for 24 h. After filtration to remove excess Zn, the solvent was removed, and the resulting oil was partitioned between $CHCl_3$ and H_2O. The $CHCl_3$ layer was evaporated to dryness, and the resulting product mixture was purified by preparative TLC on silica gel (25% EtOAc in hexane), yielding 80 mg (27%) of **13** as an oil that crystallized upon standing for a few hours. Two recrystallizations from 50% MeOH–H_2O gave **13** with a constant mp of 105–107 °C: ^1H NMR ($CDCl_3$) δ 1.41 (s, 6 H, $(CH_3)_2C$), 1.94 (s, 1 H, HS), 2.42 (s, 3 H, CH_3Ar, 3.38 (s, 3 H, CH_3O) 3.81 (d, J = 11.4 Hz, CHN), 5.54 (d, J = 11.4 Hz, NH), 7.2–7.8 (m, 4 H, p-C_6H_4).

Anal. Calcd for $C_{13}H_{19}NO_4S_2$: C, 49.18; H, 6.03. Found: C, 48.87; H, 6.06.

Acetyl D-1-(*p*-Tolylsulfonamido)-1-(methoxycarbonyl)-2-methylpropyl Disulfide (12). To a solution of 0.63 g (1.0 mmol) of disulfide **9** in 5 mL of CH_2Cl_2 at room temperature was added 1.0 mL of a 1.05 M solution of Cl_2 in CCl_4. After 10 min, a solution of 0.15 g (2.0 mmol) of freshly distilled thioacetic acid in 1.0 mL of CH_2Cl_2 was added and after 0.5 h the solvent was removed. Purification by chromatography over silica gel in 30% EtOAc in hexanes gave 0.60 g (77%) of **12** that was homogeneous by TLC, but which could not be induced to crystallize: ^1H NMR ($CDCl_3$) δ 1.35 (s, 6 H, $(CH_3)_2C$), 2.44 (s, 6 H, CH_3CO and CH_3Ar), 3.88 (s, 3 H, CH_3O), 3.83 (d, 1 H, J = 10.5 Hz, CHN), 5.79 (d, 1 H, J = 10.5 Hz, NHC), 7.0–7.8 (m, 4 H, C_6H_4). This material was used immediately to obviate problems due to disproportionation.

D-1-(*p*-Tolylsulfonamido)-1-(methoxycarbonyl)-2-methyl-2-propyl Hydrodisulfide (15) and the 2,4-Dinitrophenyl Derivative 14. To a solution of 0.13 g of **12** in 2 mL of MeOH was added 6 drops of 35% aqueous HCl. After 1.5 h the ^1H NMR spectrum of the reaction mixture no longer showed the presence of **12**. The MeOH was removed, the resulting oil was dissolved in $CHCl_3$; washed with a small volume of water, and dried by pouring through dry cotton, and the $CHCl_3$ was removed. Solutions of **15** allowed to stand in acidic methanol showed extensive decomposition in 2 h. Efforts to crystallize the oil **15** were unsuccessful: IR ($CDCl_3$, cm^{-1}) 3340 (NH), 2520 (SSH), 1750 (C=O), 1350 and 1160 (SO_2); ^1H NMR ($CDCl_3$) δ 1.29 (s, 3 H, CH_3C), 1.37 (s, 3 H, CH_3C), 2.42 (s, 3 H, CH_3Ar), 2.93 (s, 1 H, SH), 3.40 (s, 3 H, CH_3O), 3.89 (d, 1 H, CHN), 5.38 (d, 1 H, NH), 7.2–7.9 (m, 4 H, C_6H_4); ^{13}C NMR δ 170.1 (s), 143.8 (s), 136.2 (s), 129.53 (d), 127.4 (d), 61. 1 (q), 52.1 (d), 49.7 (s), 24.0 (q), 23.4 (q), 21.5 (q). After 3 days at 25 °C, the ^1H NMR spectrum was unchanged and the $CDCl_3$ was removed. An 18-mg portion of this sample of **15** was titrated with 0.96 mL of 0.053 N I_2: equiv wt calcd for $C_{13}H_{19}NO_4S_3$ 349, found, 354. The remainder of the material was dissolved in 5 mL of MeOH, and 0.10 g of 2,4-dinitrochlorobenzene was added, followed by the addition of 0.10 g of Et_3N. After 1 h, the solvent was removed, and the residue was taken up in $CHCl_3$, washed with dilute aqueous HCl, dried, and evaporated to dryness. The residue was purified by preparative TLC over silica gel in 25% EtOAc in hexanes, which provided **14** as a yellow oil that crystallized upon trituration with Et_2O. Recrystallization from EtOAc–Et_2O gave **14**, mp 125–130 °C, mmp with authentic **12** described below, 128–130 °C.

2,4-Dinitrophenyl D-1-(*p*-Tolylsulfonamido)-1-(methoxycarbonyl)-2-methyl-2-propyl Disulfide (14). To a solution of 50 mg (0.16 mmol) of **13** in 3 mL of Et_2O was added a solution of 40 mg (0.17 mmol) of 2,4-dinitrobenzenesulfenyl chloride in 2 mL of Et_2O, followed by 16 mg (0.16 mmol) of Et_3N. After 1 h at 25 °C the Et_2O was removed, and the residue was dissolved in CH_2Cl_2, washed with water, and then purified by preparative TLC (silica gel, 25% EtOAc–hexane). Recrystallization from EtOAc–Et_2O gave **14**, mp 132–133 °C, identical by TLC and ^1H NMR spectrum with **14** obtained from the reaction described above **15** with 2,4-dinitrochlorobenzene: ^1H NMR ($CDCl_3$) δ 1.37 (s, 6 H, $(CH_3)_2C$), 2.44 (s, 3 H, CH_3Ar), 3.44 (s, 3 H, CH_3O), 3.93 (d, 1 H, J = 10.5 Hz, CHN), 5.48 (d, 1 H, J = 10.5 Hz, NH), 7.2–9.1 (7 H, Ar).

Anal. Calcd for $C_{19}H_{21}N_3O_8S_3$: C, 44.27; H, 4.10; S, 18.66. Found: C, 44.28; H, 4.33; S, 18.80.

Methyl 2-(Methylsulfonamido)-3-methyl-2-butenoate (18). Crude **8** from 5.00 g (14 mmol) of **7** in 20 mL of pyridine was cooled (5 °C), and 4.6 g (40 mmol) of mesyl chloride was added. After 1 h, solvent was removed and a solution of the residue in $CHCl_3$ was washed with 3 M HCl, H_2O, dried, and evaporated; yield 3.5 g (52%) of crude **17**; ^1H NMR ($CDCl_3$) δ 1.41 (s, 3 H, CH_3C), 1.44 (s, 3 H, CH_3C), 2.98 (s, 3 H, CH_3SO_2), 3.83 (s, 3 H, CH_3O), 4.03 (d, 1 H, CHN), 5.49 (d, 1 H, NH). A solution of 0.30 g (0.62 mmol) of **17** in CH_3OH was treated with KOH (2 equiv/mol) and CH_3I. After 16 h, MeOH was removed, and the residue was dissolved in $CHCl_3$, washed with aqueous NaOH, and dried. Evaporation of the solvent yielded **18** as a mobile oil (0.15 g, 54%), which was purified by chromatography (silica gel): ^1H NMR ($CDCl_3$) δ 2.15 (s, 3 H), 2.31 (s, 3 H), 3.12 (s, 3 H), 3.11 (s, 3 H), 3.88 (s, 3 H).

Anal. Calcd for $C_8H_{15}NO_4S$: C, 43.42; H, 6.83; S, 14.49. Found: C, 43.03; H, 6.89; S, 14.64.

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Registry No. **7**, 20902-45-8; **8**, 89032-21-3; **9**, 89032-22-4; **10**, 89032-23-5; **12**, 89032-24-6; **13**, 89032-25-7; **14**, 89032-26-8; **15**, 89032-27-9; **17**, 89032-28-0; **18**, 89032-29-1; thioacetic acid, 507-09-5.

New Intermediates in the Self-Condensation of β-Aminocrotonamide

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The self-condensation of β-aminocrotonamide (**1**) is known to give 2,6-dimethyl-3*H*-4-pyrimidone (**6**) in good yields.[1,2] In an attempt to synthesize 4-pyrimidone derivatives utilizing the reaction, we have isolated new reaction intermediates **2** and **3** from the thermolysis of **1**.

These compounds have been identified as 1,2-dihydro-2,6-dimethyl-4-pyrimidon-2-ylacetamide (**2**) and 1,5-dimethyl-3,7-dioxo-2,6,9-triazabicyclo[3.3.1]nonane (**3**) on the basis of spectral analyses and elemental analysis. Compound **3** is isolated in pure form by recrystallization from methanol of the initially obtained mixture of **2** and **3**, and **2** is obtained pure by silica gel column chromatography of the remaining mother liquor after recrystallization of **3**.

A substituted 2,6,9-triazabicyclo[3.3.1]nonane was previously prepared from crotonaldehyde and methylamine,[3] but the 3,7-dioxo compound **3** has not been reported yet. Chick and Wilsmore[4] reported that the thermolysis of **1** at 110 °C gave 4-amino-3,4-dihydro-4,6-dimethyl-1*H*-2-pyridone-5-carboxamide, but Kato et al.[1,2] reinvestigated the reaction and reported that the self-condensation of **1** proceeds through β-(β′-aminocrotonylamino)crotonamide (**5**) to yield the final product **6** negating the Chick and Wi lsmore's report. Kato et al. claimed the intermediate structure **5** on the basis of an olefinic proton peak at δ 4.25 (only NMR data reported) in dimethyl sulfoxide and UV absorption at 295 nm (log ϵ 3.72). However, **5** has to show two olefinic proton peaks in the NMR spectrum. The elemental analyses of **2**, **3**, and **5** would be identical. Furthermore, **2** shows UV absorption maximum at 295 nm (log ϵ 3.85) and an olefinic proton peak at δ 4.27 in dimethyl sulfoxide. It is evident that Kato et al. worked with a 74:26 mixture of **2** and **3**. We repeated the Kato's work and

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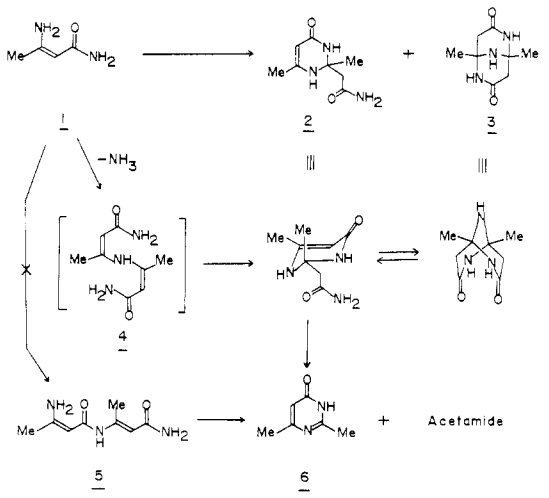
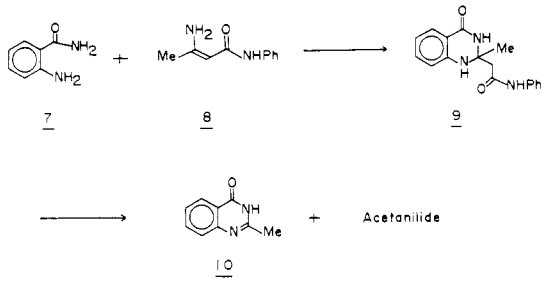
Scheme I



Scheme II



isolated **2** and **3** in the ratio of 2:3 from the self-condensation of **1** at 120 °C. The compounds **2** and **3** are probably formed via 3-(1-carbamoyl-2-propenylamino)-2-butenamide (**4**), which is difficult to isolate, although isolation of some divinylamines similar to **4** has been reported.[5]

Compounds **2** and **3** are interconvertible to each other, reaching the equilibrium from **2** and **3** in 20 and 60 min, respectively, at 110 °C in dimethyl sulfoxide ($K_{3\rightleftharpoons2}$ = 4.88). Prolonged heating of the equilibrium mixture of **2** and **3** at 110 °C yields **6**. Both **2** and **3** yield the pyrimidone **6** in quantitative yields by heating at 180 °C. The reaction pathway of **1** to **6** is shown in Scheme I. The driving forces of the reaction may be the aromaticity of **6** and electron-withdrawing effect of the 2-carbamoylmethyl group of **2** as observed in the chemistry of reduced pyridines.[6]

In order to confirm the formation of reduced pyrimidine intermediates in the self-condensation of **1**, the reaction of 2-aminobenzamide (**7**), an analogous compound of **1**, with β-aminocrotonanilide (**8**), which can cause cross-condensation, was carried out and 2-methyl-1,2-dihydro-4-quinazolinon-2-ylacetanilide (**9**) was isolated as a cross-condensation intermediate. The NMR spectrum of **9** in acetone-d_6 shows a doublet of doublets arising from the methylene protons in acetanilide part as in the case of **2**. These proton signal splittings were not observed in Me_2SO-d_6. The reduced pyrimidine intermediate **9** afforded 2-methyl-4-quinazolinone (**10**) and acetanilide on further heating at higher temperature (Scheme II). This provides definite evidence for the self-condensation mechanism of compound **1**.

Experimental Section

Physical Measurements. Melting points were determined on a Thomas-Hoover Unimelt apparatus. Infrared spectra were recorded on a Perkin-Elmer Model 283 spectrophotometer. Proton NMR spectra were recorded on a Varian FT-80A spectrometer using tetramethylsilane or 3-(trimethylsilyl)-1-propanesulfonic acid sodium salt hydrate as internal standards. Mass spectra were determined on a HP 5985 A or B spectrometer. Ultraviolet spectra were taken on a Varian Cary 219 spectrophotometer.

2,6-Dimethyl-4-pyrimidone (6). **1** (10 g, 0.1 mol) was fused at 180 °C for 12 h. After acetamide was removed under reduced pressure, methanol was added to the amount to dissolve the resultant solid, and to the solution was added diisopropyl ether until the separation of a dark oil. Concentration of the upper solvent layer afforded a yellow solid. After several recrystallizations from diisopropyl ether, 5.3 g of white solid was obtained in 85% yield, which was identical with the authentic sample.[7]

1,2-Dihydro-2,6-dimethyl-4-pyrimidon-2-ylacetamide (2) and 1,5-Dimethyl-3,7-dioxo-2,6,9-triazabicyclo[3.3.1]nonane (3). **1** (10 g, 0.1 mol) heated at 120 °C for 8 h and then left standing at room temperature. The resultant solid mass was pulverized in ethanol and filtered to give a white solid (6.4 g, 70%). The ^1H NMR spectrum of the white solid indicated a 2:3 mixture of **2** and **3**. **3** was obtained pure by recrystallization from methanol. Silica gel chromatography (70–230 mesh, Merck, 6:4 ethyl ether–ethanol) of the mother liquor gave **2** as white solid. Compound **2**: mp 192–193 °C; NMR (Me_2SO-d_6) δ 1.38 (s, 3 H, 2-CH_3), 1.77 (s, 3 H, 6-CH_3), 2.39 (d, 1 H, CH of CH_2CO, J = 14 Hz), 2.54 (1 H, d, CH of CH_2CO, J = 14 Hz), 4.27 (s, 1 H, 5-H), 6.65–7.38 (m, 4 H); NMR (D_2O) δ 1.56 (s, 3 H, 2-CH_3), 1.90 (s, 3 H, 6-CH_3), 2.60 (d, 1 H, CH of CH_2CO, J = 12.8 Hz), 2.72 (d, 1 H, CH of CH_2CO, J = 12.8 Hz), 4.55 (s, 1 H, 5-H); IR (KBr) 3330, 3160, 1650, 1550, 1400 cm^{-1}; mass spectrum, m/e 183 (M^+); UV (ethanol) λ_{max} 295 nm (ε 7095). Anal. Calcd for $C_8H_{13}N_3O_2$: C, 52.45; H, 7.15; N, 22.94. Found: C, 52.31; H, 7.19; N, 22.87. Compound **3**: mp 197–198 °C; NMR (Me_2SO-d_6) δ 1.28 (s, 6 H, $2CH_3$), 2.15 (s, 4 H, $2CH_2$), 3.45 (s, 1 H, NH), 7.89 (s, 2 H, 2CONH); NMR (D_2O) δ 1.52 (s, 6 H, $2CH_3$), 2.53 (s, 4 H, $2CH_2$); IR (KBr) 3280, 3170, 1660, 1510, 1400 cm^{-1}; mass spectrum, m/e 183 (M^+). Anal. Calcd for $C_8H_{13}N_3O_2$; C, 52.45; H, 7.15; N, 22.94. Found: C, 52.36; H, 7.24; N, 22.86.

A total of 17% of **2** was converted to **3** and 83% of **3** to **2** by heating at 110 °C in dimethyl sulfoxide, for 20 and 60 min, respectively. Continuous heating gave **6** in part as persisting in equilibria of **2** and **3**. Compounds **2** and **3** gave **6** in quantitative yields by heating at 200 °C for 10 min or at 180 °C for 30 min in dimethyl sulfoxide. The ratio of **2** and **3** was measured by NMR.

2-Methyl-1,2-dihydro-4-quinazolinon-2-ylacetanilide (9). **7** (1.0 g) was condensed with 1.3 g of **8**[8,9] at 120 °C for 12 h. The reaction mixture was dissolved in methanol. Diisopropyl ether was added to the solution, which was then allowed to stand overnight. **9** was obtained as a white solid (0.9 g, 42%) after filtration and washing with ethyl acetate. An analytical specimen was obtained by recrystallization from methanol: mp 175–176 °C; NMR (Me_2SO-d_6) δ 1.58 (s, 3 H, CH_3), 2.77 (s, 2 H, CH_2CO), 6.6–7.9 (m, 9 H, aromatic); NMR (acetone-d_6) δ 1.65 (s, 3 H, CH_3), 2.85 (d, 1 H, Ch of CH_2CO, J = 14.0 Hz), 2.96 (d, 1 H, CH of CH_2CO, J = 14.0 Hz), 6.07–7.75 (m, 9 H,aromatic); mass spectrum, m/e 295 (M^+); UV (ethanol) λ_{max} 344 (ε 2350). Anal. Calcd for $C_{17}H_{17}N_3O_2$: C, 69.13; H, 5.80; N, 14.23. Found; C, 68.94; H, 5.71; N, 14.30. Compound **9** gave **10** (54% conversion) by heating at 180 °C for 20 min. **10** was identified by comparison with an authentic sample.[10]

Registry No. **1**, 64163-94-6; **2**, 89088-70-0; **3**, 89088-71-1; **6**, 6622-92-0; **7**, 88-68-6; **8**, 59846-47-8; **9**, 81038-81-5; **10**, 1769-24-0.

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