The synthesis, spectroscopic properties, and chemical reactions of the stable (neopentylimino)-, (mesitylimino)-, and (o-tet-butylphenylimino)propadienones (6) are reported. Nucleophilic addition of amines affords the malonic amidomides 7 and 8. 3,5-Dimethylpyrazole reacts analogously to form 9b. Addition of 1,2-dimethylhydrazine produces pyrazolinones 10–12. Addition of N,N'-dimethylaminomethane, -propane, and -butane gives diazepine, diazocine, and diazoline derivatives 13–15, respectively (X-ray structures of 13c, 14a, and 15a are available). The mesoionic pyridopyrimidinium diates 18 are obtained by addition of 2-(methylamino)pyridine (X-ray structure of 18b). Primary 2-aminopyridines afford the pyridopyrimidinones 20–29 and 31 (X-ray structure of 21a). 2-Aminopyrimidines and 2-aminopyrazine afford pyrimidopyrimidinones and pyrazinopyrimidinones 33–35. Pyrimidoquinolinone 36 results from 1-aminquinolinone and pyridoquinolinone 40 from 8-aminquinoline. 2-Aminothiazolone and 2-aminothiazole afford thiazolopyrimidinone derivatives 41–43 (X-ray structure of 43a available).

Introduction

The iminopropadienones, RN=C=O, constitute a recently discovered class of compounds.1 While the simple alkyl derivatives (methyl,1 isopropyl,2 and tert-butyl2) are notoriously unstable compounds which can, however, be isolated and characterized in low-temperature matrixes, the aryl derivatives are more stable and undergo chemical reactions, often in good preparative yields, under controlled conditions at temperatures around −100 to −50 °C.3–7

We have now succeeded in preparing several iminopropadienones that are stable at room temperature, namely the neopentyl, mesityl,8 and o-tet-butylphenyl derivatives. This has allowed a more thorough investigation of the preparative potential of these compounds. The results are reported herein.

Results and Discussion

The 5-bis(methylthio)methylene derivative of Mel-c-derived, 1, undergoes nucleophilic displacement of SMe groups on reaction with amines.2–5,9 Thus, compounds 2a and 3a are obtained on reaction with 1 and 2 equiv of neopentylamine, respectively. The reaction of compounds 2 with dimethyl- and diethylamine affords 4 and 5, respectively. Compounds of type 2–5 can all be used to generate iminopropadienones 6 by flash vacuum thermolysis (FVT), but 4 is the best overall precursor, and therefore, most experiments were performed with these types of compounds (4a–c).

FVT of 4a at 700 °C afforded CO2, acetone, and (neopentylimino)propadienone (6a). Collection of the products in a cold trap at −50 °C allowed the subsequent distillation of 6a as a yellow oil, which is stable at room temperature. The IR spectrum of 6a is dominated by a very intense and complex band centered around 2250 cm−1, as is typical of iminopropadienones (see the Supporting Information).1–6
(Mesitylimino)propadienone 6b was similarly obtained by FVT of 4b at 700 °C. Between 400 and 800 °C this was the only cumulene observed by IR spectroscopy (2234/2243/2248 (vs) cm⁻¹; 2149 (w) cm⁻¹ (Ar matrix)). In CCl₄ solution at room temperature, it features an intense peak centered at 2214 cm⁻¹. The far-IR spectrum in polyethylene shows very low-frequency bands at 73 and 89 cm⁻¹, which, by analogy with C₃O₂,¹⁰ may be due to the bending of the cumulene chain at the central carbon atom. However, due to the structural complexity of 6b, further far-IR studies of simpler compounds would be required for a rigorous assignment of the vibrational modes. The Raman spectrum shows a relatively weak cumulenic band at 2217–2171 cm⁻¹. The spectra are available in the Supporting Information.

(o-tet-Butylphenyl)imino)propadienone (6c) was obtained by FVT of either 2c or 4c at 700 °C and purified by bulb-to-bulb distillation. The IR spectra show the characteristic bands at 2237 (vs) and 2139 (w) cm⁻¹. Calculations at the MP2/6-31G*//HF/6-31G* level reproduce the ¹³C carbon resonances at 66, 108, and 130 ppm (the ¹H and ¹³C NMR spectra are reproduced in the Supporting Information). Carbon suboxide, O₃C, features analogous ¹³C NMR resonances at 14.6 and 129.7 ppm.¹¹ Calculations at the MP2/6-31G*/HF/6-31G* level reproduce the ¹³C NMR shifts of C₃O₂ and the iminopropadienones very accurately.¹² The imine carbon signal at 108–112 ppm in the iminopropadienones is very broad and weak at room temperature due to the adjacent nitrogen quadrupole moment (see e.g. Figure S2). The signal intensity improves by recording the spectrum at −30 °C.

Compounds 6 are quite long-lived at room temperature, even in the presence of mild nucleophiles such as alcohols and water. Compound 6a has a half-life of almost 7 h in the presence of a 2-fold excess of methanol.¹³ We have investigated this type of reaction for other iminopropadienones and found that ketenimines are formed first, followed by addition of a second molecule of methanol to afford malonic ester imides (eq 1).³ Compounds 6 react much faster with amines than with alcohols.¹³ They react virtually spontaneously with dimethyl- and diethylamine to afford amidoamidines 7 and 8, respectively. We have demonstrated that the initial reaction involves formation of an amidoketenimine by addition of dimethylamine to the C=O group in 6b. This reaction takes place at −40 °C in CD₂Cl₂ solution, and the ketenimine was fully characterized by ¹H NMR and IR spectroscopy.¹⁵ Subsequent slow addition of a second molecule of amine gives amidoamidines 7 and 8. Such compounds are usually obtained as the unconjugated tautomers (7); however, workup by Kugelrohr distillation causes incomplete tautomerization of 7a and 8a to 7a/8a.³ 3,5-Dimethylpyrazole reacts with 6 like an amine, forming 9b with (mesitylimino)propadienone.

The reaction of 6 with hydrazines and bis(amines) affords cyclic compounds. Thus, the pyrazolinone 10 is obtained from 6a and 1,2-dimethylhydrazine at room temperature. Pyrazolinone 11 is obtained from 6b with hydrazine, and pyrazolinones 12b,c are obtained with methylhydrazine, respectively. N,N′-Dimethyl-1,2-diaminopropane, -1,3-diaminopropane, and -1,4-diaminobutane afford the perhydrodiazepine, -diazocine, and -diazonine derivatives 13a–c, 14, and 15, respectively. Compound 13a undergoes partial tautomerization to the conjugated
Phenylenediamine reacted similarly with 6b to afford the benzodiazepine derivative 16. The structures of compounds 13c, 14a, and 15a were confirmed by X-ray crystallography (see the Supporting Information). Compounds 6b, c also reacted with N,N′-dimethyl-1,3-diaminopropane to afford diazocine derivatives (14b, c), but these have so far only been obtained as oils that were difficult to purify. No cyclic amidoamidines of structures related to 13–15 are known in the literature.

The reactions of iminopropadienones with N-heterocyclic amines is particularly interesting, because of the possibility of forming mesoionic (zwitterionic) compounds.6b,14 Compounds 6 react with 2-(methylamino)pyridine to afford pyridopyrimidinium olates 18 as red-orange solids (Scheme 1). The atom connectivity in 18a was established by 2D 13C NMR experiments (HMBC and HSQC) and by X-ray crystallography for 18b (data in the Supporting Information). The structures of many mesoionic compounds show distortions toward ketene valence isomers, with long N–CO bonds and acute OCN angles.14 Compound 18b features a characteristically long N–CO bond (1.49 Å) and tilting of the C–O group toward the ring junction at N5a (∠O4–C4–N5 = 116°). A mechanism for the formation of 18 is given in Scheme 1. It is known that ketenes react with pyridine, even at very low temperatures (e.g., 40 K), to produce ketene–pyridine zwitterions.15 Furthermore, carbon suboxide, O=C=O, reacts with pyridine and other amine nucleophiles in low-temperature matrices to give, first, observable van der Waals complexes,16 which can be transformed into covalent zwitterions of the type O=C=C=O(Nu)+.17 It is postulated that the corresponding zwitterion 17 can form by interaction of 2-(methylamino)pyridine with 6. Addition of the exocyclic amino group to the imine carbon atom in 17 affords the mesoionic heterocycle 18. It would be possible to bypass 17 by postulating that the exocyclic amino group reacts with the less electrophilic C–N carbon of the cumulene 6, but this goes against all our knowledge of the initial stages of these and similar reactions.5,16,17 This reaction is reversible: FVT of 18b at 350 °C regenerates 2-(methylamino)pyridine and 6b, as proved by the IR spectrum of the products in Ar matrix at 10 K. However, the mechanisms of the synthesis and fragmentation of 18c are likely to involve different intermediates. A rational mechanism for the FVT reaction is given in Scheme 1, and this is based on a previous investigation of ring opening and fragmentation in six-membered mesoionic compounds.18 The 1,2-dihydro-2-(methylimino)pyridine initially formed in this mechanism undergoes rapid tautomerization to the observed 2-(methylamino)pyridine.18

The corresponding reactions of 6 with primary 2-aminopyridines would proceed via the analogous zwitterions 17 to the mesoions 19, followed by tautomerization to the pyridopyrimidinones 20–24 as final products (Scheme 2). These are indeed the major or exclusive products when the reactions are performed in methylene chloride solu-

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tion at room temperature, but small amounts of the alternate addition products 26–29 were also obtained from (neopentylimino)propadienone 6a. 2-Amino-6-methylpyridine gave only 24; compound 30 was not formed. Usually, the pyridine nitrogen atom is the most nucleophilic center in 2-aminopyridines, and the C=O group is more electrophilic than the C=N group in iminopropadienones, but the formation of both types of addition products, corresponding to the two alternate modes of nucleophile/electrophile interaction, has been described in a previous case.6b Moreover, the orientation of addition can be modulated by electronic substituent effects in the aromatic ring in (phenylimino)propadienones.19 The proportions of the “abnormal” isomers 26–29 were found to increase when the reactions were performed in refluxing toluene, but 20a–23a always remained the major isomer. Control experiments excluded the possibility of a rearrangement of 22a to 28. The formation of 26–29 is postulated to result from initial attack of the exocyclic amino group of the pyridine on the carbonyl group of 6, leading to the zwitterions 25. Subsequent attack of the pyridine nitrogen lone pair on the imine carbon in 25 gives 26–29. In most cases, other possible tautomers of 20–30 are not observed, but in the case of 2-aminomethylpyridine, a small amount of the hydroxy tautomer 31a was formed as well.

Compounds of type 20–24 are structurally interesting, even though they are not mesoionic, they exist in a highly zwitterionic form, as expressed by resonance structure 32.14 The X-ray structure analysis of 21a confirmed that this is the case, with short C10−N1 and N1−C2 bonds, long C2−C3 and C3−C4 bonds, an unusually long C4−N5 bond, and the C=O group at C4 tilted toward the ring junction at N5 (C10−N1 = 1.322 Å, N1−C2 = 1.353 Å, C2−C3 = C3−C4 = 1.383 Å, C4−N5 = 1.446 Å, N5−C10 = 1.376 Å; ∠C10−N1−C2 = 117.3°, N1−C2−N2 = 115.9°, N1−C2−C3 = 123.0°, C2−C3−C4 = 121.5°, C3−C4−N5 = 114.1°, O4−C4−N5 = 116.8°). Full data are reported in the Supporting Information.

2,3-Diaminopyridines react just like 2-aminopyridine, by using the pyridine ring nitrogen and the amino group in the 2-position, thus affording 33 with 6b.

2-Aminopyrimidines and 2-aminopyrazine react in a similar manner with 6 to give pyrimido- and pyrazinopyrimidinones 34 and 35. These rings are less nucleophilic

than pyridine and react much more slowly. 1-Aminoisouquinoline reacts at room temperature to afford the cyclization products 36a, b.

The reaction with 8-aminoquinoline in refluxing THF affords compound 40a, the formation of which is rationalized in Scheme 3. Initial addition to 6a by using the pyridine type lone pair leads to zwitterion 37. Cyclization affords the new zwitterion 38, which can be regarded as an intramolecular ketene–pyridine zwitterion.6b,15 Such zwitterions can be in equilibrium with the ketene valence isomer 39. The cyclization of 39 onto the C7 of the quinoline system can be described as an electrophilic aromatic substitution by a ketene. Another cyclization reaction analogous to 39 → 40 has been reported recently.18 Again, it would be possible to bypass 37 and 38 by postulating direct formation of 39. However, this would involve the initial attack of an amino group on the less electrophilic and more hindered C=N carbon in 6a and go against our current knowledge of the reactivity of iminopropadienones.

Thiazole forms a van der Waals complex with C3O2 in the same manner as pyridine,16,17 involving an interaction between the nitrogen lone pair and the cumulene system.20 Therefore, it may be expected that thiazoles and thiazolines react with ketenes in much the same manner as pyridines and that reaction with 6 will proceed analogously to Schemes 1 and 2. 2-Aminothiazoline afforded the expected addition products 41a–c in methylene chloride solution at room temperature. Similarly, 2-aminothiazoline afforded the expected addition products 42a–c under the same reaction conditions, but in refluxing toluene a small amount of the “abnormal” tautomer 43a was formed as well. The mechanism for its formation is expected to be analogous to the formation of 26–30 in Scheme 2. The structure of 43a was confirmed by X-ray crystallography (see the Supporting Information). As mentioned above, the “normal” pyridopyrimidinones of types 20–24 are highly zwitterionic, as expressed in the canonical structure 32. The bond lengths in 43a suggest a different kind of zwitterionic contribution involving the exocyclic amino group, as expressed in canonical structure 44 (bond lengths (Å): C2–C3 = 1.320, C8a–N8 = 1.296, N8–C7 = 1.398, C7–C6 = 1.416, C6–C5 = 1.372, C5–N4 = 1.400, N4–C8a = 1.374; exocyclic NH–C5 = 1.330, exocyclic NH–CH2 = 1.457).

Conclusion

Whereas simple alkyliminopropadienones are highly unstable and have the character of reactive intermediates, the neopentyl, mesityl, and o-tert-butylphenyl derivatives 6 are sufficiently stable to permit isolation at room temperature. This may appear somewhat surprising, since the steric hindrance exerted by these substituents, especially to attack on the cumulenic carbonyl groups, would seem to be very modest. Cumulenes 6 undergo a multitude of nucleophilic addition reactions, usually initiated by attack of amines on the cumulenic carbonyl group, to generate zwitterion intermediates. Subsequent ring closure reactions lead to a multitude of heterocyclic compounds containing five-, six-, seven-, eight-, and nine-membered rings, including pyrazolines, pyridopyrimidinones and mesoionic pyridopyrimidinium olates, pyrimidopyrimidinones, pyrazinopyrimidinones, and perhydrodiazepinone, -diazocinone, and -diazoninone derivatives.

Experimental Section

General Considerations. NMR spectra were recorded at 200 MHz for 1H and 50.3 MHz for 13C unless otherwise indicated. 2D 1H–13C COSY spectra were recorded using the HMBC or HSQC sequences. Mass spectra were obtained at 70 eV electron ionization. GC-MS employed a BP-4 capillary column (30 m × 0.25 mm; He carrier gas at 2 psi head pressure; injector 200 °C; detector 280 °C; column temperature 100–270 °C, programmed at 16 °C/min). Flash, column, and thin-layer chromatography were performed on silica gel. IR spectra were recorded on FT-IR spectrometers, usually at 0.5–1 cm⁻¹ resolution. Melting points are uncorrected. The

apparatus used for flash vacuum thermolysis and matrix isolation has been described.21

5-(2,2-Dimethylpropylamino)(methylthio)methylene)-2,2-dimethyl-1,3-dioxane-4,6-dione (2a). A mixture of 2,2-dimethylpropylamine (0.13 g, 15 mmol) and 1-(1.21 g, 5 mmol) in 30 mL of ethanol was refluxed for 5 h. The solvent was reduced to half its volume under vacuum, and diethyl ether (20 mL) was added. After the mixture was cooled to 0 °C in a refrigerator for 2 days, yellow crystals formed. The solution was treated with 1 mL of cold THF, and the residue recrystallized from THF/diethyl ether to yield 0.78 g (2.4 mmol, 48%) of 3a as a colorless powder. Compound 3a can also be purified by chromatography on silica gel/diethyl ether (Rf = 0.68). mp 148 °C; 1H NMR (CDCl3) δ 0.96 (s, 6 H), 1.81 (s, 6 H), 3.10 (2 H, J = 4.88 Hz), 1.93 (s, br, 2 H, 2,7-H); 13C NMR (CDCl3) δ 25.7, 26.7, 32.2, 58.1, 73.7, 101.6, 165.2, 166.3. Anal. Calcd for C17H30N2O4: C, 62.55; H, 9.03; N, 8.97. Found: C, 62.59; H, 9.57; N, 8.22.

2a (10 g, 35 mmol) was dissolved in 40 mL of dry THF. A solution of 0.03 mL (0.74 mmol) of diethylamine (1.31 g, 15 mmol) and diethylpropylamine (1.31 g, 15 mmol) was added. A yellow precipitate formed. The addition of diethylamine was stopped, and the reaction mixture was stirred for another 1 h. The precipitate had formed. The addition of HNMe2 was stopped, and the reaction mixture was stirred for another 2 h. The solvent was reduced to half its volume under vacuum, and the red-brown reaction mixture was warmed to room temperature. The solvent was evaporated, and the crude oil indicated an almost pure sample of 6a (0.78 g, 2.4 mmol, 48%). Yield: 203 mg (0.72 mmol, 65%).

Kinetics of Reaction of 6a with Methanol. (Neopentylimino)propadienone (6a) obtained from Meldrum’s acid derivative 3a was sublimed to 80 °C/4 × 10⁻⁵ mbar under an argon stream, pyrolyzed at 700 °C, and deposited on a CsI window in the cryostat at 7 K. A 1H NMR spectrum was recorded in CD3OD at 7 K. The spectra were obtained in intervals of 6 min by integration of the N-methylene protons. By plotting ln(NP-NCCCO) versus time, a straight line was obtained, indicating a first-order reaction kinetics with respect to the decreasing concentration of 6a. Regression analysis yielded ln(NP-NCCCO) = 0.0017t + 0.0059, R² = 0.9905, rate constant kₑ = 2.83 × 10⁻² s⁻¹, and tₑ = 408 min.

Matrix Isolation of (Neopentylimino)propadienone (6a). In the course of 5 min, Meldrum’s acid derivative 3a was sublimed to 80 °C/4 × 10⁻⁵ mbar under an argon stream, pyrolyzed at 700 °C, and deposited on a CsI window in the cryostat at 7 K: (1R, 7K) 2975 (m), 2313 (m), 2250 (m). The reaction mixture was stirred for another 2 h. The red-brown reaction mixture was warmed to room temperature. After evaporation of the solvent, a red thermoluminescent spectrum of the crude oil indicated an almost pure sample of 7a in a 1:0.4 ratio. Stoeberillation at 135 °C/10⁻⁴ mbar yielded 7a/7a in a 0.7:1 ratio as a yellow oil. Yield: 145 mg (0.64 mmol, 61%). 7a: 1H NMR (CDCl3) δ 0.90 (s, 9 H), 2.83 (s, 2 H), 2.94 (s, br), 2.97 (s, br), 3.05 (s, br), 3.53 (s, br, 2 H, 2,7-H); 13C NMR (CDCl3) δ 0.94 (s, 9 H), 2.67 (s, 6 H), 2.76 (s, 2 H, 7,8-H); 1H NMR (CDCl3) δ 11.0, 27.1, 31.9, 43.8–46.8 (br), 57.2, 70.5–70.7, 102.3, 163.5, 164.6. The broad signals are ascribed to hindered rotation (CH3 group at δ 13.2) or the presence of the nitrogen quadrupole moment (NCH2 signal at δ 43.8). Anal. Calcd for C16H28N2O4: C, 64.26; H, 10.84; N, 6.81. Found: C, 64.30; H, 10.26; N, 7.98.


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1,3-Dimethyl-5-(2,2-dimethylpropyl)amino)pyrazolin-3-one (10a). (Neopentyliminopropadienone (6a) obtained from Meldrum's acid derivative 4a (300 mg, 1.1 mmol) was isolated in a cold trap as above and dissolved in 50 mL of dry CH₂Cl₂ and a solution of N,N'-dimethylpropylenediamine (90 mg, 1 mmol) in 15 mL of dry CH₂Cl₂ was added. The red-brown solution was filtered through cotton wool. After evaporation of the solvent under vacuum, the brown oil was subjected to bulb-to-bulb distillation at 170–200 °C/10⁻⁵ mbar to afford 99 mg (0.43 mmol, 92%) of 15a as a colorless semisolid compound: yield 20 mg (0.08 mmol, 23%); ¹³C NMR (CDCl₃, 400 MHz) δ 0.88 (s, 9 H), 1.63–1.65 (m, 2 H), 1.69–1.73 (m, 2 H), 2.89 (s, 3 H), 2.14 (s, 3 H), 3.43 (s, 2 H), 3.58 (t, 2 H), 3.66 (t, 2 H), 3.8 (s, 2 H), 3H, 3.32, 3.42, 34.71, 48.67, 60.2, 156.2, 165.7. Anal. Calcd for C₁₂H₂₅N₅O: C, 65.23; H, 10.53; N, 17.56. Found: C, 65.53; H, 10.94; N, 17.47. For the X-ray structure, see the Supporting Information.

1,5-Dimethyl-4-(2,2-dimethylpropyl)iminopyrido[1,5]-diazizin-2-one (15a). (Neopentyliminopropadienone (6a) obtained from Meldrum's acid derivative 4a (300 mg, 1.1 mmol) was isolated in a cold trap as above and dissolved in 50 mL of dry CH₂Cl₂ and a solution of N,N'-dimethylbutylenediamine (41 mg, 0.35 mmol), dissolved in 40 mL of dry diethyl ether, was added via an automatic syringe pump over the course of 16 h. The reaction mixture was stirred for another 5 h at room temperature and was then concentrated to dryness. A 10 mL portion of methanol was added, and the solution was filtered through cotton wool. After evaporation of the solvent under vacuum, the brown oil was subjected to bulb-to-bulb distillation at 170–200 °C/10⁻⁵ mbar to afford a yellow oil. Subsequent Kugelrohr distillation at 160 °C/7 mbar gave 15a as a colorless solid: yield 20 mg (0.08 mmol, 23%); ¹³C NMR (CDCl₃, 400 MHz) δ 0.94 (s, 9 H), 1.63–1.65 (m, 2 H), 1.69–1.73 (m, 2 H), 2.89 (s, 3 H), 2.14 (s, 3 H), 3.43 (s, 2 H), 3.58 (t, 2 H), 3.66 (t, 2 H), 3.8 (s, 2 H), 3H, 3.32, 3.42, 34.71, 48.67, 60.2, 156.2, 165.7. Anal. Calcd for C₁₂H₂₅N₅O: C, 65.23; H, 10.53; N, 17.56. Found: C, 66.15; H, 10.86; N, 16.03. For the X-ray structure, see the Supporting Information.

1-Methyl-2-(2,2-dimethylpropyl)limino)-1,2-dihydropyrido[1,2-a]pyrimidin-5-ium-4-olate (18a). (Neopentyliminopropadienone (6a) obtained from Meldrum's acid derivative 4a (300 mg, 1.1 mmol) was isolated in a cold trap as above, and a solution of 2-(methylaminopyridine (119 mg; 1.1 mmol) in 15 mL of dry CH₂Cl₂ was added. The red-brown solution was transferred to a round-bottom flask, heated for 15 min under reflux, and stirred at room temperature overnight. The solvent was removed by flash-evaporation using diethyl ether/methanol (100:1) as the mobile phase to remove unreacted starting material and impurities. 18a was obtained as a red solid in 32% yield (86 mg, 0.35 mmol) by washing the column with a diethyl ether/methanol (100:70) mixture: mp 155–160 °C; ¹³C NMR (CDCl₃) δ 0.93 (s, 9 H, t-Bu), 2.74 (s, 2 H, NCH₂), 3.68 (s, 3 H, NMe), 5.02 (s, 1 H, 3-H), 7.02 (dt, 3H, J = 7.1 Hz, J = 1.2 Hz, 7-H), 7.19 (d, 1 H, 9-H), 7.89 (dt, 3H, J = 6.8 Hz, J = 1.7 Hz, 1-H, 8-H), 17.17 (dd, 3H, J = 6.8 Hz, J = 1.7 Hz, 1-H, 8-H), 165.7 ppm. The ¹³C NMR assignments are supported by an HSQC spectrum. 13: IR (KBr) 1651 (s), 1636 (vs), 1622 (s) cm⁻¹. Anal. Calcd for C₁₅H₂₅N₅O: C, 63.96; H, 10.29; N, 18.67. Found: C, 63.83; H, 10.56; N, 18.80.
the reaction mixture was refluxed in a preheated oil bath for 30 min. The solution was concentrated under vacuum to half-volume, and diethyl ether was added until the solution became cloudy. The suspension was cooled to 0 °C for several hours, and the precipitate was collected by centrifugation, washed with diethyl ether, and dried under vacuum to afford 21 mg (15%) of 26 as yellow crystals (TLC with diethyl ether/MeOH 1:1, Rf = 0.5). The supernatant was purified in the same way as described above for 20a to yield 73 mg (0.32 mmol, 53%) of 20a.

26: mp 216–218 °C dec; 1H NMR (CDCl3/MeOH-d4) ð 0.86 (s, 9 H), 3.01 (s, 2 H), 5.65 (s, 1 H), 6.83 (t, 3 J = 7.2 Hz, 1 H), 7.14 (d, 3 J = 9.2 Hz, 2 H 9 H), 7.45 (t, 3 J = 7.4, 1 H), 8.22 (d, 3 J = 7.4 Hz); 13C NMR (CDCl3) ð 27.1, 32.4, 54.4, 88.9, 113.7, 124.3, 126.1, 135.9, 150.3, 150.8, 170.3. 20a: mp 123 °C; 1H NMR (CDCl3, 400.13 MHz) ð 0.96 (s, 9 H), 3.02 (s, 2 H), 4.97 (s, br, 1 H), 5.40 (s, 1 H), 6.75 (s, 1 H), 7.38 (d, 3 J = 7.53 dt, 1 H), 8.82 (d, 3 J = 7.5 Hz); 13C NMR (CDCl3, 50.32 MHz) ð 27.3, 32.1, 55.3, 79.6, 112.2, 123.6, 127.7, 136.5, 151.0, 158.4, 162.0. Anal. Calcd for C15H19N3O: C, 67.33; H, 7.66; N, 18.08. Found: C, 67.33; H, 7.66; N, 18.08.

2-(2,2-Dimethylpropyl)amino)-9-methylpyrido[1,2-a]pyrimidin-4-one (21a), 4-(2,2-Dimethylpropyl)amino)-9-methylpyrido[1,2-a]pyrimidin-4-one (22a), and 4-(2,2-Dimethylpropyl)amino)-8-methylpyrido[1,2-a]pyrimidin-4-one (23a). Method A. (Neopentylimino)propadienone (6a) obtained from Meldrum’s acid derivative 4a (200 mg, 0.6 mmol) was isolated in a cold trap as above and treated with a solution of 2-amino-4-methylpyridine (65 mg, 0.6 mmol) in 10 mL of CH2Cl2. The reaction mixture was stirred for 2 h, and the precipitate was collected by centrifugation, washed with diethyl ether, and dried under vacuum to afford 21 mg (31%) of 21a as a yellow powder. The supernatant was purified as described above to afford 45 mg (0.2 mmol, 34%) of 21a.

28: mp 238–239 °C; 1H NMR (CDCl3, 400.13 MHz) ð 1.01 (s, 9 H), 2.29 (s, 3 H), 2.99 (d, 3 J = 3.9 Hz, 2 H), 5.70 (s, br, 1 H), 5.70 (s, 1 H), 6.60 (dd, 3 J = 7.3 Hz, 4 J = 1.7 Hz), 6.94 (s, 1 H), 8.2 (d, 3 J = 7.6 Hz); 13C NMR (CDCl3, 100.6 MHz) ð 21.1, 27.7, 32.5, 54.8, 90.2, 115.4, 122.8, 125.9, 146.7, 149.9, 151.1, 170.6.

22a: mp 179–181 °C; 1H NMR (CDCl3, 400.13 MHz) ð 0.92 (s, 9 H), 2.23 (s, 3 H), 2.98 (s, br, 2 H), 4.95 (s, br, 1 H), 5.35 (s, 1 H), 6.63 (dd, 3 J = 7.4 Hz, 4 J = 1.7 Hz), 6.95 (s, 1 H), 8.71 (d, 3 J = 7.1 Hz); 13C NMR (CDCl3, 100.6 MHz) ð 21.3, 27.3, 32.1, 53.5, 79.5, 115.0, 121.5, 127.0, 148.8, 150.9, 158.3, 162.0. Anal. Calcd for C14H19N3O: C, 68.54%; H, 7.81%; N, 17.13. Found: C, 68.31; H, 8.01; N, 16.83.

2-(2,2-Dimethylpropyl)amino)-7-methylpyrido[1,2-a]pyrimidin-4-one (23a) and 4-(2,2-Dimethylpropyl)amino)-7-methylpyrido[1,2-a]pyrimidin-2-one (29). (Neopentylimino)propadienone (6a) obtained from Meldrum’s acid derivative 4a (500 mg, 1.5 mmol) was isolated in a cold trap as above and treated with a solution of 2-amino-5-methylpyridine (162 mg, 15 mmol) in 20 mL of dry THF. The reaction mixture was refluxed for 6 h in a preheated oil bath. After the solvent had been evaporated, a 22 H NMR spectrum of the crude material was taken, indicating a mixture of 29 and 23a in a 1:0.17 ratio. Attempts to precipitate 23a from the crude mixture (in THF) with diethyl ether failed. The crude product was chromatographed (diethyl ether/methanol 100:5, 80 °C) to yield 73 mg (0.32 mmol, 53%) of 23a.

was recrystallized from THF to give 36 mg (42%) as a beige powder: mp 242 °C; 1H NMR (CDCl3) δ 0.91 (s, 9 H), 2.85 (d, J = 6.1 Hz, 2 H), 3.36 (t, 2 H), 4.34 (t, 2 H), 4.98 (t, br, 1 H), 7.62 (d, J = 4.7 Hz, 1 H), 8.69 (s, 1 H), 8.1 (d, J = 7.62 Hz), 8.81 (d, 1 H), 8.41 (d, J = 7.62 Hz); 13C NMR (CDCl3) δ 27.3, 32.2, 53.5, 82.7, 117.6, 129.2, 144.4, 151.0, 156.9, 162.3.

2-((2,2-Dimethylpropyl)amino)pyrazino[1,2-a]pyrimidin-1-one (4a) obtained from Meldrum’s acid derivative 4a (200 mg, 0.6 mmol) was isolated in a cold trap as above and treated with a solution of 2-aminopyrazine (70 mg, 0.7 mmol) in 15 mL of dry THF. The reaction mixture was heated under reflux for 4 h. The solvent was evaporated, and the brown residue was flash-chromatographed using a diethyl ether/methanol mixture (100:15, Rf 0.68) to afford 65 mg of 4a, which was recrystallized from boiling THF to give 28 mg (0.1 mmol, yield 41 mg (35%) of 41a. Neopentylinopropadienone (6a) obtained from Meldrum’s acid derivative 4a (100 mg, 0.3 mmol) was isolated in a cold trap as above, treated with a solution of 2-aminopyridine (51 mg, 0.4 mmol) in 10 mL of dry CH2Cl2, and stirred at room temperature for 16 h. The solvent was evaporated, and the brown oil was chromatographed (diethyl ether/methanol 100:1, Rf = 0.42) as the mobile phase. The crude product was recrystallized from THF to give 61 mg (37%) as a beige powder: mp 262°C; 1H NMR (CDCl3) δ 0.91 (s, 9 H), 2.98–3.04 (s, 2 Br, H), 5.23 (s, br, 1 H), 5.36 (s, 1 H), 6.74 (d, J = 7.1 Hz), 8.96 (d, J = 7.1 Hz, 1 H); 13C NMR (CDCl3) δ 25.5, 27.3, 32.1, 53.6, 78.7, 110.1, 135.8, 158.0, 163.5, 173.3.

4-(2,2-Dimethylpropyl)amino)pyrimido[2,1-a]isooquinol-4-one (36a). (Neopentylinopropadienone (6a) obtained from Meldrum’s acid derivative 4a (300 mg, 1.1 mmol) was isolated in a cold trap as above and treated with a solution of 8-aminoquinoxaline (91 mg, 0.5 mmol) in 10 mL of dry CH2Cl2, and stirred at room temperature for 16 h. The solvent was evaporated, and the brown residue was flash-chromatographed using a diethyl ether/methanol mixture (100:15, Rf 0.68) to afford 36a, which was recrystallized from boiling THF to give 2 mg (0.01 mmol, yield 4 mg (13%) of 20a, 0.08 mmol) of 20a.)

<table>
<thead>
<tr>
<th>Reagent</th>
<th>CH2Cl2, room temp, 5 h</th>
<th>toluene, reflux, 30 min</th>
</tr>
</thead>
<tbody>
<tr>
<td>2-aminopyridine</td>
<td>1/0.3 20a/26</td>
<td>1/0.6 20a/26</td>
</tr>
<tr>
<td>2-amino-4-methylpyridine</td>
<td>1/0.25 22a/26</td>
<td>1/0.72 22a/28</td>
</tr>
<tr>
<td>2-aminothiazole</td>
<td>1/0 42a/43a</td>
<td>1/0.5 42a/43a</td>
</tr>
</tbody>
</table>

* By integration of tert-butyl signals. * By integration of pyridymethyl signals.

4.98 (s, 1 H); 13C NMR (CDCl3, 100.62 MHz) δ 26.4, 27.3, 32.0, 48.3, 53.8, 57.9, 162.2, 163.0, 164.0.

7-(2,2-Dimethylpropyl)amino)[1,3]thiazolo[3,2-a]pyrimidin-5-one (42a) and 5-((2,2-Dimethylpropyl)amino)[1,3]thiazolo[3,2-a]pyrimidin-7-one (43a). Method A. (Neopentylinopropadienone (6a) obtained from Meldrum’s acid derivative 4a (200 mg, 0.6 mmol) was isolated in a cold trap as above and treated with a solution of 2-aminothiazole (61 mg, 0.6 mmol) in 10 mL of THF. The reaction mixture was refluxed for 1 h. The solvent was evaporated under vacuum, and the oily residue was chromatographed (MeOH/diethyl ether = 10:100) to afford 65 mg of 42a (46%) as a pale brown solid.

Method B. (Neopentylinopropadienone (6a) obtained from Meldrum’s acid derivative 4a (200 mg, 0.6 mmol) was isolated in a cold trap as above, treated with a solution of 2-aminothiazole (61 mg, 0.6 mmol) in 15 mL of toluene, and refluxed for 30 min. The solution was concentrated under vacuum to half-volume, and diethyl ether was added until the solution turned cloudy. After the mixture was cooled for 48 h at 0°C, the precipitate was collected by centrifugation, washed with diethyl ether, and dried under vacuum. Recrystallization from ethanol afforded 19 mg (13%, 0.08 mmol) of 43a as yellow crystals. The supernatant was purified as described above to yield 41 mg (35%) of 42a.

42a: mp 82 °C; GC retention time 12.6 min; 1H NMR (CDCl3) 400 MHz δ 0.94 (s, 9 H), 2.97 (d, J = 5.3 Hz, 2 H), 4.89 (br, 1 H), 5.2 (s, 1 H), 6.64 (d, J = 4.7 Hz), 7.78 (d, J = 4.7 Hz); 13C NMR (CDCl3, 100.62 MHz) δ 27.3, 32.1, 53.7, 78.9, 107.1, 122.2, 159.1, 162.4, 162.9. Anal. Calcd for C11H15N3OS: C, 55.58; H, 6.47; N, 17.48. Found: C, 55.58; H, 6.47; N, 17.72.

43a: mp 276 °C dec; 1H NMR (DMSO-d6, 333 K) δ 0.96 (s, 9 H), 2.99 (d, J = 4.9 Hz, 2 H), 5.31 (s, 1 H), 6.8 (s, br, 1 H), 7.26 (d, J = 5.12 Hz), 8.12 (d, J = 5.12 Hz); 13C NMR (CD3CN, DMSO-d6) δ 27.0, 32.5, 53.0, 82.4, 108.4, 120.9, 149.6, 162.8, 168.0. Anal. Calcd for C11H15N3OS: C, 55.67; H, 6.37; N, 17.17. Found: C, 55.57; H, 6.47; N, 17.72.

Attempted Isomerization of 2-((2,2-Dimethylpropyl)amino)8-methylpyrido[1,2-a]pyrimidin-4-one (22a) into 4-(2,2-Dimethylpropyl)amino)8-methylpyrido[1,2-a]pyrimidin-2-one (28a). 2-(2,2-Dimethylpropyl)amino)8-methylpyrido[1,2-a]pyrimidin-4-one (22a) (10 mg) was dissolved in 1 mL of toluene-d8 and placed in a NMR tube. The NMR tube was sealed and placed in the 200 MHz spectrometer. The probe was heated to 95 °C, and the H NMR spectra were recorded over a period of 12 h in intervals of 1 h. No change in the NMR patterns occurred, and the solution was therefore heated in
to give 12b as a pale brown solid (yield 70%): mp 138–140 °C; H NMR (CDCl₃, 400 MHz) δ 6.91 (1 H, 9), 5.90 (1 H, 9), 3.16 (2 H, 9), 3.15 (3 H, 9), 2.27 (3 H, 9), 2.23 (2 H, 6); ¹³C NMR (CDCl₃) δ 168.1, 154.7, 137.2, 135.3, 132.4, 129.3, 36.7, 31.1, 20.9, 18.2. Anal. Calc. for C₂₃H₂₇N₅O: C, 73.68; H, 7.46; N, 18.16.

1,4-Dimethyl-7-(mesitylimino)peryleno[1,4]diazepin-5-one (21b). Inopropadienone 6b obtained from 4b (332 mg, 1.0 mmol) was treated with 0.8 mmol of N,N’-dimethylacetylenediimine in 30 mL of dry ethyl ether, which was added dropwise to the stirred solution over a period of 6 h. The resulting mixture was stirred for 3 days. The solvent was evaporated, and the crude product was purified by flash chromatography (5% MeOH/ether) to give 150 mg (yield 55%) as a yellow oil which was difficult to purify to analytical accuracy. H NMR (400 MHz, CDCl₃) δ 9.1 (s, 9 H, 9), 6.51 (s, 3 H), 7.19 (dd, 3 H), 7.40 (s, 2 H); ¹³C NMR 100 MHz, CDCl₃) δ 181.1, 20.7, 124.3, 123.4, 121.4, 120.8, 113.7, 25.9. Found: C, 77.68; H, 6.53; N, 14.32. Found: C, 77.84; H, 6.64; N, 14.05.

1-Methyl-2-(mesitylimino)pyrido[1,2-a]pyrimidin-5-ium-4-olate (18b). 2-(Methylamino)pyridine in dichloromethane was added to 6b to give, after evaporation of the solvent and recrystallization of the crude product with methanol, 50 mg of 18b as an orange solid (yield 79%): mp 237–240 °C; H NMR (DMSO-d₆, 400 MHz) δ 9.00 (apparent d, 1 H), 7.91 (apppt 1 H), 7.12 (apppt 1 H), 6.82 (s, 2 H), 4.08 (s, 2 H), 3.80 (s, 3 H), 2.39 (s, 3 H), 1.94 (s, 6 H); ¹³C NMR (DMSO-d₆) δ 150.7 (C-4), 149.0 (C-9a or C-2), 148.2 (C-2 or C-9a), 145.0 (C-5), 136.3 (C-8), 129.6 (C-7H₈), 128.4 (2x CH), 128.1 (2 x C=CH₂), 114.9 (C-7), 114.1 (C-9), 76.3 (C-3), 30.7 (CH₃), 20.4 (CH₂), 17.7 (2 x CH₃) (the NMR assignments are supported by HSQC and HMBC spectra); IR (KBr) 1710, 1638, 1616, 1603, 1561, 1415 1385 cm⁻¹; ¹H NMR (14 K) 1739, 1636, 1624, 1609, 1590, 1586, 1533, 1485, 1486, 1479, 1443, 1321, 1336, 1318, 1306, 1296, 1289, 1281, 1278, 1270, 1259, 1251, 1250, 1239, 1229, 1217, 1167, 1168, 1155, 1139, 1051, 1035, 1007, 953, 782, 677, 742, 663, 552, 469 cm⁻¹ for medium effects on the IR spectra of mesoionic compounds, see ref 12). Anal. Calc. for C₂₄H₂₇N₅O: C, 73.68; H, 6.53; N, 14.33. Found: C, 73.86; H, 6.54; N, 14.27. For the X-ray structure, see the Supporting Information.

Flash Vacuum Thermolysis of 18b: Formation of 6b. 2-(Methylamino)pyridine in dichloromethane was added to 6b, and the mixture was treated with 0.5 mmol of the crude product in an Ar matrix at ca. 10 K. At 350 °C, the first major thermal event was observed (decomposition for 10 min using 70 mbar of Ar; vacuum 5 x 10⁻⁴ mbar). At 450 °C, 18b decomposed to give 6b with the characteristic bands at 2248, 2243, and 2235 cm⁻¹ and 2-(methylamino)pyridine, which was identified by comparison with the IR spectrum of an authentic sample.

2-(Methylamino)pyrido[1,2-a]pyrimidin-4-one (20b). 2-Aminopyridine in dichloromethane was added to 6b, and the solution was evaporated to give a brownish solid. The starting material was removed by sublimation, and the crude product was washed with cold ether to give 40 mg of 20b as a pale yellow solid (yield 66%): mp 240–242 °C; H NMR (CDCl₃, 400 MHz) δ 8.89 (broad d, 1 H), 7.90 (d, 1 H, J = 9.0, 7.0), 7.23 (broad d, 1 H, J = 9.0 Hz), 6.95 (s, 2H), 3.72 (s, 3H), 2.39 (s, 3 H), 2.38 (s, 3 H), 2.36 (s, 2 H); ¹³C NMR (CDCl₃, 100 MHz) δ 168.1, 154.7, 137.2, 135.3, 132.4, 129.3, 36.7, 31.1, 20.9, 18.2. Anal. Calc. for C₁₅H₁₅N₅O: C, 71.28; H, 6.39; N, 22.33. Found: C, 71.26; H, 6.48; N, 22.29.

9-Amino-2-(tert-butylamino)pyridine(1,2-a)pyrimidin-4-one (3b).
2-Diethylamino-1,3-dioxane-4,6-dione (4c).

Chemistry of Stable Iminopropadienones

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7.29 (m, 4 H), 7.45 (30%) as a pale yellow solid: mp 190 °C. Subsequently, 103.5 mg (1.1 mmol) of 2-amino-4-picoline. Flash chromatography (5% MeOH/ether) yielded 210 mg (68%) as a pale yellow solid: mp 200–201 °C; 1H NMR (400 MHz, CDCl3) δ 1.39 (s, 9 H), 2.40 (s, 3 H) 5.30 (s, 1 H), 6.27 (br, 1 H), 7.19–7.29 (m, 3 H), 7.49–7.52 (m, 2 H), 7.69 (d, J = 8.0 Hz, 1 H), 8.78 (s, 1 H); 13C NMR (100 MHz, CDCl3) δ 17.9, 30.6, 35.1, 81.9, 122.7, 129.2, 129.5, 127.3, 127.4, 127.5, 130.4, 136.1, 147.1, 149.9, 158.2, 161.3. Anal. Calcld for C19H21N3O: C, 70.94; H, 8.94; N, 13.79. Found: C, 70.8; H, 8.94; N, 13.79.

Methyl-2-((2-tert-butylyphenylimino)pyrido[1,2-a]pyrimidin-4-one (23c). Methylpyrapidine 6c obtained from Meldrum’s acid derivative 4c (346 mg, 1.0 mmol) was treated with 119.0 mg (1.1 mmol) of aminopyrazine in 15 mL of dry THF, and the resulting mixture was stirred for 1 h. The solvent was evaporated, and the crude product was sublimed to remove excess aminopyrazine. Flash chromatography (5% MeOH/ether) yielded 210 mg (68%) as a pale yellow solid: mp 200–201 °C; 1H NMR (400 MHz, CDCl3) δ 1.39 (s, 9 H), 2.40 (s, 3 H) 5.30 (s, 1 H), 6.27 (br, 1 H), 7.19–7.29 (m, 3 H), 7.49–7.52 (m, 2 H), 7.69 (d, J = 8.0 Hz, 1 H), 8.78 (s, 1 H); 13C NMR (100 MHz, CDCl3) δ 17.9, 30.6, 35.1, 81.9, 122.7, 129.2, 129.5, 127.3, 127.4, 127.5, 130.4, 136.1, 147.1, 149.9, 158.2, 161.3. Anal. Calcld for C19H21N3O: C, 70.94; H, 8.94; N, 13.79. Found: C, 70.8; H, 8.94; N, 13.79.
5.01 (s, 1 H), 6.48 (s, br, 1 H), 7.16–7.23 (m, 3 H), 7.40–7.44 (m, 1 H); \(^{13}\)C NMR (100 MHz, CDCl\(_3\)) \(\delta\) 26.7, 30.6, 35.0, 48.4, 82.3, 127.2, 127.3, 127.5, 135.7, 146.6, 161.9, 162.0, 164.7. Anal. Calcd for C\(_{16}\)H\(_{19}\)N\(_3\)OS: C, 63.76; H, 6.35; N, 13.94. Found: C, 63.47; H, 6.47; N, 13.85.

2-((2-tert-Butylphenyl)imino][1,3]thiazolo[3,2-a]pyrimidine-5-one (42c). Iminopropadienone 6c obtained from Meldrum’s acid derivative 4c (346 mg, 1.0 mmol) was treated with 110.2 mg (1.1 mmol) of 2-aminothiazole in 15 mL of dry THF, and the resulting mixture was stirred for 10 h. The solvent was evaporated, and the crude product was sublimed to remove excess trapping agent. Flash chromatography (5% MeOH/ether) yielded 210 mg (70%) of a pale yellow solid: mp 229–330 °C; \(^1\)H NMR (400 MHz, CDCl\(_3\)) \(\delta\) 1.37 (s, 9 H, t-Bu), 5.16 (s, 1H, CH), 6.59 (s, br, 1 H, NH), 6.73 (d, 1H, \(\text{CH}_3\)) = 5.0), 7.23–7.24 (m, 3H), 7.43–7.47 (m, 1H), 7.82 (d, 1H, \(\text{CH}_3\)) = 5.0); \(^{13}\)C NMR (100 MHz, CDCl\(_3\)) \(\delta\) M 30.6 (CMe\(_3\)), 35.0 (CMe\(_3\)), 80.8 (CH), 107.9, 122.2, 127.3, 127.4, 127.6, 130.0, 135.8, 146.7, 159.0, 161.6, 163.0 (CO). The assignments are supported by HSQC and HMBC spectra. Anal. Calcd for C\(_{16}\)H\(_{19}\)N\(_3\)OS: C, 64.19; H, 5.72; N, 14.04. Found: C, 64.06; H, 5.73; N, 13.91.

**Acknowledgment.** This work was supported by the Australian Research Council.

**Supporting Information Available.** Figures and tables giving vibrational spectra of 6a–c, \(^1\)H and \(^{13}\)C NMR spectra of 6a–c, 8a, 8b, 9b, 10a, 12c, 13b,c, 14a, 15a, 17b, 21a, 22a, 23a, 24a, 26a, 33b, 34a, 34b, 35a,c, 36b, 41a, and 43a, and X-ray structure data for 13c, 14a, 15a, 18b, 21a, and 43a. This material is available free of charge via the Internet at http://pubs.acs.org.

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