

Coordination Chemistry of the Benzaldehyde–(1R)–(-)–Fenchone Azine and Derivatives Fench=NN=C(H)–C₆H₄X (X = H, Cl, Br, OMe or NO₂ in the Meta or Para Positions) with Palladium

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Abstract

The benzaldehyde–(1R)–(-)–fenchone azine (**1**) and derivatives (**3**), (**4**), (**5**), (**6**) and (**7**) were prepared by heating the desired benzaldehyde derivatives and fenchone hydrazone in boiling ethanol solution in the presence of acetic acid as catalyst for 3 h. Treatment of the ligands (L) with Na₂PdCl₄H₂O or [PdCl₂(NCPh)₂] in the ratio of 1 : 1 or 2 : 1 gave the complexes of the type PdL₂Cl₂ (**2**), (**8**), (**9**), (**10**), (**11**) and (**12**) of which the palladium was bonded to the nitrogen near to fenchone residue.

Keywords: Fenchone azine, chiral terpene, palladium complexes

Abstrak

Benzaldehid –(1R)–(-)–fencon azin (**1**) dan terbitannya (**3**), (**4**), (**5**), (**6**) dan (**7**) telah disediakan dengan memanaskan terbitan benzaldehid dengan fencon hidrozina di dalam larutan etanol yang mendidih di dalam kehadiran asid asetik sebagai pemangkin selama 3 jam. Tindak balas ligand (L) bersama Na₂PdCl₄H₂O atau [PdCl₂(NCPh)₂] dengan nisbah 1 : 1 atau 2 : 1 menghasilkan kompleks-kompleks PdL₂Cl₂ (**2**), (**8**), (**9**), (**10**), (**11**) dan (**12**) dan paladium membentuk ikatan melalui atom nitrogen ligan yang hampir pada rangka fencon.

Kata kunci: Fencon azin, kiral terpena, kompleks-kompleks paladium

Introduction

There is increasing interest in the use of cyclometallation reaction to generate new coordination, organometallic or catalytic chemistry (Collman & Hegedus, 1980; Nomura & Richards, 2007; Yeamine & Richards, 2007; Fossey et al., 2007 and Smoliakova et al., 2008). The reaction involved C–H bond cleavage and the formation

of a carbon–metal σ bond. Some cyclometallated complexes have been used in organic syntheses, catalysis, asymmetric syntheses and photochemistry (González, 1994; Ding, Zou & Wu, 1998; Fossey et al., 2007; Yeamine et al., 2007). It was reported that the cyclopalladation reaction of acetophenone dimethylhydrazone gave only the exclusively in the *ortho* position of the aromatic ring and no cyclometallation was observed at the methyl (=CMe) group (Shaw et al., 1980, 1985).

In view of the interest in this cyclometallation reaction various substituents such as OMe or NO₂ to activate the reaction were prepared as reported (Bruce & Stone, 1978). In the approach to produce enantiomeric ligands we considered to incorporate the (+)-fenchone framework of the prepared ligand as this chiral terpene has rigid structure and optically active make it an important as chiral auxiliary in many enantioselective reactions (Schore, 1988).

Experimental

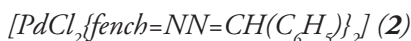
NMR spectra were recorded by using a JEOL FX-90Q spectrometer (operating frequency for ¹H was 89.5 MHz), a JEOL FX-100 spectrometer (operating frequency for ¹H was 99.5 MHz), a Bruker ARX-250 (operating frequencies for ¹H and ¹³C were 250.13 and 62.9 MHz, respectively) or a Bruker AM-400 spectrometer (operating frequencies for ¹H and ¹³C were 400.13 and 100.6 MHz respectively). ¹H and ¹³C chemical shifts are relative to tetramethylsilane and coupling constants are in Hz.

Infrared spectra were recorded by using a Perkin-Elmer model 257 grating spectrometer (4000–600 cm⁻¹) or a Pye Unicam SP2000 (4000–200 cm⁻¹), as Nujol mulls on polyethylene plates, or potassium bromide discs, or as dichloromethane solutions in calcium fluoride cells, with dichloromethane as reference.

Elemental analyses were recorded at the Chemistry Department, University of Leeds UK. Electrical conductivities were measured by using a Phillips PR 9500/01 Conductance and a Standard Conductance cell at 20°C. Mass spectra were recorded by Mass Spectroscopy Services at University of Leeds, UK.

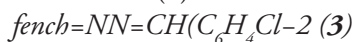
fench=NN=CH(C₆H₅) (**1**).

A solution containing (1R)-(-)-fenchone hydrazone (4.97 g, 29.8 mmol), benzaldehyde (2.92 g, 27.6 mmol) and acetic acid (0.1 cm³) in ethanol (30 cm³) was heated at 80°C for 3h. The reaction mixture was left to stand at ca. 20°C for 1h, after which it was concentrated and cooled at -30°C when the required product (**1**) precipitated as a yellow solid. This was filtered off, washed with cold ethanol and dried. Yield 3.13 g, 41%. (Found: C, 80.45; H, 8.8; N, 11.1. Calc. for C₁₇H₂₂N₂ C, 80.3; H, 8.7; N, 11.0%). *m/z* (EI): 254 (M⁺). ¹³C–{¹H}NMR (62.9 MHz CDCl₃) δ_c : 17.3 (1C, s, methyl carbon from fench residue), 24.5 (1C, s, methyl carbon from fench residue), 25.3 (1C, s, methyl carbon from fench residue), 128.9 (2C, s, phenyl carbon with H), 128.6 (2C, s, phenyl carbon with H), 130.3 (1C, s, phenyl carbon with H) and 156.9 (1C, s, NCH).



A solution containing (1) (931 mg, 3.66 mmol), benzaldehyde (2.92 g, 27.6 mmol) and $[Na_2PdCl_4H_2O]$ (673 mg, 1.83 mmol), acetic acid (0.1 cm³) in methanol (215 cm³) was heated to boiling 80°C for 5 min and left to stand at ca. 20°C for 24 hours. The mother liquor was decanted and the solid obtained, washed with water and cold methanol to give (2) as an orange solid. Yield 930 mg, 74%. (Found: C, 59.5; H, 6.6; Cl, 10.7; N, 8.15. Calc. for C₃₄H₄₄Cl₂N₄Pd C, 59.5; H, 6.4; Cl, 10.3; N, 8.1%). m/z (FAB, for ¹⁰⁶Pd and ³⁵Cl): 651 (M–2–Cl) and 613 (M–1–2Cl). ¹³C–{¹H}NMR (62.9 MHz, CDCl₃) δ_C: 21.4 (1C, s, methyl carbon from fench residue), 23.6 (1C, s, methyl carbon from fench residue), 24.6 (1C, s, methyl carbon from fench residue), 128.9 (2C, s, phenyl carbon with H), 130.0 (2C, s, phenyl carbon with H), 131.7 (1C, s, phenyl carbon with H) and 160.4 (1C, s, NCH).

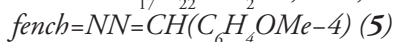
The following five compounds were prepared in a similar manner to the method described in (1).



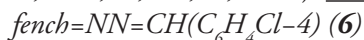
The azine (3) was prepared in 65% yield by addition of solution (1R)–(–)–fenchone hydrazone to 2-chlorobenzaldehyde. (Found: C, 70.75; H, 7.4; N, 9.6. Calc. for C₁₇H₂₁ClN₂ C, 70.6; H, 7.2; N, 9.7%). m/z (EI): 288 (M⁺). ¹³C–{¹H}NMR (62.9 MHz, CDCl₃) δ_C: 17.3 (1C, s, methyl carbon from fench residue), 24.0 (1C, s, methyl carbon from fench residue), 24.6 (1C, s, methyl carbon from fench residue), 126.8 (1C, s, phenyl carbon with H), 127.8 (1C, s, phenyl carbon with H), 129.93 (1C, s, phenyl carbon with H) and 153.4 (1C, s, NCH).



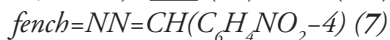
The azine (3) was prepared in 67% yield by addition of solution (1R)–(–)–fenchone hydrazone to 2-bromobenzaldehyde. (Found: C, 61.1; H, 6.25; Br, 23.9; N, 8.25. Calc. for C₁₇H₂₂BrN₂ C, 61.2; H, 6.35; Br, 23.9; N, 8.4%). m/z (EI): 322 (M⁺).



The azine (5) was prepared in 35% yield by addition of solution (1R)–(–)–fenchone hydrazone to anisaldehyde. (Found: C, 76.2; H, 8.6; Br, N, 9.8. Calc. for C₁₈H₂₄N₂O C, 76.0; H, 8.4; N, 9.8%). m/z (EI): 264 (M⁺).



The azine (5) was prepared in 61.5% yield by addition of solution (1R)–(–)–fenchone hydrazone to 4-chlorobenzaldehyde. (Found: C, 71.15; H, 7.95; Cl, 12.3; N, 9.7. Calc. for C₁₇H₂₁ClN₂ C, 70.7; H, 7.35; Cl, 12.3; N, 9.7%). m/z (EI): 288 (M⁺).



The azine (5) was prepared in 54% yield by addition of solution (1R)–(–)–fenchone hydrazone to 4-nitrobenzaldehyde. (Found: C, 68.05; H, 7.05; N, 13.5. Calc. for C₁₇H₂₁N₃O₂ C, 68.2; H, 7.1; Cl, N, 14.0%). m/z (EI): 299 (M⁺).

The following five compounds were prepared in a similar manner to the method described in (2).

$[PdCl_2\{fench=NN=CH(C_6H_4Cl-2)\}_2]$ (**8**)

The palladium complex (**8**) was prepared in 41% yield by addition of $[Na_2PdCl_4H_2O]$ to (**3**). (Found: C, 54.15; H, 5.7; Cl, 18.7; N, 7.14. Calc. for $C_{34}H_{42}Cl_4N_4Pd$ C, 54.1; H, 5.6; Cl, 18.8; N, 7.4%). m/z (FAB, for ^{106}Pd and ^{35}Cl): 755 (M+3), 719 (M+2-Cl) and 683 (M+1-2Cl). $^{13}C-\{^1H\}NMR$ (62.9 MHz, $CDCl_3$) δ_c : 21.3 (1C, s, methyl carbon from fench residue), 23.5 (1C, s, methyl carbon from fench residue), 24.4 (1C, s, methyl carbon from fench residue), 127.1 (1C, s, phenyl carbon with H), 128.4 (1C, s, phenyl carbon with H), 130.2 (1C, s, phenyl carbon with H), 132.7 (1C, s, phenyl carbon with H) and 160.5 (1C, s, NCH).

$[PdCl_2\{fench=NN=CH(C_6H_4Br-2)\}_2]$ (**9**)

The palladium complex (**9**) was prepared in 68% yield by addition of $[Na_2PdCl_4H_2O]$ to (**4**). (Found: C, 47.95; H, 5.05; N, 6.55. Calc. for $C_{34}H_{42}Br_2Cl_2N_4Pd$ C, 48.4; H, 5.0; N, 6.6%). m/z (FAB, for ^{106}Pd and ^{35}Cl): 809 (M+4-Cl) and 733 (M+3-2Cl).

$[PdCl_2\{fench=NN=CH(C_6H_4OMe-4)\}_2]$ (**10**)

The palladium complex (**9**) was prepared in 54% yield by addition of $[Na_2PdCl_4H_2O]$ to (**5**). (Found: C, 57.7; H, 6.45; Cl, 9.65; N, 7.5. Calc. for $C_{36}H_{48}Cl_2N_4O_2Pd$ C, 57.95; H, 6.5; Cl, 9.5; N, 7.56%). m/z (FAB, for ^{106}Pd and ^{35}Cl): 747 (M+3) and 709 (M-Cl) and 6783 (M-1-2Cl).

$[PdCl_2\{fench=NN=CH(C_6H_4Cl-4)\}_2]$ (**11**)

The palladium complex (**9**) was prepared in 42% yield by addition of $[Na_2PdCl_4H_2O]$ to (**6**). (Found: C, 53.8; H, 5.5; Cl, 18.85; N, 7.3. Calc. for $C_{36}H_{48}Cl_2N_4O_2Pd$ C, 54.1; H, 5.6; Cl, 18.8; N, 7.4%). m/z (FAB, for ^{106}Pd and ^{35}Cl): 755 (M+3), 719 (M-2-Cl) and 683 (M+1-2Cl).

$[PdCl_2\{fench=NN=CH(C_6H_4NO_2-4)\}_2]$ (**12**)

The palladium complex (**12**) was prepared in 40% yield by addition of $[Na_2PdCl_4H_2O]$ to (**7**). (Found: C, 50.3; H, 5.15; N, 10.35. Calc. for $C_{34}H_{42}Cl_2N_6O_4Pd$ C, 52.6; H, 5.4; N, 10.8%). m/z (FAB, for ^{106}Pd and ^{35}Cl): 739 (M-Cl) and 703 (M-1-2Cl).

Results and Discussion

The benzaldehyde-(1R)-(-)-fenchone azine (**1**) was prepared by heating benzaldehyde and fenchone hydrazone in boiling ethanol solution in the presence of acetic acid as catalyst for 3 h (Scheme 1). The product (**1**), a pale yellow solid was obtained in 41% yield. The infrared showed a band at 1648 cm^{-1} due to $\nu(C=N)$ (Table 1) and in the mass spectrum there was a parent molecular ion at $m/z = 254$.

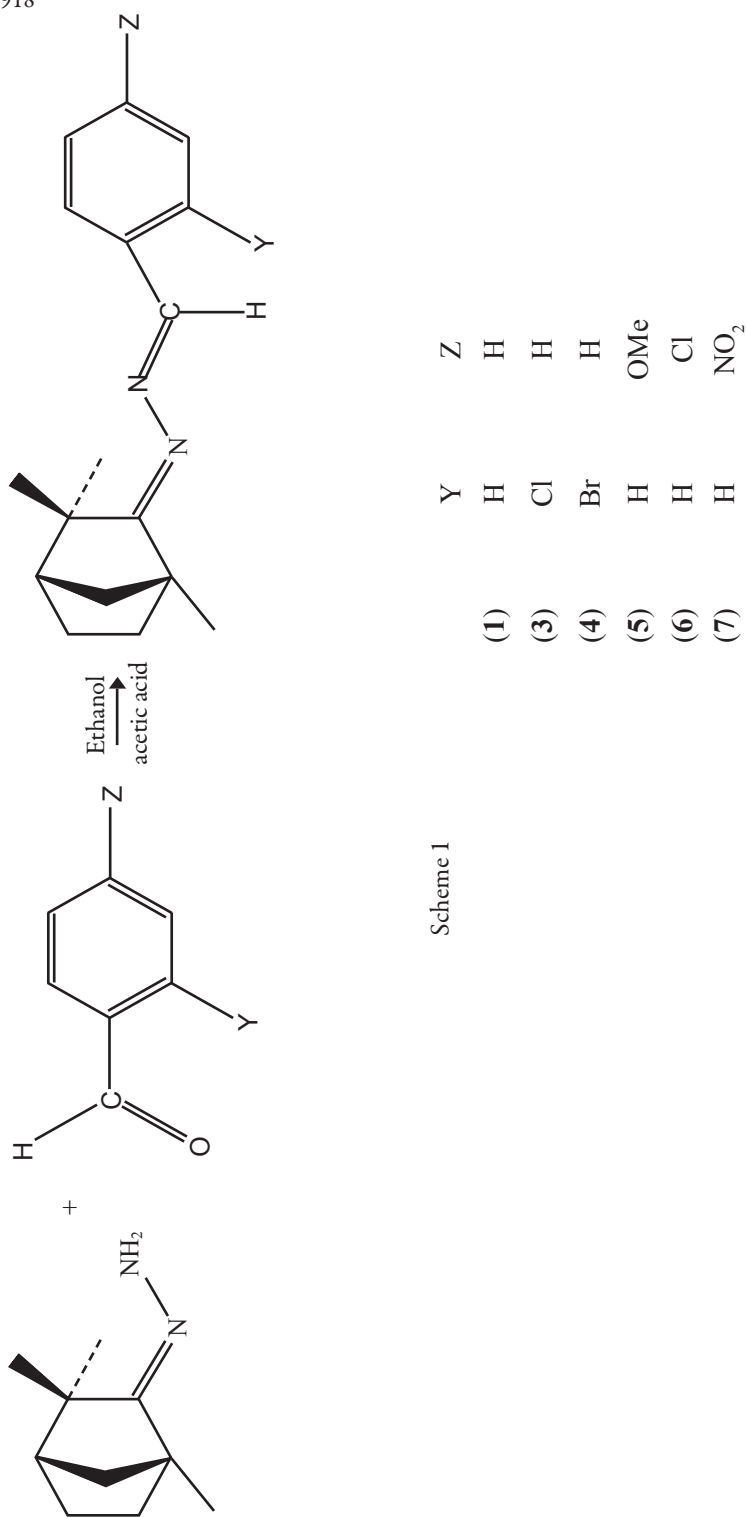
The 1H NMR spectrum of (**1**) showed the phenyl proton resonances as two sets of multiplets at 7.41 and 7.72 ppm and the $PhCH$ resonated as a singlet at 8.25 ppm. The resonances of the three methyl protons for fenchone residue were singlets at 1.31, 1.39 and 1.43 ppm. The $^{13}C-\{^1H\}NMR$ spectrum of (**1**) was also recorded with the aid of an Attached Proton Test (APT) and DEPT-135 experiment; the

assignment for the carbon from the fenchone residue were made based on comparison with the literature values (Money, 1985; Shaw & Vessey, 1994). The resonances of the three methyl carbons from the fenchone residue were singlets at 17.3, 24.5 and 24.5 ppm. The resonances of the phenyl carbons bonded to a hydrogen atom were singlets at 128.0, 128.6 and 130.3 ppm. The PhCH carbon resonated as a singlet at 156.9 ppm.

Treatment of $\text{Na}_2\text{PdCl}_4\text{H}_2\text{O}$ with 2 mole equivalents of (1) in boiling ethanol gave an orange solid (2). The elemental analytical data (C, H, N, Cl) suggested that the complex was of formula $[\text{PdCl}_2(\text{PhCH}=\text{N}-\text{N}=\text{C}_{10}\text{H}_{16})_2][\text{C}_{10}\text{H}_{16}]$ is a (1R)-(-)-fenchone residue]. The infrared spectrum of the product showed a strong band at 352 cm^{-1} indicating that the chlorides ligands were mutually trans. The mass spectrum of the product showed the molecular ion peaks which correspond to the losses of chloride atoms at $m/z = 651 (M-2-\text{Cl})$ and $613 (M-1-2\text{Cl})$.

The ^1H NMR and ^{13}C NMR spectra of (2) showed the presence of two closely related species in the ratio of minor : major of 1 : 4. Only the chemical shifts of the predominant species that is the one present with approximate relative intensity 4, are given in Table 2. In the ^1H NMR spectrum of (2) the resonance of the methyl protons for the C^{10} from the fenchone residue had shifted to high frequency, comparing to that of the ligand (1) that is from 1.31 ppm to 2.69 ppm (Table 2). This distinct shift to high frequency for the methyl protons attached to the C^{10} of the fenchone residue was similarly observed for the complexes of the α -diazine of fenchone derivatives for example $\text{C}_{10}\text{H}_{16}\text{N}=\text{N}=\text{CMe}_2$ with palladium (Shaw & Vessey, 1994). The resonance of $-\text{N}=\text{NCHPh}$ proton had shifted to high frequency, compared to that of the free ligand (Table 2). The resonances of the phenyl protons were multiplets at 7.49 and 7.88 ppm. The $^{13}\text{C}-\{^1\text{H}\}$ NMR spectrum of (2) was assigned with the aid of an Attached Proton Test (APT) and DEPT-135 experiments; the assignments for the carbon from the fenchone residue were made after comparison with the literature (Money, 1985; Shaw & Vessey, 1994). The resonance of the phenyl carbon bonded to a hydrogen atom were singlets at 128.9, 130.0 and 131.7 ppm. The $=\text{N}=\text{N}=\text{CHPh}$ carbon resonated at 160.4 ppm.

From the above observations we suggest that the product has the structure (2) in which the ligand (1) coordinate through the $\text{C}_{10}\text{H}_{16}\text{N}$ nitrogen acts as monodentate ligand (Figure 1). Several attempts have been made to promote palladium-carbon bond formation in the azine (1). Treatment of $[\text{PdCl}_2(\text{NCPh})_2]$ with two mole equivalent of (1) in dichloromethane or treatment of $[\text{Na}_2\text{PdCl}_4\text{H}_2\text{O}]$ in the presence of sodium acetate as a base did not promote cyclopalladation (Shaw et al., 1980, 1992). Treatment of $[\text{Pd}(\text{OAc})_2]$ with (1) caused some decomposition, that is metallic palladium formed.

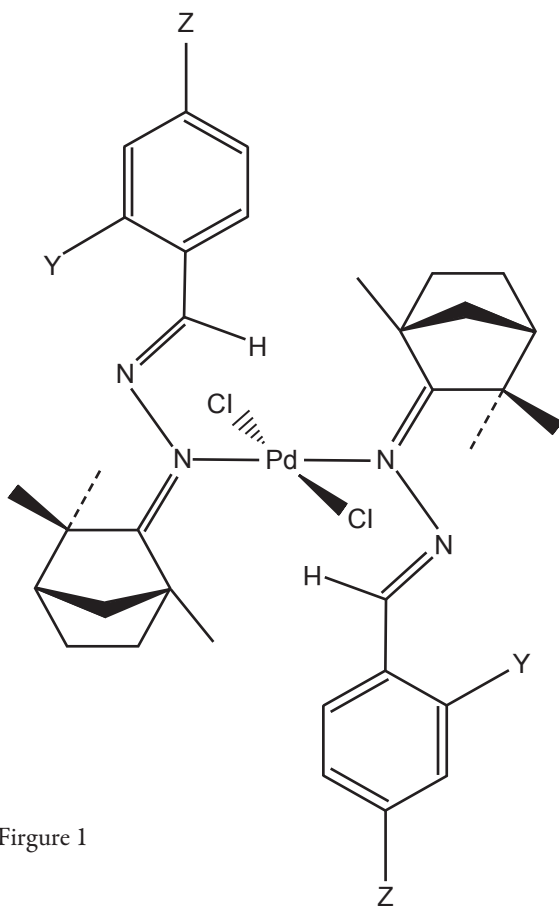


Scheme 1

Table 1 Infrared data

IR bands (cm ⁻¹)		
compound	$\nu(\text{C}=\text{N})^{\text{a}}$	$\nu(\text{M}-\text{Cl})^{\text{b}}$
(1)	1648 (s)	–
(2)	1634 (s)	352 (s)
(3)	1645 (s)	–
(4)	1650 (s)	–
(5)	1650 (s)	–
(6)	1657 (s)	–
(7)	1645 (s)	–
(8)	1642 (s)	350 (s)
(9)	1642 (s)	350 (s)
(10)	1638 (s)	355 (s)
(11)	1635 (s)	350 (s)
(12)	1635 (s)	350 (s)

^a As KBr disc. ^b In Nujol



	Y	Z
(2)	H	H
(8)	Cl	H
(9)	Br	H
(10)	H	OMe
(11)	H	Cl
(12)	H	NO ₂

Table 2 Proton NMR data

	$\delta(\text{phenyl})$	$\delta(\text{N=NCH})$	$\delta(\text{fenchone methyl})$	$\delta(\text{others})$
(1)	7.41 (3H, m) 7.72 (2H, m)	8.25 (1H, s) -	1.31 (3H, s) 1.39 (3H, s)	- -
(2)	- 7.49 (3H, m) 7.88 (2H, m)	- 9.68 (1H, s) -	1.43 (3H, s) 1.19 (3H, s) 1.26 (3H, s)	- - -
(3)	- 7.28 (3H, s) 7.36 (2H, s) 8.08 (1H, s)	- 8.66 (1H, s) -	2.69 (3H, s) 1.32 (9H, s) -	- - -
(4)	7.28 (2H, s) 7.36 (1H, s) 8.06 (1H, s)	8.61 (1H, s) - -	1.32 (3H, s) - -	- - -
(5)	7.64 (2H, d) 7.72 (2H, m)	8.21 (1H, s) -	1.18 (3H, s) 1.30 (3H, s)	3.82 (3H, s, OMe) -
(6)	- 7.41 (2H, m) 7.72 (2H, m)	- 8.25 (1H, s) -	1.33 (3H, s) 1.31 (3H, s) 1.39 (3H, s)	- - -
(7)	- 7.84 (2H, m) 7.15 (2H, m)	- 8.31 (1H, s) -	1.43 (3H, s) 1.32 (3H, s) -	- - -

Table 2 Cont'd

(8)	7.37 (2H, m)	9.99 (1H, s)	1.17 (3H, s)	-
	8.14 (1H, m)	-	1.22 (3H, s)	-
(9)	-	-	2.70 (3H, s)	-
	7.34 (2H, m)	9.89 (1H, s)	1.16 (3H, s)	-
	7.61 (1H, m)	-	1.261(3H, s)	-
	8.10 (1H, m)	-	2.69 (3H, s)	-
(10)	7.79 (2H, s)	9.53 (1H, s)	0.86 (3H, s)	3.85 (3H, s, OMe)
	7.88 (2H, s)	-	0.95 (3H, s)	-
	-	-	2.46 (3H, s)	-
(11)	7.52 (2H, s)	9.65 (1H, s)	1.18 (3H, s)	-
	7.86 (1H, s)	-	1.24 (3H, s)	-
(12)	-	-	2.67 (3H, s)	-
	7.88 (2H, d)	9.80 (1H, s)	1.32 (6H, s)	-
	8.08 (2H, m)	-	2.67 (3H, s)	-

s = singlet, d= doublet, m = multiplet and t = triplet,

Acknowledgements

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