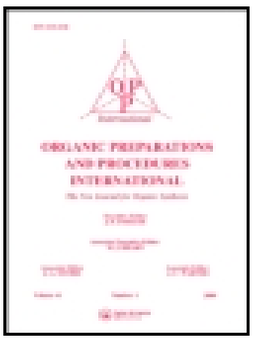

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A NOVEL METHOD FOR THE SYNTHESIS OF 4*H*-PYRAN-4-ONE DERIVATIVES

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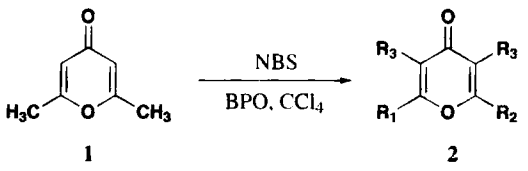
4*H*-Pyran-4-ones are heterocycles with useful biological properties.[1] These compounds are valuable as fungicides, herbicides and in the treatment of hypersensitivity conditions, such as asthma and allergies.[2] Functionalized heterocycles are often used for the synthesis of the target organic compounds. The synthesis of 2-bromomethyl-6-methyl-4*H*-pyran-4-one (**2b**) was reported by Buu-Hoi[3] and Yamamoto[4] in low yields. Both of these groups were only able to document the formation of the compound and the published data on this method is very misleading. Bromination of 2,6-dimethyl-4*H*-pyran-4-one (**1**) with two equivalents of N-bromosuccinimide in the presence of dibenzoyl peroxide in tetrachloromethane led to six brominated compounds **2a-f**, in very small yields and after a very tedious and long acquisition time (*Scheme 1*).[5]

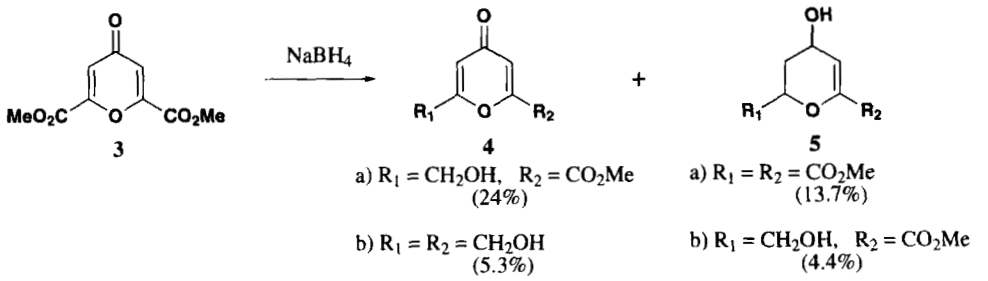


1 2

Compound	R_1	R_2	R_3	Yield (%)
a)	CH_2Br	CH_2Br	H	3.2
b)	CH_3	CH_2Br	H	6.7
c)	CH_3	$CHBr_2$	H	10.0
d)	CH_2Br	$CHBr_2$	H	3.1
e)	$CHBr_2$	$CHBr_2$	H	3.4
f)	$CHBr_2$	$CHBr_2$	Br	0.3

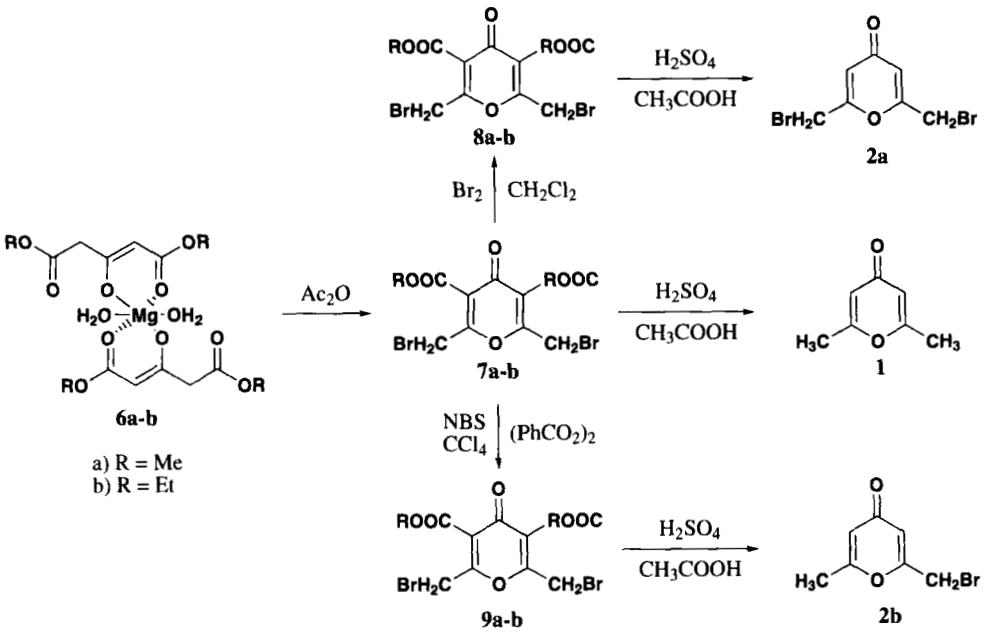
Scheme 1

The bromomethyl function could also be obtained from the appropriate primary alcohol group by reaction with hydrogen bromide. 2,6-*bis*(Hydroxymethyl)-4*H*-pyran-4-one (**4b**) has been synthesized by sodium borohydride reduction of dimethyl chelidonate (**3**),[6] albeit in poor yield and after a difficult separation process (*Scheme 2*). Although some of the 4*H*-pyran-4-ones containing a hydroxymethyl group can be prepared by fermentation[7], e.g. of kojic acid, chemical preparations in high yield have not been reported. This paper reports a novel method for the synthesis of bromomethyl, acetoxymethyl and hydroxymethyl derivatives of 4*H*-pyran-4-one substituted at positions 2 and 6.



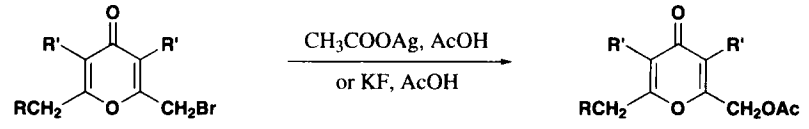
Scheme 2

In view of the low reactivity of **1** toward bromination, we were compelled to search for a compound which was not only more reactive toward bromination but which also could be easily converted to derivatives of **1**. The magnesium dimethyl acetonedicarboxylate chelate complex (**6a**) was prepared by treatment of dimethyl acetonedicarboxylate with $MgCl_2$ in the presence of aqueous ammonia in 83% yield, according to the method described by Yamato for the ethyl ester derivative **6b**.[8] Compound **6a** is a complex with a coordination number of six, which incorporates two molecules of water (elemental analysis and ^1H NMR spectrum). 2,6-Dimethyl-4-oxo-4*H*-pyran-3,5-dicarboxylic acid dimethyl ester (**7a**) was obtained in 59% yield by treatment of **6a** with acetic anhydride according to the procedure described for the diethyl ester derivative **7b**.[9] Hydrolysis of compounds **7a** or **7b** in the presence of sulfuric acid and acetic acid produced **1** in 85 and 88% yields, respectively (*Scheme 3*). 2,6-*bis*(Bromomethyl)-4-oxo-4*H*-pyran-3,5-dicarboxylic acid diethylester (**8b**) was first prepared in 1991 by Flitsch through bromination of **7b** with bromine.[10] We prepared the corresponding



Scheme 3

dimethyl ester derivative **8a** in 74% yield similarly. Acidic hydrolysis of **8a** or **8b** produced 2,6-*bis*(bromomethyl)-4*H*-pyran-4-one (**2a**) in 59 and 61% yields, respectively (*Scheme 3*). As a result we attempted to synthesize 2-bromomethyl-6-methyl-4-oxo-4*H*-pyran-3,5-dicarboxylic acid diester (**9a-b**) by means of Wohl-Ziegler bromination.[11] Bromination was performed by reaction of **7a** with 1.25 equivalent of N-bromosuccinimide in the presence of dibenzoyl peroxide in tetrachloromethane at 50° and purified by column chromatography. The first fraction was **9a** in 43% yield and the second fraction was 41% of unreacted **7a**. Bromination of **7b** under similar conditions yielded **9b** in 55% yield as the first fraction and 36% of unreacted **7b** recovered by chromatography. Acidic hydrolysis of **9a** or **9b** similarly produced **2b** in 73 and 79% yields, respectively (*Scheme 3*).

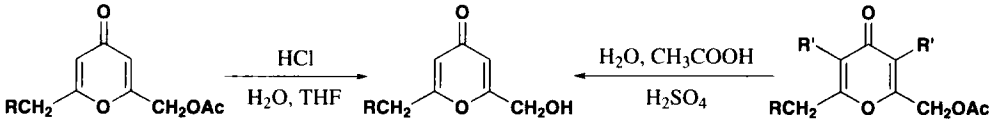


2a) R = Br, R' = H
2b) R = R' = H
8a) R = Br, R' = COOMe
8b) R = Br, R' = COOEt
9a) R = H, R' = COOMe
9b) R = H, R' = COOEt

a) R = OAc, R' = H
b) R = R' = H
c) R = OAc, R' = COOMe
d) R = OAc, R' = COOEt
e) R = H, R' = COOMe
f) R = H, R' = COOEt

Scheme 4

It is often necessary in organic synthesis to convert alcohols into alkyl halides, but only occasionally is it necessary to achieve the reverse conversion, *i. e.* the hydrolysis of alkyl halides. As a consequence relatively few reagents have been developed for this purpose.[12] The more reactive alkyl halides, *i. e.* tertiary, benzyl and allyl halides can be hydrolysed easily by water in various solvents[12] or by aqueous bicarbonate.[13] However, the hydrolysis of primary alkyl halides is more difficult and has usually been achieved using alkali metal hydroxides,[12] though in a few simple cases it has been shown that water in N-methylpyrrolidone or hexamethylphosphoramide can achieve hydrolysis.[14] However, 4*H*-pyran-4-one ring is unstable under basic conditions, therefore, direct substitution of the halide by a hydroxy group is not possible. We attempted to convert bromomethyl groups smoothly to hydroxymethyl groups under conditions that would not open the ring of 4*H*-pyran-4-one molecule. Thus, treatment of the bromomethyl derivatives **2a, 2b, 8a, 8b, 9a** or **9b** with silver acetate in glacial



10a) R = OAc
10b) R = H

4b) R = OH
11) R = H

10c) R = OAc, R' = COOMe
10d) R = OAc, R' = COOEt
10e) R = H, R' = COOMe
10f) R = H, R' = COOEt

Scheme 5

acetic acid produced the corresponding acetoxymethyl derivatives **10a-f** respectively (*Scheme 4*).[15] Yields of these reactions ranged from 78 to 89%. We also obtained these conversions by potassium fluoride in acetic acid[16] in 42 to 59% yields.

Mild acidic hydrolysis of **10a** and **10b** produced **4b** and **11** in 92 and 95% yields, respectively (*Scheme 5*). Under vigorous acidic condition **10c** or **10d** converted to **4b** in 18 and 16% yields, respectively. Similarly **10e** or **10f** converted to **11** in 22 and 27% yields, respectively (*Scheme 5*).

The data obtained from Mass, IR, ^{1}H and ^{13}C NMR spectra and elemental analyses are fully consistent with the proposed structures.

EXPERIMENTAL SECTION

Melting points were determined with an Electrothermal Instrument model 9100 and are uncorrected. Infrared (FT-IR) spectra were run on a Shimadzu 8010M Spectrophotometer as KBr disks or as smears between salt plates. The ^{1}H NMR spectra were recorded on a Varian-EM 390 spectrometer. The ^{13}C NMR spectra were determined on an FT-NMR Brucker 80 MHz spectrometer. Chemical shifts were reported in values in ppm with TMS as internal standard. Mass spectra were taken with a Shimadzu MS-QP 1100EX mass spectrometer. Elemental analyses were performed on a Heareus, CHN-O-RAPID analyzer. Starting materials were purchased from commercial sources.

Magnesium Dimethyl Acetonedicarboxylate Complex (6a).- To a mixture of 300 mL of water, 19.1 g (0.2 mole) of $MgCl_2$ and 34.8 mL (0.2 mole) of dimethyl acetonedicarboxylate cooled to 0°, was slowly added aqueous ammonia (10%) with stirring till the precipitate was formed at pH 9-10. After stirring for an hour, the precipitate was collected, washed several times with water and recrystallized from MeOH to give **6a** (33.7 g, 83%) as a white solid, mp. 79-81°. IR (KBr): 3520, 3170, 2950, 1713, 1640, 1525 and 1245 cm^{-1}. ^{1}H NMR ($CDCl_3$): δ 2.22 (broad singlet, 4H, $\mathbf{H_2O}$), 3.11 (s, 4H, -$\mathbf{CH_2}$COO-), 3.54 -3.69 (m, 12H, -COO$\mathbf{CH_3}$), 4.75 (s, 2H, -$\mathbf{CH}$=C).

Anal. Calcd. for $C_{14}H_{22}MgO_{12}$: C, 41.35; H, 5.45. Found: C, 41.20; H, 5.40

Magnesium Diethyl Acetonedicarboxylate Complex (6b).- This compound was synthesized according to the literature[8] with modification (using 10% aqueous ammonia under ice cooling and recrystalization of product from EtOH) in 87% yield as a white solid, mp. 71°, lit[8] 72°. IR (KBr): 3530, 3170, 2960, 1710, 1640, 1520 and 1242 cm^{-1}. ^{1}H NMR ($CDCl_3$): δ 1.1-1.35 (m, 12H, -$\mathbf{CH_3}$), 2.30 (broad singlet, 4H, $\mathbf{H_2O}$), 3.11 (s, 4H, -$\mathbf{CH_2}$COO-), 3.9-4.3 (m, 8H, -$\mathbf{CH_2}$CH$_3$), 4.78 (s, 2H, -$\mathbf{CH}$=C).

2,6-Dimethyl-4-oxo-4*H*-pyran-3,5-dicarboxylic Acid Dimethyl Ester (7a).- A solution of 32.5 g (0.08 mole) of **6a** in 40 mL acetic anhydride was heated 15 minutes at 100°. The reaction mixture was concentrated to one-third of volume under reduced pressure, made basic with saturated $KHCO_3$ solution, and extracted with 3x40 mL of EtOAc. The EtOAc layer was washed with 3x25 mL of water, dried over $MgSO_4$ and concentrated *in vacuo*. The residue, after cooling in the refrigerator, was filtered and recrystallized from CH_2Cl_2-cyclohexane to give **7a** (22.7g, 59%) as white crystals, mp. 88-90°. IR (KBr): 2940, 1742, 1718, 1648, 1613, 1425, 1395 and 1250 cm^{-1}. ^{1}H NMR ($CDCl_3$): δ 2.27

(s, 6H, -CH_3), 3.70 (s, 6H,-OCH_3). ^{13}C NMR ($CDCl_3$): δ 15.0 (-CH_3), 55.0 (-OCH_3), 122.5 (pyran-C-3,-5), 157.5 (pyran-C-2,-6),162.0 (-$COOCH_3$), 171.5 (pyran-C-4). MS (EI, 70eV): 240 (M^+).

Anal. Calcd. for $C_{11}H_{12}O_6$: C, 55.00; H, 5.04. Found: C, 54.90; H, 5.10

2,6-Dimethyl-4-oxo-4*H*-pyran-3,5-dicarboxylic Acid Diethyl Ester (7b).- This compound was synthesized according to literature[9] with a little modification (after heating, the reaction mixture was concentrated to one-third of volume under reduced pressure) in 65% yield as colorless crystals, mp. 80°, *lit.*[9] 79°. IR (KBr): 2950, 1740, 1715, 1650, 1615, 1410 and 1254 cm^{-1}. ^1H NMR ($CDCl_3$): δ 1.30 (t, 6H, *J* =7 Hz, CH_2CH_3), 2.32 (s, 6H, -CH_3), 4.32 (q, 4H, *J*=7 Hz, -CH_2CH_3).

2,6-*bis*(Bromomethyl)-4*H*-pyran-3,5-dicarboxylic Acid Dimethyl Ester (8a).- To a refluxing solution of 10.8 g (0.045 mole) of **7a** in 350 mL CH_2Cl_2 was added slowly with stirring a solution of 14.55 g (0.091 mole) Br_2 in 150 mL CH_2Cl_2 over 2 hrs and stirring was continued for another 1.5 hrs. The solution was then washed with saturated $NaHCO_3$ solution and dried over $MgSO_4$. The solvent was removed by distillation and the residue was recrystallized from $CHCl_3$-heptane to give **8a** (13.25 g, 74%) as a white solid, mp. 131-133°. IR (KBr): 2995, 1735, 1645, 1390, 1260, 1100 and 1040 cm^{-1}. ^1H NMR ($CDCl_3$): δ 3.65 (s, 6H, -OCH_3), 4.25 (s, 4H, -CH_2Br). ^{13}C NMR ($CDCl_3$): δ 26.0 (-CH_2Br), 55.0 (-OCH_3), 124.0 (pyran-C-3,-5), 159.0 (pyran-C-2,-6), 162.0 (-$COOCH_3$), 172.0 (pyran-C-4). MS (EI, 70 eV): 400/398/396 (M^+).

Anal. Calcd. for $C_{11}H_{10}Br_2O_6$: C, 33.20; H, 2.53. Found: C, 33.0; H, 2.60

2,6-*bis*(Bromomethyl)-4*H*-pyran-3,5-dicarboxylic Acid Diethyl Ester (8b).- This compound was synthesized according to the literature,[10] in 77% yield as a white solid, mp. 122°, *lit.*[10] 124°. IR (KBr): 3050, 2990, 1735, 1665, 1640, 1400, 1260, 1090 and 1040 cm^{-1}. ^1H NMR ($CDCl_3$): δ 1.30 (t, 6H, *J*=7 Hz, CH_2CH_3), 4.30 (s, 4H, -CH_2Br), 4.40 (q, 4H, *J*=7Hz, -CH_2CH_3).

2-Bromomethyl-6-methyl-4-oxo-4*H*-pyran-3,5-dicarboxylic Acid Dimethyl Ester (9a).- A mixture of 10.8 g (0.045 mole) of **7a**, 10 g (0.056 mole, 1.25 equivalent) of N-bromosuccinimide, 1g of dibenzoyl peroxide and 400mL of tetrachloromethane was heated at 50° for 20 hrs. The reaction mixture was concentrated under reduced pressure and 200 mL CH_2Cl_2 was added to the residue. The mixture was filtered and the filtrate washed with saturated sodium carbonate solution and with water and dried over $MgSO_4$. The solvent was removed by distillation and the residual oil was purified by column chromatography on silica gel using ethylacetate - petrolium ether (1:3) as eluent to give **9a** (6.17 g, 43%) as pale brown crystals, mp. 133.6-135.2°. IR(KBr): 2995, 1740, 1660, 1420, 1270, 1170 and 1100 cm^{-1}. ^1H NMR ($CDCl_3$): δ 2.30 (s, 3H, -CH_3), 3.70 (s, 6H, -OCH_3), 4.30 (s, 2H, -CH_2Br). ^{13}C NMR ($CDCl_3$): δ 15.0 (-CH_3), 25.0 (-CH_2Br), 53.0 (-OCH_3), 120.0 (pyran-C-5), 125.0 (pyran-C-3), 157.0 (pyran-C-6), 160.0 (pyran-C-2), 163.0 (-$COOCH_3$), 172.0 (pyran-C-4). MS (EI, 70ev): 320/318 (M^+).

Anal. Calcd. for $C_{11}H_{11}BrO_6$: C, 41.40; H, 3.47. Found: C, 41.60; H, 3.60

Compound **7a** (4.43 g, 41%) was recovered as second fraction.

2-Bromomethyl-6-methyl-4-oxo-4*H*-pyran-3,5-dicarboxylic Acid Diethyl Ester (9b).- Prepared as above from 12.1 g (0.045 mole) of **7b**. The oil was purified by column chromatography on silica gel

using ethyl acetate-petroleum ether (1.5:8.5) as eluent to give **9b** (8.59 g, 55%) as pale brown crystals, mp. 121.4 - 122.3°. IR (KBr): 2985, 1738, 1662, 1415, 1269, 1169 and 1100 cm^{-1}. ^1H NMR ($CDCl_3$): δ 1.30 (t, 6H, *J*=7.5 Hz, -CH_2**CH_3**), 2.40 (s, 3H, -**CH_3**), 4.30 (s, 2H, -**CH_2**Br), 4.40 (q, 4H, *J*=7.5 Hz, -**CH_2**CH_3). ^{13}C NMR ($CDCl_3$): δ 13.2 (-CH_2**CH_3**), 15.0 (-**CH_3**), 24.0 (-**CH_2**Br), 60.0 (-COO**CH_2**-), 122.0 (pyran-**C**-5), 125.0 (pyran-**C**-3), 157.0 (pyran-**C**-6), 160.0 (pyran-**C**-2), 162.0 (-COOCH_2-), 171.0 (pyran-**C**-4). MS (EI, 70 eV): 348/346 (M^+).

Anal. calcd. for $C_{13}H_{15}BrO_6$: C, 44.98; H, 4.36. Found: C, 45.10; H, 4.20

Compound **7b** (4.34 g, 36%) was recovered as second fraction.

General Procedure for the Synthesis of 1, 2a, 2b.- A mixture of 0.01 mole of **7-9**, 20 mL acetic acid, 20 mL water and 5 mL concentrated H_2SO_4 was refluxed for 5hrs. The mixture was neutralized with aqueous sodium hydroxide (40%) to pH 4-5 under cooling. The mixture was filtered, and the filtrate adjusted to pH 7-8 by addition of sodium carbonate. The mixture was concentrated to one-third volume under reduced pressure and extracted with 5x30 mL CH_2Cl_2 and the combined organic layer washed with 4x20 mL H_2O and dried over $MgSO_4$. The solvent was removed by distillation and the remaining solid was recrystallized from EtOH to yield pure product. Specific details are given for each compound.

2,6-Dimethyl-4*H*-pyran-4-one (1).- a) From 2.4 g of **7a**, 1.05 g (85%) of white crystals were obtained, mp. 132°, *lit.*[4] 131°. IR (KBr): 3050, 1660, 1600 and 1390 cm^{-1}. ^1H NMR ($CDCl_3$): δ 2.20 (s, 6H, -**CH_3**), 6.0 (s, 2H, pyran-C**H**-3,-5); b) From 2.68 g of **7b**, 1.09 g (88%) of white crystals with similar physical and spectral properties were obtained.

2,6-*bis*(Bromomethyl)-4*H*-pyran-4-one (2a).- a) From 3.98 g of **8a**, 1.66 g (59%) of pale brown crystals were obtained, mp. 91°, *lit.*[5] 91°. IR (KBr): 3010, 1660, 1605 and 1394 cm^{-1}. ^1H NMR ($CDCl_3$): δ 4.19 (s, 4H, -**CH_2**Br), 6.36 (s, 2H, pyran-C**H**-3,-5); b) From 4.26 g of **8b**, 1.72 g (61%) of pale brown crystals with similar physical and spectral properties were obtained.

2-Bromomethyl-6-methyl-4*H*-pyran-4-one (2b).- a) From 3.19 g of **9a**, 1.48 g (73%) of beige crystals were obtained, mp. 108°, *lit.*[5] 107°. IR (KBr): 3030, 1665, 1600 and 1390 cm^{-1}. ^1H NMR ($CDCl_3$): δ 2.65 (s, 3H, -**CH_3**), 4.20 (s, 2H, -**CH_2**Br), 6.30 (s, 2H, pyran-C**H**-3,-5); b) From 3.47 g of **9b**, 1.56 g (77%) of beige crystals with similar physical and spectral properties were obtained.

General Procedure for Acetoxylation of 2a, 2b, 8a, 8b, 9a and 9b.- A mixture of 5.0 mmoles of bromomethyl derivatives, **2b**, **9a** or **9b**, or 2.5 mmoles of *bis*(bromomethyl) derivatives, **2a**, **8a** or **8b**, 0.92 g (5.5 mmole) silver acetate and 15 mL glacial acetic acid was refluxed for 4hrs. The mixture was filtered and 50 mL of water was added to the filtrate and the mixture was extracted with 3x15 mL CH_2Cl_2. The combined organic layer was washed with 3x10 mL of H_2O, dried over $MgSO_4$ and the solvent was removed by distillation. Specific details are given for each compound.

2, 6-*bis*(Acetoxymethyl)-4*H*-pyran-4-one (10a).- From 0.71 g of **2a**, 0.52 g (86%) of a yellow oil was obtained. IR (KBr): 2946, 1754, 1677, 1415, 1230, 1046 and 931 cm^{-1}. ^1H NMR ($CDCl_3$): δ 2.09 (s, 6H, -OOCC**H_3**), 4.84 (s, 4H, -**CH_2**OOC-), 6.25 (s, 2H, pyran-C**H**-3,-5). ^{13}C NMR ($CDCl_3$): δ 20.0 (-OOC**CH_3**), 60.7 (-**CH_2**OOC-), 113.9 (pyran-**C**-3,-5), 162.2 (pyran-**C**-2,-6), 169.4 (-OO**C**CH_3),

178.6 (pyran-**C**-4). MS (EI, 70eV): 240 (M^+).

Anal. Calcd. for $C_{11}H_{12}O_6$: C, 55.0; H, 5.04. Found: C, 54.70; H, 5.20

2-Acetoxymethyl-6-methyl-4*H*-pyran-4-one (10b).- From 1.02 g of **2b**, 0.81 g (89%) of a yellow oil was obtained. IR (KBr): 2931, 1754, 1677, 1631, 1400, 1231, 1038 and 931 cm^{-1}. ^1H NMR ($CDCl_3$): δ 2.0 (s, 3H, -OOCC**H**$_3$), 2.13 (s, 3H, -C**H**$_3$), 4.74 (s, 2H, -C**H**$_2$OOC-), 6.0 (s, 1H, pyran-C**H**-5), 6.15 (s, 1H, pyran-C**H**-3). ^{13}C NMR ($CDCl_3$): δ 17.0 (-**C**H$_3$), 20.0 (-OO**C**CH$_3$), 61.0 (-**C**H$_2$OOC-), 110.0 (pyran-**C**-5), 115.0(pyran-**C**-3), 159.0 (pyran-**C**-6), 162.5 (pyran-**C**-2), 170.0 (-OO**C**CH$_3$), 179.1 (pyran-**C**-4). MS (EI,70 eV): 182 (M^+).

Anal. Calcd. for $C_9H_{10}O_4$: C, 59.34; H, 5.53. Found: C, 59.20; H, 5.70

2, 6-*bis*(Acetoxymethyl)-4-oxo-4*H*-pyran-3,5-dicarboxylic Acid Dimethyl Ester (10c).- From 1.0 g of **8a**, 0.70 g (78%) of a pale brown oil was obtained. IR (KBr): 2983, 1754, 1670, 1420, 1225, 1100 and 840 cm^{-1}. ^1H NMR ($CDCl_3$): δ 2.0 (s, 6H, -OOCC**H**$_3$), 3.70 (s, 6H, -COOC**H**$_3$), 5.0 (s, 4H, -C**H**$_2$OOC-). ^{13}C NMR ($CDCl_3$): δ 20.0 (-OO**C**CH$_3$), 55.0 (-COO**C**H$_3$), 62.0 (-**C**H$_2$OOC-), 123.0 (pyran-**C**-3,-5), 160.0 (pyran-**C**-2,-6), 162.0 (-**C**OOCH$_3$), 169.0 (-OO**C**CH$_3$), 171.0 (pyran-**C**-4). MS (EI, 70 eV): 356 (M^+).

Anal. Calcd. for $C_{15}H_{16}O_{10}$: C, 50.57; H, 4.53. Found: C, 50.50; H, 4.40

2, 6-*bis*(Acetoxymethyl)-4-oxo-4*H*-pyran-3,5-dicarboxylic Acid Diethyl Ester (10d).- From 1.07 g of **8b**, 0.80 g (83%) of a brown oil was obtained. IR (KBr): 2985, 1754, 1669, 1423, 1223, 1100 and 838 cm^{-1}. ^1H NMR ($CDCl_3$): δ 1.29 (t, 6H, *J*= 7Hz, -CH_2C**H**$_3$), 2.06 (s, 6H, -OOCC**H**$_3$), 4.30 (q, 4H, *J*= 7Hz, -C**H**$_2$CH$_3$), 5.0 (s, 4H, -C**H**$_2$OOC-). ^{13}C NMR ($CDCl_3$): δ 13.2 (-CH_2**C**H$_3$), 19.9 (-OO**C**CH$_3$), 59.5 (-C**H**$_2$CH$_3$), 61.9 (-**C**H$_2$OOC-), 122.3 (pyran-**C**-3,-5), 161.4 (pyran-**C**-2,-6), 162.1 (-**C**OOCH$_2$-), 169.4 (-OO**C**CH$_3$), 171.0 (pyran-**C**-4). MS (EI, 70 eV): 384 (M^+).

Anal. Calcd. for $C_{17}H_{20}O_{10}$: C, 53.13; H, 5.25. Found: C, 53.0; H, 5.50

2-Acetoxymethyl-6-methyl-4-oxo-4*H*-pyran-3,5-dicarboxylic Acid Dimethyl Ester (10e).- From 1.60 g of **9a**, 1.20 g (80%) of a yellow oil was obtained. IR (KBr): 2981, 1745, 1668, 1421, 1220 and 1095 cm^{-1}. ^1H NMR ($CDCl_3$): δ 2.07 (s, 3H, -OOCC**H**$_3$), 2.34 (s, 3H, -C**H**$_3$), 3.70 (s, 6H, -COOC**H**$_3$), 5.0 (s,2H,-C**H**$_2$OOC-). ^{13}C NMR ($CDCl_3$): δ 15.0 (-**C**H$_3$), 20.0 (-OO**C**CH$_3$), 54.0 (-COO**C**H$_3$), 62.0 (-**C**H$_2$OOC-), 122.0 (pyran-**C**-5), 125.0 (pyran-**C**-3), 158.5 (pyran-**C**-6), 161.0 (pyran-**C**-2), 163.0 (-**C**OOCH$_3$), 169.0 (-OO**C**CH$_3$), 171.0 (pyran-**C**-4). MS (EI, 70 eV): 298 (M^+).

Anal. Calcd. for $C_{13}H_{14}O_8$: C, 52.35; H, 4.73. Found: C, 52.60; H, 4.90

2-Acetoxymethyl-6-methyl-4-oxo-4*H*-pyran-3,5-dicarboxylic Acid Diethyl Ester (10f).- From 1.74 g of **9b**, 1.40 g (86%) of a yellow oil was obtained. IR (KBr): 2985, 1746, 1669, 1423, 1223 and 1100 cm^{-1}. ^1H NMR ($CDCl_3$): δ 1.30 (t, 6H, *J*= 7 Hz, -CH_2C**H**$_3$), 2.04 (s,3H, -OOCC**H**$_3$), 2.35 (s, 3H, -C**H**$_3$), 4.40 (q, 4H, *J*=7 Hz, -C**H**$_2$CH$_3$), 5.0 (s, 2H, -C**H**$_2$OOC-). ^{13}C NMR ($CDCl_3$): δ 12.0 (-CH_2**C**H$_3$), 15.0 (-**C**H$_3$), 20.0 (-OO**C**CH$_3$), 60.0 (-COO**C**H$_2$CH$_3$), 62.0 (-**C**H$_2$OOCCH$_3$), 122.0 (pyran-**C**-5), 126.0 (pyran-**C**-3), 159.0 (pyran-**C**-6), 162.0 (pyran-**C**-2), 163.0 (-**C**OOCH$_2$CH$_3$), 169.4 (-OO**C**CH$_3$), 171.0 (pyran-**C**-4). MS (EI, 70 eV): 326 (M^+).

Anal. Calcd. for $C_{15}H_{18}O_8$: C, 55.21; H, 5.56. Found: C, 55.40; H, 5.70.

General Procedure for Hydrolysis of 10a and 10b.- A mixture of 4.0 mmoles of **10a** or **10b**, 20 mL THF, 10 mL water and 0.5 mL concentrated hydrochloric acid was refluxed for 16 hrs. The mixture was cooled and neutralized by the addition of $NaHCO_3$ to pH 6-7. The mixture was then concentrated under reduced pressure and the residue, after complete drying, was extracted with several portions of MeOH and the combined organic solution was concentrated *in vacuo*. Specific details are given for each compound.

2, 6-*bis*(Hydroxymethyl)-4*H*-pyran-4-one (4b).- From 0.96 g of **10a**, 0.57 g (92%) of a white solid was obtained, mp. 110°, *lit.*[6] 111°. IR (KBr): 3385 (broad), 2938, 1680, 1625, 1279, 1109 and 932 cm^{-1}. ^1H NMR (DMSO-d_6): δ 3.63 (s, 2H, -CH_2**OH**), 4.29 (s, 4H, -**CH**$_2$OH), 6.17 (s, 2H, pyran-**CH**-3,-5).

2-Hydroxymethyl-6-methyl-4*H*-pyran-4-one (11).- From 0.73 g of **10b**, 0.53 g (95%) of a white solid was obtained, mp. 135°. IR (KBr): 3390 (broad), 2940, 1678, 1615, 1280, 1100 and 938 cm^{-1}. ^1H NMR (DMSO-d_6): δ 2.20 (s, 3H, -**CH**$_3$), 3.45 (s, 1H, -CH_2**OH**), 4.25 (s, 2H, -**CH**$_2$OH), 6.0 (s, 1H, pyran-**CH**-5), 6.13 (s, 1H, pyran-**CH**-3). MS (EI, 70 eV): 140 (M^+).

Anal. Calcd. for $C_7H_8O_3$: C, 60.0; H, 5.75. Found: C, 59.80; H, 5.90.

General Procedure for the One-pot Hydrolysis and Decarboxylation Reaction of 10c-f.- A mixture of 3.5 mmoles of **10c-f,** 5 mL acetic acid, 5 mL water and 1 mL concentrated H_2SO_4 was refluxed for 12 hrs. The mixture was cooled and neutralized with the addition of aqueous sodium hydroxide (50%) to pH 5-6 and then adjusted to pH 7-8 with addition of sodium carbonate. The mixture was extracted with 2x10 mL CH_2Cl_2. The aqueous layer was concentrated under reduced pressure and the residue, after complete drying, was extracted with several portions of MeOH and the combined organic solution was concentrated *in vacuo*. Specific details are given for each compound.

Compound 4b.- From 1.25 g of **10c**, 0.1 g (18%) of **4b** was obtained. From 1.35 g of **10d**, 0.09 g (16%) of **4b** was obtained. The physical and spectral properties were identical to that of **4b** reported earlier.

Compound 11.- From 1.05 g of **10e**, 0.11 g (22%) of **11** was obtained. From 1.14 g of **10f**, 0.13 g (27%) of **11** was obtained. The physical and spectral properties were identical to that of **11** reported earlier.

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