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Efficient and shortcut syntheses of some novel eight-membered ring cyclitols starting from cycloocta-1,3-diene

Kadriye Ecer, and Emine Salamci*

Department of Chemistry, Faculty of Sciences, Atatürk University, 25240 Erzurum, Turkey

ABSTRACT

Cyclooctane-1,2,3,4-tetraols, aminocyclooctanetriol, and chlorocyclooctanetriol were synthesized starting from *cis,cis*-1,3-cyclooctadiene by a concise and efficient method. Cyclooctene endoperoxide and cyclooctene epoxide obtained by photooxygenation and epoxidation, respectively, of *cis,cis*-1,3-cyclooctadiene were used as the key intermediates. The other oxygen, nitrogen, and chloro functionalities were introduced via epoxidation of the remaining double bond, ring opening of epoxide, and *cis*-hydroxylation reactions.

Keywords: Cyclitol; 3-Aminocyclooctanetriol; Cyclooctanetetraol; 3-Chlorocyclooctanetriol; Endoperoxide; Carbasugar.

*Corresponding author. Tel: +90 442 231 4429; fax: +90 442 2314109 (E.S.).

E-mail address: esalamci@atauni.edu.tr (E. Salamci).

1. Introduction

Cyclitols containing eight-membered rings are polyhydroxycyclooctanes and their derivatives. The cyclitol class of compounds has attracted considerable interest due to the fact that many biologically important molecules and natural products contain a polyhydroxylated carbocycle.[1-3] The most prominent cyclitols, such as inositols (**1**) and their derivatives (**2**), have been synthesized and evaluated in particular for their biological activities, especially glycosidase inhibition.[4-6]

Glycosidases are enzymes that catalyze the cleavage of glycosidic bonds and play critical roles in a number of biological processes. Inhibitors of these enzymes have garnered a great deal of attention and are currently used for the treatment of diabetes and HIV infection, and as antifungal agents. Therefore, they are expected to arouse increasing interest as therapeutic agents as our understanding of the role of glycosidases in recognition processes improves.[7] Some natural products or their analogues include 1,6-diepicastanospermine (**3**) and gallic acid (**4**) (Figure 1), which have glycosidase inhibitory activities and thus have potential utility as antiviral, anticancer, antidiabetic, and antiobesity drugs.[8,9]

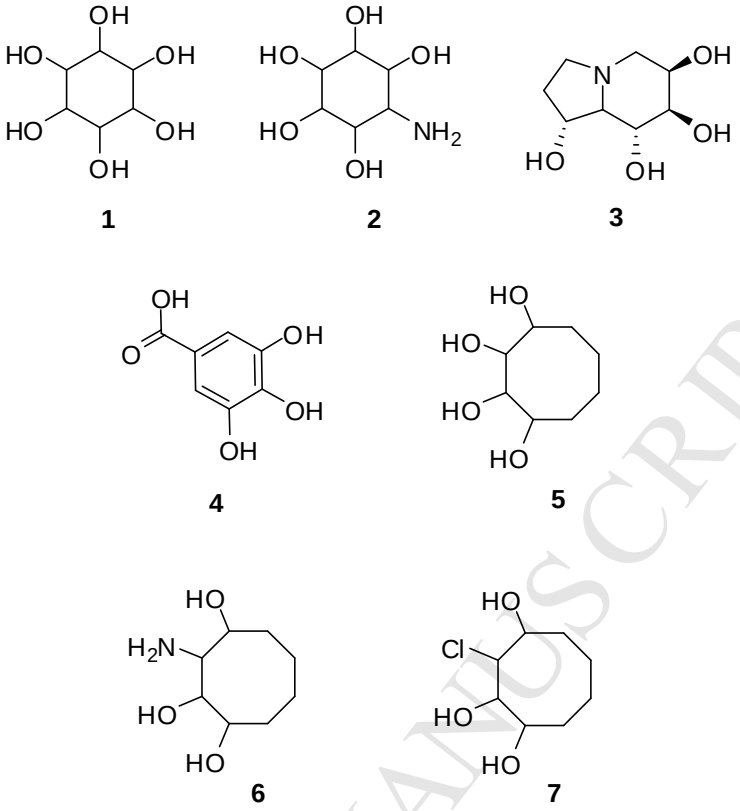


Fig. 1. Structures of some cyclitols.

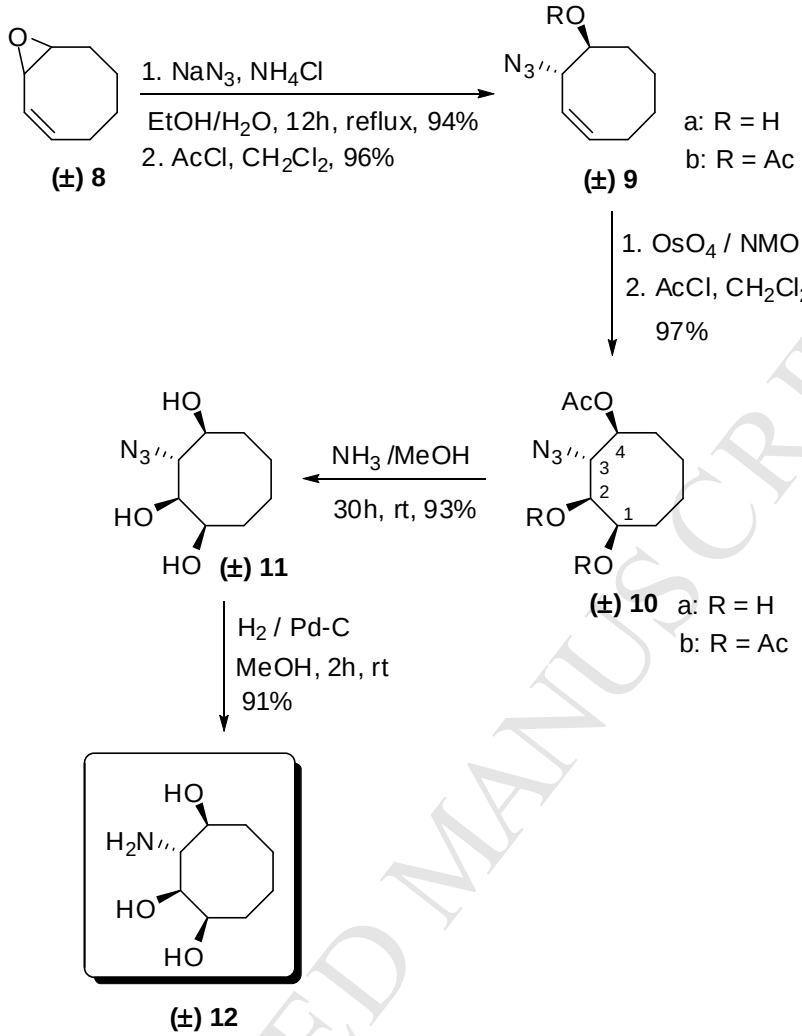
Recently, interest in seven-, eight-, and nine-membered ring systems[6,10] has been increasing in order to study the effect of the enhanced flexibility and of the new spatial distribution displayed by these structures. The configuration of the hydroxyl groups has been reported to play an important role in the active site of the enzyme. [6a, 6d, 6e]

Synthetic methods have been previously reported for a cyclitol motif on six-,[11] seven-,[12] eight-,[3,6d,6f,13] and nine-membered[10] rings, but only a few approaches are available for the synthesis of eight-membered[6a,14] aminocyclitols. More recently, we stereospecifically synthesized two stereoisomers of cyclooctane-1,2,3,4-tetraols starting from *cis,cis*-1,3-cyclooctadiene.[13e] The synthesis of isomeric cyclooctanetetrols **5** was accomplished by three different methods,[3b,13e,13f] but synthesis of 3-aminocyclooctanetriol **6**, which is an analogue of cyclooctanetetraol, and 3-chlorocyclooctanetriol **7** has not been reported in the literature (Figure 1).

Our aim in the present work was to design a concise synthetic route to new cyclooctanoic carbasugar analogues **5**, **6**, and **7**, using simple starting materials.

2. Results and Discussion

For the synthesis of the key compound, cyclooctene epoxide **8**, used in the synthesis of 3-aminocyclooctanetriol and cyclooctanetetraols, *cis,cis*-1,3-cyclooctadiene was reacted with *m*-CPBA to form epoxide **8**[15] (Scheme 1). Our initial approach to synthesize the 3-aminocyclooctanetriol was based on azidolysis of epoxide **8** with sodium azide. As reported in the literature,[16] vicinal azidohydrins have been extensively utilized as precursors of 1,2-aminoalcohols in carbohydrate chemistry or in the chemistry of carbocyclic nucleosides. For this purpose, treatment of epoxide **8** with sodium azide in the presence of NH_4Cl produced azidoalcohol **9a**.[17] The acetylation of azidoalcohol **9a** with an excess of acetyl chloride in methylene chloride resulted in the formation of azidoacetate **9b** in 96% yield (Scheme 1). Cyclooctene azidoacetate **9b** is a unique substrate for the synthesis of aminocyclooctanetriol. For that reason, the double bond in azidoacetate **9b** was submitted to a *cis*-dihydroxylation reaction with OsO_4-NMO[18] followed by acetylation to give triacetate **10b** in 97% yield. The spectroscopic data confirmed the formation of a single isomer. The exact configuration of **10b** was confirmed by both ^{1}H NMR and 2D NMR spectroscopic data (COSY, NOESY). The acetoxyl proton H-2 in **10b** resonates as a doublet of doublets with coupling constants of J = 7.6 and 2.6 Hz, clearly indicating that the neighboring protons H-2 and H-3 with a large coupling constant ($J_{2,3}$ = 7.6 Hz) are in the *trans* position. The azido proton H-3 also resonates as a doublet of doublets with coupling constants of J = 9.8 and 7.6 Hz. Furthermore, the second large coupling between the protons H-3 and H-2 ($J_{2,3}$ = 7.6 Hz) shows the *trans* relation between those protons. The fact that the proton H-4 appears as a doublet of doublet of doublets with coupling constants of J = 9.8, 5.3, and 2.9 Hz also supports the *trans* relation of the protons H-3 and H-4. The resonance signal of H-1 appears as a triplet of doublets with coupling constants of J = 7.7 and 2.6 Hz, which clearly supports the *cis* relation of the protons H-1 and H-2 with a small coupling constant ($J_{1,2}$ = 2.6 Hz). On the basis of these findings, we assigned a *trans-trans* relation to the azido group in **10b**.

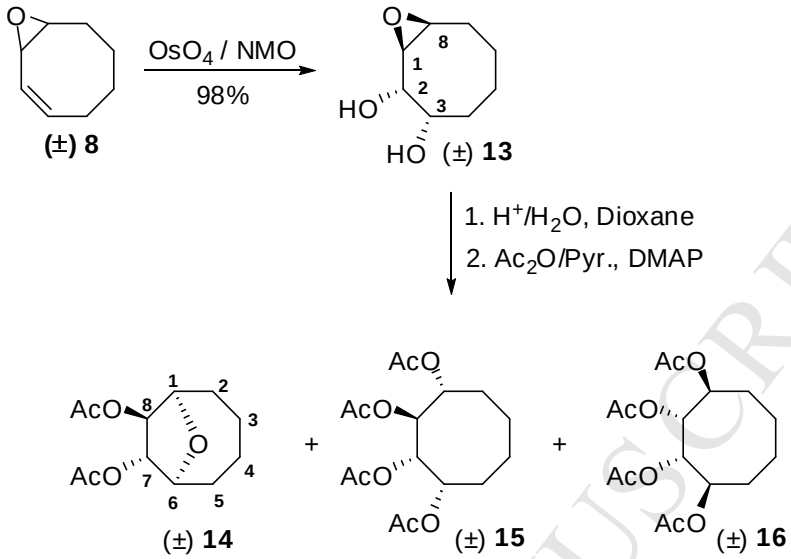


Scheme 1 Synthesis of (1R(S),2S(R),3R(S),4S(R))-3-Aminocyclooctane-1,2,4-triol (**12**).

The acetyl groups in (1R(S),2S(R),3R(S),4S(R))-3-azidocyclooctane-1,2,4-triyl triacetate (**10b**) were removed using NH_3-MeOH to give (1R(S),2S(R),3R(S),4S(R))-3-azidocyclooctane-1,2,4-triol (**11**) (93% yield). Hydrogenation of **11** gave (1R(S),2S(R),3R(S),4S(R))-3-aminocyclooctane-1,2,4-triol (**12**) in 91% yield (Scheme 1). ^{1}H and ^{13}C NMR spectroscopic data of the molecule are in agreement with the proposed structure.

The formation of **10a** from **9b** as the sole product can be explained by considering the steric effects. Since in relation to the azido group the *cis*-face of the cyclooctene double bond is blocked by hindrance of the azido group, OsO_4 approaches

the double bond in **9b** preferentially from the sterically less crowded face of the molecule (Scheme 1).

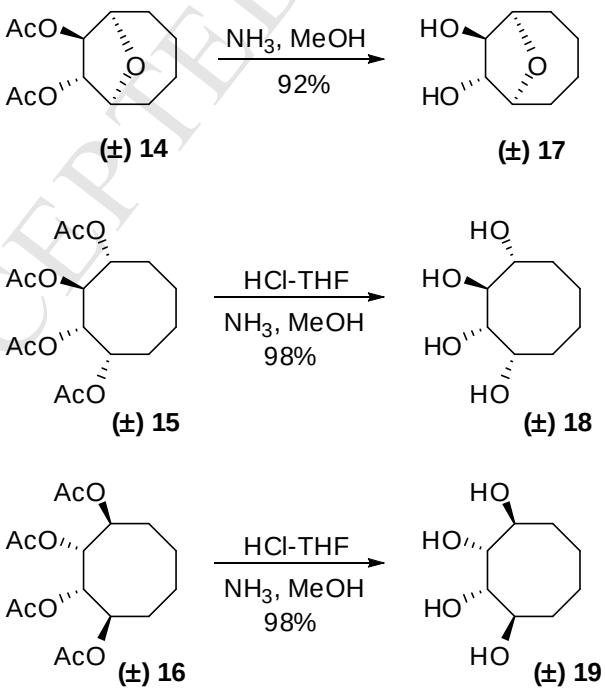


Scheme 2 Reaction of Epoxy-diol **13** with H_2SO_4 in Water.

For the synthesis of other polyhydroxylated cyclooctanes, epoxide **8** was reacted with OsO_4-NMO to give **13** as the sole isomer (Scheme 2). The exact configuration of **13** was confirmed by both ^{1}H NMR and 2D NMR spectroscopic data (COSY, NOESY). The epoxide protons (H-1 and H-8) resonate as an AB system at δ 3.19 and 3.05 and gave the most useful information for the configuration of **13**. The A part of the AB system (low field resonance, H-1) is split into a doublet of doublets ($J_{1,2}$ = 8.5 and $J_{1,8}$ = 4.7 Hz). The large coupling ($J_{1,2}$ = 8.5 Hz) between the protons H-1 and H-2 shows the *trans* relation between those protons. The small coupling ($J_{1,8}$ = 4.7 Hz) also indicates a relation between the neighboring epoxide protons H-1 and H-8. The high-field part of the AB system resonates as a triplet of doublets (J = 9.6 and $J_{1,8}$ = 4.7 Hz). Acid-catalyzed ring opening of **13** followed by acetylation with acetic anhydride in pyridine and 4-(dimethylamino)pyridine (DMAP) resulted in formation of the rearranged product **14** as the main product besides hydrolysis products **15** and **16**. The reaction mixture was chromatographed on a silica gel column with ethyl acetate/*n*-hexane (30:70) as the eluent to give the rearrangement product **14** in 49% yield and the two isomers, **15** and **16**, in 39% and 12% yields, respectively. The structures of **14**, **15**, and **16** were assigned on the basis of ^{1}H NMR spectra. The exact configuration of **14** was determined with the

help of the corresponding coupling constants between the relevant protons and 2D NMR spectroscopic data (COSY, NOESY). The acetoxy proton H-8 resonates as a doublet of doublets with coupling constants of J = 4.6 and 2.6 Hz. The large coupling ($J_{7,8}$ = 4.6 Hz) between protons H-8 and H-7 shows the *trans* relation between those protons. In addition to this, Dreiding models[18] indicate that the dihedral angle between protons H-1 and H-8 is approximately 120° whereas the dihedral angle between H-6 and H-7 is 10°. Consequently the high coupling constant value ($J_{6,7}$= 7.8 Hz) is uniquely accommodated by *exo* orientation of proton (*endo* orientation of acetoxy group) at C-7 atom, whereas, the small value ($J_{1,8}$=2.6 Hz) indicate *endo* orientation of proton (*exo* orientation of acetoxy group) at C-8 atom. This also indicates the *trans* configuration of the neighboring protons.

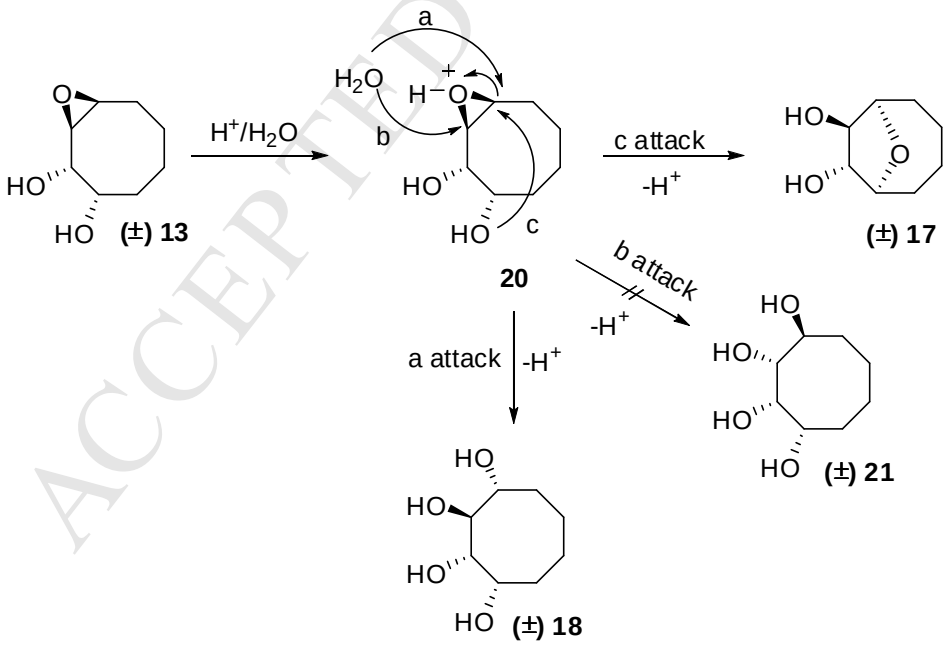
The structural assignment was made by comparison of the NMR spectra with those of (1R(S),2S(R),3R(S),4S(R))-cyclooctane-1,2,3,4-tetraacetate (**15**) and (1R(S),2R(S),3R(S),4S(R))-cyclooctane-1,2,3,4-tetraacetate (**16**). We have recently reported[12e] the synthesis of tetraacetates **15** and **16** starting from *cis,cis*-1,3-cyclooctadiene.



Scheme 3 Synthesis of Diol **17**, and Tetraols **18** and **19**.

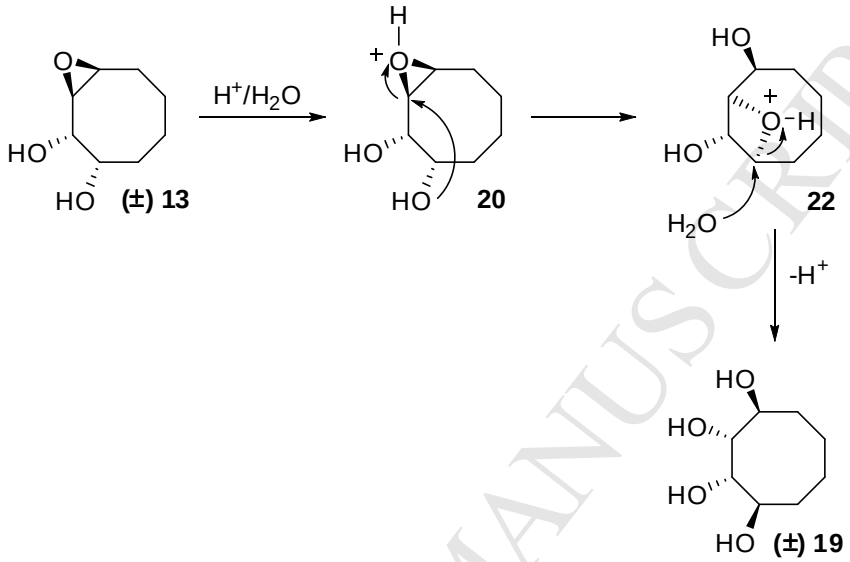
The acetyl groups in (1R(S),2S(R),3R(S),4S(R))- and (1R(S),2R(S),3R(S),4S(R))-cyclooctane-1,2,3,4-tetrayl tetraacetate (**15** and **16**) were removed using 10% HCl in THF and NH_3-MeOH to give (1R(S),2S(R),3R(S),4S(R))- and (1R(S),2R(S),3R(S),4S(R))-cyclooctane-1,2,3,4-tetraol[13e] (**18** and **19**) (98% yield), respectively. Diol **17** itself was readily obtained in 92% yield by ammonolysis of diacetate **14** in methanol. The NMR spectroscopic data of the molecule are in agreement with the proposed structure (Scheme 3).

The formation of isomers **17** and **18**[13e] is reasonably understood in terms of the mechanism outlined in Scheme 4. Tetraols **18**[13e] and **21** were the expected products in this reaction because epoxide **13** is an unsymmetrical structure. The formation of tetraol **18**[13e] arises from the attack of water to the protonated epoxide ring (intermediate **20**). However, the other hydrolysis product, **21**, was not formed (b attack), which can be explained by considering steric effects. The formation of diol **17** arises from by an SN2 attack of the hydroxyl group[13b] to the protonated epoxide ring (c attack). We assume that the hydroxyl group prefers an attack to the protonated epoxide ring from the less crowded side to produce furanoid **17**.



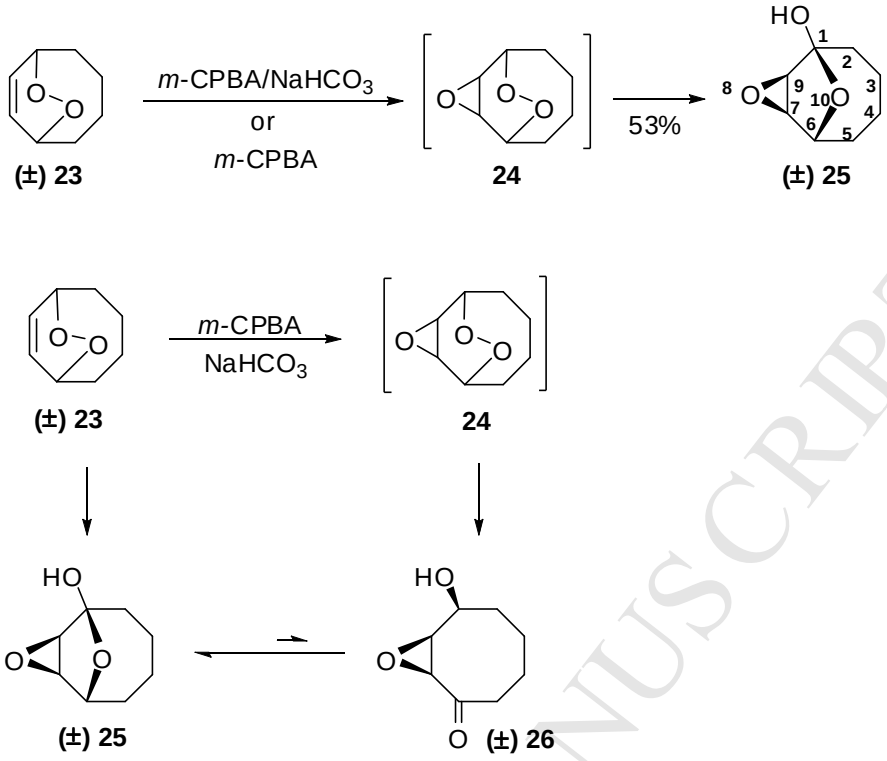
Scheme 4 Formation Mechanism of Diol **17** and Tetraol **18** from **13**.

We also assume that the symmetrical tetraol **19**[13e] is formed by the bottom hydroxyl group attacks the more hindered epoxide carbon to give an oxetane intermediate, which is then opened by an SN2 attack of water on the bottom carbon (Scheme 5).



Scheme 5 Formation Mechanism of Tetraol **19** from **13**.

For the synthesis of further cyclooctanetetraols, endoperoxide **23**[20] was reacted with *m*-CPBA to give the corresponding epoxy peroxide **24**. The reaction was carried out both in the presence of a $NaHCO_3$ buffer and in the absence of the buffer, although we were not able to isolate the epoxy peroxide **24**. Although the formation of the epoxy peroxide **24** was observed by ^1H NMR spectroscopy, during the purification of the reaction mixture, the rearrangement product **25** (in 53% yield) was obtained instead of the desired epoxy peroxide **24**. Probably, such as a Kornblum-DeLaMare rearrangement[20a,21] the initial breaking of the peroxide linkage in **24** forms the hydroxyketone intermediate **26** and the subsequent cyclization to give the epoxide **25** by intramolecular cyclization (Scheme 6). When the reaction was carried out in neutral or basic medium under concentrated reaction conditions, epoxide **25** was observed. However, when the reaction concentration was decreased in the absence of a buffer, the epoxy peroxide **24** did not rearrange to **25**. Herz[22] showed that "endo" endoperoxide-epoxides are particularly susceptible to fragmentation, in six-membered rings.

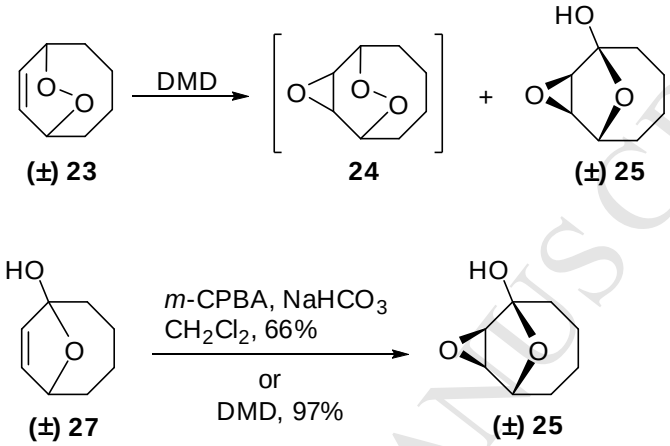


Scheme 6 Reaction of Endoperoxide **23** with *m*-CPBA.

The structure of compound **25** was assigned by both ^{1}H NMR and 2D NMR spectroscopic data (COSY, NOESY, and HMQC). The epoxide protons (H-7 and H-9) of **25** resonating at δ 3.51 (d, J_{AB} = 2.9 Hz) and 3.49 (d, J_{AB} = 2.9 Hz) as an AB system show no coupling with the adjacent proton H-6. There is no measurable coupling between the alkoxy proton H-6 and the epoxide proton H-7 in **25**. The exact configuration of the epoxide ring in **25** was established by measuring the corresponding coupling constants between the relevant protons. The alkoxy proton H-6 in **25** resonates as a doublet of doublets with two coupling constants of $J_{6,5}$ = 7.1 Hz and $J_{6,5'}$ = 1.3 Hz. For the *exo* orientation of the epoxide ring, inspection of Dreiding models indicates that the dihedral angle between related protons is approximately 90°, and the coupling constant between these protons is expected to be smaller than 1.0 Hz. In the case of an *endo* orientation of the epoxy group, the dihedral angle between related protons is approximately 0°, and a larger coupling constant (8-10 Hz) is expected. The geometry of **25** shows the *syn* configuration of the neighboring protons H-6 and H-7.

Next, for the isolation of epoxy peroxide **24**, endoperoxide **23** was also submitted to reaction with dimethyldioxirane[23] (DMDO). The reaction was carried out

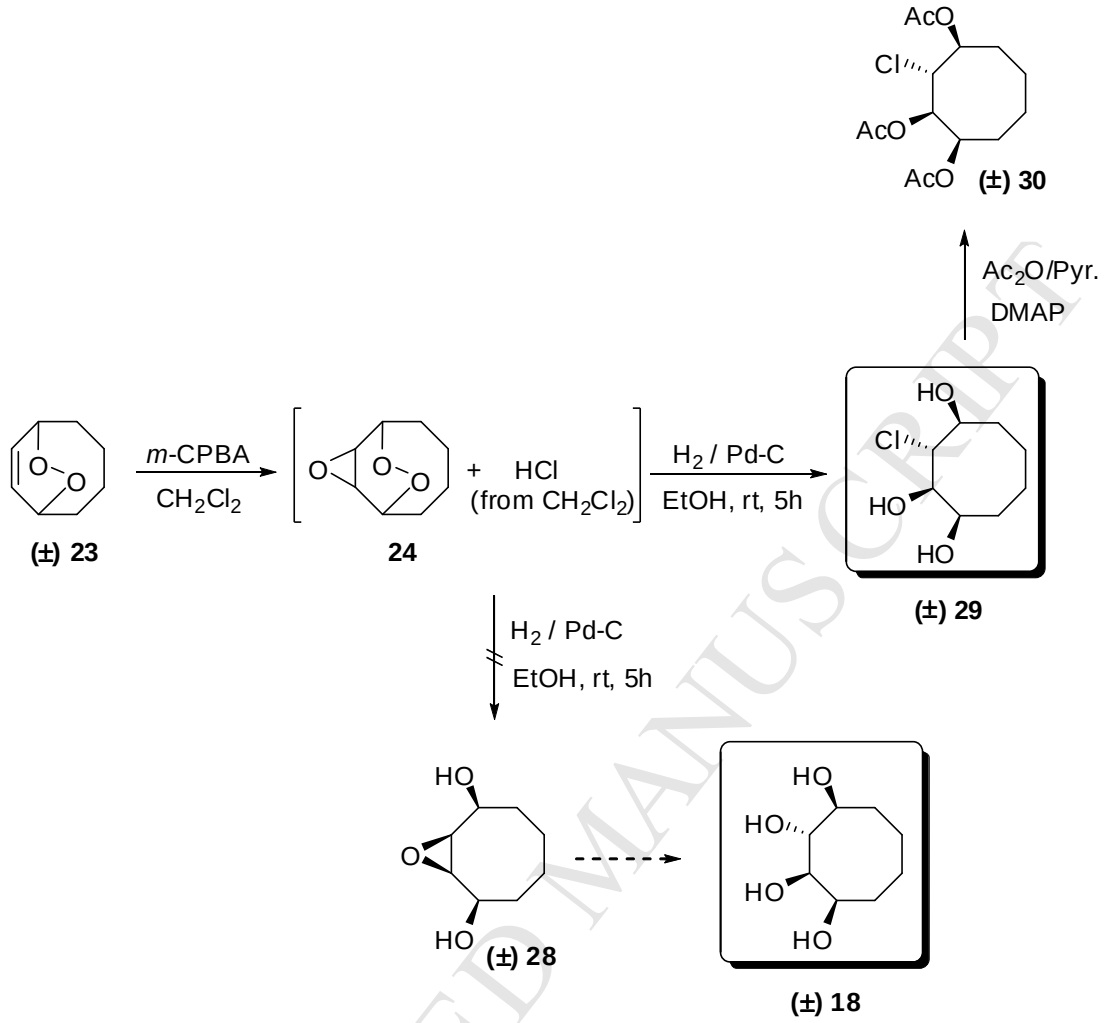
both in the presence of K_2CO_3 and without K_2CO_3 in neutral conditions. From this reaction, formation of the mixture of **24** and **25** in a 1:1 ratio (from ^{1}H NMR spectroscopy) was observed, but all attempts to isolate **24** failed (Scheme 6). We observed that, during the chromatography, compound **24** was fully rearranged to compound **25**.



Scheme 7 Synthesis of Epoxide **25**.

Independently, unsaturated oxabicycle **27**[13e,20d,24] was submitted to an epoxidation reaction both with DMDO and *m*-CPBA to confirm the structure of compound **25**. The formed epoxide **25** was identical to those obtained from the epoxidation of endoperoxide **23**. We assume that the oxidant prefers to approach the double bond in **27** from the sterically less crowded side to produce **25** as a single isomer (Scheme 7).

In the second part of this work, we turned our attention to the synthesis of cyclooctanetetraol **18** starting from endoperoxide **23**. Endoperoxide **23**[20] was reacted with *m*-CPBA to give the corresponding epoxy peroxide **24**. The crude reaction mixture without purification was subjected to hydrogenation to provide the corresponding epoxy diol **28**. Surprisingly, hydrogenation of **24** in absolute ethanol and in the presence of Pd-C resulted in the formation of chlorotriol **29** as a single product, instead of the desired epoxy diol **28**. For further structural proof, chlorotriol **29** was converted into the corresponding acetate **30** with an excess of acetic anhydride in pyridine and DMAP (Scheme 8).



Scheme 8 Synthesis of Chlorotriol **29**.

The ^{1}H and ^{13}C NMR spectra of the acetylation product **30** revealed that only three acetate groups in **30** instead of the tetraacetate groups expected were formed in a total yield of 66%.

In order to confirm the assigned structure and to establish the conformation of the molecule, X-ray diffraction analysis of **30** was undertaken (Figure 2). *cis* and *trans* stereochemistry of the substituted units can be seen explicitly in Figure 2. As shown in Figure 2b, the molecules are ordered vertically along the *b*-axis in the unit cell. Furthermore, there are closer Cl…Cl (3.355 Å) contacts in a certain direction. Short intermolecular contact corresponds to a Cl…Cl separation of less than 3.52 Å. The occurrence of Cl-Cl intermolecular contact, which is shorter than would be expected from the conventional isotropic van der Waals radius, is shown to be most common in the crystal structures of fully or highly chlorinated hydrocarbons, and is therefore a

consequence of close packing of anisotropic atoms, rather than evidence of a specific attractive force.[25]

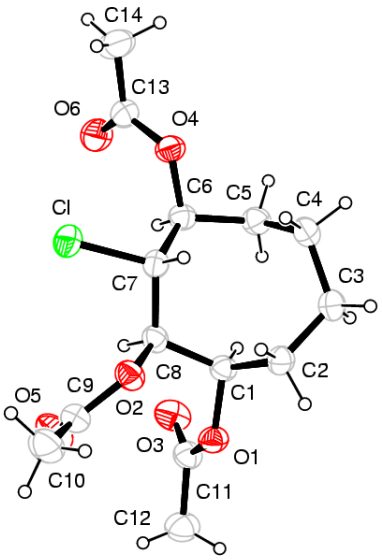


Fig. 2. a) The molecular structure of compound chlorotriacetate **30** showing the atom numbering scheme. Thermal ellipsoids are drawn at the 40% probability level.

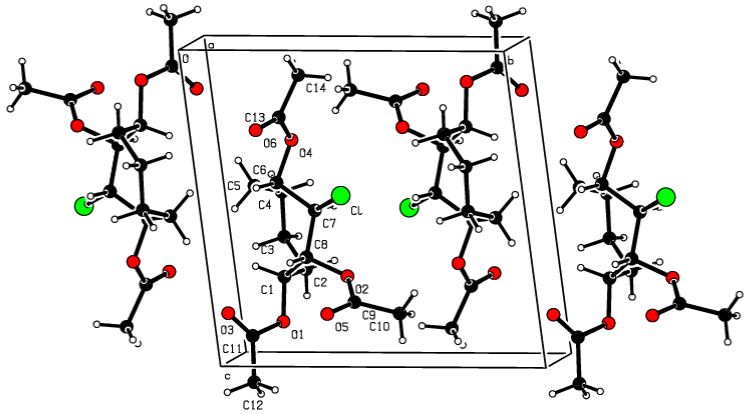


Fig. 2. b) The molecular packing of **30**.

We assume that **29** is formed by the HCl-catalyzed ring-opening reaction of epoxy diol, which is the hydrogenation product of **24**. It is clear that HCl comes from methylene chloride which is epoxidation solvent. Similar results have also been observed more recently by Balci et al in the synthesis of some cyclitols containing six-membered rings.[26] Hydrolysis of **30** with acetyl chloride in MeOH resulted in the formation of chlorotriol **29** in 92% yield (Scheme 8).

3. Conclusion

We have described here the synthesis of certain cyclitols and derivatives containing eight-membered rings: **12**, **18**, **19**, and **29**, starting from the easily available *cis*,*cis*-1,3-cyclooctadiene, concisely and efficiently. We are currently carrying out further studies to synthesize new aminocyclitols through **9a**.

4. Experimental

4.1. General experimental

Melting points are uncorrected. Infrared spectra were obtained from solution in 0.1 mm cells or KBr pellets on an FT-IR Mattson 1000 instrument. The ^{1}H and ^{13}C NMR spectra were recorded on 400 (100) MHz Varian or 400 (100) MHz Bruker spectrometer and are reported in d units with $SiMe_4$ as internal standard. HRMS spectra were obtained on a Bruker microTOF-Q instrument. Elemental analyses were carried out on a Carlo Erba 1108 model CHNS-O analyzer. Column chromatography was performed on silica gel (60 mesh, Merck). TLC was carried out on Merck 0.2 mm silica gel 60 F_{254} analytical aluminium plates.

4.2. 7,8-Dioxabicyclo[4.2.2]dec-9-ene (23). Compound **23** was prepared as described in the literature.[13e]

4.3. (Z)-9-Oxabicyclo[6.1.0]non-2-ene (8). Compound **8** was prepared as described in the literature.[15]

4.4. (1R(S),2S(R),3R(S),4S(R))-Cyclooctane-1,2,3,4-tetraol (meso-19). Compound **19** was prepared as described in the literature.[13e]

^{1}H-NMR (400 MHz, D_2O): δ 3.72-3.63 (m, 4H), 1.77-1.66 (m, 2H), 1.53-1.38 (m, 6H). ^{13}C-NMR (100 MHz, D_2O): δ 76.0, 72.5, 31.7, 23.8; IR (KBr, cm^{-1}): 3417, 2927, 2529, 2393, 1441, 1403, 1344, 1277, 1160, 1069, 1042, 901, 715, 626. HRMS (ESI): calcd for $C_8H_{16}O_4Na$ (M^+ +Na): 199.0941, found: 199.0932.

4.5. (1R(S),2R(S),3R(S),4S(R))-Cyclooctane-1,2,3,4-tetraol (rac-18). Compound **18** was prepared as described in the literature.[13e]

^{1}H-NMR (400 MHz, D_2O) δ 3.92-3.82 (m, 1H), 3.64-3.48 (m, 3H), 1.80-1.30 (series of m, 8H); ^{13}C-NMR (100 MHz, D_2O) δ 73.4, 72.9, 72.8, 70.9, 30.8, 29.3, 22.6, 20.7; IR (KBr, cm^{-1}): 3398, 2918, 2854, 1639, 1441, 1357, 1217, 1155, 1069, 968, 893, 758, 626. HRMS (ESI): calcd for $C_8H_{16}O_4Na$ (M^+ +Na): 199.0946, found: 199.0952.

4.6. (1S(R),2S(R),Z)-2-Azidocyclooct-3-enol (9a). To a stirred solution of epoxide **8** (3.00 g, 24.16 mmol) in EtOH/H_2O (45/30 mL) was added NaN_3 (9.42 g, 144.96 mmol) and NH_4Cl 3.14 g (58.69 mmol). The reaction mixture was refluxed for 12 h and then the solvent was rotoevaporated (40 °C, 20 mmHg). To the residue was added water (70 mL) and the mixture was filtered through a pad of 10.0 g of silica gel in a 50 mL sintered glass funnel with ethyl acetate. The mixture was extracted with ethyl acetate (4x30 mL). The combined ethyl acetate layers were dried (Na_2SO_4) and concentrated in *vacuo*. Evaporation of the solvent gave **9a** in 88% yield (3.60 g) as a colorless oil (lit.[17] 60%). ^{1}H-NMR (400 MHz, $CDCl_3$) δ 5.82 (q, *J*= 9.0 Hz, 1H, H-4), 5.50 (dd, *J*= 10.6, 8.1 Hz, 1H, H-3), 4.35-4.24 (m, 1H, H-2), 3.60-3.45 (m, 1H, H-1), 2.46 (bs, 1H, OH), 2.21-2.14 (m, 2H), 1.82-1.24 (m, 6H); ^{13}C-NMR (100 MHz, $CDCl_3$) δ 133.8, 127.5, 74.7, 66.0, 32.4, 28.2, 27.2, 21.3.

4.7. Acetylation of (1S(R),2S(R),Z)-2-azidocyclooct-3-enol (9a). To a magnetically stirred solution of azidol **9a (**1.60 g, 9.58 mmol) in CH_2Cl_2 (10 mL) cooled to 0°C, acetyl chloride (1.50 g, 19.16 mmol) was added and the mixture was stirred at room temperature for 12 h. Evaporation of the solvents gave pure azidoacetate **9b** (1.90 g, 96 %); as a colorless oil. (1S(R),2S(R),Z)-2-azidocyclooct-3-enyl acetate (**9b**): ^{1}H-NMR (400 MHz, $CDCl_3$) δ 5.80-5.55 (m, 1H, H-4), 5.32 (dd, *J*=10.6, 8.1 Hz, 1H, H-3), 4.83 (dt, *J*= 10.3, 4.2 Hz, 1H, H-1), 4.47 (ddd, *J*= 9.7, 8.1, 1.5 Hz, 1H, H-2), 2.22-2.07 (m,

2H), 2.06 (s, 3H, CH_3), 1.80-1.40 (m, 6H); ^{13}C-NMR (100 MHz, $CDCl_3$) δ 170.4, 133.9, 126.9, 77.3, 62.2, 30.3, 28.4, 27.5, 22.0, 21.4; IR (KBr, cm^{-1}) 2933, 2860, 2101, 1742, 1373, 1234, 1024, 964, 763. Anal. Calcd for $C_{10}H_{15}N_3O_2$: C, 57.40; H, 7.23; N, 20.08. Found: C, 57.41; H, 7.29; N, 19.57.

4.8. (1R(S),2(S)R,3R(S),4S(R))-3-Azidocyclooctane-1,2,4-triyl triacetate (10b). A 50 mL three necked, round-bottomed flask, equipped with a magnetic stirrer and a nitrogen inlet, was charged with NMO (0.88 g, 6.52 mmol), water (11.5 mL), and acetone (11.5 mL). To this solution were added OsO_4 (ca. 22.00 mg, 0.089 mmol) and azidoacetate **9b** (1.24 g, 5.93 mmol) at 0 °C. The resulting mixture was stirred vigorously under nitrogen at room temperature and after 2 days, the reaction was stopped. Sodium hydrosulfite (0.14 g) and Florisil (10.00 g) slurried in water (25 mL) were added, stirred for 15 min, and then filtered through a pad of Celite (4.50 g) in a 50 mL sintered glass funnel. The Celite cake was washed with acetone (3x50 mL). The filtrate was neutralized to pH 7 with H_2SO_4. The organic layer was removed *in vacuo*. The pH of the resulting aqueous solution was adjusted to pH 5 with sulfuric acid, and the solvents were then removed in *vacuo*. Chromatography of the residue on a silica gel column (80 g) eluting with ethyl acetate/hexane (15:85) gave azidoacetoxy diol **10a** (1.37 g, 95%) as the sole product. The azidoacetoxy diol **10a** was submitted to acetylation with AcCl following the method described above for the acetylation of **9a** to give **10b**: 1.78 g, 97%; colorless solid; mp 114-116 °C, from CH_2Cl_2/ *n*-hexane. ^{1}H-NMR (400 MHz, $CDCl_3$) δ 5.20 (dt, $J_{1,8}$= 7.7, $J_{1,2}$= 2.6 Hz, 1H, H-1), 5.04 (dd, $J_{2,3}$= 7.7, $J_{1,2}$= 2.6 Hz, 1H, H-2), 4.94 (ddd, $J_{3,4}$= 9.9, $J_{4,5}$= 5.5 Hz, $J_{4,5'}$= 2.9 Hz, 1H, H-4), 4.06 (dd, $J_{3,4}$= 9.9, $J_{2,3}$= 7.7 Hz, 1H, H-3), 2.05 (s, 3H, CH_3), 2.08 (s, 3H, CH_3), 2.10 (s, 3H, CH_3), 2.00-1.42 (m, 8H); ^{13}C-NMR (100 MHz, $CDCl_3$) δ 170.1, 170.0, 169.9, 73.9, 71.7, 71.6, 62.9, 28.5, 28.4, 21.9, 21.6, 21.3, 20.8; IR (KBr, cm^{-1}) 2946, 2108, 1744, 1434, 1371, 1230, 1023, 760, 746. Anal. Calcd for $C_{14}H_{21}N_3O_6$: C, 51.37; H, 6.47; N, 12.84. Found: C, 51.14; H, 6.27; N, 12.75.

4.9. (1R(S),2S(R),3R(S),4S(R))-3-Aminocyclooctane-1,2,4-triol (12). (1R(S),2(S)R,3R(S),4S(R))-3-Azidocyclooctane-1,2,4-triyl triacetate **(10b)** (600 mg, 1.83 mmol) was dissolved in absolute methanol (25 mL). While dry $NH_{3(g)}$ was passed

through the solution, the mixture was stirred for 30 h. Evaporation of solvent and the formed acetamide gave azidotriol **11** (340 mg, 93 %). Into a 50-mL flask were placed palladium on charcoal (40 mg, 10%) and **11** (340 mg, 1.69 mmol) in dry methanol (30 mL). The reaction mixture was hydrogenated for 2 h at room temperature under normal pressure. The catalyst was removed by filtration. Evaporation of the solvent gave **12**, which was crystallized from absolute methanol/diethyl ether to give colorless crystals (270 mg, 91%). Mp 118.5-119.5 °C; ^{1}H-NMR (400 MHz, CD_3OD) δ 3.91 (dt, *J* = 8.6, 2.8 Hz, 1H, H-1), 3.50-3.43 (m, 2H, H-2 and H-4), 3.00 (dd, *J* = 8.2, 1.2 Hz, 1H, H-3), 2.00-1.30 (series of m, 8H); ^{13}C-NMR (100 MHz, CD_3OD) δ 73.2, 73.1, 71.7, 54.6, 32.5, 30.1, 23.5, 21.1; IR (KBr, cm^{-1}) 3380, 2900, 2610, 1550, 1460, 1320, 1100, 1010, 970, 798, 690, 601. Anal. Calcd for $C_8H_{17}NO_3$: C, 54.84; H, 9.78; N, 7.99. Found: C, 54.52; H, 9.74; N, 7.96.

4.10. (1R(S),2S(R),3S(R),8S(R))-9-Oxabicyclo[6.1.0]nonane-2,3-diol (13). The same procedure as described above for 10**b** was applied for the oxidation of azidoacetate **9b** (98%, colorless crystals, mp 88-89 °C, recrystallized from CH_2Cl_2/*n*-hexane. ^{1}H-NMR (400 MHz, $CDCl_3$) δ 4.20-3.60 (m, 2H, H-3 and OH), 3.53-3.51 (m, 1H, H-2), 3.50-3.28 (m, 1H, OH), 3.19 (dd, *J*= 8.8, 4.7 Hz, 1H, H-1), 3.05 (dt, *J*= 10.2, 4.7 Hz, 1H, H-8); 2.25 (dm, *J*= 14.3 Hz, 1H), 1.97-1.08 (series of m, 7H); ^{13}C-NMR (100 MHz, $CDCl_3$) δ 73.2, 72.6, 57.2, 55.8, 32.2, 28.5, 25.4, 21.0; IR (KBr, cm^{-1}) 3386, 2931, 2868, 2336, 1636, 1460, 1239, 1053, 979, 836, 752. HRMS (ESI): calcd for $C_8H_{14}O_3Na$ (M^+ +Na): 181.0841, found: 181.0847.

4.11. Acetolysis and hydrolysis of (1R(S),2S(R),3S(R),8S(R))-9-oxabicyclo[6.1.0]nonane-2,3-diol (13). To a stirred solution of **13** (1.67 g, 10.57 mmol) in dioxane (4 mL) and water (1 mL) was added a catalytic amount of concentrated H_2SO_4 (ca. 300 mg). The reaction mixture was stirred for 5 h at 110 °C. The mixture was cooled to at room temperature and was neutralized to pH 7 with $BaCO_3$ (0.7 g). The residue was filtrated and after removal of the organic layer in *vacuo*, the aqueous layer was frozen and lyophilized to give the product mixture (1.28 g, total yield 69%). The mixture (1.28 g, 7.27 mmol) was dissolved in anhydrous pyridine (8 mL) and the solution was cooled to 0 °C. Ac_2O (5.93 g, 58.16 mmol) and 4-(Dimethylamino)pyridine (DMAP) (10 mg) were added and the solution was stirred at

room temperature for 24 h. The mixture was cooled to 0 °C and 2 N HCl (150 mL) solution was added. The mixture was extracted with ether (4x50 mL). The combined organic extracts were washed with $NaHCO_3$ solution (2x20 mL) and water (15 mL) and then dried (Na_2SO_4). Removal of the solvent under reduced pressure gave the product mixture (1.65 g, total yield 66 %). Chromatography of the mixture on a silica gel column (100 g) eluting with EtOAc/n-hexane (30:70) gave the first fraction as diacetate **14** (0.81 g, 49%), the second as tetraacetate **16**[13e] (0.200 g, 12%). and the third as tetraacetate **15**[13e] (0.64 g, 39%). Diacetate **14** was recrystallized from absolute ethanol at 0 °C as a colorless solid; mp 47-48 °C.

Data for (1R(S),6S(R),7S(R),8S(R))-9-Oxabicyclo[4.2.1]nonane-7,8-diyl diacetate (14). ^{1}H-NMR (400 MHz, $CDCl_3$) δ 5.27 (dd, $J_{6,7}$= 7.8, $J_{7,8}$= 4.7 Hz, 1H, H-7), 5.10 (dd, $J_{7,8}$= 4.6, $J_{1,8}$= 2.6 Hz, 1H, H-8), 4.69 (t, J= 6.7 Hz, 1H, H-6), 4.18-4.11 (m, 1H, H-1), 2.09 (s, 3H, CH_3), 2.08 (s, 3H, CH_3), 1.99-1.90 (m, 2H), 1.80-1.40 (m, 6H); ^{13}C-NMR (100 MHz, $CDCl_3$) δ 171.3, 170.4, 84.5, 82.9, 79.0, 78.1, 33.2, 29.5, 24.5, 24.4, 21.2, 21.0; IR (KBr, cm^{-1}) 2936, 2857, 1741, 1444, 1372, 1228, 1064, 1029, 973. Anal. Calcd for $C_{12}H_{18}O_5$: C, 59.49; H, 7.49. Found: C, 59.38; H, 7.52.

4.12. (1R(S),6S(R),7R(S),8R(S))-9-Oxabicyclo[4.2.1]nonane-7,8-diol (17). The diacetate **14** was submitted to ammonolysis with $NH_{3(g)}$ MeOH following the method described above for the ammonolysis of **10b** to give **12**: 0.12 g, 92 %; colorless solid; mp 83-85 °C, from CH_2Cl_2/*n*-hexane. ^{1}H-NMR (400 MHz, $CDCl_3$) δ 4.61-4.56 (m, 1H, OH), 4.44-4.34 (m, 2H, OCH and OH), 4.30-4.23 (m, 1H), 4.16-4.10 (m, 1H), 4.07-4.02 (m, 1H), 1.98-1.42 (series of m, 8H); ^{13}C-NMR (100 MHz, $CDCl_3$) δ 84.6, 83.7, 80.6, 79.6, 33.0, 28.8, 24.9, 24.4; IR (KBr, cm^{-1}) 3366, 2929, 1443, 1261, 1079, 1014, 752. Anal. Calcd for $C_8H_{14}O_3$: C, 60.74; H, 8.92. Found: C, 60.89; H, 9.09.

4.13. (1R(S),2R(S),3R(S),4S(R))-3-Chlorocyclooctane-1,2,4-triyl triacetate (30). To endoperoxide **23** (1.0 g, 7.14 mmol) in CH_2Cl_2 (150 mL) was added *m*-chloroperbenzoic acid (4.81 g, 27.81 mmol, 77%). The resulting mixture was stirred for 15 h at room temperature, the solvent was removed in *vacuo*. A solution of the residue in absolute ethanol (40 mL) was hydrogenated at 1 atm pressure in the presence of 10% palladium on charcoal (40 mg) at room temperature. After 5 h, the catalyst was filtered

and the subsequent solvent was removed in *vacuo*. The residue was acetylated with pyridine-acetic anhydride and DMAP as described above to give **30**. The crude product **30** was dissolved in ethyl acetate (100 mL) and cooled to 0 °C, and then 0.5% NaOH (100 mL) solution was added. The mixture was stirred for 5 min and then the mixture was extracted with ethyl acetate (3x20 mL). The combined organic extracts were washed with water (15 mL) and then dried (Na_2SO_4). Removing of the solvent under reduced pressure gave pure **30** (1.50 g, total yield 66 %) as a colorless solid, recrystallized from methylene chloride/*n*-hexane, mp 94-94.5 °C. ^{1}H-NMR (400 MHz, $CDCl_3$) δ 5.35-5.26 (m, 2H), 5.22 (ddd, *J* = 8.8, 5.9 and 2.7 Hz, 1H), 4.34 (dd, *J* = 8.8 and 7.7 Hz, 1H), 2.11 (s, 3H), 2.08 (s, 3H), 2.02 (s, 3H), 2.00-1.50 (series of m, 8H); ^{13}C-NMR (100 MHz, $CDCl_3$) δ 170.0, 169.9, 169.8, 74.6, 73.1, 71.9, 61.0, 29.3, 28.9, 22.9, 22.4, 21.2, 20.9; IR (KBr, cm^{-1}) 2941, 1744, 1443, 1370, 1231, 1025. Anal. Calcd for $C_{14}H_{21}ClO_6$: C, 52.42; H, 6.60. Found: C, 52.56; H, 6.76.

4.14. (1R(S),2R(S),3R(S),4S(R))-3-Chlorocyclooctane-1,2,4-triol (29). (1R(S),2R(S),3R(S),4S(R))-3-Chlorocyclooctane-1,2,4-triyl triacetate **(30)** (0.50 g, 1.56 mmol) was dissolved in absolute methanol (9 ml) and cooled to 0 °C. AcCl (3 mL) was added and the mixture was stirred at 0 °C for 10 min and then at room temperature for 24 h. Removal of the solvents under reduced pressure gave **29** colorless oil (0.28 g, 92 %).

^{1}H-NMR (400 MHz, D_2O) δ 4.13-4.06 (m, 1H, H-3), 3.99-3.94 (m, 1H, H-1), 3.81-3.73 (m, 2H, H-2 and H-4), 1.80-1.30 (series of m, 8H); ^{13}C-NMR (100 MHz, D_2O) δ 73.8, 72.5, 71.2, 68.8, 32.2, 30.2, 23.3, 20.7; IR (KBr, cm^{-1}) 3292, 2934, 2875, 1459, 1402, 1322, 1295, 1256, 1234, 1215, 1144, 1040, 975. Anal. Calcd for $C_8H_{15}ClO_3$: C, 49.36; H, 7.77. Found: C, C, 49.41; H, 7.74.

4.15. Epoxidation of Endoperoxide 23 with dimethyldioxirane (DMDO). Dimethyldioxirane was prepared from acetone using potassium monoperoxysulfate as described by Adam.[23] To a magnetically stirred solution of dimethyldioxirane (ca.3.7 mmol) in 200 mL of acetone was added 50 mg (0.35 mmol) of endoperoxide **23** in 3 mL of CH_2Cl_2 and stirred for 2h at -5 °C, then for 24 h at room temperature. After filtering of the precipitate, evaporation of the solvent afforded the mixture of epoxides **24** and **25**

in a ratio of 1:1 determined by ^{1}H-NMR integration (54 mg, combined yield: 97%). Purification of the residue on silica gel column (50 g) eluting with ethyl acetate and hexane (10:90) afforded epoxide **25** (52 mg, 93%).

4.16. (1R(S),6S(R),7S(R),9S(R))-8,10-Dioxatricyclo[4.3.1.0^{7,9}]decane-1-ol (25). A. From (23). To endoperoxide **23** (1.0 g, 7.14 mmol) in CH_2Cl_2 (100 mL) was added *m*-chloroperbenzoic acid (1.76 g, 10.2 mmol, 77%) and $NaHCO_3$ (0.60 g, 7.14 mmol). The resulting mixture was stirred 5 days at room temperature, then cooled to 0 °C. To the mixture, 1% NaOH (100 mL) solution was added and stirred for 15 min until it reached -5 °C. The mixture was extracted with CH_2Cl_2 (4x25 mL). The combined organic extracts were washed with saturated aqueous NaCl and then dried (Na_2SO_4). Evaporation of solvent gave **25** (0.58 g, 53%) as pure white crystals from CH_2Cl_2/*n*-hexane, mp 86.5-88 °C. ^{1}H-NMR (400 MHz, $CDCl_3$) δ 4.38 (dd, $J_{6,5}$ = 7.1 and $J_{6,5'}$ = 1.3 Hz, 1H, H-6), 3.51 (d, A-part of AB-system, J_{AB} = 2.9 Hz, 1H, H-7 or H-9), 3.49 (d, B-part of AB-system, J_{AB} = 2.9 Hz, 1H, H-7 or H-9), 3.47 (bs, -OH, 1H), 2.03-1.32 (series of m, 8H); ^{13}C-NMR (100 MHz, $CDCl_3$) δ 104.3, 74.8, 59.0, 58.5, 37.0, 31.8, 23.6, 23.3; IR (KBr, cm^{-1}) 3416, 2930, 2860, 1448, 1407, 1338, 1211, 1144, 1115, 1076, 946, 879, 794, 636. HRMS (ESI): calcd for $C_8H_{12}O_3Na$ (M^+ +Na): 179.0684, found: 179.0689.

B. From (27). with *m*-CPBA. Unsaturated oxabicycle **27** (1.10 g, 7.90 mmol) was dissolved in 13 ml of CH_2Cl_2, *m*-CPBA (1.80 g, 10.30 mmol, 77%) and $NaHCO_3$ (0.66 g, 7.90 mmol) were added, and then the reaction was stirred at reflux temperature for 16 days. The reaction mixture was cooled to -5 °C and 1% NaOH (30 mL) solution was added, and then stirred for 15 min. The mixture was extracted with CH_2Cl_2 (4x25 mL). The combined organic extracts were washed with saturated NaCl solution (20 mL) and water (20 mL) and then dried (Na_2SO_4). Evaporation of solvent gave **25** (0.80 g, 66%).

with DMDO.[23] Unsaturated oxabicycle **27** (50 mg, 0.35 mmol) was submitted to epoxidation with DMDO as in the method described above for the epoxidation of **23** to give **25**: 54 mg, 97%.

4.17. Crystal structure determination

For the crystal structure determination, the single-crystal of compound **30** was used for data collection on a four-circle Rigaku R-AXIS RAPID-S diffractometer (equipped with

a two-dimensional area IP detector). The graphite-monochromatized Mo K_α radiation (λ=0.71073 Å) and oscillation scans technique with $\Delta\omega$=5˚ for one image were used for data collection. The lattice parameters were determined by the least-squares methods on the basis of all reflections with $F^2>2\sigma(F^2)$. Integration of the intensities, correction for Lorentz and polarization effects and cell refinement was performed using CrystalClear (Rigaku/MSC Inc., 2005) software.[25b] The structures were solved by direct methods using SHELXS-97[25c] and refined by a full-matrix least-squares procedure using the program SHELXL-97.[25c] H atoms were positioned geometrically and refined using a riding model. The final difference Fourier maps showed no peaks of chemical significance. *Crystal data for* **30**: $C_{14}H_{21}O_6Cl$, crystal system, space group: triclinic, *P*-1; (no:2); unit cell dimensions: *a*= 7.5308(2), *b*= 10.5140(3), *c*= 11.0554(4) Å, α=79.43(2) β=70.50(2), γ=74.87(2)˚; volume: 792.08(5)Å^3; Z=2; calculated density: 1.34 mg/m^3; absorption coefficient: 0.264 mm^{-1}; *F*(000): 340; θ-range for data collection 2.7–26.4˚; refinement method: full-matrix least-square on F^2; data/parameters: 2165/193; goodness-of-fit on F^2: 1.028; final *R* indices [$I>2\sigma(I)$]: R_1= 0.055, wR_2=0.115; *R* indices (all data): R_1=0.087, wR_2=0.131; largest diff. peak and hole: 0.170 and -0.237 e Å^{-3}.

Crystallographic data (excluding structure factors) for the structures reported in this article have been deposited with the Cambridge Crystallographic Data Centre with supplementary publication number CCDC 787346. Copies of the data can be obtained free of charge on application to CCDC, 12 Union Road, Cambridge CB2 1EZ, UK (fax: +44-1223-336-033; e-mail: deposit@ccdc.cam.ac.uk)

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Supplementary data

^{1}H and ^{13}C NMR spectra for all new compounds, as well as selected 2D NMR spectra and crystallographic data for compound **30** are provided. Supplementary data associated with this article can be found in the online version, at http://.....tet.....

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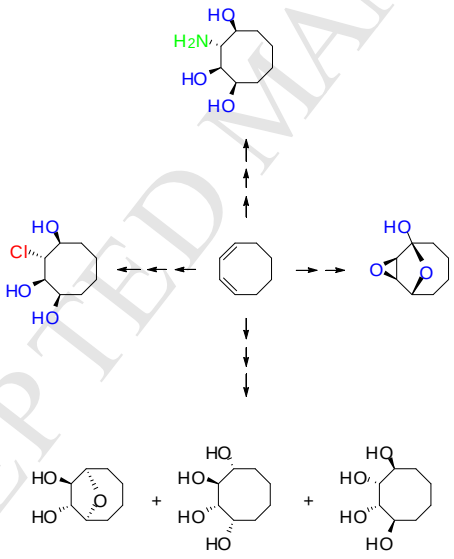
Graphical Abstract

Efficient and shortcut syntheses of some novel eight-membered ring cyclitols starting from cycloocta-1,3-diene

Kadriye Ecer, and Emine Salamci[†]

Department of Chemistry, Faculty of Sciences, Atatürk University, 25240 Erzurum, Turkey



[†]Corresponding author. Tel: +90 442 231 4429; fax: +90 442 2314109 (E.S.).

E-mail address: esalamci@atauni.edu.tr (E. Salamci).

Supplementary Material

Efficient and shortcut syntheses of some novel eight-membered ring cyclitols starting from cycloocta-1,3-diene

Kadriye Ecer, and Emine Salamci*

Department of Chemistry, Faculty of Sciences, Atatürk University, 25240 Erzurum, Turkey

*Corresponding author. Tel: +90 442 231 4429; fax: +90 442 2314109 (E.S.).

E-mail address: esalamci@atauni.edu.tr (E. Salamci).

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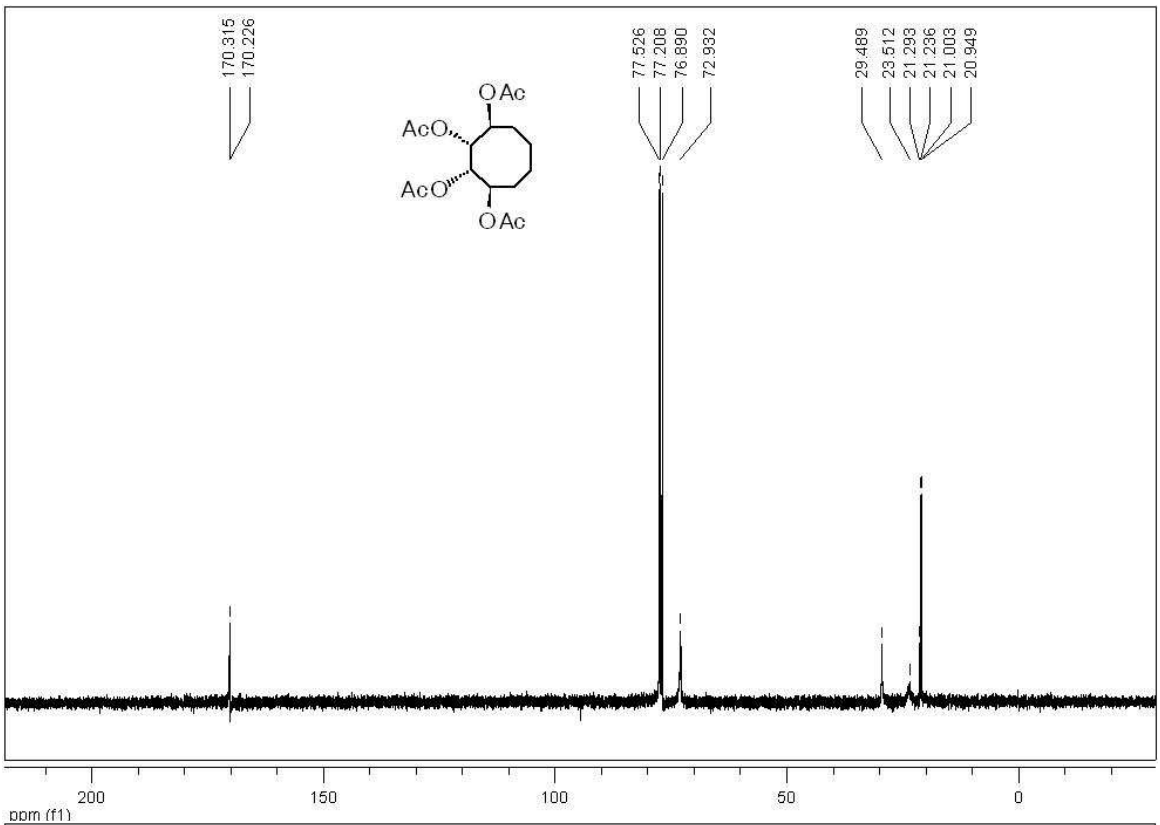
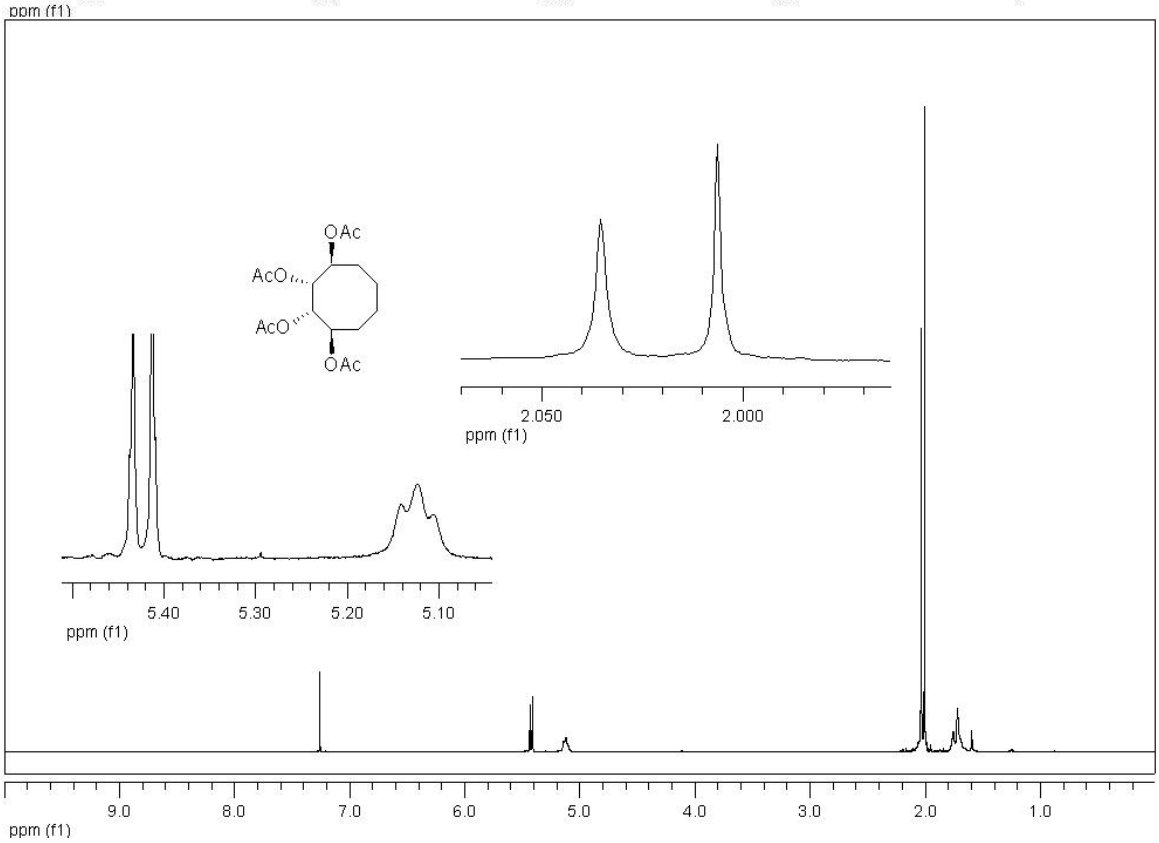
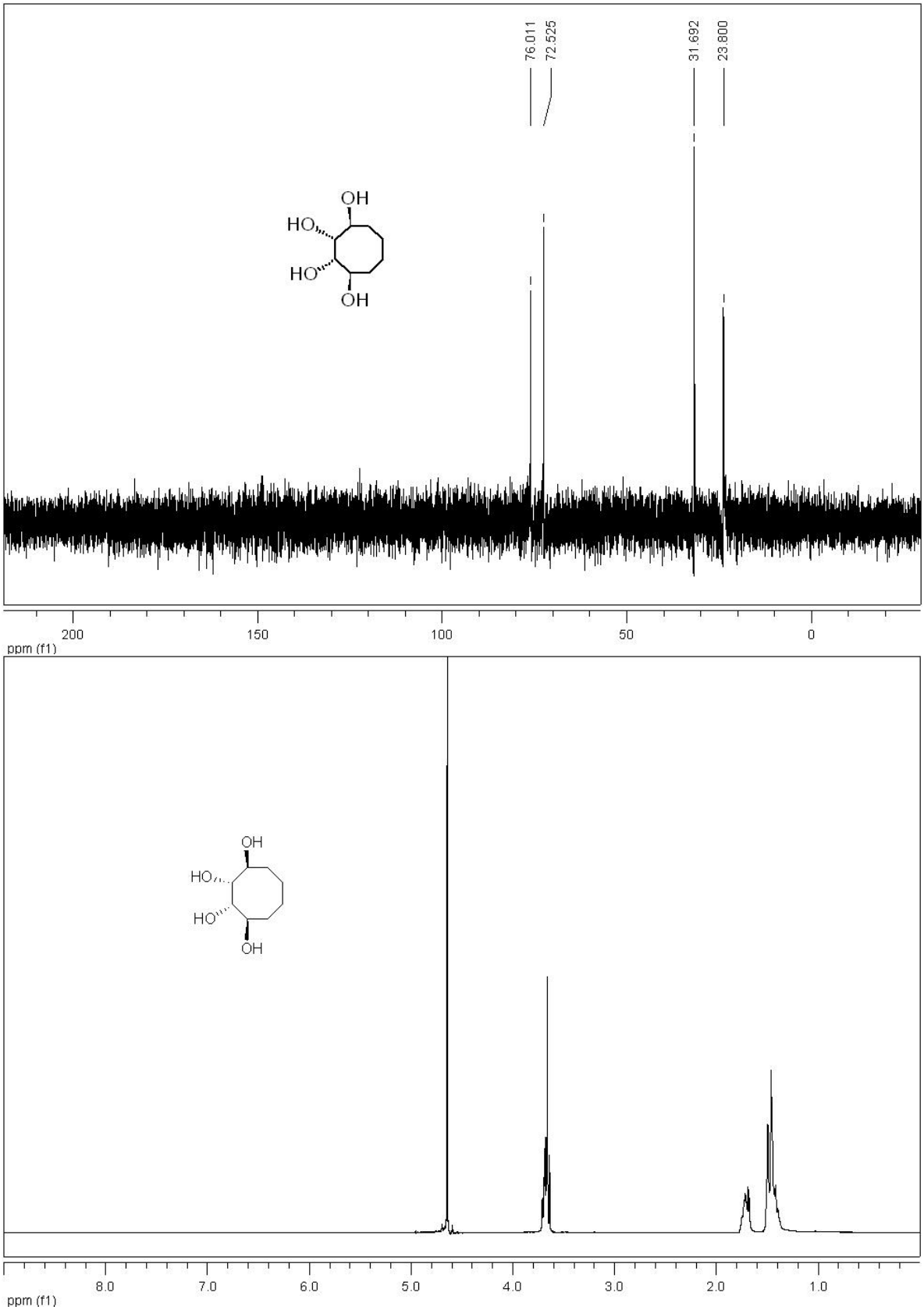
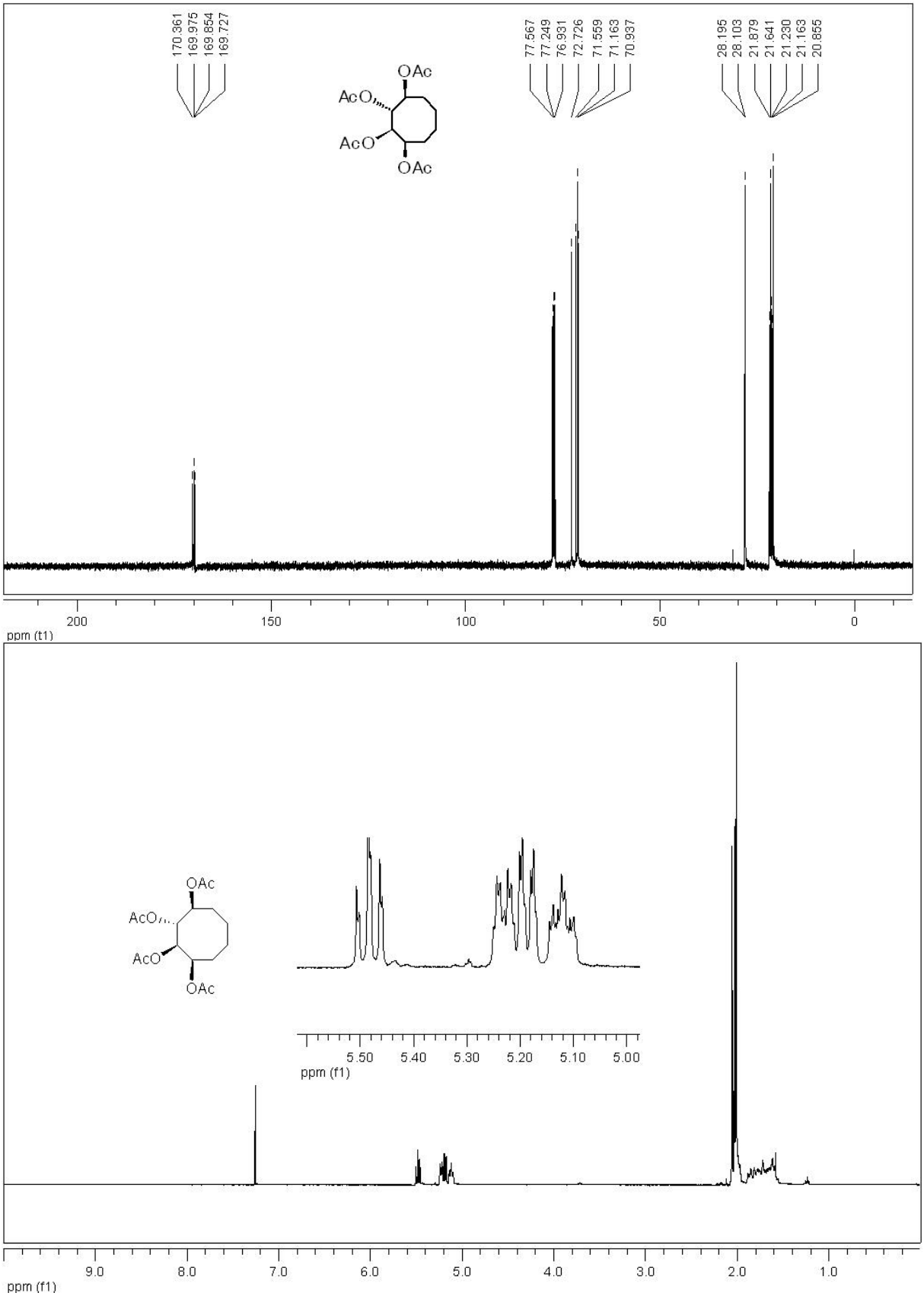




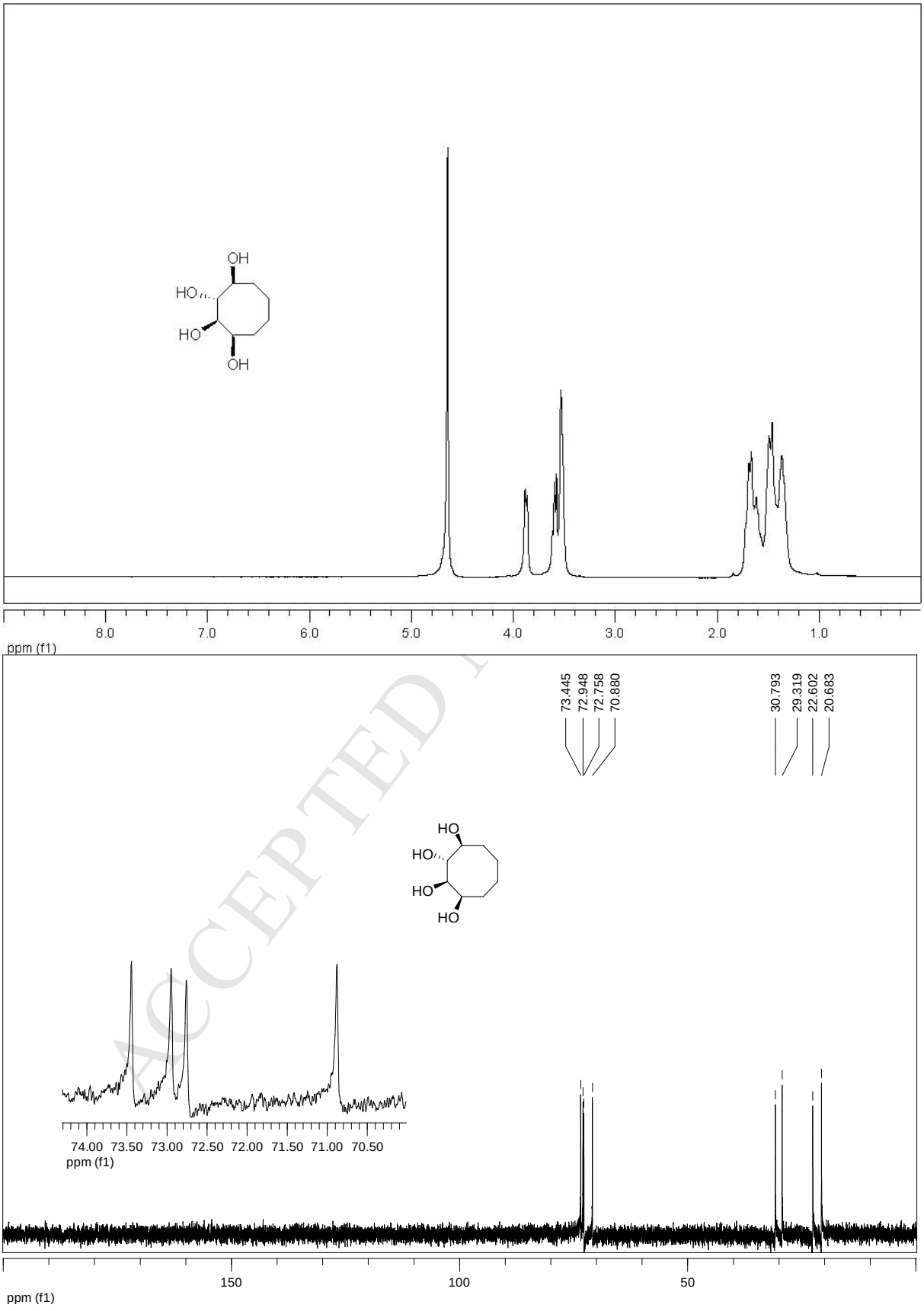
(1R(S),2S(R),3R(S),4S(R))-Cyclooctane-1,2,3,4-tetraol (meso-**19**): D_2O



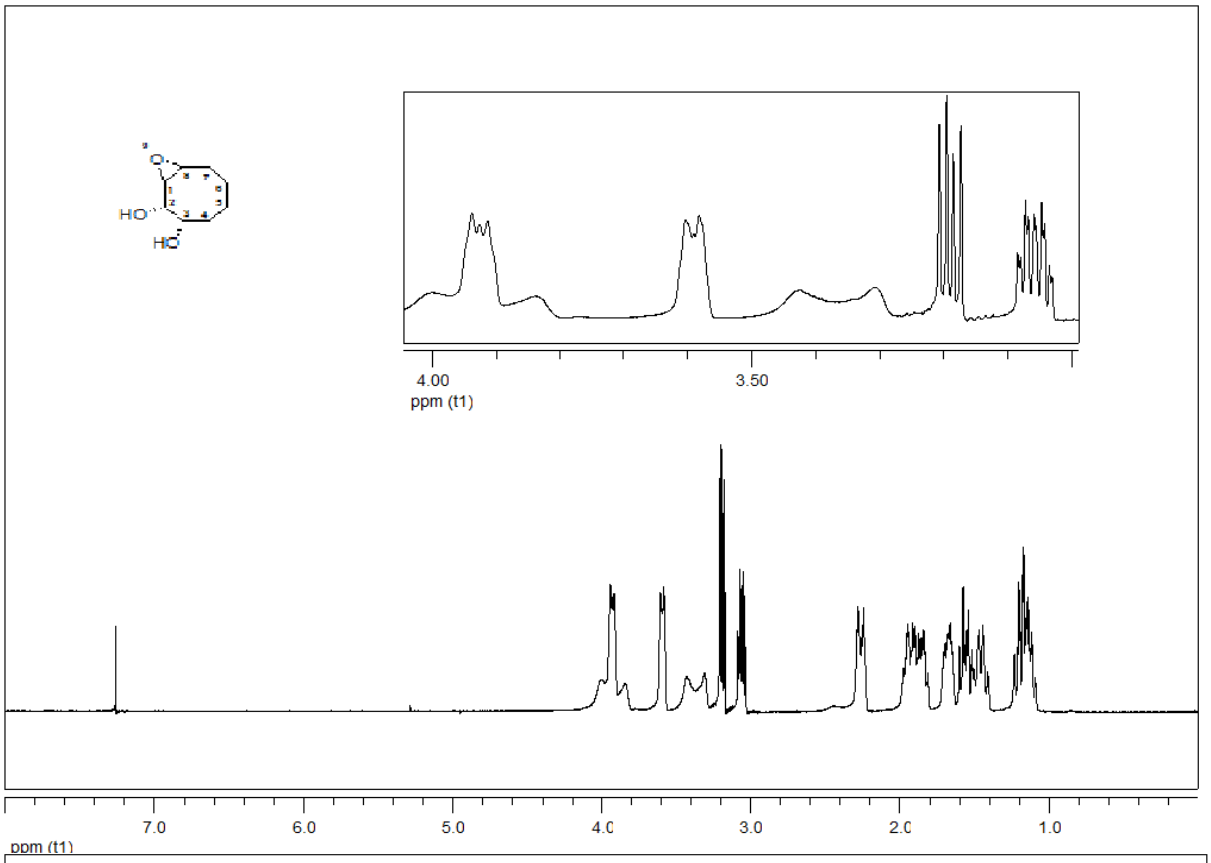
(1R(S),2R(S),3R(S),4S(R))-Cyclooctane-1,2,3,4-tetraacetate (rac-**15**): $CDCl_3$

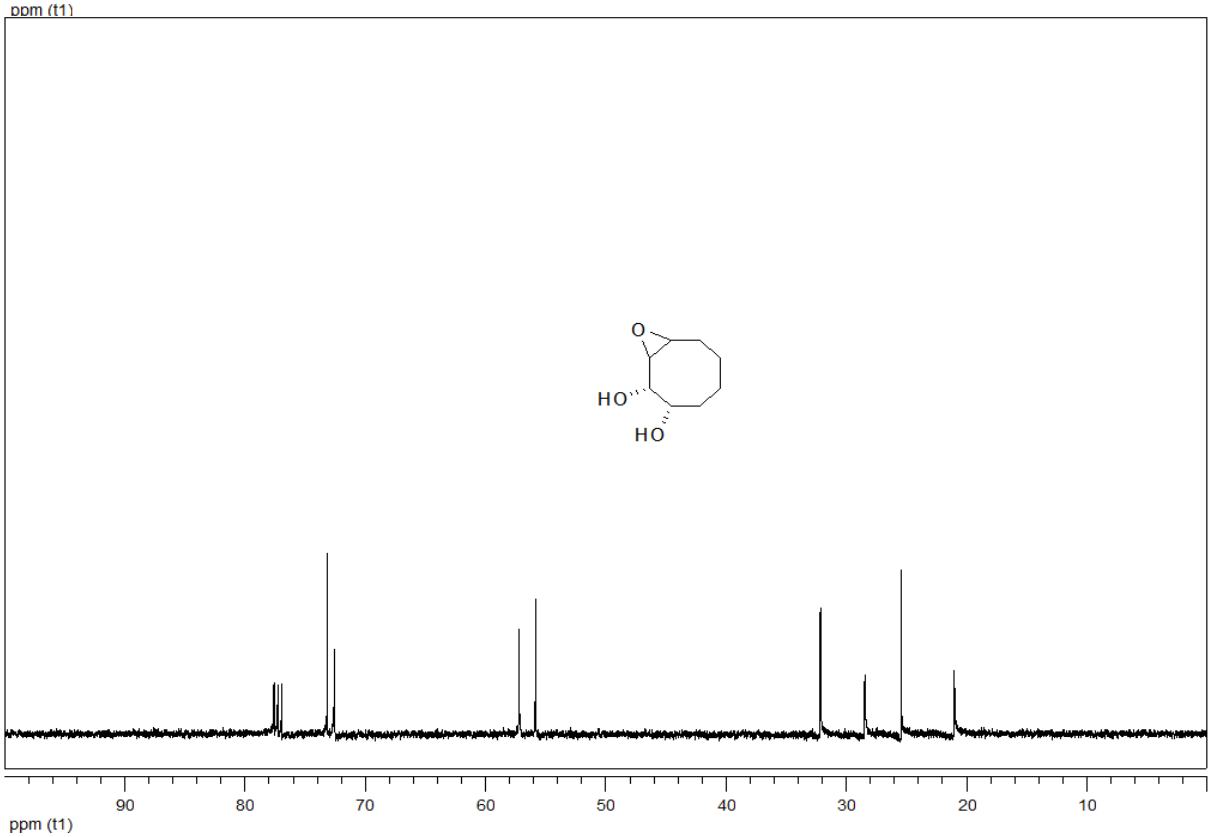


(1R(S),2R(S),3R(S),4S(R))-Cyclooctane-1,2,3,4-tetraol (rac-**18**): D_2O

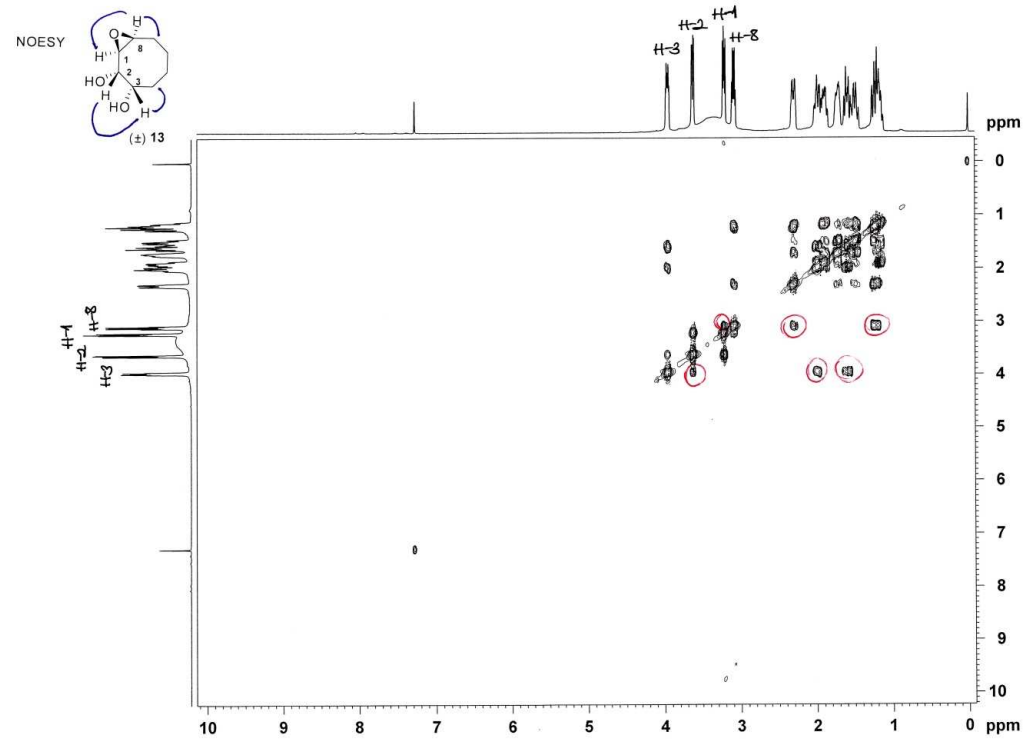


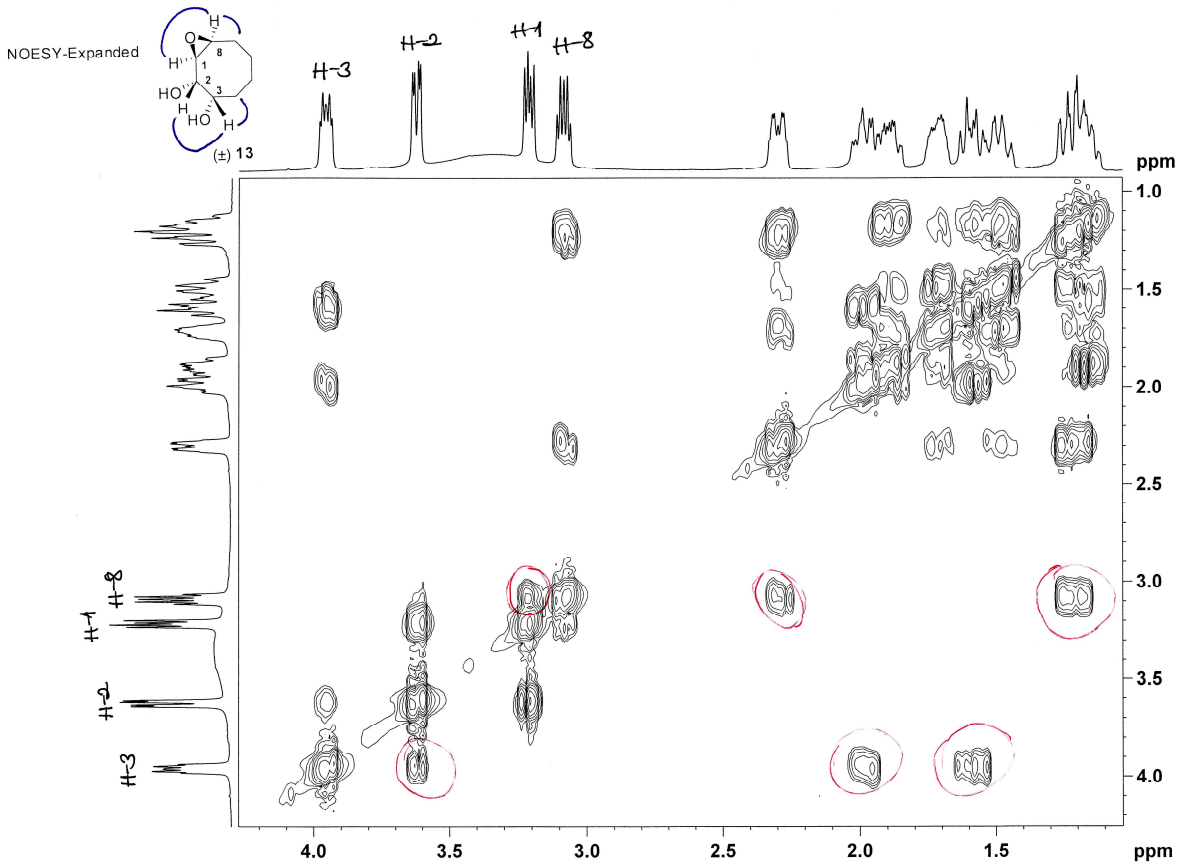
(1R(S),2S(R),3S(R),8S(R))-9-oxabicyclo[6.1.0]nonane-2,3-diol (**13**): $CDCl_3$



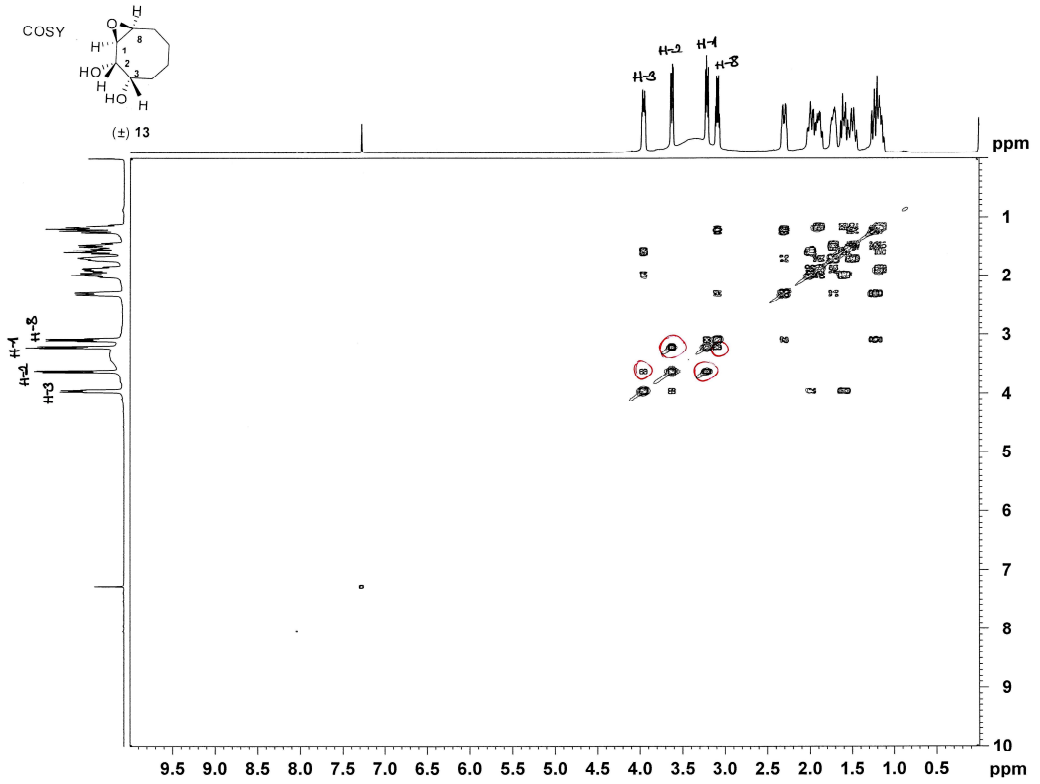


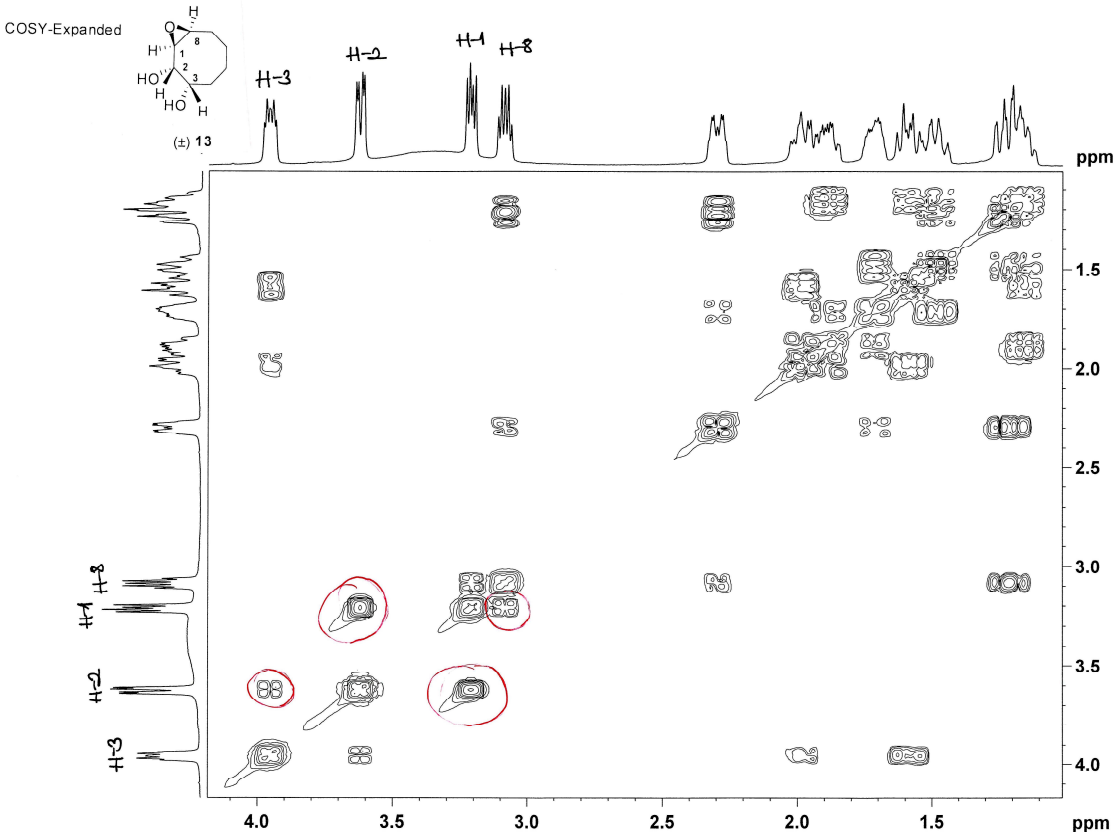
NOESY spectrum for **13**



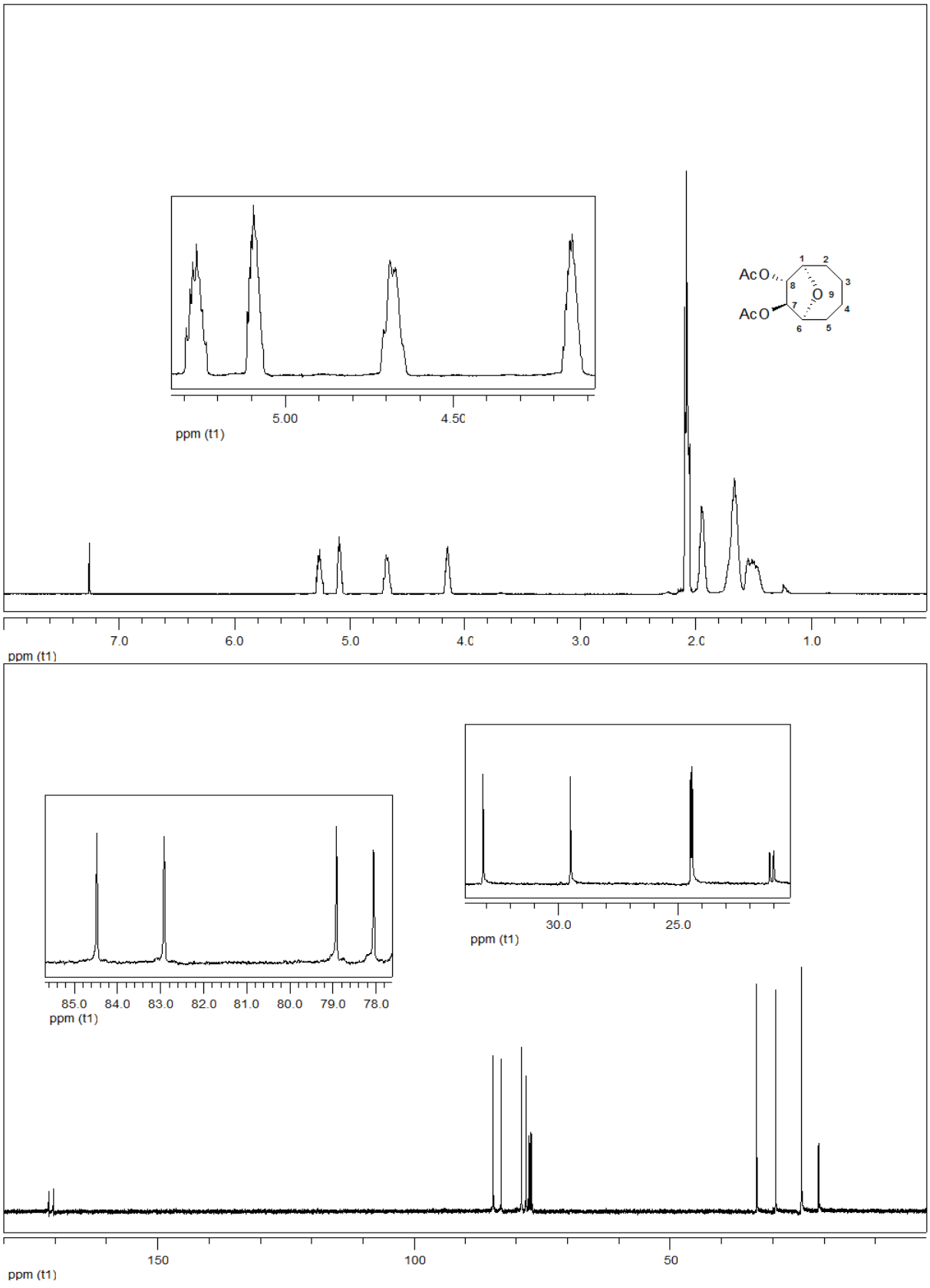


COSY spectrum for **13**

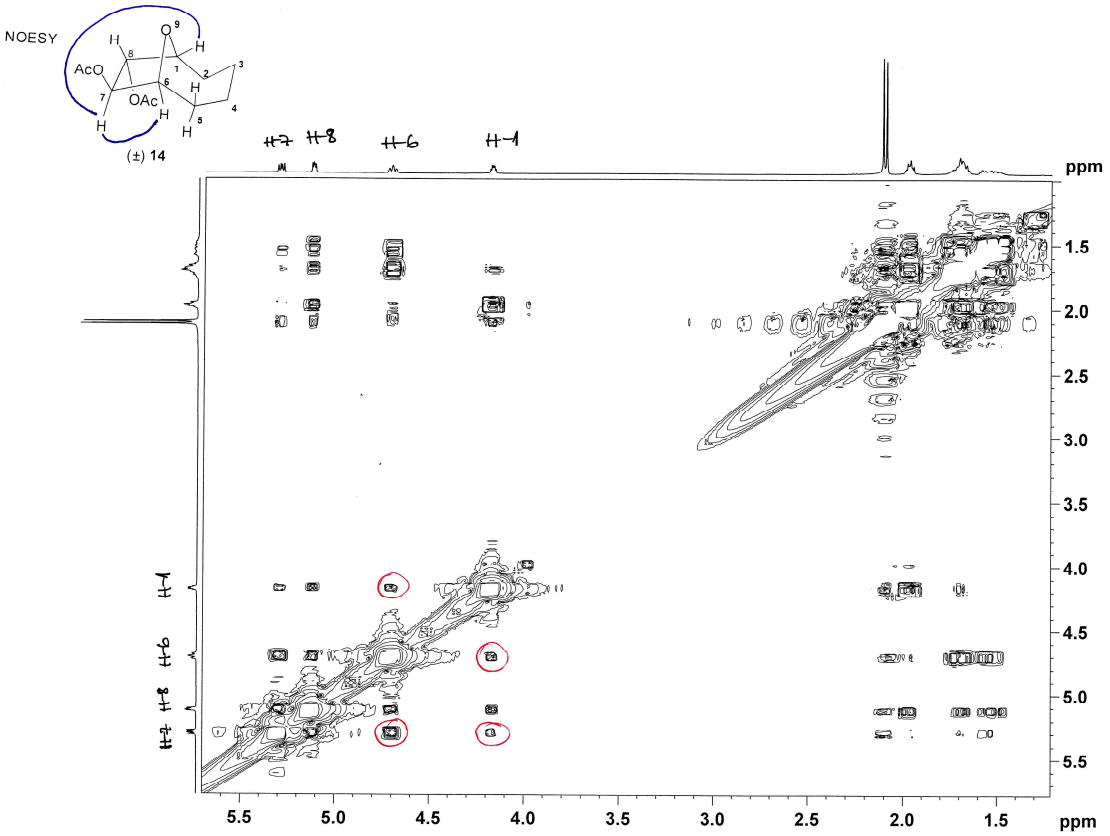


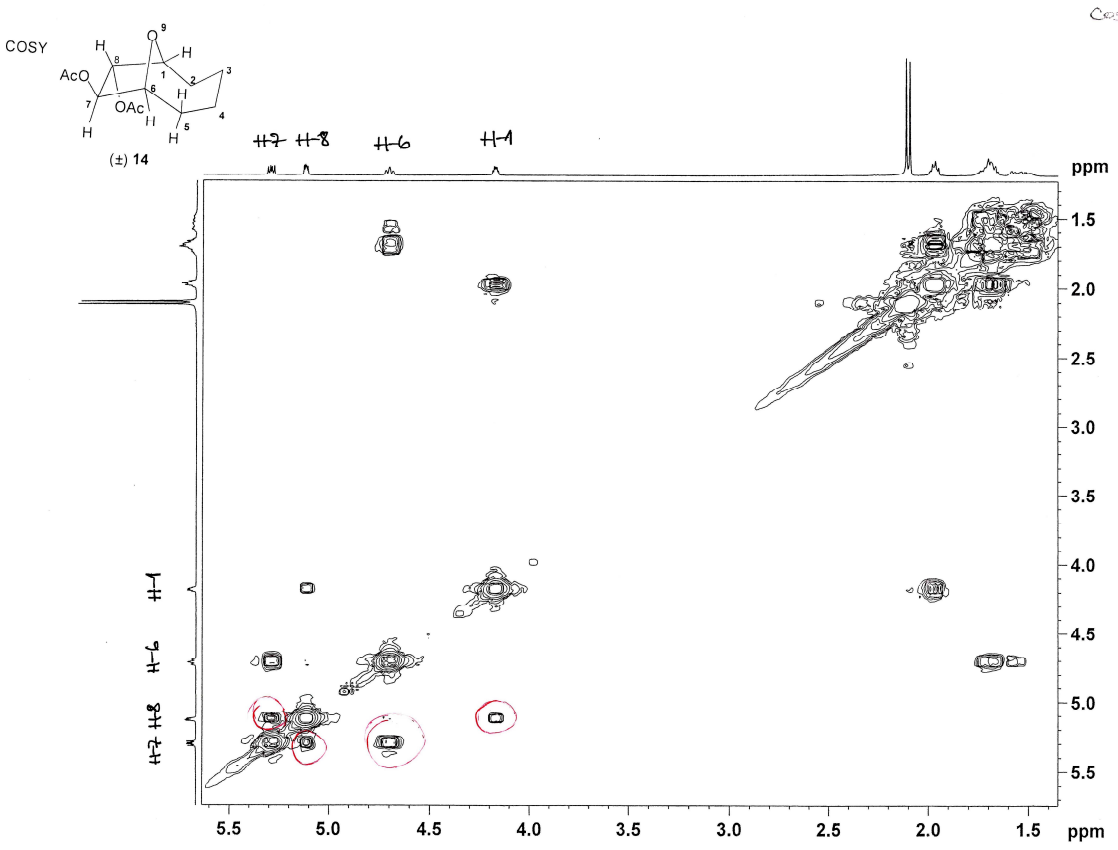


(1R(S),6S(R),7S(R),8S(R))-9-oxabicyclo[4.2.1]nonane-7,8-diyl diacetate (**14**): $CDCl_3$

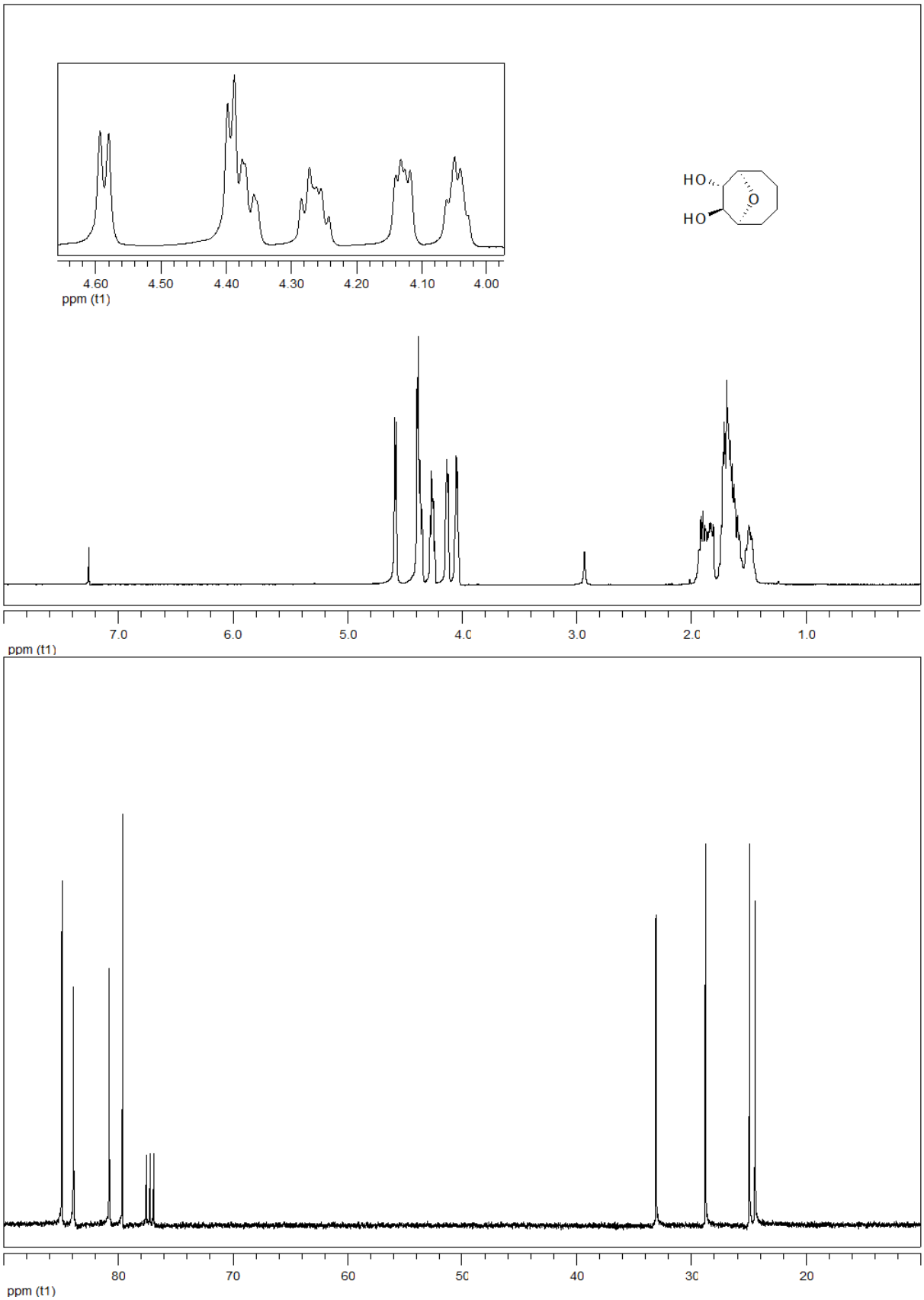


NOESY and COSY spectra for **14**

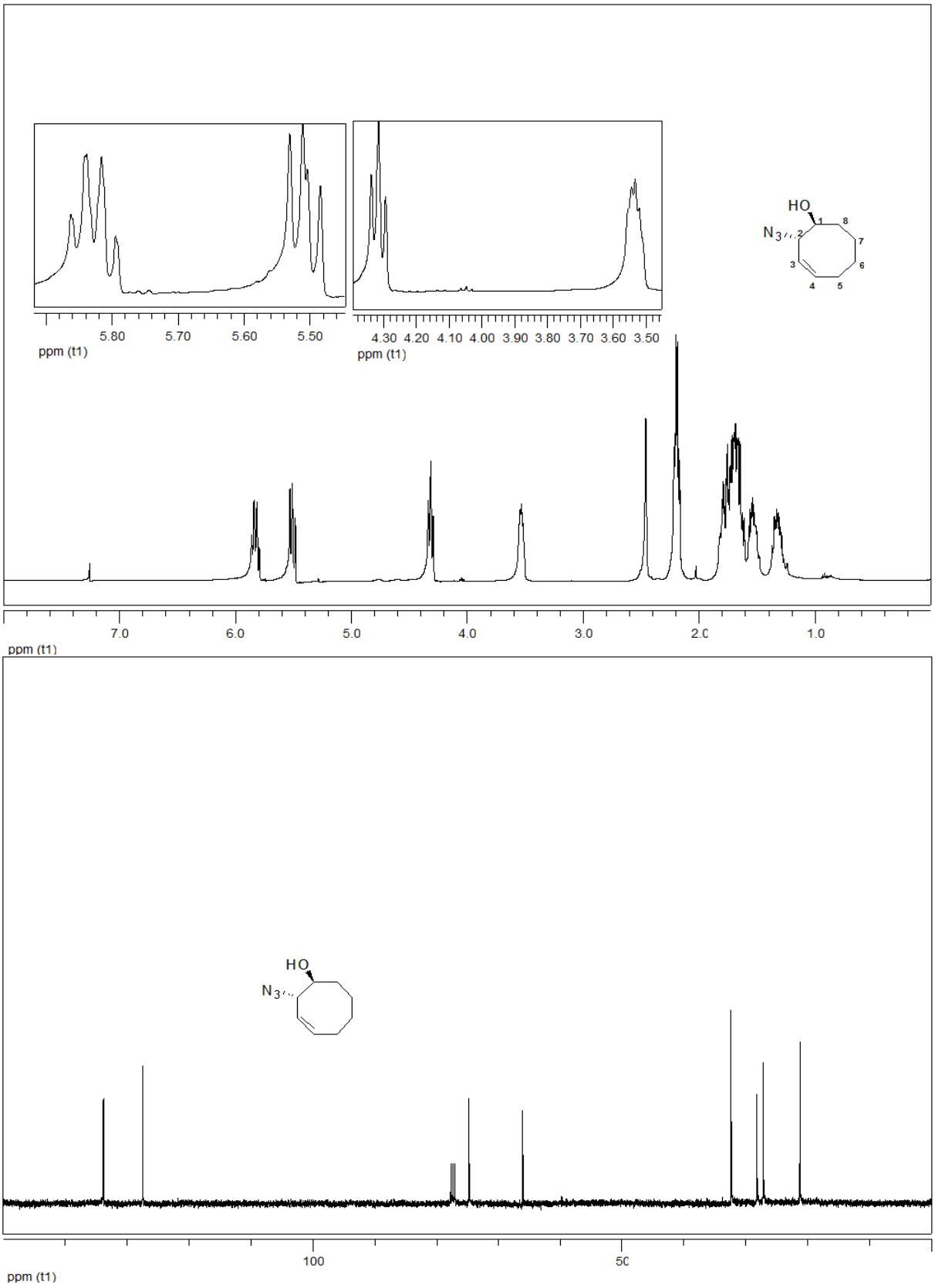




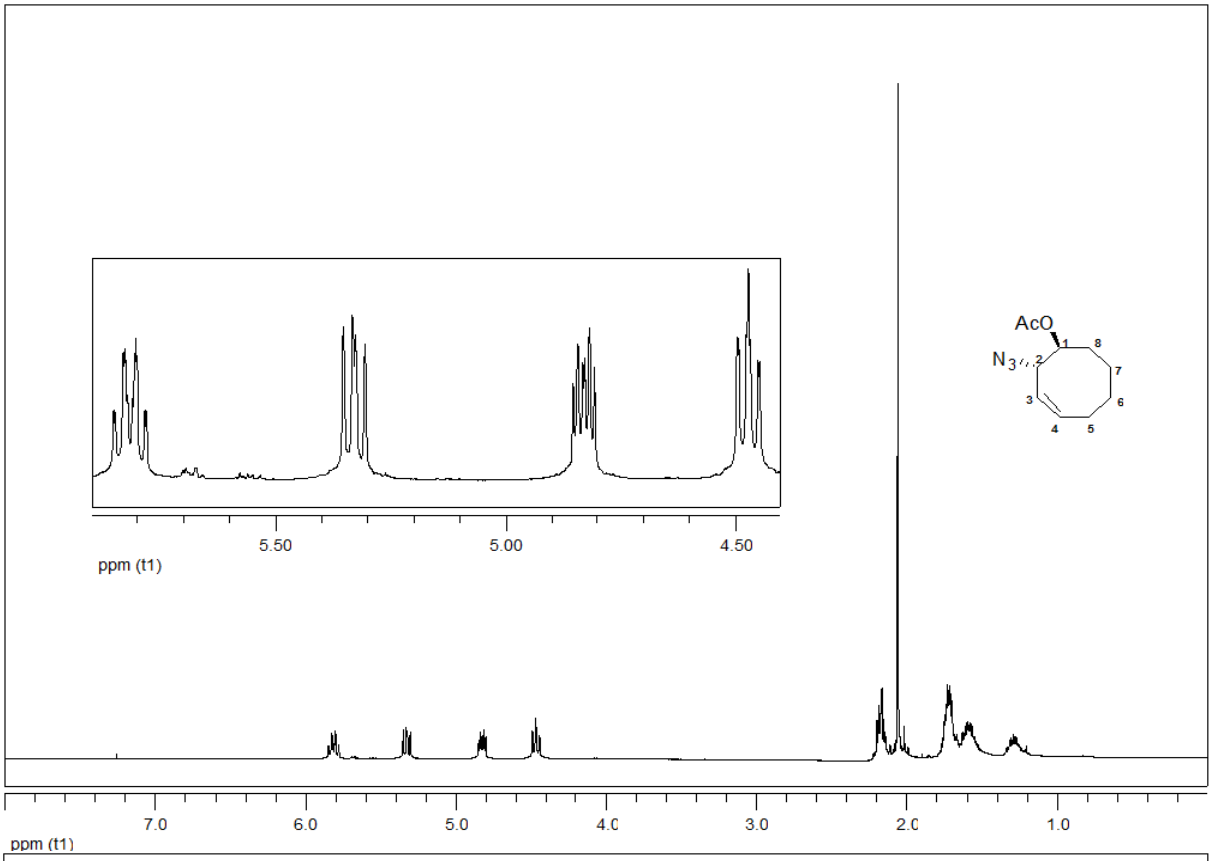
(1R(S),6S(R),7R(S),8R(S))-9-oxabicyclo[4.2.1]nonane-7,8-diol (**17**): $CDCl_3$

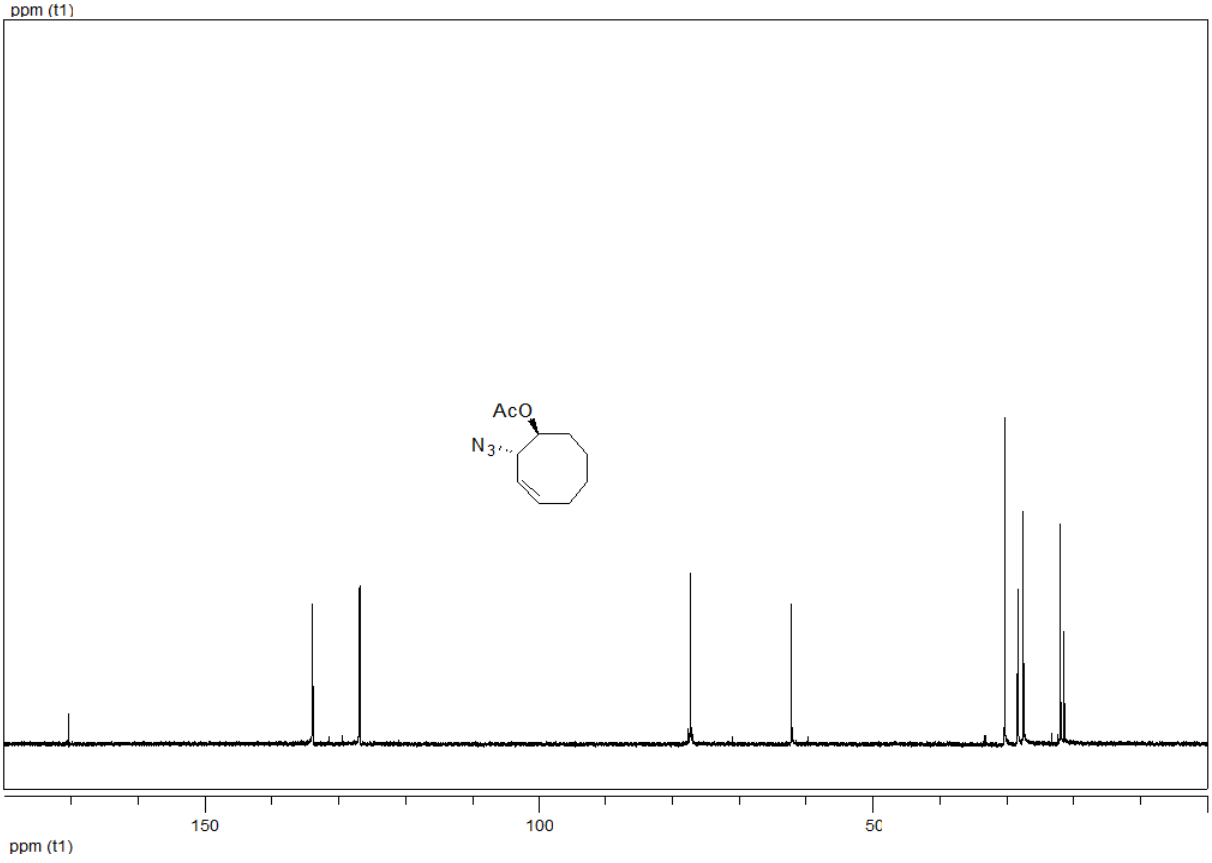


(1S(R),2S(R),Z)-2-azidocyclooct-3-enol (**9a**): $CDCl_3$

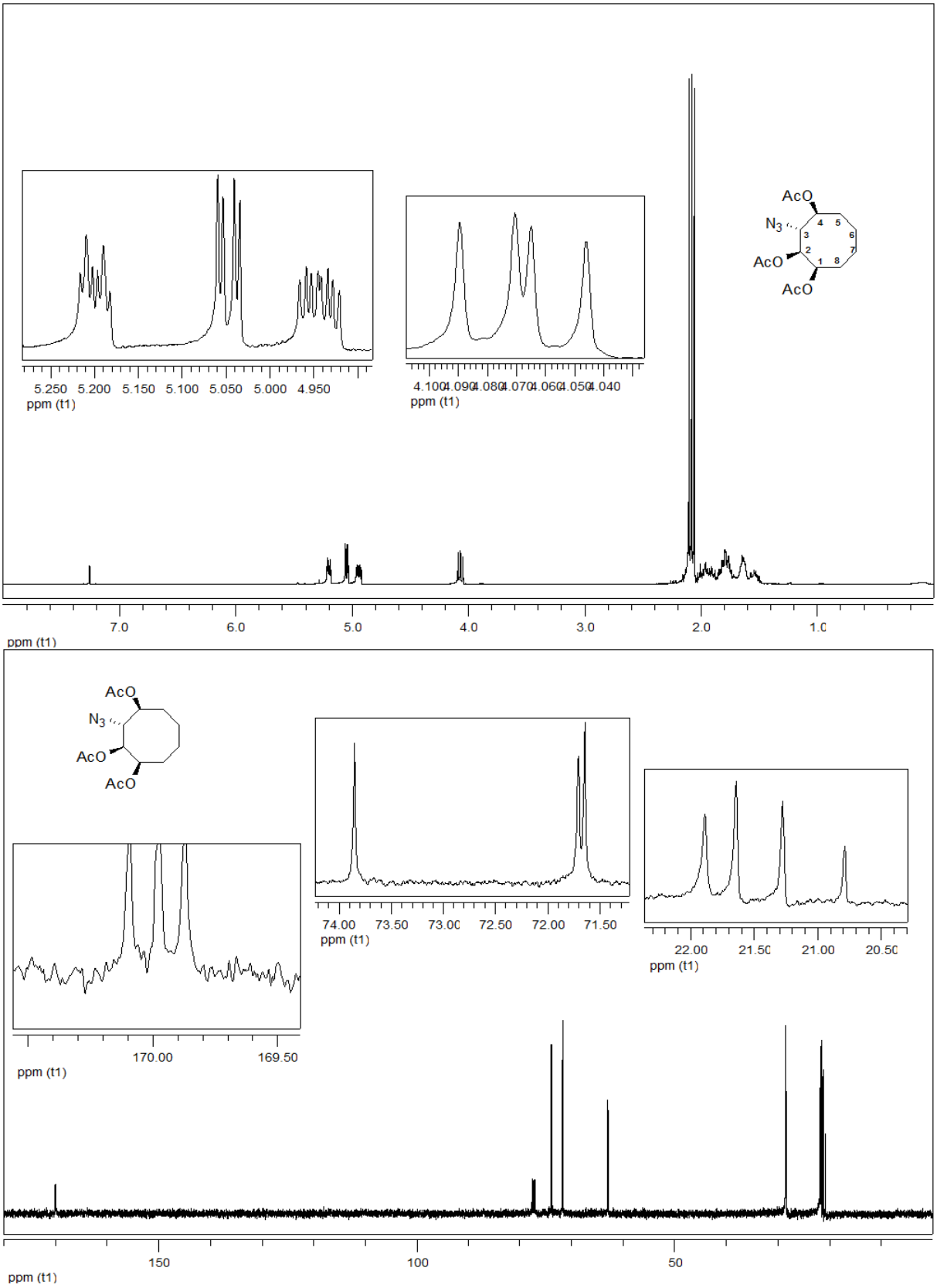


(1S(R),2S(R),Z)-2-azidocyclooct-3-enyl acetate (**9b**): $CDCl_3$

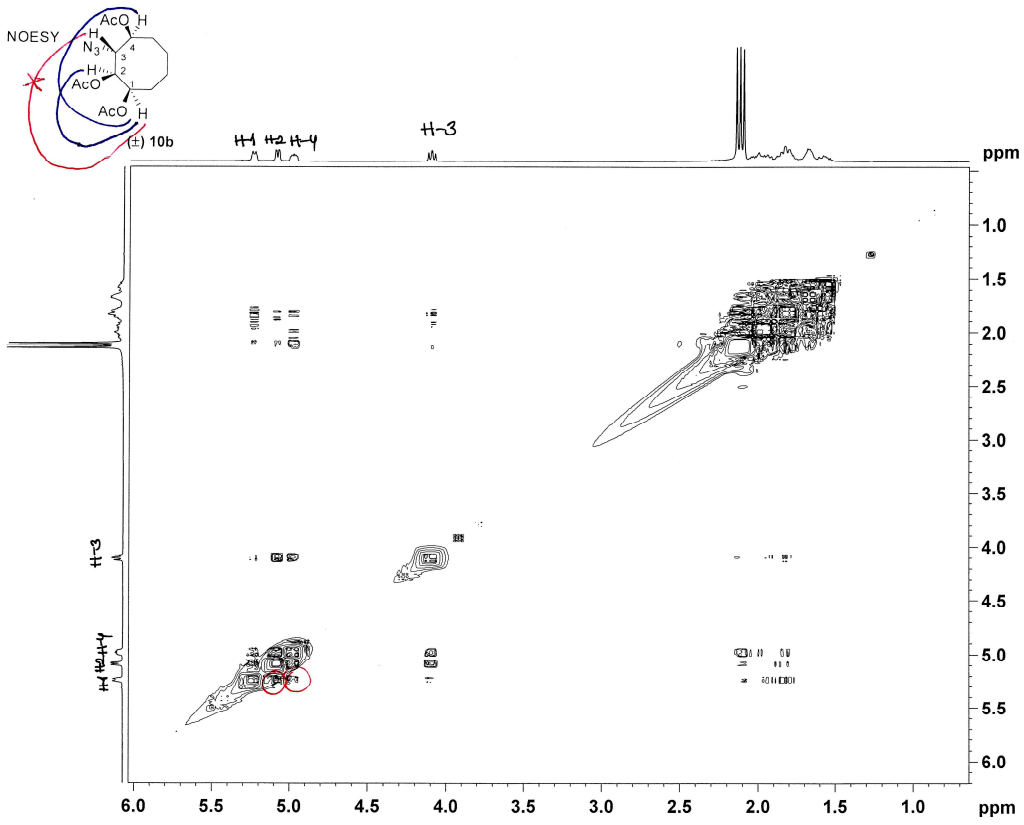


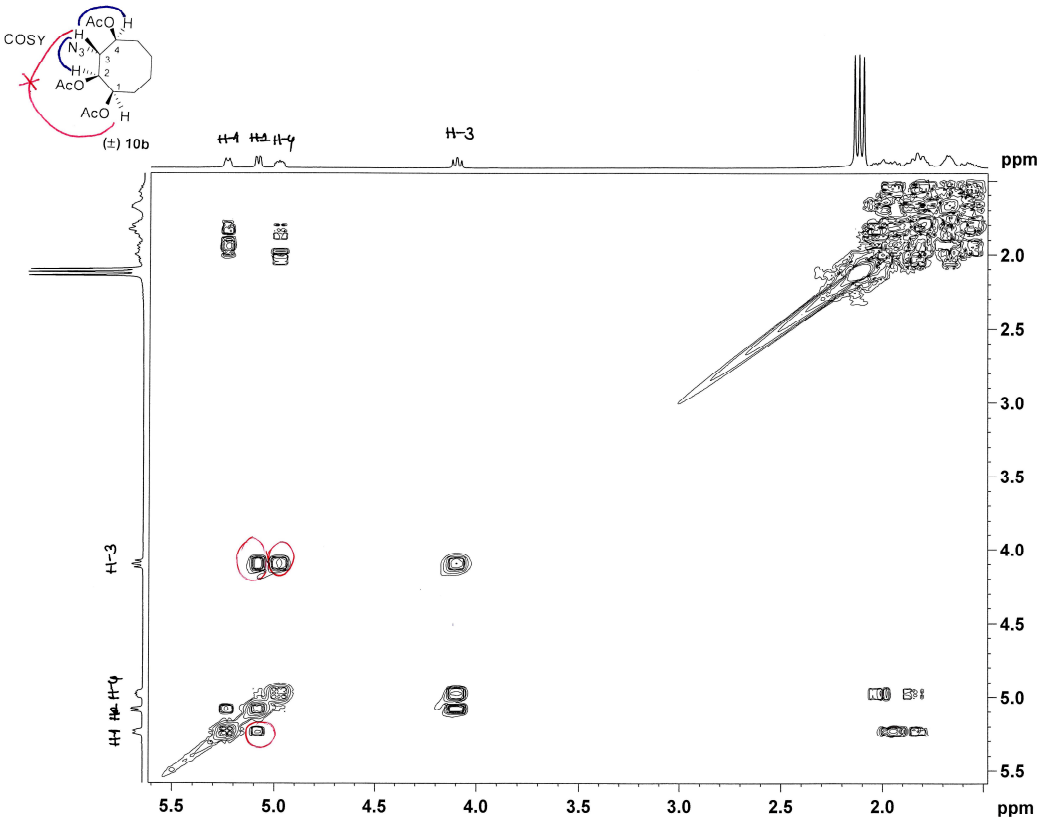


(1R(S),2(S)R,3R(S),4S(R))-3-azidocyclooctane-1,2,4-triyl triacetate (**10b**): $CDCl_3$

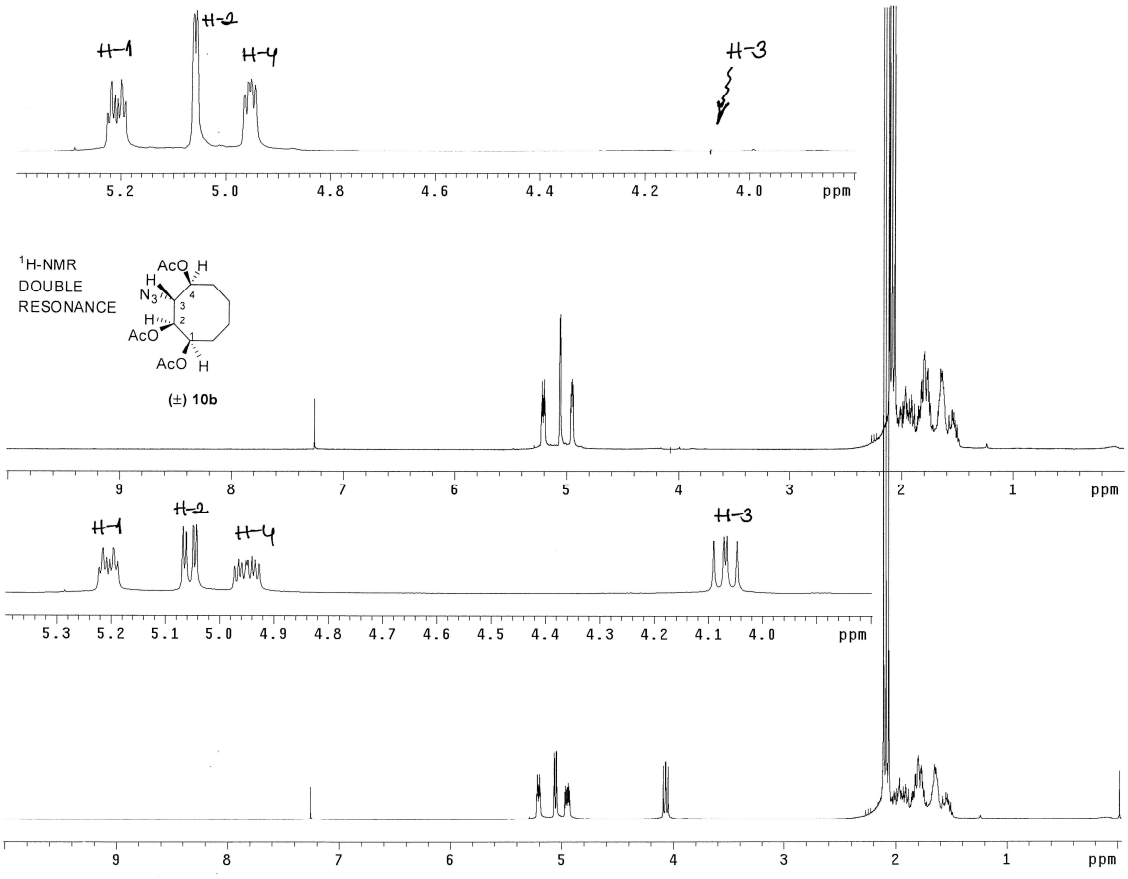


NOESY and COSY spectra for **10b**

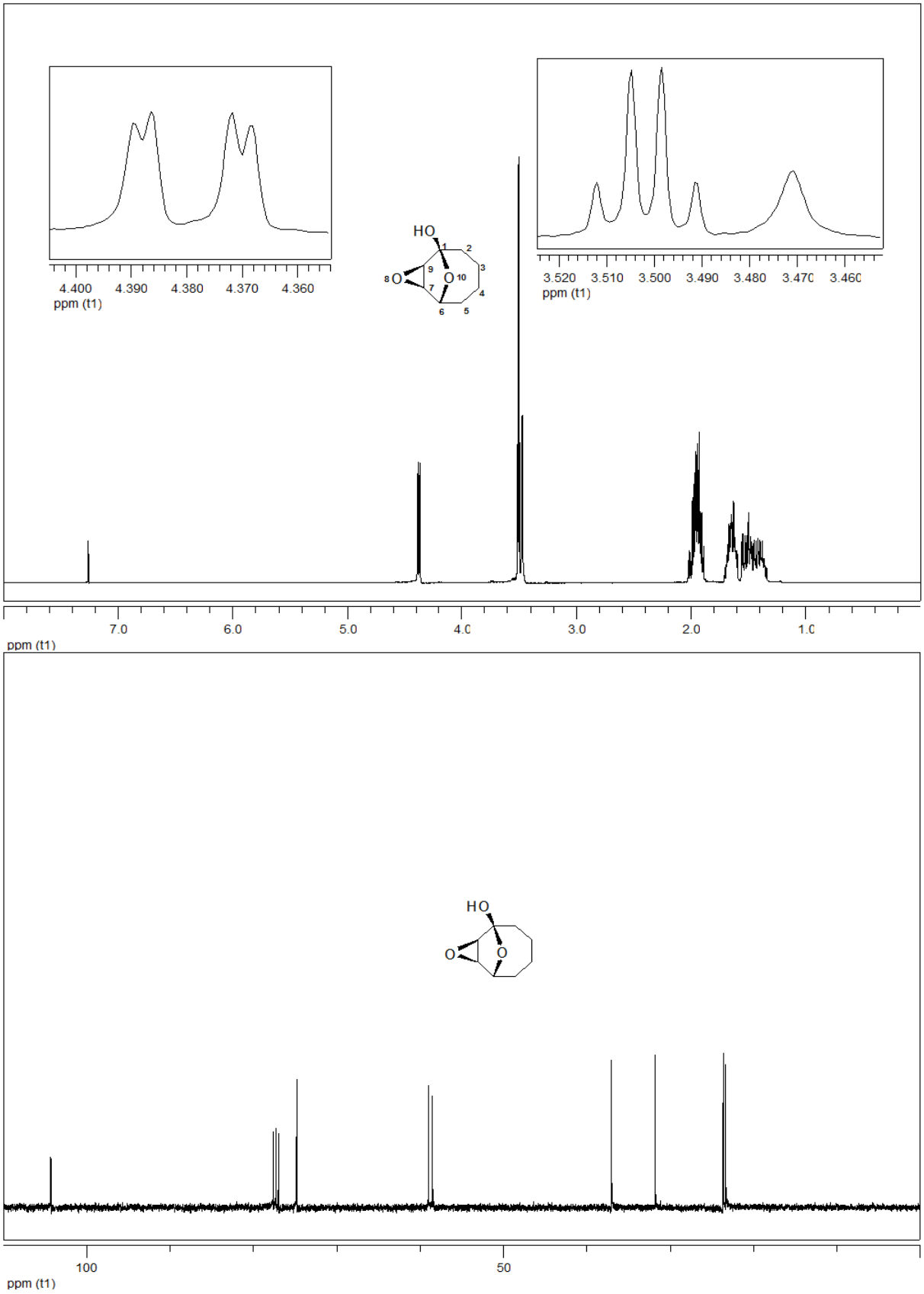




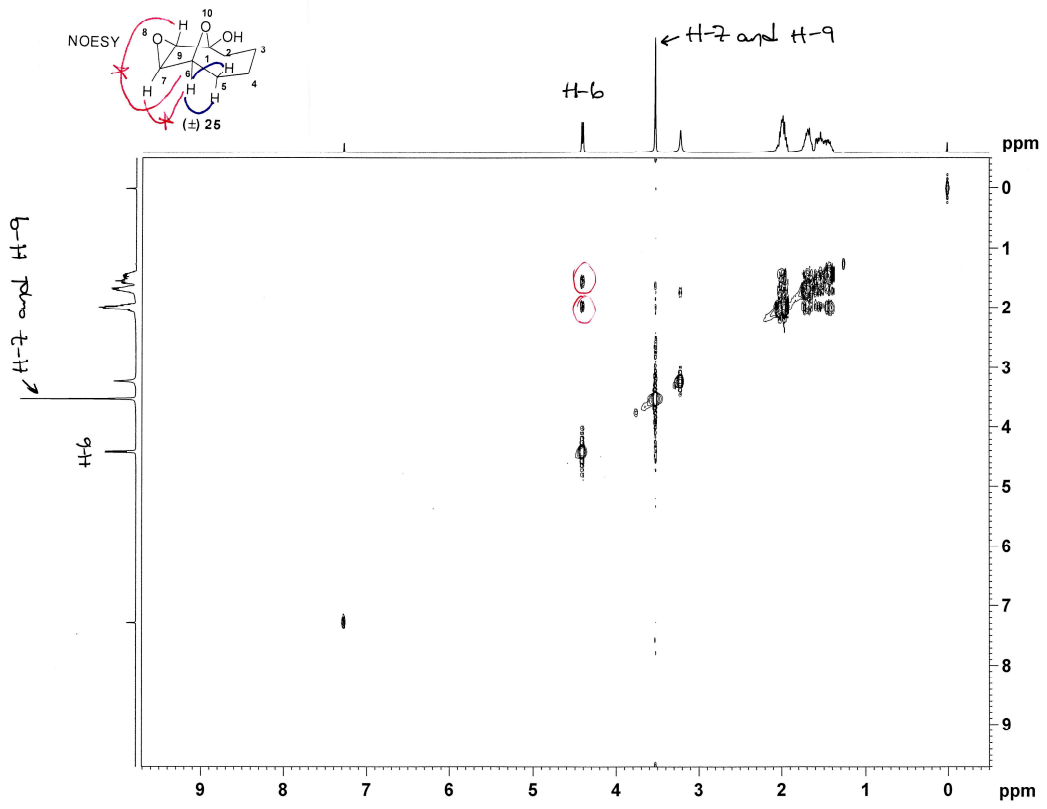
^{1}H-NMR double resonance spectrum for **10b**

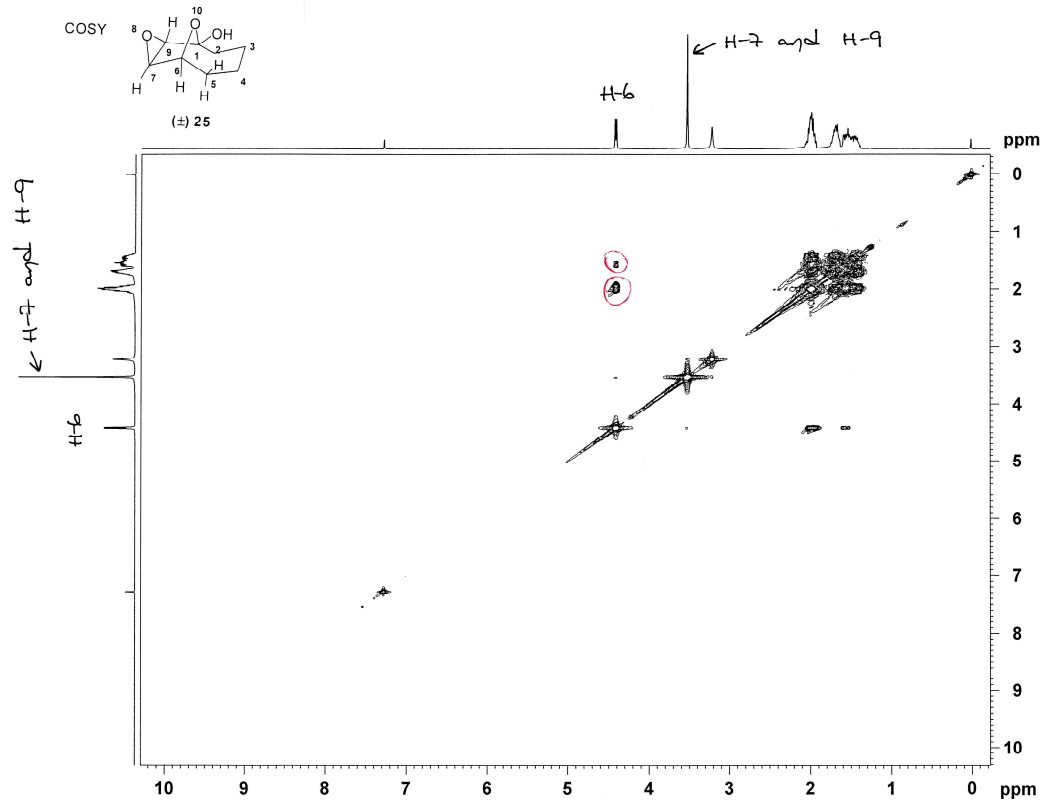


(1R(S),6S(R),7S(R),9S(R))-8,10-dioxatricyclo[4.3.1.$0^{7,9}$]decane-1-ol (**25**): $CDCl_3$

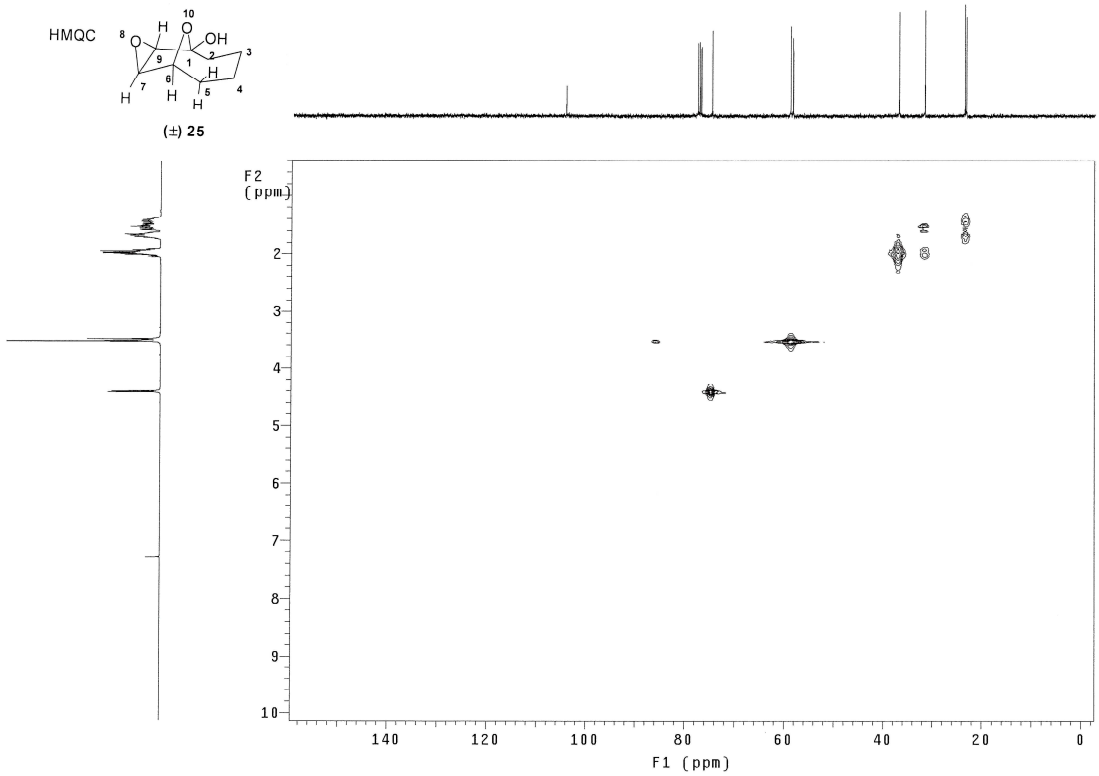


NOESY and COSY spectra for **25**

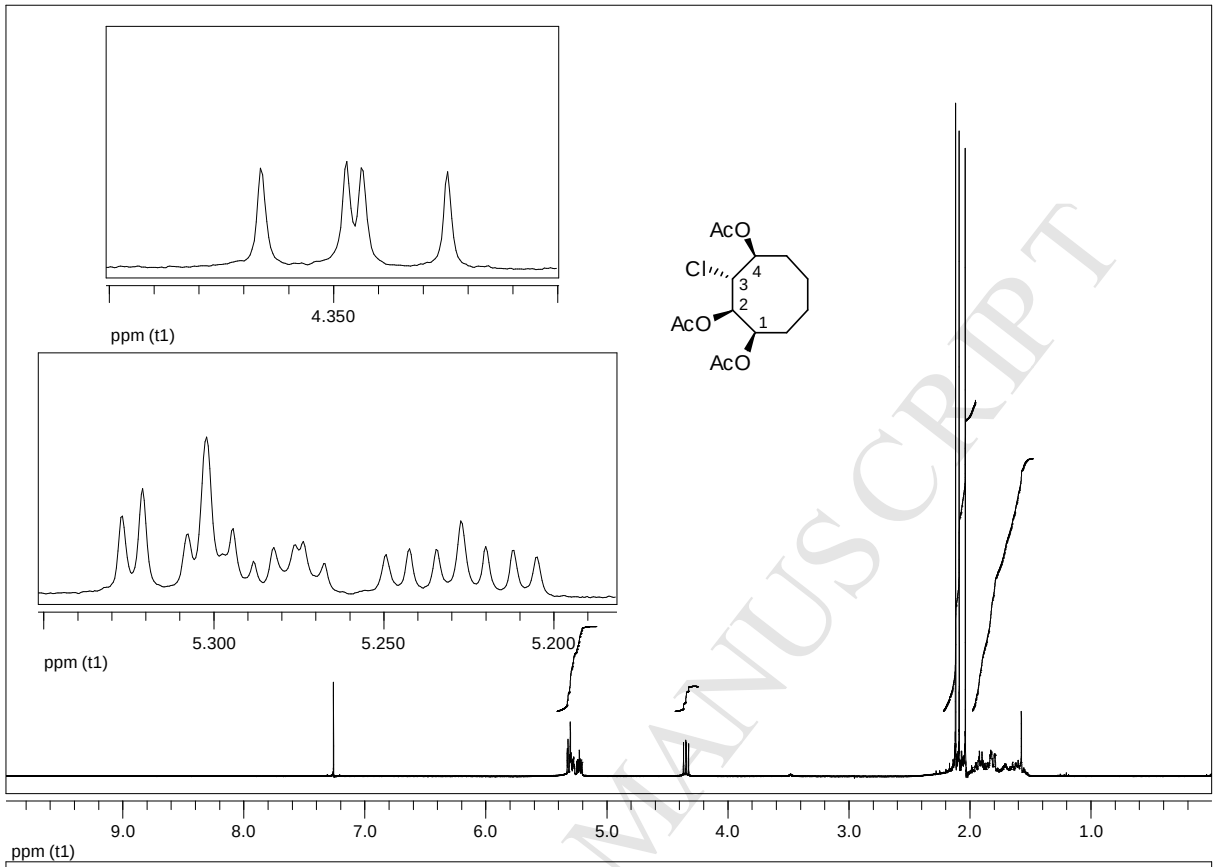


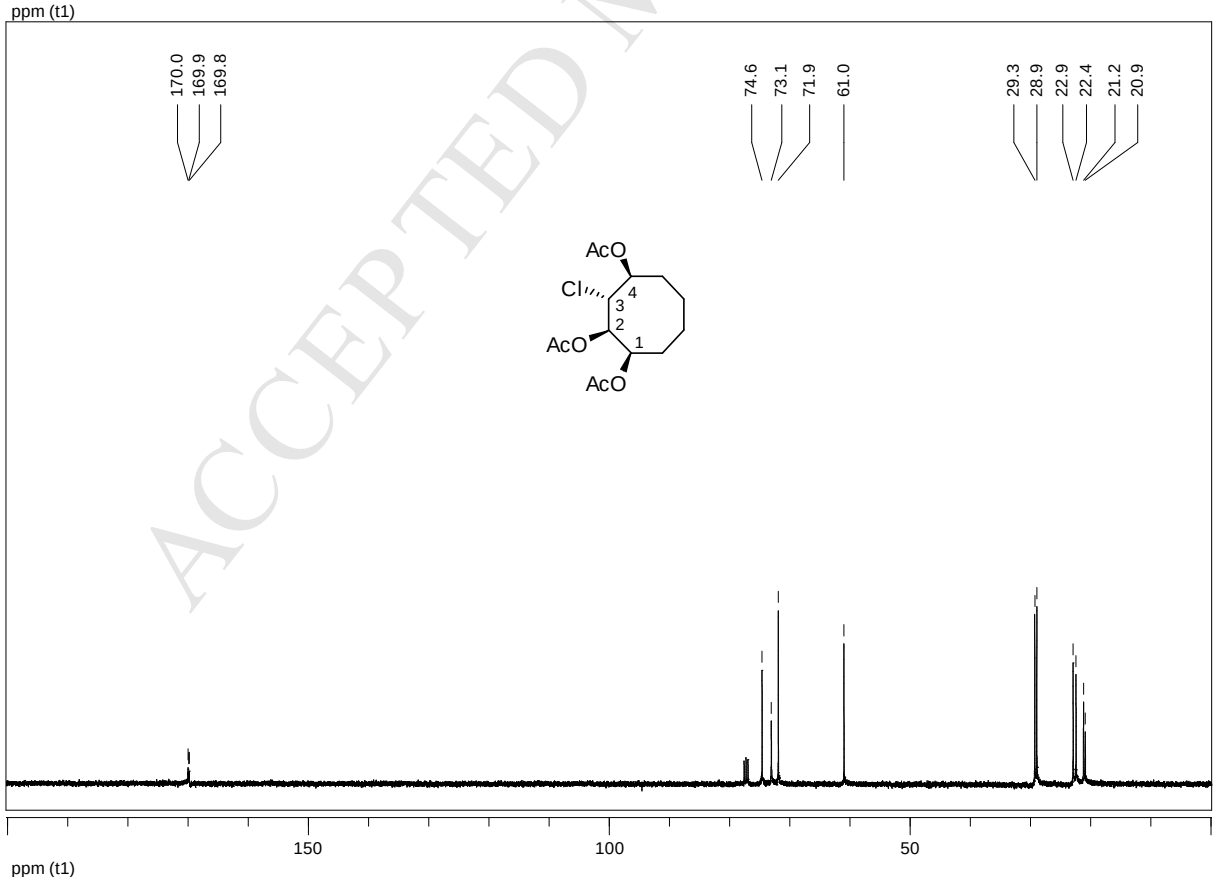


HMQC spectrum for **25**

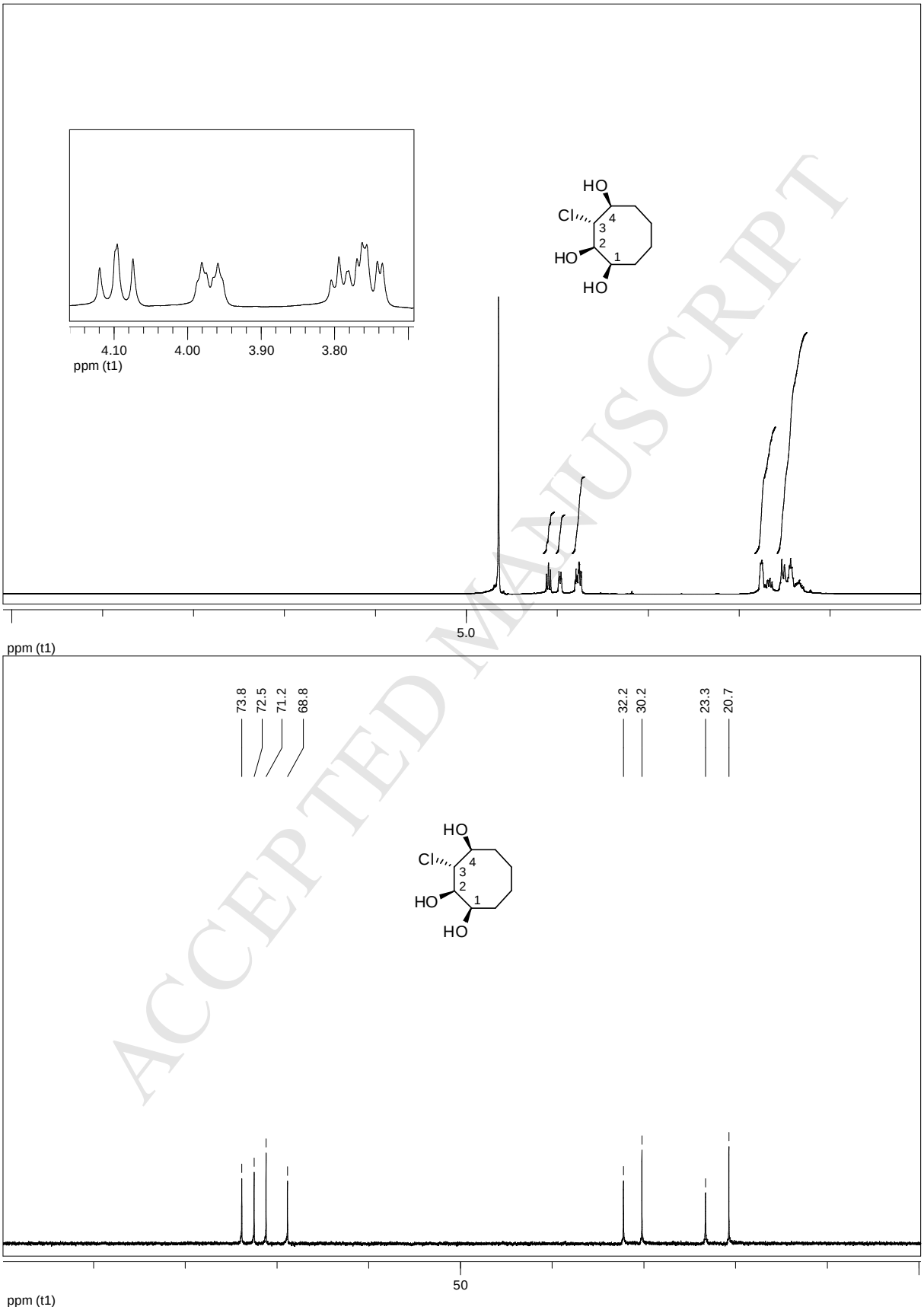


(1R(S),2R(S),3R(S),4S(R))-3-chlorocyclooctane-1,2,4-triyl triacetate (**30**): $CDCl_3$

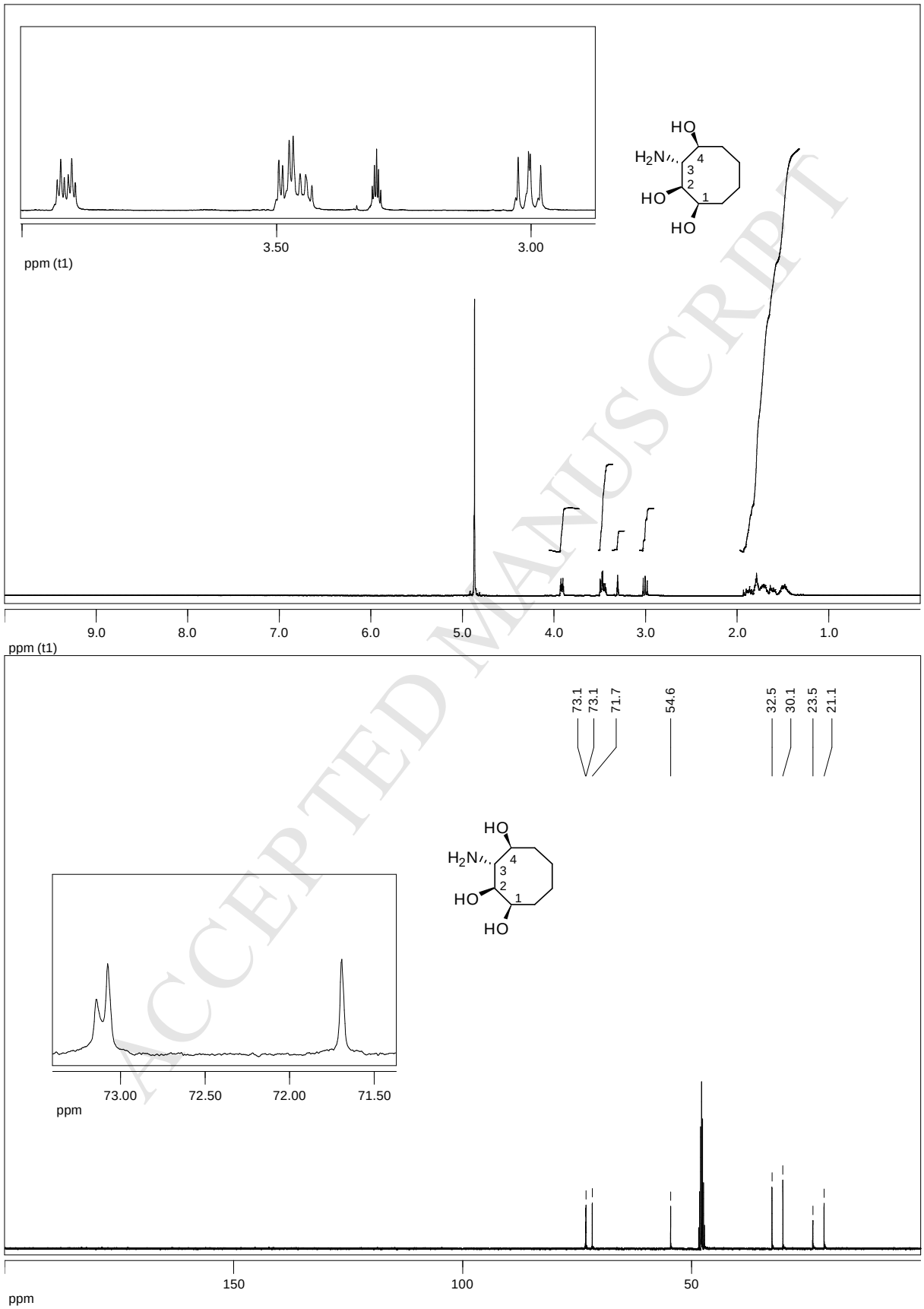




(1R(S),2R(S),3R(S),4S(R))-3-chlorocyclooctane-1,2,4-triol (**29**): D_2O



(1R(S),2S(R),3R(S),4S(R))-3-aminocyclooctane-1,2,4-triol (**12**): CD_3OD



X-Ray Crystal Structure Analysis of Chlorotriacetate 30

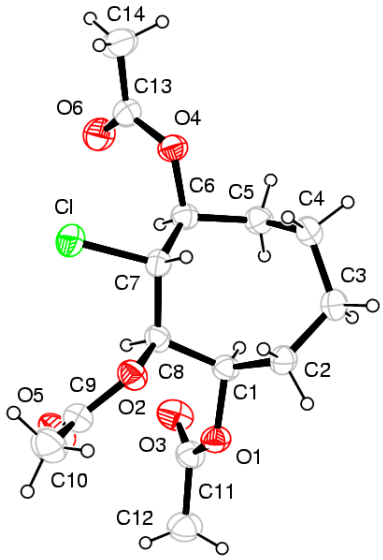


Figure 2. a) The molecular structure of compound chlorotriacetate **30** showing the atom numbering scheme. Thermal ellipsoids are drawn at the 40% probability level.

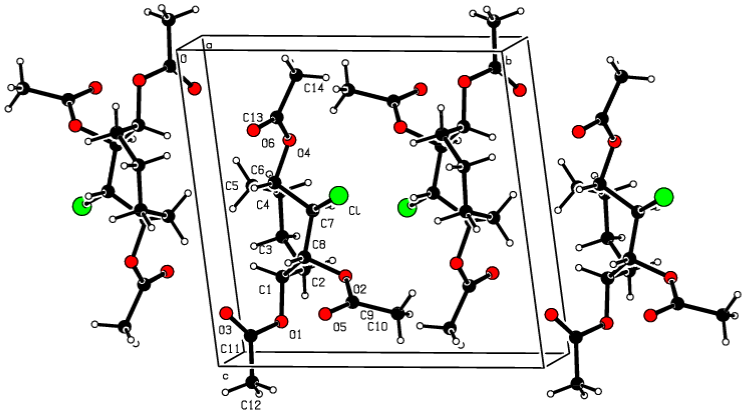


Figure 2. b) The molecular packing of **30**.

Table 1. Crystal data and structure refinement for **30**.

Identification code	esalamci-3oac (CCDC 787346)	
Empirical formula	$C_{14}H_{21}O_6Cl$	
Formula weight	320.76	
Temperature	293(2) K	
Wavelength	0.71073 Å	
Crystal system	triclinic	
Space group	*P-1*	
Unit cell dimensions	a = 7.5308(2) Å	α = 79.434(6)°
	b = 10.5140(3) Å	β = 70.502(4)°
	c = 11.0554(4) Å	γ = 74.870(5)°
Volume	792.08(5) $Å^3$	
Z	2	
Density (calculated)	1.345 Mg / m^3	
Absorption coefficient	0.264 mm^{-1}	
F(000)	340k	
Crystal	Block; opaque	
Crystal size	$0.20 \times 0.12 \times 0.11$ mm^3	
θ range for data collection	2.7 – 26.4°	
Index ranges	$-9 \le h \le 9$, $-13 \le k \le 13$, $-13 \le l \le 13$	
Reflections collected	17053	
Independent reflections	2165 [R_{int} = 0.071]	
Completeness to θ = 27.50°	99.8 %	
Max. and min. transmission	0.974 and 0.939	
Refinement method	Full-matrix least-squares on F^2	

Data / restraints / parameters	2165 / 0 / 193
Goodness-of-fit on F^2	1.028
Final *R* indices [$F^2 > 2\sigma(F^2)$]	*R1* = 0.055, *wR2* = 0.115
R indices (all data)	*R1* = 0.087, *wR2* = 0.131
Extinction coefficient	0.00
Largest diff. peak and hole	0.398 and –0.255 e Å^{-3}

Structure solution: *SHELXS97* (G. M. Sheldrick, Acta Cryst. (**1990**) A46 467–473). **Structure refinement**: *SHELXL97* (G. M. Sheldrick (**1997**), University of Göttingen, Germany). **Graphics:** *PLATON* (A.L. Spek, J. Appl. Crystallogr**. 2003**, 36, 7).

Table 2. Fractional atomic coordinates and isotropic temperature factors (Angstrom squared), with standard deviations in the least significant digits in parentheses. For anisotropic atoms, the equivalent isotropic temperature factors are shown.

	x/a	y/b	z/c	U_{eq}
CL	0.23179(10)	0.41977(7)	0.46892(7)	0.06787
O(1)	0.3776(3)	0.1796(2)	0.8749(2)	0.05537
O(2)	0.2655(2)	0.4046(2)	0.7253(2)	0.05638
O(4)	0.5735(3)	0.2620(2)	0.3097(2)	0.05663
O(3)	0.2471(3)	0.0242(2)	0.8432(2)	0.07587
O(6)	0.3597(3)	0.1736(2)	0.2693(2)	0.07732
O(5)	-0.0206(3)	0.3514(2)	0.8319(2)	0.09090
C(8)	0.3403(3)	0.2799(2)	0.6692(2)	0.04900
H(8)	0.23380	0.23659	0.68239	0.05879
C(7)	0.4276(3)	0.3173(2)	0.5252(2)	0.04921
H(7)	0.52173	0.37085	0.51430	0.05906
C(11)	0.2652(4)	0.0887(3)	0.9151(3)	0.05828
C(1)	0.4818(3)	0.1922(3)	0.7378(2)	0.04895
H(1)	0.52453	0.10436	0.70686	0.05874
C(6)	0.5258(4)	0.2028(2)	0.4423(2)	0.05006
H(6)	0.43501	0.14608	0.45541	0.06007
C(9)	0.0797(4)	0.4312(3)	0.7985(3)	0.06488
C(3)	0.8433(4)	0.1776(3)	0.6279(3)	0.06300
H(3A)	0.86816	0.08434	0.65939	0.07559
H(3B)	0.94854	0.21293	0.63072	0.07559
C(2)	0.6582(4)	0.2464(3)	0.7221(3)	0.05517
H(2A)	0.67809	0.23740	0.80586	0.06620

H(2B)	0.63255	0.34017	0.69251	0.06620
C(5)	0.7146(4)	0.1175(3)	0.4611(3)	0.05725
H(5A)	0.78451	0.07203	0.38454	0.06871
H(5B)	0.68315	0.05031	0.53279	0.06871
C(13)	0.4776(4)	0.2403(3)	0.2338(3)	0.06107
C(4)	0.8508(4)	0.1881(3)	0.4865(3)	0.06051
H(4A)	0.98180	0.15175	0.43664	0.07261
H(4B)	0.82000	0.28114	0.45517	0.07261
C(12)	0.1713(5)	0.0823(3)	1.0574(3)	0.07950
H(17C)	0.05885	0.15285	1.07654	0.11924
H(17B)	0.26018	0.09135	1.09888	0.11924
H(17A)	0.13431	-0.00129	1.08837	0.11924
C(10)	0.0193(5)	0.5713(3)	0.8310(3)	0.08261
H(10A)	-0.02613	0.62816	0.76415	0.12391
H(10B)	0.12744	0.59807	0.83835	0.12391
H(10C)	-0.08225	0.57738	0.91154	0.12391
C(14)	0.5412(5)	0.3120(4)	0.1025(3)	0.09124
H(14A)	0.48159	0.28985	0.04713	0.13686
H(14C)	0.67892	0.28649	0.06777	0.13686
H(14B)	0.50408	0.40578	0.10829	0.13686

Table 3. Vibration parameters (Angstrom squared) in the expression: -2(pi squared)(U11((h.a*)squared) + U22((k.b*)squared) + U33((l.c*)squared) + 2.U12.h.k.a*.b* + 2.U13.h.l.a*.c* +2.U23.k.l.b*.c*)

	U11	U22	U33	U12	U13	U23
CL	0.0654(5)	0.0660(5)	0.0677(5)	0.0008(3)	-.0281(4)	-.0025(3)
O(1)	0.058(1)	0.065(1)	0.046(1)	-0.024(1)	-0.014(1)	-0.003(1)
O(2)	0.051(1)	0.056(1)	0.060(1)	-0.008(1)	-0.011(1)	-0.016(1)
O(4)	0.059(1)	0.068(1)	0.046(1)	-0.021(1)	-0.017(1)	-0.004(1)
O(3)	0.082(1)	0.076(1)	0.074(1)	-0.039(1)	-0.007(1)	-0.016(1)
O(6)	0.072(1)	0.099(2)	0.075(1)	-0.032(1)	-0.028(1)	-0.014(1)
O(5)	0.062(1)	0.105(2)	0.098(2)	-0.027(1)	0.005(1)	-0.032(1)
C(8)	0.044(1)	0.053(1)	0.052(1)	-0.012(1)	-0.012(1)	-0.011(1)
C(7)	0.046(1)	0.050(1)	0.053(2)	-0.011(1)	-0.018(1)	-0.002(1)
C(11)	0.055(2)	0.061(2)	0.057(2)	-0.020(1)	-0.011(1)	-0.002(1)
C(1)	0.048(1)	0.053(1)	0.046(1)	-0.015(1)	-0.011(1)	-0.005(1)
C(6)	0.051(1)	0.053(2)	0.047(1)	-0.017(1)	-0.012(1)	-0.005(1)
C(9)	0.056(2)	0.079(2)	0.055(2)	-0.003(2)	-0.015(1)	-0.015(2)
C(3)	0.048(2)	0.079(2)	0.065(2)	-0.019(1)	-0.019(1)	-0.007(1)
C(2)	0.052(2)	0.066(2)	0.054(2)	-0.020(1)	-0.019(1)	-0.006(1)
C(5)	0.061(2)	0.052(2)	0.055(2)	-0.004(1)	-0.016(1)	-0.011(1)
C(13)	0.059(2)	0.072(2)	0.054(2)	-0.008(1)	-0.021(1)	-0.012(1)
C(4)	0.045(1)	0.068(2)	0.061(2)	-0.009(1)	-0.010(1)	-0.007(1)
C(12)	0.081(2)	0.098(2)	0.059(2)	-0.038(2)	-0.013(2)	0.002(2)
C(10)	0.080(2)	0.076(2)	0.075(2)	0.006(2)	-0.012(2)	-0.022(2)
C(14)	0.099(3)	0.125(3)	0.056(2)	-0.035(2)	-0.030(2)	0.003(2)

Table 4. Complete listing of torsion angles

H(8) - C(8) - C(7) - H(7)	172.5
H(8) - C(8) - C(7) - C(6)	-65.1
H(8) - C(8) - C(1) - H(1)	55.6
H(8) - C(8) - C(1) - C(2)	178.5
C(1) - C(8) - C(7) - H(7)	-63.7
C(7) - C(8) - C(1) - H(1)	-68.2
C(1) - C(8) - C(7) - C(6)	58.7
C(7) - C(8) - C(1) - C(2)	54.7
C(8) - C(7) - C(6) - H(6)	55.0
C(8) - C(7) - C(6) - C(5)	-69.5
H(7) - C(7) - C(6) - H(6)	177.3
H(7) - C(7) - C(6) - C(5)	52.9
O(1) - C(11) - C(12) - H(17C)	81.6
O(1) - C(11) - C(12) - H(17B)	-38.4
O(1) - C(11) - C(12) - H(17A)	-158.4
O(3) - C(11) - C(12) - H(17C)	-98.3
O(3) - C(11) - C(12) - H(17B)	141.7
O(3) - C(11) - C(12) - H(17A)	21.7
C(8) - C(1) - C(2) - C(3)	-104.5
C(8) - C(1) - C(2) - H(2A)	134.0
C(8) - C(1) - C(2) - H(2B)	17.0
H(1) - C(1) - C(2) - C(3)	18.4
H(1) - C(1) - C(2) - H(2A)	-103.2
H(1) - C(1) - C(2) - H(2B)	139.9

C(7) - C(6) - C(5) - H(5A)	-159.2
C(7) - C(6) - C(5) - H(5B)	85.2
C(7) - C(6) - C(5) - C(4)	-37.0
H(6) - C(6) - C(5) - H(5A)	76.4
H(6) - C(6) - C(5) - H(5B)	-39.3
H(6) - C(6) - C(5) - C(4)	-161.5
O(2) - C(9) - C(10) - H(10A)	87.7
O(2) - C(9) - C(10) - H(10B)	-32.3
O(2) - C(9) - C(10) - H(10C)	-152.3
O(5) - C(9) - C(10) - H(10A)	-92.4
O(5) - C(9) - C(10) - H(10B)	147.6
O(5) - C(9) - C(10) - H(10C)	27.6
H(3A) - C(3) - C(2) - C(1)	-59.3
H(3A) - C(3) - C(2) - H(2A)	62.2
H(3A) - C(3) - C(2) - H(2B)	179.2
H(3A) - C(3) - C(4) - C(5)	55.6
H(3A) - C(3) - C(4) - H(4A)	-66.2
H(3A) - C(3) - C(4) - H(4B)	177.3
H(3B) - C(3) - C(2) - C(1)	-174.7
H(3B) - C(3) - C(2) - H(2A)	-53.2
H(3B) - C(3) - C(2) - H(2B)	63.8
H(3B) - C(3) - C(4) - C(5)	170.9
H(3B) - C(3) - C(4) - H(4A)	49.2
H(3B) - C(3) - C(4) - H(4B)	-67.3
C(4) - C(3) - C(2) - C(1)	63.0
C(4) - C(3) - C(2) - H(2A)	-175.5

C(4) - C(3) - C(2) - H(2B)	-58.5
C(2) - C(3) - C(4) - C(5)	-66.8
C(2) - C(3) - C(4) - H(4A)	171.5
C(2) - C(3) - C(4) - H(4B)	55.0
C(6) - C(5) - C(4) - C(3)	100.3
C(6) - C(5) - C(4) - H(4A)	-137.9
C(6) - C(5) - C(4) - H(4B)	-21.4
H(5A) - C(5) - C(4) - C(3)	-137.5
H(5A) - C(5) - C(4) - H(4A)	-15.7
H(5A) - C(5) - C(4) - H(4B)	100.8
H(5B) - C(5) - C(4) - C(3)	-21.8
H(5B) - C(5) - C(4) - H(4A)	99.9
H(5B) - C(5) - C(4) - H(4B)	-143.6
O(4) - C(13) - C(14) - H(14A)	174.8
O(4) - C(13) - C(14) - H(14C)	54.8
O(4) - C(13) - C(14) - H(14B)	-65.2
O(6) - C(13) - C(14) - H(14A)	-5.5
O(6) - C(13) - C(14) - H(14C)	-125.5
O(6) - C(13) - C(14) - H(14B)	114.5

Table 5. Complete listing of bond distances (Angstroms)

O(1) - C(11)	1.357(4)	O(2) - C(9)	1.347(4)
O(4) - C(13)	1.356(4)	O(3) - C(11)	1.196(4)
O(6) - C(13)	1.194(4)	O(5) - C(9)	1.201(4)
C(8) - H(8)	0.980(3)	C(8) - C(7)	1.526(4)
C(8) - C(1)	1.527(4)	C(7) - H(7)	0.980(3)
C(7) - C(6)	1.524(4)	C(11) - C(12)	1.491(5)
C(1) - H(1)	0.980(3)	C(1) - C(2)	1.525(4)
C(6) - H(6)	0.980(3)	C(6) - C(5)	1.527(4)
C(9) - C(10)	1.496(5)	C(3) - H(3A)	0.970(4)
C(3) - H(3B)	0.970(3)	C(3) - C(2)	1.527(4)
C(3) - C(4)	1.530(4)	C(2) - H(2A)	0.970(3)
C(2) - H(2B)	0.970(3)	C(5) - H(5A)	0.970(3)
C(5) - H(5B)	0.970(3)	C(5) - C(4)	1.532(4)
C(13) - C(14)	1.492(5)	C(4) - H(4A)	0.970(3)
C(4) - H(4B)	0.970(3)	C(12) - H(17C)	0.960(4)
C(12) - H(17B)	0.960(3)	C(12) - H(17A)	0.960(4)
C(10) - H(10A)	0.960(4)	C(10) - H(10B)	0.960(4)
C(10) - H(10C)	0.960(4)	C(14) - H(14A)	0.960(4)
C(14) - H(14C)	0.960(4)	C(14) - H(14B)	0.960(4)

Table 6. Complete listing of bond angles (degrees)

H(8)-C(8)-C(7)	109.4(3)	H(8)-C(8)-C(1)	109.4(3)
C(7)-C(8)-C(1)	115.3(2)	C(8)-C(7)-H(7)	108.4(3)
C(8)-C(7)-C(6)	116.3(2)	H(7)-C(7)-C(6)	108.4(3)
O(1)-C(11)-O(3)	123.0(3)	O(1)-C(11)-C(12)	110.9(3)
O(3)-C(11)-C(12)	126.1(3)	C(8)-C(1)-H(1)	109.1(3)
C(8)-C(1)-C(2)	114.9(3)	H(1)-C(1)-C(2)	109.1(3)
C(7)-C(6)-H(6)	109.2(3)	C(7)-C(6)-C(5)	116.6(3)
H(6)-C(6)-C(5)	109.2(3)	O(2)-C(9)-O(5)	123.4(3)
O(2)-C(9)-C(10)	110.8(3)	O(5)-C(9)-C(10)	125.8(3)
H(3A)-C(3)-H(3B)	107.2(3)	H(3A)-C(3)-C(2)	107.8(3)
H(3A)-C(3)-C(4)	107.8(3)	H(3B)-C(3)-C(2)	107.8(3)
H(3B)-C(3)-C(4)	107.8(3)	C(2)-C(3)-C(4)	118.0(3)
C(1)-C(2)-C(3)	114.0(3)	C(1)-C(2)-H(2A)	108.7(3)
C(1)-C(2)-H(2B)	108.7(3)	C(3)-C(2)-H(2A)	108.7(3)
C(3)-C(2)-H(2B)	108.7(3)	H(2A)-C(2)-H(2B)	107.6(3)
C(6)-C(5)-H(5A)	108.0(3)	C(6)-C(5)-H(5B)	108.0(3)
C(6)-C(5)-C(4)	117.3(3)	H(5A)-C(5)-H(5B)	107.2(3)
H(5A)-C(5)-C(4)	108.0(3)	H(5B)-C(5)-C(4)	108.0(3)
O(4)-C(13)-O(6)	123.9(3)	O(4)-C(13)-C(14)	109.9(3)
O(6)-C(13)-C(14)	126.2(3)	C(3)-C(4)-C(5)	115.2(3)
C(3)-C(4)-H(4A)	108.5(3)	C(3)-C(4)-H(4B)	108.5(3)
C(5)-C(4)-H(4A)	108.5(3)	C(5)-C(4)-H(4B)	108.5(3)
H(4A)-C(4)-H(4B)	107.5(3)	C(11)-C(12)-H(17C)	109.5(3)
C(11)-C(12)-H(17B)	109.5(3)	C(11)-C(12)-H(17A)	109.5(3)

H(17C)-C(12)-H(17B)	109.5(4)	H(17C)-C(12)-H(17A)	109.5(4)
H(17B)-C(12)-H(17A)	109.5(4)	C(9)-C(10)-H(10A)	109.5(3)
C(9)-C(10)-H(10B)	109.5(3)	C(9)-C(10)-H(10C)	109.5(3)
H(10A)-C(10)-H(10B)	109.5(4)	H(10A)-C(10)-H(10C)	109.5(4)
H(10B)-C(10)-H(10C)	109.5(4)	C(13)-C(14)-H(14A)	109.5(4)
C(13)-C(14)-H(14C)	109.5(4)	C(13)-C(14)-H(14B)	109.5(3)
H(14A)-C(14)-H(14C)	109.5(4)	H(14A)-C(14)-H(14B)	109.5(4)
H(14C)-C(14)-H(14B)	109.5(4)		

Supplementary Material

Efficient and shortcut syntheses of some novel eight-membered ring cyclitols starting from cycloocta-1,3-diene

Kadriye Ecer, and Emine Salamci*

Department of Chemistry, Faculty of Sciences, Atatürk University, 25240 Erzurum, Turkey

*Corresponding author. Tel: +90 442 231 4429; fax: +90 442 2314109 (E.S.).

E-mail address: esalamci@atauni.edu.tr (E. Salamci).

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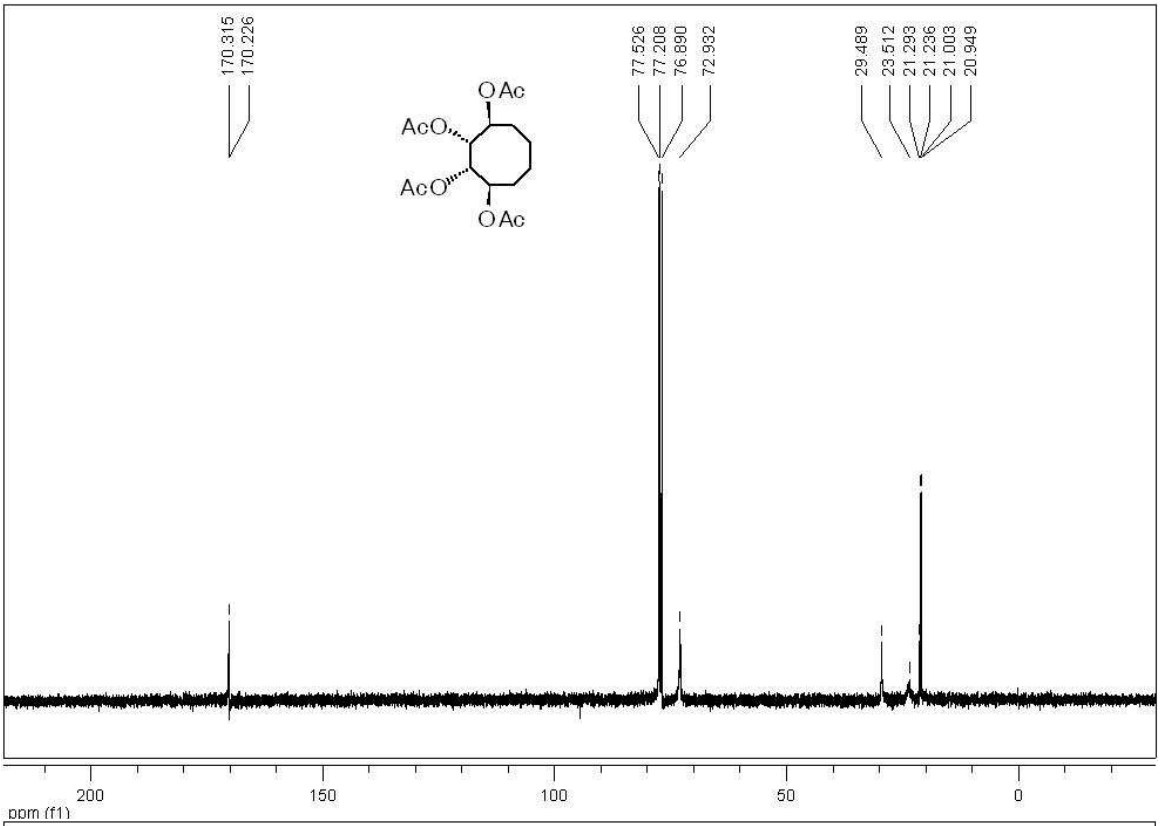
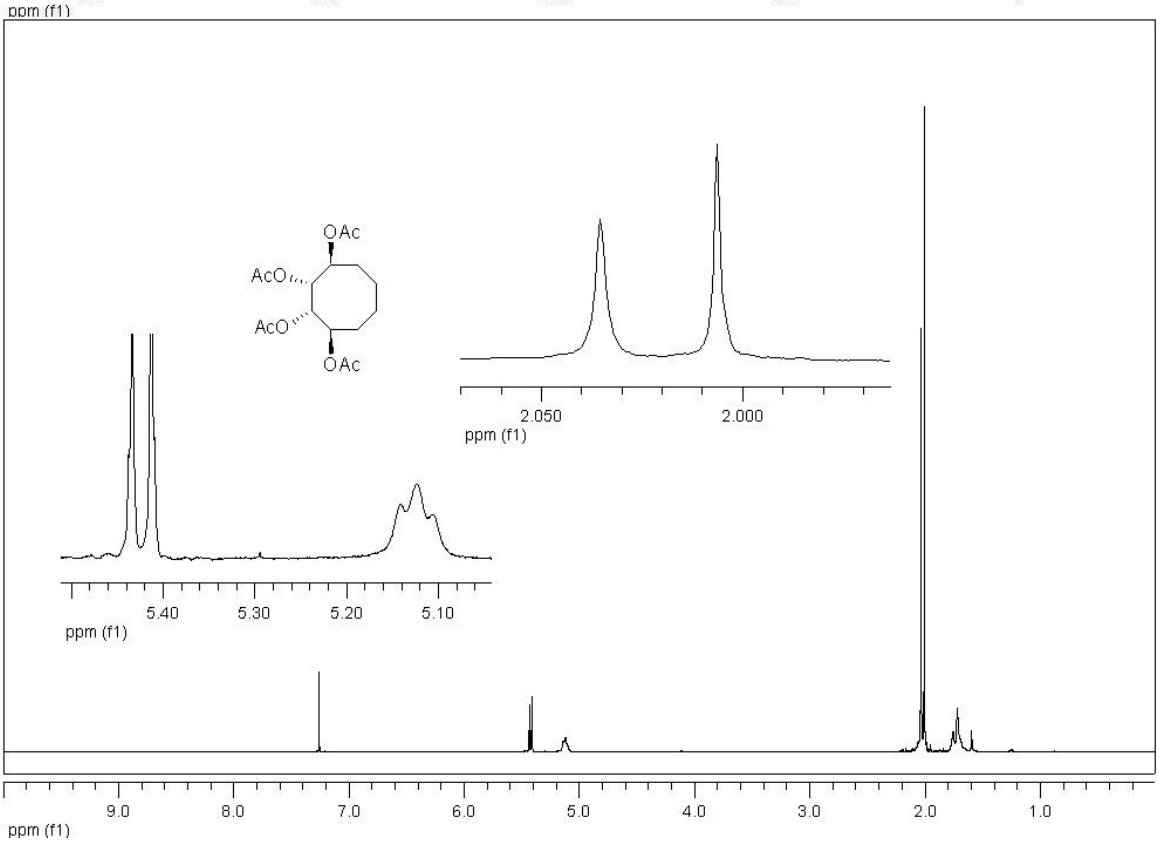
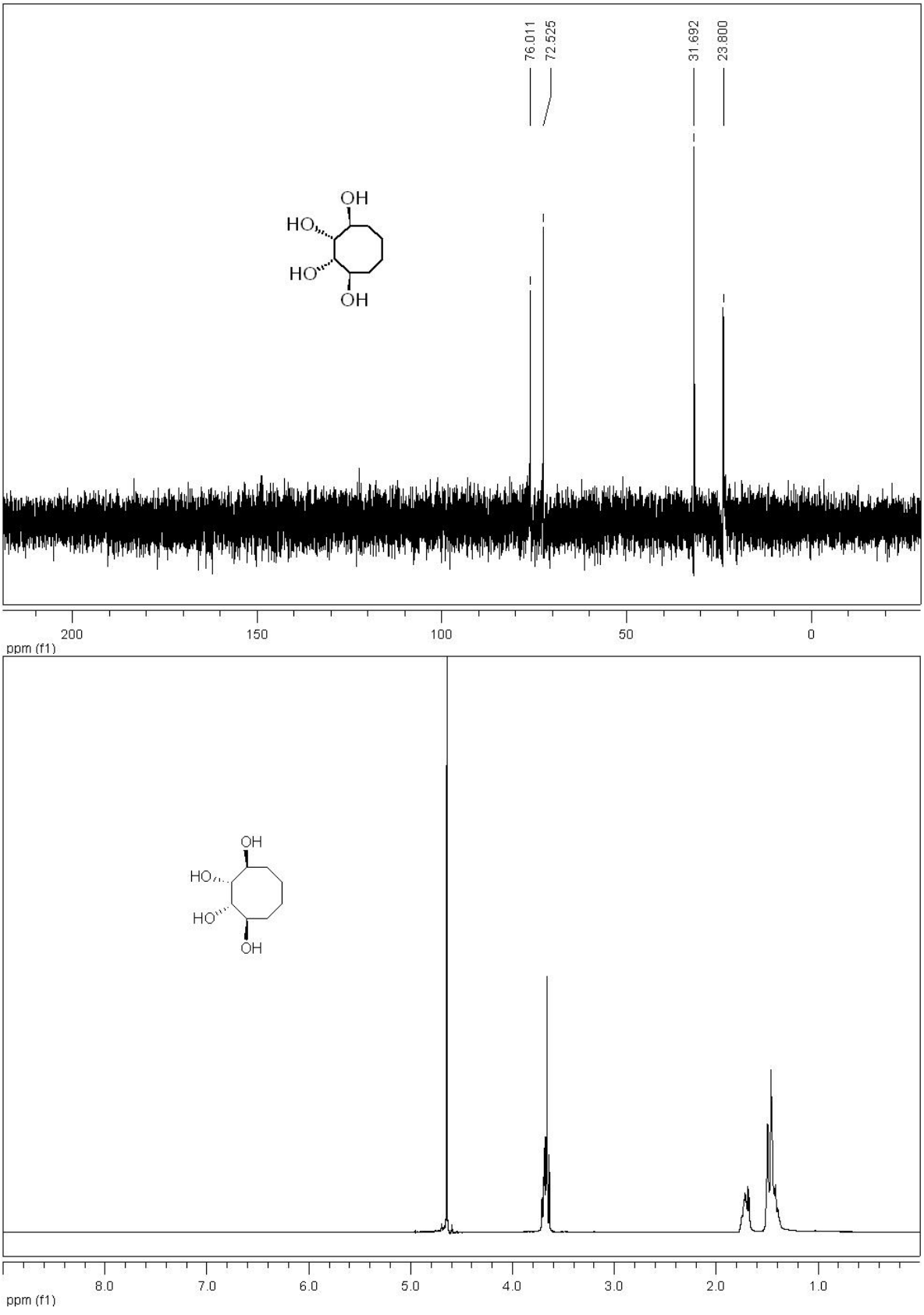
^{1}H NMR and ^{13}C NMR Spectra

(1R(S),2S(R),3R(S),4S(R))-Cyclooctane-1,2,3,4-tetraacetate (meso-**16**): $CDCl_3$

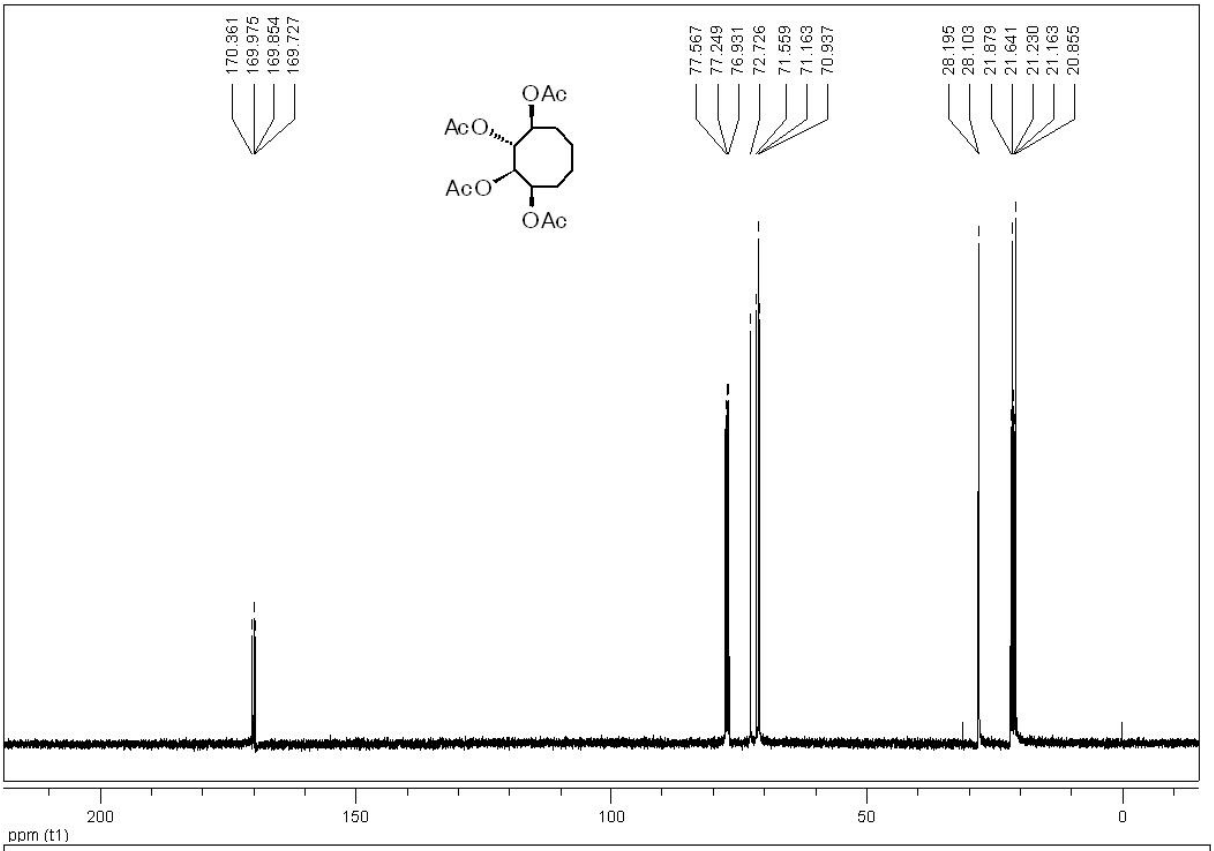


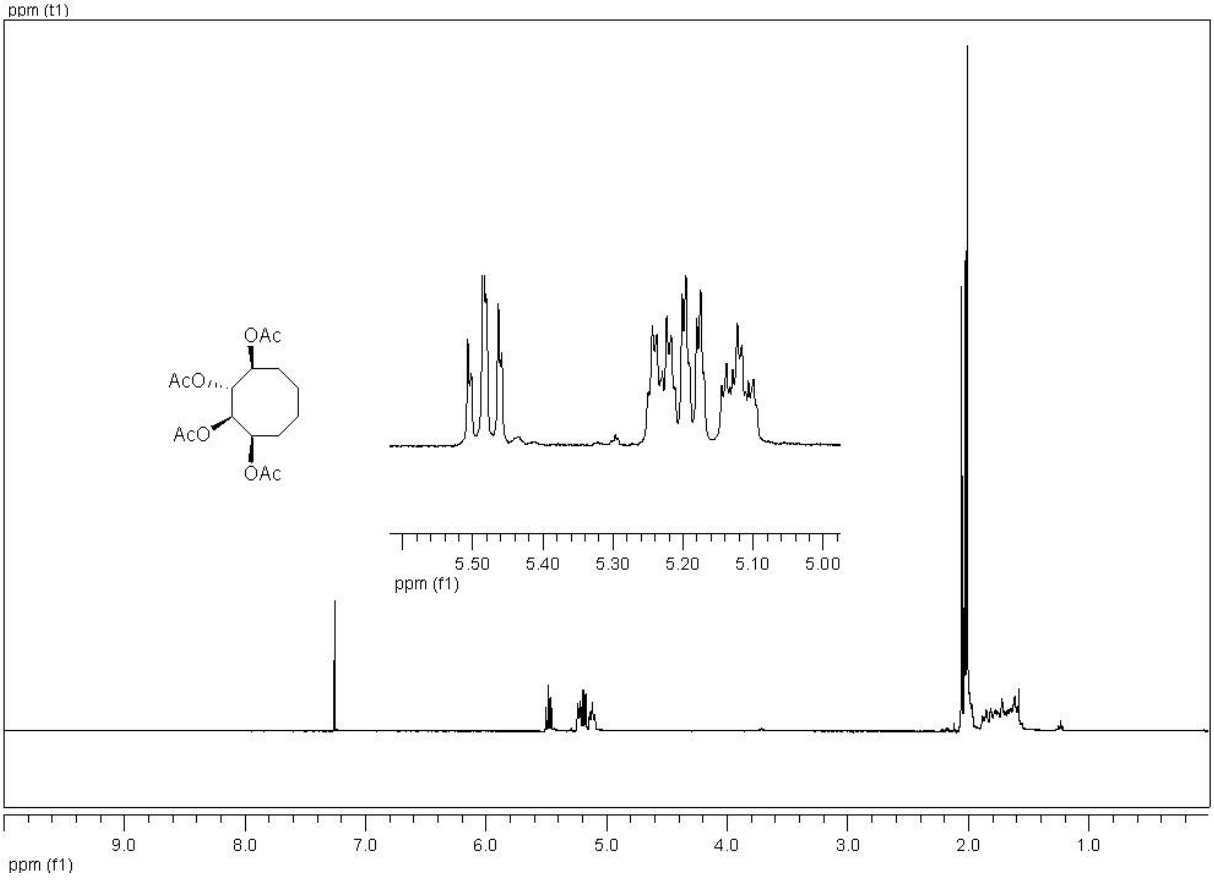


(1R(S),2S(R),3R(S),4S(R))-Cyclooctane-1,2,3,4-tetraol (meso-**19**): D_2O

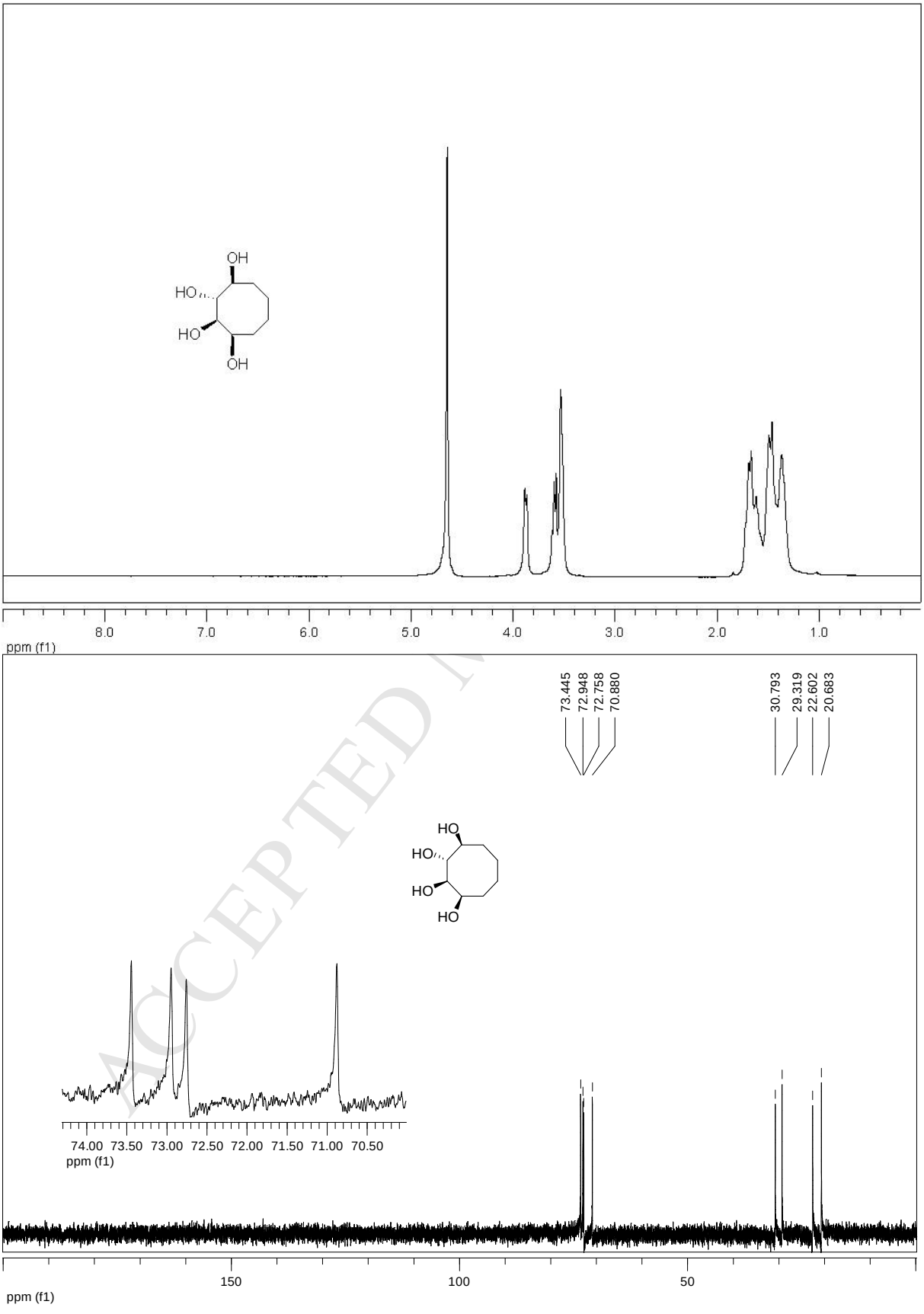


(1R(S),2R(S),3R(S),4S(R))-Cyclooctane-1,2,3,4-tetraacetate (rac-**15**): $CDCl_3$

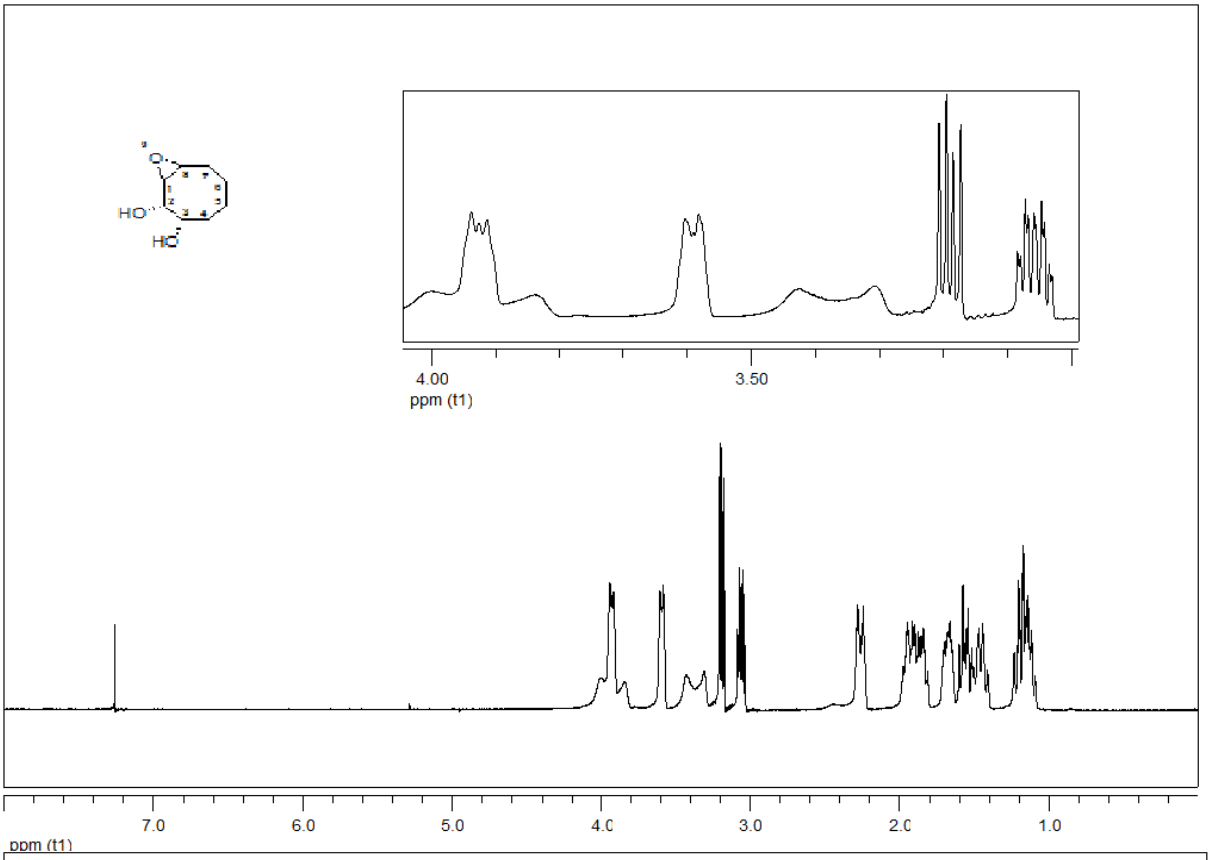


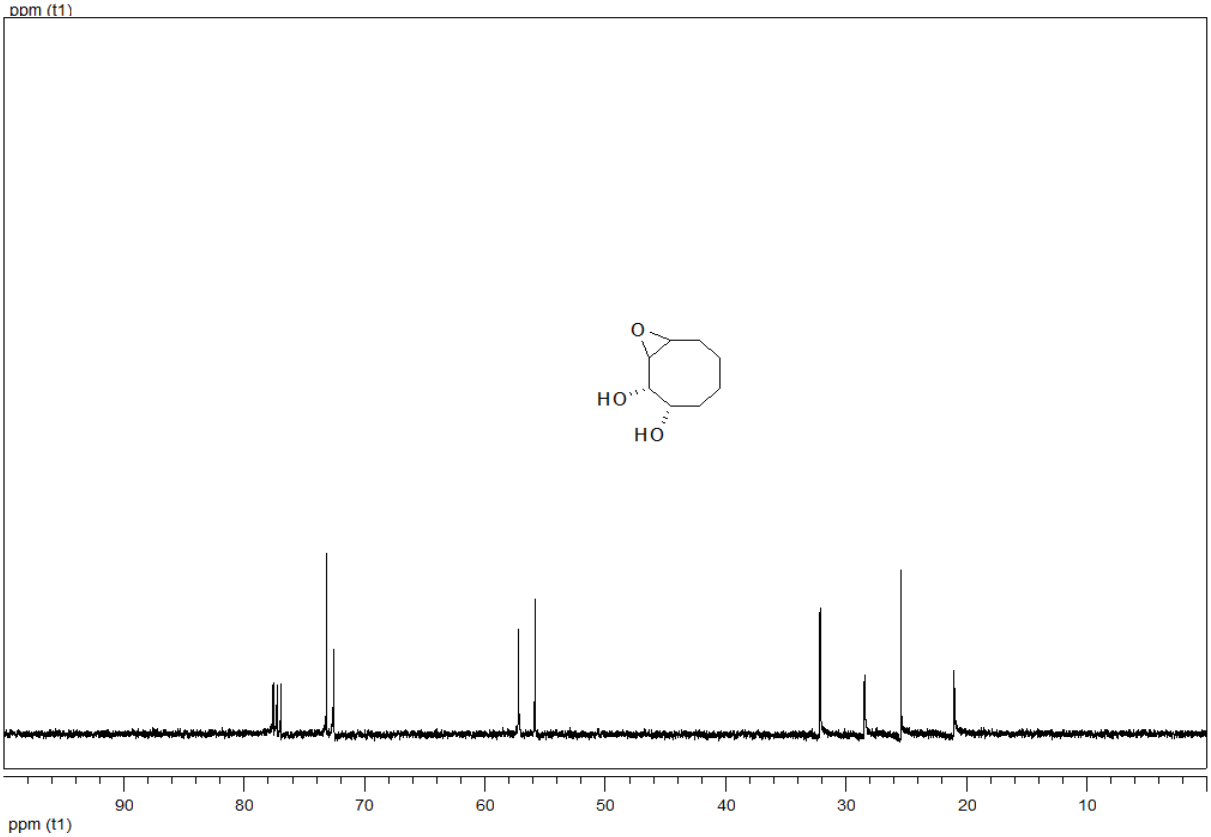


(1R(S),2R(S),3R(S),4S(R))-Cyclooctane-1,2,3,4-tetraol (rac-**18**): D_2O

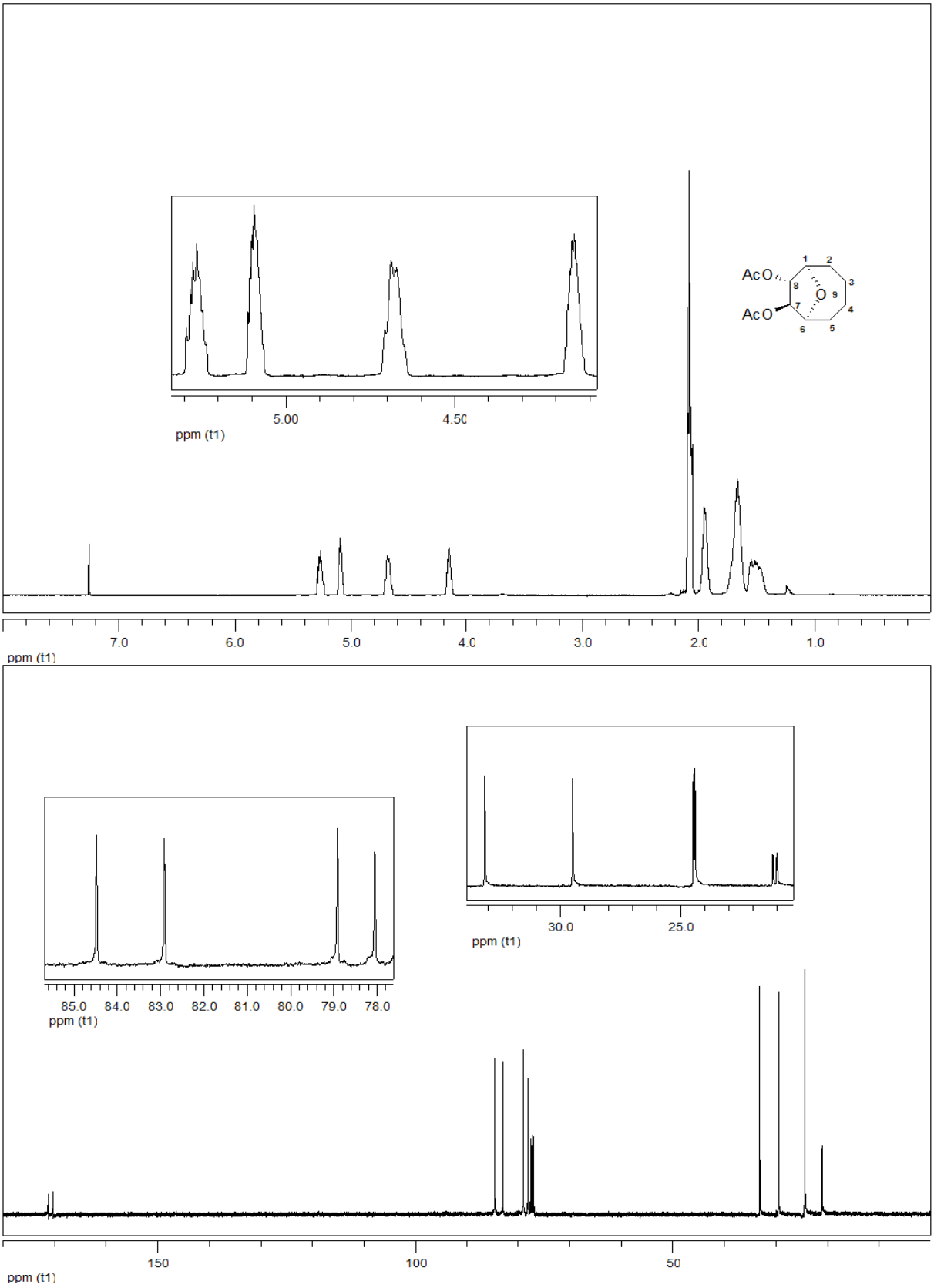


(1R(S),2S(R),3S(R),8S(R))-9-oxabicyclo[6.1.0]nonane-2,3-diol (**13**): $CDCl_3$

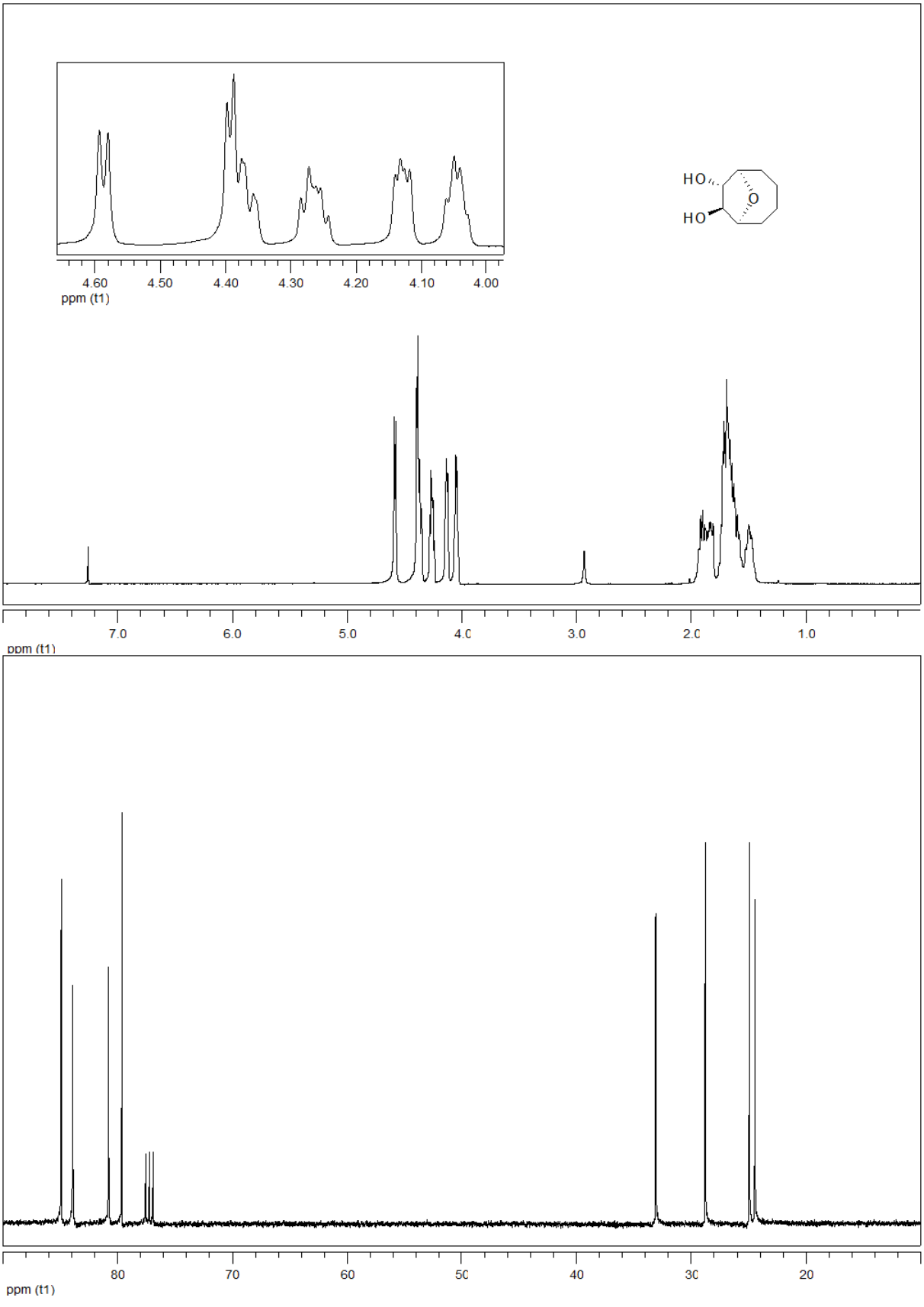




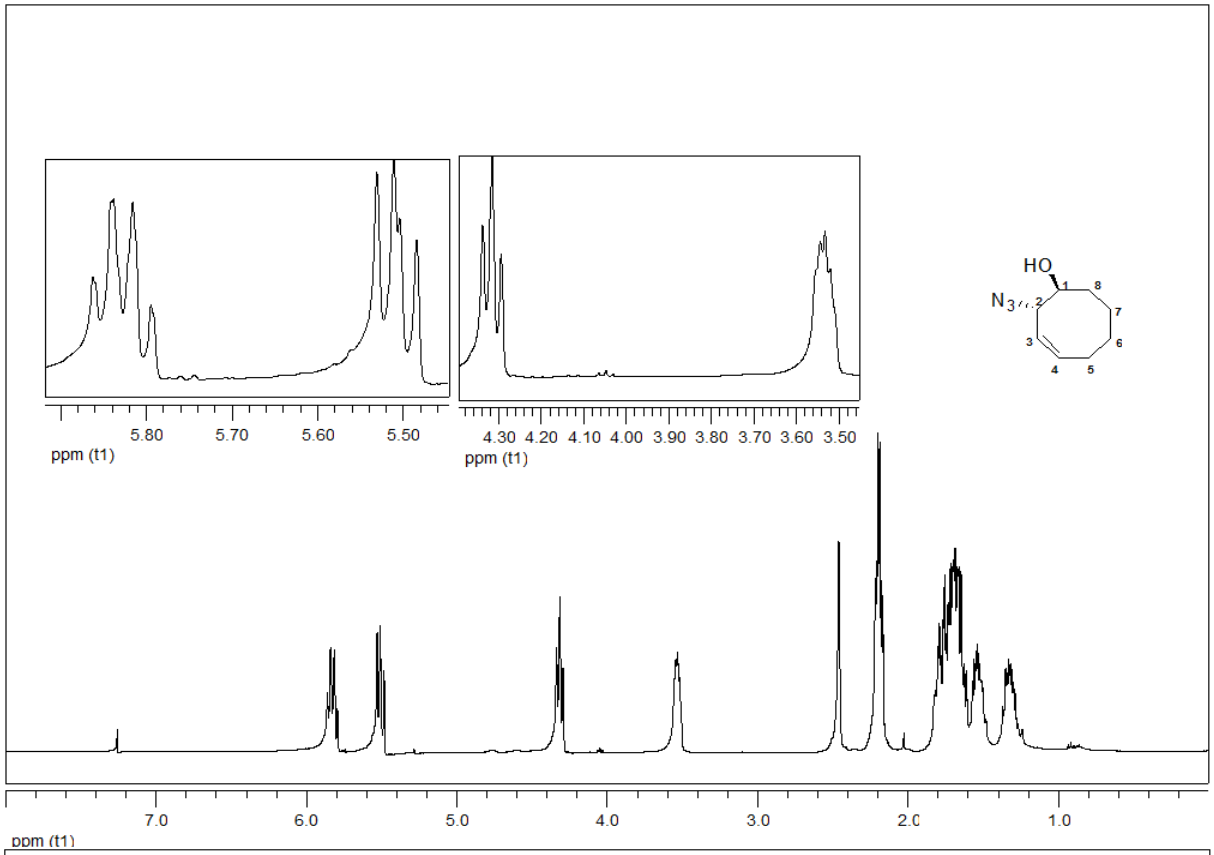
(1R(S),6S(R),7S(R),8S(R))-9-oxabicyclo[4.2.1]nonane-7,8-diyl diacetate (**14**): $CDCl_3$

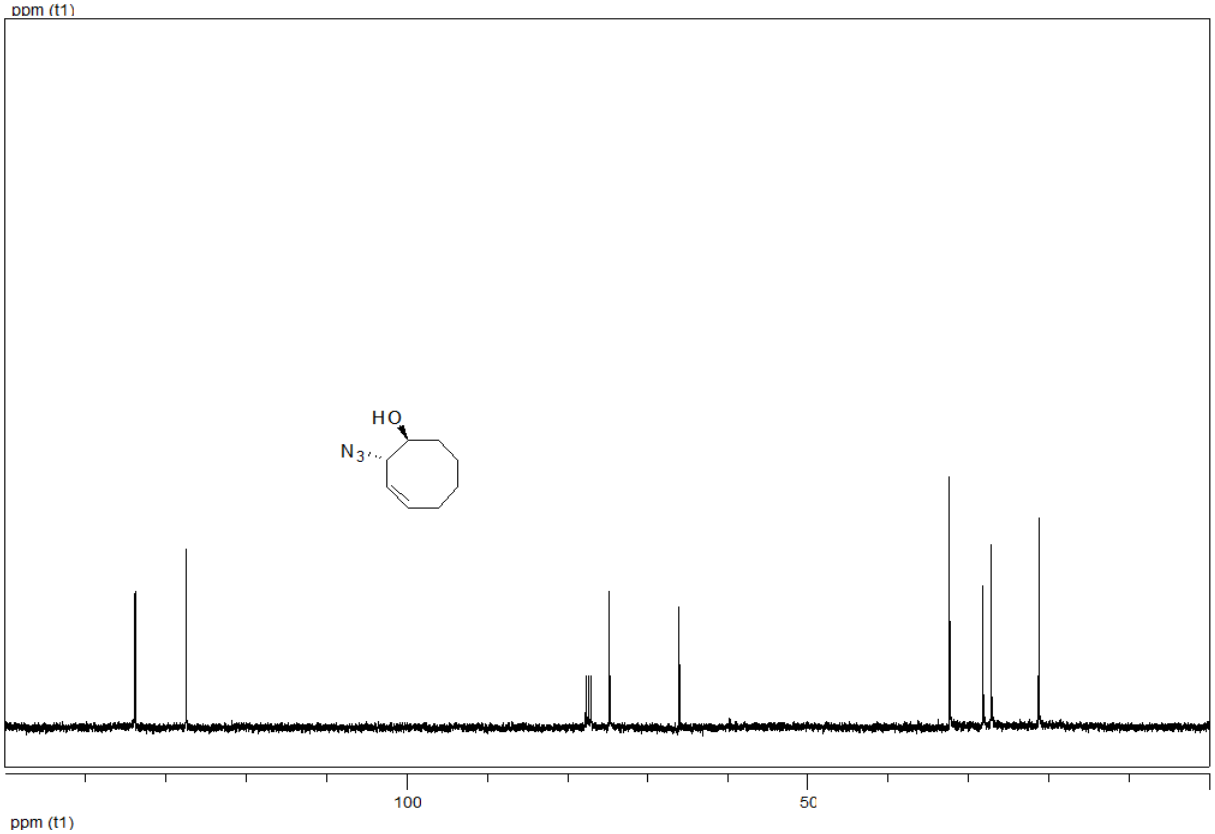


(1R(S),6S(R),7R(S),8R(S))-9-oxabicyclo[4.2.1]nonane-7,8-diol (**17**): $CDCl_3$

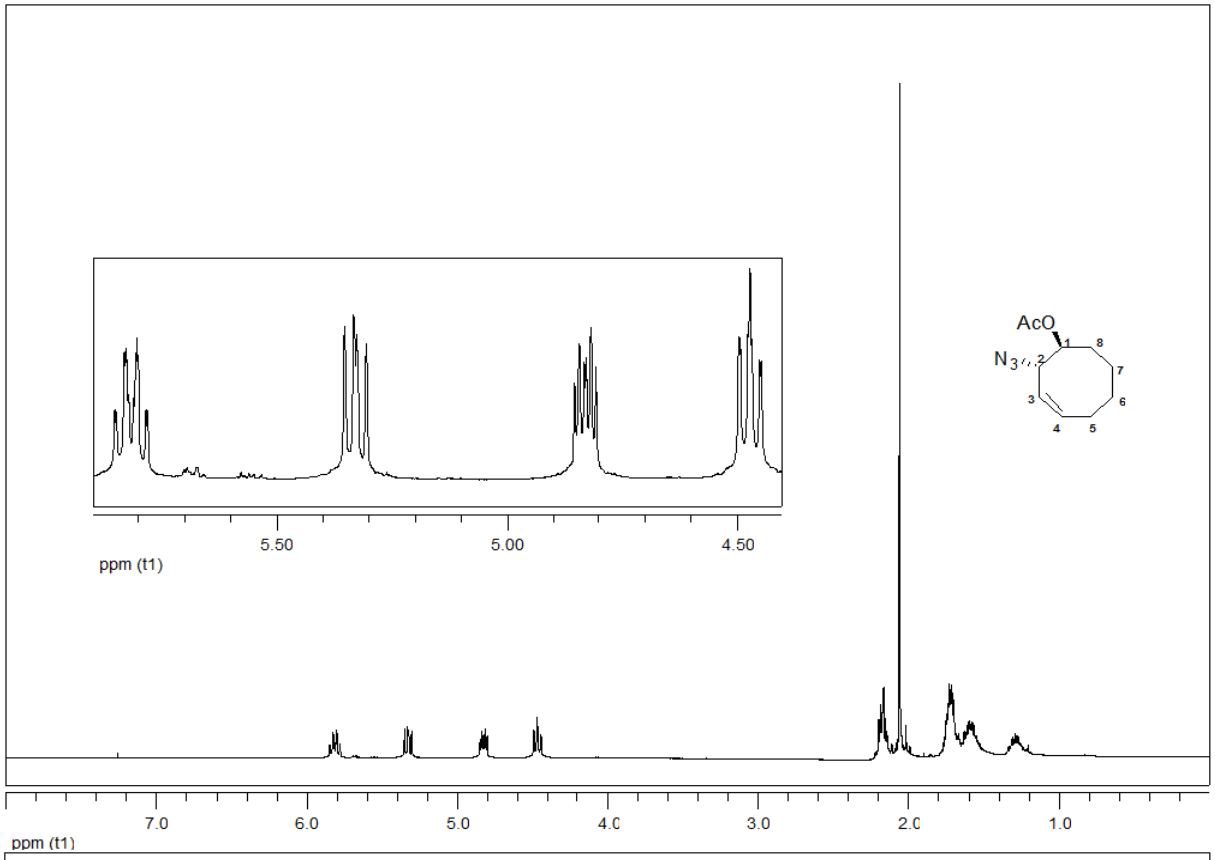


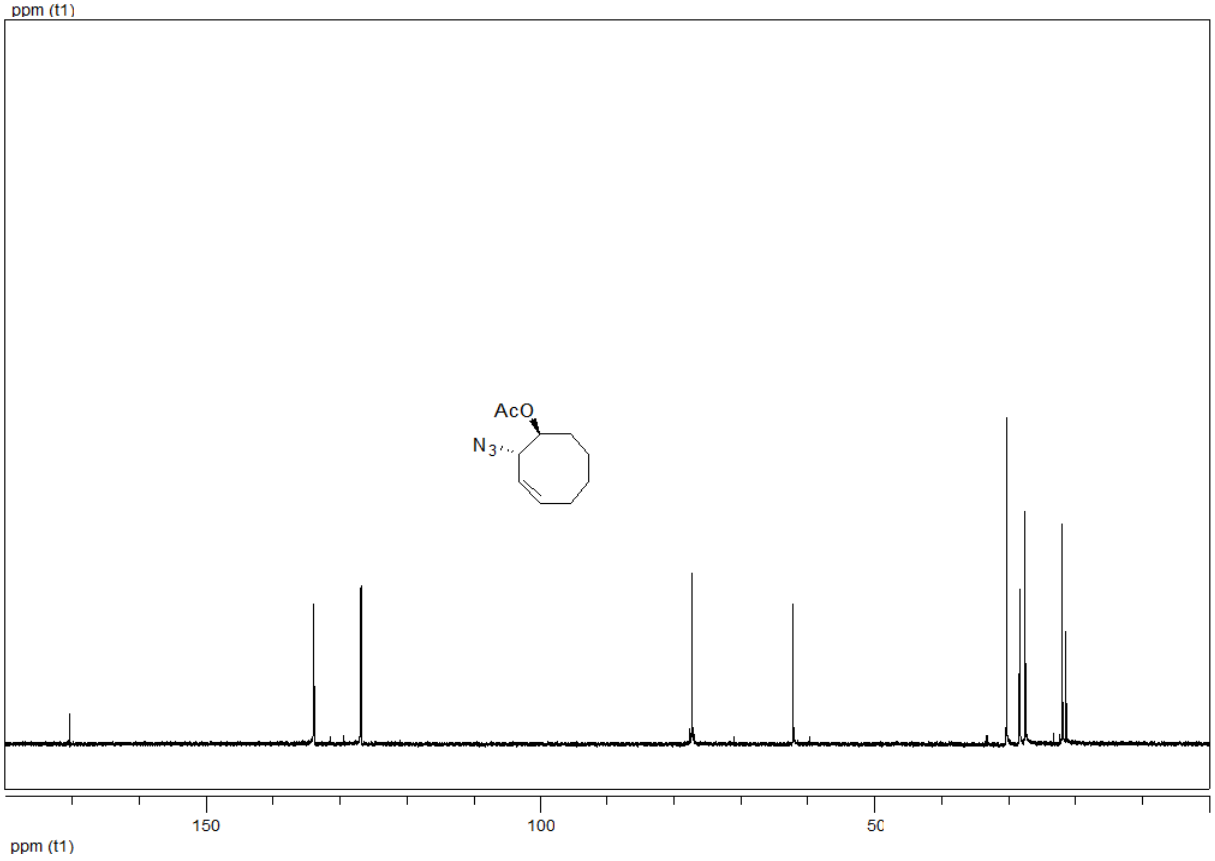
(1S(R),2S(R),Z)-2-azidocyclooct-3-enol (**9a**): $CDCl_3$



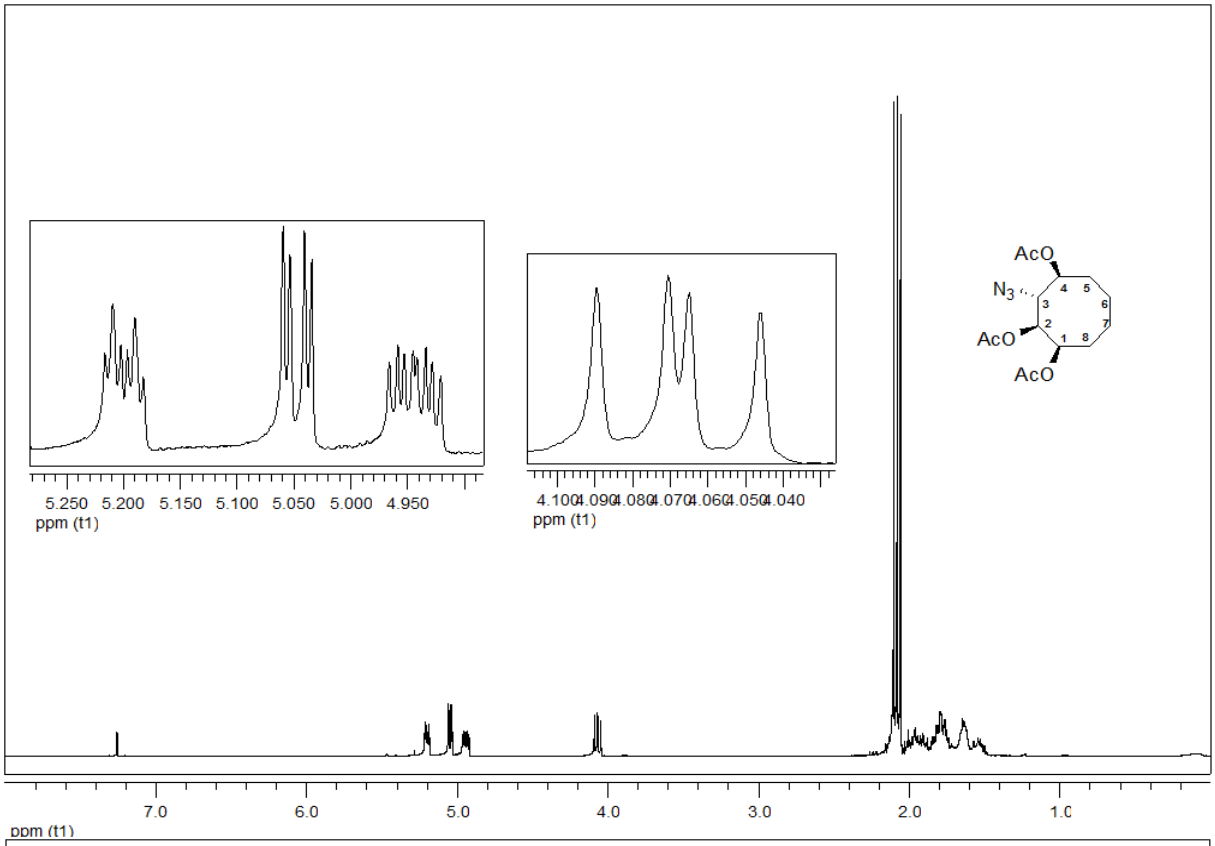


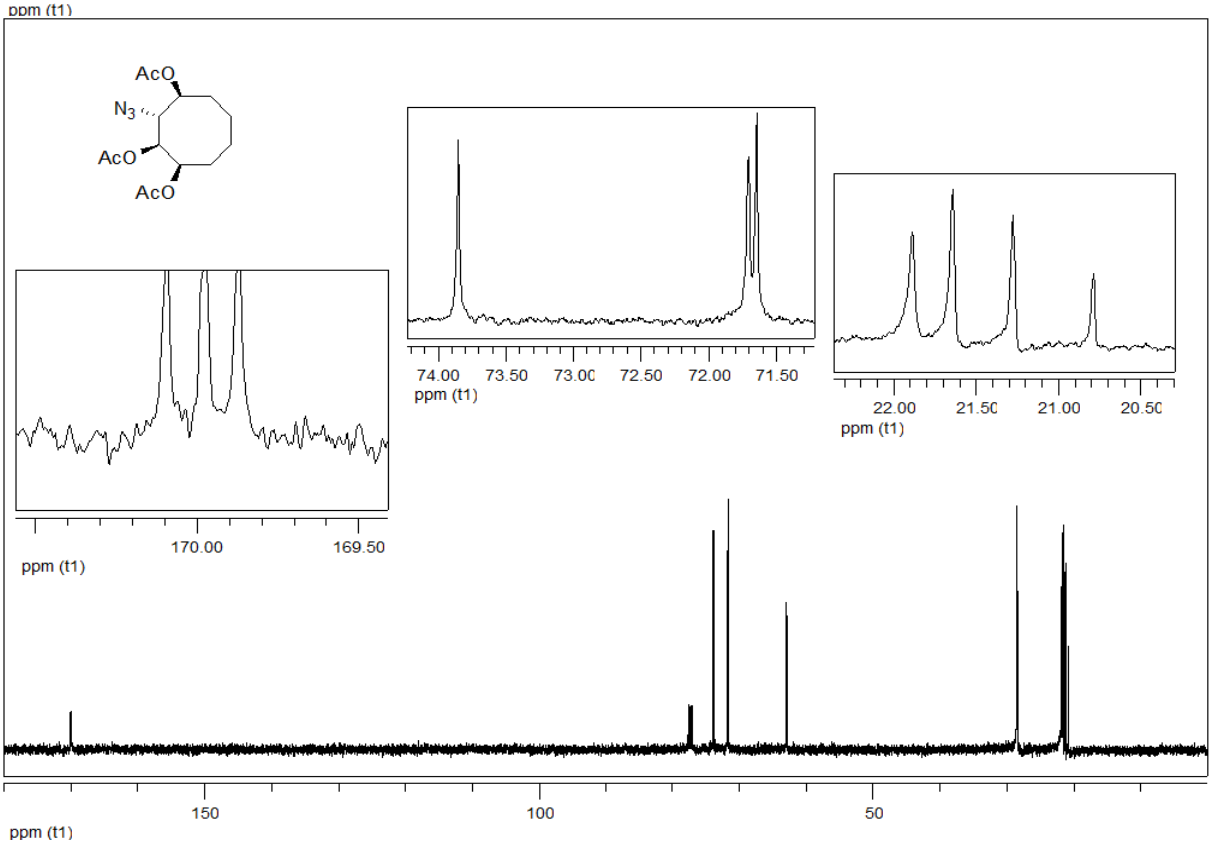
(1S(R),2S(R),Z)-2-azidocyclooct-3-enyl acetate (**9b**): $CDCl_3$



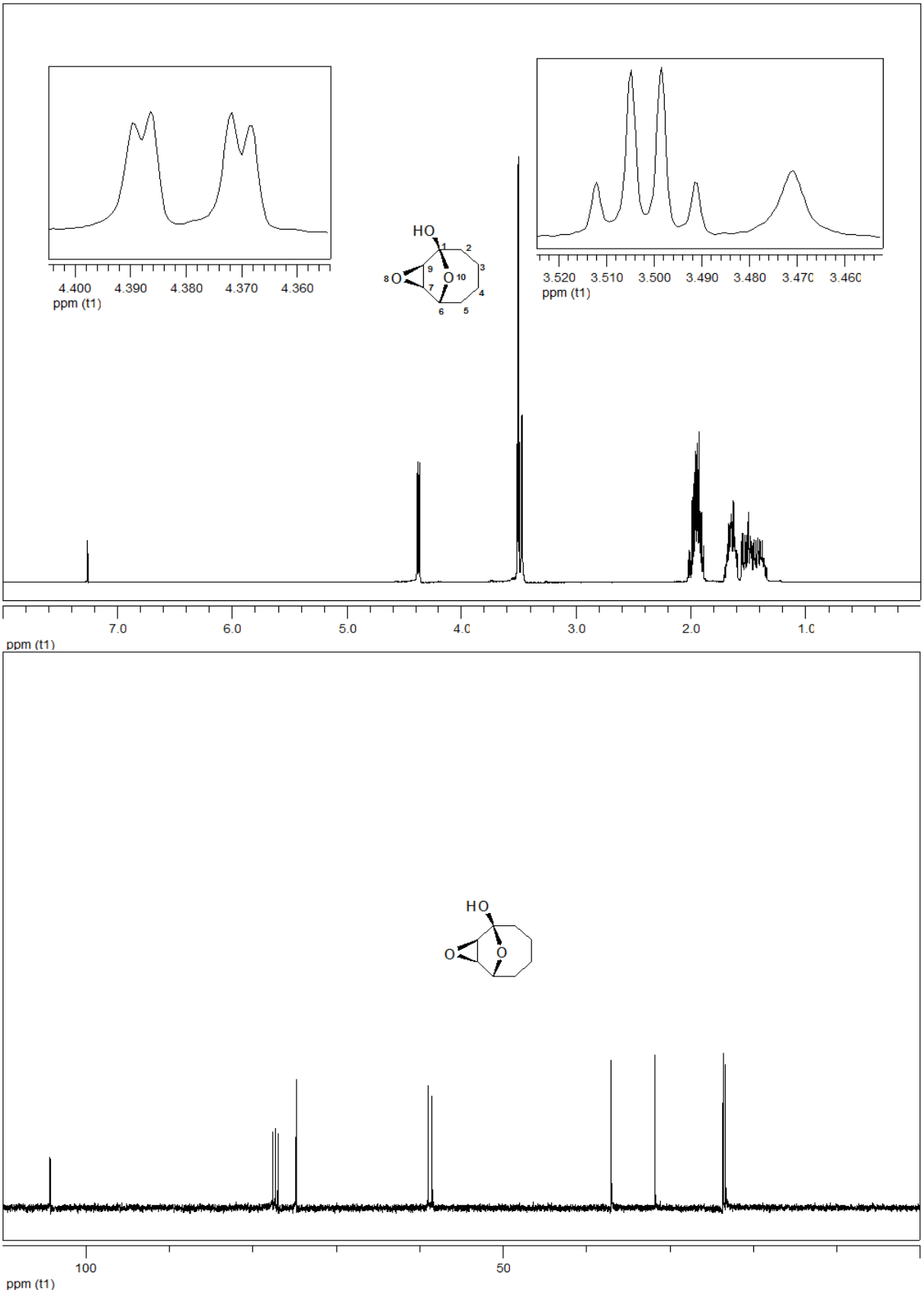


(1R(S),2(S)R,3R(S),4S(R))-3-azidocyclooctane-1,2,4-triyl triacetate (**10b**): $CDCl_3$

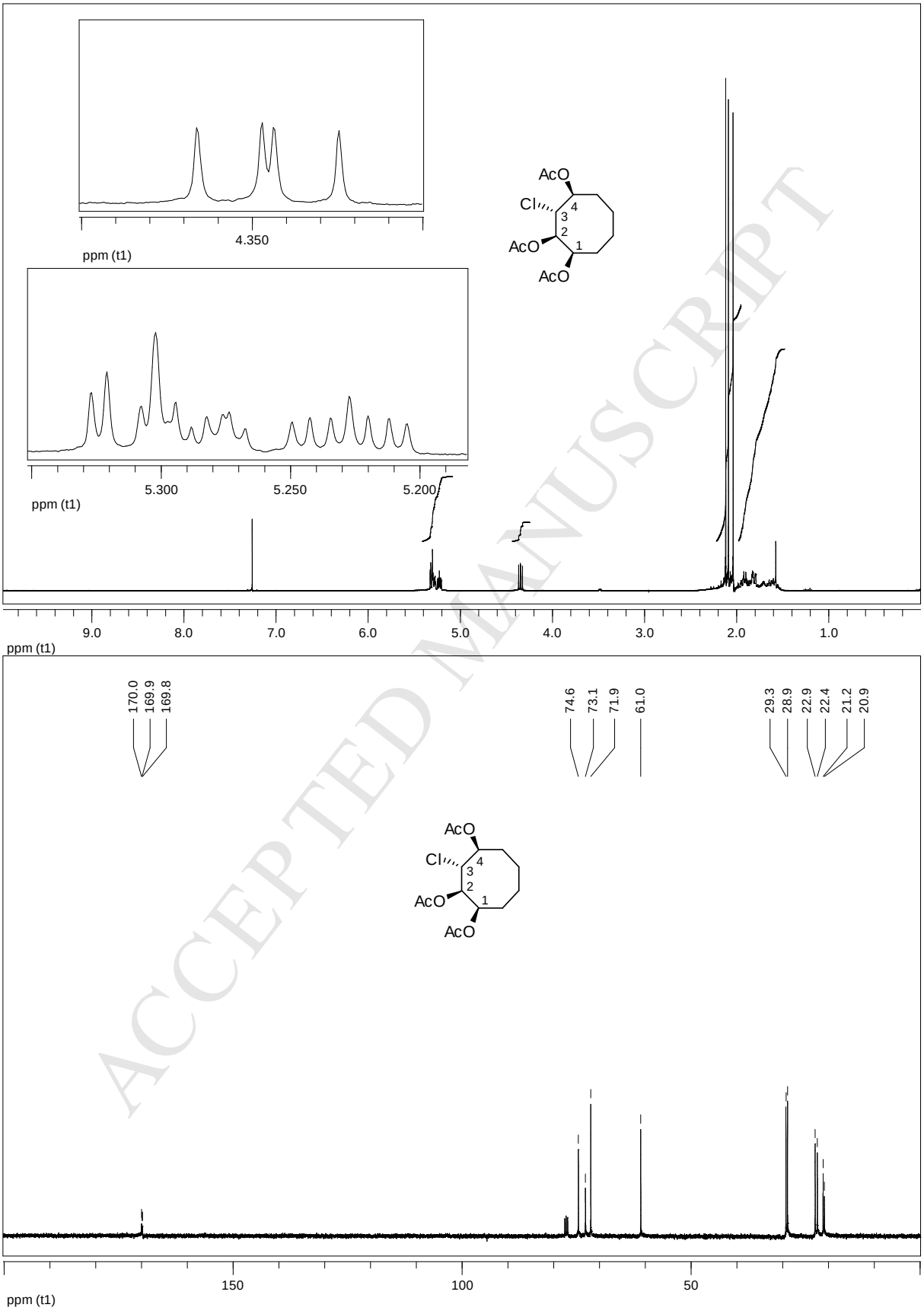




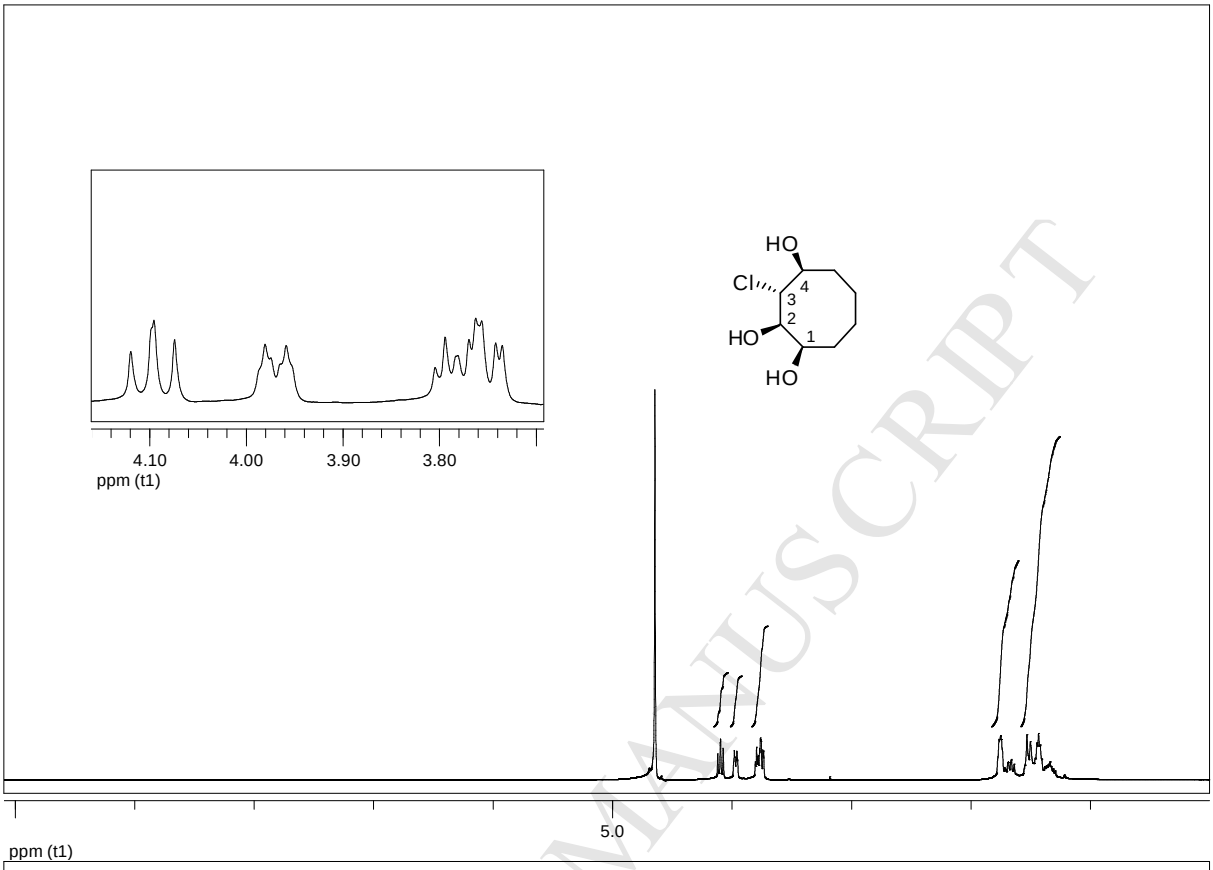
(1R(S),6S(R),7S(R),9S(R))-8,10-dioxatricyclo[4.3.1.$0^{7,9}$]decane-1-ol (**24**): $CDCl_3$

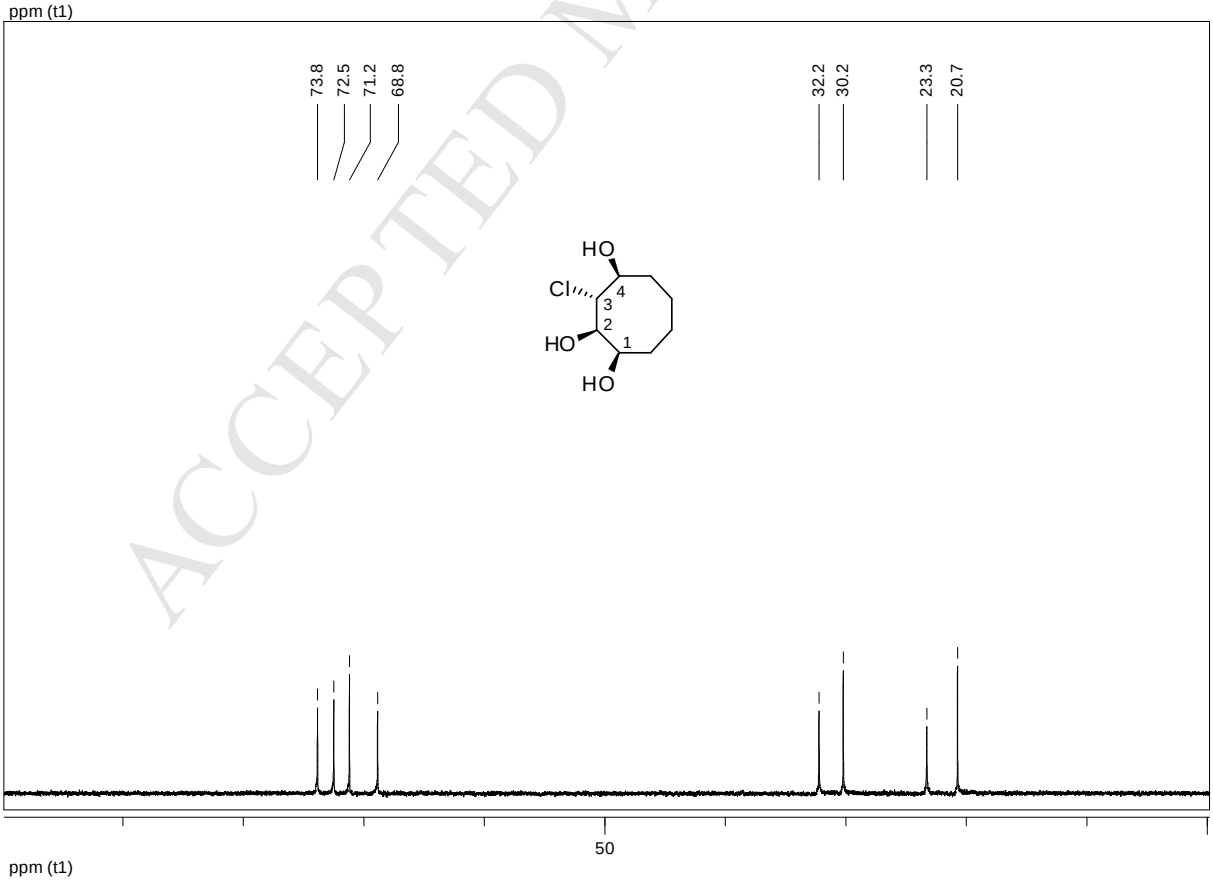


(1R(S),2R(S),3R(S),4S(R))-3-chlorocyclooctane-1,2,4-triyl triacetate (**29**): $CDCl_3$

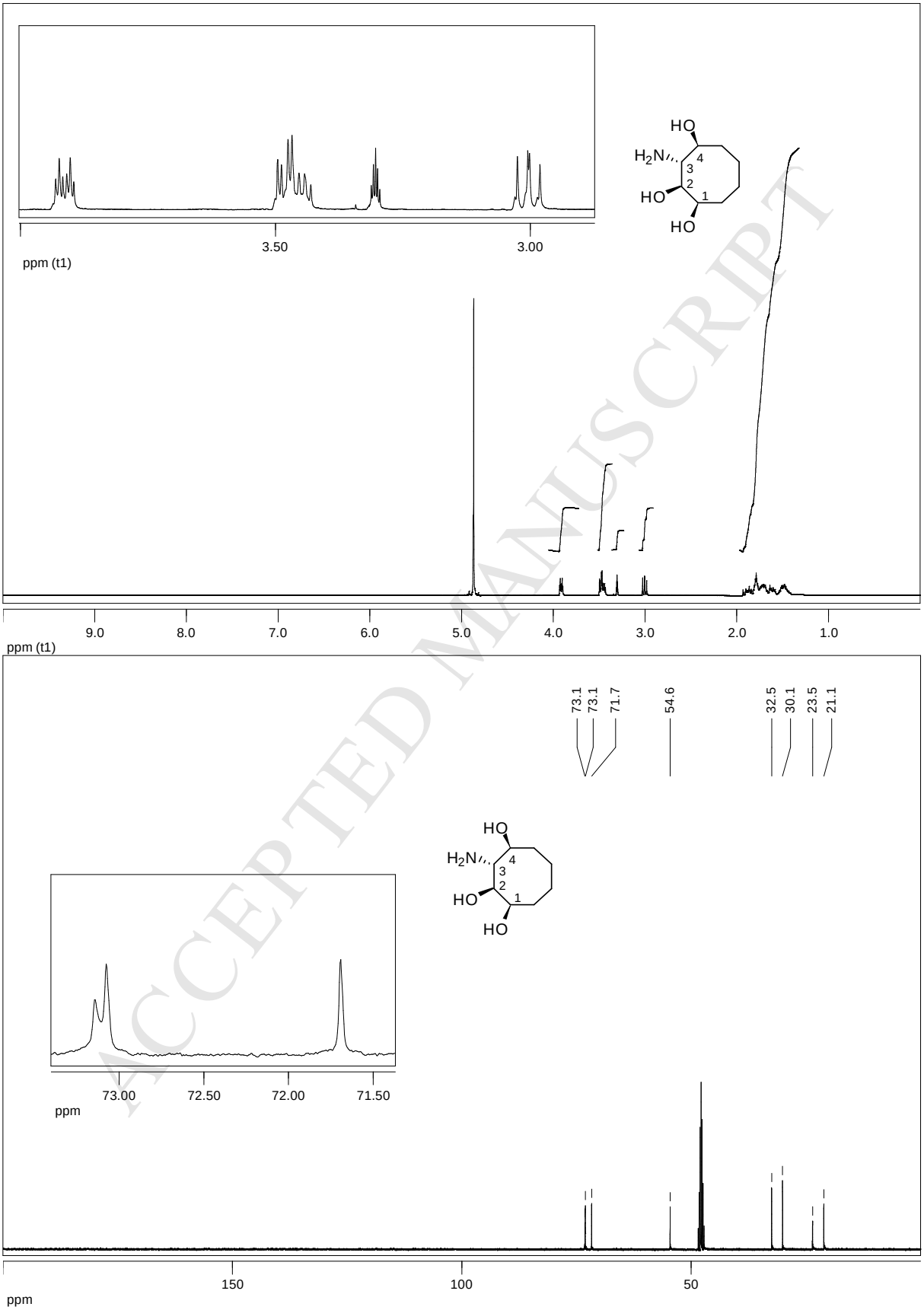


(1R(S),2R(S),3R(S),4S(R))-3-chlorocyclooctane-1,2,4-triol (**28**): D_2O





(1R(S),2S(R),3R(S),4S(R))-3-aminocyclooctane-1,2,4-triol (**12**): CD_3OD



X-Ray Crystal Structure Analysis of Chlorotriacetate 29

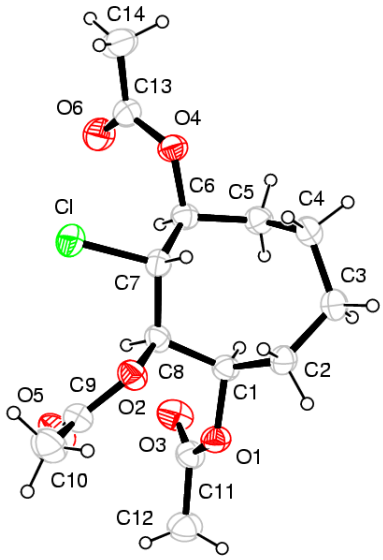


Figure 2. a) The molecular structure of compound chlorotriacetate **29** showing the atom numbering scheme. Thermal ellipsoids are drawn at the 40% probability level.

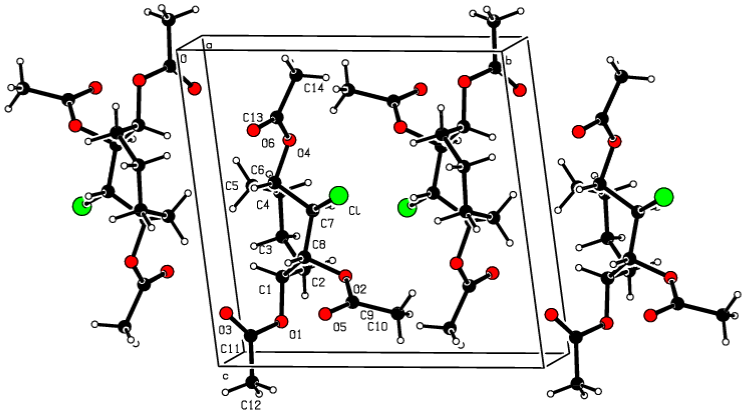


Figure 2. b) The molecular packing of **29**.

Table 1. Crystal data and structure refinement for **29**.

Identification code	esalamci-3oac (CCDC 787346)	
Empirical formula	$C_{14}H_{21}O_6Cl$	
Formula weight	320.76	
Temperature	293(2) K	
Wavelength	0.71073 Å	
Crystal system	triclinic	
Space group	*P-1*	
Unit cell dimensions	a = 7.5308(2) Å	α = 79.434(6)°
	b = 10.5140(3) Å	β = 70.502(4)°
	c = 11.0554(4) Å	γ = 74.870(5)°
Volume	792.08(5) Å^3	
Z	2	
Density (calculated)	1.345 Mg / m^3	
Absorption coefficient	0.264 mm^{-1}	
F(000)	340k	
Crystal	Block; opaque	
Crystal size	0.20 × 0.12 × 0.11 mm^3	
θ range for data collection	2.7 – 26.4°	
Index ranges	$-9 \le h \le 9$, $-13 \le k \le 13$, $-13 \le l \le 13$	
Reflections collected	17053	
Independent reflections	2165 [R_{int} = 0.071]	
Completeness to θ = 27.50°	99.8 %	
Max. and min. transmission	0.974 and 0.939	
Refinement method	Full-matrix least-squares on F^2	

Data / restraints / parameters	2165 / 0 / 193
Goodness-of-fit on F^2	1.028
Final *R* indices [$F^2 > 2\sigma(F^2)$]	*R1* = 0.055, *wR2* = 0.115
R indices (all data)	*R1* = 0.087, *wR2* = 0.131
Extinction coefficient	0.00
Largest diff. peak and hole	0.398 and –0.255 e $Å^{-3}$

Structure solution: *SHELXS97* (G. M. Sheldrick, Acta Cryst. (**1990**) A46 467–473). **Structure refinement**: *SHELXL97* (G. M. Sheldrick (**1997**), University of Göttingen, Germany). **Graphics:** *PLATON* (A.L. Spek, J. Appl. Crystallogr**. 2003**, 36, 7).

Table 2. Fractional atomic coordinates and isotropic temperature factors (Angstrom squared), with standard deviations in the least significant digits in parentheses. For anisotropic atoms, the equivalent isotropic temperature factors are shown.

	x/a	y/b	z/c	U_{eq}
CL	0.23179(10)	0.41977(7)	0.46892(7)	0.06787
O(1)	0.3776(3)	0.1796(2)	0.8749(2)	0.05537
O(2)	0.2655(2)	0.4046(2)	0.7253(2)	0.05638
O(4)	0.5735(3)	0.2620(2)	0.3097(2)	0.05663
O(3)	0.2471(3)	0.0242(2)	0.8432(2)	0.07587
O(6)	0.3597(3)	0.1736(2)	0.2693(2)	0.07732
O(5)	-0.0206(3)	0.3514(2)	0.8319(2)	0.09090
C(8)	0.3403(3)	0.2799(2)	0.6692(2)	0.04900
H(8)	0.23380	0.23659	0.68239	0.05879
C(7)	0.4276(3)	0.3173(2)	0.5252(2)	0.04921
H(7)	0.52173	0.37085	0.51430	0.05906
C(11)	0.2652(4)	0.0887(3)	0.9151(3)	0.05828
C(1)	0.4818(3)	0.1922(3)	0.7378(2)	0.04895
H(1)	0.52453	0.10436	0.70686	0.05874
C(6)	0.5258(4)	0.2028(2)	0.4423(2)	0.05006
H(6)	0.43501	0.14608	0.45541	0.06007
C(9)	0.0797(4)	0.4312(3)	0.7985(3)	0.06488
C(3)	0.8433(4)	0.1776(3)	0.6279(3)	0.06300
H(3A)	0.86816	0.08434	0.65939	0.07559
H(3B)	0.94854	0.21293	0.63072	0.07559
C(2)	0.6582(4)	0.2464(3)	0.7221(3)	0.05517
H(2A)	0.67809	0.23740	0.80586	0.06620

H(2B)	0.63255	0.34017	0.69251	0.06620
C(5)	0.7146(4)	0.1175(3)	0.4611(3)	0.05725
H(5A)	0.78451	0.07203	0.38454	0.06871
H(5B)	0.68315	0.05031	0.53279	0.06871
C(13)	0.4776(4)	0.2403(3)	0.2338(3)	0.06107
C(4)	0.8508(4)	0.1881(3)	0.4865(3)	0.06051
H(4A)	0.98180	0.15175	0.43664	0.07261
H(4B)	0.82000	0.28114	0.45517	0.07261
C(12)	0.1713(5)	0.0823(3)	1.0574(3)	0.07950
H(17C)	0.05885	0.15285	1.07654	0.11924
H(17B)	0.26018	0.09135	1.09888	0.11924
H(17A)	0.13431	-0.00129	1.08837	0.11924
C(10)	0.0193(5)	0.5713(3)	0.8310(3)	0.08261
H(10A)	-0.02613	0.62816	0.76415	0.12391
H(10B)	0.12744	0.59807	0.83835	0.12391
H(10C)	-0.08225	0.57738	0.91154	0.12391
C(14)	0.5412(5)	0.3120(4)	0.1025(3)	0.09124
H(14A)	0.48159	0.28985	0.04713	0.13686
H(14C)	0.67892	0.28649	0.06777	0.13686
H(14B)	0.50408	0.40578	0.10829	0.13686

Table 3. Vibration parameters (Angstrom squared) in the expression: -2(pi squared)(U11((h.a*)squared) + U22((k.b*)squared) + U33((l.c*)squared) + 2.U12.h.k.a*.b* + 2.U13.h.l.a*.c* +2.U23.k.l.b*.c*)

	U11	U22	U33	U12	U13	U23
CL	0.0654(5)	0.0660(5)	0.0677(5)	0.0008(3)	-.0281(4)	-.0025(3)
O(1)	0.058(1)	0.065(1)	0.046(1)	-0.024(1)	-0.014(1)	-0.003(1)
O(2)	0.051(1)	0.056(1)	0.060(1)	-0.008(1)	-0.011(1)	-0.016(1)
O(4)	0.059(1)	0.068(1)	0.046(1)	-0.021(1)	-0.017(1)	-0.004(1)
O(3)	0.082(1)	0.076(1)	0.074(1)	-0.039(1)	-0.007(1)	-0.016(1)
O(6)	0.072(1)	0.099(2)	0.075(1)	-0.032(1)	-0.028(1)	-0.014(1)
O(5)	0.062(1)	0.105(2)	0.098(2)	-0.027(1)	0.005(1)	-0.032(1)
C(8)	0.044(1)	0.053(1)	0.052(1)	-0.012(1)	-0.012(1)	-0.011(1)
C(7)	0.046(1)	0.050(1)	0.053(2)	-0.011(1)	-0.018(1)	-0.002(1)
C(11)	0.055(2)	0.061(2)	0.057(2)	-0.020(1)	-0.011(1)	-0.002(1)
C(1)	0.048(1)	0.053(1)	0.046(1)	-0.015(1)	-0.011(1)	-0.005(1)
C(6)	0.051(1)	0.053(2)	0.047(1)	-0.017(1)	-0.012(1)	-0.005(1)
C(9)	0.056(2)	0.079(2)	0.055(2)	-0.003(2)	-0.015(1)	-0.015(2)
C(3)	0.048(2)	0.079(2)	0.065(2)	-0.019(1)	-0.019(1)	-0.007(1)
C(2)	0.052(2)	0.066(2)	0.054(2)	-0.020(1)	-0.019(1)	-0.006(1)
C(5)	0.061(2)	0.052(2)	0.055(2)	-0.004(1)	-0.016(1)	-0.011(1)
C(13)	0.059(2)	0.072(2)	0.054(2)	-0.008(1)	-0.021(1)	-0.012(1)
C(4)	0.045(1)	0.068(2)	0.061(2)	-0.009(1)	-0.010(1)	-0.007(1)
C(12)	0.081(2)	0.098(2)	0.059(2)	-0.038(2)	-0.013(2)	0.002(2)
C(10)	0.080(2)	0.076(2)	0.075(2)	0.006(2)	-0.012(2)	-0.022(2)
C(14)	0.099(3)	0.125(3)	0.056(2)	-0.035(2)	-0.030(2)	0.003(2)

Table 4. Complete listing of torsion angles

H(8) - C(8) - C(7) - H(7)	172.5
H(8) - C(8) - C(7) - C(6)	-65.1
H(8) - C(8) - C(1) - H(1)	55.6
H(8) - C(8) - C(1) - C(2)	178.5
C(1) - C(8) - C(7) - H(7)	-63.7
C(7) - C(8) - C(1) - H(1)	-68.2
C(1) - C(8) - C(7) - C(6)	58.7
C(7) - C(8) - C(1) - C(2)	54.7
C(8) - C(7) - C(6) - H(6)	55.0
C(8) - C(7) - C(6) - C(5)	-69.5
H(7) - C(7) - C(6) - H(6)	177.3
H(7) - C(7) - C(6) - C(5)	52.9
O(1) - C(11) - C(12) - H(17C)	81.6
O(1) - C(11) - C(12) - H(17B)	-38.4
O(1) - C(11) - C(12) - H(17A)	-158.4
O(3) - C(11) - C(12) - H(17C)	-98.3
O(3) - C(11) - C(12) - H(17B)	141.7
O(3) - C(11) - C(12) - H(17A)	21.7
C(8) - C(1) - C(2) - C(3)	-104.5
C(8) - C(1) - C(2) - H(2A)	134.0
C(8) - C(1) - C(2) - H(2B)	17.0
H(1) - C(1) - C(2) - C(3)	18.4
H(1) - C(1) - C(2) - H(2A)	-103.2
H(1) - C(1) - C(2) - H(2B)	139.9

C(7) - C(6) - C(5) - H(5A)	-159.2
C(7) - C(6) - C(5) - H(5B)	85.2
C(7) - C(6) - C(5) - C(4)	-37.0
H(6) - C(6) - C(5) - H(5A)	76.4
H(6) - C(6) - C(5) - H(5B)	-39.3
H(6) - C(6) - C(5) - C(4)	-161.5
O(2) - C(9) - C(10) - H(10A)	87.7
O(2) - C(9) - C(10) - H(10B)	-32.3
O(2) - C(9) - C(10) - H(10C)	-152.3
O(5) - C(9) - C(10) - H(10A)	-92.4
O(5) - C(9) - C(10) - H(10B)	147.6
O(5) - C(9) - C(10) - H(10C)	27.6
H(3A) - C(3) - C(2) - C(1)	-59.3
H(3A) - C(3) - C(2) - H(2A)	62.2
H(3A) - C(3) - C(2) - H(2B)	179.2
H(3A) - C(3) - C(4) - C(5)	55.6
H(3A) - C(3) - C(4) - H(4A)	-66.2
H(3A) - C(3) - C(4) - H(4B)	177.3
H(3B) - C(3) - C(2) - C(1)	-174.7
H(3B) - C(3) - C(2) - H(2A)	-53.2
H(3B) - C(3) - C(2) - H(2B)	63.8
H(3B) - C(3) - C(4) - C(5)	170.9
H(3B) - C(3) - C(4) - H(4A)	49.2
H(3B) - C(3) - C(4) - H(4B)	-67.3
C(4) - C(3) - C(2) - C(1)	63.0
C(4) - C(3) - C(2) - H(2A)	-175.5

C(4) - C(3) - C(2) - H(2B)	-58.5
C(2) - C(3) - C(4) - C(5)	-66.8
C(2) - C(3) - C(4) - H(4A)	171.5
C(2) - C(3) - C(4) - H(4B)	55.0
C(6) - C(5) - C(4) - C(3)	100.3
C(6) - C(5) - C(4) - H(4A)	-137.9
C(6) - C(5) - C(4) - H(4B)	-21.4
H(5A) - C(5) - C(4) - C(3)	-137.5
H(5A) - C(5) - C(4) - H(4A)	-15.7
H(5A) - C(5) - C(4) - H(4B)	100.8
H(5B) - C(5) - C(4) - C(3)	-21.8
H(5B) - C(5) - C(4) - H(4A)	99.9
H(5B) - C(5) - C(4) - H(4B)	-143.6
O(4) - C(13) - C(14) - H(14A)	174.8
O(4) - C(13) - C(14) - H(14C)	54.8
O(4) - C(13) - C(14) - H(14B)	-65.2
O(6) - C(13) - C(14) - H(14A)	-5.5
O(6) - C(13) - C(14) - H(14C)	-125.5
O(6) - C(13) - C(14) - H(14B)	114.5

Table 5. Complete listing of bond distances (Angstroms)

O(1) - C(11)	1.357(4)	O(2) - C(9)	1.347(4)
O(4) - C(13)	1.356(4)	O(3) - C(11)	1.196(4)
O(6) - C(13)	1.194(4)	O(5) - C(9)	1.201(4)
C(8) - H(8)	0.980(3)	C(8) - C(7)	1.526(4)
C(8) - C(1)	1.527(4)	C(7) - H(7)	0.980(3)
C(7) - C(6)	1.524(4)	C(11) - C(12)	1.491(5)
C(1) - H(1)	0.980(3)	C(1) - C(2)	1.525(4)
C(6) - H(6)	0.980(3)	C(6) - C(5)	1.527(4)
C(9) - C(10)	1.496(5)	C(3) - H(3A)	0.970(4)
C(3) - H(3B)	0.970(3)	C(3) - C(2)	1.527(4)
C(3) - C(4)	1.530(4)	C(2) - H(2A)	0.970(3)
C(2) - H(2B)	0.970(3)	C(5) - H(5A)	0.970(3)
C(5) - H(5B)	0.970(3)	C(5) - C(4)	1.532(4)
C(13) - C(14)	1.492(5)	C(4) - H(4A)	0.970(3)
C(4) - H(4B)	0.970(3)	C(12) - H(17C)	0.960(4)
C(12) - H(17B)	0.960(3)	C(12) - H(17A)	0.960(4)
C(10) - H(10A)	0.960(4)	C(10) - H(10B)	0.960(4)
C(10) - H(10C)	0.960(4)	C(14) - H(14A)	0.960(4)
C(14) - H(14C)	0.960(4)	C(14) - H(14B)	0.960(4)

Table 6. Complete listing of bond angles (degrees)

H(8)-C(8)-C(7)	109.4(3)	H(8)-C(8)-C(1)	109.4(3)
C(7)-C(8)-C(1)	115.3(2)	C(8)-C(7)-H(7)	108.4(3)
C(8)-C(7)-C(6)	116.3(2)	H(7)-C(7)-C(6)	108.4(3)
O(1)-C(11)-O(3)	123.0(3)	O(1)-C(11)-C(12)	110.9(3)
O(3)-C(11)-C(12)	126.1(3)	C(8)-C(1)-H(1)	109.1(3)
C(8)-C(1)-C(2)	114.9(3)	H(1)-C(1)-C(2)	109.1(3)
C(7)-C(6)-H(6)	109.2(3)	C(7)-C(6)-C(5)	116.6(3)
H(6)-C(6)-C(5)	109.2(3)	O(2)-C(9)-O(5)	123.4(3)
O(2)-C(9)-C(10)	110.8(3)	O(5)-C(9)-C(10)	125.8(3)
H(3A)-C(3)-H(3B)	107.2(3)	H(3A)-C(3)-C(2)	107.8(3)
H(3A)-C(3)-C(4)	107.8(3)	H(3B)-C(3)-C(2)	107.8(3)
H(3B)-C(3)-C(4)	107.8(3)	C(2)-C(3)-C(4)	118.0(3)
C(1)-C(2)-C(3)	114.0(3)	C(1)-C(2)-H(2A)	108.7(3)
C(1)-C(2)-H(2B)	108.7(3)	C(3)-C(2)-H(2A)	108.7(3)
C(3)-C(2)-H(2B)	108.7(3)	H(2A)-C(2)-H(2B)	107.6(3)
C(6)-C(5)-H(5A)	108.0(3)	C(6)-C(5)-H(5B)	108.0(3)
C(6)-C(5)-C(4)	117.3(3)	H(5A)-C(5)-H(5B)	107.2(3)
H(5A)-C(5)-C(4)	108.0(3)	H(5B)-C(5)-C(4)	108.0(3)
O(4)-C(13)-O(6)	123.9(3)	O(4)-C(13)-C(14)	109.9(3)
O(6)-C(13)-C(14)	126.2(3)	C(3)-C(4)-C(5)	115.2(3)
C(3)-C(4)-H(4A)	108.5(3)	C(3)-C(4)-H(4B)	108.5(3)
C(5)-C(4)-H(4A)	108.5(3)	C(5)-C(4)-H(4B)	108.5(3)
H(4A)-C(4)-H(4B)	107.5(3)	C(11)-C(12)-H(17C)	109.5(3)
C(11)-C(12)-H(17B)	109.5(3)	C(11)-C(12)-H(17A)	109.5(3)

H(17C)-C(12)-H(17B)	109.5(4)	H(17C)-C(12)-H(17A)	109.5(4)
H(17B)-C(12)-H(17A)	109.5(4)	C(9)-C(10)-H(10A)	109.5(3)
C(9)-C(10)-H(10B)	109.5(3)	C(9)-C(10)-H(10C)	109.5(3)
H(10A)-C(10)-H(10B)	109.5(4)	H(10A)-C(10)-H(10C)	109.5(4)
H(10B)-C(10)-H(10C)	109.5(4)	C(13)-C(14)-H(14A)	109.5(4)
C(13)-C(14)-H(14C)	109.5(4)	C(13)-C(14)-H(14B)	109.5(3)
H(14A)-C(14)-H(14C)	109.5(4)	H(14A)-C(14)-H(14B)	109.5(4)
H(14C)-C(14)-H(14B)	109.5(4)		