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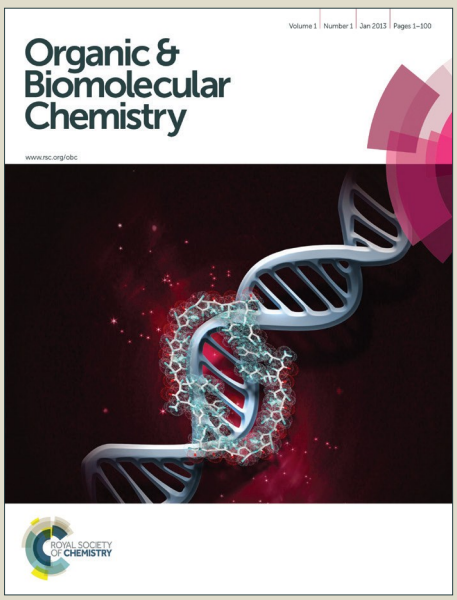

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ARTICLE

Grignard-mediated reduction of 2,2,2-trichloro-1-arylethanones: One-pot reduction/aldol routes to 2,2-dichloro-3-hydroxy-1,3-diarylpropan-1-ones and related molecules

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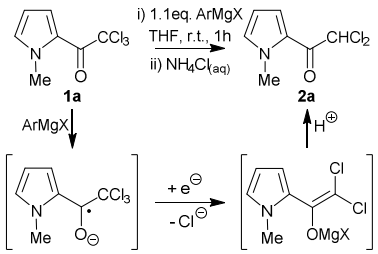
2,2,2-Trichloro-1-aryl-ethanones can be reduced by RMgX to the corresponding 2,2-dichloro-1-arylethen-1-olates and trapped with a range of electrophiles resulting in either reduction, reduction/aldol, reduction/Claisen condensation or reduction/aldol-Tishchenko products. In addition we demonstrate that 2,2-dichloro-1-arylethen-1-olates undergo counter-ion controlled Darzens condensations, which can be followed by a thermal rearrangement as a route to 1,3-diaryl-3-chloropropane-1,2-diones.

Introduction

α,α-Dichlorocarbonyls are useful intermediates for the formation of chloroalkenes[1] and chlorooxiranes (as a route to α-keto esters[2], α-haloacylsilanes[3] and heteroaromatics[4]), can be used as chlorinating agents[5] and have even been observed within natural products.[6] α,α-Dichlorocarbonyls are typically synthesised via chlorination,[7] electrochemical or metal-mediated reduction,[8] aldol reaction[9] or the cycloaddition of dichloroketenes.[10] Recently we communicated a new route to molecules of this type, namely 2,2-dichloro-1-(1-methyl-1*H*-pyrrol-2-yl)ethanones, based our investigations into the reduction of 2,2,2-trichloro-1-(1-methyl-1*H*-pyrrol-2-yl)ethan-1-one (**1a**) by aryl magnesium halides (Figure 1).[11]



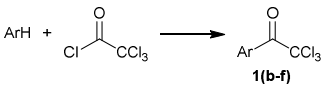
Scheme 1. ArMgX-mediated reduction of 2,2,2-trichloro-1-(1-methyl-1*H*-pyrrol-2-yl)ethanone (**1a**).

Herein we extend the synthetic utility of this reaction through the development of reduction, reduction/aldol, reduction/Claisen condensation and reduction/aldol-Tishchenko routes to functionalised α,α-dichlorocarbonyls. In addition we have investigated the influence of the counter-ion on the reactivity of 2,2-dichloro-1-arylethen-1-olates, allowing the selection between aldol or Darzens type reaction products.

Results and discussion

Following our discovery of the single electron transfer reduction of 2,2,2-trichloro-1-(1-methyl-1*H*-pyrrol-2-yl)ethan-1-one (**1a**) by aryl magnesium halides, we decided to investigate the electrophilic trapping of the magnesium 2,2-dichloro-1-arylethen-1-olate intermediates, formed *in situ* from a range of 2,2,2-trichloro-1-aryl-ethanones, as a new one-pot route to substituted α,α-dichlorocarbonyls. To explore this proposal, a selection of 2,2,2-trichloro-1-arylethanones were first synthesised via acylation of toluene, *tert*-butylbenzene, 1-methylfuran, indole and *N*-methylindole with 2,2,2-trichloroacetyl chloride under Lewis acid, neutral or pyridine-catalysed conditions as appropriate (Table 1).[11-13]

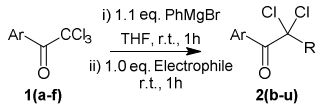
Table 1 Formation of 2,2,2-trichloro-1-arylethanones **1(b-g)**



	Product	Ar	Catalyst	Temp.	Time	Solvent	Yield
1	**1b**	*p*-tolyl	$AlCl_3$	r.t.	1 day	DCM	65%[a]
2	**1c**	4-(*tert*-butyl)phenyl	$AlCl_3$	-30 °C	2 days	DCM	45%[a]
3	**1d**	5-methylfuran-2-yl	-	r.t.	1 day	Et_2O	65%
4	**1e**	1*H*-indol-3-yl	pyr.	4 °C	7 days	DCM	87%[b]
5	**1f**	1-methyl-1*H*-indol-3-yl	pyr.	10 °C	2 days	DCM	75%[b]

[a] examples from reference 11, included for comparison. [b] structure confirmed by single-crystal X-ray analysis.

Table 2 RMgX-mediated reduction, reduction/aldol and reduction/Claisen condensation reactions of 2,2,2-trichloro-1-arylethanones (**1b-f**)



	Starting Material	Ar	Product	Electrophile (1.1 equiv.)	R	Yield[a]
1	**1a**	1-methyl-1*H*-pyrrol-2-yl	**2a**	H_2O[c]	H	94%[b,d]
2	**1b**	*p*-tolyl	**2b**	H_2O[c]	H	68%
3	**1b**	*p*-tolyl	**2b-*d***	D_2O[c]	D	50% (96% *d*)[e]
4	**1c**	4-(*tert*-butyl)phenyl	**2c**	H_2O[c]	H	71%
5	**1c**	4-(*tert*-butyl)phenyl	**2c-*d***	D_2O[c]	D	96% (88% *d*)[e]
6	**1d**	5-methylfuran-2-yl	**2d**	H_2O[c]	H	58%
7	**1d**	5-methylfuran-2-yl	**2d-*d***	D_2O[c]	D	68% (93% *d*)[e]
8	**1e**	1*H*-indol-3-yl	**2e**	H_2O[c]	H	33%[f]
9	**1f**	1-methyl-1*H*-indol-3-yl	**2f**	H_2O[c]	H	75%[b]
10	**1f**	1-methyl-1*H*-indol-3-yl	**2f-*d***	D_2O[c]	D	65% (96% *d*)[e]
11	**1a**	1-methyl-1*H*-pyrrol-2-yl	**2g**	$(C_6F_5)CHO$	$(C_6F_5)CH(OH)$	70%[d]
12	**1b**	*p*-tolyl	**2h**	$(C_6F_5)CHO$	$(C_6F_5)CH(OH)$	92%[b]
13	**1d**	5-methylfuran-2-yl	**2i**	$(C_6F_5)CHO$	$(C_6F_5)CH(OH)$	28%
14	**1e**	1*H*-indol-3-yl	**2j**	$(C_6F_5)CHO$	$(C_6F_5)CH(OH)$	57%[b,f]
15	**1f**	1-methyl-1*H*-indol-3-yl	**2k**	$(C_6F_5)CHO$	$(C_6F_5)CH(OH)$	62%[b]
16	**1a**	1-methyl-1*H*-pyrrol-2-yl	**2l**	5-Me(C_4H_2O)CHO	5-Me(C_4H_2O)CH(OH)	70%[d]
17	**1b**	*p*-tolyl	**2m**	5-Me(C_4H_2O)CHO	5-Me(C_4H_2O)CH(OH)	48%
18	**1a**	1-methyl-1*H*-pyrrol-2-yl	**2n**	4-$NO_2(C_6H_4)$CHO	4-$NO_2(C_6H_4)$CH(OH)	96%[d]
20	**1b**	*p*-tolyl	**2o**	4-$NO_2(C_6H_4)$CHO	4-$NO_2(C_6H_4)$CH(OH)	40%[b]
21	**1c**	4-(*tert*-butyl)phenyl	**2p**	4-$NO_2(C_6H_4)$CHO	4-$NO_2(C_6H_4)$CH(OH)	21%
22	**1f**	1-methyl-1*H*-indol-3-yl	**2q**	4-$NO_2(C_6H_4)$CHO	4-$NO_2(C_6H_4)$CH(OH)	64%
23	**1a**	1-methyl-1*H*-pyrrol-2-yl	**2r**	$(EtO_2C)_2CO$	$(EtO_2C)_2C(OH)$	75%[d]
24	**1b**	*p*-tolyl	**2s**	$(EtO_2C)_2CO$	$(EtO_2C)_2C(OH)$	92%
25	**1f**	1-methyl-1*H*-indol-3-yl	**2t**	$(EtO_2C)_2CO$	$(EtO_2C)_2C(OH)$	32%[b]
26	**1a**	1-methyl-1*H*-pyrrol-2-yl	**2u**	4-$NO_2(C_6H_4)$COCl	4-$NO_2(C_6H_4)$C(O)	95%[d]
27	**1b**	*p*-tolyl	**2v**	4-$NO_2(C_6H_4)$COCl	4-$NO_2(C_6H_4)$C(O)	79%
28	**1c**	4-(*tert*-butyl)phenyl	**2w**	4-$NO_2(C_6H_4)$COCl	4-$NO_2(C_6H_4)$C(O)	33%
29	**1d**	5-methylfuran-2-yl	**2x**	4-$NO_2(C_6H_4)$COCl	4-$NO_2(C_6H_4)$C(O)	65%
30	**1f**	1-methyl-1*H*-indol-3-yl	**2y**	4-$NO_2(C_6H_4)$COCl	4-$NO_2(C_6H_4)$C(O)	69%

[a] unoptimised, isolated yields. [b] structure confirmed by single-crystal X-ray analysis. [c] electrophile used in excess. [d] examples from reference 11, included for comparison. [e] % deuterium incorporation determined by ^{1}H NMR. [f] 2.2 equivalents of PhMgBr were used.

With compounds **1b-1f** in hand we could then examine their ArMgX-mediated reductions and electrophilic trapping of the enolates formed. This would allow us to investigate the influence of the aryl group on the reduction reaction, whilst also exploring a wider range of electrophiles and trapping conditions.[14] In our previous work we have shown that PhMgI gave, in some cases, slightly improved yields of the desired reduction products. However, we decided to focus our investigations on the use of the more readily available commercial reagent, PhMgBr.

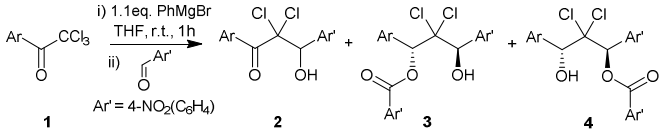
In an initial experiment, reaction of 2,2,2-trichloro-1-(*p*-tolyl)ethan-1-one (**1b**) with PhMgBr was followed by addition of an excess of H_2O or D_2O. The formation of 2,2-dichloro-1-(*p*-tolyl)ethan-1-one (**2b**) or 2,2-dichloro-1-(*p*-tolyl)ethan-1-one-2-*d* (**2b-*d***), with high levels of deuterium incorporation by NMR, was consistent with our earlier work, confirming the formation of a magnesium 2,2-dichloro-1-(*p*-tolyl)ethen-1-olate through a Grignard-mediated reduction of **1b**. Similar results were obtained by PhMgBr reduction of 2,2,2-trichloro-1-aryl-ethanones **1c**, **1d** and **1f**, followed by H_2O or D_2O trapping. In the majority of cases good yields of the reduced products were observed with high levels of deuterium incorporation. However, when 2,2,2-trichloro-1-(1*H*-indol-3-yl)ethan-1-one (**1e**) was reacted with 1.1 equivalents of PhMgBr followed by a quench with H_2O, very low yields of 2,2-dichloro-1-(1*H*-indol-3-yl)ethan-1-one (**2e**) were obtained. We postulated that reduction by PhMgBr was competing with the deprotonation of the indolic NH; thus when 2.1 equivalents of PhMgBr were used a moderate (33%) yield of the reduced product **2e** was achieved upon H_2O quench. This was confirmed by comparison to the reaction of 2,2,2-trichloro-1-(1-methyl-1*H*-indol-3-yl)ethan-1-one with 1.1 equivalents of PhMgBr, followed by addition of H_2O or D_2O. With the indolic NH replaced with a methyl group good yields of the reduced products **2f** and **2f-*d*** were obtained, indicating perhaps unsurprisingly that even weakly acidic protons are not well tolerated under the reaction conditions and that a protecting group strategy or transient protection through deprotonation is required (Table 2, entries 1-10).

We then decided to examine the trapping of the intermediate magnesium 2,2-dichloro-1-arylethen-1-olates, formed from the reduction of **1a-1f**, with more complex electrophiles including aldehydes, ketones and acid chlorides to examine the potential for reduction/aldol and reduction/Claisen condensation reactions. Reaction of 2,2,2-trichloro-1-aryl-ethanones (**1a-1f**), with 1.1 equivalents of PhMgBr (2.1 equivalents in the case of

1e), followed by addition to an aryl aldehyde or diethyl 2-oxomalonate gave reduction/aldol products (**2g-t**), whilst the addition to 4-nitrobenzoyl chloride gave reduction/Claisen products (**2u-y**), all in moderate to good isolated yields (Table 2, entries 11-30). This demonstrates that the reduction of *para*-substituted phenyl and electron-rich heteroaromatic containing 2,2,2-trichloro-1-aryl-ethanones with PhMgBr gives clean conversion to the corresponding magnesium enolates, which are in turn capable of reacting with variety of carbonyl electrophiles as a high yielding route to functionised α,α-dichlorocarbonyls.

Interestingly we observed that the reduction/aldol reactions of PhMgBr, 2,2,2-trichloro-1-aryl-ethanones **1b** and **1c** and 4-nitrobenzaldehyde gave low yields of the desired aldol products **2o** (40%) and **2p** (21%) but also an appreciable yield of two new unexpected products **3a** (23%) and **3b** (38%) (Table 3).

Table 3 RMgX-mediated reduction/aldol vs reduction/aldol-Tishchenko/ester migration reactions of 2,2,2-trichloro-1-arylethanones (**1b-c**)

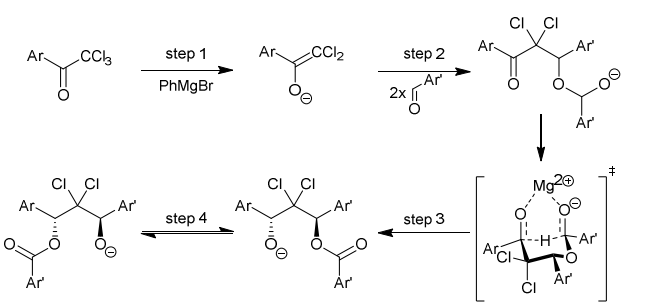


	SM	Ar	Ar'	Reaction Conditions (step ii)	Yield (**2**)[a]	Yield (**3**)[a]	Yield (**4**)[a]
1	**1b**	*p*-tolyl	4-nitro phenyl	1.1 eq. Ar'CHO, rt., 1h.	40%, **2o**	23%, **3a**[b]	-
2	**1c**	4-(*tert*-butyl) phenyl	4-nitro phenyl	1.1 eq. Ar'CHO, rt., 1h.	21%, **2p**	38%, **3b**[b]	
3	**1b**	*p*-tolyl	4-nitro phenyl	1.1 eq. Ar'CHO, -78 °C to r.t., 1h.	62%, **2o**	-	-
4	**1c**	4-(*tert*-butyl) phenyl	4-nitro phenyl	1.1 eq. Ar'CHO, -78 °C to r.t., 1h.	80%, **2p**	-	-
5	**1b**	*p*-tolyl	4-nitro phenyl	2 eq. Ar'CHO, -78 °C to r.t., 1h.	-	85%, **3a**[b]	-
6	**1c**	4-(*tert*-butyl) phenyl	4-nitro phenyl	2 eq. Ar'CHO, -78 °C to r.t., 1h.	-	90%, **3b**[b]	-
7	**1b**	*p*-tolyl	4-methoxy phenyl	2 eq. Ar'CHO, 1h	-	72%, 1:1, **3c:4c**	
8	**1b**	*p*-tolyl	4-bromo phenyl	2 eq. Ar'CHO, 1h	-	92%, 3:4, **3d**:**4d**	

[a] isolated yields. [b] structure confirmed by single-crystal X-ray analysis.

3a and **3b** were shown by ^{1}H NMR and single-crystal X-ray crystallography to be the corresponding *anti*-1,3-diol derivatives, each formed as a single major regio- and diastereoisomer, suggesting that they had been generated via an aldol-Tishchenko reaction.[15-17] We propose the reduction of **1b** and **1c** by PhMgBr (step 1) is followed by an aldol and subsequent chelation-controlled Tishchenko reaction (steps 2-3), and completed by an acyl migration (step 4) followed by protonation on work-up to give **3a** and **3b** (Scheme 3).

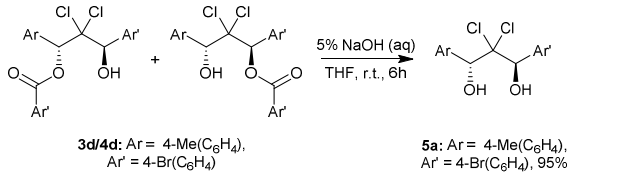
We decided to further investigate this process as a route to *anti*-2,2-dichloro-1,3-diarylpropane-1,3-diol derivatives. Optimisation of the reaction conditions showed that reduction of **1b** and **1c** to their corresponding enolates under our standard



Scheme 3. Proposed reduction/aldol-Tishchenko/acyl migration reaction sequence for the formation of **3a** and **3b**.

conditions (1.1 eq. of PhMgBr in THF for 1 hour at rt.) followed by addition to a THF solution containing one equivalent of 4-nitrobenzaldehyde at -78 °C and warming to rt. over 1 hour, resulted in the clean formation of only the reduction/aldol products **2o** (62%) and **2p** (80%) in much improved yields (Table 3, entries 3 and 4).[18] However, when solutions of the corresponding enolates (formed as above) were added to two equivalents of 4-nitrobenzaldehyde at -78 °C and allowed to warm to rt. as before, the reduction/aldol-Tishchenko products **3a** and **3b** could be isolated in 85% and 90% yields respectively (Table 3, entries 5 and 6).

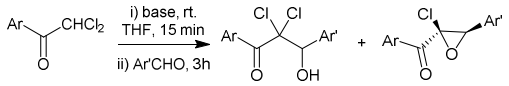
We also examined the reduction/aldol-Tishchenko reactions of **1b** with less electrophilic carbonyls; 4-methoxy and 4-bromobenzaldehyde. After reaction optimisation the corresponding reduction/aldol-Tishchenko products of **1b** and 4-methoxy or 4-bromobenzaldehyde were obtained in good yields but as inseparable mixtures of two regioisomeric esters **3c/4c** and **3d/4d** respectively, resulting from partial aryl migration (Table 3, entries 7 and 8). A single *anti*-1,3-diol **5a** could however be obtained in high yield through basic hydrolysis of **3d/4d**, helping to confirm our structural assignment (Scheme 4).



Scheme 4. Hydrolysis of regiomeric aldol/Tishchenko products **3d/4d**.

Next we investigated the counter-ion influence on the reactivity of 2,2-dichloro-1-(*p*-tolyl)ethen-1-olates, hypothesising that the presence of a chelating divalent magnesium cation would favour the formation of aldol or aldol-Tishchenko products whilst monovalent cations might lead to alternative reaction pathways. In particular we were keen to access Darzens type products as only two examples of a (2-chloro-3-aryloxiran-2-yl)(aryl)methanone are known in the literature and as it has been shown that (2-chloro-3-aryloxiran-2-yl)(aryl)methanones can be transformed into 3-chloro-1,2-diones under thermal conditions.[19] 3-Halo-1,2-diones are in turn flexible precursors for the synthesis of heteroaromatics, such as quinoxalines, (2-amino)-4-acylthiazoles and 3,4-dihydroxythiophenes,[20] as well

Table 4. Influence of enolate counter-ion on the formation of aldol verses Darzens products.



2(a-c) 2 6(a-h)

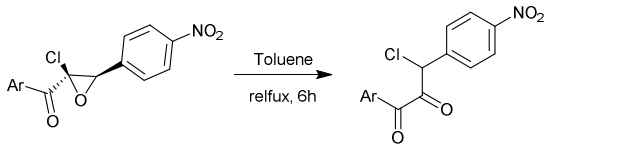
Entry	Starting Material	Ar	Base	Ar'	Yield (**2**)[a]	Yield (**6**)[a]
1	**2a**	1-methyl-1*H*-pyrrol-2-yl	NaH/$MgBr_2$	4-nitrophenyl	47%, **2n**	-
2	**2a**	1-methyl-1*H*-pyrrol-2-yl	LiHMDS	4-nitrophenyl	-	-[c]
3	**2a**	1-methyl-1*H*-pyrrol-2-yl	NaHMDS	4-nitrophenyl	-	20%, **6a**[b]
4	**2a**	1-methyl-1*H*-pyrrol-2-yl	NaH	4-nitrophenyl	-	54%, **6a**[b]
5	**2a**	1-methyl-1*H*-pyrrol-2-yl	NaH	phenyl	-	47%, **6b**
6	**2a**	1-methyl-1*H*-pyrrol-2-yl	NaH	4-bromophenyl	-	71%, **6c**
7	**2a**	1-methyl-1*H*-pyrrol-2-yl	NaH	4-iodophenyl	-	85%, **6d**
8	**2a**	1-methyl-1*H*-pyrrol-2-yl	NaH	4-methoxyphenyl	-	38%, **6e**
9	**2b**	*p*-tolyl	NaH	4-nitrophenyl	-	92%, **6f**[b]
10	**2c**	4-(*tert*-butyl)phenyl	NaH	4-nitrophenyl	-	74%, **6g**
11	**2z**[d]	phenyl	NaH	4-nitrophenyl	-	92%, **6h**[b]

[a] isolated yields. [b] structure confirmed by single-crystal X-ray analysis. [c] only starting material observed. [d] commercially available starting material

as being used by Alexakis *et al.* in an organocatalysed enantioselective domino Michael/aldol approach towards cyclopentanones.[21] However, general synthetic routes to 3-halo-1,2-diones are limited and often involve harsh oxidative halogenation conditions,[22] therefore the development of a new route to this synthetically useful class of molecules would be desirable.

Therefore we examined the conversion of our previously prepared 2,2-dichloro-1-arylethanones (**2a-c**) into their corresponding Darzens products.[23] Mono and divalent cation containing non-nucleophilic bases (NaH, NaH/$MgBr_2$, NaHMDS or LiHMDS) were used to deprotonate 2,2-dichloro-1-(1-methyl-1*H*-pyrrol-2-yl)ethan-1-one (**2a**) to give the corresponding sodium, magnesium or lithium enolates, which were added to 4-nitrobenzaldehyde.

The magnesium enolate of **2a** gave, in agreement with previous results, aldol product **2n** (Table 4, entry 1) whilst the lithium enolate of **2a** gave only recovered starting material (Table 4, entry 2). However the sodium enolate**,** formed by deprotonation of **2a** with NaHMDS or NaH, in THF gave the Darzens product **6a** in a 20% or 54% yield respectively (Table 4, entries 3 and 4), with single-crystal X-ray crystallography confirming **6a** as the *cis*-epoxide. Therefore we deprotonated our previously synthesised 2,2-dichloro-1-arylethanones (**2a-c**) and commercially available 2,2-dichloro-1-phenylethanone (**2z**) with sodium hydride followed by addition of range of arylaldehydes to give the desired *cis*-(2-chloro-3-aryloxiran-2-yl)(aryl)methanones **6b-h** in good to moderate yields (Table 4, entries 5-11). Finally we took two example molecules, **6a** and **6f**, and refluxed them in toluene.[19] After 6 hours they had been cleanly converted into **7a** and **7b** respectively, demonstrating a new simple route to 1,3-diaryl-3-chloropropane-1,2-diones (Scheme 5).



6a, Ar = 1-methyl-1*H*-pyrrol-2-yl
6f, Ar = *p*-tolyl

7a, Ar = 1-methyl-1*H*-pyrrol-2-yl (98%)
7b, Ar = *p*-tolyl (98%)

Scheme 5. Thermal rearrangement of Darzens products **6(a,f)** to give 1,3-diaryl-3-chloropropane-1,2-diones **7(a,b)**.

Conclusions

In conclusion we have shown that 2,2,2-trichloro-1-aryl-ethanones undergo facile Grignard-mediated reduction reactions. The magnesium enolates formed can be intercepted with simple electrophiles to give reduction, reduction/aldol, reduction/Claisen or reduction/aldol-Tishchenko products. Whilst sodium 2,2-dichloro-1-aryl-ethanonates react to give Darzens products which can subsequently undergo thermal rearrangement to give synthetically useful 1,3-diaryl-3-chloropropane-1,2-diones.

Experimental

General Procedure for the Reduction of 2,2,2-Trichloro-1-arylethanones

Under nitrogen, PhMgBr (2M in Et_2O, 0.55 mL, 1.1 mmol) was added to a 25 mL round-bottom flask. An appropriate 2,2,2-trichloro-1-arylethanone (1.0 mmol) was dissolved in dry THF (1 mL) and then added to the PhMgBr solution dropwise over 10 minutes at room temperature and stirred for a further one hour. The mixture was quenched by addition to saturated $NH_4Cl_{(aq)}$ (20 mL) and the product was extracted with ethyl acetate (3 x 15 mL). The combined organic extracts were dried over $MgSO_4$, filtered, the solvent removed under reduced pressure and crude product purified by column chromatography on silica gel.

2b - 2,2-dichloro-1-(*p*-tolyl) ethanone

White crystalline solid (0.138 g, 68%). Chromatography (petrol / diethyl ether 19:1). Mp: 58-59°C. R_f = 0.38 (petrol / diethyl ether, 19:1). ^{1}H NMR (300 MHz, $CDCl_3$): δ_H 7.89 (d, J = 8.0 Hz, 2H), 7.22 (d, J = 8.0 Hz, 2H), 6.61 (s, 1H), 2.35 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$): δ_C 185.7, 146.0, 129.9, 129.7, 128.8, 67.9, 21.9. IR (neat): υ_{max}/cm^{-1} 3017, 1689. HRMS (EI) calcd for $C_9H_8Cl_2O$ $[M+H]^+$: 203.0025, found 203.0027.

2c - 1-(4-(*tert*-butyl)phenyl)-2,2-dichloroethan-1-one

Colourless solid (0.175 g, 71%). Chromatography (petrol 40/60 : ether = 50 : 1). Mp: 63-64°C. R_f: 0.43 (UV active, petrol 40/60 : ether = 50: 1). ^{1}H NMR (300 MHz, $CDCl_3$): δ_H 8.05 (d, J = 8.6 Hz, 2H), 7.55 (d, J = 8.6 Hz, 2H), 6.70 (s, 1H), 1.37 (s, 9H). ^{13}C NMR (75 MHz, $CDCl_3$): δ_C 185.5, 158.6, 129.7, 128.8, 125.8, 67.8, 35.3, 30.9. IR (neat): υ_{max}/cm^{-1} 2965, 2870, 1704, 853, 701. HRMS (pNSI): calcd for $C_{12}H_{15}OCl_2$ $[M+H]^+$: 245.0494, found 245.0493.

2d - 2,2-dichloro-1-(5-methylfuran-2-yl)ethan-1-one

Brown oil (0.088 g, 58%). Chromatography (petrol 40/60 : ether = 7 : 3). R_f: 0.54 (UV active, petrol 40/60 : ether = 7: 3). ^{1}H NMR (400 MHz, $CDCl_3$): δ_H 7.42-7.40 (m, 1H), 6.52 (s, 1H), 6.27-6.25 (m, 1H), 2.43-2.42 (m, 3H). ^{13}C NMR (100 MHz, $CDCl_3$): δ_C 174.7, 160.4, 146.3, 123.6, 110.3, 66.8, 14.3. IR (neat): υ_{max}/cm^{-1} 3123, 1679, 1505, 1203, 1022, 803, 742. HRMS (pNSI): calcd for $C_7H_6O_2Cl_2$ $[M+H]^+$: 192.9818, found 192.9819.

2e - 2,2-dichloro-1-(1*H*-indol-3-yl)ethan-1-one

Colourless solid (0.108 g, 33%). Chromatography (petrol 40/60 : EtOAc = 3 : 2). Mp = 235-237 °C. R_f: 0.15 (UV active, petrol 40/60 : EtOAc = 7 : 3). ^{1}H NMR (300 MHz, *d*6-DMSO): δ_H 12.42 (s, 1H), 8.61 (s, 1H), 8.22-8.06 (m, 1H), 7.61 (s, 1H), 7.58-7.51 (m, 1H), 7.33-7.23 (m, 2H). ^{13}C NMR (100 MHz, *d*6-DMSO): δ_C 181.4, 137.5, 136.4, 126.3, 124.4, 123.3, 121.7, 113.3, 111.0, 69.3. IR (neat): υ_{max}/cm^{-1}: 3216, 2981, 1640, 1425, 1236, 1148, 740, 627. HRMS (pNSI): calcd for $C_{10}H_8Cl_2NO$ $[M+H]^+$: 227.9977, found 227.9979. *Note*: 2.2 equivalents of PhMgBr required.

2f - 2,2-dichloro-1-(1-methyl-1*H*-indol-3-yl)ethan-1-one

Yellow solid (0.180 g, 75%). Chromatography (petrol 40/60 : EtOAc = 9 : 1). Mp = 206-208 °C. R_f: 0.49 (UV active, petrol 40/60 : EtOAc = 7: 3). ^{1}H NMR (300 MHz, $CDCl_3$): δ_H 8.40-8.38 (m, 1H), 8.09 (s, 1H), 7.46-7.36 (m, 3H), 6.41 (s, 1H), 3.93 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$): δ_C 181.8, 137.4, 136.9, 127.2, 124.2, 123.6, 122.8, 110.1, 109.3, 69.3, 34.0. IR (neat): υ_{max}/cm^{-1} 3100, 1636, 1531, 1087, 741, 710, 699. HRMS (pNSI): calcd for $C_{11}H_{10}Cl_2NO$ $[M+H]^+$: 242.0134, found 242.0134.

General Procedure for the Reduction of 2,2,2-Trichloro-1-arylethanones; Trapping with D_2O

Under nitrogen, PhMgBr (2M in Et_2O, 0.55 mL, 1.1 mmol) was added to a 25 mL round-bottom flask. An appropriate 2,2,2-trichloro-1-arylethanone (1.0 mmol) was dissolved in dry THF (1 mL) and then added to the PhMgBr solution dropwise over 10 minutes at room temperature and stirred for a further one hour. The reaction was quenched with D_2O (0.02 mL) and extracted with ethyl acetate (3 x 15 mL). The combined organic solvent was dried over $MgSO_4$, filtered, evaporated under reduced pressure and purified by column chromatography on silica gel.

2b-*d* - 2,2-dichloro-2-deuterium-1-(*p*-tolyl) ethanone

Colourless oil (0.102 g, 50%, 96% deuterium incorporation by ^{1}H NMR). Chromatography (petrol / diethyl ether 19:1). R_f = 0.30 (petrol / diethyl ether, 49/1). ^{1}H NMR (300 MHz, $CDCl_3$): δ_H 8.19 (d, J = 8.4 Hz, 2H), 7.31 (d, J = 8.4 Hz, 2H), 2.46 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$): δ_C 185.7, 146.0, 130.0, 130.0, 128.8, 67.6 (t, J_{CD} = 28.0 Hz), 21.9. IR (neat): υ_{max}/cm^{-1} 2924, 1690. MS (pNSI): 225.0 (100%, $[M+H]^+$).

2c-*d* - 1-(4-(*tert*-butyl)phenyl)-2,2-dichloroethan-1-one-2-*d*

Colourless oil (0.238 g, 96%, 88% deuterium incorporation by ^{1}H NMR). Chromatography (petrol 40/60 : ether = 70 : 1). R_f: 0.33 (UV active, petrol 40/60 : ether = 70: 1). ^{1}H NMR (300 MHz, $CDCl_3$): δ_H 8.05 (d, J = 8.9 Hz, 2H), 7.55 (d, J = 8.9 Hz, 2H), 1.37 (s, 9H). ^{13}C NMR (75 MHz, $CDCl_3$): δ_C 185.5, 158.6, 129.7, 128.8, 125.8, 67.6 (t, J_{CD} = 27.1 Hz), 35.3, 30.9. IR (neat): υ_{max}/cm^{-1} 2965, 2870, 1699, 1604, 1256, 917, 768, 696. HRMS (pNSI): calcd for $C_{12}H_{13}DOCl_2$ $[M+H]^+$:246.0557, found 246.0557.

2d-*d* - 2,2-dichloro-1-(5-methylfuran-2-yl)ethan-1-one-2-*d*

Yellow oil (0.132 g, 68%, 93% deuterium incorporation by ^{1}H NMR). Chromatography (petrol 40/60 : ether = 8 : 2). R_f: 0.41 (UV active, petrol 40/60 : ether = 7: 3). ^{1}H NMR (400 MHz, $CDCl_3$): δ_H 7.41-7.40 (m, 1H), 6.27-6.25 (m, 1H), 2.42-2.41 (m, 3H). ^{13}C NMR, (100 MHz, $CDCl_3$): δ_C 174.5, 160.2, 146.1, 123.4, 110.2, 66.7 (t, J_{CD} = 27.1 Hz), 14.1. IR (neat): υ_{max}/cm^{-1} 3123, 1674, 1505, 1211, 1033, 914, 761. HRMS (pNSI): $C_7H_6DO_2Cl_2$ $[M+H]^+$:193.9880, found 193.9877.

2f-*d* - 2,2-dichloro-1-(1-methyl-1*H*-indol-3-yl)ethan-1-one-2-*d*

Colourless solid (0.158 g, 65%, 96% deuterium incorporation by ^{1}H NMR). Chromatography (petrol 40/60 : EtOAc = 9 : 1). Mp = 211-213 °C. R_f: 0.14 (UV active, petrol 40/60 : EtOAc = 9: 1). ^{1}H NMR (300 MHz, $CDCl_3$): δ_H 8.42-8.37 (m, 1H), 8.10 (s, 1H), 7.44-7.34 (m, 3H), 3.93 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$): δ_C 181.8, 137.4, 136.9, 127.2, 124.2, 123.6, 122.8, 110.1, 34.0. IR (neat): υ_{max}/cm^{-1} 3100, 2981, 1632, 1530, 1372, 1239, 740, 698, 661. HRMS (pNSI): calcd for $C_{11}H_9DCl_2NO$ $[M+H]^+$: 243.0197, found 243.0200. *Notes*: 2.2 equivalents of PhMgBr required, ^{13}C signal for **C**DCl_2 group not observed due to low intensity.

General Procedure for the Reduction of 2,2,2-Trichloro-1-arylethanones/Aldol reaction with aldehydes or ketones

Under nitrogen, PhMgBr (2M in Et_2O, 0.55 mL, 1.1 mmol) was added to a 25 mL round-bottom flask. An appropriate 2,2,2-trichloro-1-arylethanone (1.0 mmol) was dissolved in dry THF (1 mL) and then added to the PhMgBr solution dropwise over 10 minutes at room temperature and stirred for one hour. A solution of appropriate aldehyde or ketone (1 mmol) in THF (1 mL) was then added dropwise into the mixture which was stirred for a further 1 hour. The reaction was quenched with saturated $NH_4Cl_{(aq)}$ solution (10 mL) and extracted with ethyl acetate (3 x 15 mL). The combined organic solvent was dried over $MgSO_4$, filtered, evaporated under reduced pressure and purified by column chromatography on silica gel.

2h - 2,2-dichloro-3-hydroxy-3-(perfluorophenyl)-1-(*p*-tolyl)propan-1-one

Colourless solid (0.367 g, 92%). Chromatography (petrol 40/60 : ether = 7 : 3). Mp = 119-120 °C. R_f: 0.48 (UV active, petrol 40/60 : ether = 7: 3). ^{1}H NMR (300 MHz, $CDCl^3$): δ_H 8.19 (d, J = 8.3 Hz, 2H), 7.29 (d, J = 8.3 Hz, 2H), 6.07 (d, J = 6.5 Hz, 1H), 3.89 (d, J = 6.5 Hz, 1H), 2.47 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$): δ_C 188.9, 145.9, 131.49, 129.2, 128.4, 85.4, 73.1, 21.9. IR (neat): υ_{max}/cm^{-1} 3334, 1689, 1606, 1524, 1496, 994, 859. HRMS (pNSI): calcd for

$C_{16}H_{10}O_2Cl_2F_5$ $[M+H]^+$: 398.9973 found 398.9968. *Note*: ^{13}C signals for C_6F_5 group not observed due to low intensity.

2i - 2,2-dichloro-3-hydroxy-1-(5-methylfuran-2-yl)-3-(perfluorophenyl)propan-1-one

Yellow oil (0.108 g, 28%). Chromatography (petrol 40/60 : ether = 9 : 1). R_f: 0.35 (UV active, petrol 40/60 : ether = 6: 4). ^1H NMR (400 MHz, $CDCl_3$): δ_H 7.65 (dd, J = 3.6, 1H), 6.31 (d, J = 3.6 Hz, 1H), 6.09 (s, 1H), 2.48 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$): δ_C 177.0, 160.9, 145.7, 126.3, 110.3, 110.1, 85.3, 72.8, 14.3. IR (neat): υ_{max}/cm^{-1} 3390, 1656, 1499, 1292, 1148, 996, 801. HRMS (pNSI): calcd for $C_{14}H_8Cl_2F_5O_3$ $[M+H]^+$: 388.9765, found 388.9758. *Note*: ^{13}C signals for C_6F_5 group not observed due to low intensity.

2j - 2,2-dichloro-3-hydroxy-1-(1*H*-indol-3-yl)-3-(perfluorophenyl)propan-1-one

Colourless solid (0.242 g, 57%). Chromatography (petrol 40/60 : ether = 3 : 2). Mp = 229-231 °C. R_f: 0.14 (UV active, petrol 40/60 : ether = 3: 2). ^1H NMR (300 MHz, d6-DMSO): δ_H 12.31 (s, 1H), 8.57 (d, J = 3.3 Hz, 1H), 8.23 (dd, J = 6.5, 2.9 Hz, 1H), 7.67-7.45 (m, 1H), 7.32-7.24 (m, 2H), 7.20 (d, J = 6.6 Hz, 1H), 6.08 (d, J = 6.6 Hz, 1H). ^{13}C NMR (100 MHz, *d*6-DMSO): δ_C 182.7, 136.4, 136.2, 127.8, 124.0, 123.2, 121.9, 113.1, 109.4, 90.3, 72.2. IR (neat): υ_{max}/cm^{-1} 3572, 3254, 1642, 1501, 1433, 1240, 999. HRMS (pNSI): calcd for $C_{17}H_9Cl_2F_5NO_2$ $[M+H]^+$: 423.9925, found 423.9922. *Note*: ^{13}C signals for C_6F_5 group not observed due to low intensity.

2k - 2,2-dichloro-3-hydroxy-1-(1-methyl-1*H*-indol-3-yl)-3-(perfluorophenyl)propan-1-one

Colourless solid (0.271 g, 62%). Chromatography (petrol 40/60 : EtOAc = 9: 1). Mp = 209-210 °C. R_f: 0.25 (UV active, petrol 40/60 : EtOAc = 9: 1). ^1H NMR (400 MHz, $CDCl_3$): δ_H 8.40-8.35 (m, 1H), 8.35 (s, 1H), 7.42-7.33 (m, 3H), 6.12 (d, J = 5.2 Hz, 1H), 4.38(d, J = 5.2 Hz, 1H), 3.92 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$): δ_C 185.4, 138.9, 136.9, 128.1, 124.2, 123.9, 122.8, 110.2, 108.2, 100.00, 73.2, 34.1. IR (neat): υ_{max}/cm^{-1} 3467, 1646, 1524, 1504, 1230, 998, 748. HRMS (pNSI): calcd for $C_{18}H_{11}Cl_2F_5NO_2$ $[M+H]^+$:438.0082, found 438.0080. *Note*: ^{13}C signals for C_6F_5 group not observed due to low intensity.

2m - 2,2-dichloro-3-hydroxy-3-(5-methylfuran-2-yl)-1-(*p*-tolyl) propan-1-one

Green oil (0.149 g, 48 %). Chromatography (petrol / diethyl ether, 7:3). R_f = 0.66 (petrol / diethyl ether 7:3). ^1H NMR (300 MHz, $CDCl_3$): δ_H 8.21 (d, J = 8.3 Hz, 2H), 7.30 (d, J = 8.3 Hz, 2H), 6.49 (d, J = 3.2 Hz, 1H), 6.03 (dd, J = 3.2, 1.1 Hz, 1H), 5.60 (s, 1H), 3.78 (br s, 1H), 2.45 (s, 3H), 2.34 (s, 3H). ^{13}C NMR (101 MHz, $CDCl_3$): δ_C 189.6, 152.5, 148.1, 145.3, 131.3, 129.1, 129.1, 111.4, 106.7, 86.1, 73.7, 21.9, 13.7. IR (neat): υ_{max}/cm^{-1} 3427, 2923, 1683. HRMS (pNSI) calcd for $C_{15}H_{14}Cl_2O_3$ $[M+H]^+$: 313.0398, found 313.0755.

2q - 2,2-dichloro-3-hydroxy-1-(1-methyl-1*H*-indol-3-yl)-3-(4-nitrophenyl)propan-1-one

Colourless solid (0.250 g, 64%). Chromatography (petrol 40/60 : EtOAc = 4 : 1). Mp = 216-218 °C. R_f: 0.15 (UV active, petrol 40/60 : EtOAc = 4: 1). ^1H NMR (300 MHz, $CDCl_3$): δ_H 8.48-8.38 (m, 1H), 8.36 (s, 1H), 8.28 (d, J = 8.9 Hz), 7.86 (d, J = 8.9 Hz), 7.44-7.40 (m, 3H), 5.72 (d, J = 3.2 Hz, 1H), 4.57 (d, J = 3.2 Hz, 1H), 3.94 (s, 3H). ^{13}C NMR (75 MHz, $CDCl_3$): δ_C 186.1, 148.3, 143.1, 138.8, 136.9, 130.8, 128.1, 124.1, 123.8, 122.8, 122.3, 109.9, 108.8, 86.4, 33.8. IR (neat): υ_{max}/cm^{-1} 3524, 1631, 1520, 1349, 751, 711. HRMS (pNSI): calcd for $C_{18}H_{15}Cl_2N_2O_4$ $[M+H]^+$: 393.0403, found 393.0399.

2s - diethyl 2-(1,1-dichloro-2-oxo-2-(*p*-tolyl)ethyl)-2-hydroxymalonate

Yellow oil (0.345 g, 92%). Chromatography (petrol 40/60 : ether = 9 : 1). R_f: 0.21 (UV active, petrol 40/60 : ether = 9: 1). ^1H NMR (300 MHz, $CDCl_3$): δ_H 8.12 (d, J = 8.3 Hz, 2H), 7.27 (d, J = 8.3 Hz, 2H), 4.62 (s, 1H), 4.36 (q, J = 7.1 Hz, 4H), 2.43 (s, 3H), 1.32 (t, J = 7.1 Hz, 6H). ^{13}C NMR (100 MHz, $CDCl_3$): δ_C 187.6, 166.5, 144.9, 130.8, 129.0, 128.8, 100.00, 82.6, 63.3, 21.7, 13.8. IR (neat): υ_{max}/cm^{-1} 3455, 2984, 1738, 1690, 1236, 1134, 858. HRMS (pNSI): calcd for $C_{16}H_{19}O_6Cl_2$ $[M+H]^+$: 377.0559, found 377.0553.

2t - diethyl 2-(1,1-dichloro-2-(1-methyl-1*H*-indol-3-yl)-2-oxoethyl)-2-hydroxymalonate

Brown solid (0.135 g, 32%). Chromatography (petrol 40/60 : EtOAc = 40 : 1). Mp = 218-219 °C. R_f: 0.07 (UV active, petrol 40/60 : EtOAc = 40: 1). ^1H NMR (300 MHz, $CDCl_3$): δ_H 8.40 (s, 1H), 8.34-8.30 (m, 1H), 7.39-7.29 (m, 3H), 4.75 (s, 1H), 4.37 (q, J = 7.1 Hz, 4H), 3.89 (s, 3H), 1.32 (t, J = 7.1 Hz, 6H). ^{13}C NMR (75 MHz, $CDCl_3$): δ_C 183.1, 166.6, 138.0, 136.8, 128.3, 123.8, 123.3, 122.8, 109.7, 108.2, 85.9, 82.9, 62.9, 33.7, 13.8. IR (neat): υ_{max}/cm^{-1} 3517, 2984, 1754, 1736, 1635, 1519, 1223, 1127, 1094, 756, 627. HRMS (pNSI): calcd for $C_{18}H_{20}Cl_2NO_6$ $[M+H]^+$: 416.0662, found 416.0666.

2o - 2,2-dichloro-3-hydroxy-3-(4-nitrophenyl)-1-(*p*-tolyl)propan-1-one

Under nitrogen, PhMgBr (2M, 0.55 mL, 1.1 mmol) was added to a 25 mL round-bottom flask. 2,2,2-Trichloro-1-(*p*-tolyl)ethanone (**1b**) (0.237 g, 1.0 mmol) was dissolved in dry THF (1 mL) and then added to the PhMgBr solution dropwise over 10 minutes at room temperature, and stirred for one hour. The reaction mixture was added to a solution of *p*-nitrobenzaldehyde (0.151 g, 1.0 mmol) in 1 mL of THF at -78 °C. The reaction mixture was then allowed to warm to r.t. over 1 hour whilst stirring. The reaction mixture was quenched by addition to saturated $NH_4Cl_{(aq)}$ (20 mL) and the product was extracted using ethyl acetate (3 x 15 mL). The combined organic extracts were dried over $MgSO_4$, filtered and the solvent removed under reduced pressure. The crude product was purified by silica gel column chromatography (petrol / diethyl ether, 7:3) to give 2,2-dichloro-3-hydroxy-3-(4-nitrophenyl)-1-(*p*-tolyl)propan-1-one (**2o**) as a white powder (0.219 g, 62%).
Mp: 236-238°C. R_f = 0.51 (petrol / diethyl ether 7:3). ^1H NMR (300 MHz, $CDCl_3$): δ_H 8.32 – 8.21 (m, 4H), 7.88 – 7.78 (m, 2H), 7.32 (dd, J = 8.7, 0.8 Hz, 2H), 5.68 (d, J = 3.7 Hz, 1H), 4.02 (d, J = 3.7 Hz, 1H), 2.47 (s, 3H). ^{13}C NMR (101 MHz, $CDCl_3$): δ_C 190.0, 148.3, 146.0, 142.6, 131.7, 131.0, 129.2, 128.5, 122.6, 85.4, 77.1, 21.9. IR (neat): υ_{max}/cm^{-1} 3537, 2921, 1664. HRMS (pNSI) calcd for $C_{16}H_{13}Cl_2NO_4$ $[M+Na]^+$: 378.0084, found 378.0086.

2p - 1-(4-(*tert*-butyl)phenyl)-2,2-dichloro-3-hydroxy-3-(4-nitrophenyl)propan-1-one

To a 25 mL round-bottom flask under nitrogen was added PhMgBr (0.55 mL, 1.1 mmol). Into that flask was added 1-(4-(*tert*-butyl)phenyl)-2,2,2-trichloroethan-1-one (**1c**) (0.279 g, 1 mmol) in 1 mL THF and the mixture was stirred for 1 hour. The reaction mixture was added to a solution of *p*-nitrobenzaldehyde (0.151 g, 1.0 mmol) in 1 mL of THF at -78 °C. The reaction mixture was then allowed to warm to r.t. over 1 hour whilst stirring. The reaction was quenched with 10 mL of saturated $NH_4Cl_{(aq)}$ solution and extracted with 3x15 mL of ethyl acetate. The combined organic solvent was dried using $MgSO_4$, filtered and evaporated to give an oil. The crude product was purified through silica gel column chromatography (petrol 40/60 : ether = 50 : 1) to give 1-(4-(*tert*-butyl)phenyl)-2,2-

dichloro-3-hydroxy-3-(4-nitrophenyl)propan-1-one (**2p**) as a colourless solid (0.318 g, 80%).
Mp = 182-184 °C. R_f: 0.15 (UV active, petrol 40/60 : ether = 10: 1). ^{1}H NMR (300 MHz, $CDCl_3$): δ_H 8.32-8.25 (m, 4H), 7.86-7.81 (m, 2H), 7.56-7.50 (m, 2H), 5.68 (d, *J* = 3.7 Hz, 1H), 4.04 (d, *J* = 3.7 Hz, 1H), 1.38 (s, 9H). ^{13}C NMR (100 MHz, $CDCl_3$): δ_C 189.8, 158.7, 148.1, 142.5, 131.5, 130.8, 128.2, 125.3, 122.5, 85.2, 35.3, 30.9. IR (neat): υ_{max}/cm^{-1} 3554, 2965, 1671, 1599, 1512, 1345, 1255, 870, 706, 613. HRMS (pNSI): calcd for $C_{19}H_{23}N_2O_4Cl_2$ $[M+NH_4]^+$: 413.1029, found 413.1027.

General Procedure for the Reduction of 2,2,2-Trichloro-1-arylethanones/Claisen condensation with 4-nitrobenzoyl chloride

Under nitrogen, PhMgBr (2M in Et_2O, 0.55 mL, 1.1 mmol) was added to a 25 mL round-bottom flask. An appropriate 2,2,2-trichloro-1-arylethanone (1.0 mmol) was dissolved in dry THF (1 mL) and then added to the PhMgBr solution dropwise over 10 minutes at room temperature and stirred for one hour. A solution of 4-nitrobenzoyl chloride (0.185 g, 1 mmol) in THF (1 mL) was then added dropwise into the mixture which was stirred for a further 1 hour. The reaction was quenched with saturated $NH_4Cl_{(aq)}$ solution (10 mL) and extracted with ethyl acetate (3 x 15 mL). The combined organic solvent was dried over $MgSO_4$, filtered, evaporated under reduced pressure and purified by column chromatography on silica gel.

2v - 2,2-dichloro-1-(4-nitrophenyl)-3-(*p*-tolyl)propane-1,3-dione

Colourless oil; inseparable 4:1 mixture of 2,2-dichloro-1-(4-nitrophenyl)-3-(*p*-tolyl)propane-1,3-dione (**2v**) (0.278 g, 79%) and 2,2-dichloro-1-(*p*-tolyl)ethanone (**2b**) (0.046 g, 20%). Chromatography (petrol 40/60 : ether = 9 : 1). R_f: 0.35 (UV active, petrol 40/60 : ether = 9: 1). ^{1}H NMR (300 MHz, $CDCl_3$): δ_H 8.23 (d, *J* = 9.1 Hz, 2H), 8.10 (d, *J* = 9.1 Hz, 2H), 7.93 (d, *J* = 8.1 Hz, 2H), 7.25 (d, *J* = 8.4 Hz, 2H), 2.42 (s, 3H). ^{13}C NMR, (100 MHz, $CDCl_3$): δ_C 185.1, 184.1, 150.5, 146.3, 136.4, 131.4, 130.7, 129.6, 128.2, 123.7, 83.3, 21.9. IR (neat): υ_{max}/cm^{-1} 3111, 3055, 1703, 1690, 1601, 1526, 694. HRMS (pNSI): calcd for $C_{16}H_{12}NO_4Cl_2$ $[M+H]^+$: 352.0138, found 352.0134.

2w - 1-(4-(*tert*-butyl)phenyl)-2,2-dichloro-3-(4-nitrophenyl)propane-1,3-dione

Colourless oil; inseparable 4:1 mixture of 1-(4-(*tert*-butyl)phenyl)-2,2-dichloro-3-(4-nitrophenyl)propane-1,3-dione (**2w**) (0.130 g, 33%) and 1-(4-(*tert*-butyl)phenyl)-2,2-dichloroethan-1-one (**2c**) (0.020 g, 8%). Chromatography (petrol 40/60 : ether = 40 : 1). R_f: 0.28 (UV active, petrol 40/60 : ether = 30: 1). ^{1}H NMR (300 MHz, $CDCl_3$): δ_H 8.25 (dd, *J* = 9.1 Hz, 2H), 8.12 (dd, *J* = 9.1 Hz, 2H), 7.99 (d, *J* = 8.8 Hz, 2H), 7.47 (dd, J = 8.8 Hz, 2H), 1.32 (s, 9H). ^{13}C NMR (75 MHz, $CDCl_3$): δ_C 185.2, 184.2, 159.0, 150.5, 136.9, 131.4, 130.0, 129.7, 125.8, 123.5, 86.4, 35.3, 30.8. IR (neat): υ_{max}/cm^{-1} 2965, 2870, 1695, 1602, 1528, 1347, 849, 692. HRMS (pNSI): calcd for $C_{19}H_{18}NO_4Cl_2$ $[M+H]^+$:394.0607, found 394.0604.

2x - 2,2-dichloro-1-(5-methylfuran-2-yl)-3-(4-nitrophenyl)propane-1,3-dione

Yellow oil (0.221 g, 65%). Chromatography (petrol 40/60 : ether = 8 : 2). R_f: 0.45 (UV active, petrol 40/60 : ether = 7: 3). ^{1}H NMR (300 MHz, $CDCl_3$): δ_H 8.26 (d, *J* = 8.9 Hz, 2H), 8.14 (d, *J* = 8.9 Hz, 2H), 7.40 (d, *J* = 3.7 Hz, 1H), 6.19 (d, *J* = 3.7 Hz, 1H), 2.33 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$): δ_C 183.7, 172.7, 160.6, 150.5, 145.9, 136.8, 131.2, 125.2, 123.8, 110.5, 14.3. IR(neat): υ_{max}/cm^{-1}: 3119, 1713, 1682, 1531, 1504, 813, 787, 695. HRMS (pNSI): $C_{14}H_{10}Cl_2NO_5$ $[M+H]^+$: 341.9931, found 341.9927. *NB*: quaternary ^{13}C (CCl_2) not observed.

2y - 2,2-dichloro-1-(1-methyl-1*H*-indol-3-yl)-3-(4-nitrophenyl)propane-1,3-dione

Yellow solid (0.253 g, 65%). Chromatography (petrol 40/60 : EtOAc = 4 : 1). Mp = 74-75 °C. R_f: 0.26 (UV active, petrol 40/60 : EtOAc = 4: 1). ^{1}H NMR (300 MHz, $CDCl_3$): δ_H 8.40-8.35 (m, 1H), 8.22-8.13 (m, 4H), 8.03 (s, 1H), 7.38-7.36 (m, 3H), 3.87 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$): δ_C 184.8, 179.9, 150.4, 138.0, 137.0, 131.6, 127.8, 124.7, 124.2, 123.6, 122.8, 110.2, 109.3, 34.2. IR(neat): υ_{max}/cm^{-1}: 2981, 1711, 1659, 1628, 1521, 1347, 1226, 746, 693. HRMS (pNSI): calcd for $C_{18}H_{13}Cl_2N_2O_4$ $[M+H]^+$: 391.0247, found 391.0247.

3a - (1*R,3*R**)-2,2-dichloro-3-hydroxy-3-(4-nitrophenyl)-1-(*p*-tolyl)propyl 4-nitrobenzoate**

Under nitrogen, PhMgBr (2M, 0.55 mL, 1.1 mmol) was added to a 25 mL round-bottom flask. 2,2,2-Trichloro-1-(*p*-tolyl)ethanone (0.237 g, 1.0 mmol) was dissolved in dry THF (1 mL) and then added to the PhMgBr solution dropwise over 10 minutes at room temperature and stirred for a further one hour. The mixture was added to *p*-nitrobenzaldehyde (0.302 g, 2 mmol) in 1 mL of THF at -78°C and allowed to warm to r.t. over 1h. The reaction mixture was quenched by addition to saturated $NH_4Cl_{(aq)}$ (20 mL) and the product was extracted using ethyl acetate (3 x 15 mL). The combined organic extracts were dried over $MgSO_4$, filtered and the solvent removed under reduced pressure. The crude product was purified by silica gel column chromatography (petrol / diethyl ether, 7:3) to give (1*R**,3*R**)-2,2-dichloro-3-hydroxy-3-(4-nitrophenyl)-1-(*p*-tolyl)propyl 4-nitrobenzoate (**3a**) as a white powder (0.430g, 85%).
Mp: 148-150 °C. R_f = 0.16 (petrol / diethyl ether 8:2). ^{1}H NMR (300 MHz, DMSO-*d6*): δ_H 8.41 (d, *J* = 8.9 Hz, 2H), 8.33 (d, *J* = 8.9 Hz, 2H), 8.24 (d, *J* = 8.8 Hz, 2H), 7.92 (d, *J* = 8.8 Hz, 2H), 7.49 (d, *J* = 8.1 Hz, 2H), 7.21 (d, *J* = 8.1 Hz, 2H), 7.17 (d, *J* = 5.7 Hz, 1H), 6.55 (s, 1H), 5.49 (d, *J* = 5.7 Hz, 1H), 2.30 (s, 3H). ^{13}C NMR (101 MHz, DMSO-*d6*): δ_C 162.8, 151.1, 147.9, 146.7, 139.1, 134.8, 131.6, 131.5, 129.8, 128.9, 124.6, 122.8, 94.6, 78.1, 75.8, 21.2. IR (neat): υ_{max}/cm^{-1} 3497, 2960, 2872, 1727. HRMS (pNSI) calcd for $C_{23}H_{18}Cl_2N_2O_7$ $[M+NH_4]^+$: 522.0829, found 522.0825.

3b - (1*R,3*R**)-1-(4-(*tert*-butyl)phenyl)-2,2-dichloro-3-hydroxy-3-(4-nitrophenyl)propyl 4-nitrobenzoate**

To a 25 mL round-bottom flask under nitrogen was added PhMgBr (0.55 mL, 1.1 mmol). Into that flask was added 2,2,2-trichloro-1-(4-(*tert*-butylphenyl)ethan-1-one (0.279 g, 1 mmol) in 1 mL THF and the mixture was stirred for 1 hour. The mixture was added to *p*-nitrobenzaldehyde (0.302 g, 2 mmol) in 1 mL of THF at -78°C and allowed to warm to r.t. over 1h. The reaction was quenched with 10 mL of saturated $NH_4Cl_{(aq)}$ solution and extracted with 3x15 mL of ethyl acetate. The organic solvent was dried using $MgSO_4$, filtered and evaporated to give an oil. The crude product was purified through silica gel column chromatography (petrol 40/60 : ether = 9 : 1) to give (1*R**,3*R**)-1-(4-(*tert*-butyl)phenyl)-2,2-dichloro-3-hydroxy-3-(4-nitrophenyl)propyl 4-nitrobenzoate (**3b**) as a colourless solid (0.247 g, 90%).
Mp = 147-149 °C. R_f: 0.25 (UV active, petrol 40/60 : ether = 9: 1). ^{1}H NMR (300 MHz, $CDCl_3$): δ_H 7.54 – 7.38 (m, 3H). 8.44 – 8.31 (m, 2H), 8.24 (d, *J* = 8.8 Hz, 1H), 7.80 (d, *J* = 8.8 Hz, 1H), 7.64 (d, *J* = 8.4 Hz, 1H), 7.46 (d, *J* = 8.4 Hz, 1H), 6.73 (s, 1H), 5.24 (d, *J* = 5.4 Hz, 1H), 3.75 (d, *J* = 5.4 Hz, 1H), 1.35 (s, 9H). ^{13}C NMR (100 MHz, $CDCl_3$): δ_C 164.0, 152.9, 151.2, 148.2, 143.6, 134.2, 131.4, 130.6, 129.5, 125.2, 124.0, 122.8, 93.0, 78.4, 77.3, 34.8, 31.3. IR(neat):

υ_{max}/cm^{-1}: 3495, 2964, 1727, 1514. HRMS (pNSI): calcd for $C_{26}H_{28}N_3O_7Cl_2$ $[M+NH_4]^+$: 564.1299, found 564.1294.

3c/4c - (1*R,3*R**)-2,2-dichloro-3-hydroxy-3-(4-methoxyphenyl)-1-(*p*-tolyl)propyl 4-methoxybenzoate and (1*R**,3*R**)-2,2-dichloro-3-hydroxy-1-(4-methoxyphenyl)-3-(*p*-tolyl)propyl 4-methoxybenzoate**

Under nitrogen, PhMgBr (2M, 0.55 mL, 1.1 mmol) was added to a 25 mL round-bottom flask. 2,2,2-Trichloro-1-(*p*-tolyl)ethanone (0.237 g, 1.0 mmol) was dissolved in dry THF (1 mL) and then added to the PhMgBr solution dropwise over 10 minutes at room temperature and stirred for one hour. The reaction mixture was added to 4-methoxybenzaldehyde (0.544 g, 0.484 mL, 2.0 mmol) and stirred for 1h at room temperature. The mixture was quenched by addition to saturated $NH_4Cl_{(aq)}$ (20 mL) and the product was extracted using ethyl acetate (3 x 15 mL). The combined organic extracts were dried over $MgSO_4$, filtered and the solvent removed under reduced pressure. The crude product was purified by silica gel column chromatography (petrol / diethyl ether, 7:3) to give an inseparable mixture of (1*R**,3*R**)-2,2-dichloro-3-hydroxy-3-(4-methoxyphenyl)-1-(*p*-tolyl)propyl 4-methoxybenzoate (**3c**) and (1*R**,3*R**)-2,2-dichloro-3-hydroxy-1-(4-methoxyphenyl)-3-(*p*-tolyl)propyl 4-methoxybenzoate (**4c**) as a yellow solid (0.172 g, 72 %) in an approximate 1:1 ratio.
Mp: 119-121 °C. R_f = 0.20 (petrol / diethyl ether 8:2). ^{1}H NMR (300 MHz, DMSO-d_6): δ_H 8.03 (d, J = 8.8 Hz, $2H_a$ + $2H_b$), 7.54 – 7.38 (m, $2H_a$ + $2H_b$), 7.19 – 7.12 (m, $2H_a$ + $2H_b$), 7.13 (d, J = 8.8 Hz, $2H_a$ + $2H_b$), 6.94 (d, J = 6.0 Hz, $2H_a$), 6.91 (d, J = 5.8 Hz, $2H_b$). 6.62 (d, J = 5.5 Hz, $1H_a$), 6.60 (d, J = 5.5 Hz, $1H_b$), 5.19 (d, J = 5.5 Hz, $1H_a$ + $1H_b$), 3.77 (s, $3H_a$ + $3H_b$), 3.75 (s, $3H_b$), 3.74 (s, $3H_a$), 2.29 (s, $3H_a$ + $3H_b$). ^{13}C NMR (101 MHz, $CDCl_3$): δ_C 165.5, 165.4, 164.2, 160.2, 159.9, 139.1, 138.6, 134.1, 132.3, 131.8, 131.2, 130.6, 129.8, 129.3, 129.2, 128.6, 128.4, 126.9, 121.4, 121.4, 114.1, 113.2, 113.0, 95.0, 94.9, 77.4, 55.7, 55.3, 21.4, 21.3. IR(neat): υ_{max}/cm^{-1}: 3447, 2963, 2840, 1721. HRMS (pNSI): calcd for $C_{25}H_{24}Cl_2O_5$ $[M+NH_4]^+$: 492.1339, found 492.1337.

3d/4d - (1*R,3*R**)-3-(4-bromophenyl)-2,2-dichloro-3-hydroxy-1-(*p*-tolyl)propyl 4-bromobenzoate and (1*R**,3*R**)-1-(4-bromophenyl)-2,2-dichloro-3-hydroxy-3-(*p*-tolyl)propyl 4-bromobenzoate**

Under nitrogen, PhMgBr (2M, 0.55 mL, 1.1 mmol) was added to a 25 mL round-bottom flask. 2,2,2-Trichloro-1-(*p*-tolyl)ethanone (0.237 g, 1.0 mmol) was dissolved in dry THF (1 mL) and then added to the PhMgBr solution dropwise over 10 minutes at room temperature and stirred for one hour. The mixture was added to 4-bromobenzaldehyde (0.270 g, 2 mmol) at room temperature and stirred for one hour. The mixture was quenched by addition to saturated $NH_4Cl_{(aq)}$ (20 mL) and the product was extracted using DCM (3 x 15 mL). The combined organic extracts were dried over $MgSO_4$, filtered and the solvent removed under reduced pressure. The crude product was purified by silica gel column chromatography (petrol / diethyl ether, 8:2) to give an inseparable 1:1 mixture of (1*R**,3*R**)-3-(4-bromophenyl)-2,2-dichloro-3-hydroxy-1-(*p*-tolyl)propyl 4-bromobenzoate (**3d**) and (1*R**,3*R**)-1-(4-bromophenyl)-2,2-dichloro-3-hydroxy-3-(*p*-tolyl)propyl 4-bromobenzoate (**4d**) as a white/yellow solid (0.525 g, 92 %) in an approximate 3:4 ratio (shown as a:b below).
R_f = 0.30 (petrol / diethyl ether 8:2). ^{1}H NMR (300 MHz, $CDCl_3$): δ_H δ 7.99 (app d, J = 7.7 Hz, $2H_a$ + $2H_b$), 7.67 (d, J = 8.1 Hz, $2H_a$ + $2H_b$), 7.61 – 7.41 (m, $6H_a$ + $6H_b$), 7.24 – 7.18 (m, $2H_a$ + $2H_b$), 6.64 (s, $1H_a$ + $1H_b$), 5.15 (d, J = 5.5 Hz, $1H_a$), 5.10 (d, J = 5.3 Hz, $1H_b$), 3.65 (d, J = 5.3 Hz, $1H_b$), 3.19 (d, J = 5.5 Hz, $1H_a$), 2.39 (s, $3H_b$), 2.36 (s, $3H_a$). ^{13}C NMR (101 MHz, $CDCl_3$): δ_C 165.0, 164.3, 139.5, 139.1, 135.9, 133.8, 133.6, 132.2, 131.6, 131.5, 131.4, 131.1, 131.1, 130.9, 129.7, 129.5, 129.4, 129.1, 128.7, 128.6, 127.9, 123.7, 123.2, 93.9, 77.8, 77.3, 21.4. IR(neat): υ_{max}/cm^{-1} 3528, 1705. HRMS (pNSI): calcd for $C_{23}H_{18}Br_2Cl_2O_3$ $[M+NH_4]^+$: 589.9317, found 589.9313.

5a - (1*R,3*R**)-1-(4-bromophenyl)-2,2-dichloro-3-(*p*-tolyl)propane-1,3-diol**

10 mL of NaOH (5%, w/v) was added to a 25 mL round-bottom flask followed by a mixture of (1*R**,3*R**)-3-(4-bromophenyl)-2,2-dichloro-3-hydroxy-1-(*p*-tolyl)propyl 4-bromobenzoate (**3c**) and (1*R**,3*R**)-1-(4-bromophenyl)-2,2-dichloro-3-hydroxy-3-(*p*-tolyl)propyl 4-bromobenzoate (**4d**) (60 mg, 0.1 mmol). The reaction was stirred at room temperature for 6h. The solution was acidified with HCl (10%) and product was extracted with DCM (3 x 15 mL). The organic layer washed with a saturated solution of $NaHCO_{3(aq)}$ (3 x 15 mL). The combined organic extracts were dried over $MgSO_4$, filtered and the solvent removed under reduced pressure. The crude product was purified by silica gel column chromatography (petrol / diethyl ether, 9:1) to give (1*R**,3*R**)-1-(4-bromophenyl)-2,2-dichloro-3-(*p*-tolyl)propane-1,3-diol (**5a**) as a white solid (37 mg, 95 %).
Mp: 131-133˚C. R_f = 0.1(petrol / diethyl ether 8:2). ^{1}H NMR (300 MHz, $CDCl_3$): δ_H 7.52 (d, J = 8.5 Hz, 2H), 7.49 – 7.41 (m, 4H), 7.22 (d, J = 7.9 Hz, 2H), 5.30 (s, 1H), 5.27 (s, 1H), 3.86 (br s, 1H), 3.52 (br s, 1H), 2.40 (s, 3H). ^{13}C NMR (101 MHz, $CDCl_3$): δ_C 139.1, 136.2, 133.7, 131.0, 130.9, 128.9, 128.8, 123.1, 94.6, 79.7, 78.3, 21.4. IR(neat): υ_{max}/cm^{-1} 3410, 2922. HRMS (pNSI): calcd for $C_{16}H_{15}BrCl_2O_2$ $[2M+Na]^+$: 802.9113, found 802.9113.

General Procedure for Darzens Condensation of 2,2-Dichloro-1-arylethanones with Arylaldehydes

Under nitrogen, NaH (60% dispersion in mineral oil, 1.1 equivalents) was added to a 25 mL round-bottom flask. An appropriate 2,2-dichloro-1-arylethanone was dissolved in dry THF (1 mL) and then added to the NaH dropwise over 5 minutes and stirred for a further one hour at room temperature. The reaction mixture was added to a solution of arylaldehyde (1 equivalent) in dry THF (1 mL) and stirred for one hour at room temperature. The mixture was quenched by adding to a saturated $NH_4Cl_{(aq)}$ solution (20 mL), extracted using ethyl acetate (3 x 15 mL), dried over $MgSO_4$, filtered and evaporated under reduced pressure and purified by column chromatography on silica gel.

6a - (2*R,3*R**)-2-chloro-3-(4-nitrophenyl)oxiran-2-yl)(1-methyl-1*H*-pyrrol-2-yl)methanone**

0.5 mmol scale. White solid (81 mg, 54%). Chromatography (petrol / diethyl ether, 5:5). Mp = 123-124 ˚C. R_f = 0.40 (petrol / diethyl ether 5:5). ^{1}H NMR (300 MHz, $CDCl_3$): δ_H 8.33 (d, J = 8.8 Hz, 2H), 7.66 (d, J = 8.8 Hz, 2H), 7.35 (dd, J = 4.3, 1.6 Hz, 1H), 7.02 (t, J = 2.0 Hz, 1H), 6.29 (dd, J = 4.3, 2.4 Hz, 1H), 4.50 (s, 1H), 4.01 (s, 3H). ^{13}C NMR (101 MHz, $CDCl_3$): δ_C 177.0, 148.5, 138.8, 133.8, 128.4, 125.8, 123.6, 123.0, 109.8, 80.8, 61.7, 37.8. IR(neat): υ_{max}/cm^{-1} 1648. HRMS (APCI): calcd for $C_{14}H_{11}ClN_2O_4$ $[M+H]^+$: 307.0480, found 307.0482.

6b - (2*R,3*R**)-2-chloro-3-phenyloxiran-2-yl)(1-methyl-1*H*-pyrrol-2-yl)methanone**

1 mmol scale. Yellow solid (120 mg, 47%). Chromatography (petrol / diethyl ether, 1:1). Mp = 95-96 ˚C, R_f = 0.18 (petrol / diethyl ether 9:1). ^{1}H NMR (300 MHz, $CDCl_3$): δ_H 7.49 – 7.46 (m, 2H), 7.42 – 7.35 (m, 3H), 7.20 (dd, J = 4.3, 1.6 Hz, 1H), 6.97 (t, J = 2.0 Hz, 1H),

6.43 (s, 1H), 6.19 (dd, *J* = 4.3, 2.4 Hz, 1H), 3.94 (s, 3H). ^{13}C NMR (101 MHz, $CDCl_3$): δ_C 191.7, 178.1, 134.7, 134.1, 129.5, 129.1, 129.0, 127.1, 125.6, 110.3, 61.4, 37.8. IR(neat): υ_{max}/cm^{-1} 1734. HRMS (APCI): calcd for $C_{14}H_{12}ClNO_2$ $[M+H]^+$: 262.0629, found 262.028.

6c - (2*R,3*R**)-3-(4-bromophenyl)-2-chlorooxiran-2-yl)(1-methyl-1*H*-pyrrol-2-yl)methanone**

0.3 mmol scale. White solid (75 mg, 71%). Chromatography (petrol / diethyl ether, 9:1). Mp = 66-68 ˚C, R_f = 0.19 (petrol / diethyl ether 8:2). ^{1}H NMR (300 MHz, $CDCl_3$): δ_H 7.52 (d, *J* = 8.5 Hz, 2H), 7.35 (d, *J* = 8.5 Hz, 2H), 7.22 (dd, *J* = 4.4, 1.5 Hz, 1H), 7.00 – 6.99 (m, 1H), 6.39 (s, 1H), 6.21 (dd, *J* = 4.4, 2.4 Hz, 1H), 3.94 (s, 3H). ^{13}C NMR (101 MHz, $CDCl_3$): δ_C 191.1, 177.6, 135.0, 133.2, 132.3, 130.6, 127.0, 125.7, 123.8, 110.4, 60.4, 37.8. IR(neat): υ_{max}/cm^{-1} 1731. HRMS (APCI): calcd for $C_{14}H_{11}BrClNO_2$ $[M+H]^+$: 341.9712, found 341.9709.

6d - (2*R,3*R**)-2-chloro-3-(4-iodophenyl)oxiran-2-yl)(1-methyl-1*H*-pyrrol-2-yl)methanone**

0.50 mmol scale. Yellow solid (170 mg, 88%). Chromatography (petrol / diethyl ether, 9:1). Mp = 76-77 ˚C, R_f = 0.18 (petrol / diethyl ether 9:1). ^{1}H NMR (300 MHz, $CDCl_3$): δ_H 7.73 (d, *J* = 8.4 Hz, 2H), 7.24 – 7.22 (m, 1H), 7.22 (d, *J* = 8.4 Hz, 2H), 7.00 (t, *J* = 2.0 Hz, 1H), 6.36 (s, 1H), 6.22 (dd, *J* = 4.3, 2.4 Hz, 1H), 3.95 (s, 3H). ^{13}C NMR (101 MHz, $CDCl_3$): δ_C 191.1, 177.6, 138.3, 135.0, 133.9, 130.7, 127.0, 125.7, 110.4, 95.7, 60.6, 37.8. IR(neat): υ_{max}/cm^{-1} 1730. HRMS (pNSI): calcd for $C_{14}H_{11}ClINO_2$ $[M+H]^+$: 387.9596, found 387.9597.

6e - (2*R,3*R**)-2-chloro-3-(4-methoxyphenyl)oxiran-2-yl)(1-methyl-1*H*-pyrrol-2-yl)methanone**

1 mmol scale. Yellow solid (110 mg, 38%). Chromatography (petrol / diethyl ether, 9:1). Mp = 58-59 ˚C, R_f = 0.10 (petrol / diethyl ether 8:2). ^{1}H NMR (300 MHz, $CDCl_3$): δ_H 7.39 (d, *J* = 8.8 Hz, 2H), 7.20 (dd, *J* = 4.3, 1.7 Hz, 1H), 6.96 (t, *J* = 2.1 Hz, 1H), 6.90 (d, *J* = 8.8 Hz, 2H), 6.41 (s, 1H), 6.19 (dd, *J* = 4.3, 2.4 Hz, 1H), 3.93 (s, 3H), 3.80 (s, 3H). ^{13}C NMR (101 MHz, $CDCl_3$): δ_C 191.6, 178.4, 160.4, 134.6, 130.4, 127.1, 125.8, 125.5, 114.6, 110.2, 61.4, 55.4, 37.7. IR(neat): υ_{max}/cm^{-1} 1727. HRMS (APCI): calcd for $C_{15}H_{14}ClNO_3$ $[M]^+$: 291.0657, found 291.0652.

6f - (2*R,3*R**)-2-chloro-3-(4-nitrophenyl)oxiran-2-yl)(p-tolyl)methanone**

0.5 mmol scale. White solid (146 mg, 92%). Chromatography (petrol / diethyl ether, 9.5:0.5). Mp = 111-112˚C. R_f = 0.44 (petrol / diethyl ether 8:2). ^{1}H NMR (300 MHz, $CDCl_3$): δ_H 8.35 (d, *J* = 8.7 Hz, 2H), 8.06 (d, *J* = 8.1 Hz, 2H), 7.70 (d, *J* = 8.7 Hz, 2H), 7.38 (d, *J* = 8.1 Hz, 2H), 4.53 (s, 1H), 2.49 (s, 3H). ^{13}C NMR (101 MHz, $CDCl_3$): δ_C 186.5, 148.6, 146.3, 138.5, 130.2, 129.8, 129.2, 128.4, 123.6, 80.5, 61.0, 22.1. IR(neat): υ_{max}/cm^{-1} 1695. HRMS (APCI): calcd for $C_{16}H_{12}ClNO_4$ $[M+H]^+$: 318.0528, found 318.0528.

6g - (4-(*tert*-butyl)phenyl)((2*R,3*R**)-2-chloro-3-(4-nitrophenyl)oxiran-2-yl)methanone**

0.42 mmol scale. White solid (110 mg, 74%). Chromatography (petrol / diethyl ether, 9:1). Mp = 151-152˚C, R_f = 0.43 (petrol / diethyl ether 9:1). ^{1}H NMR (300 MHz, $CDCl_3$): δ_H 8.35 (d, *J* = 8.7 Hz, 2H), 8.10 (d, *J* = 8.6 Hz, 2H), 7.70 (d, *J* = 8.7 Hz, 2H), 7.59 (d, *J* = 8.6 Hz, 2H), 4.53 (s, 1H), 1.39 (s, 9H). ^{13}C NMR (101 MHz, $CDCl_3$): δ_C 186.4, 158.2, 148.6, 138.5, 130.1, 129.0, 128.4, 126.1, 123.6, 80.5, 61.0, 35.5, 31.1. IR(neat): υ_{max}/cm^{-1} 1684. HRMS (APCI): calcd for $C_{19}H_{18}ClNO_4$ $[M+H]^+$: 360.0997, found 360.0996.

6h - ((2*R,3*R**)-2-chloro-3-(4-nitrophenyl)oxiran-2-yl)(phenyl)methanone**

5 mmol scale. Colourless oil (512 mg, 34%). Chromatography (petrol / diethyl ether, 8:2). R_f = 0.34 (petrol / diethyl ether 8:2). ^{1}H NMR (300 MHz, $CDCl_3$): δ_H 8.34 (d, *J* = 8.8 Hz, 2H), 8.15 (d, *J* = 7.1 Hz, 2H), 7.73 – 7.68 (m, 3H), 7.61 – 7.55 (m, 2H), 4.56 (s, 1H). ^{13}C NMR (101 MHz, $CDCl_3$): δ_C 186.8, 148.6 , 138.3, 135.0, 131.7, 130.1, 129.1, 128.5, 123.6, 80.4, 61.0. IR(neat): υ_{max}/cm^{-1} 1694. HRMS (pNSI): calcd for $C_{15}H_{10}ClNO_4$ $[M+Na]^+$: 326.0191, found 326.0194.

7a - 3-Chloro-1-(1-methyl-1*H*-pyrrol-2-yl)-3-(4-nitrophenyl)propane-1,2-dione

A solution of ((2*R**,3*R**)-2-chloro-3-(4-nitrophenyl)oxiran-2-yl)(1-methyl-1*H*-pyrrol-2-yl)methanone (**6a**) (153 mg, 0.5 mmol) in 4 mL of toluene was refluxed for 24 hours. Petrol (10 mL) was added and the solvents were removed *in vacuo* to give 3-chloro-1-(1-methyl-1*H*-pyrrol-2-yl)-3-(4-nitrophenyl)propane-1,2-dione (**7a**) as yellow solid (150 mg, 98%).
Mp = 101-102 ˚C, R_f = 0.27 (petrol / diethyl ether 7:3). ^{1}H NMR (300 MHz, $CDCl_3$): δ_H 8.26 (d, *J* = 8.8 Hz, 2H), 7.69 (d, *J* = 8.8 Hz, 2H), 7.28 (dd, *J* = 4.4, 1.7, 1H), 7.03 (t, *J* = 2.0 Hz, 1H), 6.48 (s, 1H), 6.24 (dd, *J* = 4.4, 2.4 Hz, 1H), 3.97 (s, 3H). ^{13}C NMR (101 MHz, $CDCl_3$): δ_C 190.5, 176.8, 148.3, 141.3, 135.4, 129.9, 126.9, 126.0, 124.1, 110.6, 59.4, 37.8. IR(neat): υ_{max}/cm^{-1} 1729, 1624. HRMS (pNSI): calcd for $C_{14}H_{11}ClN_2O_4$ $[M+H]^+$: 307.0480, found 307.0484.

7b - 3-chloro-3-(4-nitrophenyl)-1-(*p*-tolyl)propane-1,2-dione

A solution of ((2*R**,3*R**)-2-chloro-3-(4-nitrophenyl)oxiran-2-yl)(*p*-tolyl)methanone (**6f**) (106 mg, 0.33 mmol) in 4 ml of toluene was refluxed for 6 hours. Petrol (4mL) was added and the solvents were removed *in vacuo* to give 3-chloro-3-(4-nitrophenyl)-1-(*p*-tolyl)propane-1,2-dione (**7b**) as a yellow solid (104 mg, 98%).
Mp = 96-98 ˚C, R_f = 0.29 (petrol / diethyl ether 8:2). ^{1}H NMR (300 MHz, $CDCl_3$): δ_H 8.28 (d, *J* = 8.8 Hz, 2H), 7.89 (d, *J* = 8.2 Hz, 2H), 7.70 (d, *J* = 8.8 Hz, 2H), 7.32 (d, *J* = 8.2 Hz, 2H), 6.38 (s, 1H), 2.46 (s, 3H). ^{13}C NMR (101 MHz, $CDCl_3$): δ_C 190.4, 189.8, 148.5, 147.2, 140.3, 130.5, 130.0, 129.9, 129.4, 124.2, 59.5, 22.1. IR(neat): υ_{max}/cm^{-1} 1720, 1663. HRMS (pNSI): calcd for $C_{16}H_{12}ClNO_4$ $[M+H]^+$: 318.0528, found 318.0526.

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Notes and references

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Electronic supplementary information (ESI) available: Experimental procedures and spectral information for compounds **1d**, **1e** and **1f**, crystal data and structure refinement tables for **1e**, **1f**, **2a**, **2f**, **2h**, **2j**, **2k**, **2o**, **2t**, **3a**, **3b**, **6a**, **6f** and **6h** and ^{1}H and ^{13}C spectra for all new compounds. Crystallographic data for **1e**, **1f**, **2a**, **2f**, **2h**, **2j**, **2k**, **2o**, **2t**, **3a**, **3b**, **6a**, **6f** and **6h** have been deposited with the CCDC, deposition nos: CCDC 1020127-1020139 and 1037684. For ESI see DOI: XXX

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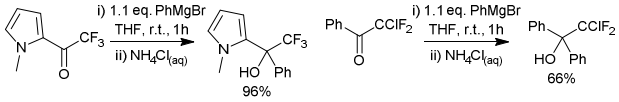

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