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An efficient synthetic approach towards fully functionalized tetronic acids: The use of 1,3-dioxolane-2,4-diones as novel protected-activated synthons of α-hydroxy acids.

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An efficient synthetic approach towards fully functionalized tetronic acids: The use of 1,3-dioxolane-2,4-diones as novel protected-activated synthons of α-hydroxy acids.

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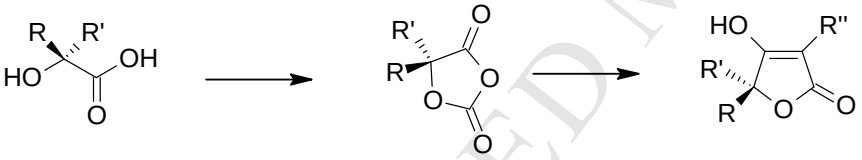


Keywords:
Tetronic Acids,
O-carboxyahydrides,
Chirality
X-Ray

Abstract.

A new strategy for the synthesis of tetronic acids with control over the regioselective introduction of substituents at the C-5 position has been developed. The construction of the densely functionalized quaternary carbon center within these molecules is of great importance. The key element for the proposed protocol was the utilization of O-carboxyanhydrides (OCA's) of optically active α-hydroxy acids, as promising bidentate protective/activating precursors. The

structure of the new compounds was investigated by using NMR spectral data and X-ray structural analyses.

Introduction.

Tetronic acid derivatives (4-hydroxy-5[H]-furan-2-ones) represent a unique class of five-membered heterocyclic compounds that have attracted significant attention over the years due to their occurrence in naturally bioactive materials, and their synthetic utility as versatile intermediates for the construction of highly functionalized heterocycles.[1] Many natural products containing the 2,4-furanodione ring have been isolated displaying a wide variety of biological functions properties[2] such as antibiotic,[3] anticoagulant,[4] antiepileptic,[5] antifungal,[6] insecticidal,[7] anti-inflammatory,[8] antitumour,[9] and skin-whitening effects.[10] In addition, 3-carboxamide tetronic acids were investigated as inhibitors of undecaprenyl pyrophosphate synthase (UPPS) for use as antimicrobial agents, [11] while compounds that have been isolated from natural products and exhibit such activity are: tetronasin,[12] RK-682 (3-alkanoyl-5-hydroxymethyl tetronic acid) as selective inhibitors of protein tyrosine phosphatases (PTPs),[13] HIV protease inhibitors,[14] and the well-known family of compounds named vulpinic acids.[15] Moreover, several non-natural 3-functionalized tetronic acids have been reported as antioxidant and anti-inflammatory compounds.[16]

The wide range of biological properties and the potency of pharmaceutical applications have attracted continuous interest in the development of new methods for the synthesis of optically active tetronic acids. Several methodologies include Dieckmann cyclization,[17] [2+2]-photocycloaddition,[18] reaction of active methylene compounds with activated α-hydroxy acids,[19] Wittig-Claisen reaction of α-hydroxyesters,[20] lactonization and enzymatic reactions.[21]

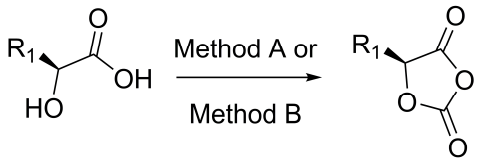
We have been interested in the chemistry and new strategies for the preparation of functionalized five-membered oxygen heterocycles,[22] containing the β-diketo moiety, as well as their study as "model ligands" for binding with divalent metal ions, which are critical cofactors at the enzymes' catalytic site.[23] Additionally, these scaffolds are revealed as promising systems for the development of new supramolecular architectures.[24]

Results and discussion

Our continuing interest on the chemistry of five-membered heterocyclic systems, tetramic, tetronic, thiotetronic acids, as pharmacological agents,[25] we would provide an alternative and ultimately more general approach for the construction of the tetronic acid nucleus with control over the regioselective introduction of substituents at the C-5 position. Construction of the densely functionalized quaternary carbon center found within these molecules is of great importance.[26]

The key control element of the proposed protocol was the utilization of O-carboxyanhydrides (OCA's) of optically active α-hydroxy acids as promising bidendate protecting/activating precursors. Our interest in OCAs of α-hydroxy acids stems from their possible use as chiral scaffolds to introduce a quaternary carbon within the γ-lactone core. Consequently, we saw in them a potential class of building blocks that would provide access to highly functionalized tetronic acids with retention of chirality of the C-5 stereogenic center, under the proposed reaction conditions.

Scheme 1[a]**.** Synthesis of O-carboxyanhydrides from α-hydroxy acids



1. R_1 = H
2. R_1 = Me
3. R_1 = Ph
4. R_1 = Bn
5. R_1 = i-Pr

6a. R_1 = H
6b. R_1 = Me
6c. R_1 = Ph
6d. R_1 = Bn
6e. R_1 = i-Pr

[a] Reagents and Conditions: Method A, phosgene solution, THF, 50–60 °C, 24 h,[27] Method B, diphosgene, activated charcoal, THF, 8−16 h, r.t. [28]

The synthesis of the requisite anhydrides followed a modified procedure reported by Toyooka,[28] which involves the reaction of (*S*)-mandelic acid (**3**) with diphosgene (trichloromethyl chloroformate) and activated charcoal (see experimental).[27] Following this modified procedure, the OCA's of optically active α-hydroxy acids, the 1,3-dioxolan-2,4-diones (**6a−e**), have been prepared, as acylating scaffolds, in very good yields. The whole process is outlined in **Scheme 1**

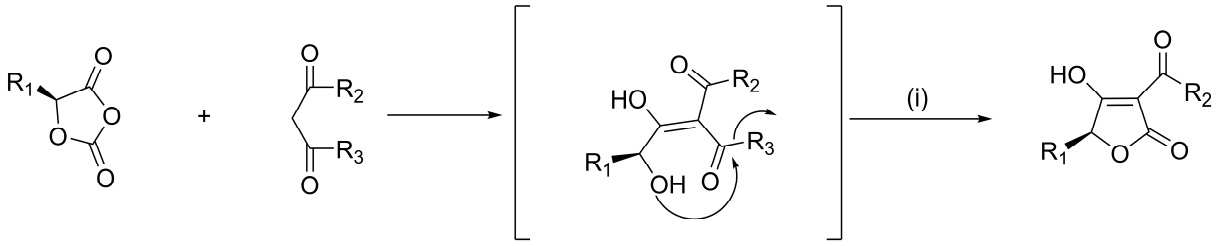
To explore this approach, we first attempted the synthesis of tetronic acids starting from the O-carboxyanhydride of (*S*)-mandelic acid, the (*S*)-phenyl-1,3-dioxolan-2,4-dione (**6c**). It is

worthwhile to note that the requisite anhydride was found to react in a regioselective manner at the C-4 site, with carbon nucleophiles derived from anions of β-ketoesters **(7−9) Scheme 2**, or appropriately substituted ethyl acetates (**11−13**), **Scheme 3**, to generate the desired 5-(*S*)-phenyl-3-functionalized tetronic acids **10c, 10d** and **14a−14c**, respectively, with retention of the integrity of the stereogenic center C-5 in a great extent. The OCAs of mandelic acid is an important agent for the preparation of cephalosporin antibiotics. Many mandelic acid derivatives also act as chiral auxiliaries for the introduction of chiral centers in stereoselective transformations.[29] To our knowledge, there has been no previous report concerning an analogous nucleophilic attack of OCA's by active methylene compounds.

Encouraged by these interesting results, we continued to focus on the optimization of reaction conditions, and on the screening of various OCAs of α-hydroxy acids for their efficiency as acylating agents to the proposed reaction.

Owing to the importance of the naturally occurring 3-acyl-tetronic acids, our initial investigations focused on the C-acylation reaction of β-ketoesters **(7−9) Scheme 2**. The proposed protocol involves (i) deprotonation of an active methylene compound, (ii) nucleophilic attack at the C-4 carbonyl of the 5-substituted 1,3-dioxolan-2,4-dione, and (iii) in situ intramolecular cyclization of the "intermediate" precursor **X**, affording the tetronic acids **10a−g,** with flexible substituents, incorporating the chiral center of the starting α-hydroxy acid into the final spatial arrangement of the C-5 carbon of the γ-lactone nucleus.

Scheme 2. Synthesis of 3-alkoxy- and 3-keto-substituted tetronic acids



6a-e **7**. $R_2 = R_3 = OMe$; **8**. $R_2 = R_3 = OEt$; **9**. $R_2 = Me$, $R_3 = OEt$ **X** **10a-g**

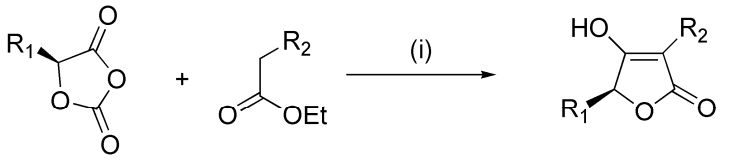
entry	R_1	R_2	Yields %

10a	H	OEt	65
10b	Me	Me	60
10c	Ph	OMe	80
10d	Ph	OEt	70
10e	Bn	OEt	73
10f	Bn	Me	67
10g	iPr	OMe	78

Reagents and Conditions: (i) NaH, THF, 0 °C to r.t., 2−4 h.

Application of this methodology was further evaluated using as carbon nucleophiles lithium enolates derived from arylacetates (**11-13**) **Scheme 3**.

Scheme 3. Synthesis of 3-aryl-5-substituted tetronic acids



6c - e

11. R_2 = Ph
12. R_2 = Ph(3-OMe)
13. R_2 = Ph(4-OMe)

14a. R_1 = Ph, R_2 = Ph
14b. R_1 = Ph, R_2 = (3-OMe)Ph
14c. R_1 = Ph, R_2 = (4-OMe)Ph
14d. R_1 = Bn, R_2 = Ph
14e. R_1 = Bn, R_2 = (4-OMe)Ph
14f. R_1 = i-Pr, R_2 = Ph
14g. R_1 = i-Pr, R_2 = (3-OMe)Ph
14h. R_1 = i-Pr, R_2 = (4-OMe)Ph

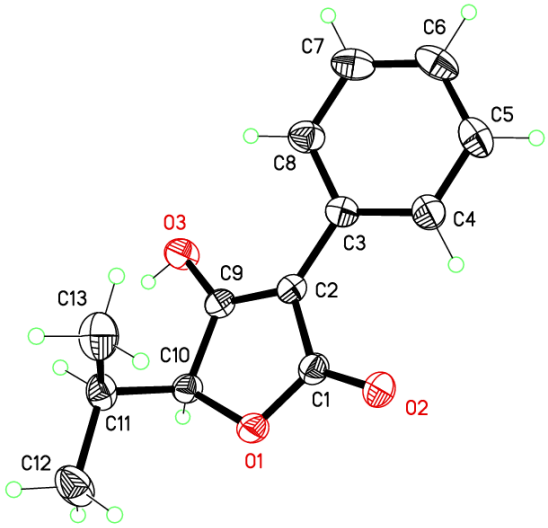
entry	**R_1**	**R_2**	**Yields (%)**

14a	Ph	Ph	65
14b	Ph	3-OMe-Ph	70
14c	Ph	4-OMe-Ph	72
14d	CH_2Ph	Ph	80
14e	CH_2Ph	4-OMe-Ph	70
14f	$(CH_3)_2CH$	Ph	55
14g	$(CH_3)_2CH$	3-OMe-Ph	56
14h	$(CH_3)_2CH$	4-OMe-Ph	60

Reagents and Conditions: (i) LDA, THF, 1 h, −78 °C, 1 h r.t.

The corresponding optically active 3-aryl-5-substituted tetronic acids (**14a−h**) were isolated from "one-pot" reactions in good yields. The C-acylation/cyclization experiments were conducted at −78 ^{o}C using lithium base (LDA), in THF, to achieve the desired tetronic acids possessing an aromatic ring at position 3.

A single crystal X-ray structure determination[30] was carried out on compound **14f** to determine the structure in the solid state. The molecular structure and numbering scheme for compound **14f** are shown in Figure 1, and bond lengths and angles are given in Table I. There is some double bond character evident in the O1-C1 bond (1.354(2) Å), and C2-C9 bond (1.354(2) Å), compared to the O1-C10 bond (1.4463(18) Å) and the O3-C9 bond is distinctly longer than the conventional carbonyl distance for O2-C1, (1.3228(19) Å) and 1.222(2) Å), respectively. There is an angle of 17.456(71)° between the mean planes of the two rings. An intermolecular



hydrogen bond between the alcohol and the carbonyl of an adjacent molecule forms hydrogen bonded chains running parallel to the *c* axis ((O3····O2A 2.6355(17) Å, Figure 2). There are no other striking intermolecular interactions.

Figure 1, Perspective view of **14f** with thermal ellipsoids drawn at the 50% probability level.

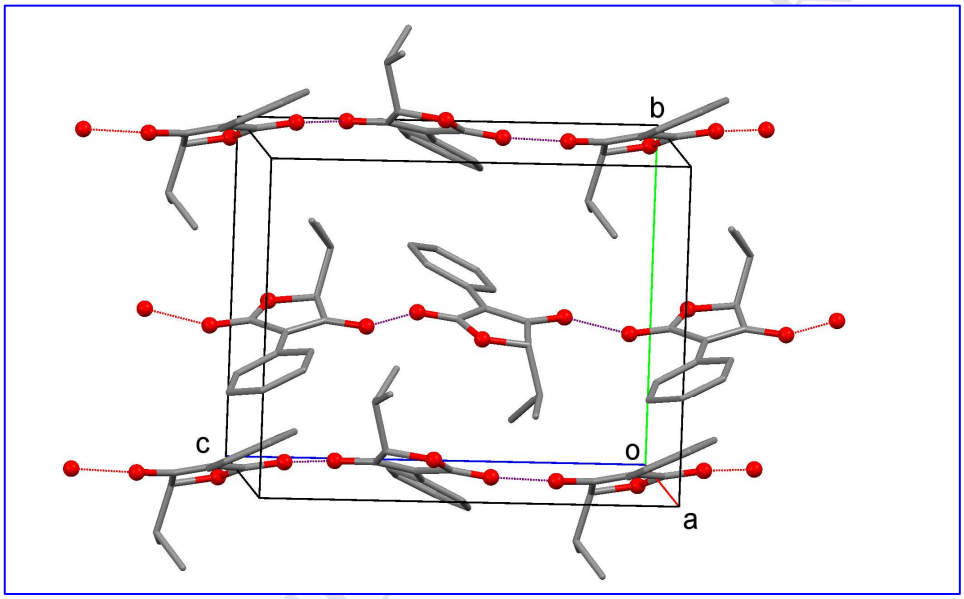


Figure 2.Unit cell packing diagram for **14f**, dashed lines represent hydrogen bonds.

Table I
Bond lengths [Å] and angles [°] for **14f**.

O1—C1	1.354 (2)	C5—C6	1.386 (3)
O1—C10	1.4463 (18)	C6—C7	1.378 (3)
C1—O2	1.222 (2)	C7—C8	1.391 (3)
C1—C2	1.454 (2)	C9—O3	1.3228 (19)
C2—C9	1.354 (2)	C9—C10	1.501 (2)
C2—C3	1.474 (2)	C10—C11	1.532 (2)
C3—C8	1.394 (2)	C11—C12	1.529 (3)
C3—C4	1.404 (2)	C11—C13	1.528 (3)
C4—C5	1.389 (2)		

C1—O1—C10	108.99 (12)	C7—C6—C5	119.40 (17)
O2—C1—O1	118.94 (15)	C6—C7—C8	120.86 (18)
O2—C1—C2	129.75 (16)	C7—C8—C3	120.50 (17)
O1—C1—C2	111.30 (13)	O3—C9—C2	127.48 (15)
C9—C2—C1	105.46 (14)	O3—C9—C10	121.60 (14)
C9—C2—C3	129.42 (15)	C2—C9—C10	110.90 (14)
C1—C2—C3	125.13 (14)	O1—C10—C9	103.05 (13)
C8—C3—C4	118.20 (16)	O1—C10—C11	110.09 (13)
C8—C3—C2	120.58 (15)	C9—C10—C11	114.05 (14)
C4—C3—C2	121.21 (15)	C12—C11—C13	111.43 (16)
C5—C4—C3	120.66 (17)	C12—C11—C10	110.10 (16)
C6—C5—C4	120.36 (18)	C13—C11—C10	112.05 (15)

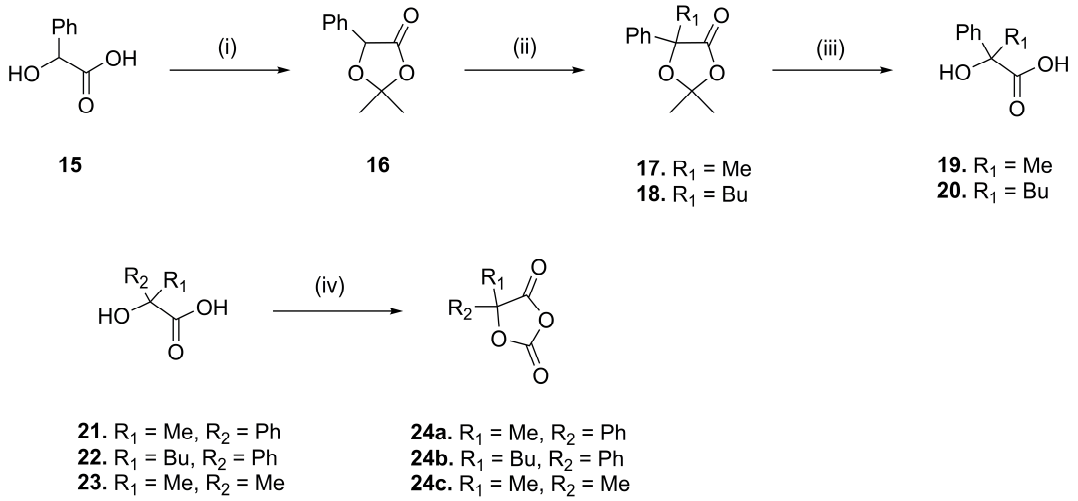
Table II
Hydrogen bond geometry for **14f** [Å, °].

D—H···*A*	*D*—H	H···*A*	*D*···*A*	*D*—H···*A*
O3—H3···O2^{i}	0.86 (2)	1.78 (2)	2.6355 (17)	173 (2)

Symmetry code: (i) −*x*+1/2, −*y*, *z*+1/2.

The next challenge was to examine the validity of our strategy to access functionalized tetronic acids, generating a quaternary carbon stereocenter at the 5-position of the γ-lactone core. In this aim, the 5,5-disubstituted-1,3-dioxolane-2,4-diones (**24a−c**) **Scheme 4,** were used as scaffolds to generate the functionalized tetronic acids with different patterns of substitution at C-5. The construction of such architectures with a quaternary pattern is of particular importance and attracts continuing interest because such motifs exist in a great number of natural products and pharmaceutically relevant compounds. Thus, treatment of (*R,S*)-mandelic acid **15** with acetone under acidic conditions (c. H_2SO_4/−20 °C) generates 2,2-dimethyl-5-phenyl-1,3-dioxolane-4-one **16** (**Scheme 4).**[32b] Deprotonation of this dioxolanone with LDA led to the corresponding lithium enolate which was alkylated by an appropriate halide (R_1X), introducing a second substituent at C-5.[31,32b] Sodium hydroxide hydrolysis of compounds **17** and **18**, in methanol, generates the α-methyl- and α-butyl-mandelic acids **21** and **22,**[32c] which undergo a new transformation to 5,5-disubstituted-1,3-dioxolane-2,4-dione **24a** and **24b.** Adopting the one-pot protocol as our standard, substitution of the phenyl group on **24a** for methyl, the 5,5-dimethyl-1,3-dioxolane-2,4-dione (**24c**) was produced.

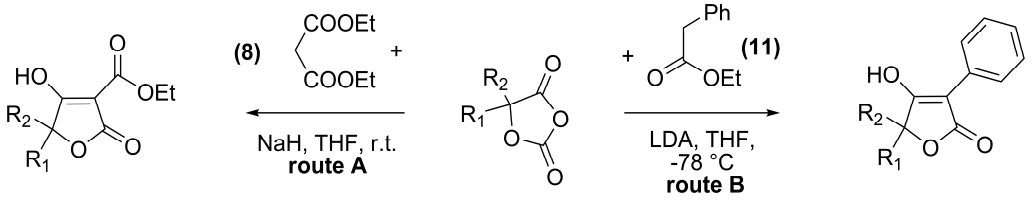
Scheme 4. Synthetic procedure for preparation of 1,3-dioxolane-2,4-diones



Reagents and Conditions: (i) acetone / c. H_2SO_4 / −20 °C 1 h, (ii) LDA / R_1X / −78 °C, (iii) aq. NaOH 2 N / MeOH / 2 h reflux, (iv) triphosgene / Et_3N / THF reflux 24 h.

It is worthwhile to note that the proposed methodology proceeded to generate 5,5-disubstituted tetronic acids, **26a−c** and **25a−c,** using the sodium enolate of malonic esters (**8**) or the lithium enolate of ethyl phenyl acetate (**11**), **Scheme 5.**

Scheme 5 . Synthesis of 5,5-disubstituted tetronic acids



26a. R_1 = Me, R_2 = Ph
26b. R_1 = Bu, R_2 = Ph
26c. R_1 = Me, R_2 = Me

24a. R_1 = Me, R_2 = Ph
24b. R_1 = Bu, R_2 = Ph
24c. R_1 = Me, R_2 = Me

25a. R_1 = Me, R_2 = Ph
25b. R_1 = Bu, R_2 = Ph
25c. R_1 = Me, R_2 = Me

entry	R_1	R_2	Yields (%)
25a	Me	Ph	67
25b	Bu	Ph	55
25c	Me	Me	62
26a	Me	Ph	50
26b	Bu	Ph	45
26c	Me	Me	66

Reagents and Conditions: Route A, **8**, NaH, THF, at 0 °C to r.t. 4 h; Route B, **11**, LDA, THF, 1 h −78 °C, 1 h r.t.

A single crystal X-ray structure analysis of **26a** was carried out to determine the structure in the solid state. The molecular structure and the numbering scheme for compound **26a** are shown in Figure 3, and bond lengths and angles are given in Table III. The structure resembles the enol-tautomer with an endocyclic C=C bond. There is some double bond character evident in the C2−C6 bond (1.344(2) Å), and the O5−C6 bond is distinctly longer than the conventional carbonyl distance for O2−C1, 1.3188(18) and 1.1953(18) Å , respectively. The hydrogen atom bonded to O5 was located in the difference Fourier maps. The alcohol group acts as donor for a

bifurcated hydrogen bond with both an intramolecular component (O-5 ··· O-3 2.7717(15) Å) and an intermolecular component (O-5 … O-3 2.9905(15) Å under symmetry operation −*x*+2, −*y*+1, −*z*+2), resulting in formation of hydrogen bonded dimers (Figure 4). There is some π-stacking involving the carbonyl groups which packs the dimers into columns; surprisingly, there is no indication of significant π–π interactions between the phenyl groups.

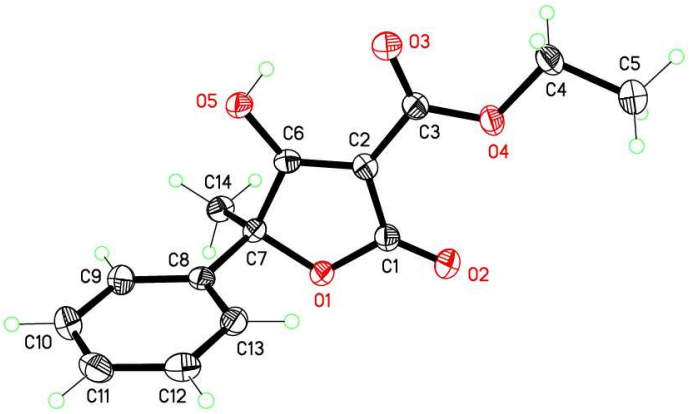
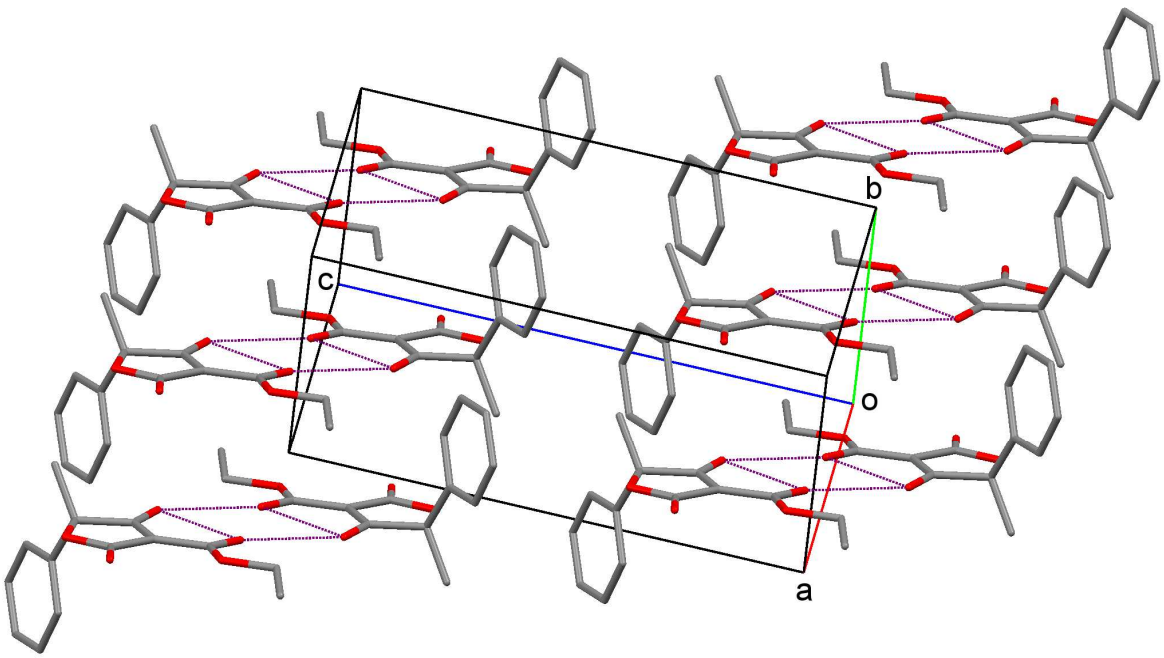


Figure 3. *Perspective view of **26a** with 50% displacement ellipsoids.*

Figure 4. Unit cell packing diagram for **26a.** Dashed lines represent hydrogen bonds, hydrogen atoms omitted for clarity.

Table III.
Geometric parameters (Å, º) for for **26a**



O1—C1	1.3821 (18)	C6—O5	1.3188 (18)
O1—C7	1.4557 (17)	C6—C7	1.514 (2)
C1—O2	1.1953 (18)	C7—C14	1.520 (2)
C1—C2	1.467 (2)	C7—C8	1.525 (2)
C2—C6	1.344 (2)	C8—C9	1.387 (2)
C2—C3	1.459 (2)	C8—C13	1.395 (2)
C3—O3	1.2232 (18)	C9—C10	1.392 (2)
C3—O4	1.3194 (17)	C10—C11	1.378 (2)
O4—C4	1.4608 (18)	C11—C12	1.383 (2)
C4—C5	1.502 (2)	C12—C13	1.384 (2)
C1—O1—C7	111.40 (11)	O1—C7—C6	101.70 (11)
O2—C1—O1	120.62 (14)	O1—C7—C14	107.81 (12)
O2—C1—C2	131.74 (14)	C6—C7—C14	112.26 (12)
O1—C1—C2	107.64 (12)	O1—C7—C8	108.96 (11)
C6—C2—C3	122.83 (14)	C6—C7—C8	110.18 (12)
C6—C2—C1	108.05 (13)	C14—C7—C8	115.01 (12)
C3—C2—C1	129.11 (13)	C9—C8—C13	118.85 (14)
O3—C3—O4	125.16 (14)	C9—C8—C7	121.79 (13)
O3—C3—C2	121.00 (13)	C13—C8—C7	119.27 (13)
O4—C3—C2	113.84 (13)	C8—C9—C10	120.19 (15)
C3—O4—C4	116.68 (12)	C11—C10—C9	120.49 (15)
O4—C4—C5	107.26 (13)	C10—C11—C12	119.73 (15)
O5—C6—C2	129.82 (14)	C11—C12—C13	120.08 (15)
O5—C6—C7	119.02 (12)	C12—C13—C8	120.65 (14)
C2—C6—C7	111.15 (13)		

Table IV
Hydrogen-bond geometry (Å, º) for **26a**

D—H···*A*	*D*—H	H···*A*	*D*···*A*	*D*—H···*A*
O5—H5···O3	0.857 (19)	2.074 (18)	2.7717 (15)	138.2(16)
O5—H5···O3^{i}	0.857 (19)	2.336 (18)	2.9905 (15)	133.4 (15)

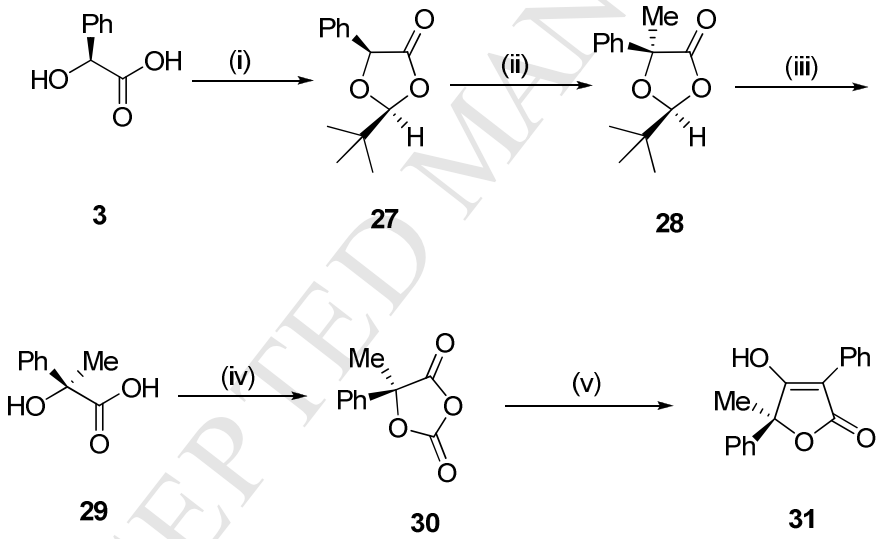
Symmetry code: (i) −*x*+2, −*y*+1, −*z*+2.

The successful synthesis of tetronic acids with a quaternary carbon at C-5 prompted us to investigate the synthesis of optically active C^{α}-tetrasubstituted α-hydroxy acids and the

chemistry that incorporates their chiral center into the final spatial arrangement of atoms at the C-5 tetrasubstituted stereocenter of compound **30 (Scheme 6).**

The asymmetric synthesis of optically active α-hydroxy acids with a quaternary stereocenter has been exploited by Seebach and co-workers.[33] Mandelic acid derivatives were utilized as convenient precursors for the introduction of a chiral center in stereoselective transformations.[34] For this transformation we employed the "self-reproduction chirality" approach of Seebach,[35] which incorporates lactic acid into a dioxolane ring to direct alkylation at the C-5 carbon, taking advantage of the bulky [R] group of the newly formed stereocenter at C-2. Thus, the 1,3-dioxolanone **27** is formed by treating (*S*)-mandelic acid **3** with pivaldehyde under acidic catalysis **Scheme 6** .

Scheme 6[a] Enantioselective synthesis of 5,5-disubstituted tetronic acids.



[a] Reagents and Conditions: (i) Trifluoromethanesulphonic acid, pentane / Dean-Stark, reflux, (ii) LDA / MeI / −78 °C,[35] (iii) aq. KOH 2.5 M / MeOH / 2 h,[36] (iv) triphosgene / Et_3N / THF reflux 24 h,[37] (v) **11**, LDA, THF, 1h, −78 °C, 1 h r.t.

Treatment of **27** with LDA at −78 °C followed by alkylation with methyl iodide proceeds in 90% yield to provide a cis:trans mixture 93:7 of **28**. Potassium hydroxide hydrolysis in methanol affords (*S*)-atrolactic acid **29** after two recrystallizations from toluene**,** possessing $[\alpha]_{20}$ +35.2° (c 0.99 in ethanol), 99% ee.[37]

Excellent results were obtained when this optically active α-hydroxy acid was transformed to the corresponding carboxyanhydride **30**, bearing a methyl group and the bulky phenyl group at the C-5 stereogenic carbon. Interestingly, when lithium phenylacetate was used as the enolate source, the corresponding (*S*)-5-methyl-3,5-diphenyl tetronic acid (**31**) was obtained from the attack of the enolate on the carbonyl at position 4, in 60% yield and high optical purity (99:1 e.r., 98% e.e.).

In conclusion we have developed a convenient and efficient methodology for the construction of functionally substituted tetronic acids possessing a quaternary stereocenter with high diastereo- and enantiostereo-control. The chiral C-5 carbon was constructed by introducing new activated precursors, the 1,3-dioxolane-2,4-diones as chiral synthons. Of particular significance is the generality of this reaction and the stereoselectivity achieved under mild reaction conditions. Our efforts are directed towards the synthesis of more complex ligands in the "tetronate" series.

Experimental section

All reagents and solvents were commercial grade and purified prior to use when necessary. Tetrahydrofuran (THF) was freshly distilled before use from Na/Ph_2CO. Melting points were determined with a Gallenkamp MFB-595 melting point apparatus. Thin layer chromatography (TLC) was performed using pre-coated TLC plates with Silica Gel 60 F_{254} (Macherey Nagel). Flash column chromatography was carried out on silica gel Macherey-Nagel 0.063-0.2 mm/70-230 mesh.

Nuclear magnetic resonance spectra (NMR) were recorded with a Varian Gemini-2000 300 MHz spectrometer operating at 300 MHz (^{1}H) and 75 MHz (^{13}C). Chemical shifts are reported in parts per million relative to $CDCl_3$ (^{1}H: δ = 7.26 ppm, ^{13}C: δ = 77.16 ppm). Optical Rotations were measured on a Perkin-Elmer 241 polarimeter. HRMS spectra were recorded on UHPLC LC-MSn Orbitrap Velos-Thermo instrument in the Institute of Biology, Medicinal Chemistry and Biotechnology of the National Hellenic Research Foundation, in Greece. Some of HRMS were carried out in the Department of Chemistry & Biochemistry of the University Notre Dame, IN, USA, on a micrOTOF, ESI instrument. HPLC separations were performed by using a DAICEL CHIRALPAK AS (4.6 mm x 250 mm) column, incorporated in an HPLC system consisting of a Varian 2510 HPLC pump, and UV detector. (Conditions for the analysis of

compounds **14a−c** and **31** were:flow rate = 0.8 mL/min, eluent solvent system = isocratic ethanol/hexane (50:50) with 0.1% trifluoroacetic acid and wave length = 210 nm).

General procedure for the synthesis of 1,3-dioxolane-2,4-diones (6a−e).

Method A: To a solution of α-hydroxy acid (13.0 mmol) in anhydrous THF (10 mL), a phosgene solution (20% in toluene) (14.95 mmol, 7.40 mL) was added at once, and the resulting mixture was stirred at 50-55 °C for 1 h. Then an additional aliquot of phosgene (3.25 mmol, 1.60 mL) was added and the reaction mixture stirred for 24 h at r.t.. The solvents were evaporated and the anhydrides **6a−e** were isolated in an oily form or precipitated as solids after triturating with petroleum ether and were collected by filtration. The final products were dried under high vacuum over P_2O_5 for 2 h.

Method B: Diphosgene (1.50 mL, 11.26 mmol) was added to a solution of α-hydroxy acid (10 mmol) in anhydrous THF (10 mL), and the reaction mixture was treated with activated charcoal (50 mg). The resulting suspension was stirred overnight at r.t. Then the mixture was filtered through a small celite pad, the filtrates were concentrated and dried under high vacuum (2 h over P_2O_5) in order to give the desired anhydrides.

1,3-Dioxolane-2,4-dione (6a). (According to method B) Starting from glycolic acid **(1)** (0.76 g, 10.0 mmol), the title compound was obtained as brownish oil and used in the next step without any further purification, (1.86 g, 97%). ^{1}H NMR (300 MHz, $CDCl_3$/drops DMSO-d_6): δ 4.85 (2H, s). ^{13}C NMR (75 MHz, $CDCl_3$ drops DMSO-d_6): δ 67.6, 149.2, 165.1.

(*S*)-5-methyl-1,3-dioxolane-2,4-dione (6b). (According to method A) Starting from (*S*)-lactic acid **(2)** (1.17 g, 13.0 mmol), the title compound was obtained as colorless oil and used in the next step without any further purification. The crude product was solidified on addition of n-hexane. The solid was crystallized from ether to give the title compound **6b (83%).** [28a] Mp: 54−56 °C (Lit.[28a] mp 58−60 °C).

(*S*)-5-phenyl-1,3-dioxolane-2,4-dione (6c). (According to method B) Starting from (*S*)-mandelic acid **(3)** (1.52 g, 13.0 mmol), the title compound was obtained as a white solid (1.74 g, 98%).[27] Mp: 78−80 °C (Lit.[28a] mp 74−75 °C). ^{1}H NMR (300 MHz, $CDCl_3$): δ 6.01 (1H, s), 7.41-7.51 (5H, m). ^{13}C NMR (75 MHz, $CDCl_3$): δ 80.6, 126.3, 129.4, 129.7, 130.9, 148.2, 165.5.

(*S*)-5-benzyl-1,3-dioxolane-2,4-dione (6d).[28b] (According to method B) Starting from (*S*)-2-hydroxy-3-phenylpropanoic acid **(4)** (1.66 g, 10.0 mmol), compound **6d** was obtained as a white solid (1.86 g, 97%). Mp: 101−103 ^{o}C ^{1}H NMR (300 MHz, $CDCl_3$): δ 3.25 (1H, dd, *J* = 4.8, 15.0 Hz) 3.39 (1H, dd, *J* = 4.8, 15.0 Hz) 5.30 (1H, t, *J* = 4.8 Hz) 7.21 – 7.24 (2H, m), 7.33 – 7.38 (3H, m). ^{13}C NMR (75 MHz, $CDCl_3$): δ 36.6, 80.0, 128.6, 129.3, 129.8, 131.7, 147.9, 166.4.

(*S*)-5-isopropyl-1,3-dioxolane-2,4-dione (6e). [28b] (According to method B) Starting from (*S*)-2-hydroxy-3-methylbutanoic acid **(5)** (1.18 g, 10.0 mmol), the title compound was obtained as a white solid (1.60 g, 87%). ^{1}H NMR (300 MHz, $CDCl_3$): δ 1.08 (3H, d, *J* = 6.9 Hz), 1.15 (3H, d, *J* = 6.9 Hz), 2.33 – 2.39 (1H, m), 4.90 (1H, d, *J* = 2.7 Hz). ^{13}C NMR (75 MHz, $CDCl_3$): δ 16.1, 17.5, 30.7, 84.2, 148.6, 166.6.

General procedure for the synthesis of tetronic acids 10a−g. The appropriate active methylene compound **7−9** (4.0 mmol) was added in a dropwise manner to an ice-cooled suspension of sodium hydride (60% in oil, 0.16 g, 4.0 mmol) in freshly distilled THF (10 mL) and the mixture was stirred at 0 °C for 30 min under nitrogen. Then, a solution of the appropriate 1,3-dioxolane-2,4-dione **(6a−e)** (2.0 mmol) in anhydrous THF (2 mL) was added, and the reaction mixture was allowed to warm to r.t. and stirred for 2−4 h. Water (5 mL) was added to the reaction mixture and the THF evaporated under vacuum. The aqueous layer was then washed with Et_2O (15 mL), acidified with HCl10% in an ice-water bath. Compounds **10c−e** were precipitated as white solids, collected by filtration, washed with Et_2O and dried under high vacuum over P_2O_5 for 2 h. In case of compounds **10a, 10b, 10f, 10g**, the acidified aqueous layer was extracted three times with CH_2Cl_2 (3 x 20 mL) and the combined organic extracts were dried over anhydrous Na_2SO_4 and concentrated under reduced pressure to afford the crude product which was solidified after triturating with diethyl ether or petroleum ether, collected by filtration, and dried for 3 – 4 h under high vacuum over P_2O_5.

3-Ethoxycarbonyltetronic acid (10a). Starting from 1,3-dioxolane-2,4-dione **(6a)** (2.0 mmol, 0.20 g) and using diethyl malonate **8** (4.0 mmol, 0.64 g) the title compound was obtained as a white solid (0.20 g,65%). Mp: 110–112 °C (Lit.[19c] mp 112–114 ^{o}C). ^{1}H NMR (300 MHz, DMSO-d_6): δ 1.21 (3H, t, *J* = 6.9 Hz), 4.14 (2H, q, *J* = 6.9 Hz), 4.68 (2H, s). ^{13}C NMR (75 MHz, DMSO-d_6): δ 14.3, 59.2, 66.4, 92.0, 161.0, 169.5, 185.9. ESI – MS:m/z 171.25 $[M - H]^-$.

(*S*)-3-Acetyl-5-methyltetronic acid (10b). Starting from (*S*)-5-methyl-1,3-dioxolane-2,4-dione **(6b)** (2.0 mmol, 0.23 g) and using ethyl acetoacetate **9** (4.0 mmol, 0.52 g) the title

compound was obtained as a white solid (0.19 g, 60%).[3e] Mp: 63–65 °C (Lit.[19d] m.p. 70–71 °C), $[\alpha]_D^{20}$ –8.74 (c 0.5, MeOH). ^{1}H NMR (300 MHz, $CDCl_3$): δ 1.49 (3H, t, *J* = 6.9 Hz), 2.52 (3H, s), 4.68 (0.4H, q, *J* = 6.9 Hz), 4.81 (0.6H, q, *J* = 6.9 Hz), 12.96 (1H, br s). ^{13}C NMR (75 MHz, $CDCl_3$): δ16.7/16.9, 19.6/22.4, 76.4/81.9, 97.3/100.2, 99.1/101.2, 127.3/127.4, 128.6/128.7, 129.8, 134.1/134.6, 167.8/175.8, 188.5/194.5, 195.3/200.3. ESI – MS: m/z 155.17 $[M - H]^-$. **ESI-HRMS** : m/z $[M - H]^-$ calcd for $C_7H_7O_4$ 155.0347, found 155.0339.

(*S*)-3-Methoxycarbonyl-5-phenyltetronic acid (10c). Starting from (*S*)-5-phenyl-1,3-dioxolane-2,4-dione **(6c)** (2.0 mmol, 0.36 g) and using dimethyl malonate **7** (4.0 mmol, 0.53 g) the title compound was obtained as a white solid (0.37 g, 80%). Mp: 176–178 °C (Lit.[19c] mp 188–189 °C), $[\alpha]_D^{20}$ +81.0 (c 1.0, MeOH), (Lit.[19c] $[\alpha]_D^{20}$ +86.6). ^{1}H NMR (300 MHz, DMSO-d_6): δ 3.66 (3H, s), 5.77 (1H, s), 7.34 - 7.44 (5H, m). ^{13}C NMR (75 MHz, DMSO-d_6): δ 50.7, 78.8, 90.8, 127.3, 128.8, 129.1, 135.1, 162.1, 169.3, 186.9. ESI – MS: m/z 233.15 $[M - H]^-$.

(*S*)-3-Ethoxycarbonyl-5-phenyltetronic acid (10d). Starting from (*S*)-5-phenyl-1,3-dioxolane-2,4-dione **(6c)** (2.0 mmol, 0.36 g) and using diethyl malonate **8** (4.0 mmol, 0.64 g) the title compound was obtained as a white solid (0.35 g, 70%). Mp: 166−168 °C (Lit.[19c] mp 156–157 °C), $[\alpha]^{20}_D$ + 83.1 (c 1.0, MeOH), (Lit.[19c] $[\alpha]_D^{20}$ +71,1). ^{1}H NMR (300 MHz, $CDCl_3$), δ 1.42 (3H, t, *J* = 6.9 Hz), 4.44 (2H, q, *J* = 14.4, 6.9 Hz), 5.82 (1H, s), 7.35-7.44 (5H, m). ^{13}C NMR (75 MHz, $CDCl_3$): δ 14.3, 62.4, 78.6, 94.3, 126.5, 129.2, 129.9, 132.5, 166.3, 166.5, 190.2. ESI – MS: m/z 247.33 $[M - H]^-$.

(*S*)-5-Benzyl-3-ethoxycarbonyl tetronic acid (10e). Starting from (*S*)-5-benzyl-1,3-dioxolane-2,4-dione **(6d)** (2.0 mmol, 0.38 g) and using diethyl malonate **8** (4.0 mmol, 0.64 g) the title compound was obtained as a white solid (0.38 g, 73 %). Mp: 166–168 °C, $[\alpha]_D^{20}$ –76.0 (c 0.5, MeOH); ν_{max}(KBr) 3200, 2950, 1740, 1650, 1610, 1345 cm^{-1}; 1H NMR (300 MHz, $CDCl_3$): δ 1.36 (3H, t, *J* = 7.2 Hz), 3.06 (1H, dd, *J* = 6.6, 14.7 Hz) 3.33 (1H, dd, *J* = 4.2, 14.7 Hz), 4.30-4.41 (2H, m), 5.11 (1H, dd, *J* = 7.2, 3.9 Hz), 5.29 (1H, t, *J* = 4.8), 7.23-7.31 (5H, m). ^{13}C NMR (75 MHz, $CDCl_3$): δ 14.1, 37.4, 62.2, 95.8, 127.6, 128.7, 129.7, 133.7, 166.1, 166.4, 190.4. ESI – MS: m/z 261.33 $[M - H]^-$. **ESI-HRMS** : m/z $[M - H]^-$ calcd for $C_{14}H_{13}O_5$ 261.0768, found 261.0757.

(*S*)-3-Acetyl-5-benzyltetronic acid (10f). Starting from (*S*)-5-benzyl-1,3-dioxolane-2,4-dione **(6d)** (2.0 mmol, 0.38 g) and using ethyl acetoacetate **9** (4.0 mmol, 0.52 g) the title compound was obtained as a white solid (0.31 g, 67 % yield; Mp: 90–92 °C; $[\alpha]_D^{20}$ –179.7 (c 0.3, MeOH);

ν_{max}(KBr) 3120, 2950, 1745, 1642, 1594, 1187 cm^{-1}; ^{1}H NMR (300 MHz, $CDCl_3$): δ 2.30/2.34 (3H, two s), 2.88-2.94 (1H, m), 3.14 (1H, dd, *J* = 4.2, 14.1 Hz), 4.70 (0.4H, dd, *J* = 3.9, 6.9 Hz), 4.83 (0.6H, dd, *J* = 4.2, 6.6 Hz), 7.07-7.17 (5H, m), 11.57 (1H, br); ^{13}C NMR (75 MHz, $CDCl_3$): δ19.6/22.1, 37.1/37.2, 80.2/85.5, 99.1/101.2, 127.3/127.4, 128.6/128.7, 129.7, 134.1/134.6, 167.6/175.7, 188./199.1, 193.9/194.1. ESI – MS: m/z 231.25 $[M - H]^-$. **ESI-HRMS** : m/z $[M - H]^-$ calcd for $C_{13}H_{11}O_4$ 231.0652, found 231.0655.

(*S*)-3-Methoxycarbonyl-5-isopropyltetronic acid (10g). Starting from (S)-5-isopropyl-1,3-dioxolane-2,4-dione **(6e)** (2.0 mmol, 0.29 g) and using dimethyl malonate **7** (4.0 mmol, 0.53 g) the title compound was obtained as a white solid (0.31 g, 78 %). Mp: 80 – 82 °C (Lit.[19c] mp 57–58 °C); $[\alpha]_D^{20}$ –69.1 (c 1.0, MeOH), (Lit[19c] $[\alpha]_D^{20}$ –73.5). ^{1}H NMR (300 MHz, DMSO-d_6): δ 0.69 (3H, d, *J* = 6.9 Hz), 1.02 (3H, d, *J* = 6.9 Hz), 2.15 – 2.25 (1H, m), 3.66 (3H, s), 4.74 (1H, d, *J* = 3.0 Hz), 9.92 (1H, br). ^{13}C NMR (75 MHz, DMSO-d_6): δ 14.1, 19.0, 29.0, 50.8, 80.8, 92.8, 161.6, 168.8, 186.8. ESI – MS: m/z 199.25 $[M - H]^-$.

General procedure for the synthesis of compounds 14a-h. A solution of the appropriate aryl acetates **11-13** (4 mmol) in THF (2 mL) was added drop wise via a syringe over a period of 10 min to a solution of lithium diisopropylamide (LDA) 2.0 M solution in THF/hexane/ ethylbenzene (4 mmol, 2 ml) in THF (10 mL) at −78°C under nitrogen. The mixture was stirred for 45 min, then the appropriate 1,3-dioxolane-2,4-dione **(6c-d)** (2.0 mmol) in THF (2 mL) was added drop wise over 10 min. The reaction mixture was stirred for 1h at −78 °C and 1 h at room temperature, quenched with water (5 mL), and the THF evaporated in vacuum. The resulting aqueous layer was then washed with Et_2O (15 mL) and acidified with HCl 10% to pH=1 – 2 in an ice-water bath, to give the corresponding compounds (**14a-e)** as solid products, which were dried in vacuum over P_2O_5 for 2–3 hours. Otherwise **14a-e** were isolated by extraction of aqueous layer with CH_2Cl_2 (3 x 30 mL), the combined organic layers were dried over Na_2SO_4 and concentrated under reduced pressure, to give the final products.

(*S*)-3,5-Diphenyltetronic acid (14a). Starting from (S)-5-phenyl-1,3-dioxolane-2,4-dione **(6c)** (2.0 mmol, 0.36 g) and using ethyl phenyl acetate **11** (4.0 mmol, 0.66 g) the title compound was obtained as a white solid, (0.33 g, 65%). Mp: 207–209 °C, $[\alpha]_D^{20}$ –24.8 (c 0.5, MeOH), d.r. 97:3, e.e. 94%; ν_{max}(KBr) 2945, 2655, 1690, 1642, 1605, 1573, 1490 cm^{-1}; ^{1}H NMR (300 MHz, DMSO-d_6): δ 5.94 (1H, s), 7.27 (1H, t, *J* = 7.5 Hz), 7.38-7.47 (7H, m), 7.92 (2H, d, *J* = 7.5 Hz). ^{13}C NMR (75 MHz, DMSO-d_6): δ 78.2, 98.6, 126.6, 126.8, 128.1, 128.1, 128.8, 129.4, 130.3,

135.2, 172.1, 175.3. ESI – MS: m/z 251.17 [M – H]$^-$. **ESI-HRMS** : m/z [M – H]$^-$ calcd for $C_{16}H_{11}O_3$ 251.0703, found 251.0703.

(*S*)-3-(3-Methoxyphenyl)-5-phenyltetronic acid (14b). Starting from (*S*)-5-phenyl-1,3-dioxolane-2,4-dione **(6c)** (2.0 mmol, 0.36 g) and using ethyl 2-(3-methoxyphenyl)acetate **12** (4.0 mmol, 0.78 g) the title compound was obtained as a white solid (0.40 g, 70%). Mp: 168–170 °C, $[\alpha]_D^{20}$ –33.5 (c 0.5, MeOH), d.r. 97:3, e.e. 94%; ν_{max}(KBr) 2960, 2635, 1685, 1605, 1510, 1370 cm^{-1}; ^{1}H NMR (300 MHz, DMSO-d_6): δ 3.77 (3H, s), 5.93 (1H, s), 6.84-6.88 (1H, m), 7.30-7.48 (6H, m), 7.56-7.58 (2H, m); ^{13}C NMR (75 MHz, DMSO-d_6): δ 54.7, 78.2, 98.5, 112.1, 112.5, 119.3, 128.1, 128.9, 129.1, 129.4, 131.5, 135.1, 159.0, 172.0, 175.5. **ESI-HRMS**: m/z [M+H]$^+$ calcd for $C_{17}H_{15}O_4$ 283.0965, found 283.0963.

(*S*)-3-(4-Methoxyphenyl)-5-phenyltetronic acid (14c). Starting from (*S*)-5-phenyl-1,3-dioxolane-2,4-dione **(6c)** (2.0 mmol, 0.36 g) and using ethyl 2-(4-methoxyphenyl)acetate **13** (4.0 mmol, 0.78 g) the title compound was obtained as a white solid (0.41 g, 72%). Mp: 179–181 °C; $[\alpha]_D^{20}$ –34.8 (c 0.5, MeOH), d.r. 95:5, e.e. 90%; ν_{max}(KBr) 2950, 2644, 1680, 1645, 1610, 1523, 1385 cm^{-1}; ^{1}H NMR (300 MHz, DMSO-d_6): δ 3.77 (3H, s), 5.91 (1H, s), 6.99 (2H, d, *J* = 9.0 Hz), 7.37-7.46 (5H, m), 7.90 (2H, d, *J* = 9.0 Hz). ^{13}C NMR (75 MHz, DMSO-d_6): δ 55.1, 78.2, 98.6, 113.6, 122.6, 128.1, 128.2, 128.8, 129.4, 135.3, 157.9, 172.2,173.6. ESI – MS: m/z 281.17 [M – H]$^-$. **ESI-HRMS** : m/z [M + H]$^+$ calcd for $C_{17}H_{15}O_4$ 283.0965, found 261.0956

(*S*)-5-Benzyl-3-phenyltetronic acid (14d). Starting from (*S*)-5-benzyl-1,3-dioxolane-2,4-dione **(6d)** (2.0 mmol, 0.38 g) and using ethyl phenyl acetate **11** (4.0 mmol, 0.66 g) the title compound was obtained as a white solid (0.43 g, 80%). Mp: 228–230 °C; $[\alpha]_D^{20}$ –168.3 (c 0.2, MeOH); ν_{max}(KBr) 2982, 2620, 1682, 1605, 1573, 1564 cm^{-1}; ^{1}H NMR (300 MHz, DMSO-d_6): δ 2.94 (1H, dd, *J* = 7.2, 14.4 Hz), 3.38 (1H, dd, *J* = 3.0, 14.4 Hz), 5.15 (1H, dd, *J* = 3.0, 7.2 Hz), 7.17-7.35 (8H, m), 7.77 (2H, d, *J* = 7.8 Hz); ^{13}C NMR (75 MHz, DMSO-d_6): δ 37.4, 76.8, 99.1, 126.6, 126.7, 126.8, 128.1, 128.2, 129.5, 130.4, 135.7, 171.8, 175.5. ESI – MS: m/z 265.25 [M – H]$^-$. **ESI-HRMS** : m/z [M – H]$^-$ calcd for $C_{17}H_{13}O_3$ 265.0859, found 265.0859.

(*S*)-5-Benzyl-3-(4-methoxyphenyl)tetronic acid (14e). Starting from (*S*)-5-benzyl-1,3-dioxolane-2,4-dione **(6d)** (2.0 mmol, 0.38 g) and using ethyl 2-(4-methoxyphenyl)acetate **13** (4.0 mmol, 0.78 g) the title compound was obtained as a white solid (0.42 g, 70%). Mp: 212–214 °C; $[\alpha]_D^{20}$ –168.5 (c 0.5, MeOH); ν_{max}(KBr) 2980, 2640, 1645, 1612, 1520, 1164 cm^{-1}; ^{1}H NMR

(300 MHz, DMSO-d_6): δ 2.93 (1H, dd, *J* = 7.5, 14.4 Hz), 3.38 (1H, dd, *J* = 3.3, 14.4 Hz), 3.74 (3H, s), 5.13 (1H, dd, *J* = 3.3, 7.5 Hz), 6.89 – 6.94 (2H, m), 7.16-7.35 (5H, m), 7.70 – 7.75 (2H, m); ^{13}C NMR (75 MHz, DMSO-d_6): δ 37.4, 55.0, 76.6, 98.7, 113.5, 122.7, 126.6, 127.8, 128.1, 129.4, 135.8, 157.7, 171.8, 173.9. **ESI-HRMS** : m/z $[M+H]^+$ calcd for $C_{18}H_{17}O_4$ 297.1121, found 297.1132.

(*S*)-5-Isopropyl-3-phenyltetronic acid (14f). Starting from (*S*)-5-isopropyl-1,3-dioxolane-2,4-dione **(6e)** (2.0 mmol, 0.29 g) and using ethyl phenyl acetate (**11)** (4.0 mmol, 0.66 g) the title compound was obtained as a colorless crystalline solid after crystallization with diethyl ether/ petroleum ether (0.24 g, 55%). Mp: 132–134 °C; $[\alpha]_D^{20}$ –106.9 (c 0.3, MeOH); ν_{max}(KBr) 2950, 2680, 1710, 1605, 1520, 1163 cm^{-1}; ^{1}H NMR (300 MHz, $CDCl_3$): δ 0.83 (3H, d, *J* = 6.9 Hz), 1.15 (3H, d, *J* = 6.9 Hz), 2.35 – 245 (1H, m), 4.78 (1H, d, *J* = 2.7 Hz), 7.27 (1H, t, *J* = 7.2 Hz), 7.38 (2H, t, *J* = 7.2 Hz), 7.71 (2H, d, *J* = 7.2 Hz), 9.98 (1H, br s). ^{13}C NMR (75 MHz, $CDCl_3$): δ 14.3, 19.5, 29.9, 82.5, 102.4, 127.7, 127.8, 128.7, 128.8, 159.0, 175.5, 175.7. ESI – MS: m/z 217.22 $[M–H\ ]^-$.

(*S*)-5-Isopropyl-3-(3-methoxyphenyl)tetronic acid (14g). Starting from (*S*)-5-isopropyl-1,3-dioxolane-2,4-dione **(6e)** (2.0 mmol, 0.29 g) and using ethyl 2-(3-methoxyphenyl)acetate (**12)** (4.0 mmol, 0.78 g) the title compound was obtained as a white solid (0.28 g, 56%). Mp: 202–204 °C; $[\alpha]_D^{20}$ –88.5 (c 0.5, MeOH); ν_{max}(KBr) 2955, 2705, 1631, 1605, 1514, 1392 cm^{-1}; ^{1}H NMR (300 MHz, DMSO-d_6): δ 0.67 (3H, d, *J* = 6.9 Hz), 1.10 (3H, d, *J* = 6.9 Hz), 2.36 (1H, m), 3.75 (3H, s), 4.82 (1H, s), 6.82 (1H, d, *J* = 6.9 Hz), 7.28 (2H, t, *J* = 8.1 Hz), 7.50 (2H, m). ^{13}C NMR (75 MHz, DMSO-d_6): δ 13.4, 19.6, 28.7, 54.9, 80.2, 98.7, 111.9, 112.3, 119.1, 129.1, 131.7, 159.0, 173.2, 175.9. **ESI-HRMS**: m/z $[M+H]^+$ calcd for $C_{17}H_{14}O_4$ 249.1121, found 249.1120.

(*S*)-5-Isopropyl-3-(4-methoxyphenyl)tetronic acid (14h). Starting from (*S*)-5-isopropyl-1,3-dioxolane-2,4-dione **(6e)** (2.0 mmol, 0.29 g) and using ethyl 2-(4-methoxyphenyl)acetate (**13)** (4.0 mmol, 0.78 g) the title compound was obtained as a white solid (0.30 g, 60%). Mp: 164–166 °C; $[\alpha]_D^{20}$ –97.6 (c = 0.5 in MeOH); ν_{max}(KBr) 3067, 1660, 1608, 1516, 1374 cm^{-1}; ^{1}H NMR (300 MHz, $CDCl_3$ / drop DMSO-d_6): δ 0.79 (3H, d, *J* = 6.9 Hz), 1.14 (3H, d, *J* = 6.9 Hz), 2.30 – 2.36 (1H, m), 3.78 (3H, s), 4.67 (1H, d, *J* = 2.4 Hz), 6.89 (2H, d, *J* = 8.4 Hz), 7.77 (2H, d, *J* = 8.4 Hz), 10.82 (1H, br s). ^{13}C NMR (75 MHz, $CDCl_3$/drop DMSO-d_6): δ 14.0, 19.6, 29.7,

55.3, 81.7, 101.2, 113.8, 122.3, 129.0, 158.6, 173.8, 174.5. ESI – MS: m/z 247.17 $[M - H]^-$. **ESI-HRMS**: m/z $[M+H]^+$ calcd for $C_{17}H_{14}O_4$ 249.1121, found 249.1120.

Procedure for the synthesis of (R,S)-2,2-dimethyl-5-phenyl-1,3-dioxolane-4-one (16). Prepared according literature procedure[32a] with some modifications. To a solution of (*R,S*)-mandelic acid[32a,b] (10.0 g, 65.6 mmol) in acetone (30 mL) was added dropwise c.H_2SO_4 (6.33 g, 65.6 mmol) at −10°C. The reaction mixture was allowed to stir for 1h at this temperature, then poured into a solution of Na_2CO_3 (16.67 g) in water (60 mL) and crushed ice (60 g). The precipitated white solid was collected by filtration, and dissolved in dichloromethane (60 mL). The solution dried over Na_2SO_4, filtered and the solvent removed under reduced pressure. The oily residue was solidified to a white solid (10.08 g, 80%), after extensive drying under high vacuum (2h) over P_2O_5. Mp: 51−53 °C (Lit.[38] mp 50−52 °C) ; ^{1}H NMR (300 MHz, $CDCl_3$): δ 1.75 (3H, s), 1.80 (3H, s), 5.40 (1H, s), 7.37-7.49 (5H, m); ^{13}C NMR (75 MHz, $CDCl_3$): δ, 27.2, 27.3, 76.0, 111.0, 126.5, 128.8, 129.0, 134.5, 171.5.

General procedure for the preparation of compounds 17, 18.[31] To a solution of freshly distilled diisopropylamine (1.27 g, 12.5 mmol) in anhydrous THF (25 mL) was added dropwise a solution of *n*-BuLi 2.5 M in hexane (4.4 mL, 11.0 mmol) at 0 ºC, under nitrogen, then the solution was stirred for 20–30 min, and cooled to –78 ºC. After 5 min a solution of 2,2-dimethyl-5-phenyl-1,3-dioxolan-4-one **(16)**, (1.92 g, 10.0 mmol) in THF (10 mL) was added dropwise. The resulting solution was stirred at –78 ºC for 30–40 min, then a solution of the corresponding alkyl halide (1.25 mmol) in THF (5 mL) was added dropwise. The reaction mixture was warmed to r t. and stirred for 2–3 h. The progress of the reaction was monitored by TLC. The reaction mixture was quenched by addition of sat aqueous NH_4Cl (30 mL), extracted with diethylether (3 x 50 mL) and the combined organic layers washed with 50 ml aqueous $Na_2S_2O_3$ (5%), brine, dried ($NaSO_4$), filtered and concentrated under vacuum.

(*R,S*)-2,2,5-trimethyl-5-phenyl-1,3-dioxolane-4-one (17). Starting from 2,2-dimethyl-5-phenyl-1,3-dioxolane-4-one **(16)**, (1.92 g, 10.0 mmol), and iodomethane (1.56 g, 11.0 mmol), the title compound was isolated after drying under high vacuum for 2 h over P_2O_5 and used without any further purification (1.85 g, 90%).[32b] ^{1}H NMR (300 MHz, $CDCl_3$) δ 1.45 (3H, s), 1.70 (3H, s), 1.76 (3H, s), 7.31−7.40 (3H, m), 7.61–7.64 (2H, m); ^{13}C NMR (75 MHz, $CDCl_3$) δ 27.8, 28.6, 29.4, 80.7, 110.2, 124.7, 128.2, 128.6, 141.1.

(*R,S*)-5-butyl-2,2-dimethyl-5-phenyl-1,3-dioxolane-4-one (18). Starting from 2,2-dimethyl-5-phenyl-1,3-dioxolane-4-one **(16)**, (1.92 g, 10.0 mmol), and iodobutane (2.02 g, 11.0 mmol), the title compound was isolated after purification by column chromatography on siliga gel (petroleum ether/diethylether (95:5), R_f= 0.65) and dried under high vacuum for 2 h over P_2O_5 (2.3 g, 93%).[39] ^{1}H NMR (300 MHz, $CDCl_3$) δ 0.87 (3H, t, *J* = 6.9 Hz), 1.70 (3H, s), 1.25-1.36 (4H, m), 1.41 (3H, s), 1.69 (3H, s), 1.87-2.03 (2H, m), 7.27-7.38 (3H, m), 7.59-7.63 (2H, m); ^{13}C NMR (75 MHz, $CDCl_3$)δ 13.9, 22.6, 26.3, 27.9, 41.8, 83.7, 110.1, 124.9, 128.0, 128.5, 140.3, 173.4.

Synthesis of (*R,S*)-2-hydroxy-2-phenylalkanoic acids 19, 20. Compounds 19 and 20 were synthesized as previously described according to the literature procedure,[32a,b] and used in the next step without any further purrification.

(*R,S*)-2-hydroxy-2-phenylpropanoic acid (19).[32b] The title compound was isolated as white solid, (97% yield). Mp: 114–116 °C (Lit.[39] mp 115–116 °C); ^{1}H NMR (300 MHz, $CDCl_3$) δ 1.75 (3H, s), 7.44-7.48 (3H, m), 7.52-7.55 (2H, m); ^{13}C NMR (75 MHz, $CDCl_3$) δ 26.8, 75.8, 125.3, 128.3, 128.6, 141.9, 180.2.

(*R,S*)-2-hydroxy-2-phenylhexanoic acid (20).[32c] The title compound was isolated as white solid, (98% yield). Mp: 100–102 °C (Lit.[32c] mp 101–102 °C); ^{1}H NMR (300 MHz, $CDCl_3$) δ 0.90 (3H, t, *J* = 6.9 Hz), 1.26-1.45 (4H, m), 2.00-2.10 (1H, m), 2.27 (1H, m), 7.28-7.40 (3H, m), 7.60-7.64 (2H, m); ^{13}C NMR (75 MHz, $CDCl_3$) δ 14.0, 22.9, 25.8, 39.5, 78.5, 125.6, 128.1, 128.5, 141.1, 180.8.

General procedure for the synthesis of 1,3-dioxolane-2,4-diones (24a-c).[37a,b] To a solution of the appropriate α-hydroxy acid **21-23** (7 mmol) and dry triethylamine (14 mmol, 1.42 g) in anhydrous THF (16 mL), was added dropwise a solution of triphosgene (4.69 mmol, 1.39 g) in THF (3.5 mL) over 30 min, and the resulting mixture was refluxed overnight. After the reaction mixture was cooled to r.t., diethylether (50 mL) was added, the hydrochloride salt of triethylamine was filtered off, and the solvents were evaporated under reduced pressure. The 1,3-dioxolane-2,4-diones **24a-c** were isolated in an brownish oily form, dried under high vacuum for 2 h over P_2O_5 and were used immediately to the next step without any further purification.

(*R,S*)-5-Methyl-5-phenyl-1,3-dioxolane-2,4-dione (24a). Starting from the α-hydroxy acid **21** (7 mmol, 1.16 g) the title compound was obtained as an oil (1.35 g, quantitative yield). ^{1}H NMR

(300 MHz, $CDCl_3$) δ 2.03 (3H, s), 7.44-7.48 (3H, m), 7.52-7.55 (2H, m); ^{13}C NMR (75 MHz, $CDCl_3$): δ 25.7, 87.1, 124.3, 129.4, 130.1, 134.6, 147.5, 168.5.

(*R,S*)-5-Butyl-5-phenyl-1,3-dioxolane-2,4-dione (24b). Starting from the α-hydroxy acid **22** (7 mmol, 1.46 g) the title compound was obtained as an oil (1.74 g, quantitative yield); ^1H NMR (300 MHz, $CDCl_3$) δ 0.91 (3H, t, *J* = 7.2 Hz), 1.3-1.45 (4H, m), 2.22-2.29 (2H, m), 7.43-7.47 (3H, m), 7.52-7.56 (2H, m); ^{13}C NMR (75 MHz, $CDCl_3$): δ 13.7, 22.2, 25.3, 39.2, 90.2, 124.4, 129.3, 129.8, 134.0, 147.8, 168.3.

5,5-Dimethyl-1,3-dioxolane-2,4-dione (24c). Starting from the α-hydroxy acid **23** (7 mmol, 0.73 g) the title compound was obtained as an oil (1.01 g, quantitative yield). ^1H NMR (300 MHz, $CDCl_3$) δ 1.69 (6H, s); ^{13}C NMR (75 MHz, $CDCl_3$): δ 23.7, 84.8, 147.6, 170.3.

General procedure for the synthesis of tetronic acids 25a-c. The final compounds **25a-c** were prepared as described in general procedure for compounds **14a-h** with some modifications, using lithium diisopropylamide 2.0 M solution in THF/hexane/ethylbenzene (9 mmol, 4.5 mL) in THF (22.5 mL), ethyl phenylacetate (9 mmol, 1.48 g) and the appropriate 1,3-dioxolane-2,4-dione **24a-c** (3 mmol). Tetronic acids **25a-c** were isolated by extraction of the acidified aqueous layer with ethyl acetate (3 x 30 mL), the combined organic layers were dried over Na_2SO_4 and concentrated under reduced pressure. The crude oily products were purified by silica column chromatography, otherwise by crystallization, and dried under high vacuum for 2 h over P_2O_5.

(*R,S*)-5-Methyl-3,5-phenyltetronic acid (25a). Starting from (*R,S*)-5-methyl-5-phenyl-1,3-dioxolane-2,4-dione **(24a)** (3.0 mmol, 0.58 g), the title compound was obtained as a white solid after purification by column chromatography (silica gel, petroleum ether/ethyl acetate/acetic acid, 70:28:2), (0.54 g, 67% yield). Mp: 165–167 °C; ν_{max}(KBr) 2960, 1775, 1680, 1605, 1545, cm^{-1}; ^1H NMR (300 MHz, $CDCl_3$) δ 1.95 (3H, s), 7.23 (1H, t, *J* = 7.8 Hz), 7.32-7.38 (5H, m), 7.50 (2H, d, *J* = 8.1 Hz), 7.80 (2H, d, *J* = 8.1 Hz). ^{13}C NMR (75 MHz, $CDCl_3$): δ, 23.8, 83.6, 101.0, 125.7, 128.0, 128.6, 128.77, 128.81, 128.9, 137.8, 172.9, 176.9. **ESI-HRMS** : m/z $[M+Na]^+$ calcd for $C_{17}H_{14}NaO_3$ 289.0835, found 289.0828.

(*R,S*)-5-Butyl-3,5-phenyltetronic acid (25b). Starting from (*R,S*)-5-butyl-5-phenyl-1,3-dioxolane-2,4-dione **(24b)** (3.0 mmol, 0.70 g), the title compound was obtained as a white crystalline solid after purification by crystallization with hexane/diethylether at −18° C, (0.51 g, 55% yield). Mp: 127–129 °C; ν_{max}(KBr) 2950, 1780, 1682, 1605, 1550 cm^{-1}; ^1H NMR (300 MHz, DMSO-d_6): δ 0.88 (3H, t, *J* = 6.9 Hz), 1.32 (4H, m), 2.14-2.34 (2H, m), 7.20-7.42 (6H, m),

7.48-7.53 (4H, m), 8.96 (1H, br s); ^{13}C NMR (75 MHz, $CDCl_3$): δ 22.3, 25.4, 36.6, 86.3, 101.8, 125.5, 128.0, 128.1, 128.4, 128.6, 128.7, 128.8, 138.0, 173.3, 175.9. **ESI-HRMS** : m/z $[M+Na]^+$ calcd for $C_{20}H_{20}NaO_3$ 331.1305, found 331.1297.

(*R,S*)-5,5-Dimethyl-3-phenyltetronic acid (25c). Starting from 5,5-dimethyl-1,3-dioxolane-2,4-dione **(24c)** (3.0 mmol, 0.39 g), the title compound was obtained as a white crystalline solid after purification by crystallization with hexane/diethylether at −18 °C, (0.24 g, 62%). Mp: 208–211 °C (Lit.[40] m.p. 210–213 °C); ^{1}H NMR (300 MHz, $CDCl_3$/DMSO d_6): δ 1.53 (6H, s), 7.20 (1H, pt), 7.33 (2H, pt), 7.81 (2H, pd); ^{13}C NMR (75 MHz, $CDCl_3$): δ 14.0, 80.3, 98.8, 126.9, 127.9, 128.2, 130.3, 172.1, 178.9. ESI–MS: m/z 203.16 $[M - H]^-$

General procedure for the synthesis of tetronic acids 26a-c. Final compounds **26a-c** were prepared as described in general procedure for compounds **10a-g**, with some modifications, using diethylmalonate (**8)** (0.96 g, 6 mmol,), sodium hydride (0.24 g, 6 mmol, 60% in oil) in THF (15 mL), and appropriate 1,3-dioxolane-2,4-dione **(24a-c)** (2 mmol) in THF (3 mL). The oily crude products were purified by column chromatography on silica gel otherwise with crystallization, and dried under high vacuum for 2 h over P_2O_5.

(*R,S*)-3-Ethoxycarbonyl-5-methyl-5-phenyltetronic acid (26a). Starting from (*R,S*)-5-methyl-5-phenyl-1,3-dioxolane-2,4-dione **(24a)** (3.0 mmol, 0.58 g), the title compound was isolated as an orange crystalline solid after purification by crystallization with hexane/ dichloromethane at −18 °C, (0.39 g, 50% yield). Mp: 90–92 °C; ν_{max}(KBr) 3100, 2705, 1720, 1612, 1540 cm^{-1}; ^{1}H NMR (300 MHz, $CDCl_3$/ drop DMSO-d_6): δ 1.39 (3H, t, *J* = 6.9 Hz), 1.83 (3H, s), 4.41 (2H, q, *J* = 6.9 Hz), 7.33-7.43 (3H, m), 7.48-7.54 (2H, m), 10.49 (1H, br s); ^{13}C NMR (75 MHz, $CDCl_3$): δ 14.3, 24.8, 62.3, 83.3, 93.0, 125.1, 128.9, 129.1, 137.2, 165.6, 166.9, 193.4. **ESI-HRMS** : m/z $[M+Na]^+$ calcd for $C_{14}H_{14}NaO_5$ 285.0733, found 285.0730.

(*R,S)*-3-Ethoxycarbonyl-5-butyl-5-phenyltetronic acid (26b). Starting from (R,S)-5-butyl-5-phenyl-1,3-dioxolane-2,4-dione **(24b)** (3.0 mmol, 0.70 g), the title compound was isolated as a solid after purification by column chromatography (silica gel, dichloromethane/methanol/acetic acid (95:5:5), (0.39 g, 45%). ν_{max}(KBr) 3150, 2705, 1750, 1692, 1625, 1540 cm^{-1}; NMR (300 MHz, DMSO-d_6 recorded at 85°C): δ 0.83 (3H, t, *J* = 6.9 Hz), 1.14-1.27 (7H, m), 1.90 (2H, t, *J* = 3.6 Hz), 4.00 (2H, q, *J* = 6.9 Hz), 7.19-7.31 (3H, m), 7.48 (2H, d, *J* = 7.5 Hz); ^{13}C NMR (75 MHz, $CDCl_3$): δ NMR (75 MHz, DMSO-d_6): δ 13.9, 14.6, 22.2, 25.0/25.3, 36,8/37.3, 58.0/59.7,

83.0/85.5, 124.8, 126.9, 127.8/128.0, 139.9/141.0, 166.0, 172.5, 194.8. **ESI-HRMS** : m/z [M+ H]$^+$ calcd for $C_{17}H_{21}O_5$ 305.1384, found 305.1373.

(*R,S)*-5,5-Dimethyl-3-ethoxycarbonyltetronic acid (26c). Starting from 5,5-dimethyl-1,3-dioxolane-2,4-dione **(24c)** (3.0 mmol, 0.39 g), the title compound was solidified after refrigerated overnight, triturated with petroleum ether and isolated as white solid (0.40 g, 66% yield). Mp: 82–84 °C (Lit.[41] m.p. 83–84 °C); ^{1}H NMR (300 MHz, $CDCl_3$/drops DMSO-d_6): δ 1.37 (3H, t, *J* = 6.9 Hz), 1.54 (6H, s), 4.38 (2H, q, *J* = 6.9 Hz); ^{13}C NMR (75 MHz, $CDCl_3$/drops DMSO-d_6): δ 14.2, 23.9, 62.1, 80.8, 93.3, 165.6, 166.7, 194.6. ESI – MS: m/z 199.24 [M – H]$^-$

(*2S,5S*)-*cis*-2-*tert*-butyl-5-phenyl-1,3-dioxolane-4-one (27). Compound **27** was synthesized according to the literature procedure [35] starting from (*S*)-mandelic acid and pivalaldehyde, and used in the next step without any further purrification. Mp: 138–140 °C (Lit.[35] m.p. 140 °C), $[\alpha]_D^{20}$ +87.4 (c 1.2, chloroform), (Lit.[35] $[\alpha]_D^{20}$ + 88.7 (c 1.2, chloroform); ^{1}H NMR (300 MHz, DMSO-d_6) δ 1.01 (9H, s), 5.47 (1H, d, *J* = 1.5 Hz), 5.56 (1H, d, *J* = 1.5 Hz), 7.41-7.45 (5H, m); ^{13}C NMR (75 MHz, DMSO-d_6) δ 23.3, 33.9, 76.5, 108.2, 127.4, 128.7, 129.1, 134.2, 172.0.

(*2S,5S*)-2-*tert*-butyl-5-methyl-5-phenyl-1,3-dioxolane-4-one (28). To a solution of (*2S,5S*)-*cis*-2-*tert*-butyl-5-phenyl-1,3-dioxolane-4-one **(27)** (0.7 g, 3.18 mmol) in anhydrous THF (18 mL) was added dropwise at −78 ºC a solution of lithium diisopropylamide (2.0 M in THF/hexane/ ethylbenzene), (1.75 mL, 3.5 mmol). The resulting solution was stirred at –78 ºC for 30–40 min and then a solution of iodomethane (0.68 g, 4.77 mmol) in THF (1 mL) was added dropwise. The reaction mixture was allowed to warm to 0 ºC and stirred for 2–3 h. The progress of the reaction was monitored by TLC. After this time, the reaction mixture was poured into satd aqueous NH_4Cl (30 mL), extracted with Et_2O (3 x 30 mL), the combined organic layers washed with a 5% aqueous $Na_2S_2O_3$ (50 mL), brine, dried (Na_2SO_4) and concentrated under reduced pressure. The crude product was purified by column chromatography on silica gel (petroleum ether/Et_2O 95:5) to afford the compound **28** as colorless oil (0.64 g, 87%, mixture of diastereomers d.r. 93:7).[35] ^{1}H NMR (300 MHz, $CDCl_3$) δ 1.03 (9H, s), 1.76 (3H, s), 5.39 (1H, s), 7.31-7.46 (3H, m), 7.63-7.66 (2H, m); ^{13}C NMR (75 MHz, $CDCl_3$) δ 23.5, 23.8, 34.8, 79.9, 99.4, 107.8, 125.0, 125.9, 128.3, 139.3, 174.34.

(*S*)-2-Hydroxy-2-phenylpropanoic acid (29).

The title compound was sythesized according to the general procedure for the preparation of compounds **19** and **20**; m.p. 111–113°C (Lit.[36] m.p. 112−114 °C), $[\alpha]_D^{20}$ +36.5 (c 0.2, ethanol), (Lit.[36] $[\alpha]_D^{20}$ + 36.0 (c 0.99, ethanol); ^{1}H NMR (300 MHz, $CDCl_3$/DMSO-d_6) δ 2.92 (1H, dd, *J* = 7.2, 13.8 Hz), 3.14 (1H, dd, *J* = 3.9, 13.8 Hz), 4.38 (1H, dd, *J* = 7.2, 3.9 Hz), 7.15 (5H, m); ^{13}C NMR (75 MHz, $CDCl_3$ / DMSO-d_6) δ 40.3, 70.9, 126.6, 128.2, 129.6, 137.0, 176.2.

(*S*)-5-Methyl-5-phenyl-1,3-dioxolane-2,4-dione (30). Compound **30** was synthesized according to the method for the synthesis of compounds **24a−c**. Starting from α-hydroxy acid **29** (3 mmol, 0.50 g) the title compound was obtained as a brown oil (0.58 g, quantitative yield) which was used to the next step without any further purification. ^{1}H NMR (300 MHz, $CDCl_3$): δ 2.03 (3H, s), 7.4–7.47 (3H, m), 7.51–7.55 (2H, m). ^{13}C NMR (75 MHz, $CDCl_3$): δ 25.7, 87.1, 124.3, 129.4, 130.1, 134.6, 147.5, 168.5.

(*S*)-5-methyl-3,5-phenyltetronic acid (31). Compound **31** was synthesized according to general method for the synthesis of compounds **25a−c.** Starting from (S)-5-methyl-5-phenyl-1,3-dioxolane-2,4-dione **(30)** (3.0 mmol, 0.58 g), the title compound was obtained as a white solid after purification by column chromatography (silica gel, petroleum ether/ethyl acetate/acetic acid, 70:28:2), (0.50 g, 62% yield). M.p. 166–168°C $[\alpha]_D^{20}$ −6.3 (c 0.2, methanol), d.r. 99:1, e.e. 98%; ν_{max}(KBr) 2955, 1780, 1684, 1605, 1552, cm^{-1}; ^{1}H NMR (300 MHz, DMSO-d_6) δ 1.93 (3H, s), 7.24 (1H, t, *J* = 7.2 Hz), 7.36–7.48 (6H, m), 7.80 (2H, d, *J* = 7.5 Hz). ^{13}C NMR (75 MHz, $CDCl_3$/drop DMSO-d_6) δ, 23.1, 82.8, 99.6, 126.1, 127.1, 128.1, 128.3, 128.5, 128.6, 129.9, 138.6, 172.6, 177.8. **ESI-HRMS** : m/z $[M–H]^-$ calcd for $C_{17}H_{13}O_3$ 265.0859, found 265.0859.

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checkCIF/PLATON report

Structure factors have been supplied for datablock(s) kp460

THIS REPORT IS FOR GUIDANCE ONLY. IF USED AS PART OF A REVIEW PROCEDURE FOR PUBLICATION, IT SHOULD NOT REPLACE THE EXPERTISE OF AN EXPERIENCED CRYSTALLOGRAPHIC REFEREE.

No syntax errors found. CIF dictionary Interpreting this report

Datablock: kp460

```
Bond precision:  C-C = 0.0020 A          Wavelength=0.71073

Cell:          a=5.4989(5)       b=8.1210(8)      c=13.8310(13)
               alpha=93.570(2)   beta=92.751(2)   gamma=93.963(2)
Temperature:   150 K
```

	Calculated	Reported
Volume	614.12(10)	614.12(10)
Space group	P -1	P -1
Hall group	-P 1	-P 1
Moiety formula	C14 H14 O5	C14 H14 O5
Sum formula	C14 H14 O5	C14 H14 O5
Mr	262.25	262.25
Dx,g cm-3	1.418	1.418
Z	2	2
Mu (mm-1)	0.108	0.108
F000	276.0	276.0
F000’	276.17	
h,k,lmax	7,10,17	7,10,17
Nref	2827	2814
Tmin,Tmax	0.990,0.998	0.775,0.862
Tmin’	0.977	

```
Correction method= MULTI-SCAN

Data completeness= 0.995          Theta(max)= 27.499

R(reflections)= 0.0416( 2218)     wR2(reflections)= 0.1026( 2814)

S = 1.036                  Npar= 175
```

The following ALERTS were generated. Each ALERT has the format
test-name_ALERT_alert-type_alert-level.
Click on the hyperlinks for more details of the test.

Alert level G

```
PLAT154_ALERT_1_G The su's on the Cell Angles are Equal .........    0.00200 Degree
PLAT180_ALERT_4_G Check Cell Rounding: # of Values Ending with 0 =          3
PLAT793_ALERT_4_G The Model has Chirality at C7      .............          S Verify
PLAT910_ALERT_3_G Missing # of FCF Reflections Below Th(Min) .....          1 Report
PLAT912_ALERT_4_G Missing # of FCF Reflections Above STh/L=  0.600         11 Note
```

```
   0 ALERT level A = Most likely a serious problem - resolve or explain
   0 ALERT level B = A potentially serious problem, consider carefully
   0 ALERT level C = Check. Ensure it is not caused by an omission or oversight
   5 ALERT level G = General information/check it is not something unexpected

   1 ALERT type 1 CIF construction/syntax error, inconsistent or missing data
   0 ALERT type 2 Indicator that the structure model may be wrong or deficient
   1 ALERT type 3 Indicator that the structure quality may be low
   3 ALERT type 4 Improvement, methodology, query or suggestion
   0 ALERT type 5 Informative message, check
```

It is advisable to attempt to resolve as many as possible of the alerts in all categories. Often the minor alerts point to easily fixed oversights, errors and omissions in your CIF or refinement strategy, so attention to these fine details can be worthwhile. In order to resolve some of the more serious problems it may be necessary to carry out additional measurements or structure refinements. However, the purpose of your study may justify the reported deviations and the more serious of these should normally be commented upon in the discussion or experimental section of a paper or in the "special_details" fields of the CIF. checkCIF was carefully designed to identify outliers and unusual parameters, but every test has its limitations and alerts that are not important in a particular case may appear. Conversely, the absence of alerts does not guarantee there are no aspects of the results needing attention. It is up to the individual to critically assess their own results and, if necessary, seek expert advice.

Publication of your CIF in IUCr journals

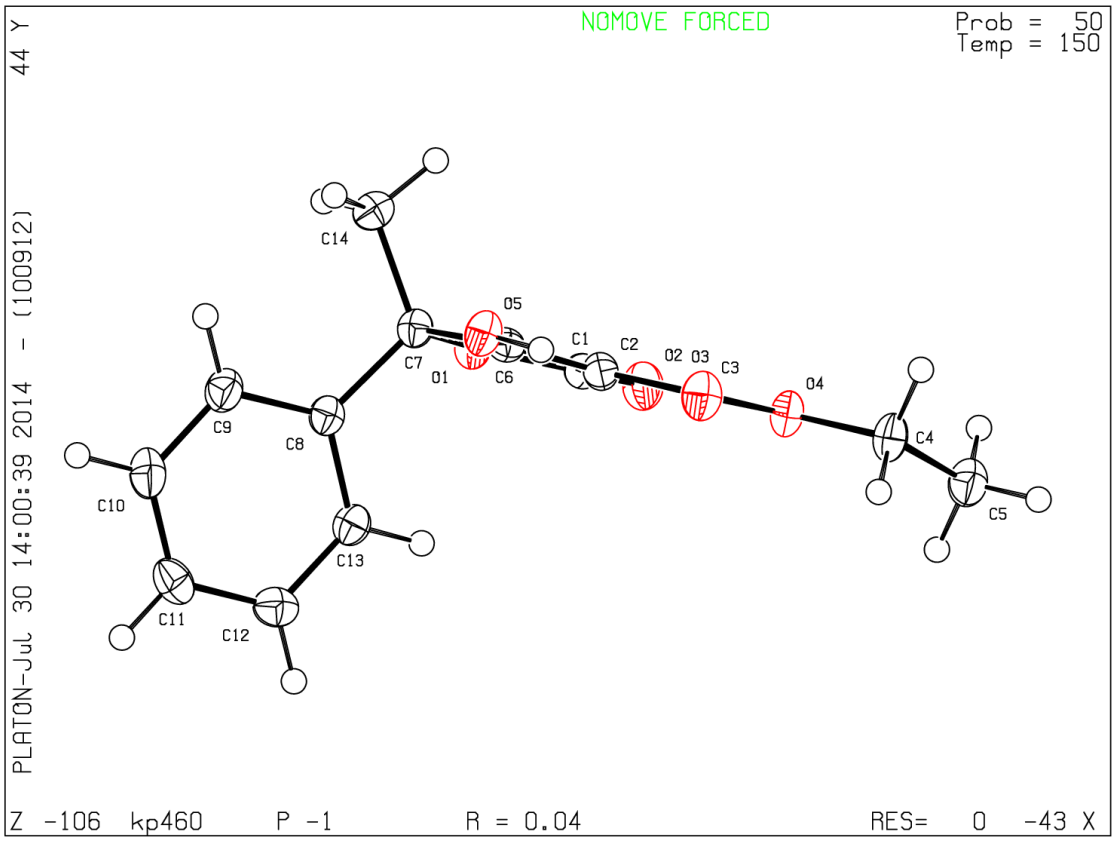
A basic structural check has been run on your CIF. These basic checks will be run on all CIFs submitted for publication in IUCr journals (*Acta Crystallographica*, *Journal of Applied Crystallography*, *Journal of Synchrotron Radiation*); however, if you intend to submit to *Acta Crystallographica Section C* or *E*, you should make sure that full publication checks are run on the final version of your CIF prior to submission.

Publication of your CIF in other journals

Please refer to the *Notes for Authors* of the relevant journal for any special instructions relating to CIF submission.

PLATON version of 24/07/2014; check.def file version of 24/07/2014

Datablock kp460 - ellipsoid plot



checkCIF/PLATON report

Structure factors have been supplied for datablock(s) kp596

THIS REPORT IS FOR GUIDANCE ONLY. IF USED AS PART OF A REVIEW PROCEDURE FOR PUBLICATION, IT SHOULD NOT REPLACE THE EXPERTISE OF AN EXPERIENCED CRYSTALLOGRAPHIC REFEREE.

No syntax errors found. CIF dictionary Interpreting this report

Datablock: kp596

Bond precision: C-C = 0.0025 A Wavelength=0.71073

Cell: a=9.1910(5) b=10.1637(5) c=12.5040(7)
alpha=90 beta=90 gamma=90
Temperature: 150 K

	Calculated	Reported
Volume	1168.06(11)	1168.06(11)
Space group	P 21 21 21	P 21 21 21
Hall group	P 2ac 2ab	P 2ac 2ab
Moiety formula	C13 H14 O3	C13 H14 O3
Sum formula	C13 H14 O3	C13 H14 O3
Mr	218.24	218.24
Dx,g cm-3	1.241	1.241
Z	4	4
Mu (mm-1)	0.088	0.088
F000	464.0	464.0
F000’	464.25	
h,k,lmax	11,13,16	11,13,16
Nref	2672[1547]	2672
Tmin,Tmax	0.983,0.986	0.779,0.862
Tmin’	0.980	

Correction method= MULTI-SCAN

Data completeness= 1.73/1.00 Theta(max)= 27.500

R(reflections)= 0.0313(2453) wR2(reflections)= 0.0826(2672)

S = 1.021 Npar= 149

The following ALERTS were generated. Each ALERT has the format
test-name_ALERT_alert-type_alert-level.
Click on the hyperlinks for more details of the test.

Alert level G

PLAT791_ALERT_4_G The Model has Chirality at C10 ..... S Verify

---

0 **ALERT level A** = Most likely a serious problem - resolve or explain
0 **ALERT level B** = A potentially serious problem, consider carefully
0 **ALERT level C** = Check. Ensure it is not caused by an omission or oversight
1 **ALERT level G** = General information/check it is not something unexpected

0 ALERT type 1 CIF construction/syntax error, inconsistent or missing data
0 ALERT type 2 Indicator that the structure model may be wrong or deficient
0 ALERT type 3 Indicator that the structure quality may be low
1 ALERT type 4 Improvement, methodology, query or suggestion
0 ALERT type 5 Informative message, check

It is advisable to attempt to resolve as many as possible of the alerts in all categories. Often the minor alerts point to easily fixed oversights, errors and omissions in your CIF or refinement strategy, so attention to these fine details can be worthwhile. In order to resolve some of the more serious problems it may be necessary to carry out additional measurements or structure refinements. However, the purpose of your study may justify the reported deviations and the more serious of these should normally be commented upon in the discussion or experimental section of a paper or in the "special_details" fields of the CIF. checkCIF was carefully designed to identify outliers and unusual parameters, but every test has its limitations and alerts that are not important in a particular case may appear. Conversely, the absence of alerts does not guarantee there are no aspects of the results needing attention. It is up to the individual to critically assess their own results and, if necessary, seek expert advice.

Publication of your CIF in IUCr journals

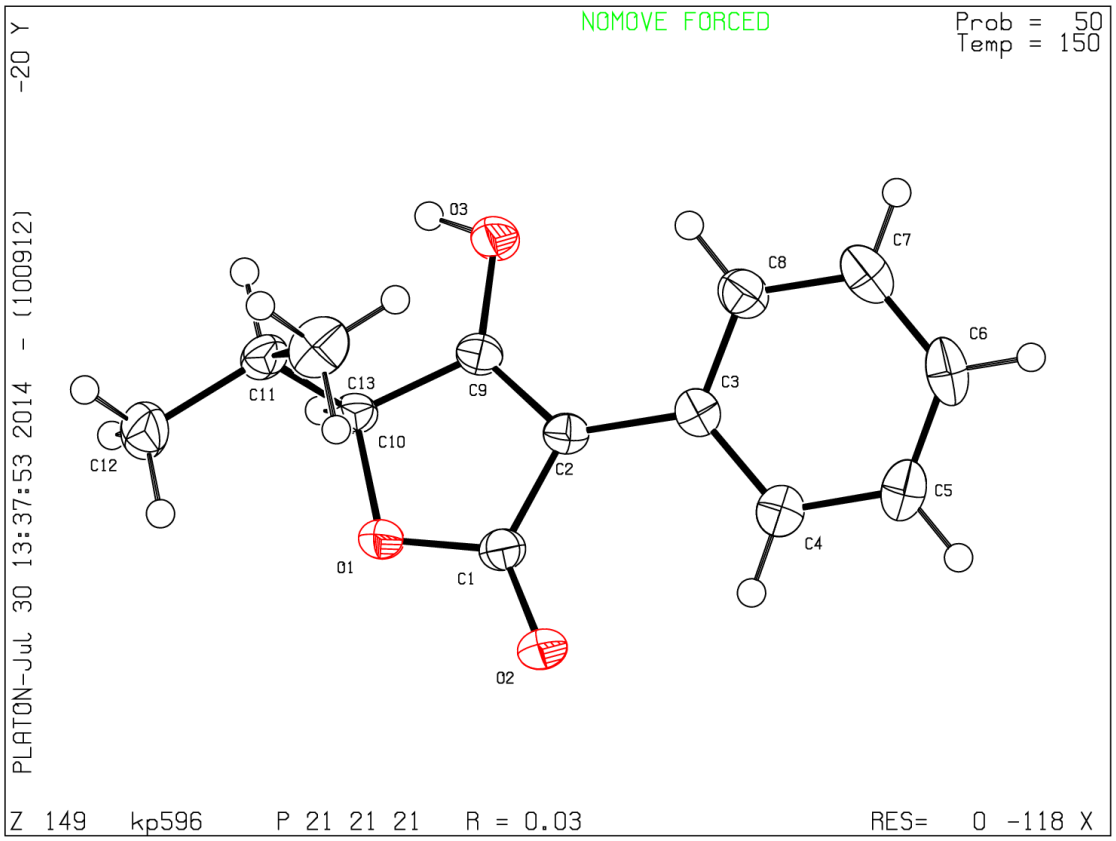
A basic structural check has been run on your CIF. These basic checks will be run on all CIFs submitted for publication in IUCr journals (*Acta Crystallographica, Journal of Applied Crystallography, Journal of Synchrotron Radiation*); however, if you intend to submit to *Acta Crystallographica Section C* or *E*, you should make sure that full publication checks are run on the final version of your CIF prior to submission.

Publication of your CIF in other journals

Please refer to the *Notes for Authors* of the relevant journal for any special instructions relating to CIF submission.

PLATON version of 24/07/2014; check.def file version of 24/07/2014

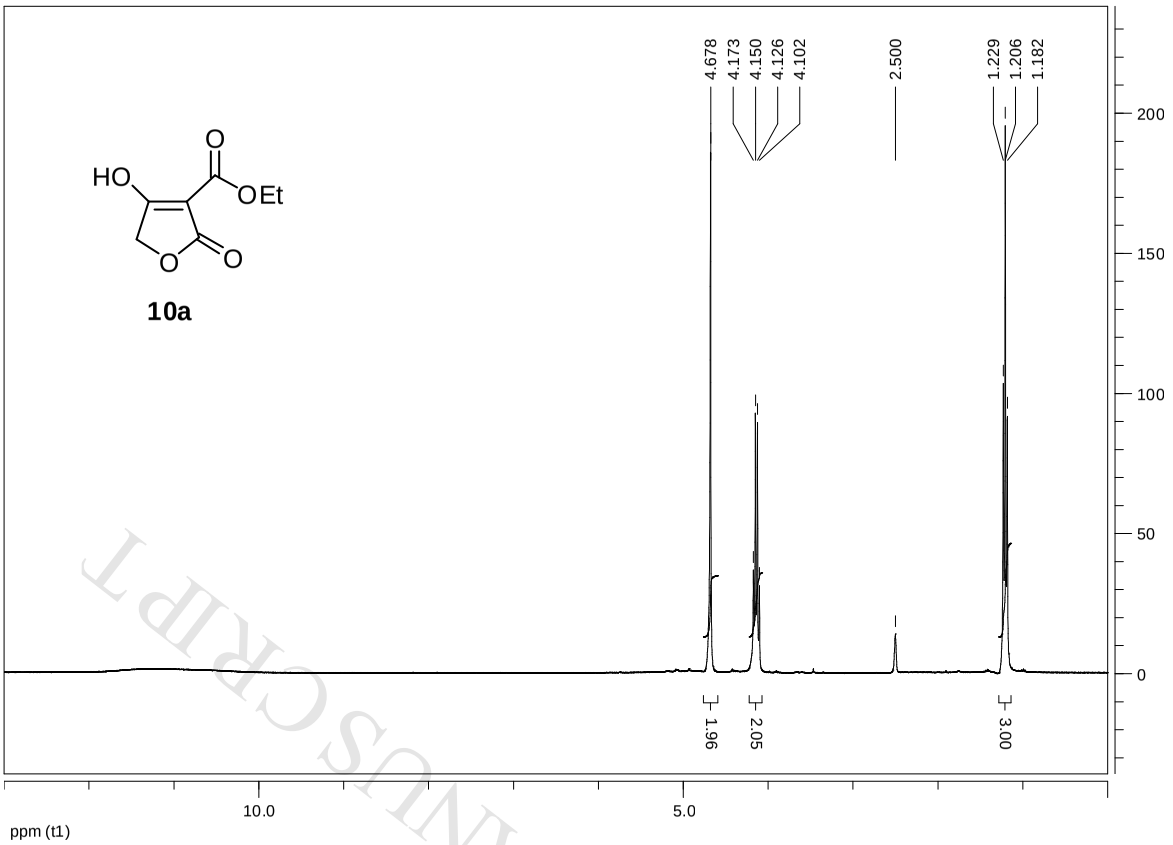
Datablock kp596 - ellipsoid plot

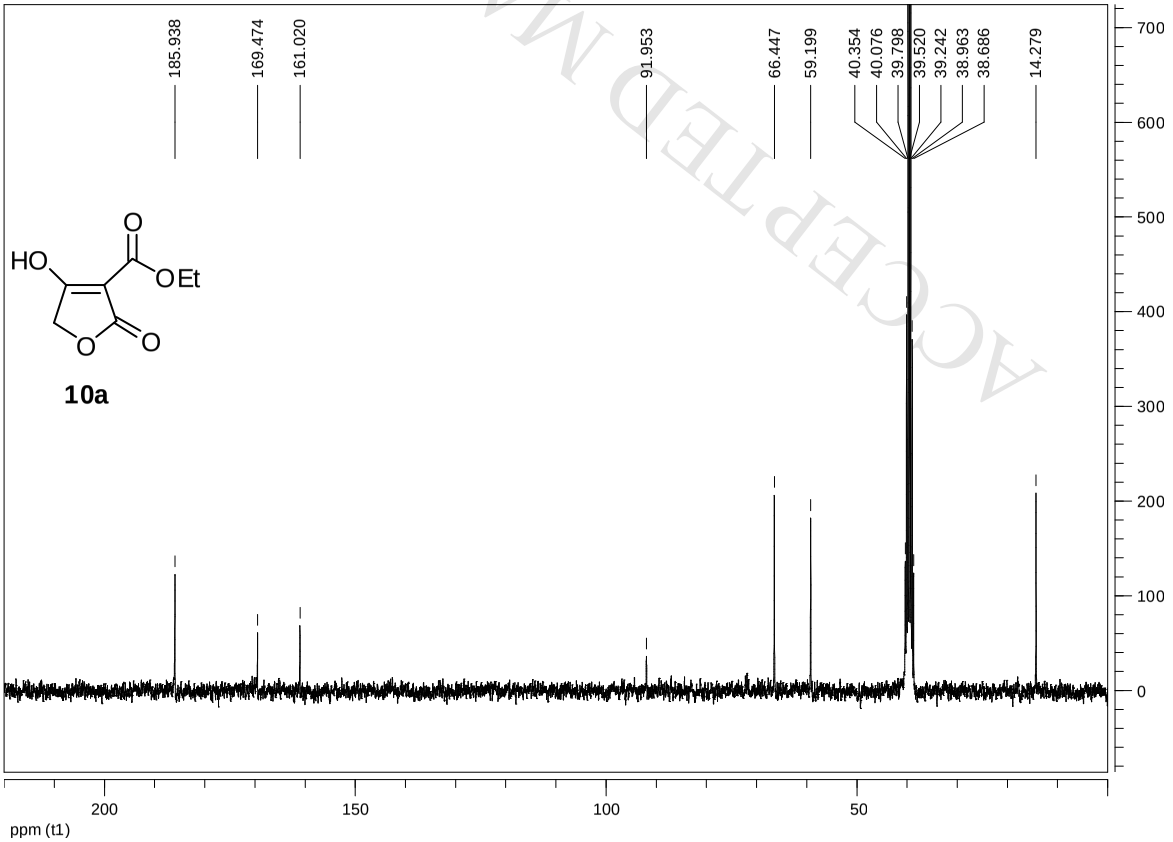


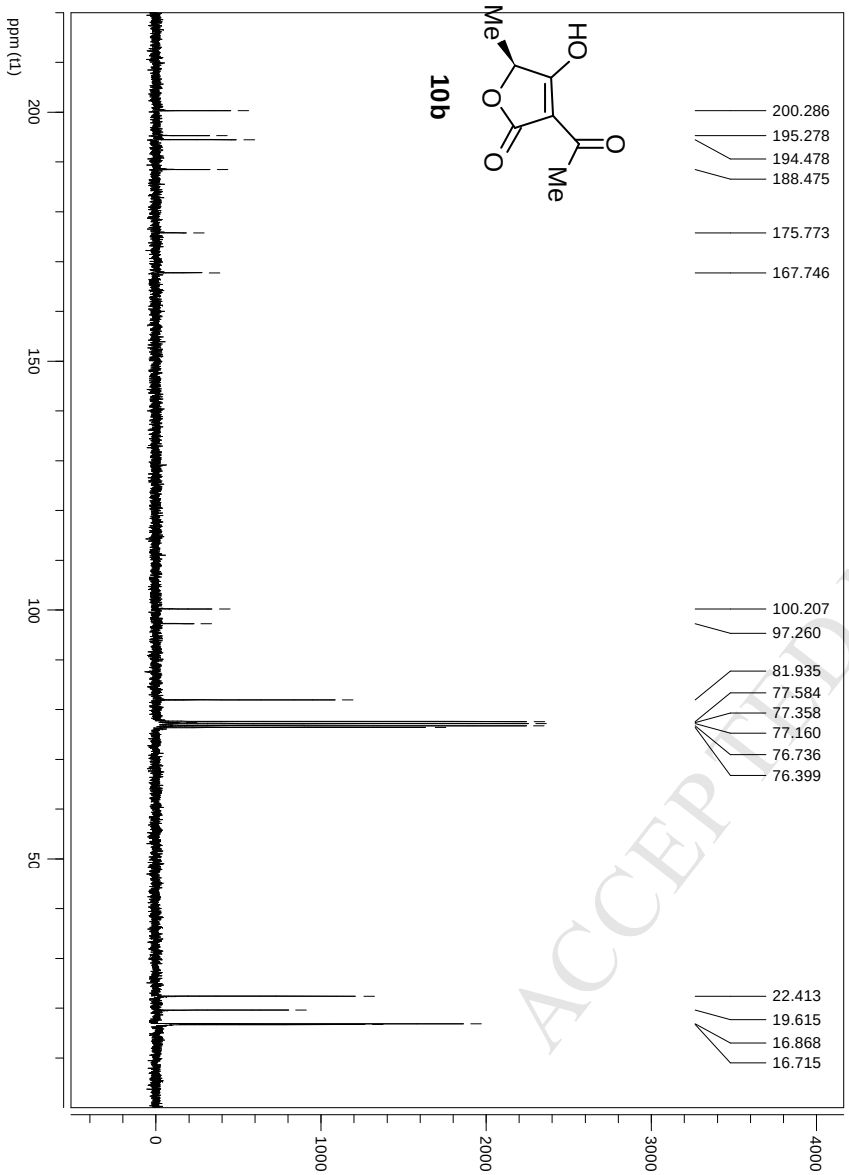
Supporting Information

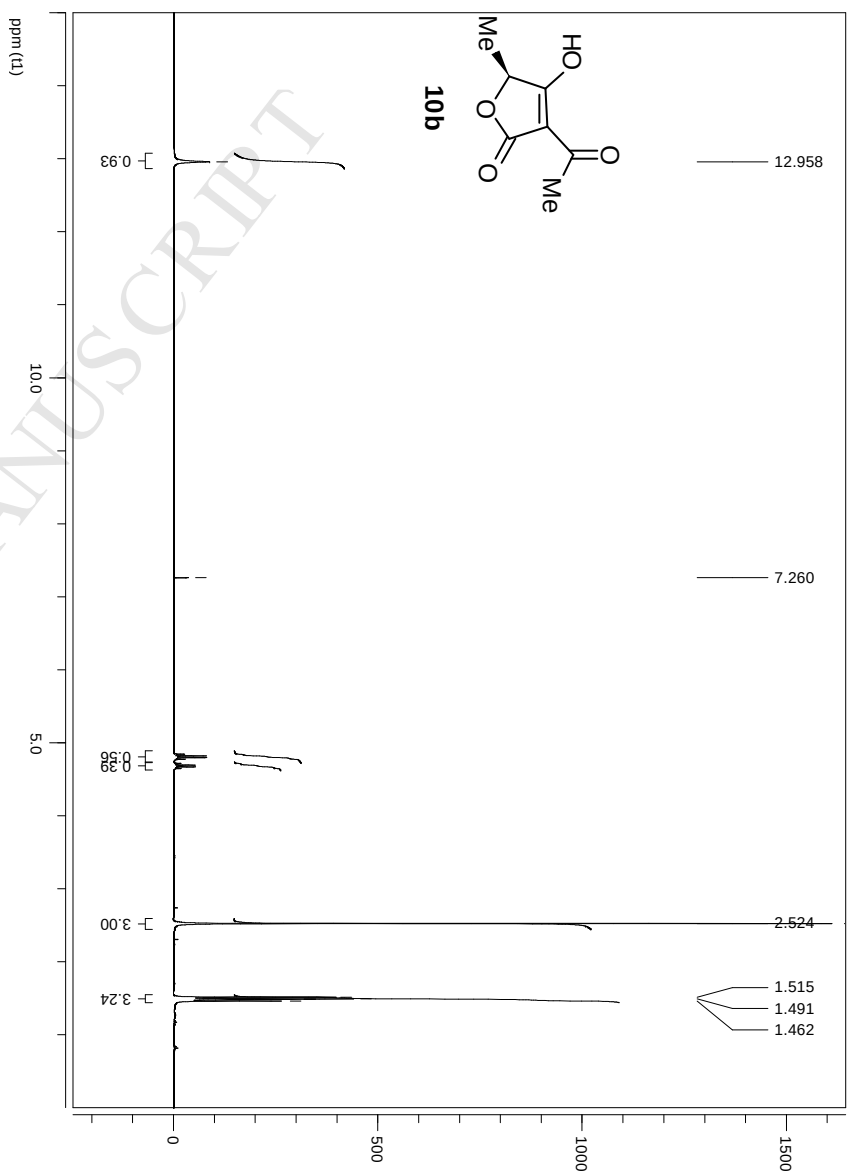
An efficient synthetic approach towards fully functionalized tetronic acids: The use of 1,3-dioxolane-2,4-diones as a novel protected-activated synthons of α-hydroxy acids.

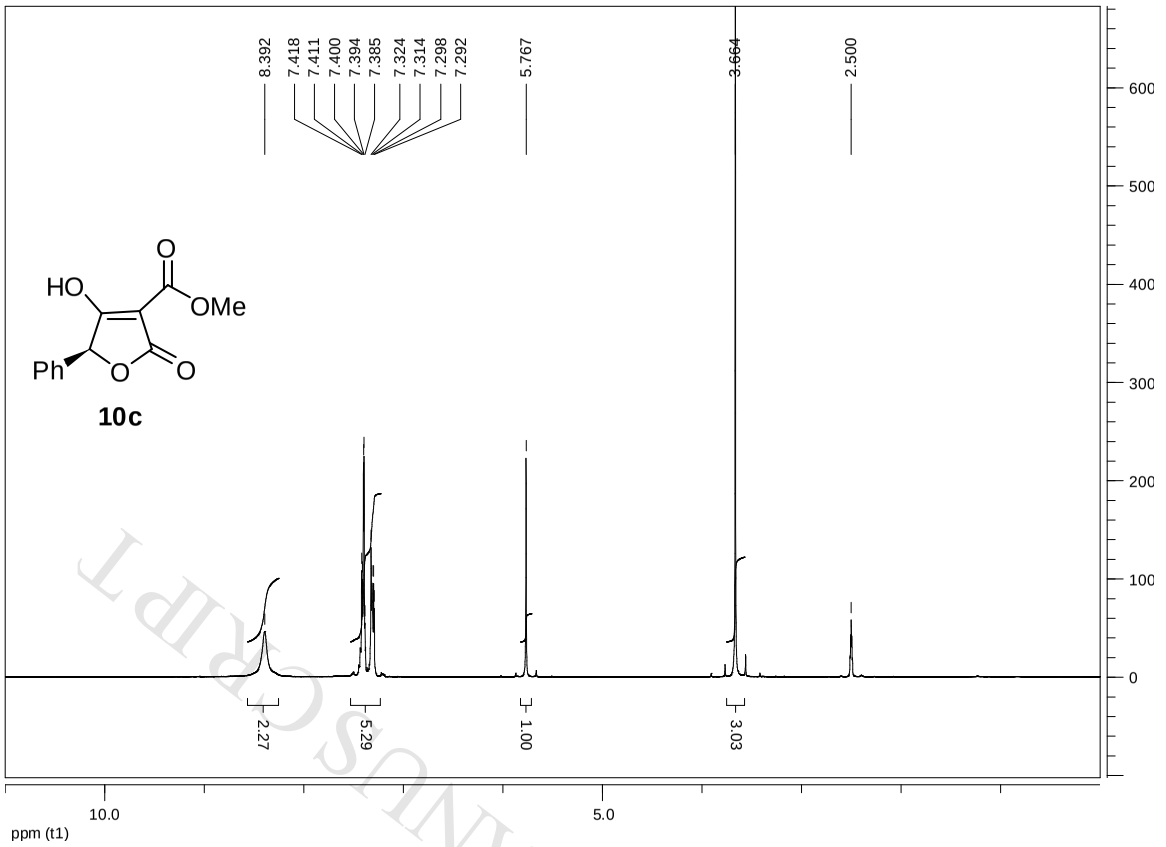
^{1}H and ^{13}C NMR

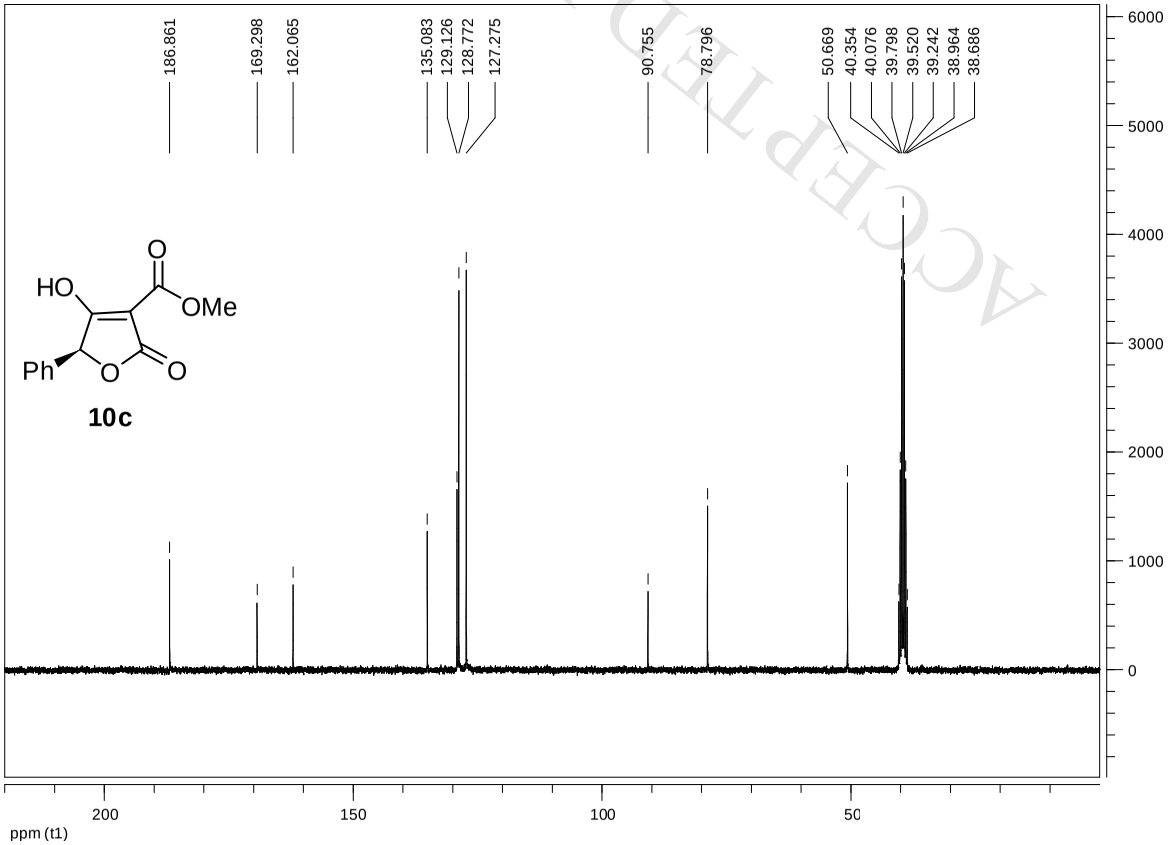


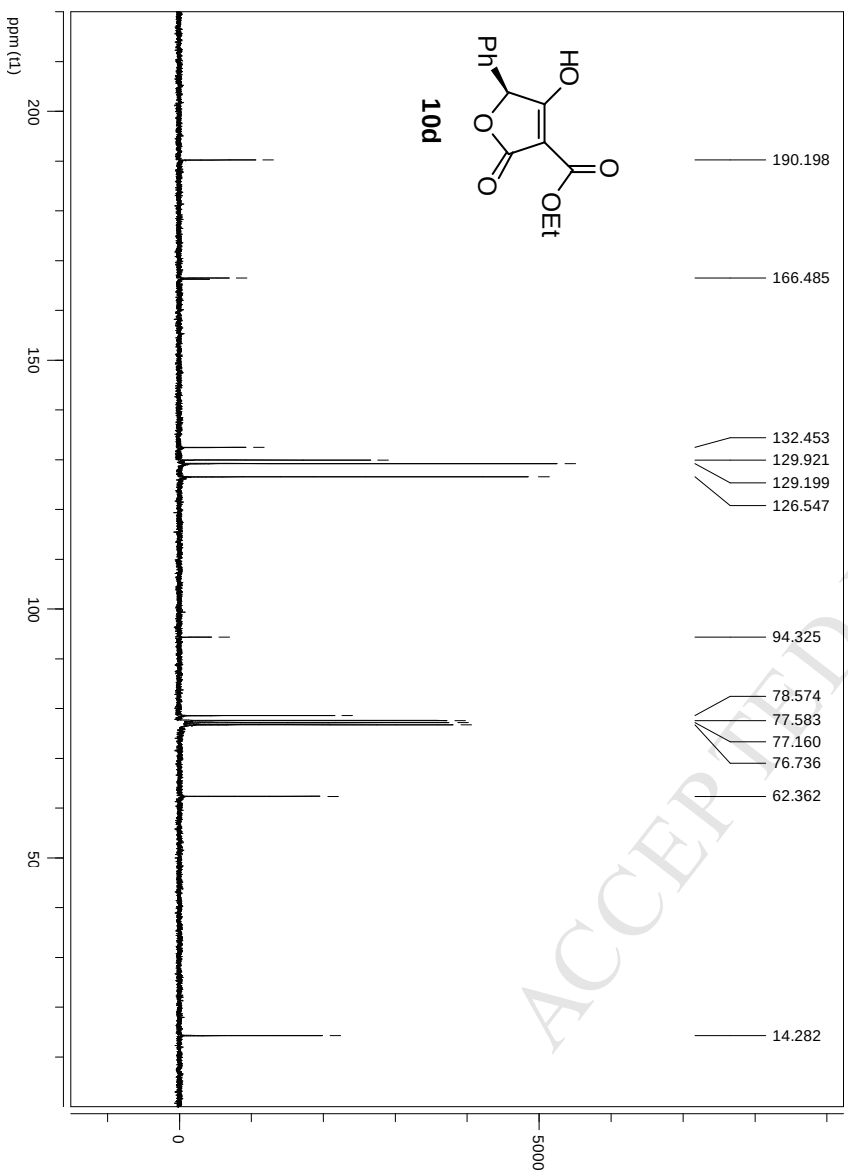


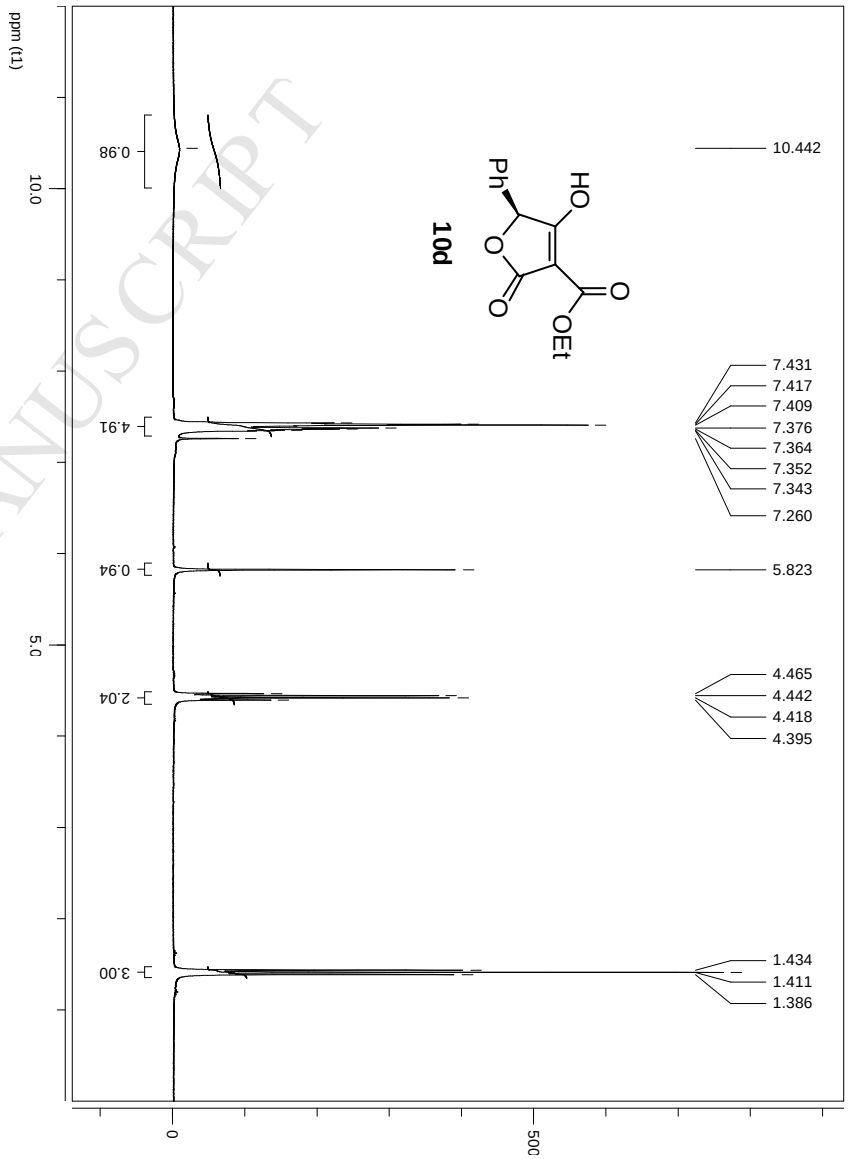


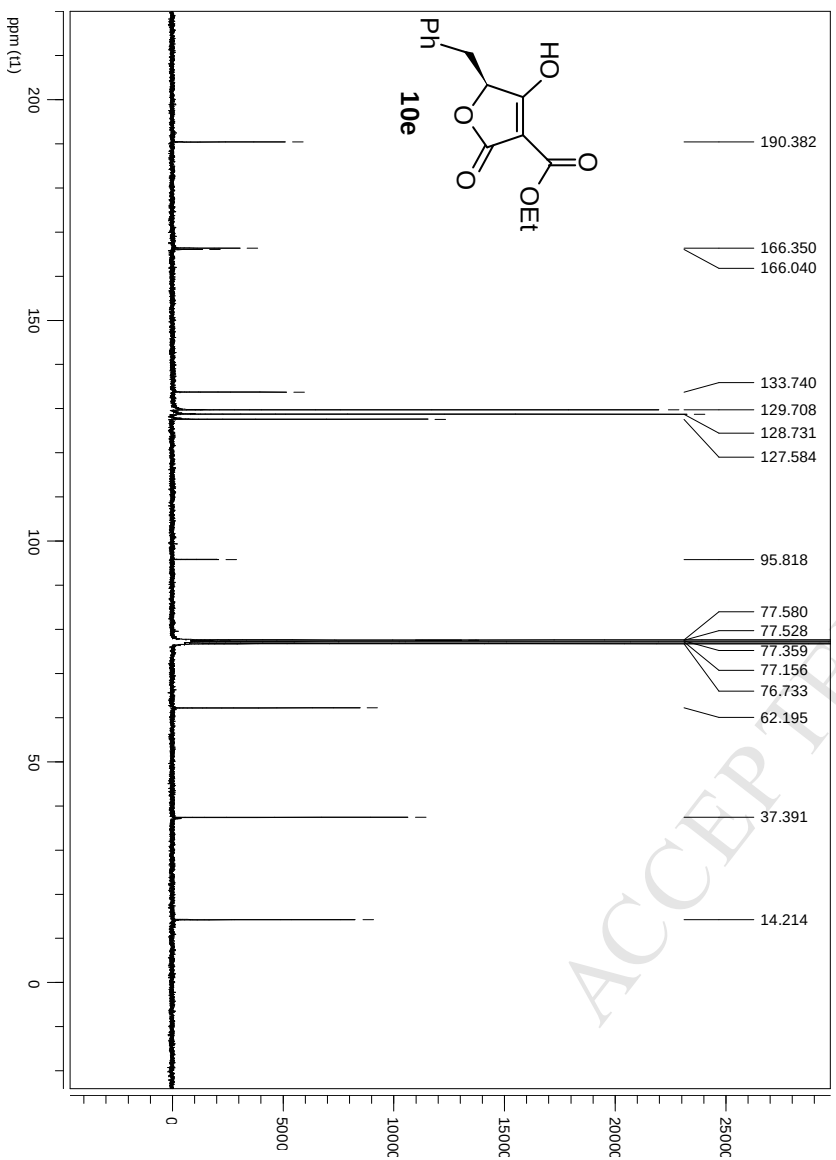


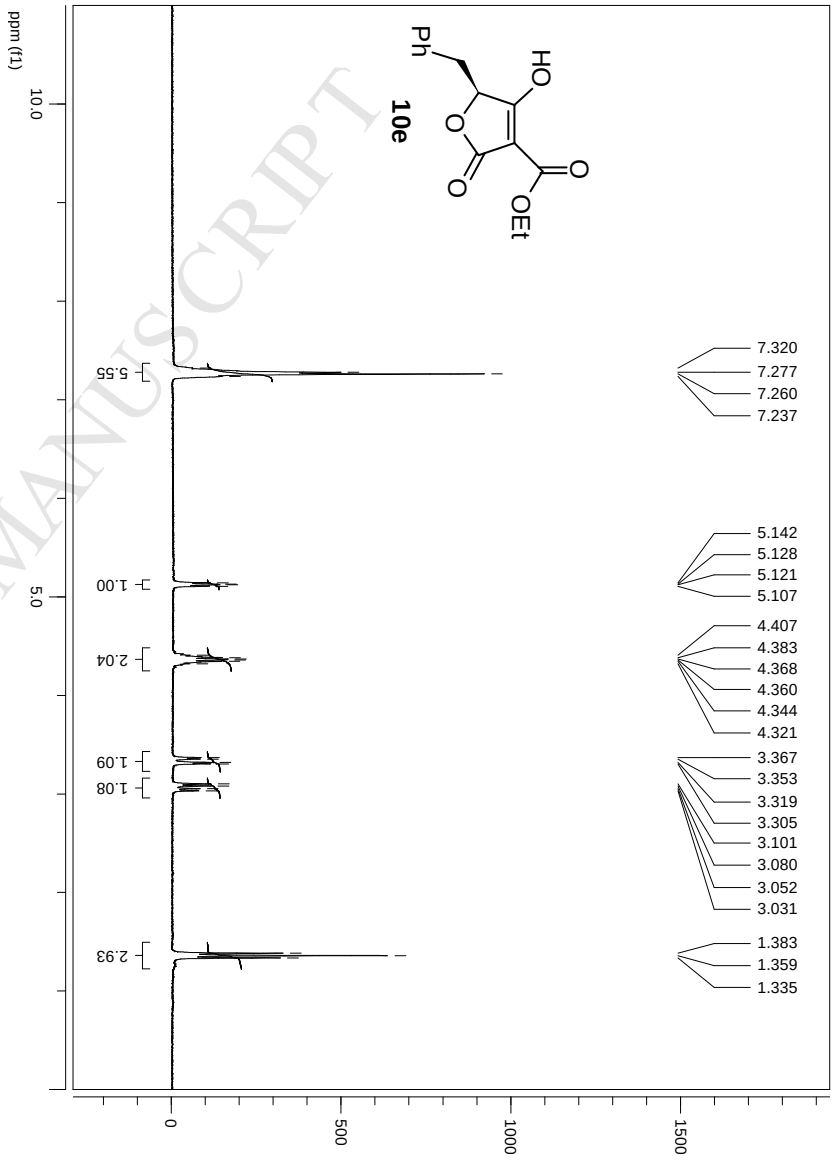


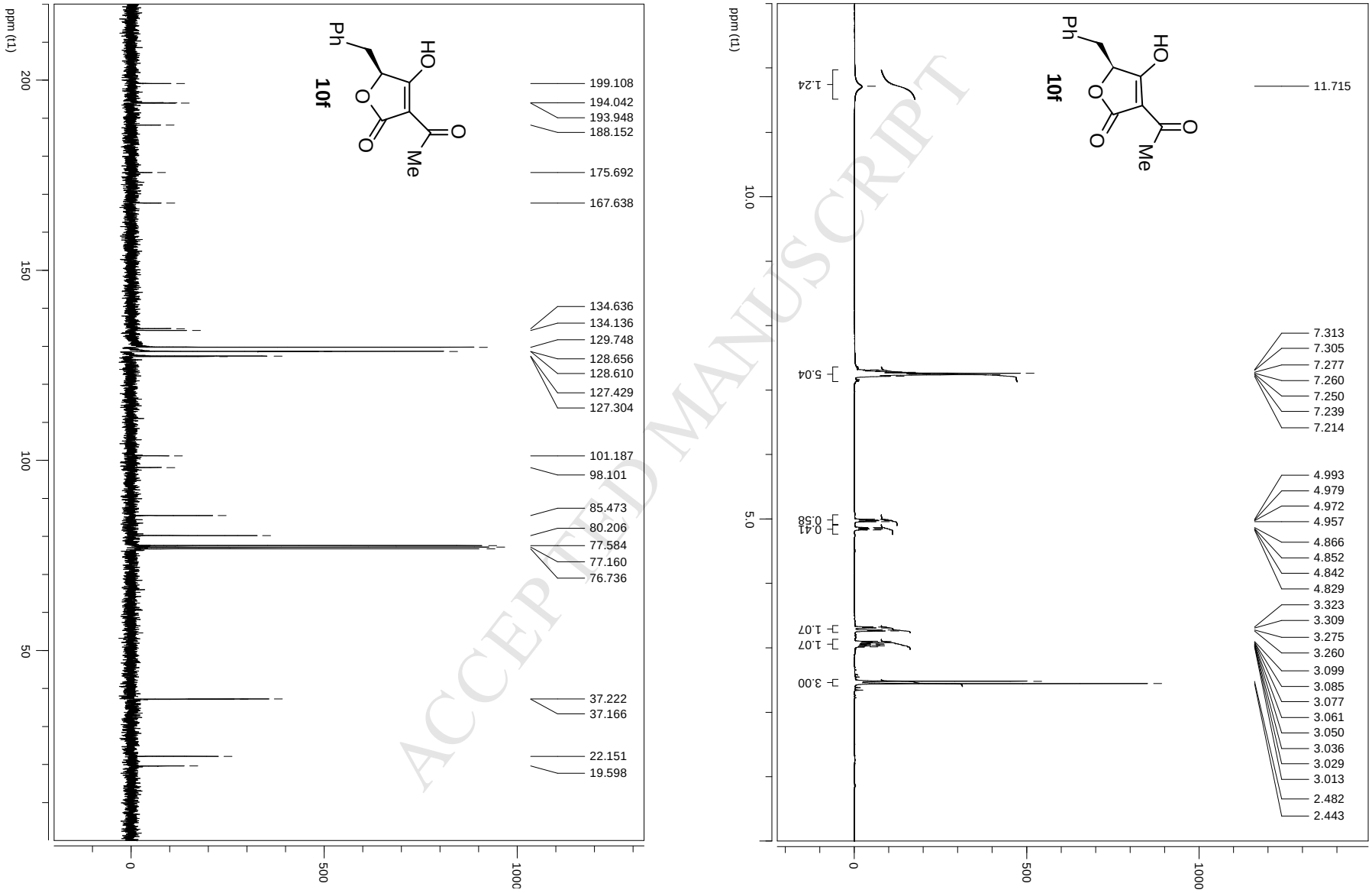


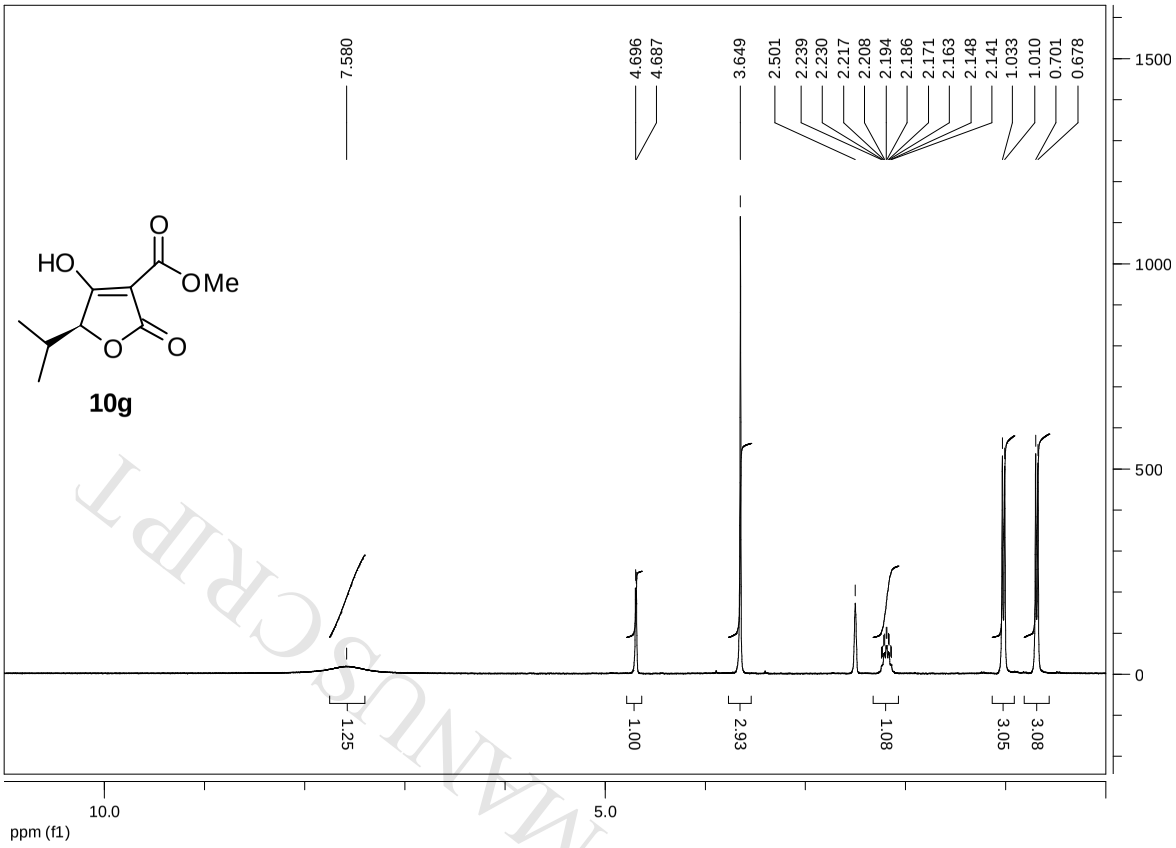


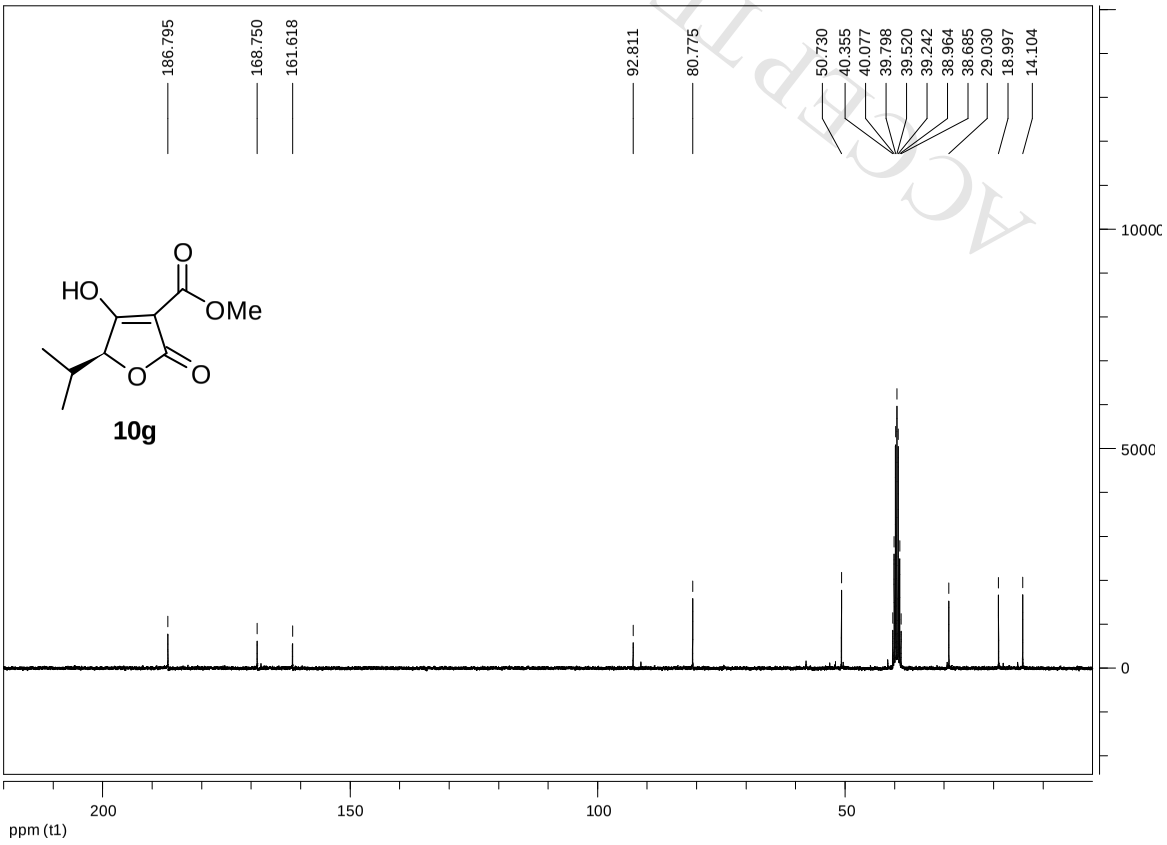


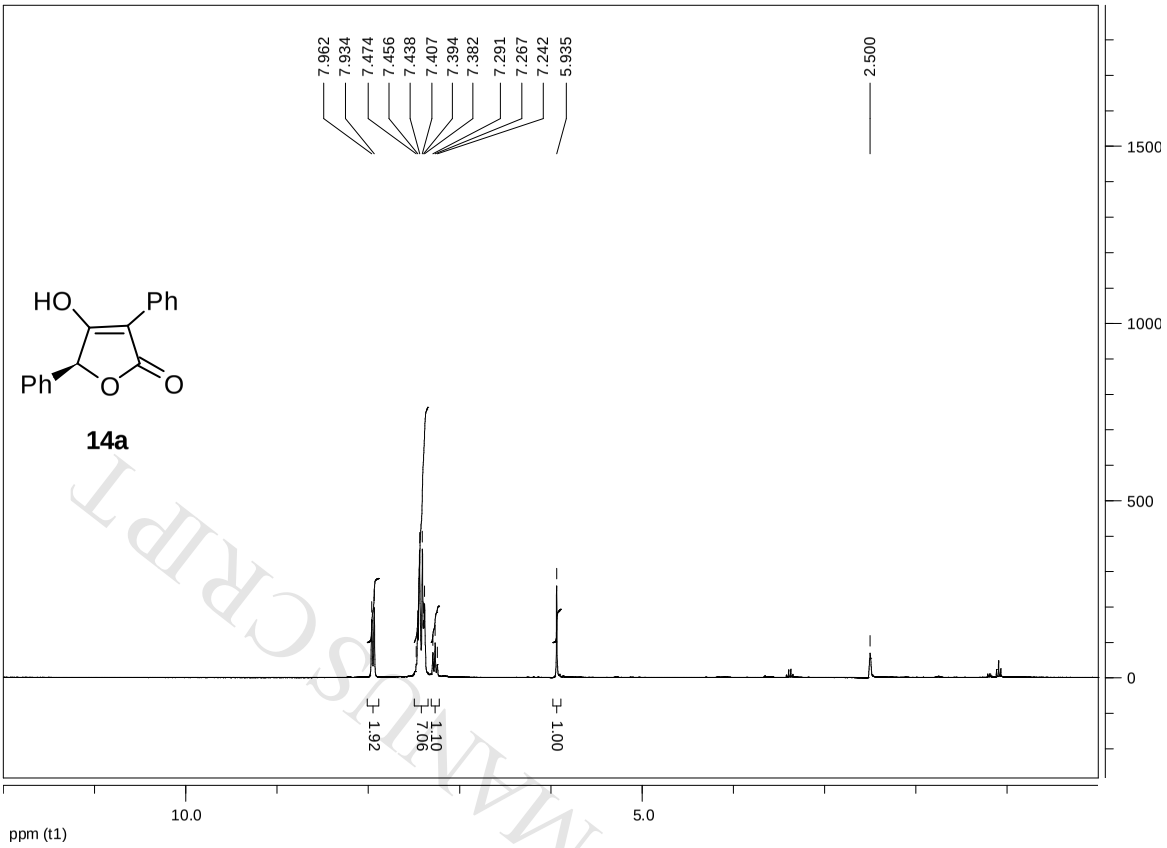


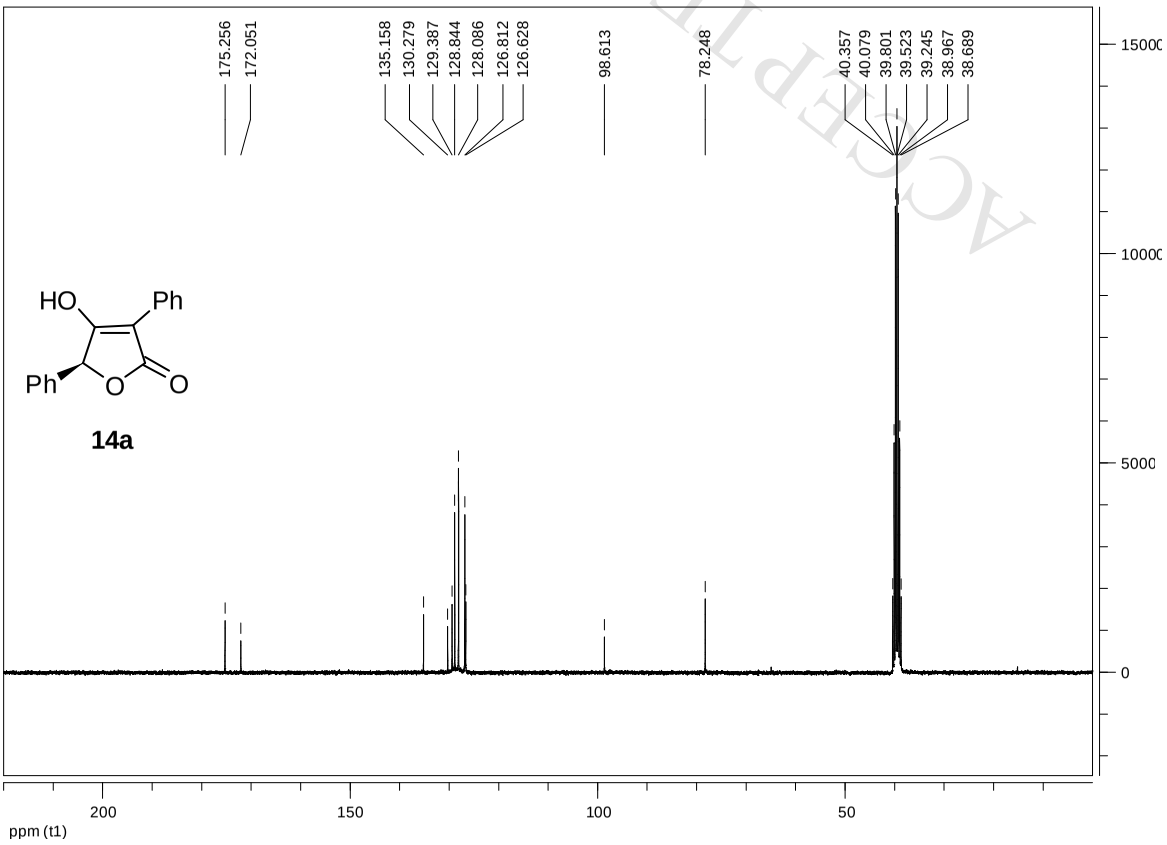


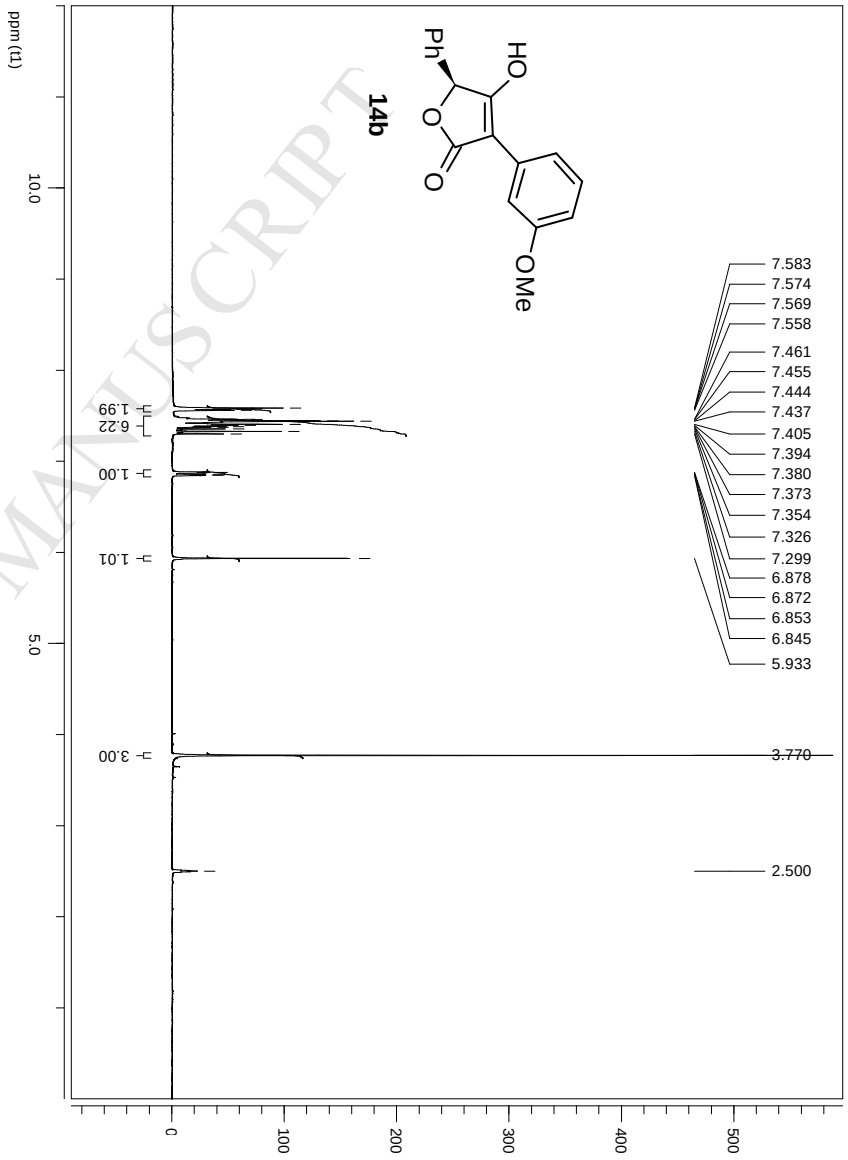


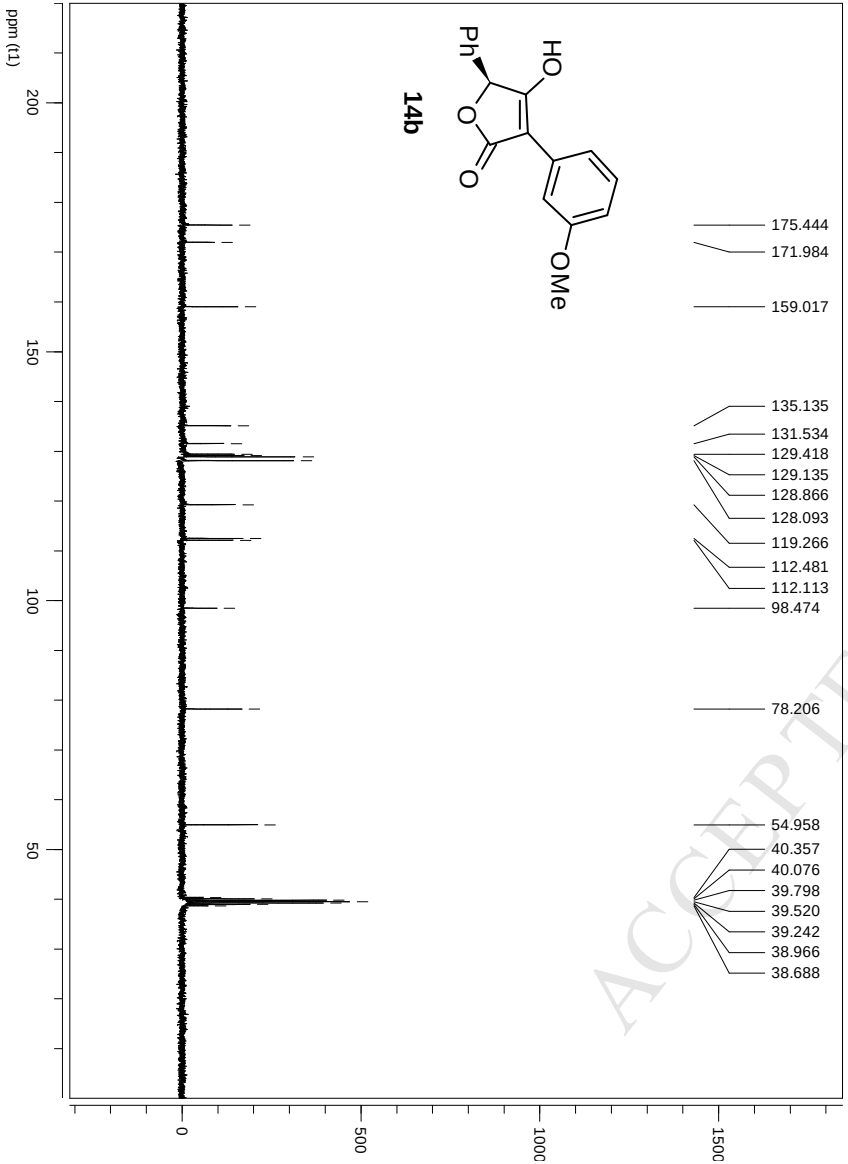


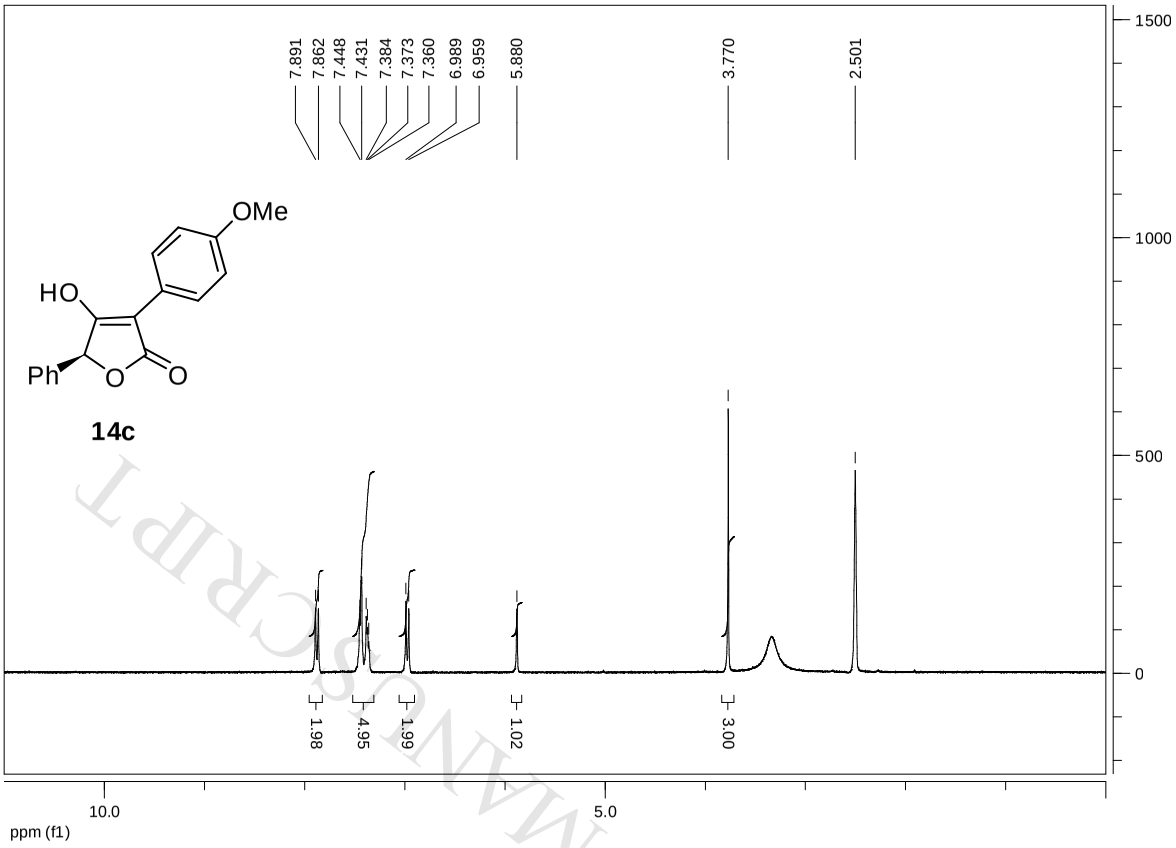


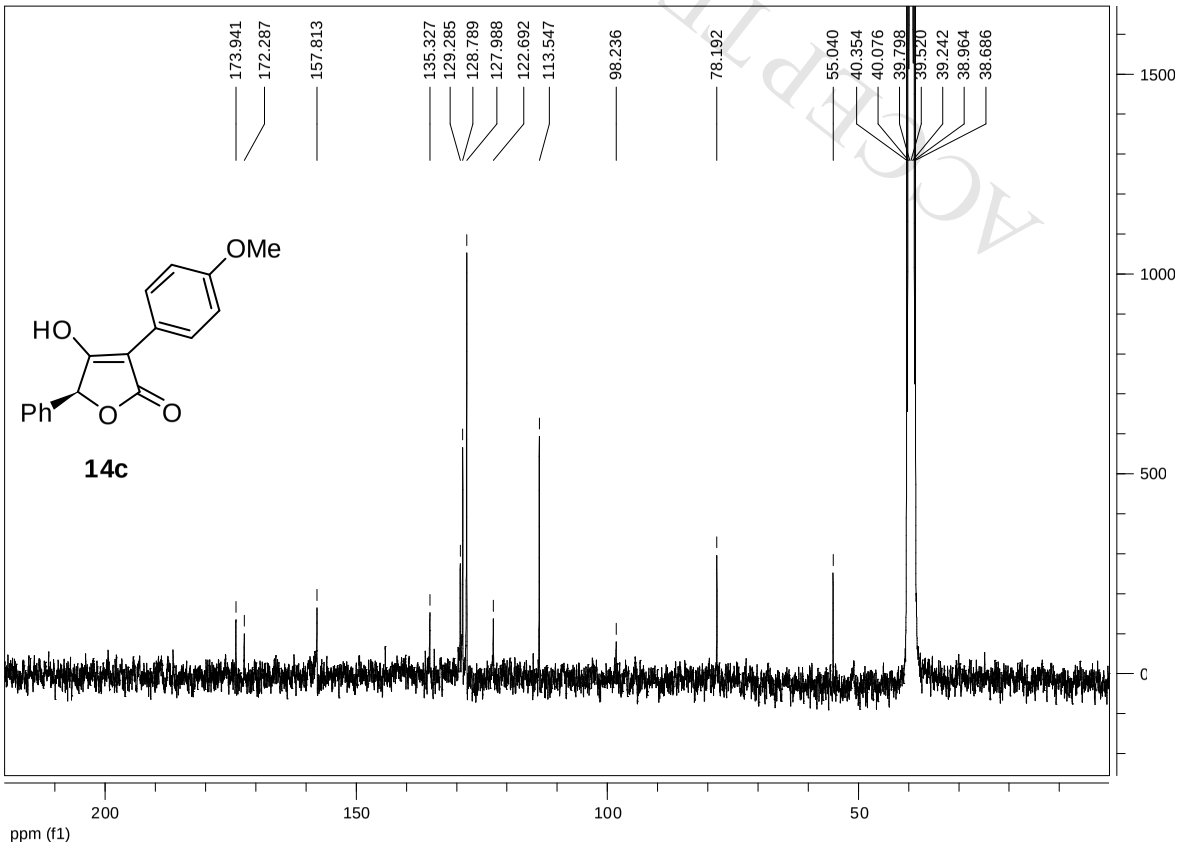


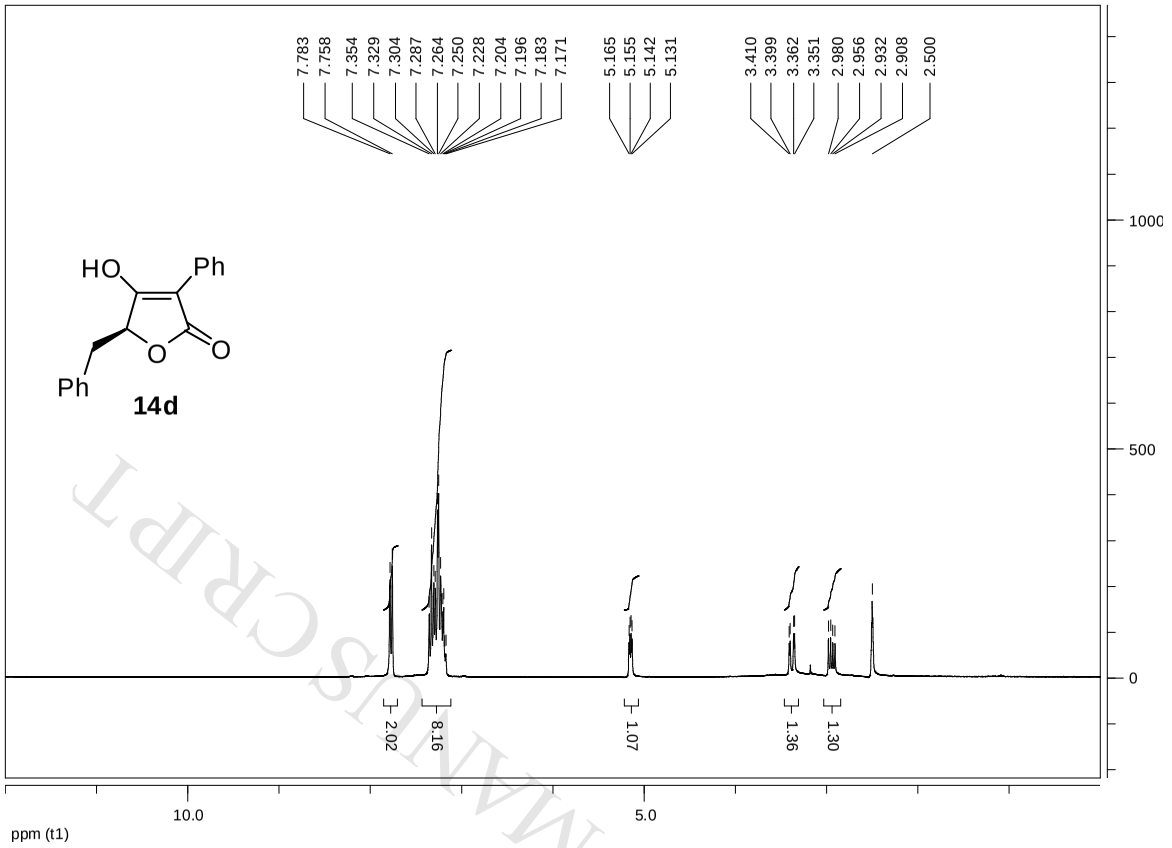


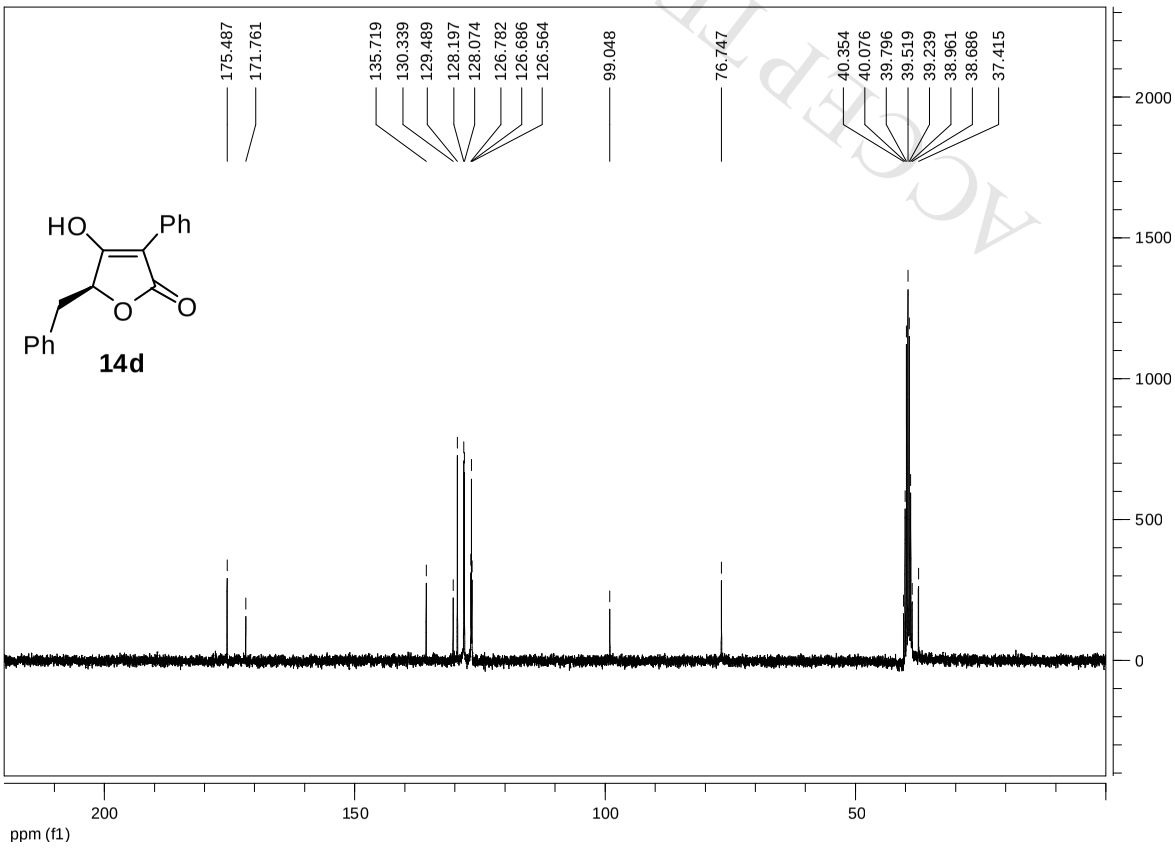


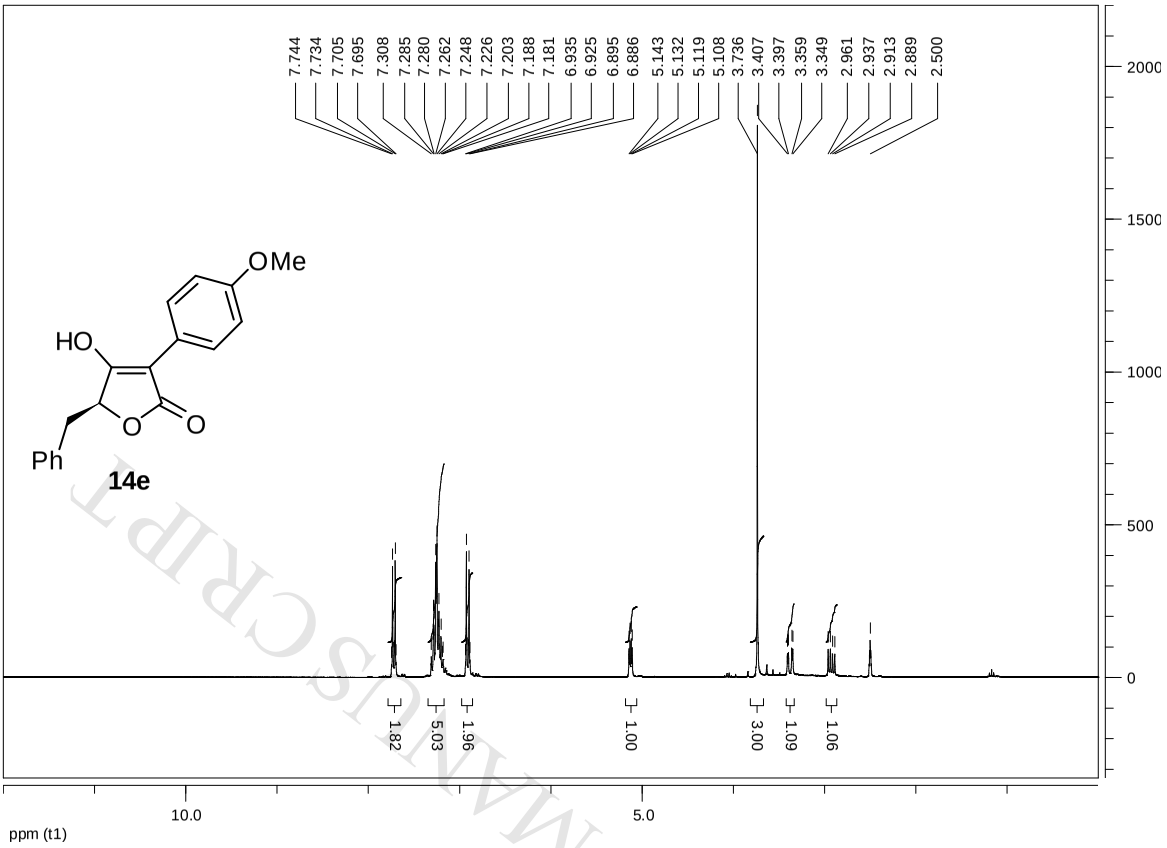


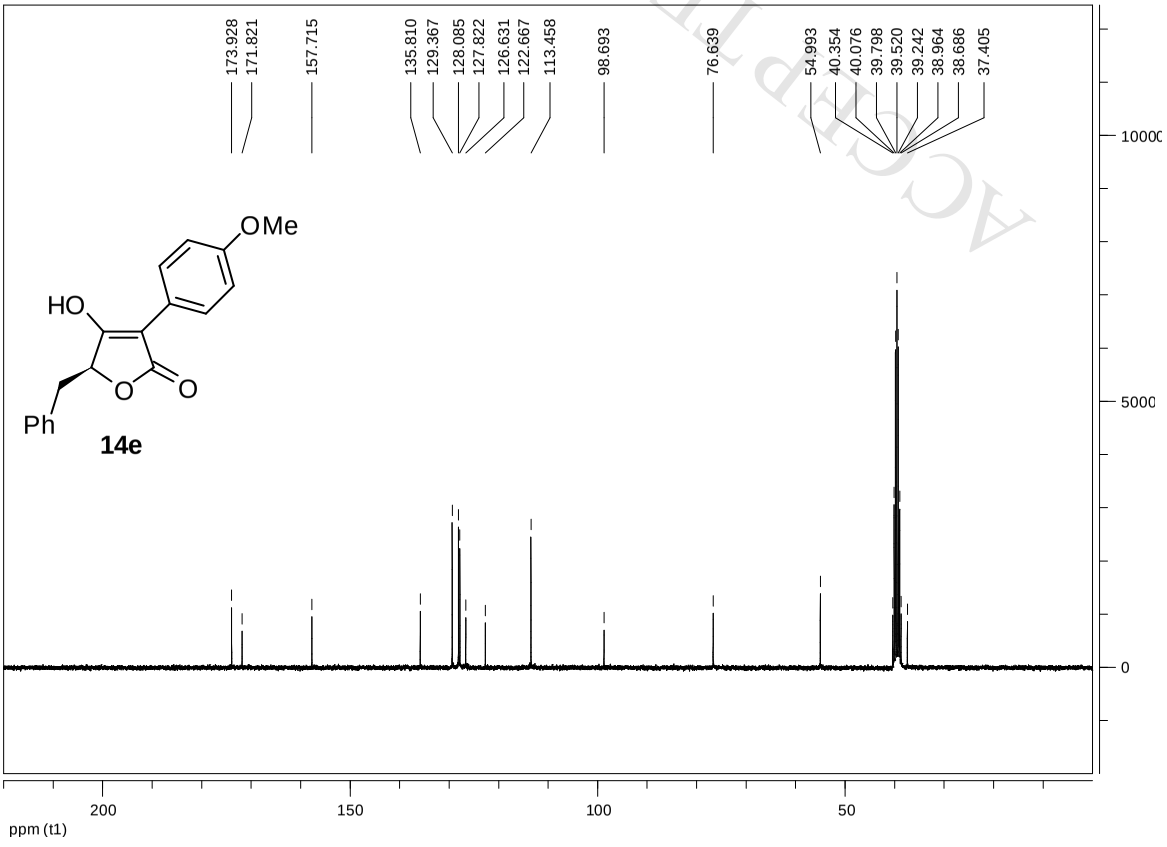


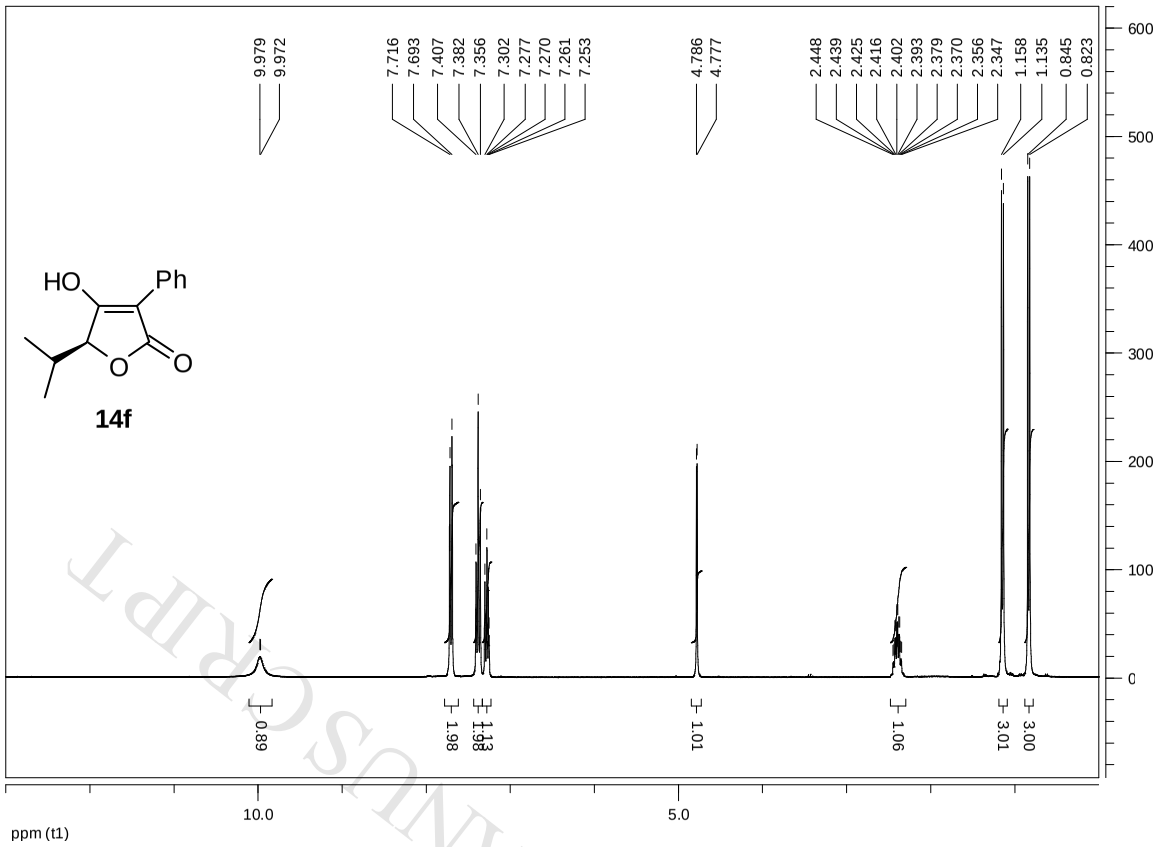


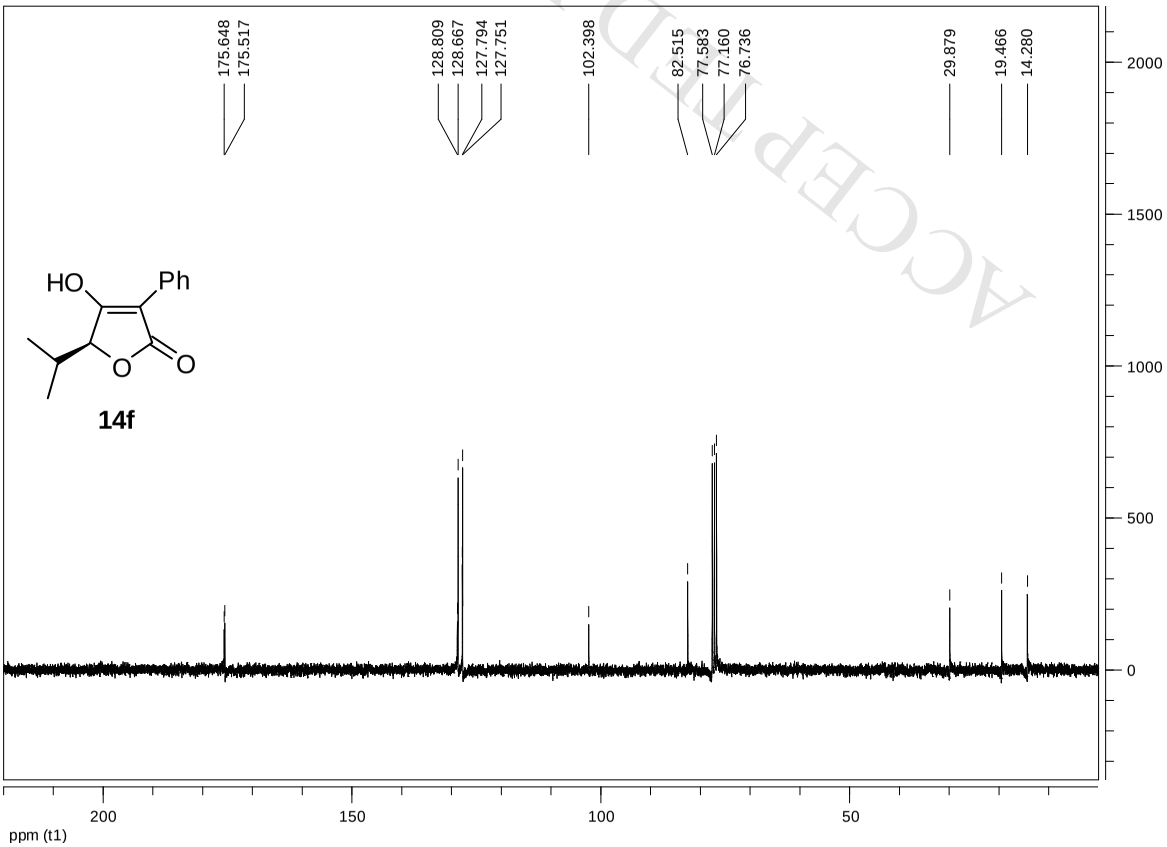


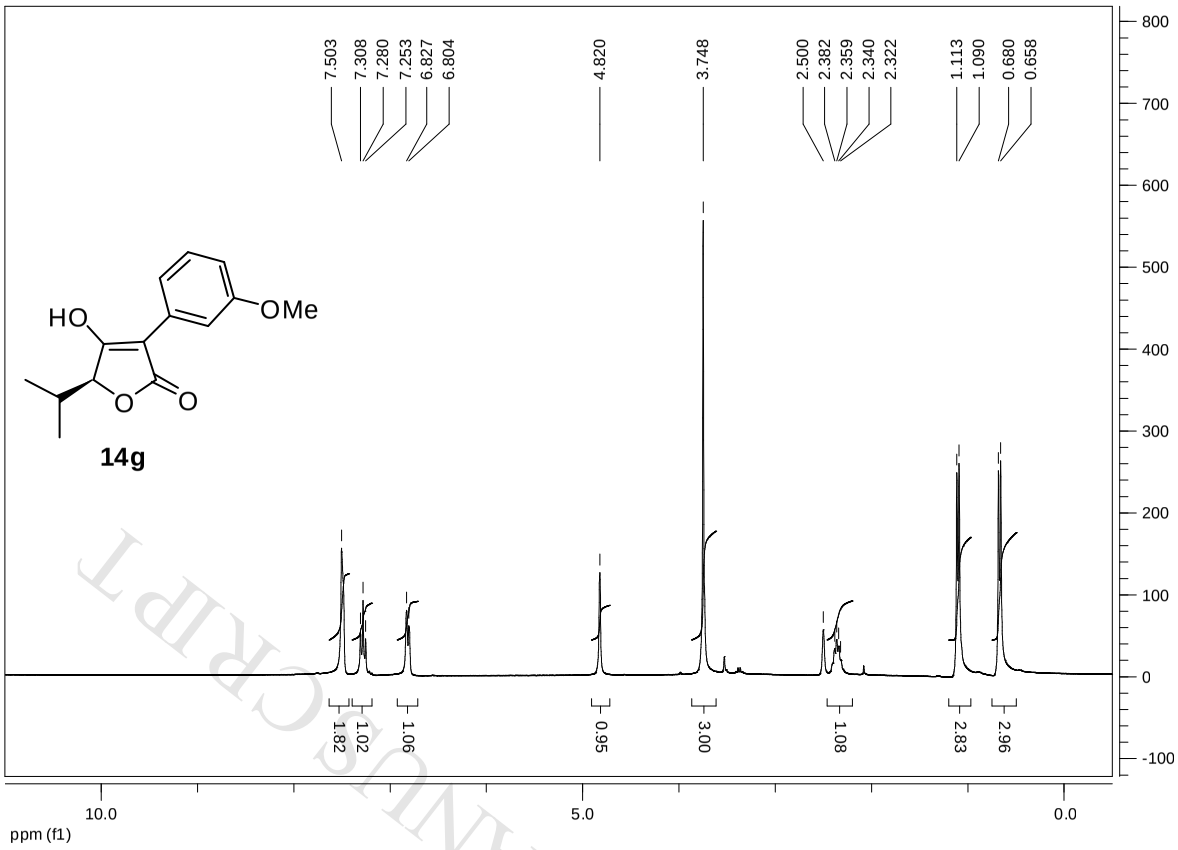


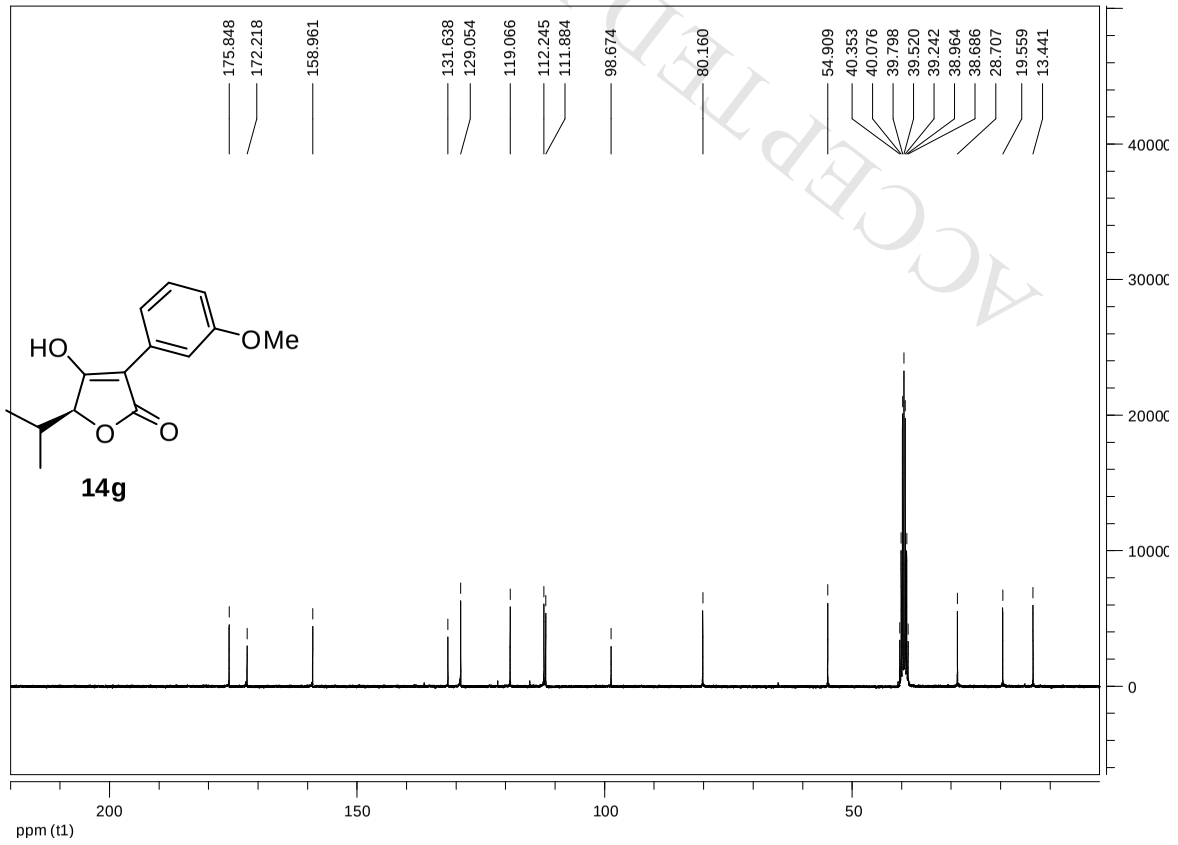


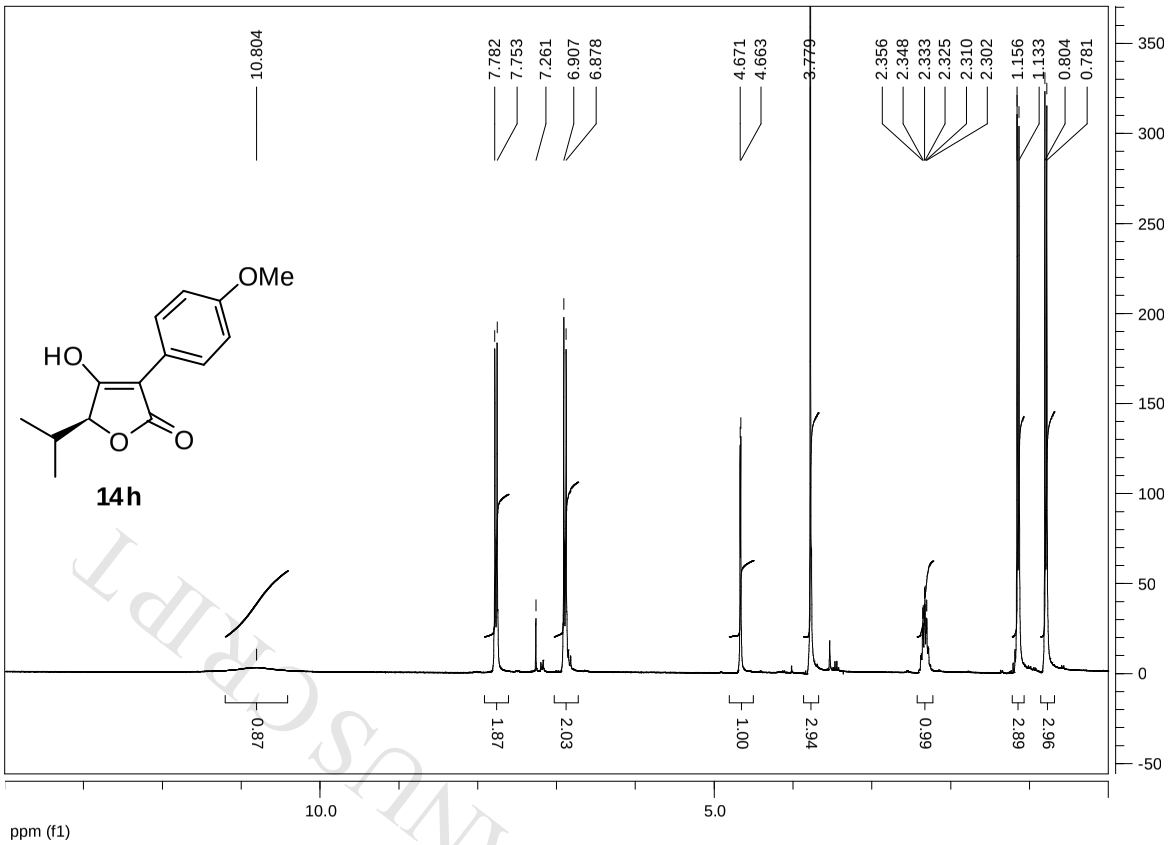


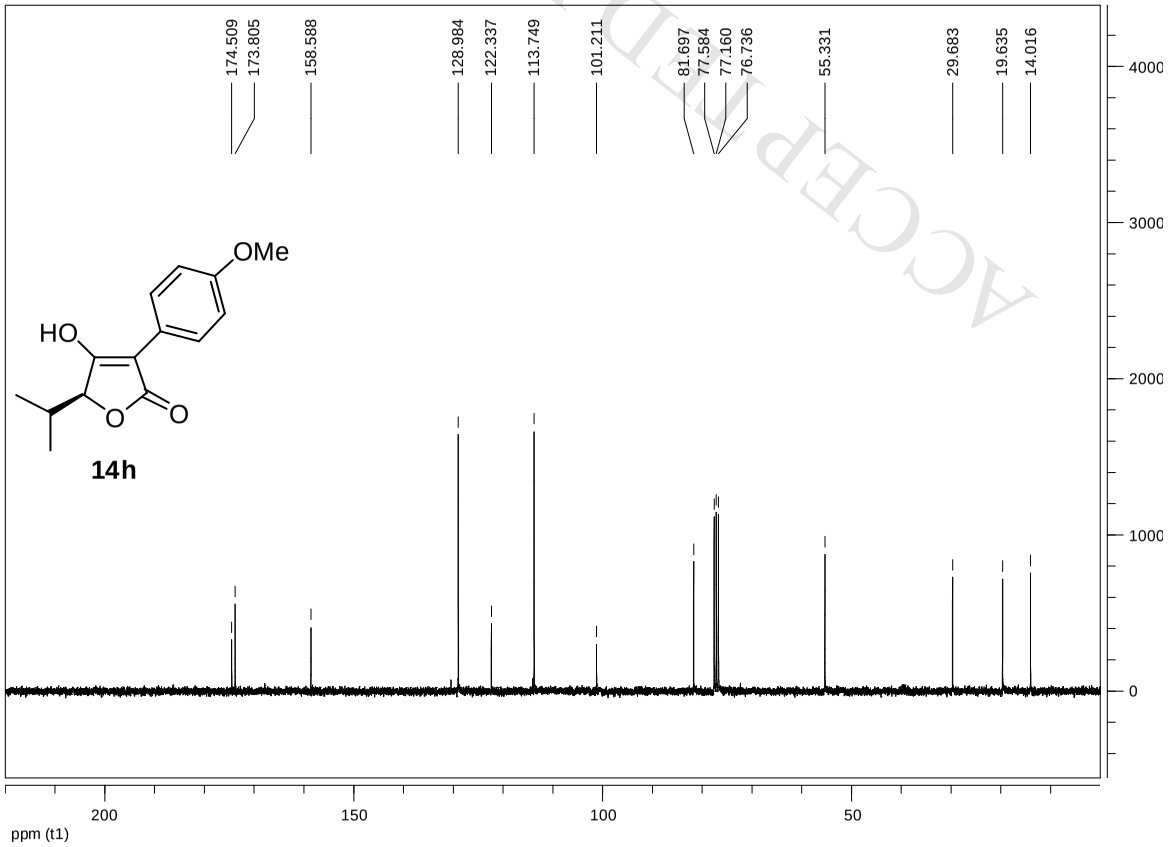


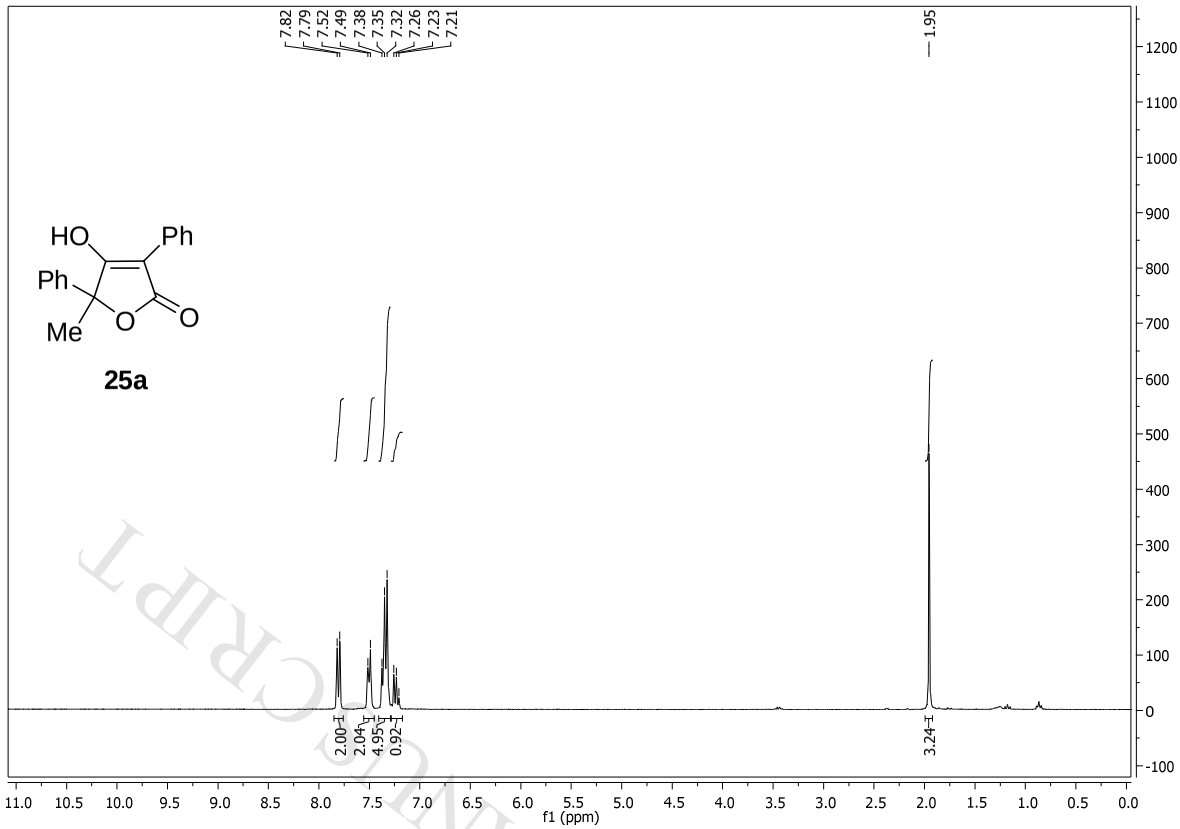


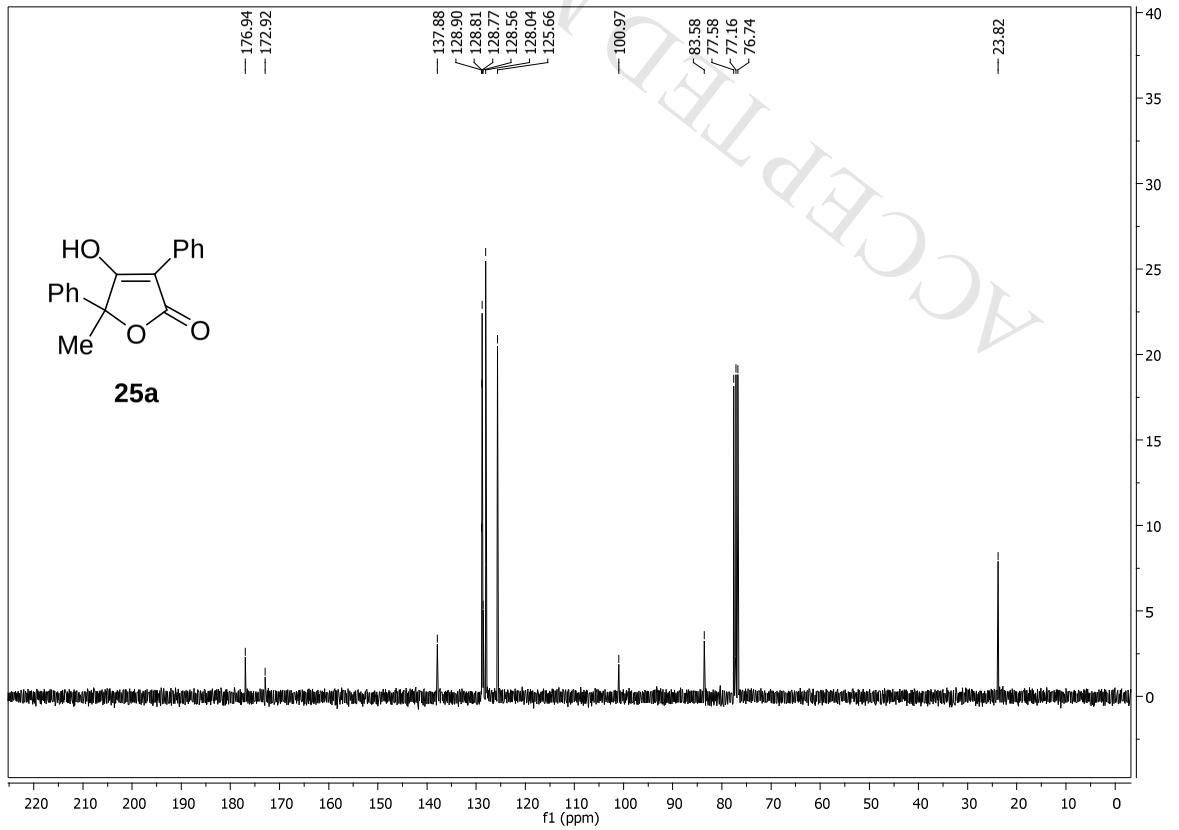


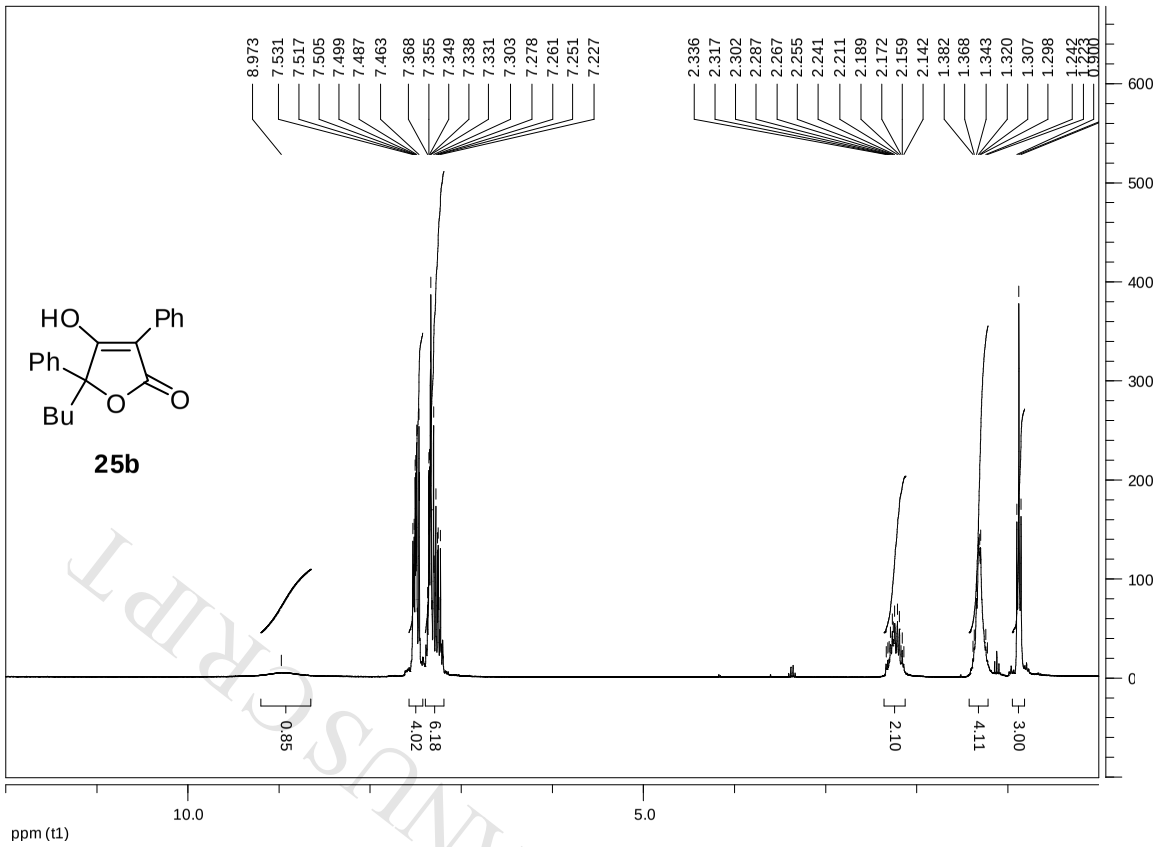


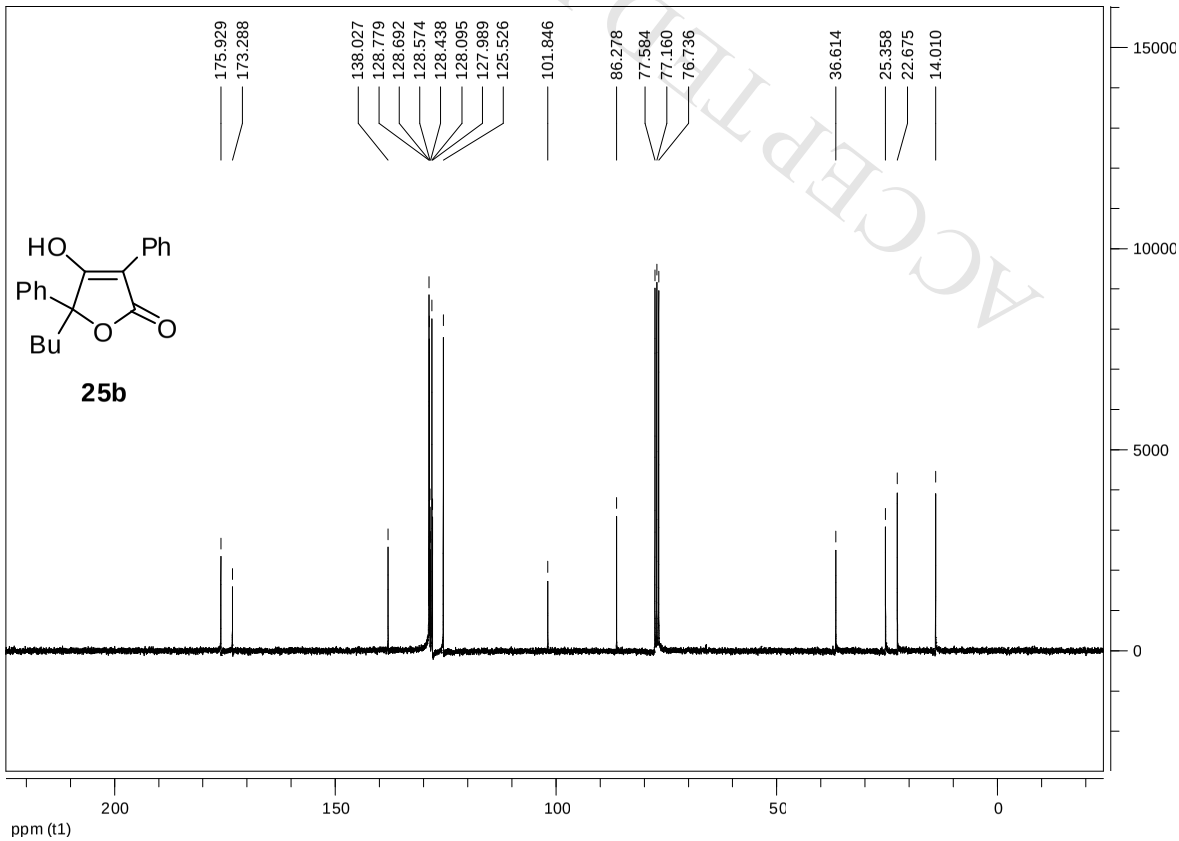


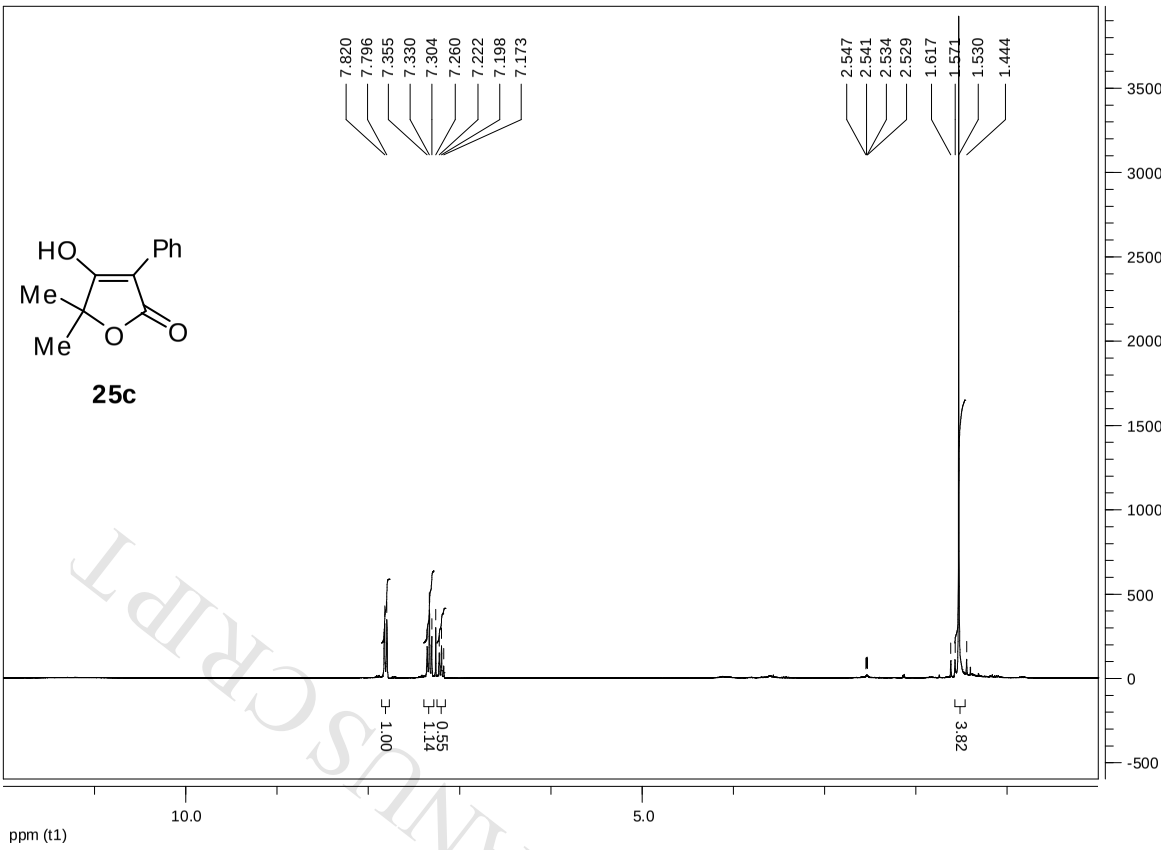


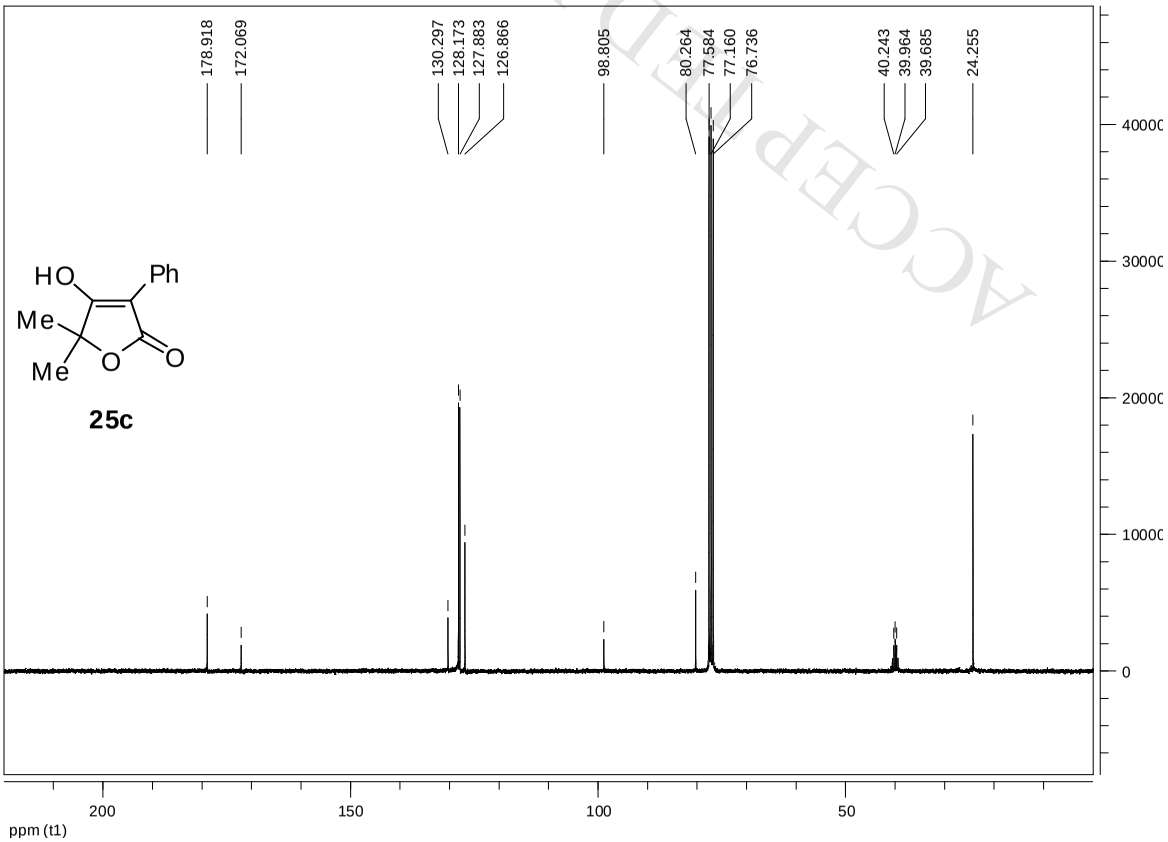


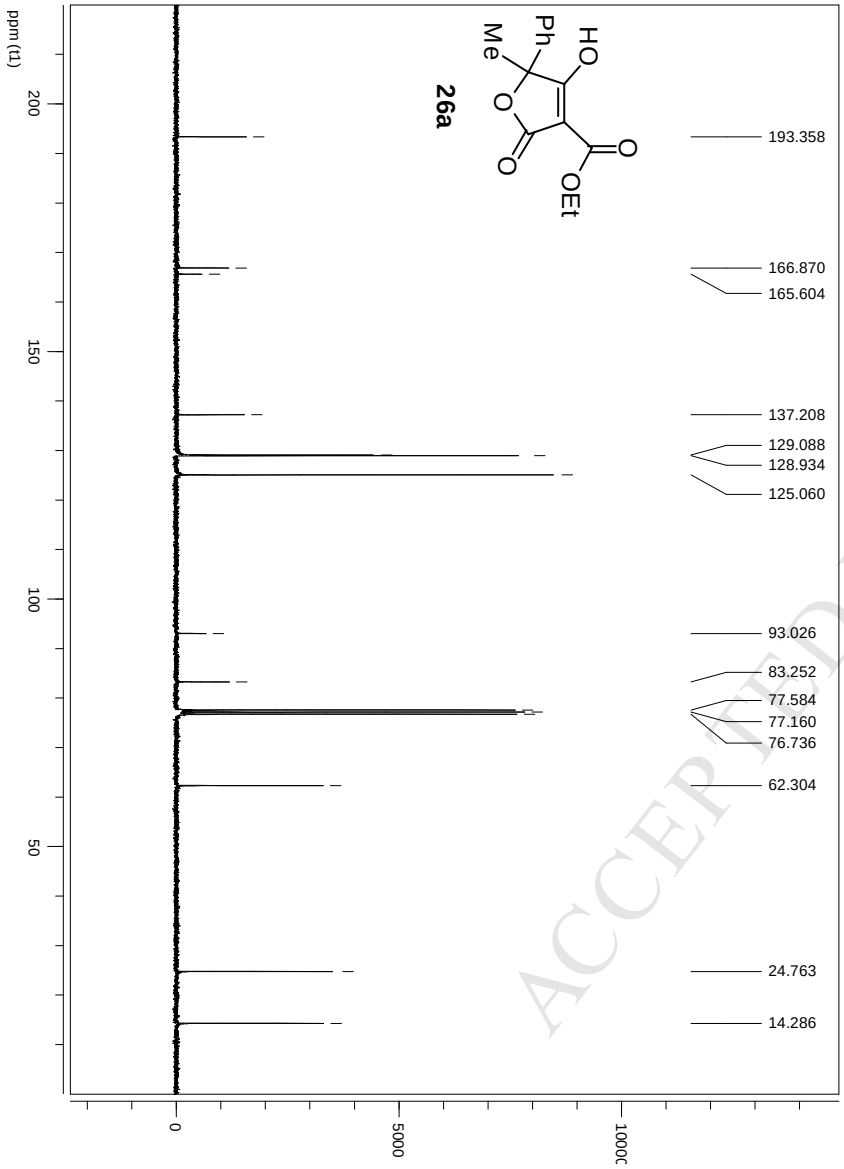


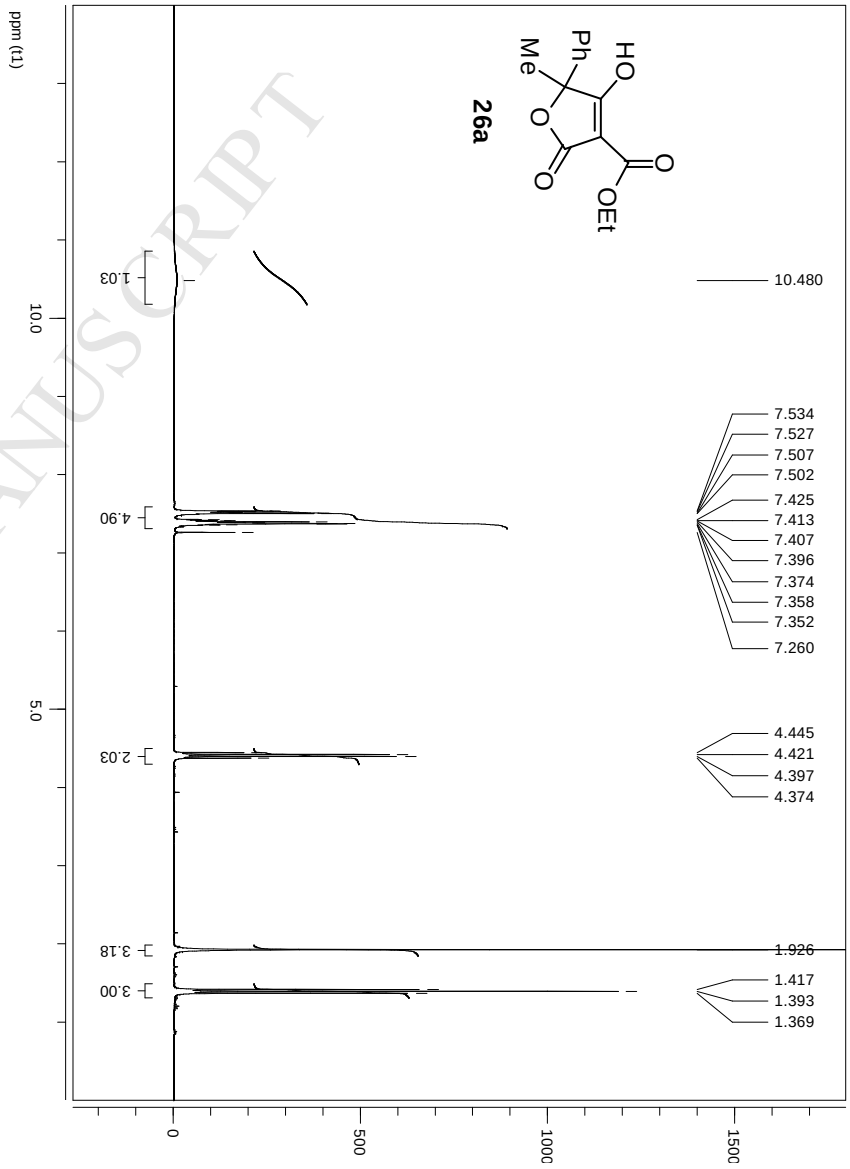


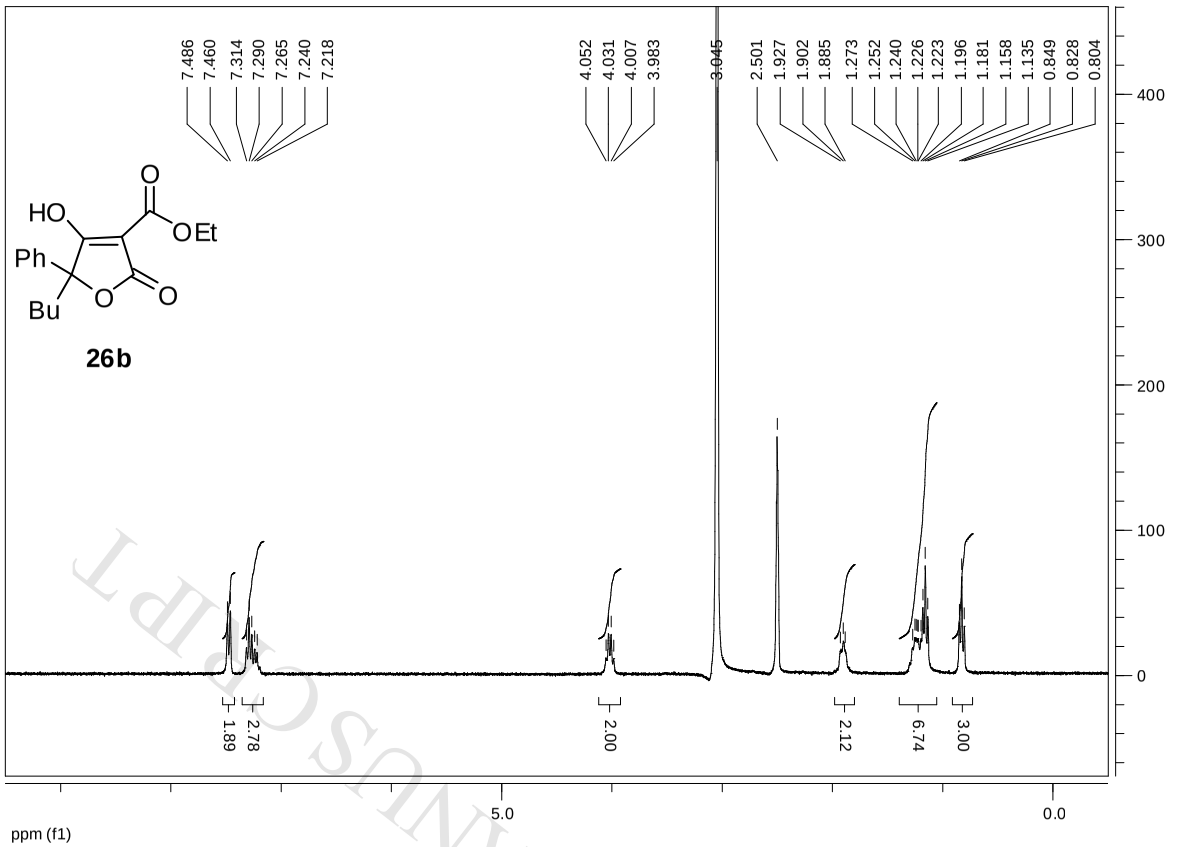


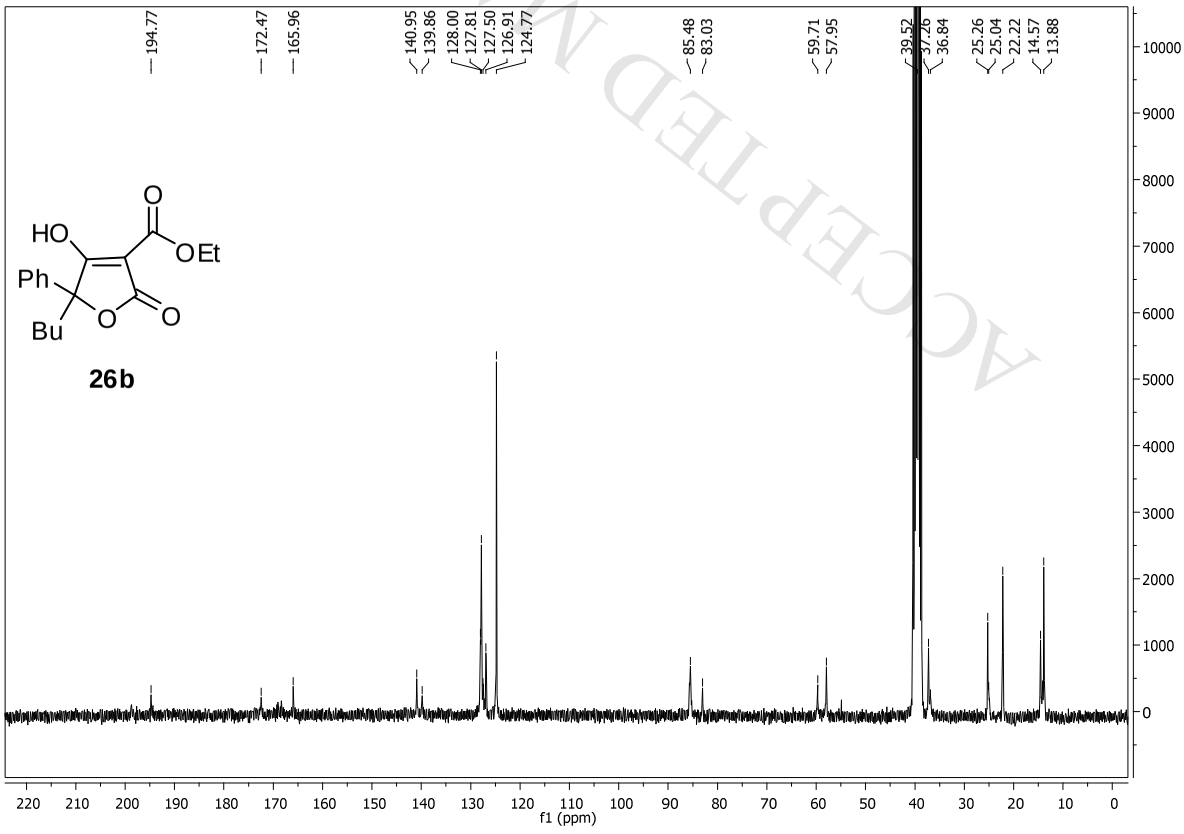


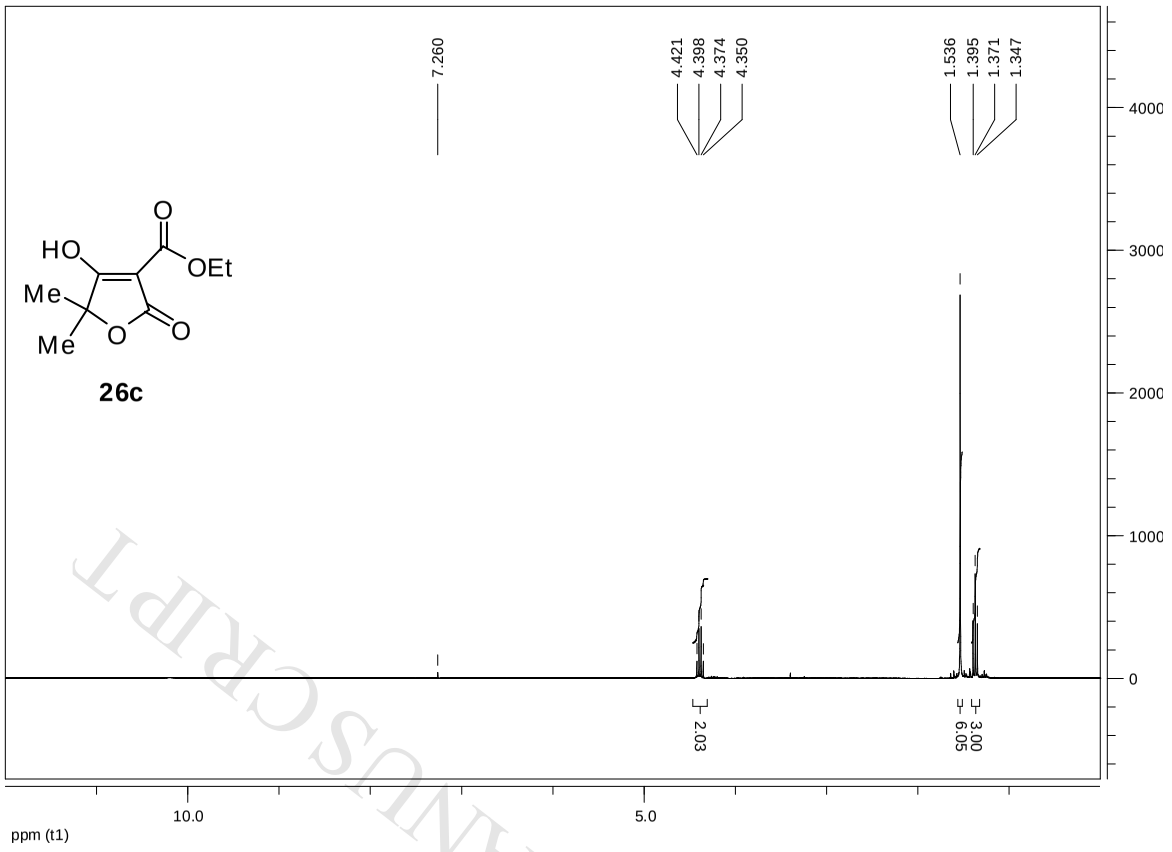


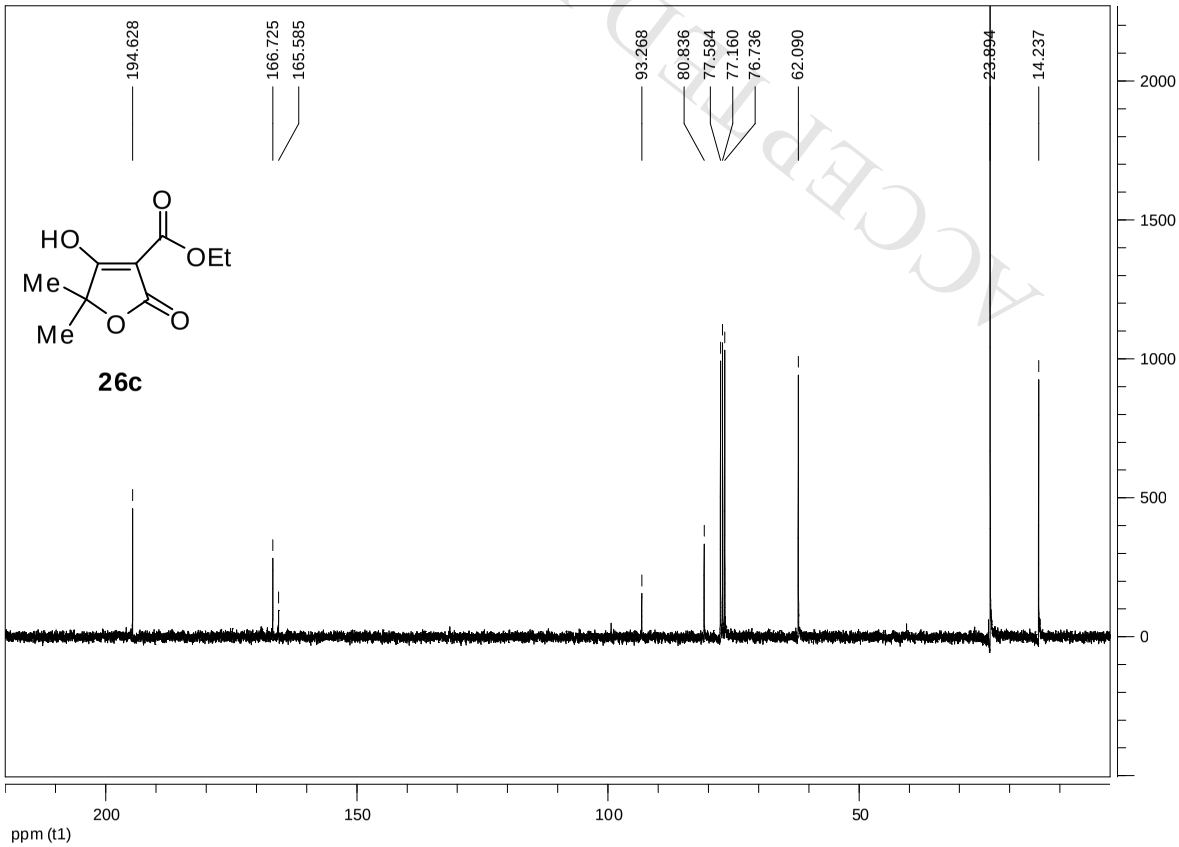


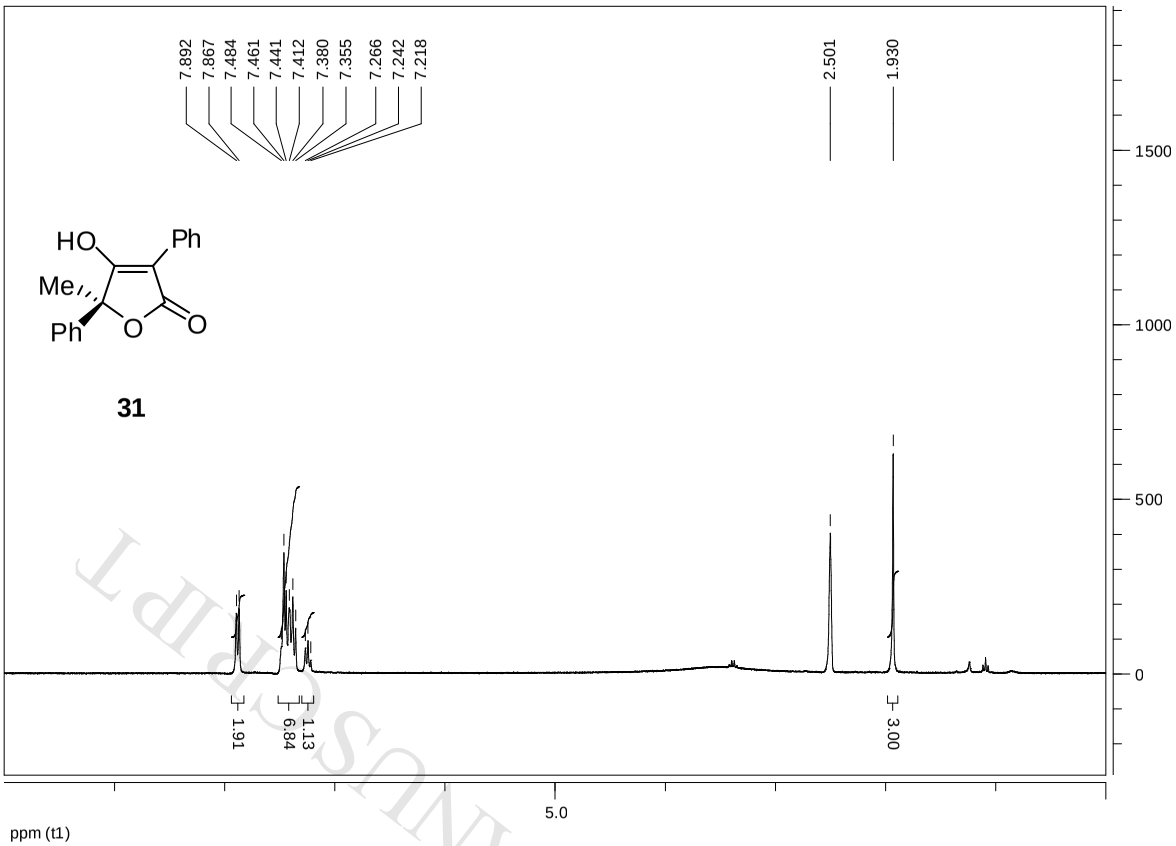


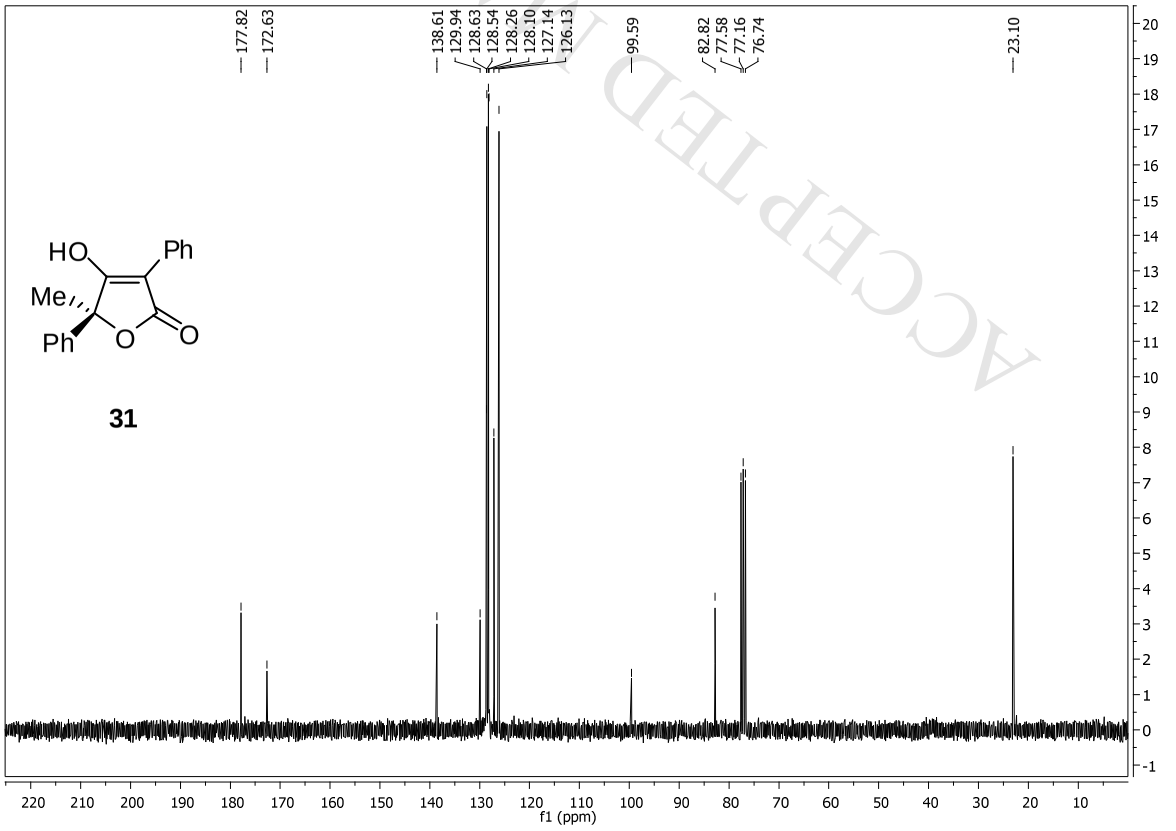












Crystallographic Data for 14f

The data were collected at 150(2)K on a Bruker Apex II CCD diffractometer. The structure was solved by direct methods and refined on F^2 using all the reflections[1]. All the non-hydrogen atoms were refined using anisotropic atomic displacement parameters and hydrogen atoms bonded to carbon were inserted at calculated positions using a riding model. The hydrogen atom bonded to O3 was located from difference maps and its coordinates were allowed to refine. The light-atom data do not permit determination of the absolute configuration, the *S*-configuration at C10 is based on information provided with the crystal. Parameters for data collection and refinement are summarised in the Crystal Data tables below.

1. G.M. Sheldrick, Acta Cryst. 2008, A64, 112-122.

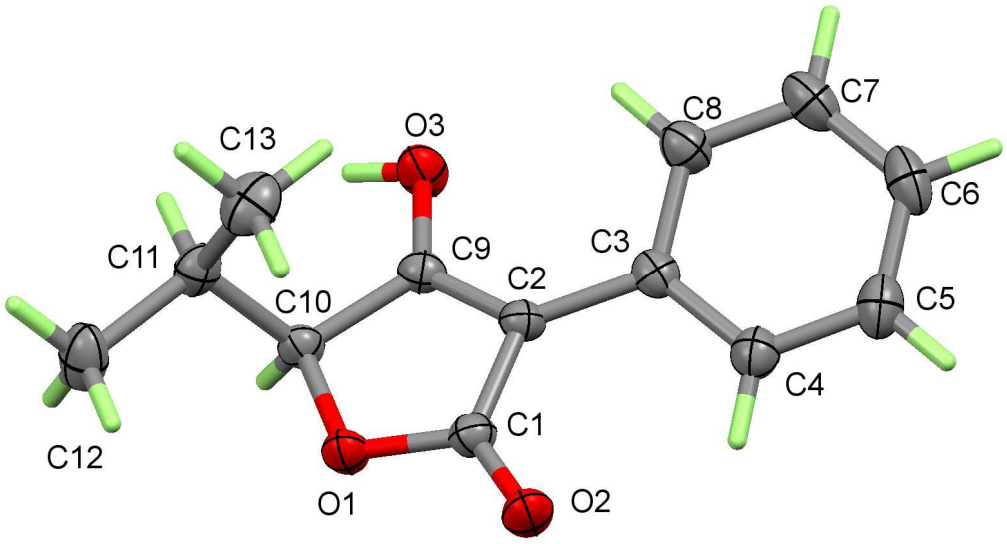


*Fig S1. Perspective view of **14f** with 50% displacement ellipsoids.*

Fig S1 shows the numbering scheme, bond lengths and angles are given in the tables below. There is some double bond character evident in the C1-O1 and C2-C9 distances and C1-O2 is a conventional carbonyl bond (1.222(2) Å). There is an angle of 17.46(7)° between the mean planes of the two rings.

An intermolecular hydrogen bond between the alcohol and the carbonyl of an adjacent molecule forms hydrogen bonded chains running parallel to the *c* axis (O3···O2A 2.6355(17) Å under symmetry operation -*x*+1/2, -*y*, *z*+1/2, Fig S2). There are no other striking intermolecular interactions.

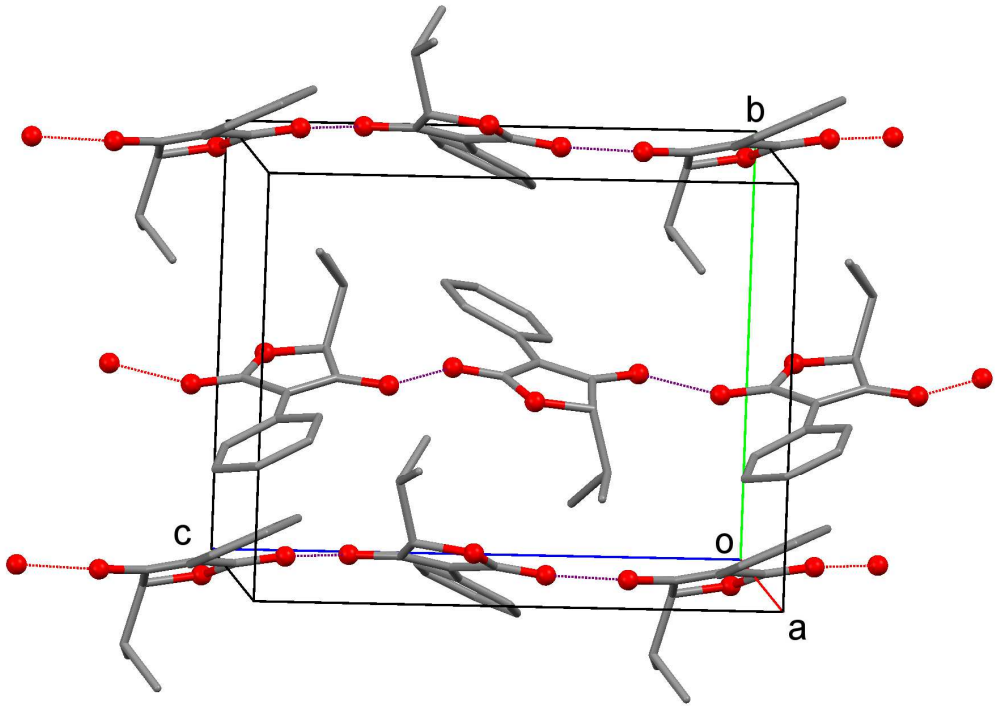


Fig S2. Unit cell packing diagram. Dashed lines represent hydrogen bonds, hydrogen atoms omitted for clarity.

Computing details

Data collection: Bruker *APEX2*; cell refinement: Bruker *SAINT*; data reduction: Bruker *SAINT*; program(s) used to solve structure: *SHELXS97* (Sheldrick, 2008); program(s) used to refine structure: *SHELXL2014*/6 (Sheldrick, 2014); molecular graphics: Bruker *SHELXTL*, CCDC *Mercury*; software used to prepare material for publication: Bruker *SHELXL*, IUCr PublCIF.

Compound 14f (kp596)

Crystal data

$C_{13}H_{14}O_3$	D_x = 1.241 Mg m^{-3}
M_r = 218.24	Mo *K*α radiation, λ = 0.71073 Å
Orthorhombic, $P2_12_12_1$	Cell parameters from 4212 reflections
a = 9.1910 (5) Å	θ = 2.6–28.0°
b = 10.1637 (5) Å	μ = 0.09 mm^{-1}
c = 12.5040 (7) Å	*T* = 150 K
V = 1168.06 (11) Å^3	Trigonal, colourless
Z = 4	0.23 × 0.16 × 0.16 mm

$F(000) = 464$	

Data collection

Bruker APEX 2 CCD diffractometer	2453 reflections with $I > 2\sigma(I)$
Radiation source: fine focus sealed tube	$R_{int} = 0.029$
ω rotation with narrow frames scans	$\theta_{max} = 27.5°$, $\theta_{min} = 2.6°$
Absorption correction: multi-scan *SADABS* v2008/1, Sheldrick, G.M., (2008)	$h = -11 \rightarrow 11$
$T_{min} = 0.779$, $T_{max} = 0.862$	$k = -13 \rightarrow 13$
11367 measured reflections	$l = -16 \rightarrow 16$
2672 independent reflections	

Refinement

Refinement on F^2	Secondary atom site location: structure-invariant direct methods
Least-squares matrix: full	Hydrogen site location: mixed
$R[F^2 > 2\sigma(F^2)] = 0.031$	H atoms treated by a mixture of independent and constrained refinement
$wR(F^2) = 0.083$	$w = 1/[\sigma^2(F_o^2) + (0.0472P)^2 + 0.1329P]$ where $P = (F_o^2 + 2F_c^2)/3$
$S = 1.02$	$(\Delta/\sigma)_{max} < 0.001$
2672 reflections	$\Delta\rangle_{max} = 0.19$ e Å^{-3}
149 parameters	$\Delta\rangle_{min} = -0.17$ e Å^{-3}
0 restraints	Absolute structure: Refined as an inversion twin (check for v small Flack -0.3(12)).
Primary atom site location: structure-invariant direct methods	

Special details

Geometry. All esds (except the esd in the dihedral angle between two l.s. planes) are estimated using the full covariance matrix. The cell esds are taken into account individually in the estimation of esds in distances, angles and torsion angles; correlations between esds in cell parameters are only used when they are defined by crystal symmetry. An approximate (isotropic) treatment of cell esds is used for estimating esds involving l.s. planes.
Refinement. Refined as a 2-component inversion twin.

Fractional atomic coordinates and isotropic or equivalent isotropic displacement parameters (Å^2)

	x	*y*	*Z*	U_{iso}*/U_{eq}
O1	0.32674 (13)	0.04103 (12)	0.53174 (9)	0.0280 (3)
C1	0.20582 (18)	-0.00257 (16)	0.48111 (13)	0.0254 (3)
O2	0.21028 (13)	-0.02068 (14)	0.38455 (9)	0.0336 (3)
C2	0.08622 (17)	-0.02121 (16)	0.55570 (12)	0.0228 (3)
C3	-0.06150 (18)	-0.06467 (16)	0.52631 (13)	0.0246 (3)
C4	-0.08914 (19)	-0.12582 (18)	0.42774 (15)	0.0307 (4)
H4	-0.0111	-0.1416	0.3796	0.037*
C5	-0.2294 (2)	-0.16346 (19)	0.39990 (16)	0.0355 (4)
H5	-0.2466	-0.2047	0.3329	0.043*
C6	-0.3443 (2)	-0.14122 (19)	0.46932 (17)	0.0374 (5)
H6	-0.4404	-0.1659	0.4498	0.045*
C7	-0.3179 (2)	-0.0830 (2)	0.56691 (17)	0.0377 (4)
H7	-0.3963	-0.0689	0.6151	0.045*
C8	-0.17808 (19)	-0.04472 (18)	0.59580 (14)	0.0318 (4)
H8	-0.1619	-0.0046	0.6634	0.038*
C9	0.14096 (17)	0.00926 (16)	0.65316 (12)	0.0233 (3)
O3	0.07395 (13)	0.00178 (14)	0.74658 (9)	0.0318 (3)
H3	0.140 (2)	0.009 (2)	0.7956 (18)	0.038*
C10	0.29420 (18)	0.05904 (17)	0.64396 (12)	0.0241 (3)
H10	0.3606	0.0032	0.6882	0.029*
C11	0.3125 (2)	0.20401 (17)	0.67485 (13)	0.0284 (4)
H11	0.2947	0.2116	0.7535	0.034*
C12	0.4686 (2)	0.2486 (2)	0.65331 (17)	0.0410 (5)
H12A	0.5364	0.1902	0.6907	0.062*
H12B	0.4879	0.2454	0.5763	0.062*
H12C	0.4815	0.3389	0.6791	0.062*
C13	0.2024 (2)	0.29235 (19)	0.61807 (17)	0.0407 (5)
H13A	0.1036	0.2613	0.6334	0.061*
H13B	0.2132	0.3830	0.6436	0.061*
H13C	0.2197	0.2895	0.5408	0.061*

Atomic displacement parameters (Å^2)

	U^{11}	U^{22}	U^{33}	U^{12}	U^{13}	U^{23}
O1	0.0240 (6)	0.0396 (7)	0.0205 (6)	-0.0028 (5)	0.0032 (5)	-0.0032 (5)
C1	0.0260 (7)	0.0279 (8)	0.0222 (7)	0.0012 (7)	0.0011 (6)	-0.0019 (6)
O2	0.0323 (6)	0.0470 (7)	0.0214 (6)	-0.0045 (6)	0.0038 (5)	-0.0069 (5)

C2	0.0233 (7)	0.0236 (7)	0.0216 (7)	0.0024 (6)	0.0013 (6)	0.0004 (6)
C3	0.0241 (8)	0.0232 (7)	0.0265 (8)	0.0010 (6)	-0.0013 (7)	0.0049 (6)
C4	0.0308 (9)	0.0296 (9)	0.0317 (9)	-0.0005 (7)	-0.0024 (8)	-0.0008 (7)
C5	0.0374 (10)	0.0313 (9)	0.0378 (10)	-0.0064 (8)	-0.0099 (8)	0.0000 (8)
C6	0.0274 (9)	0.0344 (10)	0.0506 (12)	-0.0093 (8)	-0.0087 (8)	0.0109 (9)
C7	0.0261 (9)	0.0428 (10)	0.0441 (11)	-0.0021 (8)	0.0034 (9)	0.0100 (8)
C8	0.0279 (9)	0.0375 (10)	0.0300 (9)	-0.0007 (7)	0.0017 (7)	0.0034 (7)
C9	0.0245 (8)	0.0235 (8)	0.0218 (7)	0.0015 (6)	0.0020 (6)	0.0022 (6)
O3	0.0281 (6)	0.0490 (8)	0.0182 (5)	-0.0053 (6)	0.0009 (5)	0.0027 (6)
C10	0.0239 (8)	0.0299 (8)	0.0186 (7)	0.0002 (6)	0.0011 (6)	0.0009 (6)
C11	0.0356 (9)	0.0301 (9)	0.0193 (7)	-0.0063 (8)	-0.0001 (7)	0.0002 (6)
C12	0.0434 (11)	0.0470 (11)	0.0327 (10)	-0.0195 (9)	0.0005 (9)	0.0023 (9)
C13	0.0532 (12)	0.0296 (9)	0.0394 (10)	0.0011 (9)	-0.0043 (10)	0.0032 (8)

*Geometric parameters (Å, º) for (**14f**)*

O1—C1	1.354 (2)	C5—C6	1.386 (3)
O1—C10	1.4463 (18)	C6—C7	1.378 (3)
C1—O2	1.222 (2)	C7—C8	1.391 (3)
C1—C2	1.454 (2)	C9—O3	1.3228 (19)
C2—C9	1.354 (2)	C9—C10	1.501 (2)
C2—C3	1.474 (2)	C10—C11	1.532 (2)
C3—C8	1.394 (2)	C11—C12	1.529 (3)
C3—C4	1.404 (2)	C11—C13	1.528 (3)
C4—C5	1.389 (2)		
C1—O1—C10	108.99 (12)	C7—C6—C5	119.40 (17)
O2—C1—O1	118.94 (15)	C6—C7—C8	120.86 (18)
O2—C1—C2	129.75 (16)	C7—C8—C3	120.50 (17)
O1—C1—C2	111.30 (13)	O3—C9—C2	127.48 (15)
C9—C2—C1	105.46 (14)	O3—C9—C10	121.60 (14)
C9—C2—C3	129.42 (15)	C2—C9—C10	110.90 (14)
C1—C2—C3	125.13 (14)	O1—C10—C9	103.05 (13)
C8—C3—C4	118.20 (16)	O1—C10—C11	110.09 (13)
C8—C3—C2	120.58 (15)	C9—C10—C11	114.05 (14)
C4—C3—C2	121.21 (15)	C12—C11—C13	111.43 (16)
C5—C4—C3	120.66 (17)	C12—C11—C10	110.10 (16)
C6—C5—C4	120.36 (18)	C13—C11—C10	112.05 (15)

*Hydrogen-bond geometry (Å, º) for (**14f**)*

D—H···*A*	*D*—H	H···*A*	*D*···*A*	*D*—H···*A*
O3—H3···O2^{i}	0.86 (2)	1.78 (2)	2.6355 (17)	173 (2)

Symmetry code: (i) -*x*+1/2, -*y*, *z*+1/2.

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Crystallographic Data for 26a

The data were collected at 150(2)K on a Bruker Apex II CCD diffractometer. The structure was solved by direct methods and refined on F^2 using all the reflections[1]. All the non-hydrogen atoms were refined using anisotropic atomic displacement parameters. Hydrogen atoms bonded to carbon were inserted at calculated positions using a riding model; the hydrogen atom of the alcohol group was located from difference maps and its coordinates refined freely. Parameters for data collection and refinement are summarised in the Crystal Data tables below.

1. G.M. Sheldrick, Acta Cryst. 2008, A64, 112-122.

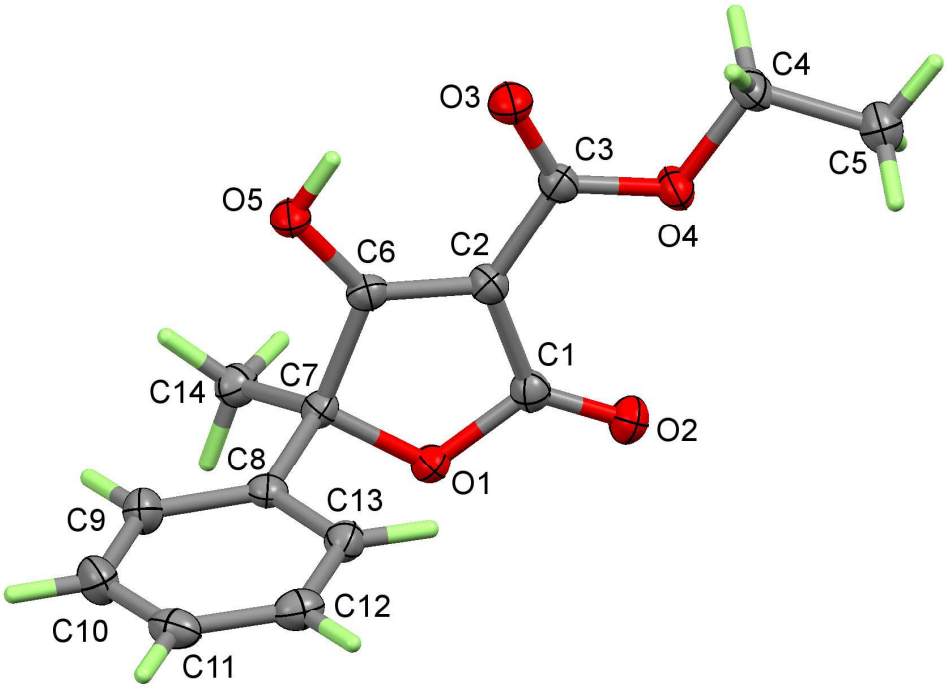

*Fig S3. Perspective view of **26a** with 50% displacement ellipsoids.*

Fig S3 shows the numbering scheme, bond lengths and angles are given in the tables below. There is some double bond character evident in the C1–O1 and C2–C6 distances, while C1–O2 and C3–O3 are conventional carbonyl bonds (1.1953(18) and 1.2232(18) Å, respectively). There is an angle of 85.92(5)° between the mean planes of the two rings.

The alcohol group acts as donor for a bifurcated hydrogen bond with both an intramolecular component (O5 ··· O3 2.7717(15) Å) and an intermolecular component (O5 … O3 2.9905 (15) Å under symmetry operation -*x*+2, -*y*+1, -*z*+2), resulting in formation of hydrogen bonded dimers (Figure S4). There some π-stacking involving the carbonyl groups (Figure S4) which stacks the dimers into columns (Figure S5); surprisingly, there is no indication of significant π–π interaction between the phenyl groups.

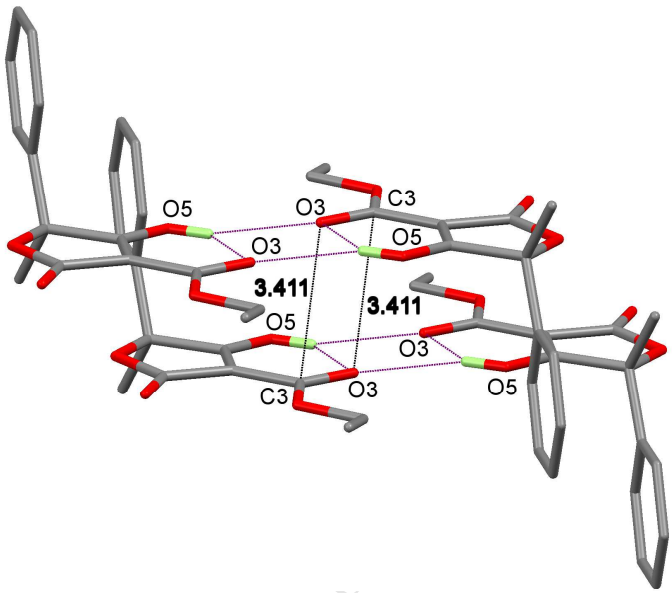

*Fig S4. Intra- and intermolecular interactions in **26a**. Dashed purple lines represent hydrogen bonds, dashed black lines indicate π interaction. Hydrogen atoms omitted for clarity.*

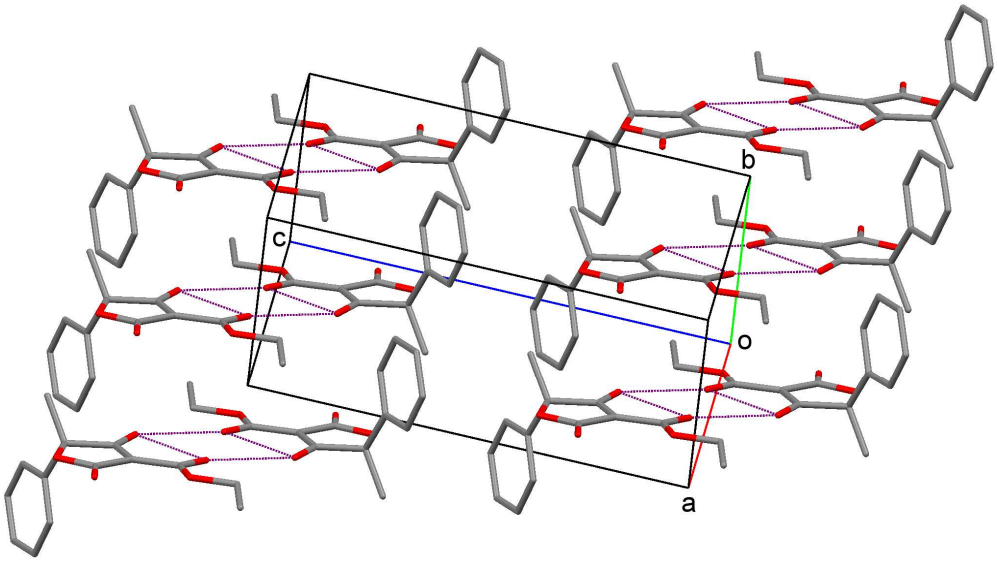

Fig S5. Unit cell packing diagram. Dashed lines represent hydrogen bonds, hydrogen atoms omitted for clarity.

Computing details

Data collection: Bruker *APEX2*; cell refinement: Bruker *SAINT*; data reduction: Bruker *SAINT*; program(s) used to solve structure: *SHELXS97* (Sheldrick, 2008); program(s) used to refine structure: *SHELXL2014*/6 (Sheldrick, 2014); molecular graphics: Bruker *SHELXTL*; software used to prepare material for publication: Bruker *SHELXTL*.

Compound 26a (kp460)

Crystal data

$C_{14}H_{14}O_5$	$Z = 2$
$M_r = 262.25$	$F(000) = 276$
Triclinic, $P\bar{1}$	$D_x = 1.418$ Mg m^{-3}
$a = 5.4989$ (5) Å	Mo $K\alpha$ radiation, $\lambda = 0.71073$ Å
$b = 8.1210$ (8) Å	Cell parameters from 1636 reflections
$c = 13.8310$ (13) Å	$\theta = 2.5$–$26.7°$
$\alpha = 93.570$ (2)°	$\mu = 0.11$ mm^{-1}
$\beta = 92.751$ (2)°	$T = 150$ K
$\gamma = 93.963$ (2)°	Lath, colourless
$V = 614.12$ (10) Å^3	0.22 × 0.08 × 0.02 mm

Data collection

Bruker APEX 2 CCD diffractometer	2218 reflections with $I > 2\sigma(I)$
Radiation source: fine focus sealed tube	$R_{int} = 0.027$
ω rotation with narrow frames scans	$\theta_{max} = 27.5°$, $\theta_{min} = 2.5°$
Absorption correction: multi-scan *SADABS* v2008/1, Sheldrick, G.M., (2008)	$h = -7 \rightarrow 7$
$T_{min} = 0.775$, $T_{max} = 0.862$	$k = -10 \rightarrow 10$
6033 measured reflections	$l = -17 \rightarrow 17$
2814 independent reflections	

Refinement

Refinement on F^2	Primary atom site location: structure-invariant direct methods
Least-squares matrix: full	Secondary atom site location: structure-invariant direct methods
$R[F^2 > 2\sigma(F^2)] = 0.042$	Hydrogen site location: mixed
$wR(F^2) = 0.103$	H atoms treated by a mixture of independent and constrained refinement
$S = 1.04$	$w = 1/[\sigma^2(F_o^2) + (0.0435P)^2 + 0.1629P]$

	where $P = (F_o^2 + 2F_c^2)/3$
2814 reflections	$(\Delta/\sigma)_{max} = 0.001$
175 parameters	$\Delta\rangle_{max} = 0.26$ e Å^{-3}
0 restraints	$\Delta\rangle_{min} = -0.23$ e Å^{-3}

Special details

Geometry. All esds (except the esd in the dihedral angle between two l.s. planes) are estimated using the full covariance matrix. The cell esds are taken into account individually in the estimation of esds in distances, angles and torsion angles; correlations between esds in cell parameters are only used when they are defined by crystal symmetry. An approximate (isotropic) treatment of cell esds is used for estimating esds involving l.s. planes.

Fractional atomic coordinates and isotropic or equivalent isotropic displacement parameters (Å^2)

	x	*y*	*z*	U_{iso}*/U_{eq}
O1	0.43855 (18)	0.27827 (12)	0.68360 (7)	0.0219 (2)
C1	0.3869 (3)	0.22995 (18)	0.77491 (11)	0.0218 (3)
O2	0.2131 (2)	0.13758 (14)	0.78600 (8)	0.0285 (3)
C2	0.5764 (3)	0.31027 (18)	0.84378 (11)	0.0214 (3)
C3	0.6001 (3)	0.30363 (18)	0.94896 (11)	0.0216 (3)
O3	0.7652 (2)	0.38420 (14)	0.99682 (8)	0.0282 (3)
O4	0.42990 (19)	0.20586 (13)	0.98465 (7)	0.0246 (3)
C4	0.4431 (3)	0.1934 (2)	1.08966 (11)	0.0279 (4)
H4A	0.4705	0.3048	1.1233	0.034*
H4B	0.5795	0.1268	1.1089	0.034*
C5	0.2044 (3)	0.1114 (2)	1.11614 (12)	0.0314 (4)
H5A	0.2069	0.1009	1.1864	0.047*
H5B	0.0710	0.1784	1.0968	0.047*
H5C	0.1796	0.0012	1.0825	0.047*
C6	0.7383 (3)	0.39663 (18)	0.79335 (10)	0.0199 (3)
O5	0.93961 (19)	0.48622 (13)	0.82391 (8)	0.0238 (2)
H5	0.952 (3)	0.487 (2)	0.8859 (14)	0.029*
C7	0.6633 (3)	0.38466 (18)	0.68627 (10)	0.0200 (3)
C8	0.6043 (3)	0.55404 (18)	0.65371 (10)	0.0202 (3)
C9	0.7547 (3)	0.6417 (2)	0.59424 (11)	0.0272 (4)
H9	0.8929	0.5932	0.5692	0.033*
C10	0.7038 (3)	0.8006 (2)	0.57117 (12)	0.0313 (4)
H10	0.8070	0.8597	0.5301	0.038*
C11	0.5047 (3)	0.8727 (2)	0.60743 (11)	0.0286 (4)
H11	0.4721	0.9818	0.5922	0.034*
C12	0.3524 (3)	0.7857 (2)	0.66606 (11)	0.0266 (3)

H12	0.2141	0.8347	0.6907	0.032*
C13	0.4012 (3)	0.62733 (19)	0.68888 (11)	0.0230 (3)
H13	0.2954	0.5680	0.7289	0.028*
C14	0.8442 (3)	0.29656 (19)	0.62561 (11)	0.0243 (3)
H14A	0.9975	0.3658	0.6262	0.036*
H14B	0.8751	0.1909	0.6528	0.036*
H14C	0.7765	0.2762	0.5588	0.036*

Atomic displacement parameters (Å^2)

	U^{11}	U^{22}	U^{33}	U^{12}	U^{13}	U^{23}
O1	0.0199 (5)	0.0244 (5)	0.0208 (5)	-0.0027 (4)	-0.0005 (4)	0.0026 (4)
C1	0.0217 (7)	0.0211 (7)	0.0234 (8)	0.0033 (6)	0.0035 (6)	0.0035 (6)
O2	0.0246 (6)	0.0290 (6)	0.0314 (6)	-0.0057 (5)	0.0012 (5)	0.0056 (5)
C2	0.0218 (7)	0.0214 (7)	0.0210 (7)	0.0014 (6)	0.0012 (6)	0.0035 (6)
C3	0.0220 (7)	0.0209 (7)	0.0224 (8)	0.0021 (6)	0.0009 (6)	0.0038 (6)
O3	0.0265 (6)	0.0334 (6)	0.0236 (6)	-0.0043 (5)	-0.0024 (4)	0.0035 (5)
O4	0.0278 (6)	0.0269 (6)	0.0189 (5)	-0.0040 (5)	0.0029 (4)	0.0041 (4)
C4	0.0326 (9)	0.0332 (9)	0.0179 (7)	-0.0017 (7)	0.0017 (6)	0.0048 (6)
C5	0.0312 (9)	0.0345 (9)	0.0289 (9)	-0.0006 (7)	0.0054 (7)	0.0070 (7)
C6	0.0183 (7)	0.0205 (7)	0.0208 (7)	0.0031 (6)	-0.0008 (5)	0.0011 (6)
O5	0.0215 (5)	0.0302 (6)	0.0186 (5)	-0.0041 (4)	-0.0011 (4)	0.0015 (4)
C7	0.0168 (7)	0.0224 (7)	0.0205 (7)	-0.0016 (6)	0.0002 (5)	0.0023 (6)
C8	0.0198 (7)	0.0244 (7)	0.0158 (7)	-0.0003 (6)	-0.0025 (5)	0.0009 (6)
C9	0.0236 (8)	0.0330 (9)	0.0256 (8)	0.0011 (7)	0.0043 (6)	0.0063 (7)
C10	0.0325 (9)	0.0333 (9)	0.0287 (9)	-0.0024 (7)	0.0028 (7)	0.0113 (7)
C11	0.0350 (9)	0.0242 (8)	0.0259 (8)	0.0022 (7)	-0.0069 (7)	0.0042 (6)
C12	0.0250 (8)	0.0285 (8)	0.0258 (8)	0.0049 (6)	-0.0034 (6)	-0.0020 (6)
C13	0.0209 (7)	0.0261 (8)	0.0216 (7)	-0.0014 (6)	0.0013 (6)	0.0013 (6)
C14	0.0222 (7)	0.0280 (8)	0.0225 (8)	0.0024 (6)	0.0016 (6)	-0.0011 (6)

Geometric parameters (Å, º) for 26a (kp460)

O1—C1	1.3821 (18)	C6—O5	1.3188 (18)
O1—C7	1.4557 (17)	C6—C7	1.514 (2)
C1—O2	1.1953 (18)	C7—C14	1.520 (2)
C1—C2	1.467 (2)	C7—C8	1.525 (2)
C2—C6	1.344 (2)	C8—C9	1.387 (2)
C2—C3	1.459 (2)	C8—C13	1.395 (2)
C3—O3	1.2232 (18)	C9—C10	1.392 (2)
C3—O4	1.3194 (17)	C10—C11	1.378 (2)
O4—C4	1.4608 (18)	C11—C12	1.383 (2)

C4—C5	1.502 (2)	C12—C13	1.384 (2)
C1—O1—C7	111.40 (11)	O1—C7—C6	101.70 (11)
O2—C1—O1	120.62 (14)	O1—C7—C14	107.81 (12)
O2—C1—C2	131.74 (14)	C6—C7—C14	112.26 (12)
O1—C1—C2	107.64 (12)	O1—C7—C8	108.96 (11)
C6—C2—C3	122.83 (14)	C6—C7—C8	110.18 (12)
C6—C2—C1	108.05 (13)	C14—C7—C8	115.01 (12)
C3—C2—C1	129.11 (13)	C9—C8—C13	118.85 (14)
O3—C3—O4	125.16 (14)	C9—C8—C7	121.79 (13)
O3—C3—C2	121.00 (13)	C13—C8—C7	119.27 (13)
O4—C3—C2	113.84 (13)	C8—C9—C10	120.19 (15)
C3—O4—C4	116.68 (12)	C11—C10—C9	120.49 (15)
O4—C4—C5	107.26 (13)	C10—C11—C12	119.73 (15)
O5—C6—C2	129.82 (14)	C11—C12—C13	120.08 (15)
O5—C6—C7	119.02 (12)	C12—C13—C8	120.65 (14)
C2—C6—C7	111.15 (13)		

Hydrogen-bond geometry (Å, º) for 26a (kp460)

D—H···*A*	*D*—H	H···*A*	*D*···*A*	*D*—H···*A*
O5—H5···O3	0.857 (19)	2.074 (18)	2.7717 (15)	138.2(16)
O5—H5···O3^{i}	0.857 (19)	2.336 (18)	2.9905 (15)	133.4 (15)

Symmetry code: (i) -*x*+2, -*y*+1, -*z*+2.

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