhydrous MeOH with the tautomers, (Z)-2-(4,5-dimethylthiazol-2-yl)-1-phenylethenol 20a and 2-(4,5-dimethylthiazol-2-yl)-1-phenylethanone 20b, (0.337 g, 1.46 mmol) in 5 mL MeOH by the general procedure used for the synthesis and purification of 24 and 25. The molarities of DMAD and tautomers are 0.44 M and 0.15 M, respectively. The eluent used for column chromatography over silica gel was silica gel, 1:2 $\rightarrow$ 3:1 ethyl acetate: hexane. The compound 30, (0.175 g, 32.3%), eluted first followed by the compound 31 (0.08 g, 16%) and compound 32 (0.173 g, 23.1%). Trace amount of (E) and (Z)-dimethyl 2-methoxymaleate 28 and 29 were also isolated as by products.

Synthesis of compounds 30, 31 and 32 under other reaction conditions

The open chain intermediate 30 (0.249 g, 45.8%), the 5,6-ring-fused compound 31, (0.102 g, 20.5%) and the 5,7-ring-fused compound 32 (0.05 g, 7%) were prepared by combining solutions of DAMDC (0.313 g, 2.18 mmol, 1.5 eq.) in anhydrous MeOH.
(5 mL), and the tautomers 20a and 20b (0.336 g, 1.45 mmol, 1 eq.) in anhydrous MeOH (5 mL) and then the general procedure mentioned above was followed. The molarities of DMAD and tautomers are 0.22 M and 0.15 M, respectively.

Dimethyl (2E)-2-[1-(4,5-Dimethyl-1,3-thiazol-2-yl)-2-oxo-2-phenylethylidene]succinate (30)

Rf = 0.50 (ethyl acetate/hexane = 2:1); brown sticky oil.

IR (neat): 3060, 3023, 2997, 2981, 2951, 2925, 2847, 1736, 1714, 1672, 1628, 1294, 1254, 1491, 1407, 1205, 1170, 1121, 939, 785, 729, 689 cm⁻¹.

¹H NMR (300 MHz, CDCl₃): δ 8.06 (d, J = 7.50 Hz, C₆H₅ ortho, 2H), 7.55 (t, J = 7.21 Hz, C₆H₅ para, 1H), 7.45 (dd, J = 7.50 and 7.21 Hz, C₆H₅ meta, 2H), 4.12 (s, –CH₂CO₂CH₃, 3H), 3.79 (s, =C(CO₂CH₃)--, 3H), 3.55 (s, –CH₂CO₂CH₃, 3H), 2.33 (s, =NC(CH₃)=C(CH₃)S), 2.30 (s, =NC(CH₃)=C(CH₃)S, 3H).

¹³C NMR (75 MHz, CDCl₃): δ 194.67 (–COC₆H₅), 171.33 (–CH₂CO₂CH₃), 166.34 (–C(CO₂CH₃)--), 154.98 (N,S=– or =NC(CH₃)=C(CH₃)S–), 151.20 (N,S=– or =NC(CH₃)=C(CH₃)S–), 144.00 (–C(COC₆H₅)--), 135.61 (–C(CO₂CH₃)– or –COC₆H₅ ipso), 133.32 (–C(CO₂CH₃)– or –COC₆H₅ ipso), 131.79 (–COC₆H₅, para), 128.83 (–COC₆H₅, ortho), 128.66 (–COC₆H₅, meta), 129.95 (NC(CH₃)=C(CH₃)S–), 52.35 (–C(CO₂CH₃)--), 51.94 (–CH₂CO₂CH₃), 35.10 (–CH₂CO₂CH₃), 14.70 (–NC(CH₃)=C(CH₃)S–), 11.17 (–NC(CH₃)=C(CH₃)S–).

DEPT 135 NMR (150 MHz, CDCl₃): δ 133.47, 128.96, 128.81, 52.49, 52.08, 35.23, 14.84, 11.37.

Methyl 8-Benzoyl-2,3-dimethyl-5-oxo-5H-[1,3]thiazolo[3,2-a]pyridine-7-carboxylate (31)

Rf = 0.58 (ethyl acetate/hexane = 1:1); yellow solid; mp = 172-174 °C.

IR (neat): 3081, 3030, 2970, 2981, 2951, 2936, 1733, 1683, 1608, 1598, 1539, 1480, 1443, 1413, 1323, 1310, 1280, 1249, 1174, 1123, 981, 947, 847, 780, 694 cm⁻¹.

¹H NMR (600 MHz, CDCl₃): δ 7.56 (d, J = 7.84 Hz, C₆H₅ ortho, 2H), 7.51 (t, J = 7.02 Hz, C₆H₅ para, 1H), 7.44 (dd, J = 7.84 and 7.02 Hz, C₆H₅ meta, 2H), 6.53 (s, -CH=C(CO₂CH₃)=, 1H), 3.15 (s, CO₂CH₃, 3H), 2.82 (s, >NC(CH₃)=C(CH₃)S =, 3H), 2.35 (s, >NC(CH₃)C(CH₃)S =, 3H).

¹³C NMR (150 MHz, CDCl₃): δ 191.07 (–COC₆H₅), 166.55 (–CO₂CH₃), 161.06 (>NCOCH=) or N,S=O =, 155.57 (>NCOCH=) or N,S=O =, 141.50 (=C(CO₂CH₃)=), 139.73 (–COC₆H₅ ipso), 133.24 (>NC(CH₃)=C(CH₃)S =), 131.61 (–COC₆H₅ para), 128.44 (–COC₆H₅ ortho), 127.85 (–COC₆H₅ meta), 122.59 (>NC(CH₃)=C(CH₃)S =), 111.68 (>NCOCH=), 107.19 (=C(COC₆H₅)=), 52.25 (–CO₂CH₃), 15.11 (>NC(CH₃)=C(CH₃)S =), 11.61 (>NC(CH₃)=C(CH₃)S =).

DEPT 135 NMR (150 MHz, CDCl₃): δ 131.71, 128.53, 127.94, 111.77, 52.34, 15.21, 11.71.


Tetramethyl (5S*,6S*)-9-Benzoyl-2,3-dimethyl-5,6-dihydro[1,3]thiazolo[3,2-a]azepine-5,6,7,8-tetracarboxylate (32)

Rf = 0.45 (ethyl acetate/hexane = 3:1); yellowish orange solid; mp = 216-218 °C.

IR (neat): 2996, 2949, 2840, 1738, 1709, 1549, 1449, 1333, 1348, 1213, 1137, 997, 786, 740, 700, 662 cm⁻¹.

¹H NMR (600 MHz, CDCl₃): δ 7.53 (d, J = 7.16 Hz, C₆H₅ ortho, 2H), 7.38 (t, J = 7.34 Hz, C₆H₅ para, 1H), 7.31 (dd, J = 7.16 and 7.34 Hz, C₆H₅ meta, 2H), 5.76 (d, J =
5.2 Hz, >NCH(CO₂CH₃)=, 1H), 4.98 (d, J = 5.2 Hz, −CH(CO₂CH₃)−C(CO₂CH₃)=, 1H), 3.71 (s, −CH(CO₂CH₃)−C(CO₂CH₃)=, 3H), 3.68 (s, −C(CO₂CH₃)−C(COC₆H₅)=, 3H), 3.67 (s, −CH(CO₂CH₃)−C(CO₂CH₃)=, 3H) 3.03 (s, >NCH(CO₂CH₃)=, 3H), 2.24, 2.21 (s, >NC(CH₃)=C(CH₃)S=, 6H).

13C NMR (150 MHz, CDCl₃): δ 189.64 (−COC₆H₅), 169.06, 167.73, 167.70, 167.08 (four −CO₂CH₃), 160.25 (N,S−C=), 142.15 (−C(CO₂CH₃)−C(COC₆H₅)= or −COC₆H₅ ipso), 140.86 (=C(CO₂CH₃)−C(COC₆H₅)= or −COC₆H₅ ipso), 132.81 (>NC(CH₃)=C(CH₃)S=), 130.45 (−COC₆H₅, para), 129.34 (−COC₆H₅, ortho), 127.53 (−COC₆H₅, meta), 119.90 (−CH(CO₂CH₃)−C(CO₂CH₃)=), 116.90 (>NC(CH₃)=C(CH₃)S=), 97.59 (=C(COC₆H₅)=), 64.12 (>NCHCO₂CH₃), 53.16, 53.07, 52.35, 51.93, (four −CO₂CH₃), 46.32 (=CH(CO₂CH₃)−C(CO₂CH₃)=), 12.51 and 11.43 (>NC(CH₃)=C(CH₃)S=, 2C).

DEPT 135 NMR (150 MHz, CDCl₃): δ 130.52, 129.41, 127.60, 64.19, 53.23, 53.15, 52.43, 52.00, 46.39, 12.58, 11.50.


**Reaction of Tautomeric Pair 21a,b with Dimethyl Acetylenedicarboxylate**

The open chain intermediate product 33, the 5,6-ring-fused product 34 and the 5,7-ring-fused product 35 were synthesized by reacting DMAD (0.601 g, 4.19 mmol, 2.51 eq.) in anhydrous MeOH (5 mL) and the tautomers, (Z)-2-(4,5-dimethyloxazol-2-yl)-1-phenylethenol 21a and 2-(4,5-dimethyloxazol-2-yl)-1-phenylethanone 21b, (0.360 g, 1.67 mmol, 1 eq.) in MeOH (5 mL) by the general procedure used for the synthesis and purification of 24 and 25. The molarities of DMAD and the tautomers are 0.42 M and 0.17 M, respectively. The eluent used for column chromatography over silica
gel was 1:2 → 4:1 ethyl acetate: hexane. The intermediate product 33 (0.212 g, 35.5%), eluted first followed by 36 (0.011 g, 1.3%), 5,6-ring-fused compound 34 (0.023 g, 4.3%) and 5,7 ring-fused compound 35 (0.392 g, 47%). Trace amount of (E) and (Z)-dimethyl 2-methoxymaleate 28 and 29 were also isolated.

**Synthesis of compounds 33 and 35 under other reaction conditions**

The open chain intermediate product 33 (0.206 g, 44.2%) and 5,7-ring-fused product 35 (0.166 g, 19.8%) were prepared by stirring the tautomers 21a and 21b (0.363 g, 1.68 mmol, 1 eq.) and DAMDC (0.242 g, 1.68 mmol, 1 eq.) in anhydrous MeOH (10 mL) at room temperature for 24 h. The starting tautomers (16.5%) were recovered at a 21a:21b ratio of 1:2.73. The molarities of both DMAD and tautomers are 0.17 M. The 5,6-ring-fused compound was not detected on TLC.

**Dimethyl (2Z)-2-[1-(4,5-Dimethyl-1,3-oxazol-2-yl)-2-oxo-2-Phenylethylidene]succinate (33)**

Rf = 0.65 (ethyl acetate/hexane = 1:1); yellow solid, mp = 110-111 °C.

IR (neat): 3084, 3066, 3029, 2959, 2935, 2850, 1736, 1708, 1601, 1434, 1361, 1335, 1279, 1248, 1216, 1195, 1174, 1120, 942, 896, 866 cm⁻¹.

¹H NMR (600 MHz, CDCl₃): δ 8.02 (d, J = 7.92 Hz, C₆H₅ ortho, 2H), 7.55 (t, J = 7.30 Hz, C₆H₅ para, 1H), 7.46 (dd, J = 7.92 and 7.30 Hz, C₆H₅ meta, 2H), 4.22 (s, –CH₂CO₂CH₃, 2H), 3.78 (s, –C(CO₂CH₃)–, 3H), 3.55 (s, –CH₂CO₂CH₃, 3H), 2.16 (s, =NC(CH₃)=C(CH₃)O–, 3H), 2.07 (s, =NC(CH₃)=C(CH₃)O–, 3H).

¹³C NMR (150 MHz, CDCl₃): δ 192.63 (–COC₆H₅), 171.13 (–CH₂CO₂CH₃), 166.14 (–C(CO₂CH₃)–), 154.61 (N,O=–), 145.93 (–C(CO₂CH₃)–), 138.17 (–C(CO₂CH₃)– or –COC₆H₅ ipso or =NC(CH₃)=C(CH₃)O–), 136.16 (–C(CO₂CH₃)– or –COC₆H₅ ipso or =NC(CH₃)=C(CH₃)O–), 134.06 (–C(CO₂CH₃)– or –COC₆H₅, ipso or
=NC(\text{CH}_3)C(\text{CH}_3)\text{O}^–), 133.22 (−\text{COC}_6\text{H}_5, \text{para}), 128.77 (−\text{COC}_6\text{H}_5, \text{ortho}), 128.65 (−\text{COC}_6\text{H}_5, \text{meta}), 126.95 (\text{NC}(\text{CH}_3)=\text{C}(\text{CH}_3)\text{O}^–), 52.44 (=\text{C}(\text{CO}_2\text{CH}_3)^–), 52.09 (−\text{CH}_2\text{CO}_2\text{CH}_3), 34.94 (−\text{CH}_2\text{CO}_2\text{CH}_3), 11.19 (−\text{NC}(\text{CH}_3)=\text{C}(\text{CH}_3)\text{O}^–), 10.05 (−\text{NC}(\text{CH}_3)=\text{C}(\text{CH}_3)\text{O}^–).

DEPT 135 NMR (150 MHz, CDCl$_3$): δ 133.30, 128.86, 128.74, 52.52, 52.17, 35.02, 11.28, 10.14.

HRMS (ESI, [M+H]$^+$): calcd for C$_{19}$H$_{20}$NO$_6$: 358.1291; found: 358.1261.

Single crystals were grown for X-ray crystallography by the vapor diffusion method. Hexane was diffused into a solution of compound 33 dissolved in chloroform.

Methyl 8-Benzoyl-2,3-dimethyl-5-oxo-5$^H$-[1,3]oxazolo[3,2-a]pyridine-7-carboxylate (34)

R$_f$ = 0.44 (ethyl acetate/hexane = 2:1); yellow solid; mp = 162-164 °C.

IR (neat): 3079, 2993, 2973, 2950, 2935, 1733, 1706, 1663, 1640, 1444, 1428, 1270, 1154, 971 cm$^{-1}$.

$^1$H NMR (600 MHz, CDCl$_3$): δ 7.56 (d, $J$ = 8.42 Hz, C$_6$H$_5$, ortho, 2H), 7.50 (t, $J$ = 7.38 Hz, C$_6$H$_5$, para, 1H), 7.44 (dd, $J$ = 8.42 and 7.38 Hz, C$_6$H$_5$, meta, 2H), 6.54 (s, −CH=C(OC$_2$CH$_3$)=, 1H), 3.16 (s, −CO$_2$CH$_3$, 3H), 2.83, 2.35 (s, >OC(CH$_3$)=C(CH$_3$)N<, 6H).

$^{13}$C NMR (150 MHz, CDCl$_3$): δ 189.57 (−\text{COC}_6\text{H}_5), 166.08 (−\text{CO}_2\text{CH}_3), 158.48 (>\text{NCOCH}^= or (N,O=\text{C}=), 153.22 (>\text{NCOCH}^= or (N,O=\text{C}=), 142.76 (=\text{C}(\text{CO}_2\text{CH}_3)^–), 142.10 (>\text{NC}(\text{CH}_3)=\text{C}(\text{CH}_3)\text{O}^–), 138.43 (−\text{COC}_6\text{H}_5$, ipso), 132.84 (−\text{COC}_6\text{H}_5$, para), 128.69 (−\text{COC}_6\text{H}_5$, ortho), 128.45 (−\text{COC}_6\text{H}_5$, meta), 119.38 (>\text{NC}(\text{CH}_3)=\text{C}(\text{CH}_3)\text{O}^–), 109.85 (>\text{NCOCH}^=), 97.77 (=\text{C}(\text{COC}_6\text{H}_5)^–), 52.62 (−\text{CO}_2\text{CH}_3), 9.95, 9.79 (>\text{NC}(\text{CH}_3)=\text{C}(\text{CH}_3)\text{O}^–).
DEPT 135 NMR (150 MHz, CDCl₃): δ 132.91, 128.76, 128.52, 109.92, 52.68, 10.00, 9.85.


Single crystals were obtained for X-ray crystallography by the vapor diffusion method. Hexane was diffused into a solution of compound 34 dissolved in chloroform.

Tetramethyl (5S*,6S*)-9-Benzoyl-2,3-dimethyl-5,6-dihydro[1,3]oxazolo[3,2-a]azeepine-5,6,7,8-tetracarboxylate (35)

Rₚ = 0.35 (ethyl acetate/hexane = 4:1); intense yellow solid; mp = decompose at 170 °C.

IR (neat): 2997, 2991, 2980, 2930, 1729, 1683, 1657, 1570, 1515, 1430, 1232, 1227, 1225, 1170, 1120, 1097, 1000, 855, 768, 716, 695 cm⁻¹.

¹H NMR (600 MHz, CDCl₃): δ 7.60 (d, J = 7.58 Hz, C₆H₅ ortho, 2H), 7.39 (t, J = 7.25 Hz, C₆H₅ para, 1H), 7.31 (dd, J = 7.58 and 7.25 Hz, C₆H₅ meta, 2H), 5.42 (d, J = 4.9 Hz, >NCH(CO₂CH₃)=, 1H), 5.26 (d, J = 4.9 Hz, –CH(CH₂CO₂CH₃)=C(CO₂CH₃)=, 1H), 3.74 (s, –CH(CH₂CO₂CH₃)=C(CO₂CH₃)=, 3H), 3.73 (s, –C(CH₂CO₂CH₃)=C(CO₂CH₃)=, 3H), 3.69 (s, –CH(CH₂CO₂CH₃)=C(CO₂CH₃)=, 3H), 3.65 (s,  >NCH(CH₃)=O−, 3H), 2.05, 1.83 (s, >NC(CH₃)=C(CH₃)O−, 6H).

¹³C NMR (75 MHz, CDCl₃): δ 192.37 (–CO₂CH₃), 170.38, 168.76, 167.08, 166.58 (four –CO₂CH₃), 158.96 (N,S>–C–), 144.31 (=C(CH₂CO₂CH₃)=C(CO₂CH₃)= or –CO₂CH₃ ipso), 141.85 (=C(CH₂CO₂CH₃)=C(CO₂CH₃)= or –CO₂CH₃ ipso), 138.12 (–CH(CH₂CO₂CH₃)=C(CH₂CO₂CH₃)= or (>NC(CH₃)=C(CH₃)O−), 130.69 (–CO₂CH₃, para), 128.40 (–CO₂CH₃, ortho), 127.71 (–CO₂CH₃, meta), 121.44 (–CH(CH₂CO₂CH₃)=C(CH₂CO₂CH₃)= or (>NC(CH₃)=C(CH₃)O−), 110.70 (>NC(CH₃)=C(CH₃)O−), 89.79 (=C(CO₂CH₃)=, 60.29 (>NC(CH₃)=C(CH₃)O−), 53.28, 53.16,
52.32, 52.25, (four –CO₂CH₃), 44.93 (–CH(CO₂CH₃)–C(CO₂CH₃)=), 9.59, 7.59
(>NC(CH₃)=C(CH₃)O–, 2C).

DEPT 135 NMR (150 MHz, CDCl₃): δ 130.75, 128.49, 127.78, 60.40, 53.31,
53.21, 52.36, 52.30, 45.06, 9.64, 7.65.


Single crystals were grown for X-ray crystallography by the vapor diffusion method.
Hexane was diffused into a solution of compound 35 dissolved in acetone.

Figure S1 The X-ray crystal structures of two independent molecules of 35. Solvent molecules (acetone) are not shown for clarity. CCDC: 888332.

**Tetramethyl 6-(4,5-Dimethyl-1,3-oxazol-2-yl)biphenyl-2,3,4,5-tetracarboxylate (36)**

Rᵣ = 0.35 (ethyl acetate/hexane = 2:3); off white solid; mp = 124-126 °C.

IR (neat): 3023, 3018, 3001, 2981, 2956, 2928, 1735, 1438, 1335, 1209, 1187,
1176, 1153, 1094, 924, 857, 824, 715 cm⁻¹.
$^1$H NMR (600 MHz, CDCl₃): δ 7.29 (m, C6H₅ para and meta, 3H), 7.06 (d, $J = 7.19$ Hz, C6H₅ ortho, 2H), 3.90, 3.88, 3.76, 3.50 (s, four $\text{CO}_2\text{CH}_3$, 12H), 1.99, 1.92 (s, >NC(CH₃)=C(CH₃)O–, 6H).

$^{13}$C NMR (150 MHz, CDCl₃): δ 166.71, 166.42, 165.85, 165.82 (four $\text{CO}_2\text{CH}_3$), 154.26 (N,O>C=), 144.52, 142.90, 136.44, 135.98, 135.27, 131.75, 131.48, 130.99, 129.89 (aromatic, 7C and >NC(CH₃)=C(CH₃)O–, 2C), 53.24, 53.20, 52.88, 52.51 (four $\text{CO}_2\text{CH}_3$), 11.08, 9.57 (>NC(CH₃)=C(CH₃)O–).

DEPT 135 NMR (150 MHz, CDCl₃): δ 128.47, 128.03, 127.88, 53.30, 53.26, 52.57, 11.14, 9.63.

HRMS (ESI, [M+H]+): calcd for C₂₅H₂₄NO₉: 482.1451; found: 482.1435.

**Reaction of Tautomeric pair 22a,b with Dimethyl Acetylenedicarboxylate**

The open chain intermediate product 37 and the 5,6-ring-fused product 38, were synthesized by reacting DMAD (0.308 g, 2.15 mmol, 1.5 eq.) in anhydrous MeOH (5 mL) with the tautomers (Z)-2-(benzo[d]oxazol-2-yl)-1-phenylethenol 22a and 2-(benzo[d]oxazol-2-yl)-1-phenylethanone 22b (0.339 g, 1.43 mmol, 1 eq.) in MeOH (5 mL) by the general procedure used for the synthesis and purification of 24 and 25. The molarities of DMAD and tautomers are 0.22 M and 0.14 M, respectively. The eluent used for column chromatography over silica gel was ethyl acetate: hexane = 1:3. The compound 37 (0.01 g, 2%), eluted first followed by the compound 38 (0.46 g, 93%).

**Syntheses of compounds 37 and 38 under other reaction conditions**

(Z)-Dimethyl 2-(1-(benzo[d]oxazol-2-yl)-2-oxo-2-phenylethylidene)succinate 37 (0.172 g, 35.3%) and methyl 4-benzoyl-1-oxo-1H-benzo[4,5]oxazolo[3,2-a]pyridine-3-carboxylate 38 (0.049 g, 11%) were prepared by combining solutions of DAMDC (0.279 g, 1.94 mmol, 1.51 eq.) in anhydrous MeOH (10 mL), and the tautomers 22a and
22b (0.305 g, 1.28 mmol, 1 eq.) in anhydrous MeOH (15 mL) and then following the general procedure mentioned above. The molarities of DMAD and tautomers are 0.08 M and 0.05 M, respectively. The starting tautomers (40.6%) were recovered in a 22a:22b ratio of 1.11:1.

**Dimethyl (2Z)-2-[1-(1,3-Benzoxazol-2-yl)-2-oxo-2-phenylethylidene]succinate (37)**

R<sub>f</sub> = 0.48 (ethyl acetate/hexane = 1:2); yellow solid; mp = 130-132 °C.

IR (neat): 3086, 3067, 2981, 2952, 2923, 2849, 1743, 1720, 1694, 1596, 1534, 1449, 1434, 1296, 1243, 1209, 1181, 1001, 944, 753, 725, 692 cm<sup>-1</sup>.

<sup>1</sup>H NMR (300 MHz, CDCl<sub>3</sub>): δ 8.08 (d, J = 8.53 Hz, C<sub>6</sub>H<sub>5</sub> ortho, 2H), 7.77-7.73 (m, aromatic H), 7.57 (t, J = 7.93 Hz, C<sub>6</sub>H<sub>5</sub> para, 1H), 7.50-7.47 (m, aromatic H), 7.37-7.33 (m, aromatic H), 4.38 (s, -CH<sub>2</sub>CO<sub>2</sub>CH<sub>3</sub>, 2H), 3.81 (s, =C(CO<sub>2</sub>CH<sub>3</sub>)--, 3H), 3.61 (s, -CH<sub>2</sub>CO<sub>2</sub>CH<sub>3</sub>, 3H).

<sup>13</sup>C NMR (75 MHz, CDCl<sub>3</sub>): δ 192.12 (=C(C<sub>6</sub>H<sub>5</sub>), 170.72 (=CH<sub>2</sub>CO<sub>2</sub>CH<sub>3</sub>), 165.75 (=C(CO<sub>2</sub>CH<sub>3</sub>)--), 158.21 (N,O=C--), 150.05 (=NC=O--), 141.13 (=C(COC<sub>6</sub>H<sub>5</sub>)--), 138.43 (=C(CO<sub>2</sub>CH<sub>3</sub>)-- or =NC=O--), 135.96 (=CO<sub>2</sub>C<sub>6</sub>H<sub>5</sub>, ipso), 133.64 (=CO<sub>2</sub>C<sub>6</sub>H<sub>5</sub>, para), 132.39 (=C(CO<sub>2</sub>CH<sub>3</sub>)-- or =NC=O--), 128.93 (=CO<sub>2</sub>C<sub>6</sub>H<sub>5</sub>, ortho), 128.90 (=CO<sub>2</sub>C<sub>6</sub>H<sub>5</sub>, meta), 126.92, 125.25, 121.12, 111.10 (aromatic C) 52.86 (=C(CO<sub>2</sub>CH<sub>3</sub>)--), 52.47 (=CH<sub>2</sub>CO<sub>2</sub>CH<sub>3</sub>), 35.45 (=CH<sub>2</sub>CO<sub>2</sub>CH<sub>3</sub>).

DEPT 135 NMR (150 MHz, CDCl<sub>3</sub>): δ 133.64, 128.97, 128.92, 126.93, 125.28, 121.15, 111.13, 52.85, 52.48, 35.45.

HRMS (ESI, [M+H]<sup>+</sup>): calcd for C<sub>21</sub>H<sub>18</sub>NO<sub>6</sub>: 380.1134; found: 380.1115.

**Methyl 4-Benzoyl-1-oxo-1H-pyrido[2,1-b][1,3]benzoxazole-3-carboxylate (38)**

R<sub>f</sub> = 0.48 (ethyl acetate/hexane = 1:1); pale yellow solid; mp = 193-195 °C.
IR (neat): 3081, 3040, 3006, 2952, 1739, 1687, 1648, 1634, 1599, 1516, 1441, 1418, 1297, 1250, 1164, 1050, 1000, 850, 790, 782, 757, 623 cm⁻¹.

¹H NMR (600 MHz, CDCl₃): δ 8.63 (d, J = 7.49 Hz, C₆H₅ ortho, 2H), 7.85 (d, J = 7.74 Hz, aromatic, 1H), 7.61 (t, J = 7.31 Hz, C₆H₅ para, 1H), 7.50-7.44 (m, aromatic, 5H), 6.89 (s, −CH=C(CO₂CH₃)−, 1H). 3.61 (s, −CH=C(CO₂CH₃)−, 3H).

¹³C NMR (150 MHz, CDCl₃): δ 189.40 (−COC₆H₅), 165.57 (−CO₂CH₃ or >NCOCH= or N,O>C=), 158.07 (−CO₂CH₃ or >NCOCH= or N,O>C=), 152.87 (>NCOCH=), 147.03 (=C(CO₂CH₃)− or (>NC≥CO−), 143.08 (=C(CO₂CH₃)− or (>NC≥CO−), 137.96 (−COC₆H₅, ipso), 133.34 (−COC₆H₅, para), 128.99 (−COC₆H₅, ortho), 128.69 (−COC₆H₅, meta), 127.72 (aromatic CH), 126.44 (>NC≥CO−), 125.56 117.37, 112.76 (aromatic CH), 110.96 (>NCOCH=), 98.16 (=C(COC₆H₅)−), 52.94 (−CO₂CH₃).

DEPT 135 NMR (150 MHz, CDCl₃): δ 133.40, 129.04, 128.75, 127.78, 125.62, 117.42, 112.82, 111.02, 52.99.


Single crystals of 38 were obtained for X-ray crystallography by the vapor diffusion method. Hexane was diffused into a solution of compound 38 dissolved in chloroform.

Reaction of Tautomeric pair 23a,b with Dimethyl Acetylenedicarboxylate

The 5,6-ring-fused product 40 was synthesized by reacting DMAD (0.226 g, 1.57 mmol, 1.5 eq.) in anhydrous MeOH (5 mL) and the tautomers, (Z)-2-(benzo[d]thiazol-2-yl)-1-phenylethenol 23a and 2-(benzo[d]thiazol-2-yl)-1-phenylethanone 23b, (0.261 g, 1.03 mmol, 1 eq.) in MeOH (15 mL) by the general procedure used for the synthesis and purification of 24 and 25. The molarities of
tautomers: DMAD = 0.05:0.08. The eluent used for column chromatography over silica gel was ethyl acetate: hexane = 1:2. The compound 40 (0.317 g, 84.8%) was isolated as the only product.

**Synthesis of compound 40 under other reaction conditions**

DAMDC (0.141 g, 0.98 mmol, 1 eq.) in anhydrous MeOH (5 mL) was added dropwise to a solution of the tautomers 23a and 23b (0.261 g, 1.03 mmol, 1 eq.), (0.247 g, 0.98 mmol) in anhydrous MeOH (15 mL) at room temperature under nitrogen. The molarities of both DMAD and tautomers are 0.05 M. After 24 h stirring at room temperature, the 5,6-ring-fused product 40 (0.230 g, 64.7%) was isolated along with 21.8% starting tautomers at 23a:23b = 1.62:1. The products were worked up by the general procedure.

**Methyl 4-Benzoyl-1-oxo-1H-pyrido[2,1-b][1,3]benzothiazole-3-carboxylate (40)**

Rf = 0.43 (ethyl acetate/hexane = 1:2); intense yellow solid; mp = 234-236 °C.

IR (neat): 3126, 3094, 3068, 3013, 2981, 2952, 1719, 1672, 1621, 1559, 1492, 1434, 1409, 1289, 1264, 1244, 1196, 1120, 1066, 996, 945, 858, 805, 762, 679, 620 cm⁻¹.

¹H NMR (600 MHz, CDCl₃): δ 9.32 (d, J = 8.14 Hz, C₆H₅ ortho, 2H), 7.81 (d, J = 7.32 Hz, aromatic, 1H), 7.63 (t, J = 7.5 Hz, C₆H₅ para, 1H), 7.60-7.53 (m, aromatic, 3H), 7.47 (dd, J = 7.5 and 8.14 Hz, C₆H₅ meta, 2H), 6.83 (s, −CH=C(CO₂CH₃)−, 1H), 3.23 (s, −CH=C(CO₂CH₃)−, 3H).

¹³C NMR (150 MHz, CDCl₃): δ 191.72 (−COC₆H₅), 166.09 (−CO₂CH₃), 161.13 (>NCOCH=), 154.90 (N,S>C=, 141.70 (=C(CO₂CH₃)−), 139.25 (>N=S=C=) or −COC₆H₅, ipso), 137.20 (>N=S=C=) or −COC₆H₅, ipso), 132.12 (−COC₆H₅, para), 128.61 (−COC₆H₅, ortho), 128.35 (>N=S=C=), 127.98 (−COC₆H₅, meta), 127.48 127.06,
121.66, 120.34 (aromatic CH), 113.92 (>\text{NCOCH}=), 108.16 (=\text{C(COC}_6\text{H}_5)-), 52.46 (\text{CO}_2\text{CH}_3).

DEPT 135 NMR (150 MHz, CDCl$_3$): $\delta$ 132.19, 128.68, 128.05, 127.54, 127.13, 121.41, 120.41, 113.98, 52.53.

HRMS (ESI, [M+H]$^+$): calcd for C$_{20}$H$_{14}$NO$_4$S: 364.0644; found: 364.0600.

**Conversion of the Open-Chain Product 37 into the 5,6-Ring-Fused Product 38**

The open chain product 37 (0.20 g, 0.53 mmol) was dissolved in anhydrous MeOH (3 mL) and refluxed. The reaction was monitored by TLC. The spot for 37 was not observed after 15 h. MeOH was removed by rotary evaporation and residue was dissolved in dichloromethane (10 mL) and washed with water (2 $\times$ 10 mL). Organic layer was dried with anhydrous sodium sulfate. Sodium sulphate was filtered and dichloromethane was removed. The 5,6-ring-fused compound 38 was isolated in 98.9% (0.182 g) yield.

**Synthesis of the 5,6-Fused-Ring Product 25 from the Open-Chain Product 24 by Treatment with Sodium Hydride**

The open chain intermediate 24 (0.301 g, 0.84 mmol) in THF (10 mL) was added to a suspension of NaH (in 60% mineral oil) (0.051, 1.28 mmol, 1.5 eq.) in THF (10 mL) at room temperature under nitrogen. Hydrogen bubbles were evolved. The unreacted 24 was not observed on the TLC after refluxing for 7 h. Then THF was removed by rotary evaporation. The residue was dissolved in 30 mL dichloromethane, washed with water (2 $\times$ 20 mL) and dried over anhydrous sodium sulfate. After removal of dichloromethane by rotary evaporation, the crude product was purified by column chromatography (silica gel, ethyl acetate/hexane = 1:1). The 5,6-ring-fused product 25 (0.086 g, 76%) was isolated.
This general procedure was also used for the syntheses of compounds 31, 34 and 38 from 30, 25 and 37, respectively, discussed in this section.

**Synthesis of the 5,6-Fused-Ring Product 31 from the Open-Chain Product 30 by Treatment with Sodium Hydride**

The 5,6-ring-fused product 31 (0.064 g, 61%) was synthesized by refluxing the open chain intermediate product 30 (0.114 g, 0.31 mmol, 1 eq.) and NaH (0.02 g, 0.5 mmol, 1.6 eq.) in THF (20 mL) for 8 h. The unreacted 30 was not observed on the TLC. The product was purified by the general procedure used in synthesizing 31 from 30. The eluent used for column chromatography over silica gel was 1:2 ethyl acetate: hexane.

**Synthesis of the 5,6-Fused-Ring Product 34 from the Open-Chain Product 33 by Treatment with Sodium Hydride**

The 5,6-ring-fused product 34 (0.073 g, 40%) was synthesized by refluxing the open chain intermediate product 33 (0.203 g, 0.57 mmol) and NaH (0.034 g, 0.85 mmol, 1.5 eq.) in THF (20 mL) for 24 h. The products were purified by the general procedure used in synthesizing 25 from 24. The eluent used for column chromatography over silica gel was 1:1 ethyl acetate: hexane. 38.6% of 33 was recovered.

The 5,6-ring-fused product 33 (0.013 g, 7%) was synthesized by refluxing the open chain intermediate product 34 (0.208 g, 0.58 mmol) and NaH (0.035 g, 0.88 mmol, 1.5 eq.) in 1,4-dioxane (20 mL) for 24 h. The products were purified by the general procedure used in synthesizing 25 from 24. The eluent used for column chromatography over silica gel was 1:1 ethyl acetate: hexane. 31.6% of 33 was recovered. Reaction solution became very dark brown while refluxing. A dark brown spot was seen on the base line on the TLC.
Synthesis of the 5,6-Fused-Ring Product 38 from the Open-Chain Product 37 by Treatment with Sodium Hydride

The 5,6-ring-fused product 38 (0.088 g, 79%) was synthesized by refluxing the open chain intermediate product 37 (0.121 g, 0.32 mmol) and NaH (0.02 g, 0.5 mmol, 1.6 eq.) in THF (20 mL) for 8 h. The unreacted 37 was not observed on the TLC after refluxing for 8 h. The products were purified by the general procedure used in synthesizing 24 from 25. The eluent used for column chromatography over silica gel was 1:1 ethyl acetate: hexane.

Reaction of the Tautomeric Pair 20a,b with Dimethyl Acetylenedicarboxylate in the presence of Sodium Methoxide in Methanol

DMAD (0.523 g, 3.64 mmol, 2.5 eq.) in anhydrous MeOH (5 mL) was added dropwise to a solution of the tautomers 20a and 20b (0.337 g, 1.46 mmol) in anhydrous MeOH (5 mL) at room temperature under nitrogen. Then, 25 wt% NaOMe in MeOH (0.1 ml, 0.5 mmol, 0.32 eq.) was added. This solution was refluxed for 24 h under nitrogen and then MeOH was removed by rotary evaporation. The residue was dissolved in 40 mL dichloromethane, washed with water (2 × 40 mL) and dried over anhydrous sodium sulfate. After removal of dichloromethane by rotary evaporation, the crude product was purified by column chromatography (silica gel, ethyl acetate/hexane = 1:2) and isolated. The 5,6-ring-fused product 31 (0.221 g, 44.4%) eluted first followed by 59 (0.067 g, 9.2%). A mixture (0.069 g) of (E)-dimethyl 2-methoxymaleate 28 and (Z)-dimethyl 2-methoxymaleate 29 was also isolated. The 5,7-ring-fused product 32 was not detected on TLC.

Tetramethyl 6-(4,5-Dimethyl-1,3-thiazol-2-yl)biphenyl-2,3,4,5-tetracarboxylate (59)

Rf = 0.50 (ethyl acetate/hexane =1:2); off white solid; mp = 165-166 °C.
IR (neat): 3081, 3030, 2981, 2936, 1733, 1683, 1608, 1598, 1539, 1480, 1443, 1413, 1310, 1280, 1249, 947, 789, 747, 726, 694 cm⁻¹.

¹H NMR (600 MHz, CDCl₃): δ 7.36–7.29 (m, C₆H₅ para and meta, 3H), 7.11 (d, J = 7.68 Hz, C₆H₅ ortho, 2H), 3.89, 3.87, 3.72, 3.47 (s, four –CO₂CH₃, 12H), 2.26, 2.20 (s, >NC(CH₃)=C(CH₃)S, 6H).

¹³C NMR (150 MHz, CDCl₃): δ 166.81, 166.08, 156.93 (N,S>Ç=), 148.01, 141.68, 135.96, 135.81, 135.28, 134.94, 131.41, 130.18, 130.99 (aromatic, 7C and >NC(CH₃)=C(CH₃)S=, 2C), 129.50 (–C₆H₅, ortho), 128.55 (–C₆H₅, para), 128. 14 (–C₆H₅, meta), 53.15, 53.10, 52.49, 52.40 (four –CO₂CH₃), 14.41, 11.18 (>NC(CH₃)=C(CH₃)S=).

DEPT 135 NMR (150 MHz, CDCl₃): δ 129.63, 128.67, 128.26, 53.27, 52.22, 52.61, 52.52, 14.54, 11.31.


Reaction of Tautomeric pair 21a,b with Dimethyl Acetylenedicarboxylate in the presence of Sodium Methoxide in Methanol

The 5,6-ring-fused product 34 and the substituted biphenyl derivative 36 were synthesized by reacting DMAD (0.599 g, 4.17 mmol, 2.5 eq.), tautomers 21a and 21b (0.359 g, 1.67 mmol), and NaOMe (0.1 mL, 0.5 mmol, 0.28 eq.) in MeOH (10 mL).

Products were purified by the procedure used for the synthesis and purification of 31 and 59. The eluent used for column chromatography over silica gel was 1:1 ethyl acetate:hexane. The compound 34 (0.286 g, 36.1%) eluted first followed by compound 36 (0.089 g, 17%). The 5,7-ring-fused product 35 was not detected on TLC.
Reaction of Succinate 33 with Dimethyl Acetylenedicarboxylate in the presence of Sodium Methoxide

DMAD (0.112 g, 0.78 mmol, 1.1 eq.) in anhydrous MeOH (2 mL) was added dropwise to a solution of 33 (0.255 g, 0.71 mmol) in anhydrous MeOH (3 mL) at room temperature under nitrogen. Then, 25 wt% NaOMe in MeOH (1.5 μL, 0.01 eq.) was added. This solution was refluxed for 24 h under nitrogen and then MeOH was removed by rotary evaporation. The residue was dissolved in 40 mL dichloromethane, washed with water (2 × 40 mL) and dried over anhydrous sodium sulfate. After removal of dichloromethane by rotary evaporation, the crude product was purified by column chromatography (silica gel, ethyl acetate/hexane = 1:2) and isolated. The 5,7-ring-fused product 35 was not detected on TLC. Instead the 5,6-ring-fused product 34 (0.15 g, 65%) and 36 (0.012 g, 3.6%) was isolated. Further, 18% of the starting ring open intermediate 33 was recovered.

Reaction of 5,7-Ring-Fused Product 35 with Sodium Methoxide in Methanol

NaOMe in MeOH (0.09 ml, 0.4 mmol, 0.9 eq.) was added to 35 (0.2 g, 0.4 mmol) in MeOH at room temperature. The intense yellow color of the 35 in MeOH changed to dark brown color. The solution was analyzed by TLC after stirring for 15 minutes at room temperature. The spot for the starting 5,7-ring-fused compound 35 disappeared while a new spot appeared on TLC plate. The new spot was identified as compound 36. After 15 minutes, MeOH was removed by rotary evaporation. Products were purified by the procedure used for the synthesis and purification of 31 and 59. The eluent used for column chromatography over silica gel was 1:1 ethyl acetate: hexane. Compound 36 (0.072 g, 37.1%) was isolated.
Reaction of Tautomeric Pair 18a,b with Methyl Propiolate in Refluxing Methanol

Methyl propiolate (0.691 g, 8.14 mmol, 1.5 eq.) in 10 mL of anhydrous MeOH was added dropwise to a stirred solution of the tautomers 18a,b (1.1 g, 5.4 mmol, 1 eq.) in 15 mL of anhydrous MeOH at room temperature under nitrogen. The molarities of methyl propiolate and the starting tautomers are 0.33 M and 0.22 M, respectively. This solution was refluxed for 24 h under nitrogen and then MeOH was removed by rotary evaporation. The residue was dissolved in dichloromethane (40 mL), washed with water (2 × 40 mL) and dried over anhydrous sodium sulfate. Two very close spots were detected on the TLC (Rf = 0.65, 0.62; ethyl acetate:hexane = 3:2) in addition to the spot for unreacted 18a,b. After removal of dichloromethane by rotary evaporation, the crude product was purified by column chromatography (silica gel, ethyl acetate/hexane = 1:4 → 1:2) and isolated. The starting tautomers 18a,b were recovered in 14% yield as the first fraction. The compounds corresponding to the two very close spots seen on TLC were collected as a single fraction (yellow solid; 0.21 g) This fraction had a complex 1H NMR spectra. The compounds representing the two TLC spots could not be separated by column chromatography by changing the eluting solvent’s polarity using different ethyl acetate/hexane or acetone/hexane ratios. Further purification of this fraction was attempted by crystallization which was carried out by diffusion of hexane vapor into a solution of this yellow solid in chloroform. A yellow solid was formed as a precipitate and this had a very broad melting point range from 178 °C-190 °C. The 1H NMR spectra of this solid is exactly the same as that of the solid before recrystallization. The 1H, 13C and DEPT 135 NMR spectra of this unidentified solid are given in Figures S3 and S4, respectively. This general purification procedure was used in the other reactions discussed below.
Reaction of Tautomeric Pair 21a,b with Methyl Propiolate in Refluxing Methanol

Methyl propiolate (0.264 g, 3.11 mmol, 1.51 eq.) in 5 mL of anhydrous MeOH was added dropwise to a stirred solution of the tautomers 21a and 21b (0.444 g, 2.06 mmol, 1 eq.) in 10 mL of anhydrous MeOH at room temperature under nitrogen. The molarities of methyl propiolate and tautomers are 0.21 M and 0.14 M, respectively. This solution was refluxed for 24 h under nitrogen and then MeOH was removed by rotary evaporation. Two new spots were detected on TLC in addition to the spot for unreacted 21a,b (ethyl acetate:hexane = 1:2). The above-mentioned general procedure was used for the purification and isolation of products. The crude product was purified by column chromatography using ethyl acetate/hexane = 1:3 and then 1:1 over silica gel. The unreacted starting tautomers 21a,b (0.291, 65.5%) were collected first in a 21a:21b ratio of 1:3.03 in CDCl₃. Next, compound 65 (0.022 g, 4.3%) was isolated. A more polar high-intense yellow solid (0.026 g) corresponding to the third spot was also isolated. The Rₐ of this last fraction is 0.29 (ethyl acetate:hexane = 1:2). Figure S5 shows its ¹H NMR spectrum.

This reaction was repeated with 21a,b (0.37 g, 1.7 mmol, 1 eq.), methyl propiolate (0.222 g, 2.61 mmol, 1.52 eq.) in refluxing MeOH (10 mL) for 27 h. The unreacted starting tautomers 21a,b (0.15 g, 40.5%), 65 (0.03 g, 5.8%) and the same intense yellow solid (0.058 g) described in the above reaction were isolated.

Methyl (2E)-3-[4,5-Dimethyl-2-(2-oxo-2-phenylethylidene)-1,3-oxazol-3(2H)-yl]acrylate (65)

Rₐ = 0.40 (ethyl acetate/hexane = 1:2); yellow solid, mp = 150-152°C.

IR (neat): 3084, 3001, 2951, 2850, 1699, 1635, 1597, 1573, 1450, 1351, 1326, 1289, 1239, 1222, 1152, 1123, 1064, 978, 924, 861, 834, 763, 680 cm⁻¹.
$^1$H NMR (600 MHz, CDCl$_3$): δ 8.09 (d, $J = 14.95$ Hz, >NCH=, 1H), 7.46 (m, C$_6$H$_5$, 5H), 6.70 (s, =CH(COPh), 1H), 5.32 (d, $J = 14.95$ Hz, =CH(CO$_2$CH$_3$), 1H), 3.75 (s, =CH(CO$_2$CH$_3$), 3H), 2.03 and 1.72 (s, =NC(CH$_3$)=C(CH$_3$)O–, 6H).

$^{13}$C NMR (150 MHz, CDCl$_3$): δ 203.52 (–COC$_6$H$_5$), 168.84 (=CH(CO$_2$CH$_3$), 167.46 (N,O=C=), 162.13 (–COC$_6$H$_5$ ipso), 134.10 (>NCH=), 131.51 (–COC$_6$H$_5$ para), 129.44 (–COC$_6$H$_5$ ortho), 129.39 (–NC(CH$_3$)=C(CH$_3$)O–), 127.24 (–COC$_6$H$_5$, meta), 120.34 (=CH(CO$_2$CH$_3$), 99.73 (=CH(COPh)), 75.44 (=NC(CH$_3$)=C(CH$_3$)O–), 51.57 (=CH(CO$_2$CH$_3$), 23.39 (–NC(CH$_3$)=C(CH$_3$)O–), 18.25 (–NC(CH$_3$)=C(CH$_3$)O–).

DEPT 135 NMR (150 MHz, CDCl$_3$): δ 134.16, 131.53, 129.49, 127.29, 120.44, 99.85, 51.58, 23.41, 18.25

HRMS (ESI, [M+2H]$^+$): calcd for C$_{17}$H$_{19}$NO$_4$: 301.1314; found: 301.1407.

Note: The NOESY spectrum of 65 does not show clear evidence for a NOE interaction between the vinyl protons on the β–carbon and on the carbon next to nitrogen of the side chain alkene. This might be due to the low rotational barrier about the exocyclic double bond which could prevent observation of the NOE interaction. Therefore, the exo-ring double bond geometry ((Z) or (E)) at the β-carbon of 65 is unknown.

Reaction of Tautomeric pair 21a,b with Methyl Propiolate in MeOH at Room Temperature

Methyl propiolate (0.097 g, 1.1 mmol, 1 eq.) in 10 mL of anhydrous MeOH was added dropwise to a stirred solution of the tautomers 21a and 21b (0.24 g, 1.1 mmol, 1 eq.) in 15 mL of anhydrous MeOH at room temperature under nitrogen. The molarities of methyl propiolate and 18a,b were both 0.05 M. Then this solution was stirred for 18 h under nitrogen. MeOH was removed by rotary evaporation. The general work up
procedure mentioned above was then employed. The crude product was purified by
column chromatography using ethyl acetate/hexane = 1:3 then 2:1 over silica gel.
The title compound 68 (0.042 g, 16%) was isolated along with the un-reacted starting
tautomers 21a,b (0.096 g, 38.9%) in a 21a:21b ratio of 1:2.86.

Reaction of 21a,b (0.269 g, 1.25 mmol, 1 eq.) with methyl propiolate (0.109 g,
1.28 mmol, 1 eq.) in 20 mL MeOH at room temperature for 24 h afforded 68 in 13%
(0.036 g) yield.

A control reaction was carried out in the presence of water without methyl
propiolate to see if 68 would form from 21a,b in the presence of water. Water (10 mL)
was added to tautomers 21a,b (0.282 g, 1.31 mmol) in methanol (10 mL). Then solution
was refluxed for 24 h at about 80 °C. The crude product mixture was purified according
to the general procedure used for purification and isolation of products 24 and 25.
Compound 68 (0.032 g, 11%) was isolated showing that methyl propiolate was not
involved in its formation.

2-Acetyl-2-methyl-6-phenyl-2,3-dihydro-4H-1,3-oxazin-4-one (68)

\[ R_f = 0.45 \text{ (ethyl acetate/hexane } = 1:2) \text{; pale yellow solid, } mp = 142-144 \, ^\circ C. \]

IR (neat): 3168, 3055, 2895, 1727, 1652, 1451, 1394, 1197, 1108, 1053, 1021,
952, 900, 825, 769, 684, 664 cm\(^{-1}\).

\(^1\)H NMR (300 MHz, CDCl\(_3\)): \( \delta \) 8.37 (s, >NH, 1H), 7.78 (d, \( J = 7.37 \, Hz \), C\(_6\)H\(_5\)
ortho, 2H), 7.54-7.44 (m, C\(_6\)H\(_5\) meta and para, 3H), 5.83 (s, =CH\(\equiv\), 1H), 2.33 (s, –
C\(_{OCH_3}\), 3H), 1.79 (s, >CCH\(\equiv\)), 3H).

\(^13\)C NMR (75 MHz, CDCl\(_3\)): \( \delta \) 205.48 (–COCH\(_3\)), 165.55 (–CONH– or
=\(\bar{C}(C_6H_5)O–\)), 164.12 (–CONH– or =\(\bar{C}(C_6H_5)O–\)), 131.67 (–C\(_6\)H\(_5\) para), 131.45 (–C\(_6\)H\(_5\)
ipso), 128.76 (–C₆H₅ meta), 126.56 (–C₆H₅ ortho), 96.55 (=CH–), 91.09 (>CH₃–), 24.80 (–COCH₃), 22.09 (>CH₃–).


Single crystals were grown for X-ray crystallography by the vapor diffusion method. Hexane was diffused into a solution of compound 68 dissolved in chloroform.

![Crystal structure](image)

Figure S2 The crystal structure of 68. This crystal structure contains two independent molecules, which are enantiomers.

**Reaction of (Z)-2-(benzo[d]thiazol-2-yl)-1-phenylethenol (23a) and 2-(benzo[d]thiazol-2-yl)-1-phenylethanone (23b) with methyl propiolate in refluxing MeOH**

A solution of the tautomers 23a,b (0.202 g, 0.80 mmol, 1 eq.) and methyl propiolate (0.102 g, 1.20 mmol, 1.5 eq.) in 10 mL of anhydrous MeOH was refluxed for 23 h. The molarities of the tautomers 23a,b and methyl propiolate are 0.08 M and 0.12 M, respectively. Two new spots were seen on TLC in addition to the spot for 23a,b after
23 h. Then the general work up procedure mentioned above was followed. The crude product was purified by column chromatography using ethyl acetate/hexane = 1:3 over silica gel. The starting tautomers 23a,b (fraction 1) were recovered in 58.9% (0.119 g) yield. Fraction 2 (Rf = 0.44; ethyl acetate/hexane = 1:3) and fraction 3 (Rf = 0.29; ethyl acetate/hexane = 1:3) were separated and each fraction weighted 0.03 g each. These two fractions were unidentified. The ¹H NMR spectra of these two fractions are given in Figures S6 and S7.
NMR spectra of unidentified fractions collected from column separation

Reaction of the tautomers (Z)-1-phenyl-2-(thiazol-2-yl)ethenol (18a) and 1-phenyl-2-(thiazol-2-yl)ethanone (18b) with methyl propiolate

Figure S3: $^1$H NMR spectrum (600 MHz, CDCl$_3$) of two inseparable spots collected as one fraction
Figure S4: $^{13}$C and DEPT 135 NMR spectra (150 MHz, CDCl$_3$) of two inseparable spots collected as one fraction
Reaction of the tautomers (Z)-2-(4,5-dimethylloxazol-2-yl)-1-phenylethenol (21a) and 2-(4,5-dimethylloxazol-2-yl)-1-phenylethanone (21b) with methyl propiolate

Figure S5: $^1$H NMR spectrum (600 MHz, CDCl$_3$) of the last fraction ($R_f = 1:2$; ethyl acetate-hexane)

Reaction of the tautomers (Z)-2-(benzo[d]thiazol-2-yl)-1-phenylethenol (23a) and 2-(benzo[d]thiazol-2-yl)-1-phenylethanone (23b) with methyl propiolate

Figure S6: $^1$H NMR spectrum (600 MHz, CDCl$_3$) of the fraction 2 ($R_f = 0.44$; ethyl acetate-hexane = 1:3)
Figure S7: $^1$H NMR spectrum (600 MHz, CDCl$_3$) of the fraction 3 ($R_f = 0.29$; ethyl acetate-hexane = 1:3)

References
