Reactivity of 4-Azido- and 4-Amino-6-methyl-2*H*-pyran-2-one. Preparation of 1-(6-Methyl-2-oxopyran-4-yl)-1,2,3-triazoles and 5-Oxopyrano[4,3-*b*]pyridines

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1,3-Dipolar cycloadditions of stable 4-azido-6-methyl-2*H*-pyran-2-one **1** with electron-rich alkenes and alkynes lead to 4,5-substituted 1-(6-methyl-2-oxopyran-4-yl)-1,2,3-triazoles. Iminophosphoranes derived from **1** have also been synthesized. 5-Oxopyrano[4,3-*b*]pyridines are prepared by reaction of 4-amino-6-methyl-2*H*-pyran-2-one **2** with β-dicarbonyl compounds.

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Introduction.

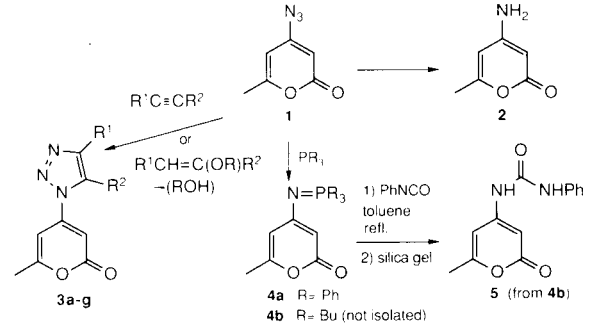
A large number of publications deals with the chemistry of 6-alkyl-2-pyrones but few of these compounds bear a nitrogen substituent at the C-4 position of the pyrone ring [1]. In the course of a synthetic project our group prepared 4-azido-6-methyl-2*H*-pyran-2-one, **1** [2], from the easily available 4-hydroxy-6-methyl-2*H*-pyran-2-one (triacetic acid lactone). Azide **1** was quantitatively converted into 4-amino-6-methyl-2*H*-pyran-2-one **2** [2] and showed enough stability for storage and easy handling [3].

Since stable vinyl azides are not too common [4] we decided to explore further the reactivity of **1**. Dipolarophiles with electron-donating substituents would seem to be the best choice to react with our electron-poor azide through dipole LUMO-dipolarophile HOMO controlled cycloaddition reaction [5].

Results.

Our experiments leading to 4,5-substituted 1-(6-methyl-2-oxo-2*H*-pyran-4-yl)-1,2,3-triazoles, **3**, (Scheme 1) are summarized in Table 1. Structure **3h** was assigned on the basis of spectroscopic data to the only product isolated from the reaction of **1** with 3,4-dihydropyran (3,4-DHP) (run 8, Table 1 and Scheme 2). This compound can arise by opening of the initially formed triazoline, loss of nitrogen and hydrolysis of the resulting enamine (Scheme 2).

Scheme 1



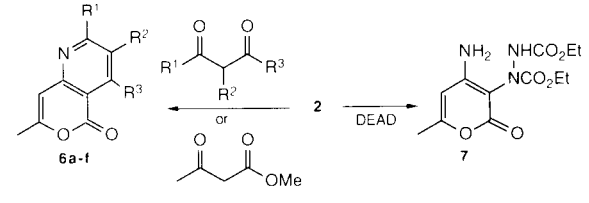


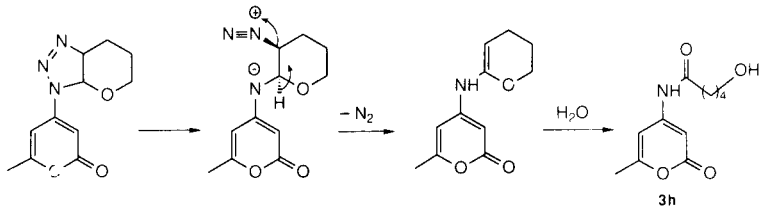
Table 1

Reactions of 1 with Dipolarophiles

Run	**1**: dipolarophile	solvent/T (°C)/t (h)	**3** (%) [a]	R^1	R^2
1	(1:1)$AcOCH{=}CH_2$	toluene/60-70/120	**3a** (66)	H	H
2	(1:1)*n*-$BuOCH{=}CH_2$	toluene/80/24	**3a** (68)	H	H
3	(1:35)$AcOC(Me){=}CH_2$	none/90/51	**3b** (56)	H	Me
4	(1:1.7)PhC≡CPh	none/80/120	**3c** (51)	Ph	Ph
5	(1:1)PhC≡CH	$(ClCH_2)_2$/reflux/72 [b]	**3d** (36) [c]	Ph	H
			3e	H	Ph
6	(1:1.5)$HOCH_2C{\equiv}CCH_2OH$	none/80/30	**3f** (66)	CH_2OH	CH_2OH
7	(1:1.4)HC≡C-OEt [d]	THF/20-30/336	**3g** (24) [e]	H	OEt
8	(1:64)3,4-Dihydropyran	none/rt/168	**3h** (62)	see formula	

[a] Yields of isolated products. [b] Then, one equivalent of dipolarophile was added and the new mixture was kept in a closed reactor at 80° for 84 hours. and at 120° for 48 hours. [c] Mixutre of **3d** and **3e** (2:3 ratio based on pmr integration). Samples of each regioisomer were obtained by recrystallization from chloroform. [d] Reagent added as a 50% hexane solution. Reaction carried out in a closed reactor. [e] Yield 57% based on consumed azide.

Scheme 2



The structures of the regioisomers obtained from runs 3,5 and 7 (Table 1) were elucidated by NOE experiments. Thus, irradiation of *H*-C3 of the pyrone ring at δ 6.28 in compound **3b** results in 5.8% NOE effect in the signal at δ 2.56, attributed to the methyl group of the triazole ring, whereas irradiation of *H*-C5 at δ 6.81 produces 4.2 and 1.7% NOE effects in the signals at δ 2.41 and 2.56, the first one being assigned to the methyl group in the pyrone ring. In no case was the signal at δ 7.61 (*H*-C4 of the triazole ring) affected. These NOE experiments also point out that the preferred conformation of **3b** around the bond linking both heterocyclic rings is as indicated in formula **3** (Scheme 1). Also, NOE experiments permitted assignment of structures to isomers **3d** and **3e**. Thus, irradiation at δ 6.44 (*H*-C3 of the pyrone ring) of one isomer results in a NOE effect of 9.3% in the signal at δ 8.25 (*H*-C5 of the triazole ring), therefore the isomer being identified as **3d**. However, NOE experiments were inconclusive with regard to structure **3g** that was assigned to the product of run 7 on the basis of SDEPT experiments (See reference [11]). It is interesting to note that, with the exception of the cycloaddition of phenylacetylene, the other cycloadditions of unsymmetrical substrates appeared to occur regiospecifically.

Next, we used **1** as a substrate in the Staudinger reaction [6] (Scheme 1). Although the iminophosphorane **4a** was easily formed and isolated, it did not react with 2,4-pentanedione in boiling benzene or on microwave irradiation of the mixture in the presence of Montmorillonite KSF, and no defined products could be isolated when it was treated with *p*-nitrobenzaldehyde. When cinnamaldehyde was added to the presumable more reactive [7] *in situ* generated **4b**, a complex mixture was obtained. Reaction of **4b** with phenyl isocyanate gave, after chromatography on silica gel, 6-methyl-4-(*N'*-phenyl)ureido-2*H*-pyran-2-one, **5** (Scheme 1).

Few 5-oxopyrano[4,3-*b*]pyridines have been described and they have been prepared only by methods that are far from general [8,9]. The amino compound **2** reacts with β-dicarbonyl compounds to afford 7-methyl-5-oxopyrano-[4,3-*b*]pyridines **6** (Scheme 1, Table 2). Several reaction conditions have been tested (Table 2). Toluene was a good reaction medium but **2** is almost completely insoluble in it.

Use of 2-propanol, titanium tetrachloride [10] in dichloromethane or microwave energy did not improve the yields. The method fails for the less reactive dibenzoylmethane. Treatment with methyl 3-oxobutanoate afforded **6f** (keto

Table 2

Reactions of **2** with Carbonyl Compounds

Run	carbonyl cpd [a]	catalyst	solvent/T (°C)/t (h)	**6** or **7** (%) [b]	R^1	R^2	R^3
1	$CH_3COCH_2COCH_3$	pyridine	none/reflux/22	**6a** (36)	Me	H	Me
2	$CH_3COCH_2COCH_3$	*p*-TsOH	*i*-PrOH/reflux/72	**6a** (27)	Me	H	Me
3	$CH_3COCH_2COCH_3$	-----	AcOH/120/32	**6a** (52)	Me	H	Me
4	$CH_3COCH{=}C(Cl)CH_3$	-----	toluene/125/72	**6a** (27)	Me	H	Me
5	$PhCOCH_2COCH_3$	*p*-TsOH	toluene/reflux/70	**6b** (18)	Ph	H	Me
6	$PhCOCH_2COCH_3$	-----	AcOH/120/144 [c]	**6b** (21)	Ph	H	Me
7	$CH_3COCH(Me)COCH_3$	*p*-TsOH	toluene/reflux/54	**6c** (50)	Me	Me	Me
8	$((MeO)_2CH)_2CH_2$	*p*-TsOH	toluene/reflux/17	**6d** (21)	H	H	H
9	$CH_3COCH_2CH(OMe)_2$	*p*-TsOH	toluene/reflux/40	**6e** (15)	Me	H	H
10	$CH_3COCH_2CH(OMe)_2$	-----	AcOH/110/24	**6e** (43)	Me	H	H
11	CH_3COCH_2COOMe	*p*-TsOH	toluene/reflux/17	**6f** (16) [d]	OH	H	Me
12	CH_3COCH_2COOMe	-----	AcOH/120/72 [e]	**6f** (8)	OH	H	Me
13	EtOCON=NCOOEt	-----	toluene/100-140/72	**7** (47)	see formula		

[a] Ratio **2**:carbonyl compound 1:1 except for run 1 (1:10) and run 3 (1:1.3). [b] Yields of isolated products. [c] Then, *p*-TsOH (10%) was added and the mixture kept for 48 hours. [d] Keto tautomer. [e] More ketoester was added (3 equivalents) and the mixture kept for 144 hours.

tautomer). When formation of more than one regioisomer is possible (runs 5-6, 9-10 and 11-12 in Table 2), assignments of structures were made on the basis of the cmr spectra with the program Selective Distorsionless Enhancement by Polarization Transfer (SDEPT) developed by Sánchez-Ferrando and coworkers [11] in our Department. Thus, by selectively pulsing the CH_3 protons of the pyridine ring of compound **6e** at δ 2.60 only the coupled carbon atoms C2 (two bond coupling) and C3 (three bond coupling) at δ 166.0 and 122.4 show signals enhanced by polarization transfer (SDEPT effect). Should the isomeric structure, with the methyl group at C4 in the pyridine ring have been the real one, SDEPT effects for signals due to C3, C4 and C4a would have been observed. Detailed spectroscopic assignments will be published elsewhere by Sánchez-Ferrando and coworkers.

Reaction of **2** with diethyl azodicarboxylate (DEAD) (Scheme 1, run 13 in Table 2) led to compound **7**. Reactions of **2** with ethyl 3-amino-2-butenoate, 2-butenal, dimethyl acetylenedicarboxylate, benzoin [12] and 2-chloroacetone were unsuccessful.

In summary, azide **1** has proved to be a good dipole for 1,3-dipolar cycloaddition reactions, good regioselectivities being observed by appropriate choice of dipolarophiles [5]. On the other hand, reactions of amine **2** with β-diketones and β-ketoesters provide a method of preparing heterocycles **6**.

EXPERIMENTAL

1-(6-Methyl-2-oxopyran-4-yl)-1,2,3-triazole (**3a**), (run 1, Table 1).

A mixture of 0.400 g (2.65 mmoles) of **1**, 2.280 g (2.65 mmoles) of vinyl acetate and anhydrous toluene (15 ml) was heated under argon at 60° for 24 hours and at 70° for 96 hours (pmr monitoring). The solid formed was filtered and identified as **3a** (0.310 g, 66% yield), mp 238-240° dec (chloroform); ir (potassium bromide): 1735 (br), 1647 cm^{-1}; pmr (deuteriodimethyl sulfoxide): 2.31 (s, 3H), 6.77 (d, J = 1.8 Hz, 1H), 7.11 (s, 1H), 8.06 (d, J = 1.2 Hz, 1H), 9.00 (d, J = 1.2 Hz, 1H); ms: (m/z) 177 (M, 21), 149 (10), 109 (19), 43 (100).

Anal. Calcd. for $C_8H_7N_3O_2$: C, 54.24; H, 3.99; N, 23.71. Found: C, 54.06; H, 3.92; N, 23.64.

5-Methyl-1-(6-methyl-2-oxopyran-4-yl)-1,2,3-triazole (**3b**), (run 3, Table 1).

A mixture of 0.400 g (2.65 mmoles) of **1** and freshly distilled isopropenyl acetate (10 ml) was heated under argon at 90° for 50 hours. A crop of **3b** (130 mg) precipitated upon ice-cooling. The solid was filtered off and the filtrate was evaporated to afford a solid that was washed with diethyl ether to afford 156 mg of **3b** (overall yield 286 mg, 56%). The combined solids were purified through a silica gel column with hexane-ethyl acetate as eluent. Compound **3b** has mp 154-157° (ethyl acetate-diethyl ether); ir (potassium bromide): 1722, 1644 cm^{-1}; pmr (deuteriochloroform): 2.41 (s, 3H), 2.56 (d, J = 1.2 Hz, 3H), 6.28 (d, J = 1.9 Hz, 1H), 6.81 (broad s, 1H), 7.61 (broad s, 1H); cmr (deuteriochloroform): 10.4, 20.1, 100.1, 101.7, 133.7, 135.0, 149.2, 161.9, 164.2.

Anal. Calcd. for $C_9H_9N_3O_2$: C, 56.54; H, 4.75; N, 21.97. Found: C, 56.15; H, 4.74; N, 21.76.

1-(6-Methyl-2-oxopyran-4-yl)-4,5-diphenyl-1,2,3-triazole (**3c**), (run 4, Table 1).

A mixture of 0.400 g (2.65 mmoles) of **1** and 0.810 g (4.54 mmoles) of diphenylacetylene was heated under argon at 80° for 5 days (tlc monitoring). The resulting mixture was chromatographed through a silica gel column with hexane-ethyl acetate mixtures to afford **3c** (492 mg, 51%), mp 173-174° (ethyl acetate-hexane); ir (potassium bromide): 1734, 1647 cm^{-1}; pmr (deuteriochloroform): 2.31 (s, 3H), 5.77 (d, J = 1.8 Hz, 1H), 6.58 (broad s, 1H), 7.34 (m, 5H), 7.54 (m, 5H); cmr (deuteriochloroform): 20.1, 99.9, 102.8, 126.8, 127.0, 128.3, 128.4, 129.5, 129.7, 130.4, 133.2, 145.9, 148.8, 161.7, 163.6.

Anal. Calcd. for $C_{20}H_{15}N_3O_2$: C, 72.93; H, 4.60; N, 12.75. Found: C, 73.05; H, 4.72; N, 12.65.

1-(6-Methyl-2-oxopyran-4-yl)-4-phenyl-1,2,3-triazole (**3d**) and 1-(6-Methyl-2-oxopyran-4-yl)-5-phenyl-1,2,3-triazole (**3e**), (run 5, Table 1).

A mixture of 0.400 g (2.65 mmoles) of **1**, 0.271 g (2.65 mmoles) of phenylacetylene and anhydrous 1,2-dichloroethane (25 ml) was initially refluxed under argon for 72 hours. Since the reaction did not progress the mixture was transferred to a closed reactor, more phenylacetylene was added (0.271 g, 2.65 mmoles) and the new mixture heated at 80° for 84 hours and finally at 120° for 48 hours. The solvent was evaporated and the residue was chromatographed through a silica gel column with mixtures of hexane-ethyl acetate as eluents to afford 244 mg (36%) of a 2:3 mixture of **3d** and **3e**. A sample of isomer **3e** was obtained by recrystallization from chloroform and sublimation at 160°/18 mm Hg. From the mothers liquors a sample of **3d** could be isolated by crystallization in chloroform and recrystallization from ethyl acetate-diethyl ether. Compound **3d** had mp 158-163°; ir (potassium bromide): 1715, 1643 cm^{-1}; pmr (deuteriochloroform): 2.44 (s, 3H), 6.44 (d, J = 2.0 Hz, 1H), 7.03 (broad s, 1H), 7.50 (m, 3H), 7.87 (m, 2H), 8.25 (s, 1H). Compound **3e**, had mp 191-195°; ir (potassium bromide): 1729, 1649 cm^{-1}; pmr (deuteriochloroform): 2.33 (s, 3H), 5.95 (d, J = 1.9 Hz, 1H), 6.53 (broad s, 1H), 7.44 (m, 5H), 7.83 (s, 1H); ms: (m/z) 253 (M, 3), 43 (100).

Anal. Calcd. for $C_{14}H_{11}N_3O_2$: C, 66.39; H, 4.38; N, 16.58. Found: C, 66.03; H, 4.50; N, 16.63.

4,5-bis(Hydroxymethyl)-1-(6-methyl-2-oxopyran-4-yl)-1,2,3-triazole (**3f**), (run 6, Table 1).

A mixture of 0.383 g (2.54 mmoles) of **1** and 0.342 g (3.97 mmoles) of 2-butyne-1,4-diol was heated in a closed reactor at 80° for 30 hours (tlc monitoring). The residue was chromatographed through a silica gel column with ethyl acetate as eluent to afford 0.383 g (66%) of **3f**, mp 163-166° (ethyl acetate); ir (potassium bromide): 3400-3100, 1720, 1647 cm^{-1}; pmr (hexadeuteriodimethyl sulfoxide): 2.36 (s, 3H), 4.62 (d, J = 6.2 Hz, 2H), 4.71 (d, J = 6.2 Hz, 2H), 5.28 (t, J = 6.2 Hz, 1H), 5.82 (t, J = 6.2 Hz, 1H), 6.77 (d, J = 1.2 Hz, 1H), 6.96 (broad s, 1H); cmr (hexadeuteriodimethyl sulfoxide): 19.7, 50.3, 54.0, 100.0, 102.1, 135.0, 147.3, 148.9, 161.9, 164.2; ms: (m/z) 237 (M, 2), 109 (10), 43 (100).

Anal. Calcd. for $C_{10}H_{11}N_3O_4$: C, 50.63; H, 4.68; N, 17.71. Found: C, 50.53; H, 4.66; N, 17.59.

5-Ethoxy-1-(6-methyl-2-oxopyran-4-yl)-1,2,3-triazole (**3g**), run 7,

Table 1).

A mixture of 0.770 g (5.09 mmoles) of **1**, 1 g of 50% solution of ethoxyacetylene in hexanes (7.13 mmoles) and anhydrous tetrahydrofuran (18 ml) was left in a closed reactor for 7 days. The formed precipitate of **3g** (85 mg) was filtered off and the filtrate was left 7 days more at 30°, more precipitate being formed and filtered. The mother liquor contained unreacted **1**. The combined precipitates were washed with hexane to afford pure **3g** (24% overall yield, 57% with respect to consumed **1**), mp 159-161° (ethyl acetate-hexane); ir (potassium bromide): 1714, 1647 cm^{-1}; pmr (deuteriochloroform): 1.59 (t, J = 7.5 Hz, 3H), 2.37 (broad s, 3H), 4.33 (q, J = 7.5 Hz, 2H), 6.75 (d, J = 1.2 Hz, 1H), 7.00 (m, 1H), 7.19 (s, 1H); cmr (deuteriochloroform): 14.4, 20.3, 70.1, 98.0, 98.4, 114.8, 153.2, 162.9, 163.5.

Anal. Calcd. for $C_{10}H_{11}N_3O_3$: C, 54.29; H, 5.02; N, 18.99. Found: C, 54.30; H, 5.17; N, 19.13.

N-(6-Methyl-2-oxopyran-4-yl)-5-hydroxypentanamide (**3h**), (run 8, Table 1).

A mixture of 0.400 g (2.65 mmole) of **1** and 3,4-dihydropyran (10 ml) was left at room temperature for 7 days. The excess dihydropyran was evaporated and the residue was crystallized from ethyl acetate to afford **3h** (373 mg, 62%), mp 128-130° (ethyl acetate); ir (potassium bromide): 3317 (br), 3264, 1709, 1677, 1644 cm^{-1}; pmr (hexadeuteriodimethyl sulfoxide): 1.5 (m, 4H), 2.17 (s, 3H), 2.38 (t, J = 6.8 Hz, 2H, partially masked), 3.38 (m, 2H, partially masked), 4.39 (t, J = 5.0 Hz, 1H), 6.24 (broad s, 1H), 6.53 (d, J = 2.0 Hz, 1H), 10.27 (broad s, 1H); cmr (hexadeuteriodimethyl sulfoxide): 19.5, 21.2, 31.8, 36.4, 60.4, 92.8, 98.8, 151.4, 162.1, 163.3, 173.4; ms: (m/z) 225 (M, 2), 125 (27), 110 (25), 97 (75), 54 (56), 43 (100).

Anal. Calcd. for $C_{11}H_{15}NO_4$: C, 58.65; H, 6.73; N, 6.21. Found: C, 57.46; H, 6.64; N, 6.09.

(6-Methyl-2-oxopyran-4-ylimino)triphenylphosphorane (**4a**).

A solution of 0.500 g (3.31 mmoles) of **1** in anhydrous benzene (10 ml) was added dropwise under argon to an ice-cooled, magnetically stirred solution of 0.868 g (3.31 mmoles) of triphenylphosphine in anhydrous benzene (10 ml). The mixture was left for 20 minutes at room temperature and the solvent was evaporated, affording 0.868 g (68% yield) of **4a**, mp 160° dec (anhydrous dichloromethane/pentane); ir (potassium bromide) 1686, 1635 cm^{-1}; pmr (deuteriochloroform): 2.15 (s, 3H), 4.88 (broad s, 1H), 6.03 (broad s, 1H), 7.69 (m, 15H); cmr (deuteriochloroform): 19.4, 92.2, 92.9, 107.5, 108.9, 125.4, 128.5, 129.1, 130.4, 132.0, 159.0, 165.0; ms: (m/z) 386 (19), 385 (M, 66), 384 (10), 358 (13), 357 (56), 356 (35), 304 (17), 262 (21), 201 (18), 185 (38), 184 (21), 183 (100), 108 (22), 43 (16).

Anal. Calcd. for $C_{24}H_{20}NO_2P$: C, 74.79; H, 5.24; N, 3.63. Found: C, 74.59; H, 5.17; N, 3.58.

6-Methyl-4-(*N'*-phenyl)ureido-2*H*-pyran-2-one (**5**).

A solution of 0.447 g (2.21 mmoles) of tributylphosphine in 5 ml of anhydrous toluene was added dropwise under argon to an ice-cooled solution of 0.400 g of **1** in 5 ml of toluene. The mixture was kept at 0° for 30 minutes. Then, 0.379 g (3.18 mmoles) of phenyl isocyanate was added and the mixture was refluxed for 26 hours. The solvent was evaporated and the residue was chromatographed through a silica gel column (hexane-ethyl acetate as eluent) to afford **5** (0.087 g, 16%), mp 214-217°; ir (potassium bromide): 3350, 3310, 1730, 1685 cm^{-1}; pmr (hexadeuteriodimethyl sulfoxide): 2.16 (s, 3H), 6.19 (broad s, 1H), 6.25 (broad s, 1H), 7.28 (m, 5H), 9.00 (broad s, 1H), 9.25 (broad s, 1H); ms: (m/z) 244 (M, 12), 152 (7), 125 (26), 119 (83), 110 (31), 97 (74), 54 (98), 52 (92), 43 (100).

Anal. Calcd. for $C_{13}H_{12}N_2O_3$: C, 63.92; H, 4.96; N, 11.46. Found: C, 63.84; H, 4.75; N, 11.51.

2,4,7-Trimethyl-5-oxopyrano[4,3-*b*]pyridine (**6a**), (run 3, Table 2).

A mixture of 0.400 g (3.20 mmoles) of **2**, 0.416 g (4.16 mmoles) of pentane-2,4-dione and glacial acetic acid (20 ml) was heated with stirring at 120° for 32 hours. The solvent was evporated and the residue extracted with diethyl ether to afford **6a** (314 mg, 52% yield). An analytical sample was obtained by chromatography through silica gel recrystallization from diethyl ether, mp 92-93°; ir (potassium bromide): 1732, 1659 cm^{-1}; pmr (deuteriochloroform): 2.31 (s, 3H), 2.60 (s, 3H), 2.77 (s, 3H), 6.46 (s, 1H), 7.05 (s, 1H); cmr (deuteriochloroform): 19.4, 21.9, 24.6, 105.9, 112.7, 124.9, 152.3, 155.9, 158.0, 161.8, 164.4; ms: (m/z) 190 (M+1, 8), 189 (M, 77), 174 (89), 147 (20), 118 (93), 77 (35), 43 (100).

Anal. Calcd. for $C_{11}H_{11}NO_2$: C, 69.83; H, 5.86; N, 7.40. Found: C, 69.97; H, 5.86; N, 7.45.

4,7-Dimethyl-2-phenyl-5-oxopyrano[4,3-*b*]pyridine (**6b**), (run 5, Table 2).

A mixture of 0.600 g (4.8 mmoles) of **2**, 0.778 g (4.8 mmoles) of 1-phenyl-1,3-butanedione, *p*-toluenesulfonic acid hydrate (0.090 g, 0.48 mmole) and toluene (15 ml) was refluxed for 70 hours. Complete dissolution was never achieved. After cooling more toluene was added (45 ml), the insoluble solid was rejected and the toluene solution was washed with aqueous sodium hydrogen carbonate and with water. The organic layer was dried and evaporated to afford 0.946 of an orange solid that upon column chromatography through silica gel with hexane-ethyl acetate mixtures afforded **6b** (0.212 g, 18%), 0.235 g of the starting diketone being also recovered. Compound **6b** has mp 173-174°; ir (potassium bromide): 1727, 1660; pmr (deuteriochloroform): 2.34 (s, 3H), 2.90 (s, 3H), 6.59 (s, 1H), 7.53 (m, 4H), 8.10 (m, 2H); cmr (deuteriochloroform): 19.5, 22.4, 106.4, 113.5, 121.6, 127.4, 128.6, 130.1, 137.8, 152.9, 156.2, 158.0, 161.5, 161.8; ms: (m/z) 251 (100), 236 (48), 180 (25).

Anal. Calcd. for $C_{16}H_{13}NO_2$: C, 76.49; H, 5.21; N, 5.57. Found: C, 75.99; H, 5.19; N, 5.41.

2,3,4,7-Tetramethyl-5-oxopyrano[4,3-*b*]pyridine (**6c**), (run 7, Table 2).

Compound **6c** was obtained as for **6b** under the conditions specified in Table 2. The residue after strongly evaporting the solvent was practically pure **6c** (0.486 g, 50%), mp 124-125° (diethyl ether); ir (potassium bromide): 1723, 1663 cm^{-1}; pmr deuteriochloroform): 2.29 (s, 3H), 2.32 (s, 3H), 2.63 (s, 3H), 2.81 (s, 3H), 6.39 (s, 1H); cmr (deuteriochloroform): 15.1, 17.1, 19.3, 24.4, 106.0, 113.1, 130.1, 149.6, 153.1, 156.9, 162.3, 163.1.

Anal. Calcd. for $C_{12}H_{13}NO_2$: C, 70.92; H, 6.45; N, 6.89. Found: C, 70.60; H, 6.27; N, 6.86.

7-Methyl-5-oxopyrano[4,3-*b*]pyridine (**6d**), (run 8, Table 2).

Product **6d** was obtained in 21% yield as for **6c** under the conditions specified in Table 2. Compound **6d** has mp 99-100° (diethyl ether); ir (potassium bromide): 1735, 1662 cm^{-1}; pmr (deuteriochloroform): 2.37 (s, 3H), 6.59 (s, 1H), 7.42 (dd, J = 7.6

and 4.9, 1H), 8.54 (dd, J = 7.6 and 1.7, 1H), 8.92 (broad d, J = 4.9, 1H); cmr (deuteriochloroform): 19.8, 105.8, 116.3, 122.5, 137.5, 155.0, 158.9, 162.4.

Anal. Calcd. for $C_9H_7NO_2$: C, 67.08; H, 4.38; N, 8.69. Found: C, 66.78; H, 4.32; N, 8.52.

2,7-Dimethyl-5-oxopyrano[4,3-*b*]pyridine (**6e**), (run 10, Table 2).

A mixture of 0.500 g (3.99 mmoles) of **2**, 0.528 g (3.99 mmoles) of 4,4-dimethoxy-2-butanone and acetic acid (25 ml) was heated at 100° for 20 hours (tlc monitoring). The solvent was evaporated and the black residue was digested with chloroform. The chloroform solution was evaporated to afford a residue that upon recrystallization gave 0.300 g (43%) of **6e**, mp 73-75°; pmr (deuteriochloroform): 2.39 (s, 3H), 2.73 (s, 3H), 6.59 (s, 1H), 7.29 (d, J = 7.6 Hz, 1H), 8.45 (d, J = 7.6 Hz, 1H); cmr (deuteriochloroform): 19.7, 25.1, 105.5, 113.6, 122.4, 137.2, 154.4, 158.6, 162.3, 166.0; ms: (m/z) 175 (M, 100), 160 (59), 104 (25).

4,7-Dimethyl-5-oxopyrano[4,3-*b*]-2-pyridone (**6f**), (run 11, Table 2).

Compound **6f** was prepared as for **6b** under the conditions specified in Table 2. The formed solid was filtered off and dissolved in chloroform. The chloroform solution was washed with aqueous sodium hydrogen carbonate and with water, dried and evaporated to afford 0.143 g (16%) of **6f**, mp 280° dec (dichloromethane/diethyl ether); ir (potassium bromide): 1740, 1673 cm^{-1}; pmr (deuteriochloroform): 2.31 (s, 3H), 2.65 (s, 3H), 6.27 (s, 1H), 6.37 (s, 1H); cmr (deuteriochloroform): 29.5, 32.0, 107.1, 108.8, 128.9, 160.2, 161.6, 169.4, 171.6, 172.5; ms: (m/z) 191 (M, 100), 176 (53), 120 (21), 43 (22).

Anal. Calcd. for $C_{10}H_9NO_3$: C, 62.83; H, 4.76; N, 7.34. Found: C, 62.99; H, 4.77; N, 7.30.

4-Amino-3-(1,2-bis(ethoxycarbonyl)hydrazino)-6-methyl-2*H*-pyran-2-one (**7**), (run 13 in Table 2).

A mixture of 0.400 g (3.20 mmoles) of **2**, 0.557 g (3.20 mmoles) of diethyl azodicarboxylate and toluene (15 ml) was heated in a closed reactor at 100° for 24 hours, then at 120° for 24 hours and finally for one day more at 140° (tlc monitoring). The solid formed was filtered and chromatographed through silica gel to afford **7** (0.369 g, 47% yield), mp 110-120° dec (dichloromethane/diethyl ether); ir (potassium bromide): 3380, 3355, 3264, 3210, 3180, 1733, 1684, 1640, cm^{-1}; pmr (deuteriochloroform): 1.25 (t, J = 7.0 Hz, 3H), 1.28 (t, J = 7.0 Hz, 3H), 2.17 (s, 3H), 4.20 (two q, J = 7.0 Hz, 4H), 5.68 (broad s, 1H), 6.0 (broad signal, 2H), 7.34 (broad s, 1H); cmr (deuteriochloroform): 14.2, 20.0, 62.4, 63.3, 99.4, 100.6, 156.4, 158.2, 161.9, 163.0; ms: (m/z) 299 (M, 33), 227 (26), 226 (100), 180 (44), 154 (42), 43 (42).

Anal. Calcd. for $C_{12}H_{17}N_3O_6$: C, 48.15; H, 5.74; N, 14.00. Found: C, 48.08; H, 5.83; N, 13.95.

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