Synthesis of the (*Z*) and (*E*) Isomers of 1,2-Diaryl-3-methyl-4,5-dioxo-3-pyrrolidinecarboxylic Acid Esters. Structural Assignment by NMR and Mass Spectroscopy

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Reaction of *N*-benzylideneaniline, **1a**, with 3-methyl-2-oxobutanedioic acid diethyl ester, **2a**, produced isomeric 3-methyl-4,5-dioxo-1,2-diphenyl-3-pyrrolidinecarboxylic acid ethyl esters, **3a** and **3b**. The higher melting isomer, **3a**, was shown to have the (*Z*) configuration by nmr spectroscopy. The (*Z*) and (*E*) isomers of 3-methyl-4,5-dioxo-1,2-diphenyl-3-pyrrolidinecarboxylic acid methyl esters, **3c** and **3d**, were prepared from **1a** and 3-methyl-2-oxobutanedioic acid dimethyl ester, **2b**. The higher melting isomer, **3c**, was shown to have the (*Z*) configuration. Similarly, *N*-benzylidene-*p*-toluidine, **1b**, reacted with **2a** to form (*Z*) and (*E*) isomers of 3-methyl-4,5-dioxo-1-(4-methylphenyl)-2-phenyl-3-pyrrolidinecarboxlic acid ethyl esters, **3e** and **3f**. Assignment of the ^{13}C carbonyl carbon nmr chemical shift was made by preparing 2-methyl-3-oxobutanedioic-1-^{13}C acid diethyl ester, **4**, and from it the corresponding (*Z*) and (*E*) isomers of 3-methyl-4,5-dioxo-1,2-diphenyl-3-pyrrolidinecarboxylic ^{13}C acid ester, **5a** and **5b**. The mass spectra of the (*Z*) isomers exhibit prominent ions corresponding to the masses of the Schiff bases used to make them, and ions corresponding to the loss of ArNCOCO from the parent ion. The (*E*) isomers **3b**, **3d** and **5b** exhibit a prominent ion of mass 264; **3f** gives mass 278, corresponding to the loss of the carboalkoxy group.

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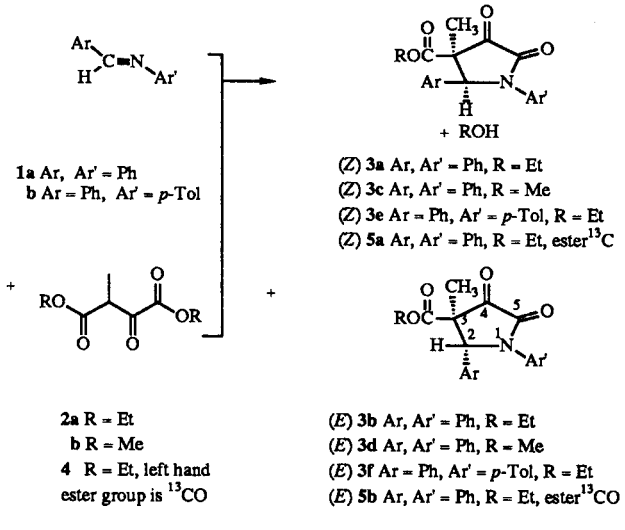
Vaughan and Covey reported [1] a reaction between *N*-benzylideneaniline, **1a**, and oxosuccinic esters, **2**, which has proved to have some generality and utility in synthesis [2]. The reaction was exemplified by the preparation of 3-methyl-4,5-dioxo-1,2-diphenyl-3-pyrrolidinecarboxylic acid ethyl ester, **3**, which was reported to exist in "dimorphic forms" [1] **3** (hm), melting at 165°, and **3** (lm), melting at 119°, where "hm" and "lm" refer to the high melting and low melting forms, respectively. The infrared spectra of chloroform solutions of the two "dimorphic" forms were reported to be identical [1].

Scheme 1



We prepared **3a-f** (Scheme 1) and found that two compounds were separable from each of the three reaction mixtures by thin layer chromatography and/or fractional crystallization. There were significant differences between the geometrical isomers in the high field proton magnetic resonance spectra. The higher melting isomer of each pair had a lower rf value by tlc. An examination of the table of proton nmr data reveals that the higher melting (low rf) isomers **3a**, **3c**, and **3e** have similar chemical shifts for the ring methyl and benzylic hydrogens. The lower melting (high rf) isomers **3b**, **3d** and **3f** likewise have similar chemical shifts for these hydrogens. The structural assignments for the (*Z*) and (*E*) isomers are based on their nmr spectra.

When the ring methyl group was irradiated, the nuclear Overhauser effect (nOe) [3] for the proton on ring position 2 was stronger for the higher melting isomers of **3** than it was for the lower melting isomers (*Z*) of each pair. This is consistent with the closer proximity of CH_3 and H in the (*Z*) isomers. Thus the high melting isomers have the (*Z*) configuration and the low melting isomers the (*E*). In addition the NMR signal of the methyl group at ring position 3 is shifted upfield by about 0.7 ppm in each of the (*E*) isomers relative to the (*Z*) isomers. This probably reflects the proximity of the CH_3 group to the shielding region of the phenyl group at ring position 2. The -OCH_3 proton signal of the **3c** isomer appear at 3.24 ppm, about 0.4 ppm upfield from the expected value for methyl esters again reflecting the position of this group in the shielding region of the phenyl group at ring position 2. These assignments are reinforced by a report that the OCH_3 signals of (*Z*) and (*E*) 2-phenyl-3-pyrrolidinecarboxylic acid methyl ester are observed at 3.20 δ and 3.67 δ, respectively [4]. While the CH_2 protons in both the (*Z*) and (*E*) isomers are diastereotopic, for two isomers, **3b** and **3f**, the CH_2 proton signal of

the ethyl group is a quartet which is to be expected with essentially unhindered rotation. However, the CH_2 signal of (*Z*) isomers **3a** and **3e** consists of four quartets. The CH_2 protons have significantly different chemical shifts and not only split each other but each signal is split by the adjacent CH_3 as well. The adjacent CH_3 signal is a normal triplet because the coupling constants of CH_3 with each of the CH_2 protons is the same. A somewhat similar example of an anisosynchronous methylene in a hindered ethyl ester has been reported before [5].

Space filling models of **3a** and **3e** reveals that rotation of the ethyl group about the CO bond is indeed quite hindered and the phenyl group is very close to the CH_2 protons. This causes the environments of the CH_2 protons to be different enough so that separate signals are observed. While the signals for the CH_2 protons move closer together at higher temperatures the signal does not collapse to a quartet even at 140°. The ir spectra of the compounds, **3**, displayed three distinct carbonyl bands in KBr disks but **3b, 3d, 3f,** and **5b** in the liquid phase and **3a** and **3b** in chloroform solution showed only two large carbonyl peaks at approximately 1773 and 1720 cm^{-1}. Compounds **3d** and **3f** showed a small shoulder at 1739 cm^{-1} and **3a** in chloroform solution had a small peak at 1747 cm^{-1}. The ir spectra of the compounds, **3**, displayed three distinct carbonyl bands in potassium bromide disks but only two in chloroform as previously reported [1]. Two 2,4-dinitrophenylhydrazones of **3c** were prepared and these derivatives lacked the high frequency (1779 cm^{-1}) band in the ir spectrum in KBR indicating that the high frequency band is the keto group and not the ester carbonyl.

Table

Proton NMR Data, δ

Structural Element

Compound	Aromatic	CH_3	Ring H	$-OCH_2-$	$-OCH_3$	$-OCH_2CH_3$
(*Z*)-**3a**	7.6-7.1 (m)	1.76	5.34	3.84, 3.69	–	0.95
(*E*)-**3b**	7.6-7.1 (m)	1.05	5.85	4.25	–	1.27
(*Z*)-**3c**	7.6-7.1 (m)	1.76	5.34	–	3.24	–
(*E*)-**3d**	7.6-7.1 (m)	1.06	5.84	–	3.82	–
(*Z*)-**3e**	7.5-7.1 (m)	1.75	5.30	3.76, 3.52	–	0.94
(*E*)-**3f**	7.5-7.1 (m)	1.04	5.84	4.25	–	1.27

Much was learned about the fragmentation patterns of the subject compounds by varying the aryl group on N, the alkyl group of the ester function and by labelling the ester carbonyl with ^{13}C. All of the (*Z*) isomers **3a, 3c, 3e** and **5a** which have the C-2 phenyl group and the C-3 carboalkoxy group on the same side of the pyrrolidine ring give prominent ions having the formula of the Schiff base, **1a** or **1b** which was used in the synthesis, *e.g.* m/z 181 for **3a, 3c,** and **5a** m/z 195 for **3e**. All of the (*E*) isomers, **3b, 3d, 3f** and **5b**, which have the C-2 hydrogen and the carboalkoxy group on the same side of the ring, exhibit prominent ions corresponding to the loss of the carboalkoxy group: m/z 264 in the cases of **3b, 3d** and **5b**, 278 in the case of **3f**. The (*Z*) isomers all display a prominent ion at a mass corresponding to the loss of ArNCOCO from the parent; thus **3a** and **3e** yield m/z 190, **5a** yields m/z 191, while **3c** yields m/z 176.

EXPERIMENTAL

The ir spectra were obtained neat, in potassium bromide disks, or as chloroform solutions on an Analect 6200 FTIR spectrometer. Mass spectra (70 eV) were determined using a Hewlett-Packard Model 5988 GC-MS system employing a 30 m x 0.32 mm DB-5 column. The nmr spectra were recorded on a Varian VXR-300 with TMS or deuteriochloroform as internal references. Microanalyses were performed by Desert Analytics of Tucson, AZ. All melting points are uncorrected.

Preparation of *N*-Phenylmethylenebenzenemine (**1a**).

A mixture of equimolar quantities of benzaldehyde and aniline in ethanol yielded the product [6].

Preparation of 4-Methyl-*N*-phenylmethylenebenzenamine (**1b**).

An equimolar mixture of benzaldehyde and *p*-toluidene yielded the product [7].

Preparation of 3-Methyl-2-oxobutanedioic Acid Diethyl Ester (**2a**).

To a mixture of ethyl propionate (10.2 g, 100 mmoles) and diethyl oxalate (14.6 g, 100 mmoles) in a mixture of ethyl ether and petroleum ether were added 2 ml of absolute ethanol and sodium hydride (4.4 g, 180 mmoles). The sidearm flask containing the mixture was stoppered and a drying tube containing Drierite and soda lime was attached to the sidearm. The mixture was shaken occasionally over a period of 48 hours. The reddish brown oil was filtered to remove a small quantity of solid residue and the resulting oil was then treated with an ice cold mixture of 3 ml concentrated sulfuric acid and 50 ml of water. The layers were separated and the acid layer was extracted with two portions of ethyl ether. The combined extract was extracted with dilute sodium bicarbonate followed by an extraction with concentrated brine. The extract was dried over anhydrous sodium sulfate and concentrated to 9.5 g on a rotary evaporator. A 4.0 g portion of the concentrate was subjected to a Kugelrohr distillation at <1 Torr. The yield of distillate boiling at 103-105° was 3.6 g. The compound has previously been prepared [8]; pmr (deuteriochloroform): δ 1.25 (3H, t, OCH_2CH_3, J = 7.2 Hz) 1.38 (3H, t, OCH_2CH_3, J = 7.2 Hz), 1.41 (3H, d, CH_3, J = 7.2 Hz), 4.11 (1H, q, CH, J = 7.2 Hz), 4.20 (2H, q, OCH_2, J = 7.2 Hz), 4.35 (2H, q, OCH_2, J = 7.2 Hz); cmr (deuteriochloroform): δ 11.60 (q, CH_3), 13.79 (q, OCH_2CH_3), 48.23 (d, CH), 61.40 (t, OCH_2), 62.55 (t, OCH_2), 160.16 (s, CO), 169.52 (s, CO), 189.56 (s, CO); ir (neat): 1755, 1734, 1657, 1456, 1369, 1303, 1253, 1203, 1121, 1093, 1046, 860 cm^{-1}; eims: (m/z) 202 (0.3), 129 (100), 102 (25), 101 (28), 74 (19), 73 (21), 57 (35), 56 (16).

Preparation of 3-Methyl-2-oxobutanedioic Acid Dimethyl Ester (**2b**).

To a mixture of methyl propionate (8.8 g, 100 mmoles) and dimethyl oxalate (11.8 g, 100 mmoles) in 30 ml of ether were added sodium hydride (4.25 g, 174 mmoles) 1 ml of absolute methanol and petroleum ether. The mixture, contained in a sidearm flask equipped with a Drierite-soda lime drying tube, was shaken occasionally over a period of 24 hours. The reaction mixture consisted of a liquid and a solid which were separated. The liquid was treated with 100 ml of 2*M* sulfuric acid whereupon an intractable emulsion formed which was extracted with four 25 ml portions of ether. The solid was treated with 2*M* sulfuric acid and extracted with ether. The ether extracts from both the liquid and the solid were combined, extracted with concentrated brine and dried over anhydrous sodium sulfate. The extract was concentrated and Kugelrohr distillation of the concentrate yielded 0.70 g of liquid bp 77-83°/.1 Torr, lit 110°/8 Torr [9]. It was shown to be of excellent purity by gc/ms analysis; pmr (deuteriochloroform): δ 1.41 (3H, d, CH_3, J = 7.2 Hz), 3.74 (3H, s, OCH_3), 3.91 (3H, s, OCH_3), 4.15 (1H, q, CH, J = 7.2 Hz); cmr (deuteriochloroform): δ 11.39 (q, CH_3), 48.00 (d, CH), 52.40 (q, OCH_3), 52.97 (q, OCH_3), 160.48 (s, CO), 170.09 (s, (CO), 188.92 (s, CO); ir (neat): 1736, 1665, 1440, 1308, 1258, 1214, 1122, 1085, 1048 cm^{-1}; eims: (m/z) 174 (0.3), 146 (12), 115 (93), 87 (23), 59 (100), 55 (11), 43 (13).

Preparation of (*Z*) and (*E*)-3-Methyl-4,5-dioxo-1,2-diphenyl-3-pyrrolidinecarboxylic Acid Ethyl Esters **3a** and **3b**.

To a pear shaped flask were added 3-methyl-2-oxobutanedioic acid diethyl ester, **2a**, (0.20 g, 1.0 mmole), *N*-phenylmethylenbenzeneamine, **1a**, (0.18 g, 1.0 mmole) and 5 ml of ethyl ether. The mixture was refluxed for 6 hours. After cooling a solid separated which was recrystallized from ethanol. The resulting product, **3a**, melted at 165-166°, lit [1] 165-166°; pmr (deuteriochloroform): δ 0.94 (3H, t, OCH_2CH_3, J = 7.2 Hz), 1.75 (3H, s, ring CH_3), 3.54 (1H, dq, OCH_2, J = 10.8, 7.2), 3.76 (1H, dq, OCH_2 J = 10.8, 7.2), 5.30 (1H, s, ring H), 7.1-7.6 (10H, m, Ph); cmr (deuteriochloroform): δ 13.48 (q, OCH_2CH_3), 19.81 (q, ring CH_3), 56.52 (s, ring H), 62.05 (t, OCH_2), 68.01 (d, ring CH), 122.04 (d, Ph), 126.88 (d, Ph), 127.22 (d, Ph), 128.66 (d, Ph), 129.03 (d, Ph), 133.91 (s, Ph), 136.49 (s, Ph), 157.96 (s, CO), 167.48 (s, CO), 196.07 (s, CO); ir (potassium bromide): 1779, 1720, 1694, 1596, 1496, 1456, 1369, 1311, 1261, 1177, 1019, 775, 741, 700, 688 cm^{-1}; ir (chloroform): 1773, 1720 cm^{-1}; eims: (m/z) 337 (36), 190 (100), 181 (89), 180 (41), 161 (25), 145 (55), 144 (40), 117 (73), 116 (95), 115 (74), 91 (40), 77 (77), 51 (24) **3b**. The ether filtrate was evaporated. The residue was dissolved in chloroform and subjected to preparative tlc on silica gel GF. Two bands which fluoresced under long wavelength uv light were observed. The faster migrating component was isolated yielding **3b**, mp 88-89° lit [1] 119-120°; pmr (deuteriochloroform): δ 1.04 (3H, s, ring CH_3), 1.27 (3H, t, OCH_2CH_3, J = 7.2 Hz), 4.25 (2H, q, OCH_2, J = 7.2 Hz), 5.84 (1H, s, ring H), 7.1-7.6 (10H, m, Ph); cmr (deuteriochloroform): δ 13.94 (q, OCH_2CH_3), 16.32 (q, ring CH_3), 63.19 (t, OCH_2), 66.38 (d, ring CH), 121.56 (d, Ph), 126.90 (d, broad, Ph), 127.04 (d, Ph), 129.16 (d, Ph), 129.37 (d, Ph), 135.42 (s, Ph), 137.37 (s, Ph), 157.85 (s, CO), 168.75 (s, CO), 195.50 (s, CO); ir (potassium bromide): 1776, 1739, 1710, 1596, 1501, 1459, 1406, 1306, 1245, 1166, 1114, 1009, 860, 752, 700 cm^{-1}; ir (chloroform); 1773, 1720 cm^{-1}; eims (m/z) 337 (15), 265 (20), 264 (100), 181 (32), 180 (32), 161 (15), 145 (30), 144 (17), 117 (56), 116 (69), 115 (65), 91 (37), 77 (66), 51 (21).

Preparation of (*Z*) and (*E*)-3-Methyl-4,5-dioxo-1,2-diphenyl-3-pyrrolidinecarboxylic Acid Methyl Esters **3c** and **3d**.

In an Erlenmeyer flask were placed 3-methyl-2-oxobutanedioic acid dimethyl ester, **2b**, (0.175 g, 1.0 mmole) and *N*-phenylmethylenebenzenamine, **1a**, (0.18 g, 1.0 mmole) and enough ether to form a solution. The flask was stoppered and allowed to stand for 3 days. The solid was filtered off, triturated with ether and filtered again yielding 0.080 g of **3c** which was chromatographically pure and melted at 194-195°; pmr (deuteriochloroform): δ 1.76 (3H, s, ring CH_3), 3.24 (3H, s, OCH_3), 5.34, (1H, s, ring H), 7.1-7.6 (10H, m, Ph); cmr (deuteriochloroform): δ 19.69 (q, ring CH_3), 52.43 (q, OCH_3), 56.54 (s, ring C), 68.01 (d, ring CH), 122.04 (d, Ph), 126.94 (d, Ph), 127.06 (d, Ph), 128.72 (d, Ph), 129.05 (d, Ph), 133.84 (s, Ph), 136.42 (s, Ph), 157.90 (s, CO), 167.82 (s, CO), 195.88 (s, CO); ir (potassium bromide): 1779, 1747, 1710, 1498, 1456, 1374, 1308, 1237, 1208, 1106, 1024, 780, 752, 739, 688 cm^{-1}; eims: (m/z) 323 (30), 181 (51), 180 (23), 176 (75), 145 (24), 144 (25), 117 (50), 116 (100), 115 (63), 91 (38), 77 (68), 51 (21).

Anal. Calcd. for $C_{19}H_{17}NO_4$: C, 70.57; H, 5.29; N, 4.33. Found: C, 70.58; H, 5.25; N, 4.28.

The filtrate was evaporated leaving a 0.16 g of a yellow solid which was dissolved in a hot mixture of benzene and hexane, treated with Norit pellets and filtered. On addition of more hexane and cooling, the solution yielded 0.061 g of solid which was subjected to preparative tlc on silica gel GF using chloroform. The yellow fluorescing faster moving compound, **3d**, was isolated, mp 114-116°; pmr (deuteriochloroform): δ 1.06 (3H, s, ring CH_3), 3.82 (3H, s, OCH_3), 5.89 (1H, s, ring H), 7.1-7.7 (10H, m, Ph); cmr: δ 16.57 (q, ring CH_3), 54.00 (q, OCH_3), 57.32 (s, ring C), 66.29 (d, ring CH), 121.55 (d, Ph), 126.90 (d, broad, Ph), 127.07 (d, Ph), 129.19 (d, Ph), 129.42 (d, Ph), 135.36 (s, Ph), 137.34 (s, Ph), 157.71 (s, CO), 169.40 (s, CO), 195.28 (s, CO); ir (potassium bromide): 1776, 1747, 1710, 1596, 1501, 1456, 1398, 1311, 1242, 1175, 1169, 1121, 1014, 756, 700, 688 cm^{-1}; eims: (m/z) 323 (22), 264 (86), 181 (34), 180 (34), 176 (26), 145 (20), 117 (49), 116 (100), 115 (67), 91 (41), 77 (69), 51 (22).

Anal. Calcd. for $C_{19}H_{17}NO_4$: C, 70.57; H, 5.29; N, 4.33. Found: C, 70.52; H, 5.38; N, 4.14.

Preparation of (*Z*) and (*E*)-3-Methyl-4,5-dioxo-1-(4-methylphenyl)-2-phenyl-3-pyrrolidinecarboxylic Acid Ethyl Esters **3e** and **3f**.

In a test tube were placed 3-methyl-2-oxobutanedioic acid diethyl ester, **2a**, (0.1 g, 0.5 mmole) and 4-methyl-*N*-phenylmethylenebenzenamine, **1b**, (0.1 g, 0.5 mmole). The tube was heated briefly at 190°. The reaction also occurred at 100° or in ether. A portion of the reaction mixture was subjected to preparative tlc on silica gel GF with double development using chloroform. The slower moving component, **3e**, melted at 174-175°; pmr (deuteriochloroform): δ 0.94 (3H, t, OCH_2CH_3, J = 7.2 Hz), 1.75 (3H, s, ring CH_3), 2.28 (3H, s, $ArCH_3$), 3.54 1H, dq, OCH_2, J = 10.8, 7.2), 3.77 (1H, dq, OCH_2, J = 10.8, 7.2), 5.30 (1H, s, ring CH), 7.1-7.5 (9H, m, *p*-Tol, Ph); cmr (deuteriochloroform): δ 13.32 (q, OCH_2CH_3), 19.58 (q, ring CH_3), 20.84 (q, $ArCH_3$), 56.35 (s, ring C), 61.82 (t, OCH_2), 67.69 (d, ring CH), 121.68 (d, Ph), 121.92 (d, Ph), 127.12 (d, Ph), 128.42 (d, Ph), 128.47 (d, Ph), 128.74 (d, Ph), 129.42 (d, Ph), 133.79 (s, Ph), 133.87 (s, Ph), 136.64 (s, Ph), 157.80 (s, CO), 167.42 (s, CO), 196.12 (s, CO); ir (potassium bromide): 1782, 1744, 1707, 1514, 1456, 1374, 1353, 1308, 1237, 1200, 1103, 1027, 1006, 818, 767, 749, 705 cm^{-1}; eims: (m/z): 351 (76), 195 (100), 190 (73), 145 (42), 117 (52), 116 (70), 115 (49), 91 (54).

Anal. Calcd. for $C_{21}H_{21}NO_4$: C, 71.78; H, 6.02; N, 3.99. Found: C, 71.87; H, 6.03; N, 3.95.

The faster moving component, **3f**, had mp 94-95° pmr (deuteriochloroform): δ 1.04 (3H, t, OCH_2CH_3, J = 7.2 Hz), 1.27 (3H, s, ring CH_3), 2.28 (3H, s, $ArCH_3$), 4.25 (2H, q, OCH_2, J = 7.2 Hz), 5.84 (1H, s, ring H), 7.1-7.5 (9H, m, Tol, Ph); cmr (deuteriochloroform): δ 13.93 (q, ring CH_3), 16.30 (q, OCH_2CH_3), 20.93 (q, $ArCH_3$), 57.23 (s, ring C), 63.12 (t, OCH_2), 66.42 (d, ring CH), 121.48 (d, Ph), 126.89 (d, broad, Ph), 129.08 (d, Ph), 129.31 (d, Ph), 129.66 (d, Ph), 134.80 (s, Ph), 135.46 (s, Ph), 137.04 (s, Ph), 157.84 (s, CO), 168.72 (s, CO), 195.60 (s, CO); ir (potassium bromide): 1766, 1733, 1707, 1517, 1459, 1396, 1308, 1235, 1143, 1108, 1006, 873, 821, 785, 764, 708 cm^{-1}; eims: (m/z) 351 (27), 278 (100), 195 (29), 117 (28), 116 (35), 115 (32), 91 (33).

Anal. Calcd. for $C_{21}H_{21}NO_4$: C, 71.78; H, 6.02; N, 3.99. Found: C, 71.51; H, 6.09; N, 4.04.

Preparation of 2,4-Dinitrophenylhydrazones of **3c**.

A 5.0 mg quantity of **3c** was dissolved in 0.5 ml of methanol and added to a solution of 40 mg of 2,4-dinitrophenylhydrazine in 0.2 ml of sulfuric acid, 0.03 ml of water and 0.1 ml of methanol. Yellow crystals formed on standing and were purified by preparative tlc. The majority of the product was a yellow, low rf component with a mp 208-209°; ir (potassium bromide): 1726, 1697 cm^{-1}; a small amount of a higher rf yellow material melted at 249-250°; ir (potassium bromide): 1739, 1686 cm^{-1}.

Preparation of Propanoic-1-^{13}C Acid Ethyl Ester [10,11].

To 1.00 g of dried propanoic-1-^{13}C acid sodium salt (Aldrich 99 atom % ^{13}C) (1.03 mmoles) was added 10 ml of triethyl phosphate. The mixture was refluxed for 3.5 hours then allowed to cool and stand overnight. A trap cooled in liquid nitrogen was attached to the reflux condenser and the system was evacuated. The product was obtained in 97% yield; pmr (deuteriochloroform): δ 1.14 (3H, dt, CH_3CH_2CO, J = 7.5, 5.4 Hz), 1.26 (3H, t, OCH_2CH_3, J = 7.2 Hz), 2.32 (2H, q, CH_3CH_2CO, J = 7.5 Hz), 4.13 (2H, dq, OCH_2CH_3, J = 7.2, 3.0 Hz); ir (neat): 1699, 1464, 1345, 1177, 1085, 1035 cm^{-1}.

2-Methyl-3-oxo-butanedioic-1-^{13}C Acid Diethyl Ester, (**4**).

To 1.03 g (10.0 mmoles) of ethyl propionate-1-^{13}C and 1.46 g (10.0 mmoles) of diethyl oxalate in 11 ml of ether was added 1.0 ml of absolute ethanol and, in portions, 0.54 g of sodium hydride, 50% in mineral oil (11.2 mmoles). The flask was connected to a drying tube and allowed to stand at room temperature for 4½ days. Ether was added to the solidified mixture and the solid was broken up and filtered off. To the solid was added 2*M* sulfuric acid and the mixture was extracted with three portions of ether. The ether extract was dried over anhydrous sodium sulfate and the ether was removed. The residue was subjected to a Kugelrohr distillation at < 1 Torr. The material boiling at an oven temperature of 95 to 100° was shown to be pure by gc-ms analysis, yield, 0.94 g, 46%; pmr (deuteriochloroform): J ^{13}CCH = 3.3 Hz, J ^{13}CCCH$_3$ = 5.1 Hz; cmr (deuteriochloroform): δ 169.77 (s, CO (keto)), 173.50 (s, CO (enol)); ir (neat): 1736, 1705, 1636, 1456, 1369, 1248, 1200, 1048 cm^{-1}; eims: (m/z) 203 (0.2), 130 (100), 103 (22), 102 (16), 101 (10), 75 (16), 74 (10), 73 (9), 58 (12), 57 (21), 56 (9). The ether filtrate was shaken with 2*M* sulfuric acid, dried and distilled after removal of the ether. The product, boiling at 70 to 100° contained less pure **4** and weighed 0.74 g.

Preparation of (*Z*) and (*E*)-3-Methyl-4,5-dioxo-1,2-diphenyl-3-pyrrolidinecarboxylic-^{13}C Acid Ethyl Ester, **5a** and **5b**.

In a 25 ml Erlenmeyer flask were placed 0.23 g of the less pure fraction of **4**, 0.18 g (1.0 mmole) of *N*-phenylmethylenebenzenamine, and 6 ml of ether. After 24 hours an additional 0.10 g of the less pure fraction of **4** was added. After 2 days the mixture was chilled and filtered. The solid was recrystallized from absolute alcohol yielding 17 mg of **5a**, mp 163.5-164.5°; pmr (deuteriochloroform): J ^{13}CCCH$_3$ = 6.3 Hz, J ^{13}CCCH = 2.7 Hz; cmr (deuteriochloroform): δ 167.44 (s, ester CO); eims: (m/z) 338 (53), 191 (100), 181 (87), 180 (45), 146 (36), 145 (54), 117 (72), 116 (94), 115 (77), 91 (39), 77 (67). Additional **5a** was obtained by evaporating the filtrate and recrystallizing the solid from cyclohexane and absolute alcohol. The filtrate was evaporated to dryness, taken up in chloroform and some of it was subjected to preparative tlc on silica gel GF using chloroform. The high rf band yielded **5b**; pmr (deuteriochloroform): J ^{13}CCCH$_3$ = 6.3 Hz, J ^{13}CCCH = 2.7 Hz; cmr (deuteriochloroform): δ 168.84 (s, ester CO); eims: (m/z) 338 (14), 265 (18), 264 (100), 181 (20), 145 (16), 117 (30), 116 (38), 115 (40), 91 (21), 77 (29).

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