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Efficient kinetic resolution of 2-benzenesulfonylcyclopentanone derivatives

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Abstract

Efficient kinetic resolution of 2-benzenesulfonylcyclopentanones **1**, bearing 3-alkyl, 3-aryl, or 3-benzyl substituents, has been achieved by bakers' yeast mediated reduction. With the unsubstituted 2-benzenesulfonylcyclopentanone **1a**, efficient asymmetric reduction to form (1*S*,2*R*)-*cis*-2-benzenesulfonylcyclopentanol **2a** is observed under the same conditions. Excellent enantioselectivities (up to > 95% ee) are obtained.

Keywords: Bakers' yeast; Reduction; β-Keto sulfones; Chiral derivatives; Cyclopentane derivatives; Kinetic resolution

1. Introduction

As the cyclopentane subunit forms an integral part of many significant, bioactive compounds e.g. the prostaglandins, development of new methodology for the asymmetric synthesis of cyclopentane derivatives is important, especially those which bear versatile functionality which can be subsequently modified or employed to introduce further substituents to the cyclopentane skeleton. As part of our research programme in this area we decided to explore stereoselective reduction of 2-sulfonyl cyclopentanone derivatives. This paper describes efficient kinetic resolution of 2-benzenesulfonyl-3-alkyl, phenyl, or benzyl substituted cyclopentanone derivatives employing bakers' yeast mediated reduction as shown in Scheme 1.

Asymmetric reduction of ketones with bakers' yeast (*Saccharomyces cerevisiae*) as reducing agent has attracted considerable attention in recent years, largely due to the ready availability and versatility of this microorganism, and the ease with which this microbial reduction can be undertaken [1]. Bakers' yeast mediated reduction of ketones bearing sulfur functional groups has been recently reviewed [1,2]. Notably simple acyclic β-keto sulfones have been enantioselectivity reduced using bakers' yeast [3]; however the efficiency and enantioselectivity observed decreased considerably as the alkyl chain was extended [4]. The enantioselectivity of this microbial reduction can be enhanced

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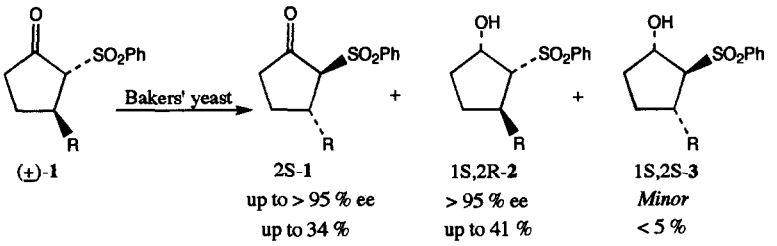


Scheme 1.

considerably by introduction of a hydroxyl group at the end of the alkyl chain [5]. Ketones bearing more remote sulfonyl substituents have also been reduced by bakers' yeast [6].

Cyclopentanone derivatives, especially those which are substituted at the 2-position with an ester substituent, have been successfully reduced using bakers' yeast [1,7]. 2-Phenylthiocyclopentanone and 2-phenylthiocyclohexanone have been reduced to the corresponding cycloalkanol derivatives with excellent stereocontrol [8]. However bakers' yeast reduction of cycloalkanone derivatives bearing a sulfonyl substituent at the 2-position has not been reported, to the best of our knowledge.

2. Results and discussion

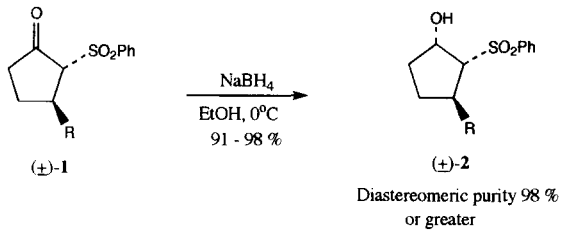
Exploration of the reduction of a series of *trans*-2-benzenesulfonyl cyclopentanones [9–11] **1** with bakers' yeast was undertaken the results of which are displayed in the Table 1. Racemic samples of the corresponding cyclopentanols **2** for comparison with the enantio-enriched samples were prepared in each case by reduction of the cyclopentanone derivative with sodium borohydride (Scheme 2). This reduction proceeds with excellent diastereoselectivity (typically > 98% de) to form the cyclopentanols in which the hydroxy and sulfonyl groups are on the same face of the cyclopentane system. Evidently the bulky benzenesulfonyl substituent directs approach of the borohydride to the opposite face of the ketone.

The X-ray analysis [1] of crystals of racemic **2e** (R = ^{n}Bu) established unequivocally the stereochemistry as shown in Scheme 2 and Fig. 1. The molecular dimensions are in accord with anticipated values. In the crystal lattice the side-chain at C8–C9 is disordered over two sites but this does not affect the determination of stereochemistry. The cyclopentane ring adopts a C1 envelope conformation. Molecules of **2e** link to form centrosymmetric hydrogen bonded dimers by O–H · · · O hydrogen bonds 2.884(11) Å (Fig. 1). The stereochemistry of each of the other cyclopentanol derivatives **2a–2d** and **2f–2h** was assigned by analogy [2].

In most cases the efficiency of the yeast reductions were satisfactory with total recovery typically 50–70%. Recovery of the methyl derivatives **1b** and **2b** were slightly lower, probably due to difficulty in extracting these com-

[1] Crystals of **2e** are monoclinic, space group $P2_1/c$ with four molecules of $C_{15}H_{22}O_3S$ in a unit cell of dimensions a = 13.148(5), b = 5.551(3), c = 21.501(8) Å, b = 94.09(4)°, V = 1565(1) Å^3, $F(000)$ 608, μ = 0.20 mm^{-1}. Some 2752 reflections in the θ range 2–25° were measured. Of these the 887 with $I > 2.5\sigma(I)$ were used in the structure solution and refinement. The structure was solved by direct methods and refined by full-matrix least-squares methods. Final R factors are R = 0.078, w_R = 0.094. Full details of molecular dimensions, fractional coordinates, thermal parameters and structure factor listing are available from the authors and have been deposited with the Cambridge Crystallographic Data Centre.

[2] Most importantly the signals in the ^{1}H NMR spectrum for the protons geminal to the hydroxy group are very distinctive; chemical shift and coupling constants depend strongly on the relative stereochemistry of the hydroxy and sulfonyl substituents. The two diastereomers **2** and **3** are easily distinguished in this manner.



Scheme 2.

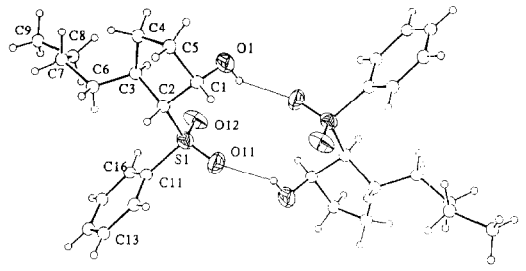


Fig. 1. A view of **2e** showing the stereochemistry and the hydrogen bonded dimer. Oxygen and sulfur atoms are shown as ellipsoids drawn at the 30% level; for clarity carbon and hydrogen atoms are shown as small spheres of an arbitrary size.

pounds from the aqueous layer. However the recovery of unreacted 3-benzyl substituted cyclopentanone **1g** was much lower than for **1a–1f**; it is possible that the benzyl derivative undergoes another yeast mediated biotransformation, possibly at the benzylic methylene group, even though no isolable products were detected. Significantly when the yeast reductions of **1c** and **1d** were conducted on slightly larger scales (500 mg for **1c** and 300 mg for **1d**) the enantioselectivity (only a single enantiomer of each of the compounds **1c**, **1d**, **2c** and **2d** could be detected) and diastereoselectivity (in the reduction of **1c** the cyclopentanol **2c** was isolated as a single diastereomer) observed is more satisfactory than for the 100 mg scale reactions. Therefore these kinetic resolutions are readily amenable to increase in scale.

In the case of 2-benzenesulfonyl cyclopentanone **1a** reduction with bakers' yeast proceeded very efficiently to form the corresponding *cis*-cyclopentanol **2a** in good yield (79%) with excellent enantioselectivity [only one enan-

Table 1
Efficient kinetic resolution of 2-benzenesulfonylcyclopentanone derivatives 1 via Bakers' yeast mediated reduction [a]

Cyclopentanone(R)	Recovered cyclopentanone			Cyclopentanones **2** and **3**			
	Yield [b] (%)	$[\alpha]_D^{20}$ [c]	% ee [d]	Yield [b] (%)	$[\alpha]_D^{20}$ [c]	Diastereomeric ratio [e] **2:3**	% ee [f]
1a(H)	≈ 4	–	–	79	+6.5° (7.9)	97:3	> 95
1b(Me)	10	+70° (1.0)	> 95	29	+22° (2.9)	82:18	> 95
1c(Et)	28	+78° (2.8)	> 95	40	+27° (4.0)	94:6	> 95
1d(^{n}Pr)	26	+48° (2.6)	95	36	+24° (3.6)	93:7	> 95
1e(^{n}Bu)	34	+21° (3.4)	60	32	+24° (3.2)	> 98:2	> 95
1f(Ph)	20	+44° (2.0)	86	31	+4° (3.1)	> 98:2	> 95
1g(CH_2Ph)	–	–	–	22	≈ 0° (2.2)	95:5	> 95

[a] The reactions were conducted on a 100 mg sample of cyclopentanone in each case. Each of the yeast reductions listed in the table have been conducted at least twice; efficiencies and enantioselectivity data are reproducible within limits of experimental error. However the diastereoselectivities obtained can vary by ±15% between different experiments.

[b] The yields reported are for compounds isolated by chromatography on silica gel. The diastereomers **2** and **3** were obtained as a mixture which could not be separated by this technique.

[c] Concentration in dichloromethane (g/100 ml).

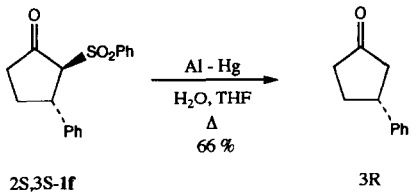
[d] Enantiomeric purity of the cyclopentanones **1** determined by ^{1}H NMR spectroscopy (270 MHz) in the presence of the chiral shift reagent Eu(hfc)$_3$. When only a single enantiomer could be detected the enantiomeric excess is quoted as > 95%. The enantiomeric purity was confirmed for some samples of **1b** and **1d** by chiral HPLC analysis on Chiralcel–ODH, and for some samples of **1c** by chiral GC analysis.

[e] Diastereomeric ratio **2:3** determined by ^{1}H NMR spectroscopy (270 MHz). When only a single diastereomer could be detected the ratio is quoted as > 98:2.

[f] Enantiomeric purity of the principal diastereomer **2** of the cyclopentanols determined by ^{1}H NMR spectroscopy in the presence of Eu(hfc)$_3$. When only a single enantiomer could be detected the enantiomeric excess is quoted as > 95%. The enantiomeric purity was confirmed for some samples of **2b** and **2d** by chiral HPLC analysis on Chiralcel–ODH.

tiomer was detected by ^{1}H NMR spectroscopy in the presence of the chiral shift reagent Eu(hcf)$_3$]; clearly epimeriszation of the labile stereogenic centre occurred in the reduction medium and the 2*R*-enantiomer was selectively reduced by yeast enzymes. 3% of the *trans*-cyclopentanol **3a** could be detected by ^{1}H NMR spectroscopy.

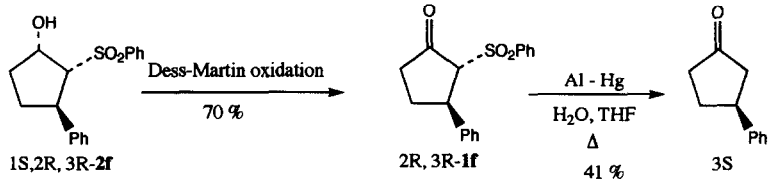
For the 2-benzenesulfonyl cyclopentanones substituted at the 3-position efficient kinetic resolution was obtained on reduction with bakers' yeast; the 2*R*,3*S*-enantiomers of the alkyl substituted derivatives **1b–1e** were selectively reduced leaving the 2*S*,3*R*-enantiomers of the cyclopentanones unchanged. Similarly for **1f** and **1g** the absolute stereochemistry of the reduction follows the same course: the 2*R*,3*R*-enantiomer is selectively reduced while the 2*S*,3*S*-enantiomer remains unchanged (priority of groups at C-3 altered). There was no evidence of epimerisation at the 2-position in the reductions of **1b–1h**; in all cases the 2-benzenesulfonyl and 3-alkyl/aryl/benzyl substituent remained *trans* in both the recovered cyclopentanones and the cyclopentanols. Furthermore the 2*R*-enantiomers of the cyclopentanones **1** were reduced with high diastereoselectivity to produce the 1*S*,2*R*-diastereomers of the cyclopentanols **2** as the principal diastereomer of the cyclopentanol formed in each case. The relative stereochemistry of the stereogenic centres in the cyclopentanol products was assigned by comparison with the racemic samples from the sodium borohydride reductions. The absolute stereochemistry of the recovered cyclopentanone (+)-**1f** was determined by desulfonylation with aluminium amalgam to form the (*R*)-3-phenylcyclopentanone (Scheme 3) and comparison of the specific rotation with literature values [12,13]. The cyclopentanol (+)-**2f** was oxidised (Dess–Martin [14]) to the corresponding cyclopentanone (−)-**1f** which furnished the opposite enantiomer of 3-phenylcyclopentanone on desulfonylation (Scheme 4) [12,13]. The absolute stereochemistry of **1b** was assigned by comparison of the specific rotation with the reported value [11].



Scheme 3.

The stereochemistry of the minor diastereomers of the cyclopentanols formed in some of the yeast mediated reductions has also been assigned as shown in Scheme 2. Hence the 2*S*-enantiomers of the cyclopentanones can undergo reduction less efficiently by bakers' yeast than the 2*R*-enantiomers. Notably the stereochemistry of the reduction is the same as that observed for the 2*R*-enantiomers leading to the 1*S*,2*S*-enantiomer as a minor diastereomer.

The most variable factor in these yeast reductions is the diastereoselectivity – while the cyclopentanols **2** are sometimes isolated as essentially a single stereoisomer, on some occasions there can be appreciable amounts of the minor diastereomer **3** present. This variability is presumably due to the presence of a number of different enzymes in the yeast cell, which display different selectivities for the two enan-



Scheme 4.

tiomers of the cyclopentanone derivatives **1a–1g** and whose activity is very sensitive to the precise reaction conditions. Under certain conditions only those enzymes which reduce specifically the 2*R*-enantiomers are active leading to isolation of the 1*S*,2*R*-cyclopentanols **2a–2g** as a single diastereomer; a slight change of conditions results in a small amount of reduction of the 2*S*-enantiomer as well leading to the presence of a minor amount of the 1*S*,2*S*-diastereomer **3a–3g** in the product. Research is underway to control the formation of this minor diastereomer.

In conclusion efficient kinetic resolution of the cyclopentane derivatives **1** and **2** has been achieved employing bakers' yeast reduction. This provides a very simple route to these chiral cyclopentane derivatives; the synthetic utility of these compounds as chiral synthons is currently being explored.

2.1. Experimental

All solvents were dried and distilled before use. Thin layer chromatography (TLC) was carried out on precoated silica gel plates (Merck 60 F_{254}); preparative thin layer chromatography was conducted using Merck silica gel 60 PF_{254}; column chromatography was conducted using Merck silica gel 60. *Saccharomyces cerevisiae* (Bakers' yeast) Sigma Type II was used for the reductions. Bulb to bulb distillation was achieved by use of a Kugelrohr apparatus.

Mass spectra were recorded on a Kratos Profile HV-4 double focusing high resolution mass spectrometer (E.I. unless otherwise specified). Elemental analyses were performed in the Microanalysis Laboratory at University College Cork on a Perkin Elmer 240 elemental analyser. Optical rotations were measured on a Perkin Elmer 141 Polarimeter at 589 nm in a 10 cm cell; concentrations are expressed in g/100 ml. Melting points were determined on a Uni-melt Thomas Hoover Capillary melting point apparatus and are uncorrected.

^{1}H (270 MHz) and ^{13}C (67.8 MHz) NMR spectra were recorded on a JEOL GSX 270 NMR spectrometer in $CDCl_3$, unless otherwise specified, using TMS as internal standard. Chemical shifts are expressed in parts per million (ppm) and coupling constants in Hertz (Hz). Infrared spectra were recorded as KBr discs (solids) or thin films on NaCl plates (oils) on a Perkin Elmer Paragon 1000 FT-IR spectrometer or a Mattson Polaris FT-IR spectrometer.

2.2. Spectral characteristics of the racemic cyclopentanones *1* and cyclopentanols *2*

2.2.1. 2-Benzenesulfonylcyclopentanone *1a* [3]

A white crystalline solid; m.p. 113–114°C [lit. 114–114.5°C]; ν_{max} (KBr) 1742, 1302, 1148 cm^{-1}; δ_H($CDCl_3$) 1.80–2.03 (1H, m, one of C(4)H_2), 2.11–2.55 (4H, m, one of C(4)H_2, one of C(5)H_2, C(3)H_2), 2.65–2.80 (1H, m, one of C(5)H_2), 3.73–3.82 (1H, dd, *J* 9, 7.5 Hz, C*H*SO_2Ph), 7.46–8.05 (5H, m, aromatic H); δ_C ($CDCl_3$) 20.01 (*C*H_2), 24.95 (*C*H_2), 38.66 (*C*H_2CO), 69.41 (*C*HSO$_2$Ph), 129.07 (*C*H), 134.06 (*C*H), 138.15 (*C*), 207.04 (*C*O).

2.2.2. *trans*-2-Benzenesulfonyl-3-methylcyclopentanone *1b* [4]

A white crystalline solid; m.p. 124–126°C [lit. [11] 124–125°C]; ν_{max} (KBr) 1744, 1304, 1143 cm^{-1}; δ_H ($CDCl_3$) 1.27–1.32 (3H, d, *J* 7 Hz, CH_3), 1.40–1.53 (1H, m, one of C(4) H_2, 2.26–2.39 (3H, m, one of C(4)H_2, C(5)H_2),

[3] 2-Benzenesulfonylcyclopentanone **1a** was prepared by oxidation of 2-phenylthiocyclopentanone with Oxone (99% yield) [9].

[4] The *trans*-2-benzenesulfonylcyclopentanones **1b–1g** were prepared by rhodium(II) acetate catalysed intramolecular C–H insertion of the corresponding 1-benzenesulfonyl-1-diazo-2-alkanones as described in refs. [10] and [11]. In some cases the products of the intramolecular C–H insertion were a mixture of *cis* and *trans* isomers of the cyclopentanone derivatives; epimerisation by base treatment furnished the cyclopentanones as exclusively *trans* isomers for use in the yeast reductions. Full experimental details for the preparation of **1a–1g** will be described elsewhere.

2.94–3.02 (1H, m, C *H*Me), 3.31–3.37 (1H, d, *J* 8 Hz, C*H*SO_2Ph), 7.55–7.95 (5H, m, aromatic H); δ_C ($CDCl_3$) 20.41 (*C*H_3), 28.37 (*C*H_2), 33.21 (*C*HMe), 38.89 (*C*H_2CO), 75.60 (*C*HSO_2Ph), 128.53 (*C*H), 134.09 (*C*H), 138.36 (*C*), 206.77 (*C*O).

2.2.3. *trans-2-Benzenesulfonyl-3-ethylcyclopentanone* **1c**

A white crystalline solid; m.p. 79–81°C; (Found: C, 62.12; H, 6.56; S. 12.74. $C_{13}H_{16}O_3S$ requires C, 61.88; H, 6.39; S, 12.71); ν_{max} (KBr) 1746, 1298, 1144 cm^{-1}; δ_H ($CDCl_3$) 0.85–0.91 (3H, t, *J* 7 Hz, C*H*$_3$), 1.43–1.57 (2H, m), 1.76–1.86 (1H, m) (C*H*$_2$CH$_3$, one of C(4)*H*$_2$), 2.33–2.43 (3H, m, one of C(4)*H*$_2$, C(5)*H*$_2$), 2.83–2.92 (1H, m, C*H*Et), 3.38–3.41 (1H, d, *J*7 Hz, C*H*SO_2Ph), 7.55–7.98 (5H, m, aromatic H); δ_c ($CDCl_3$) 11.14 (*C*H$_3$), 25.81 (*C*H$_2$), 28.12 (*C*H$_2$), 38.37 (*C*H$_2$CO), 39.39 (*C*HEt), 74.51 (*C*HSO_2Ph), 129.06 (*C*H), 134.02 (*C*H), 138.22 (*C*), 2 06.98 (*C*O).

2.2.4. *trans-2-Benzenesulfonyl-3-n-propylcyclopentanone* **1d**

A white crystalline solid; m.p. 64–66°C; (Found: C, 62.86; H, 6.72; S, 12.30. $C_{14}H_{18}O_3S$ requires C, 63.13; H, 6.81; S, 12.04); ν_{max} (KBr) 1746, 1306, 1142, cm^{-1}; δ_H ($CDCl_3$) 0.89–0.98 (3H, t, *J* 7 Hz, C*H*$_3$), 1.36–1.85 (5H, m, C*H*$_2$C*H*$_2$CH$_3$, one of C(4)*H*$_2$), 2.33–2.43 (3H, m, one of C(4)*H*$_2$, C(5)*H*$_2$), 2.81–2.93 (1H, m, C*H*^{n}Pr), 3.37–3.39 (1H, d, *J*7 Hz, C*H*SO_2Ph), 7.55–7.89 (5H, m, aromatic H); δ_C ($CDCl_3$) 13.84 (*C*H$_3$), 20.00 (*C*H$_2$), 26.33 (*C*H$_2$), 37.55 (*C*H$_2$), 37.72 (*C*H^{n}Pr), 38.43 (*C*H$_2$CO), 74.85 (*C*HSO_2Ph), 128.83 (*C*H), 134.09 (*C*H), 138.29 (*C*), 207.07 (*C*O).

2.2.5. *trans-2-Benzenesulfonyl-3-n-butylcyclopentanone* **1e**

A white crystalline solid; m.p. 38–40°C; (Found: C, 64.42; H, 7.26; S, 11.52. $C_{15}H_{20}O_3S$ requires C, 64.26; H, 7.19; S, 11.44); ν_{max} (KBr) 1748, 1307, 1150 cm^{-1}; δ_H ($CDCl_3$) 0.84–0.94 (3H, t, *J* 7 Hz, C*H*$_3$), 1.26–1.73 (7H, m, C*H*$_2$C*H*$_2$C*H*$_2$CH$_3$, one of C(4)*H*$_2$), 2.33–2.43 (3H, m, one of C(4)*H*$_2$, C(5)*H*$_2$), 2.86–2.97 (1H, m, C*H*^{n}Bu), 3.37–3.39 (1H, d, *J*7 Hz, C*H*SO_2Ph), 7.55–7.89 (5H, m, aromatic H); δ_C ($CDCl_3$) 13.94 (*C*H$_3$), 22.46 (*C*H$_2$), 26.35 (*C*H$_2$), 28.95 (*C*H$_2$), 35.10 (*C*H$_2$), 37.90 (*C*H^{n}Bu), 38.43 (*C*H$_2$CO), 78.85 (*C*HSO_2Ph), 129.10 (*C*H), 134.07 (*C*H), 138.27 (*C*), 207.09 (*C*O).

2.2.6. *trans-2-Benzenesulfonyl-3-phenylcyclopentanone* **1f**

A white crystalline solid; m.p. 96–98°C; (Found: C, 67.85; H, 5.50; S, 10.71. $C_{17}H_{16}O_3S$ requires C, 67.98; H, 5.37; S, 10.67); ν_{max} (KBr) 1749, 1307, 1150 cm^{-1}; δ_H ($CDCl_3$) 1.94–2.05 (1H, m, one of C(4)*H*$_2$), 2.51–2.64 (3H, m, one of C(4)*H*$_2$, C(5)*H*$_2$),3.78–3.85 (1H, d, *J* 7.5 Hz, C*H*SO_2Ph), 4.06–4.14 (1H, sym m, *J* 7.5 Hz, C*H*Ph), 7.12–7.32 (5H, m, aromatic H of phenyl group), 7.47–7.82 (5H, m, aromatic H of benzenesulfonyl group); δ_C ($CDCl_3$) 29.50 (*C*H$_2$), 39.20 (*C*H$_2$CO), 43.73 (*C*HPh), 75.43 (*C*HSO_2Ph), 126.80 (*C*H), 127.20 (*C*H), 129.90 (*C*H), 134.11 (*C*H), 137.90 (*C*), 142.10 (*C*), 206.20 (*C*O).

2.2.7. *trans-2-Benzenesulfonyl-3-benzylcyclopentanone* **1g**

A white crystalline solid; m.p. 85–86°C; (Found: C, 68.13; H, 5.72; S, 10.34. $C_{18}H_{18}O_3S$ requires C, 68.76; H, 5.77; S, 10.20); ν_{max} (KBr) 1748, 1307, 1151 cm^{-1}; δ_H ($CDCl_3$) 1.62–1.68 (1H, m, one of C(4)*H*$_2$), 2.09–2.38 (3H, m, C(5)*H*$_2$, one of C(4)*H*$_2$), 2.74–2.82 (1H, dd, *J* 13, 9 Hz, one of C*H*$_2$Ph), 3.03–3.17 (1H, dd, *J* 13, 6 Hz, one of C*H*$_2$Ph), 3.10–3.28 (1H, m, C*H*Bn), 3.47–3.50 (1H, d, *J* 7 Hz, C*H*SO_2Ph), 7.16–7.33 (5H, m, aromatic H of phenyl group), 7.54–7.86 (5H, m, aromatic H of benzenesulfonyl group); δ_C ($CDCl_3$) 29.26 (*C*H$_2$), 38.24 (*C*H$_2$), 39.51 (*C*HBn), 40.41 (C*H*$_2$) 73.54 (*C*HSO_2Ph), 126.77 (*C*H), 128.44 (*C*H), 128.83 (*C*H), 129.07 (*C*H), 130.86 (*C*H),

134.09 (*C*H), 137.87 (*C*), 138.25 (*C*), 206.95 (*C*O).

2.2.8. cis-2-Benzenesulfonylcyclopentanol ***2a***

A white crystalline solid; m.p. 113–114°C; ν_{max} (KBr) 3506 (br), 1302, 1143 cm^{-1}; δ_H ($CDCl_3$) 1.60–1.82 (1H, m, one of C(4)H_2), 1.85–2.17 (4H, m, one of C(4)H_2, C(3)H_2, one of C(5)H_2), 2.28–2.48 (1H, m, one of C(5)H_2), 3.23–3.34 (1h, ddd, *J* 14, 8, 4 Hz, C*H*SO_2Ph), 3.50 (1H, br s, O*H*), 4.38–4.45 (1H, m, C*H*OH), 7.55–7.98 (5H, m, aromatic H); δ_C ($CDCl_3$) 21.22 (*C*H_2), 23.46 (*C*H_2), 34.26 (*C*H_2), 67.98, 72.45 (*C*HOH and *C*HSO_2Ph), 128.07 (*C*H), 129.33 (*C*H), 133.86 (*C*); Found (HRMS, EI): *m/z* 226.0664. $C_{11}H_{14}O_3S$ requires M^+ 226.0664.

2.2.9. 2-Benzenesulfonyl-3-methylcyclopentanol ***2b***

A white crystalline solid; m.p. 81–83°C (Found: C, 60.30; H, 6.47; S, 13.62. $C_{12}H_{16}O_3S$ requires C, 59.97; H, 6.71; S, 13.34); ν_{max} (KBr) 3495 (br), 1294, 1136 cm^{-1}; δ_H ($CDCl_3$) 1.08–1.15 (3H, d, *J* 7 Hz, C*H*$_3$), 1.29–1.39 (1H, m, one of C(4)H_2), 1.73–1.81 (2H, m, one of C(4)H_2, one of C(5)H_2), 2.26–2.34 (1H, m, one of C(5)H_2), 2.79–2.86 (1H, m, C*H*Me), 2.94–2.99 (1H, dd, *J* 5, 11 Hz, C*H*SO_2Ph), 3.50 (1H, br s, O*H*), 4.29–4.36 (1H, ddd, *J* 4, 4, 4 Hz, C*H*OH), 7.40–8.00 (5H, m, aromatic H); δ_C ($CDCl_3$) 21.10 (*C*H_3), 31.51 (*C*H_2), 32.50 (*C*HCH_3), 33.13 (*C*H_2), 73.76, 74.33 (*C*HOH and *C*HSO_2Ph), 128.24 (*C*H), 129.65 (*C*H), 133.59 (*C*H), 139.99 (*C*).

2.2.10. 2-Benzenesulfonyl-3-ethylcyclopentanol ***2c***

A white crystalline solid; m.p. 40–42°C (Found: C, 61.00; H, 7.29; S, 12.39. $C_{13}H_{18}O_3S$ requires C, 61.39; H, 7.13; S, 12.61); ν_{max} (KBr) 3506 (br), 1300, 1143 cm^{-1}; δ_H ($CDCl_3$) 0.85–0.90 (3H, t, *J* 7.5 Hz, C*H*$_3$), 1.20–1.52 (2H, m, one of C*H*$_2$CH$_3$, one of C(4)H_2), 1.67–1.74 (3H, m, one of C*H*$_2$CH$_3$, one of C(4)H_2, one of C(5)H_2), 2.16–2.24 (1H, m, one of C(5)H_2), 2.61–2.74 (1H, m, C*H*Et), 3.03–3.08 (1H, dd, *J* 9, 4 Hz, C*H*SO_2Ph), 3.51 (1H, br s, O*H*), 4.23–4.32 (1H, ddd, *J* 3, 3, 3 Hz, C*H*OH), 7.55–7.98 (5H, m, aromatic H); δ_C ($CDCl_3$) 11.81 (*C*H$_3$), 28.07 (*C*H$_2$), 28.35 (*C*H$_2$), 33.24 (*C*H$_2$), 39.22 (*C*HEt), 72.32, 73.66 (*C*HOH and *C*HSO_2Ph), 128.24 (*C*H), 129.28 (*C*H), 133.82 (*C*H), 140.03 (*C*); Found (HRMS, EI): *m/z* 254.0964. $C_{13}H_{18}O_3S$ requires M^+ 254.0977.

2.2.11. 2-Benzenesulfonyl-3-n-propylcyclopentanol ***2d***

A white crystalline solid; m.p. 50–52°C; (Found: C, 63.00; H, 7.57; S, 11.67. $C_{14}H_{20}O_3S$ requires C, 62.76; H, 7.51; S, 11.95); ν_{max} (KBr) 3502 (br), 1300, 1145 cm^{-1}; δ_H ($CDCl_3$) 0.83–0.88 (3H, t, *J* 7 Hz, C*H*$_3$), 1.08–1.49 (4H, m, one of C(4)H_2, C*H*$_2$CH$_3$, one of C*H*$_2$CH$_2$CH$_3$), 1.62–1.82 (3H, m, one of C(4)H_2, one of C(5)H_2, one of C*H*$_2$CH$_2$CH$_3$), 2.17–2.35 (1H, m, one of C(5)H_2), 2.67–2.84 (1H, m, C*H*^{n}Pr), 3.02–3.07 (1H, dd, *J* 9, 4 Hz, C*H*SO_2Ph), 3.52 (1H, br s, O*H*), 4.26–4.34 (1H, ddd, *J* 4, 4, 4 Hz, C*H*OH), 7.55–7.98 (5H, m, aromatic H); δ_C ($CDCl_3$) 13.97 (*C*H$_3$), 20.81 (*C*H$_2$), 28.53 (*C*H$_2$), 33.26 (*C*H$_2$), 37.57 (*C*H^{n}Pr), 37.97 (*C*H$_2$), 72.78, 73.56 (*C*HOH and *C*HSO_2Ph), 128.29 (*C*H), 129.29 (*C*H), 133.82 (*C*H), 139.99 (*C*).

2.2.12. 2-Benzenesulfonyl-3-n-butylcyclopentanol ***2e***

A white crystalline solid; m.p. 53–54°C; (Found: C, 63.62; H, 8.10; S, 11.01. $C_{15}H_{22}O_3$ S requires C, 63.80; H, 7.85; S, 11.35); ν_{max} (KBr) 3498 (br), 1298, 1143 cm^{-1}; δ_H ($CDCl_3$) 0.85–0.87 (3H, t, *J* 8 Hz, C*H*$_3$), 1.08–1.48 (6H, m, one of C(4)H_2, C*H*$_2$C*H*$_2$CH$_3$, one of C*H*$_2$CH$_2$CH$_2$CH$_3$), 1.51–1.81 (3H, m, one of C(4)H_2, one of C(5)H_2, one of C*H*$_2$CH$_2$CH$_2$CH$_3$), 2.19–2.28 (1H, m, one of C(5)H_2), 2.67–2.85 (1H, m, C*H*^{n}Bu), 3.02–3.07 (1H, dd, *J* 9, 5 Hz, C*H*SO_2Ph), 3.50 (1H,

br s O*H*), 4.29–4.31 (1H, ddd, *J* 3, 3, 3 Hz, C*H*OH), 7.55–7.98 (5H, m, aromatic H); δ_C ($CDCl_3$) 13.95 (*C*H_3), 22.57 (*C*H_2), 28.46 (*C*H_2), 29.56 (*C*H_2), 33.26 (*C*H_2), 37.92 (*C*H^{n}Bu), 37.97 (*C*H_2), 72.78, 73.62 (*C*HOH and *C*HSO_2Ph), 128.28 (*C*H), 129.27 (*C*H), 134.07 (*C*H), 140.05 (*C*).

2.2.13. 2-Benzenesulfonyl-3-phenylcyclopentanol **2f**

A white crystalline solid; m.p. 174–175°C (Found: C, 67.59; H, 6.08; S, 10.69. $C_{17}H_{18}O_3S$ requires C, 67.52; H, 6.00; S, 10.60); ν_{max} (KBr) 3498 (br), 1298, 1143 cm^{-1}; δ_H($CDCl_3$) 1.65–1.78 (1H, m, one of C(4)*H*$_2$), 1.93–2.12 (2H, m, one of C(4)*H*$_2$, one of C(5)*H*$_2$), 2.47–2.61 (1H, m, one of C(5)*H*$_2$), 3.10 (1H, br s, O*H*), 3.58–3.63 (1H, dd, *J* 5, 11 Hz, C*H*SO_2Ph), 3.78–3.88 (1H, m, C*H*Ph), 4.81–4.85 (1H, ddd, *J* 3, 3, 3, Hz, C*H*OH), 6.97–7.14 (5H, m, aromatic H of phenyl group), 7.26–7.63 (5H, m, aromatic H of benzenesulfonyl group); δ_C ($CDCl_3$) 33.35 (*C*H_2), 33.52 (*C*H_2), 44.32 (*C*HPh), 74.11, 74.65 (*C*HOH and *C*HSO_2Ph), 126.63 (*C*H), 127.09 (*C*H), 127.53 (*C*H), 128.24 (*C*H), 128.52 (*C*H), 128.93 (*C*H), 134.09 (*C*H), 139.76 (*C*), 142.29 (*C*).

2.2.14. 2-Benzenesulfonyl-3-benzylcyclopentanol **2g**

A white crystalline solid; m.p. 84–86°C; ν_{max} (KBr) 3461 (br), 1288, 1141 cm^{-1}; δ_H ($CDCl_3$) 1.48–1.86 (3H, m, C(4)*H*$_2$, one of C(5)*H*$_2$), 1.99–2.16 (1H, m, one of C(5)*H*$_2$), 2.43–2.57 (1H, dd, *J* 14, 11 Hz, one of C*H*$_2$Ph), 3.00–3.09 (2H, m, one of C*H*$_2$Ph, C*H*Bn), 3.15–3.20 (1H, dd, *J* 9, 4.5 Hz, C*H*SO_2Ph), 3.54 (1H, br s O*H*), 4.27–4.33 (1H, ddd, *J* 4, 4, 4 Hz, C*H*OH), 7.12–7.31 (5H, m, aromatic H of benzyl group), 7.57–8.01 (5H, m, aromatic H of benzenesulfonyl group); δ_C ($CDCl_3$) 27.99 (*C*H_2), 33.13 (*C*H_2), 39.07 (*C*HBn), 41.07 (*C*H_2), 71.73, 73.55 (*C*HOH and *C*HSO_2Ph), 126.37 (*C*H), 128.28 (*C*H), 128.44 (*C*H), 129.16 (*C*H), 129.39 (*C*H), 133.93 (*C*H), 139.44 (*C*), 139.89 (*C*); Found (HRMS, EI): *m/z* 316.1133. $C_{18}H_{20}O_3S$ requires M^+ 316.1138.

2.3. Reduction of the cyclopentanones **1a–1g** with sodium borohydride

2.3.1. cis-2-Benzenesulfonylcyclopentanol **2a**

Sodium borohydride (9 mg, 0.24 mmol) was added to 2-benzenesulfonylcyclopentanone **1a** (30 mg, 0.13 mmol) in ethanol (10 ml) while stirring at 0°C under nitrogen. Stirring was continued for two hours while allowing the reaction mixture to slowly return to room temperature. The solvent was removed at reduced pressure and the residue was shaken in dichloromethane (10 ml) and water (10 ml). The aqueous layer was washed with dichloromethane (3 × 10 ml); the combined organic layers were washed with brine (10 ml), dried ($MgSO_4$), filtered and concentrated under reduced pressure to give the crude product which was recrystallised from ether to give the cyclopentanol **2a** as a white crystalline solid (28 mg, 95%).

The minor diastereomer *trans*-2-benzenesulfonylcyclopentanol **3a** could be detected in the ^{1}H NMR spectrum at δ_H 4.67–4.75 (1H, m, C*H*OH) (~ 2%).

2.3.2. 2-Benzenesulfonyl-3-methylcyclopentanol **2b**

This was prepared from *trans*-2-benzenesulfonyl-3-methylcyclopentanone **1b** (30 mg, 0.13 mmol), sodium borohydride (9 mg, 0.24 mmol) in ethanol (10 ml) following the procedure described for **2a** to give the cyclopentanol **2b** as a white crystalline solid (28 mg, 95%).

Signals for the minor diastereomer **3b** could be detected at δ_H 0.88–0.95 (d, *J* 7 Hz, C*H*$_3$), 4.58–4.69 (ddd, *J* 6, 6, 6 Hz, C*H*OH) (~ 2%).

2.3.3. 2-Benzenesulfonyl-3-ethylcyclopentanol **2c**

This was prepared from *trans*-2-benzenesulfonyl-3-ethylcyclopentanone **1c** (30 mg, 0.12 mmol), sodium borohydride (9 mg, 0.24 mmol) in ethanol (10 ml) following the procedure de-

scribed for **2a** to give the cyclopentanol **2c** as a white crystalline solid (29 mg, 98%).

A signal for the minor diastereomer **3c** could be detected at δ_H 0.70–0.76 (t, *J* 7.5 Hz, CH_3) (~ 1%).

2.3.4. *2-Benzenesulfonyl-3-n-propylcyclopentanol* **2d**

This was prepared from *trans*-2-benzenesulfonyl-3-*n*-propylcyclopentanone **1d** (60 mg, 0.23 mmol), sodium borohydride (17 mg, 0.45 mmol) in ethanol (10 ml) following the procedure described for **2a** to give the cyclopentanol **2d** as a white crystalline solid (55 mg, 91%).

Signals for the minor diastereomer **3d** could be detected at δ_H 0.70–0.80 (t, *J* 7 Hz, CH_3), 4.59–4.68 (ddd, *J* 6, 6, 6 Hz, C*H*OH) (~ 2%).

2.3.5. *2-Benzenesulfonyl-3-n-butylcyclopentanol* **2e**

This was prepared from *trans*-2-benzenesulfonyl-3-*n*-butylcyclopentanone **1e** (50 mg, 0.18 mmol), sodium borohydride (9 mg, 0.23 mmol) in ethanol (10 ml) following the procedure described for **2a** to give the cyclopentanol **2e** as a white crystalline solid (46 mg, 93%).

A signal for the minor diastereomer **3e** could be detected at δ_H 4.61–4.68 (ddd, *J* 6, 6, 6 Hz, C*H*OH) (~ 2%).

2.3.6. *2-Benzenesulfonyl-3-phenylcyclopentanol* **2f**

This was prepared from *trans*-2-benzenesulfonyl-3-phenylcyclopentanone **1f** (60 mg, 0.20 mmol), sodium borohydride (9 mg, 0.23 mmol) in ethanol (10 ml) following the procedure described for **2a** to give the cyclopentanol **2f** as a white crystalline solid (59 mg, 98%).

A signal for the minor diastereomer **3f** could be detected at δ_H 4.90–5.00 (m, C*H*OH) (~ 2%).

2.3.7. *2-Benzenesulfonyl-3-benzylcyclopentanol* **2g**

This was prepared from *trans*-2-benzenesulfonyl-3-benzylcyclopentanone **1g** (50 mg, 0.16 mmol), sodium borohydride (8 mg, 0.20 mmol) in ethanol (10 ml) following the procedure described for **2a** to give the cyclopentanol **2g** as a white crystalline solid (46 mg, 91%).

A signal for the minor diastereomer **3g** could be detected at δ_H 4.66–4.76 (ddd, *J* 6, 6, 6 Hz, C*H*OH) (~ 2%).

2.4. *Reduction of the cyclopentanones* **1a–1g** *with bakers' yeast*

2.4.1. *(+)-(1S,2R)-cis-2-Benzenesulfonylcyclopentanol* **2a**

A suspension of baker's yeast (Sigma, Type II, 10 g) and sucrose (10 g) in tap water (60 ml) was warmed slowly to 27–29°C while stirring gently. The mixture was stirred for 30 min then the cyclopentanone **1a** (0.10 g, 0.45 mmol) in DMSO (1 ml) and tap water (2 ml) was added slowly and the mixture was stirred at 27–29°C for 24 h. Sucrose (5 g) was added and stirring continued at 27–29°C for 96 h. Celite (5 g) was added and the mixture was stirred for 30 min at room temperature. Filtration through Celite, which was then washed with water (50 ml), saturation of the aqueous solution with sodium chloride, extraction with ethyl acetate (3 × 100 ml), drying ($MgSO_4$) and evaporation gave the crude product. Purification by preparative thin layer chromatography on silica with ethyl acetate–hexane (1:1) as eluant gave the cyclopentanol **2a** as a white crystalline solid (79 mg, 79%). Spectral characteristics were in agreement with those of the racemic compound. $[\alpha]_D^{20}$ +6.5° (*c* 7.9, CH_2Cl_2). ^{1}H NMR studies in the presence of Eu(hfc)$_3$ demonstrated that the enantiomeric purity of the cyclopentanol was > 95% ee.

The minor diastereomer *trans*-2-benzenesulfonylcyclopentanol **3a** could be detected in the ^{1}H NMR spectrum at δ_H 4.66–4.74 (m, C*H*OH) (3% by integration).

A small amount of the cyclopentanone **1a** was recovered (4 mg, 4%) but no attempt was made to determine its enantiomeric purity.

2.4.2. (+)-(2S,3R)-2-Benzenesulfonyl-3-methylcyclopentanone 1b and (+)-(1S,2R,3S)-2-benzenesulfonyl-3-methylcyclopentanol 2b

The cyclopentanone **1b** (100 mg, 0.42 mmol) was reduced with bakers' yeast following the procedure described for reduction of **1a** to give the cyclopentanone (+)-**1b** (10 mg, 10%) and the cyclopentanol (+)-**2b** (29 mg, 29%). Spectral characteristics were in agreement with those of the racemic compounds. (+)-**1b** $[\alpha]_D^{20}$ +70° (*c* 1.0, CH_2Cl_2); > 95% ee by ^1H NMR studies in the presence of Eu(hfc)$_3$. [lit. [11] for 3*S*-enantiomer (~ 30% ee) of **1b** $[\alpha]_D^{20}$ −49.9° (*c* 7.1, CH_2Cl_2)]. (+)-**2b** $[\alpha]_D^{20}$ +22° (*c* 2.9, CH_2Cl_2); > 95% ee by ^1H NMR studies in the presence of Eu(hfc)$_3$.

Signals for the minor diastereomer **3b** could be detected at δ_H 0.93 (d, *J* 7 Hz, CH_3), 4.58–4.69 (ddd, *J* 6, 6, 6 Hz, C*H*OH) (18% by integration).

2.4.3. (+)-(2S,3R)-2-Benzenesulfonyl-3-ethylcyclopentanone 1c and (+)-(1S,2R,3S)-2-benzenesulfonyl-3-ethylcyclopentanol 2c

The cyclopentanone **1c** (100 mg, 0.40 mmol) was reduced with bakers' yeast following the procedure described for reduction of **1a** to give the cyclopentanone (+)-**1c** (28 mg, 28%) and the cyclopentanol (+)-**2c** (40 mg, 40%). Spectral characteristics were in agreement with those of the racemic compounds. (+)-**1c** $[\alpha]_D^{20}$ +78° (*c* 2.8, CH_2Cl_2); > 95% ee by ^1H NMR studies in the presence of Eu(hfc)$_3$. (+)-**2c** $[\alpha]_D^{20}$ +27° (*c* 4.0, CH_2Cl_2); > 95% ee by ^1H NMR studies in the presence of Eu(hfc)$_3$.

Signals for the minor diastereomer **3c** could be detected at δ_H 0.70–76 (t, *J* 15 Hz, CH_3), 4.58–4.69 (ddd, *J* 6, 6, 6 Hz, C*H*OH) (6% by integration).

2.4.4. (+)-(2S,3R)-2-Benzenesulfonyl-3-n-propylcyclopentanone 1d and (+)-(1S,2R,3S)-2-benzenesulfonyl-3-n-propylcyclopentanol 2d

The cyclopentanone **1d** (100 mg, 0.38 mmol) was reduced with bakers' yeast following the procedure described for reduction of **1a** to give the cyclopentanone (+)-**1d** (26 mg, 26%) and the cyclopentanol (+)-**2d** (36 mg, 36%). Spectral characteristics were in agreement with those of the racemic compounds. (+)-**1d** $[\alpha]_D^{20}$ +48° (*c* 2.6, CH_2Cl_2); 95% ee by ^1H NMR studies in the presence of Eu(hfc)$_3$. (+)-**2d** $[\alpha]_D^{20}$ +24° (*c* 3.6, CH_2Cl_2); > 95% ee by ^1H NMR studies in the presence of Eu(hfc)$_3$.

Signals for the minor diastereomer **3d** could be detected at δ_H 0.71–0.78 (t, *J* 7 Hz, CH_3), 4.59–4.68 (ddd, *J* 6, 6, 6 Hz, C*H*OH) (7% by integration).

2.4.5. (+)-(2S,3R)-2-Benzenesulfonyl-3-n-butylcyclopentanone 1e and (+)-(1S,2R,3S)-2-benzenesulfonyl-3-n-butylcyclopentanol 2e

The cyclopentanone **1e** (100 mg, 0.36 mmol) was reduced with bakers' yeast following the procedure described for reduction of **1a** to give the cyclopentanone (+)-**1e** (34 mg, 34%) and the cyclopentanol (+)-**2e** (32 mg, 32%). Spectral characteristics were in agreement with those of the racemic compounds. (+)-**1e** $[\alpha]_D^{20}$ +21° (*c* 3.4, CH_2Cl_2); 60% ee by ^1H NMR studies in the presence of Eu(hfc)$_3$. (+)-**2e** $[\alpha]_D^{20}$ +24° (*c* 3.2, CH_2Cl_2); > 95% ee by ^1H NMR studies in the presence of Eu(hfc)$_3$.

The minor diastereomer **3b** could not be detected in the ^1H NMR (> 98:2 diastereomeric purity).

2.4.6. (+)-(2S,3S)-2-Benzenesulfonyl-3-phenylcyclopentanone 1f and (+)-(1S,2R,3R)-2-benzenesulfonyl-3-phenylcyclopentanol 2f

The cyclopentanone **1f** (100 mg, 0.32 mmol) was reduced with bakers' yeast following the procedure described for reduction of **1a** to give the cyclopentanone (+)-**1f** (20 mg, 20%) and the cyclopentanol (+)-**2f** (31 mg, 31%). Spectral characteristics were in agreement with those of the racemic compounds. (+)-**1f** $[\alpha]_D^{20}$ +44° (*c* 2.0, CH_2Cl_2); 86% ee by ^1H NMR studies in the presence of Eu(hfc)$_3$. (+)-**2f** $[\alpha]_D^{20}$ +4° (*c* 3.1, CH_2Cl_2); > 95% ee by ^1H NMR studies in the presence of Eu(hfc)$_3$.

The minor diastereomer **3f** could not be detected in the ^{1}H NMR (> 98:2 diastereomeric purity).

*2.4.7. (1S,2R,3R)-2-Benzenesulfonyl-3-benzylcyclopentanol **2g***

The cyclopentanone **1g** (100 mg, 0.32 mmol) was reduced with bakers' yeast following the procedure described for reduction of **1a** to give the cyclopentanol (+)-**2g** (22 mg, 22%). Spectral characteristics were in agreement with those of the racemic compound. Only traces of the cyclopentanone **1g** could be detected by TLC. (+)-**2g** $[\alpha]_D^{20} \sim 0°$ (*c* 2.2, CH_2Cl_2); > 95% ee by ^{1}H NMR studies in the presence of Eu(hfc)$_3$.

A signal for the minor diastereomer **3g** could be detected at δ_H 4.66–4.74 (ddd, *J* 6, 6, 6 Hz, C*H*OH) (5% by integration).

*2.4.8. (−)-(2R,3R)-2-Benzenesulfonyl-3-phenylcyclopentanone **1f***

The cyclopentanol **2f** [175 mg, 0.58 mmol, > 95% ee, diastereomeric ratio > 98:2 i.e. **3f** not detected, $[\alpha]_D^{20}$ 0° (*c* 9.0, CH_2Cl_2)] in dichloromethane (30 ml) was added to a solution of the Dess–Martin periodinane, 1,1,1-triacetoxy-1,1-dihydro-1,2-benziodoxol-3-(1H)-one [14] (320 mg, 0.75 mmol) in dichloromethane (15 ml) while stirring under nitrogen. Stirring was continued for 30 min (until the starting material could no longer be detected by TLC) then the mixture was poured into saturated sodium bicarbonate solution (50 ml) containing sodium thiosulfate (500 mg). The resulting mixture was stirred for 5 min then the layers were separated and the organic layer was washed with saturated sodium bicarbonate solution (15 ml) and water (15 ml), dried ($MgSO_4$), filtered and concentrated under reduced pressure. The crude product mixture was purified by chromatography on silica gel using hexane/ether (2:3) as eluant to give (−)-**1f** as a white crystalline solid (123 mg, 70%). Spectral characteristics were in agreement with those of the racemic compound. (−)-**1f** $[\alpha]_D^{20}$ −42.3° (*c* 12.3, CH_2Cl_2); 96% ee by ^{1}H NMR studies in the presence of Eu(hfc)$_3$.

*2.4.9. Desulfonylation of (−)-(2R,3R)-2-Benzenesulfonyl-3-phenylcyclopentanone **1f***

2.4.9.1. Preparation of aluminium amalgam [15]. Aluminium foil was scratched with sand paper, then immersed in aqueous sodium hydroxide (15%) for 30 s, washed quickly with water, then immersed in aqueous mercuric chloride (0.5%) for 2 min. The sequence of immersion in base, water and mercuric chloride was repeated then the amalgamated metal was washed rapidly with water, ethanol and ether and used immediately.

Aluminium amalgam freshly prepared as described above from aluminium foil (308 mg, 11.4 mmol) was added to a solution of (−)-(2*R*,3*R*)-2-benzenesulfonyl-3-phenylcyclopentanone **1f** [113 mg, 0.38 mmol, 96% ee, $[\alpha]_D^{20}$ −42.3° (*c* 12.3, CH_2Cl_2)] in THF (3 ml) and water (5 ml) and the mixture was stirred at 65°C for 2.5 h. The mixture was cooled, filtered through Celite which was washed with ether (20 ml). The layers were separated and the aqueous layer washed with ether (3 × 10 ml). The aqueous layer was then saturated with sodium chloride and reextracted with ether (3 × 10 ml). The combined organic extracts were dried ($MgSO_4$), filtered and concentrated under reduced pressure to give the crude product. The cyclopentanone was purified by preparative thin layer chromatography using ether/hexane (1:1) as eluent to give (*S*)-3-phenylcyclopentanone (25 mg, 41%) δ_H ($CDCl_3$) 1.91–2.08 (1H, m, one of C(4)H_2), 2.23–2.55 (4H, m, one of C(2)H_2, one of C(4)H_2, C(5)H_2), 2.57–2.77 (1H, dd, *J* 18, 11 Hz, one of C(2)H_2), 3.40–3.50 (1H, m, C*H*Ph), 7.15–7.39 (5H, m, Ph); δ_C ($CDCl_3$) 31.12 (*C*H$_2$), 38.85 (*C*H$_2$), 42.25 (*C*HPh), 45.80 (*C*H$_2$), 126.73 (*C*H), 128.37 (*C*H), 128.70 (*C*H), 143.09 (*C*), 218.29 (*C*O). $[\alpha]_D^{20}$ −69.4° (*c* 2.5, $CHCl_3$); lit. [12] $[\alpha]_D^{20}$ −84.9° (*c* 0.72, $CHCl_3$) for the 3*S*-enantiomer; lit. [13]

$[\alpha]_D^{20}$ +69.4° (*c* 1.42, $CHCl_3$) for the 3*R*-enantiomer (76% ee).

2.4.10. Desulfonylation of (+)-(2S,3S)-2-Benzenesulfonyl-3-phenylcyclopentanone ***1f***

(+)-(2*S*,3*S*)-2-Benzenesulfonyl-3-phenylcyclopentanone **1f** [21 mg, 0.07 mmol, 86% ee, $[\alpha]_D^{20}$ +42.6° (*c* 2.1, CH_2Cl_2)] was desulfonylated using aluminium amalgam (prepared from 111 mg aluminium foil) in THF (2 ml) and water (2 ml) following the procedure described for (−)-**1f**. The crude product was purified by Kugelrohr distillation, oven temperature 155°C, 10 mmHg to give (*R*)-3-phenylcyclopentanone (3.5 mg, 66%). Spectral characteristics were identical to those of the (*S*)-enantiomer described above. $[\alpha]_D^{20}$ +45.2° (*c* 0.35, $CHCl_3$); lit. [12] $[\alpha]_D^{20}$ −84.9° (*c* 0.72, $CHCl_3$) for the 3*S*-enantiomer; lit. [13] $[\alpha]_D^{20}$ +69.4° (*c* 1.42, $CHCl_3$) for the 3*R*-enantiomer (76% ee).

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